

Geo-technical Investigation

Title of project-	Implementation of Rebuilding and Improving Access to Basic Services and Climate Resilient Community Infrastructure on Behalf of the Government of Ethiopia.
Project Assignment:	Response-Recovery-Resilience for Conflict Affected Communities in Ethiopia
Project Sites:	Construction of Classrooms, Administration Building, and Toilets at the following 4 sites in Tigray, 2 selected Woredas: <ul style="list-style-type: none">• Kisad Gaba Primary School;• Gelewsa Primary School;• Serenga Primary School;• Meswaeti Primary School.
Beneficiaries:	The Project will cover conflict-affected communities in Ethiopia. However, this assignment is specific to beneficiaries in Tigray Region selected Woredas in Tigray Regional State <ul style="list-style-type: none">• Endmahoni Woreda, South Zone; and• Asgede Woreda, Western Zone.
Donor-	World Bank
Implementer-	UNOPS-ETMCO on behalf of the Government of Federal Democratic Republic of Ethiopia
Test Sample Collection:	UNOPS-ETMCO (Samer Hatoum & Asfaw Eshetu)
Laboratory Test Analysis:	Opal Soil Investigation Center, Mekelle, Tigray Region, Ethiopia.

Summary Report

The region is predominantly covered with leached laterite red clay soil to considerable depth exceeding of 10m depth. This clay is known for its moderate bearing capacity and relatively low swelling- shrink character. During the site visit, exploration has been made using test pit dug to a depth of 1.5m -2.0m to verify and confirm the characteristics of the soil layer. The hand dug test pit has been carried out at the location of the classroom, administration building and latrine. The soil profile in all the test pit explored has shown literally uniform layer the depth reached.

Due to the proposed simple structure, as well as the uniform nature of the soil exhibited in all the test pits, UNOPS determined to collect a disturbed representative soil sample from the test pit for laboratory analysis.

A basic laboratory test (i.e sieve analysis, specific gravity and atterberg limit tests) has been conducted for the representative sample to characterize the soil in accordance with the Unified Classification of Soil and determine the engineering properties of the soil. The test conducted in both sites has shown that about 70% of the soil composition belong to Silty-clay soil with plastic index of ranging 4% -27%. The geo-technical expert of UNOPS-ETMCO has applied the Terzaghi theory for determining the bearing capacity of the soil for engineering design and foundation of the building. The analysis has shown a bearing capacity of 250 KPa to be used for Kisd Gaba, Gelewsa and Meswaeti Primary schools, whereas 200KPa for Seregna Primary School with a safety factor of 3.0. This report comprises information on the location of the test pits, pictures, log report and results of the laboratory analysis.

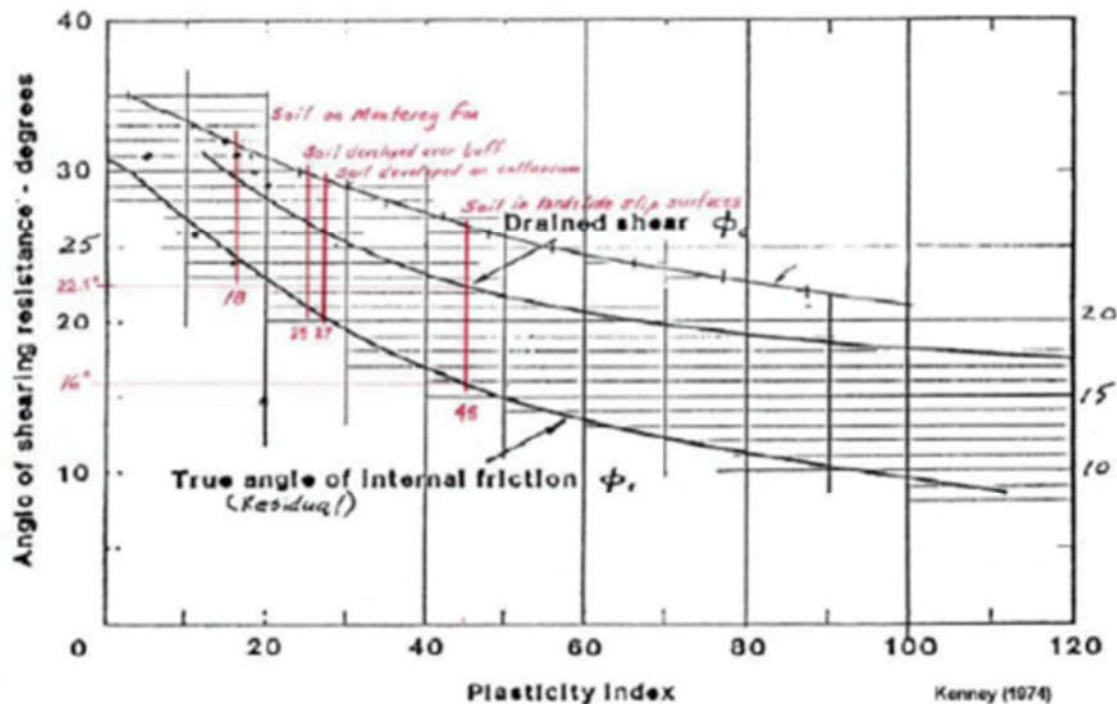
Geo-technical Investigation

Response-Recovery-Resilience for Conflict Affected Communities in Tigray, Ethiopia Construction of Classrooms and Administration

The purpose of this report is to describe the soil in place at the designated site for the construction of:

- New gender separated toilets, classrooms and administration building for existing primary schools in Tigray, Ethiopia.

Two tests pits have been carried out at the right location of the proposed construction for the respective school sites. Two representative disturbed soil sample have been collected from each school with a total of 8 samples. The test pits have been dug up to 2.0m depth. Soil samples were collected from 1.5m to 2.0m depth for further laboratory test, where identification tests have been conducted that include grain size analysis, Atterberg limit and specific gravity of soil. In all the sites, no ground water table has been encountered and almost same type of soil observed throughout the depth. As no direct mechanical test has been conducted and as the structure planned for the construction are very simple (i.e. single floor buildings) and are not supposed to communicate significant pressures to the underneath soils of foundation, a correlation between the Plastic Index and the Effective Friction Angle has been used in order to estimate the mechanical properties. This correlation is well known in the geotechnical literature and is given by the following chart:



Simple structure (one story buildings) and the soil is predominantly non-cohesive soil up to weathered rock with good bearing strength. The geo-tech report uses the plot of Kenney (1974) to correlate between plasticity index and the true angle of internal friction.

Based on the laboratory test results that include sieve analysis and Atterberg Limits, and the correlations in the chart, the following table depicts the soil classifications, the measured Plastic Index (PI), the estimated apparent cohesion and the correlated effective friction angle.

Site	Soil Sample No.	Soil Identification: Unified Soil Classification Systems (USCS)	Measured Plastic Index (PI) %	Correlated Friction Angle (Degrees)	Estimated Apparent Cohesion "c" (KPa)
Kisad Gaba Primary school	T.P.No. 01	SM- Non- Plastic silty SAND with traces of gravel	4	28	5
	T.P.No.02	SM- Non- Plastic silty SAND with traces of gravel	6	27	7
Gelewsa Primary School	T.P.No. 01	SC- Plastic Clayey SAND with traces of gravel	18	22	15
	T.P.No. 02	MH- plastic Clayey SILT	19	22	15
Seregna Primary School	T.P.No. 01	ML- plastic Clayey SILT	19	22	15
	T.P.No.02	CH- Plastic stiff Clay soil	22	20	18
Meswaety Primary School	T.P.No. 01	ML- plastic Clayey SILT	14	26	10
	T.P.No.02	ML- plastic Clayey SILT	16	24	12

The ultimate bearing capacity will be estimated according to Terzaghi theory. Indeed Terzaghi equation for a shallow square footings will be used.

Bearing Capacity Equations and Factors Table (Look, 2007)

Table 21.4 Bearing capacity equation.

Consideration	Cohesion	Embedment	Unit weight	Comments
Bearing capacity factors	N_c	N_q	N_γ	These factors are non dimensional and depend on ϕ . See next Table
Ultimate bearing capacity (q_{ult})	$c N_c +$	$q N_q +$	$0.5 \gamma B N_\gamma$	Strip footing
	$1.3 c N_c +$	$q N_q +$	$0.4 \gamma B N_\gamma$	Square footing
	$1.3 c N_c +$	$q N_q +$	$0.3 \gamma B N_\gamma$	Circular footing

Where;

c- Apparent cohesion to be taken from the table above;

$q = \gamma D$

γ - Weight of the soil estimated 18kN/m³

D – Embedment of Footing = 2.0m

B = 1.0m (Considering the smallest size of footing)

N_c , N_q and N_γ are factors given by Terzaghi and are related to effective friction angle. These factors are given in the following table.

Terzaghi's Bearing Capacity Factors

Friction Angle	N_c	N_q	N_γ
0	5.7	1	0
5	7.3	1.6	0.5
10	9.6	2.7	1.2
15	12.9	4.4	2.5
20	17.7	7.4	5
25	25.1	12.7	9.7
30	37.2	22.5	19.7
34	52.6	36.5	35.0
35	57.8	41.4	42.4
40	95.7	81.3	100.4
45	172.3	173.3	297.5

Terzaghi's bearing capacity equation for Square footing is given by:

$$Q_u = 1.3 c N_c + \gamma D N_q + 0.4 \gamma B N_\gamma$$

Accordingly; the ultimate bearing capacities for each sites and test pit No.1 and No.2 are given in the following table:

Sites	Friction angle (Degrees)	Cohesion (c) KPa	B (m)	D (m)	Nc	Nq	Ng	Ultimate Bearing Capacity Qu(Kpa)
Kisad Gaba PS	28	5	1.0	2.0	32.4	18.6	15.7	993.2
	27	7	1.0	2.0	29.9	16.6	13.7	968.3
Gelewsa PS	22	15	1.0	2.0	20.7	9.5	6.9	795.3
	22	15	1.0	2.0	20.7	9.5	6.9	795.3
Seregna PS	22	15	1.0	2.0	20.7	9.5	6.9	795.3
	20	18	1.0	2.0	17.7	7.4	5.0	716.6
Meswaeti PS	26	10	1.0	2.0	27.5	14.7	11.7	970.9
	24	12	1.0	2.0	23.6	11.6	8.8	849.1

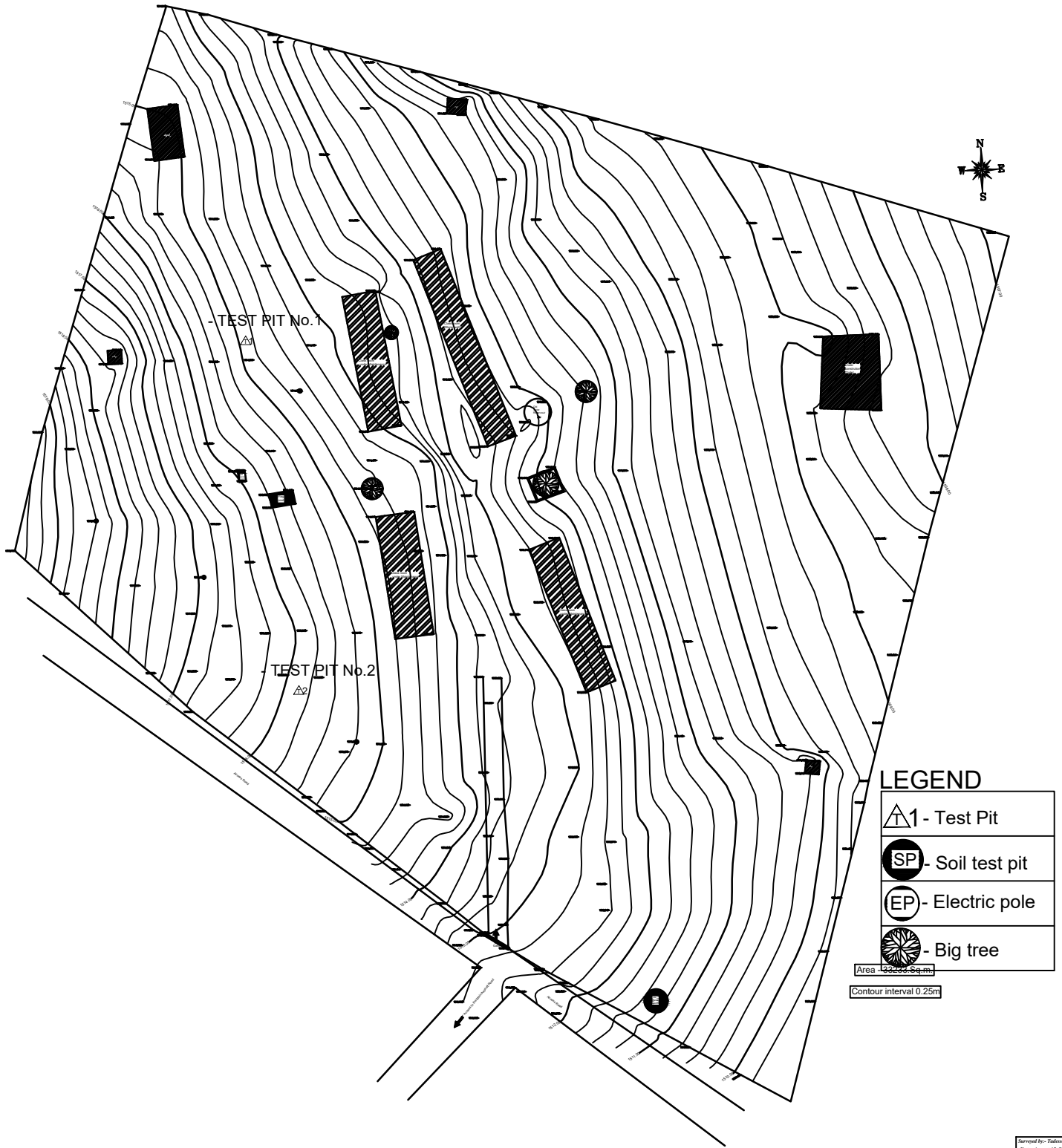
Considering a Safety Factor (SF) = 3.0, and the lower values among the test pits, the admissible bearing capacities will be calculated for each site as follows:

Site	Ultimate Bearing Capacity (KPa)	Allowable Bearing Capacity (KPa)
Kisad Gaba Primary School	968.3	322.8
Gelewsa Primary School	795.3	265.1
Seregna Primary School	716.6	238.9
Meswaeti Primary School	849.1	283.0

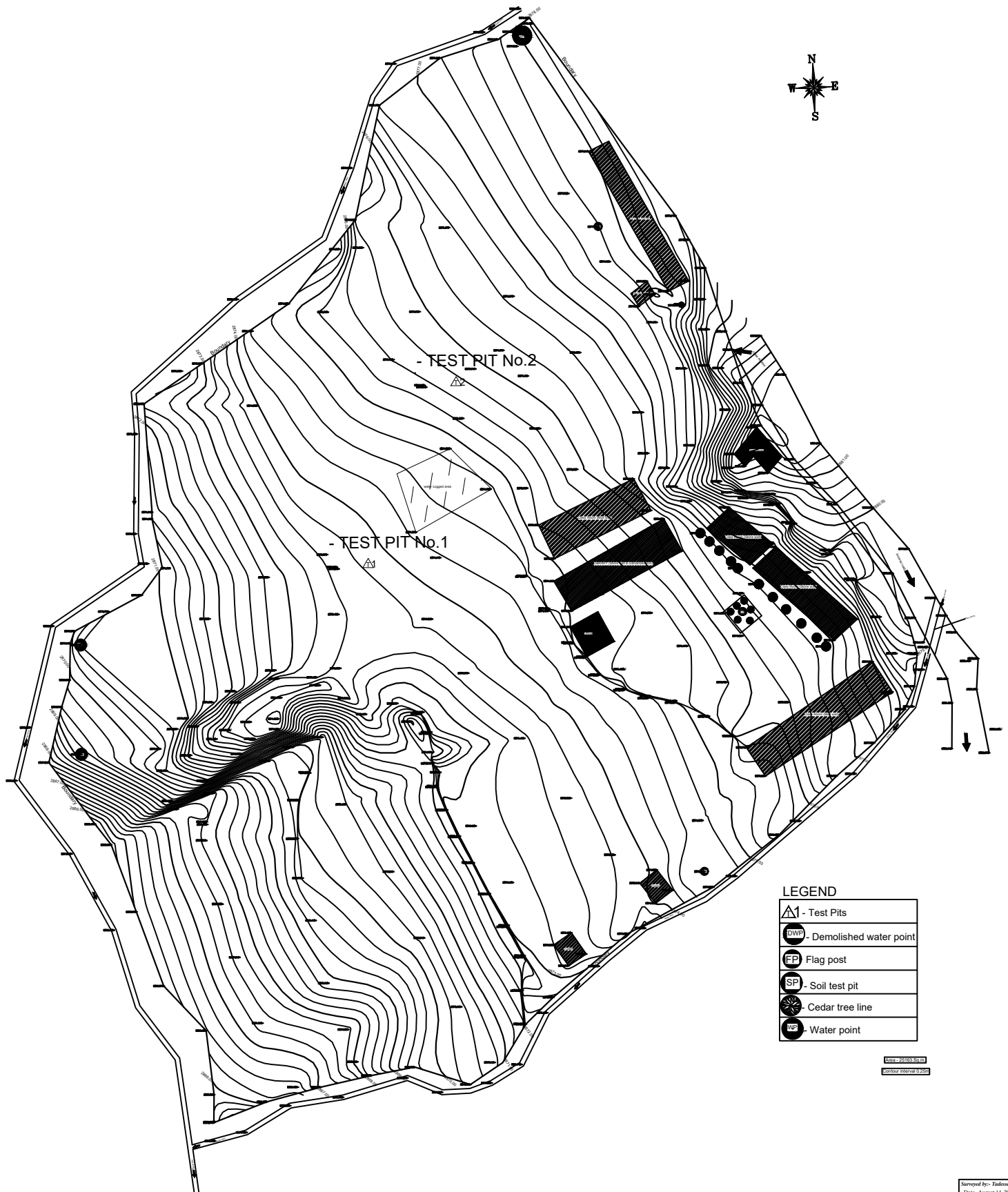
A recommended value of 250 KPa will be provided to the structural engineer for the design of foundations to Kisad Gaba, Gelwesa and Meswaeti Primary schools. Seregna PS will be designed with a recommended value of 200 KPa.

The Laboratory Results, Location of test pits and pictures are attached in the following pages.

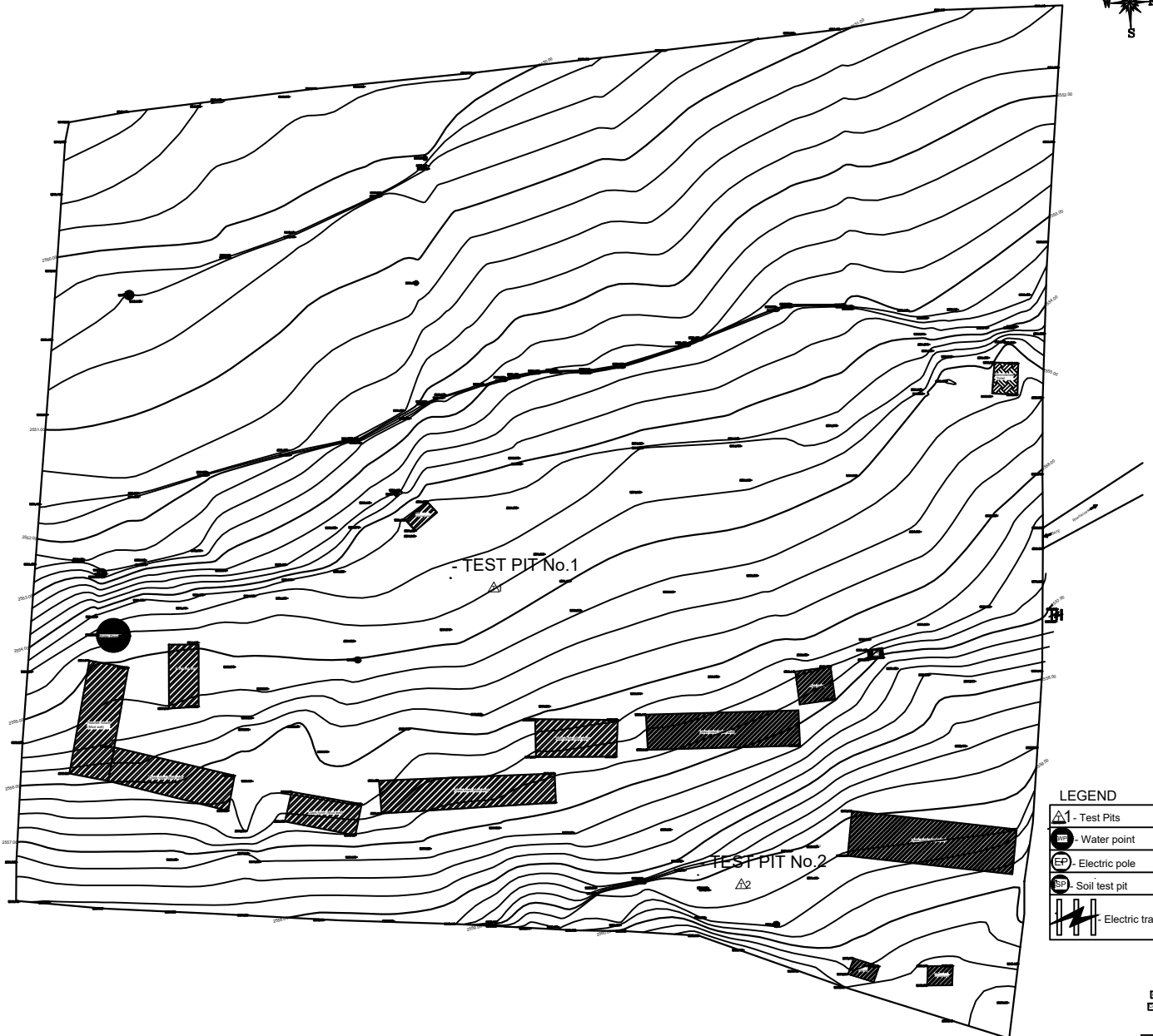
Topographic map of KESAD GABA Primary School



Topographic map of Endamhoni / GELEWSA Primary School



Topographic map of Endamhoni / SERNGA Primary School

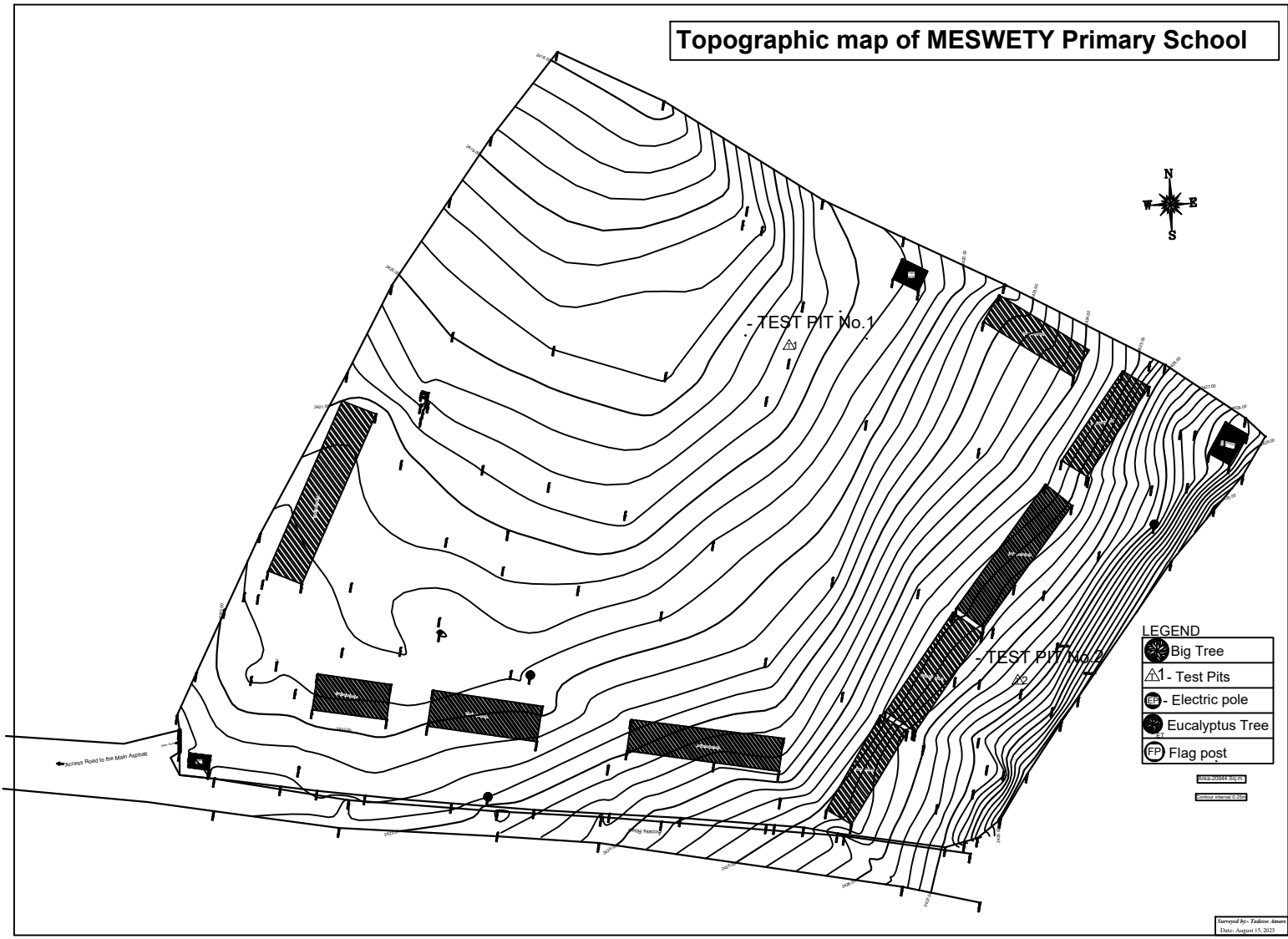


LEGEND	
	1 - Test Pits
	- Water point
	EP - Electric pole
	SP - Soil test pit
	Electric transformer

Scale 1:5000
Date: August 14, 2023

Surveyed by: Student Army
Date: August 14, 2023

Topographic map of MESWETY Primary School





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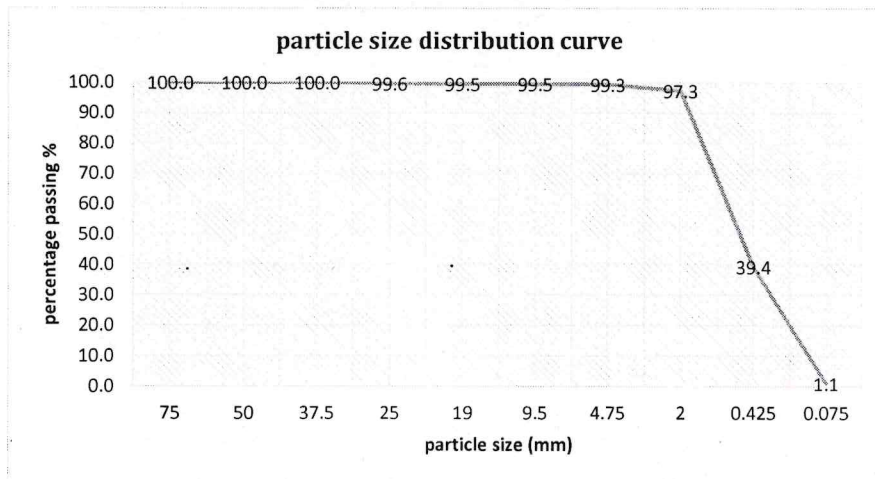
Represent Section	kisab gedad primary school room	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1Pits
Material Description	reddish brown silty sand soil	Test No	1

Particle Size Distribution of Sieve Analysis

ASTM D422

Sieve Size (mm)	weight Retained	% Retained	% pass	Commu Retained
75	0	0	100.0	0
50	0	0	100.0	0
37.5	0	0	100.0	0
25	4	0.3649635	99.6	4
19	2	0.54744526	99.5	6
9.5	0	0.54744526	99.5	6
4.75	2	0.72992701	99.3	8
2	22	2.73722628	97.3	30
0.425	634	60.5839416	39.4	664
0.075	420	98.9051095	1.1	1084
Pan	12	100	0.0	1096
Total	1096			

gravel %	sand %	finer (silt/clay) %
2.737	57.85	39.4161



lab Engineer

Material Engineer



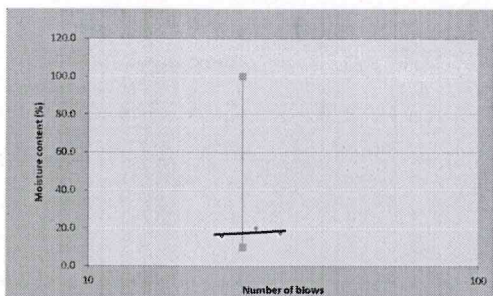


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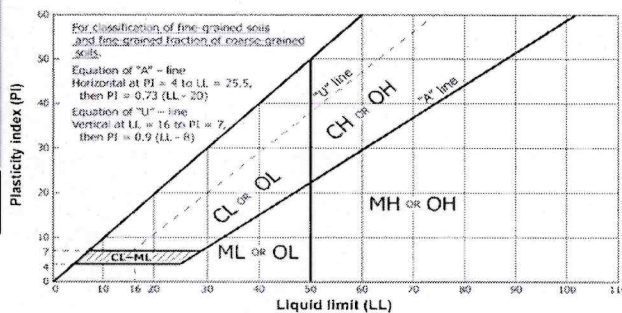
Represent Section	kisab gedad primary school room	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1Pits
Material Description	reddish brown silty sand soil	Test No	1

DETERMINATION OF LIQUID LIMIT & PLASTIC LIMIT OF SOIL TEST METHOD: ASTM D4318

Determination	Liquid Limit				Plastic Limit			
Number of blows		31	27	22				
Test	No	1	2	3	1	1		
Container	No	1	2	7	1	2		
wt of wt soil	(g)	0.04	0.03	0.03	0.02	0.02		
Wt. of container + dry soil,	(g)	0.07	0.05	0.06	0.055	0.05		
wt of container	(g)	0.04	0.03	0.04	0.04	0.03		
Wt. of water,	(g)	0.01	0.01	0.00	0.00	0.00		
Wt. of dry soil,	(g)	0.03	0.03	0.03	0.02	0.02		
Moisture container,	(%)	17.3	20.0	16.0	17.3	10.5		
Average	(%)	18.00				14.0		



Determination of (PI) (LL - PL)	LL	18
	PL	14
	PI	4



Remark

lab Engineer	Material Engineer
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OPAL soil investigation center

Represent Section	kisab gedad primary school room	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1Pits
Material Description	reddish brown silty sand soil	Test No	1

Specific gravity ASTM 854-90 Oven dried


S/no	Description	Determination number	
		1	2
1	Temperature in "c	31	31
2	Weight of bottle (w1) in g	18.56	18.46
3	Weight of bottle +dry soil (W 2)in g	28.56	28.52
4	Weight of bottle +soil + water (W3) in g	90.82	90.22
5	Weight of bottle + water (W4) in g	84.74	83.85
6	Specific gravity $G = \frac{W2-W1}{(W4-W1)-(W3-W2)}$	2.55102041	2.72629
7	Average G at 31 "c	2.63865384	
8	corrected G at 27" = $G * (\text{relative density of water at room temprature} / \text{density of water at 27" c})$	2.63554795	

relative density of ewater at room
temprature=0.995369

relative density of water at 27"C=0.996542

SJS



 OPAL soil investigation center			
Represent Section	kisab gedad primary school room	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1Pits
Material Description	reddish brown silty sand soil	Test No	1

free swell

Additive content	sample 1	sample 2
Vd = Volume of the soil specimen read		
from the graduated cylinder containing distilled water,	11.2	12.1
Vk = Volume of the soil specimen read		
from the graduated cylinder containing kerosene,	10	10
Free swell index = $(Vd - Vk / Vk) \times 100 (\%)$	12	21
Average Free swell index	16.5 %	

SP





OPAL soil investigation center

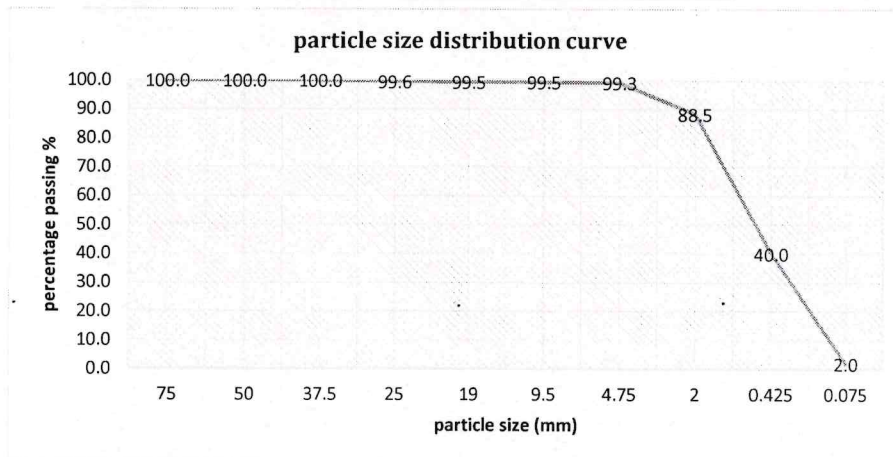
Represent Section	kisab gedad primary Admin building	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1Pits
Material Description	reddish brown silty sand soil	Test No	2

Particle Size Distribution of Sieve Analysis

ASTM D422

Sieve Size (mm)	weight Retained	% Retained	% pass	Comm Retained
75	0	0	100.0	0
50	0	0	100.0	0
37.5	0	0	100.0	0
25	4	0.3606853	99.6	4
19	2	0.54102795	99.5	6
9.5	0	0.54102795	99.5	6
4.75	2	0.7213706	99.3	8
2	120	11.5419297	88.5	128
0.425	537	59.9639315	40.0	665
0.075	422	98.0162308	2.0	1087
Pan	22	100	0.0	1109
Total	1109			

gravel %	sand %	fines (silt/clay) %
11.54	48.42	40.03606853



lab Engineer

Material Engineer



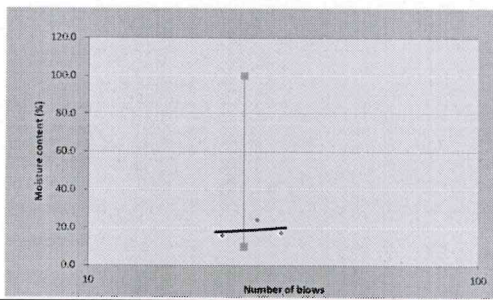


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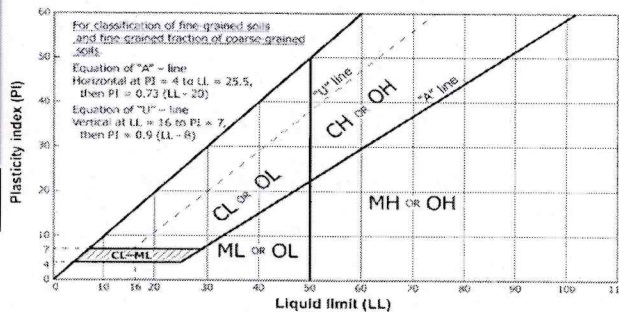
Represent Section	kisab gedad primary Admin building	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1 Pits
Material Description	reddish brown silty sand soil	Test No	2 1

DETERMINATION OF LIQUID LIMIT & PLASTIC LIMIT OF SOIL TEST METHOD: ASTM D4318

Determination	Liquid Limit				Plastic Limit			
Number of blows		31	27	22				
Test	No	1	2	3	1	1		
Container	No	1	2	7	1	2		
wt of wt soil	(g)	0.04	0.03	0.03	0.02	0.02		
Wt. of container + dry soil,	(g)	0.07	0.05	0.06	0.055	0.05		
wt of container	(g)	0.04	0.03	0.04	0.04	0.03		
Wt. of water,	(g)	0.01	0.01	0.00	0.00	0.00		
Wt. of dry soil,	(g)	0.03	0.03	0.03	0.02	0.02		
Moisture container,	(%)	17.3	24.0	16.0	17.3	10.3		
Average	(%)	20.00				14.0		



Determination of (PI)	LL	20
(LL - PL)	PL	14
	PI	6




Remark

lab Engineer

Material Engineer



 OPAL soil investigation center			
Represent Section		kisab gedad primary Admin building	Date Sampled
owner	UNOPS		Date Tested
Type of Material	foundation material	Sample No	1 Pits
Material Description	reddish brown silty sand soil	Test No	2


Specific gravity ASTM 854-90 Oven dried

S/no	Description	Determination number	
		1	2
1	Temperature in "c	31	31
2	Weight of bottle (w1) in g	18.56	18.46
3	Weight of bottle +dry soil (W 2)in g	28.43	28.56
4	Weight of bottle +soil + water (W3) in g	90.82	90.22
5	Weight of bottle + water (W4) in g	84.74	83.85
6	Specific gravity $G = \frac{W2-W1}{(W4-W1)-(W3-W2)}$	2.60422164	2.70777
7	Average G at 31 "c	2.65599822	
8	corrected G at 27" =G*(relative density of water at room temprature/density of water at 27"c)	2.65287192	

relative density of ewater at room
temprature=0.995369

relative density of water at 27"C=0.996542



 OPAL soil investigation center			
Represent Section	kisab gedad primary Admin building		Date Sampled
owner	UNOPS		Date Tested
Type of Material	foundation material	Sample No	1Pits
Material Description	reddish brown silty sand soil	Test No 2	1

free swell

Additive content	sample 1	sample 2
Vd = Volume of the soil specimen read		
from the graduated cylinder containing distilled water,	11.3	11.6
Vk = Volume of the soil specimen read		
from the graduated cylinder containing kerosene,	10	10
Free swell index = $(Vd - Vk / Vk) \times 100 (\%)$	13	16
Average Free swell index	14.5	%





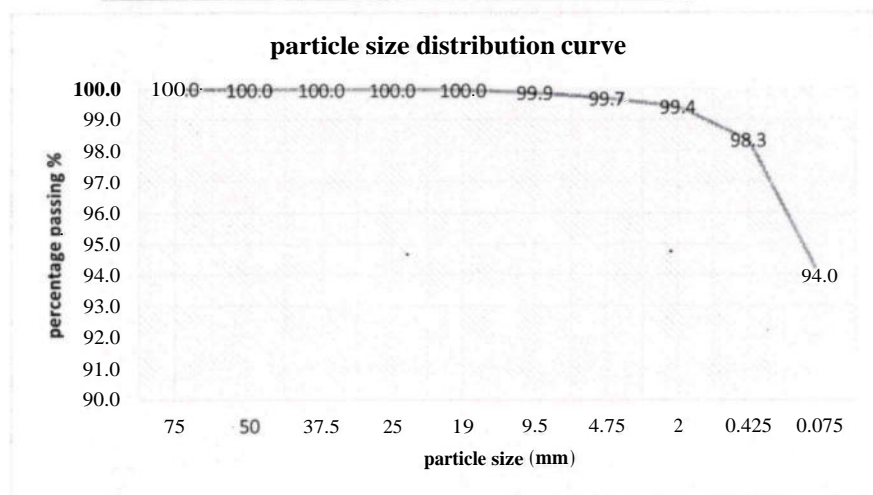
OPAL soil investigation center

Represent Section	Gelewsa class room	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1 Pits
Material Description	Brown Clayey Sand Soil	Test No	1

Particle Size Distribution of Sieve Analysis ASTM D422

Sieve Size (mm)	weight Retainer	% Retained	% pass	Comm Retained
75	0	0	100.0	0
50	1	0.04472272	100.0	1
37.5	0	0.04472272	100.0	1
25	0	0.04472272	100.0	1
19	0	0.04472272	100.0	1
9.5	2	0.13416816	99.9	3
4.75	4	0.31305903	99.7	7
2	6	0.58139535	99.4	13
0.425	24	1.65474061	98.3	37
0.075	98	6.03756708	94.0	135
Pan	2101	100	0.0	2236
Total	2236			

gravel %	sand %	finer (silt/clay) %
0.581	1.073	98.35



lab Engineer	Material Engineer



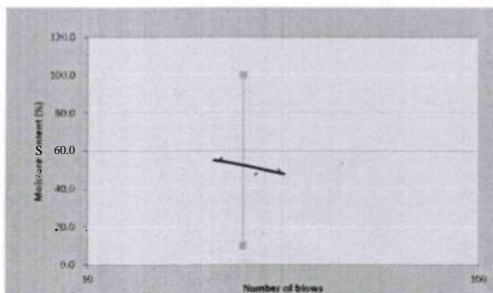


OPAL soil investigation center

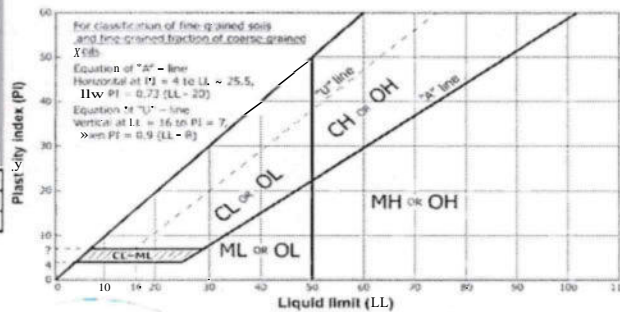
Represent Section	Gelcwsa class room	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1 Pits
Material Description	Brown Clayey Sand Soil	Test No	I

DETERMINATION OF LIQUID LIMIT & PLASTIC LIMIT OF SOIL TEST METHOD: ASTM D4318

Determination	Liquid Limit				Plastic Limit			
Number of blows		31	27	22				
Test	No	1	2	3	1	1		
Container	No	1	2	7	1	2		
wt of wt soil	(g)	0.05	0.04	0.04	0.03	0.03		
Wt. of container + dry soil	(g)	0.07	0.05	0.06	0.055	0.05		
wt of container	(g)	0.04	0.03	0.04	0.04	0.03		
Wt. of water	(g)	0.02	0.01	0.01	0.01	0.01		
Wt. of dry soil	(g)	0.03	0.03	0.03	0.02	0.02		
Moisture container	(%)	50.0	48.11	56.0	50.0	54.0		
Average	(%)	51.33				32.0		



Determination of (Pi)	LL	51
(LL - PI)	PL	32
	PI	19



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lab Engineer

[Signature]

Material Engineer

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 OPAL soil investigation center			
Represent Section		Gelewsa class room	Date Sampled
owner	UNOPS		Date Tested
Type of Material	foundation material	Sample No	1 Pits
Material Description	Brown Clayey Sand Soil	Test No	1

Specific gravity ASTM 854-90 Oven dried

S/no	Description	Determination number	
		1	2
1	Temperature in °c	31	31
2	Weight of bottle (w1) in g	18.42	18.23
3	Weight of bottle +dry soil (W 2)in g	28.96	28.95
4	Weight of bottle +soil + water (W3) in g	90.82	90.22
5	Weight of bottle + water (W4) in g	85.3	84.5
6	Specific gravity $G = \frac{W2-W1}{(W4-W1)-(W3-W2)}$	2.09960159	2.144
7	Average G at 31 °c	2.1218008	
8	corrected G at 27° =G*(relative density of water at room temprature/density of water at 27°c)	2.11930329	

relative density of ewater at room
temprature=0.995369

relative density of water at 27°C=0.996542





OPAL soil investigation center

Represent Section	Gelewsa toilet	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1Pits
Material Description	brown silty clay soil	Test No	2 1

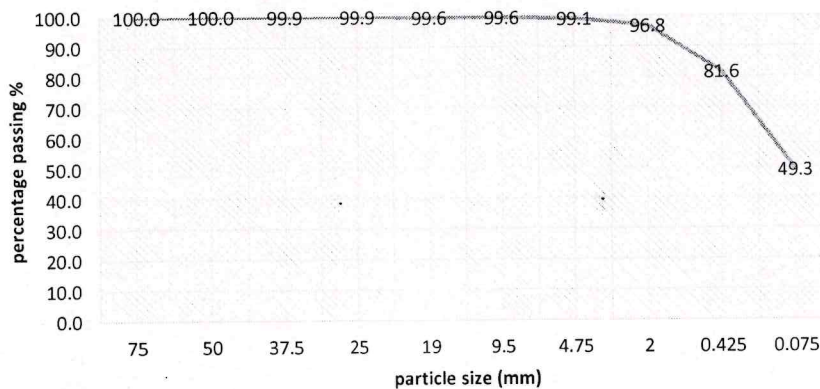
Particle Size Distribution of Sieve Analysis

ASTM D422

Sieve Size (mm)	weight Retained	% Retained	% pass	Commu Retained
75	0	0	100.0	0
50	0	0	100.0	0
37.5	2	0.09510223	99.9	2
25	0	0.09510223	99.9	2
19	7	0.42796006	99.6	9
9.5	0	0.42796006	99.6	9
4.75	9	0.85592011	99.1	18
2	49	3.18592487	96.8	67
0.425	320	18.4022825	81.6	387
0.075	680	50.7370423	49.3	1067
Pan	1036	100	0.0	2103
Total	2103			

gravel %	sand %	finer (silt/clay) %
3.186	15.22	81.5977


particle size distribution curve



lab Engineer

Material Engineer



 OPAL soil investigation center			
Represent Section		Gelewsa toilet	Date Sampled
owner		UNOPS	Date Tested
Type of Material	foundation material	Sample No	1 Pits
Material Description	brown silty clay soil	Test No 2	1


Specific gravity ASTM 854-90 Oven dried

S/no	Description	Determination number	
		1	2
1	Temperature in °C	31	31
2	Weight of bottle (w1) in g	18.87	18.46
3	Weight of bottle +dry soil (W2) in g	28.79	28.52
4	Weight of bottle +soil + water (W3) in g	90.82	90.22
5	Weight of bottle + water (W4) in g	84.74	83.85
6	Specific gravity $G = \frac{W2 - W1}{(W4 - W1) - (W3 - W2)}$	2.58333333	2.72629
7	Average G at 31 °C	2.6548103	
8	corrected G at 27° = $G \times (\text{relative density of water at room temperature} / \text{density of water at 27°C})$	2.6516854	

relative density of water at room
temperature=0.995369

relative density of water at 27°C=0.996542



 OPAL soil investigation center			
Represent Section	Gelewsa toilet	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1 Pits
Material Description	brown silty clay soil	Test No	2

free swell

Additive content	sample 1	sample 2
Vd = Volume of the soil specimen read		
from the graduated cylinder containing distilled water,	11.1	11.5
Vk = Volume of the soil specimen read		
from the graduated cylinder containing kerosene,	10	10
Free swell index = $(Vd - Vk / Vk) \times 100 (\%)$	11	15
Average Free swell index	13 %	





OPAL soil investigation center

Represent Section	Serenga class room	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1 Pits
Material Descriptor	Clayey SILT Soil	Test No	1

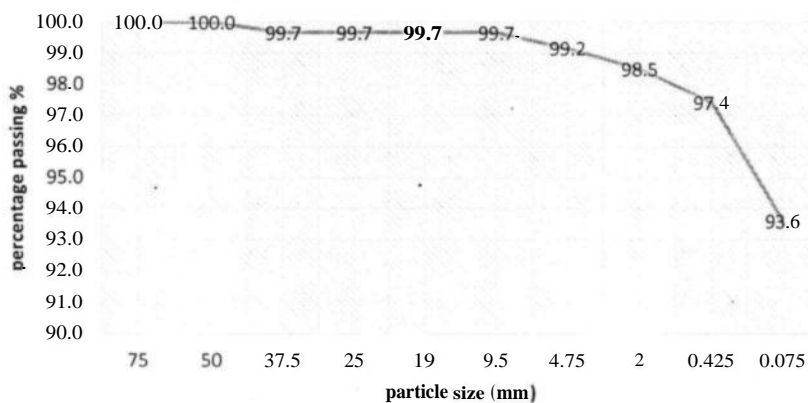
Particle Size Distribution of Sieve Analysis

ASTEM D422

Sieve Size (mm)	weight Retained	% Retained	% pass	Commu Retained
75	0	0	100.0	0
50	0	0	100.0	0
37.5	4	0.33167496	99.7	4
25	0	0.33167496	99.7	4
19	0	0.33167496	99.7	4
9.5	0	0.33167496	99.7	4
4.75	6	0.8291874	99.2	10
2	8	1.49253731	98.5	18
0.425	13	2.57048093	97.4	31
0.075	46	6.38474295	93.6	77
Pan	1129	100	0.0	1206
Total	1206			

gravel %	sand %	fines (silt/clay) %
1.493	1.078	97.43

particle size distribution curve



lab Engineer

Material Engineer



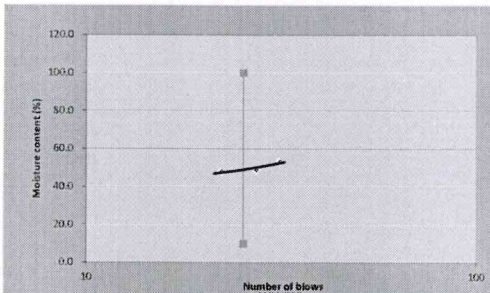


OPAL soil investigation center

Represent Section	Serenga class room	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1 Pits
Material Description	brown clay soil	Test No	1

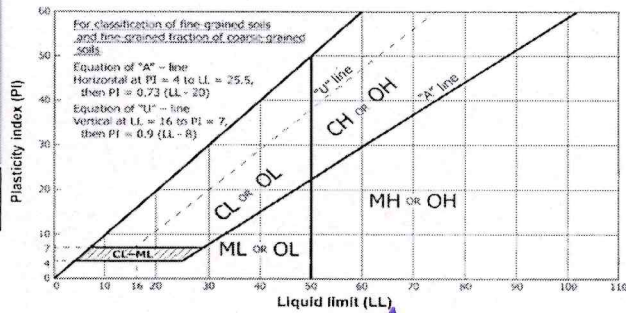
DETERMINATION OF LIQUID LIMIT & PLASTIC LIMIT OF SOIL TEST METHOD: ASTM D4318

Determination	Liquid Limit				Plastic Limit			
Number of blows		31	27	22				
Test	No	1	2	3	1	1		
Container	No	1	2	7	1	2		
Wt of wt soil	(g)	0.05	0.04	0.04	0.03	0.03		
Wt. of container + dry soil,	(g)	0.07	0.05	0.06	0.055	0.05		
Wt of container	(g)	0.04	0.03	0.04	0.04	0.03		
Wt. of water,	(g)	0.02	0.01	0.01	0.01	0.01		
Wt. of dry soil,	(g)	0.03	0.03	0.03	0.02	0.02		
Moisture content,	(%)	53.3	48.8	48.0	29.5	28.5		
Average	(%)	48.40				29.0		



Determination of (PI) (LL - PL)	LL	48
	PL	29
	PI	19

Remark



Lab Engineer

Material Engineer





OPAL soil investigation center

Represent Section	Serenga class room	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1Pits
Material Description	brown clay soil	Test No	1

Specific gravity ASTM 854-90 Oven dried

S/no	Description	Determination number	
		1	2
1	Temperature in °c	31	31
2	Weight of bottle (w1) in g	18.49	18.46
3	Weight of bottle +dry soil (W2)in g	27.12	28.23
4	Weight of bottle +soil + water (W3) in g	90.82	90.22
5	Weight of bottle + water (W4) in g	85.3	83.9
6	Specific gravity $G = \frac{W2 - W1}{(W4 - W1) - (W3 - W2)}$	2.77491961	2.83188
7	Average G at 31 °c	2.80340184	
8	corrected G at 27° = $G * (\text{relative density of water at room temprature} / \text{density of water at 27°c})$	2.80010203	

relative density of ewater at room
temprature=0.995369

relative density of water at 27°C=0.996542

SP



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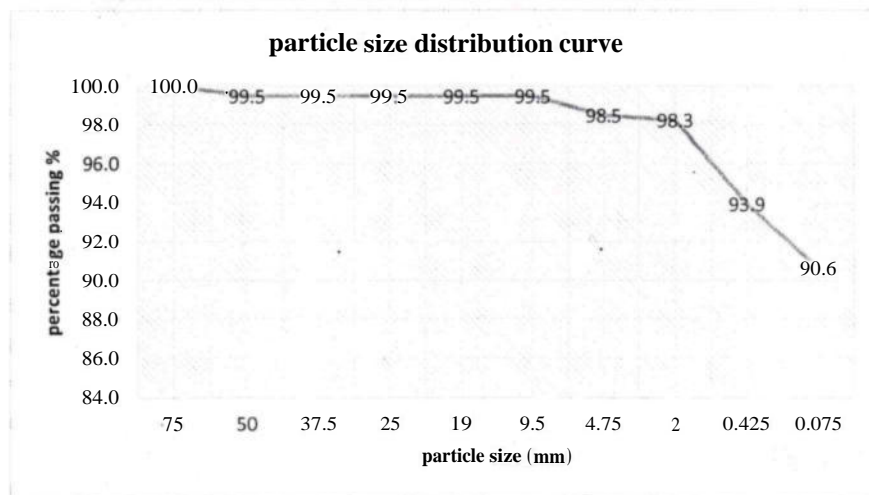
OPAL soil investigation center

Represent Section	Serenga Toilet	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1 Pits
Material Description	Gray Clay Soil	Test No	2 1

Particle Size Distribution of Sieve Analysis

VSTEM D422				
Sieve Size (mm)	weight Retained	% Retained	% pass	Comm Retained
75	0	0	100.0	0
50	6	0.49751244	99.5	6
37.5	0	0.49751244	99.5	6
25	0	0.49751244	99.5	6
19	0	0.49751244	99.5	6
9.5	0	0.49751244	99.5	6
4.75	12	1.49253731	98.5	18
2	3	1.74129353	98.3	21
0.425	52	6.05306799	93.9	73
0.075	40	9.36981758	90.6	113
Pan	1093	100	0.0	1206
Total	1206			

gravel %	sand %	fines (silt/clay) %
1.741	4.312	93.95



lab Engineer	Material Engineer

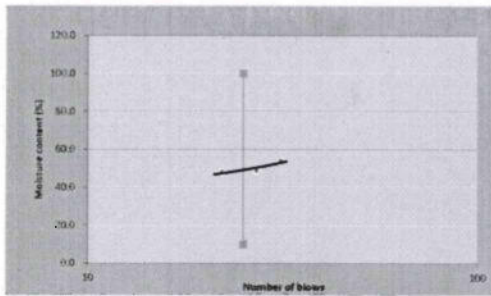




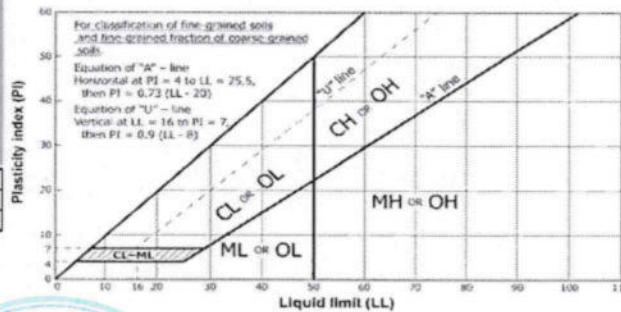
Represent Section	Screen Toilet	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	2
Material Description	Gray Clay Soil	Test No	1

DETERMINATION OF LIQUID LIMIT & PLASTIC LIMIT OF SOIL
TEST METHOD: ASTM D4318

Determination		Liquid Limit			Plastic Limit			
Number of blows		25	27	22				
Test	No	1	2	3	1	1		
Container	No	1	2	7	1	2		
wt of wt soil	(g)	0.05	0.04	0.04	0.03	0.03		
Wt. of container + dry soil	(g)	0.07	0.05	0.06	0.055	0.05		
wt of container	(g)	0.04	0.03	0.04	0.04	0.03		
Wt. of water	(g)	0.02	0.01	0.01	0.01	0.01		
Wt. of dry soil	(g)	0.03	0.03	0.03	0.02	0.02		
Moisture container	(%)	54.11	16.8	48.0	28.3	28.1		
Average	(%)		50.27			28.4		



Determination of (PI) (LL - PL)	LL	50
	PL	28
	PI	22



Remark

lab Engineer

Material Engineer





OPAL soil investigation center

Represent Section	Serenga Toilet	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	IPits
Material Description	Gray Clay Soil	Test No	2

Specific gravity ASTM 854-90 Oven dried

S/no	Description	Determination number	
		1	2
1	Temperature in °c	31	31
2	Weight of bottle (wl) in g	18.49	18.48
3	Weight of bottle +dry soil (W2) in g	27.12	28.2
4	Weight of bottle +soil + water (W3) in g	90.82	90.22
5	Weight of bottle + water (W4) in g	85.3	83.9
6	Specific gravity $G = \frac{W2 - W1}{(W4 - W1) - (W3 - W2)}$	2.77491961	2.85882
7	Average G at 31 °c	2.81687157	
8	corrected G at 27° = $G \times (\text{relative density of water at room temprature} / \text{density of water at 27°c})$	2.81355592	

relative density of ewater at room
temprature=0.995369

relative density of water at 27°C=0.996542

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OPAL soil investigation center

Represent Section	Mbewati class room	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1 Pits
Material Description	Clayey SILT Soil	Test No	1

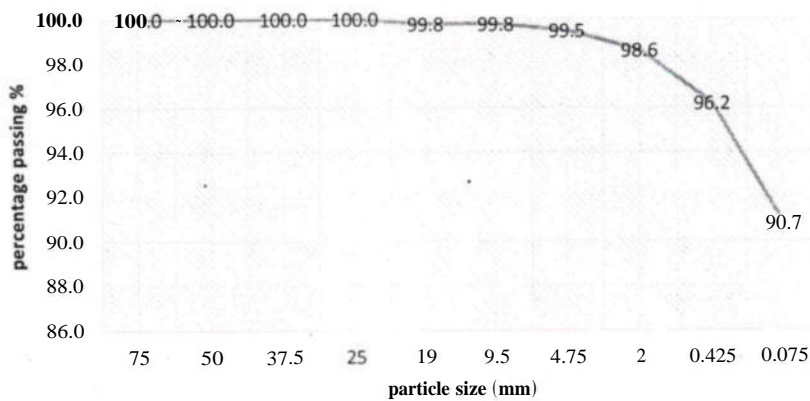
Particle Size Distribution of Sieve Analysis

VSTEM D422

Sieve Size (mm)	weight Retained	% Retained	% pass	Commu Retained
75	0	0	100.0	0
50	0	0	100.0	0
37.5	0	0	100.0	0
25	0	0	100.0	0
19	3	0.2238806	99.8	3
9.5	0	0.2238806	99.8	3
4.75	4	0.52238806	99.5	7
2	12	1.41791045	98.6	19
0.425	32	3.80597015	96.2	51
0.075	73	9.25373134	90.7	124
Pan	1216	100	0.0	1340
Total	1340			

gravel %	sand %	finer (silt/clay) %
1.418	2.388	96.19

particle size distribution curve



lab Engineer

Material Engineer

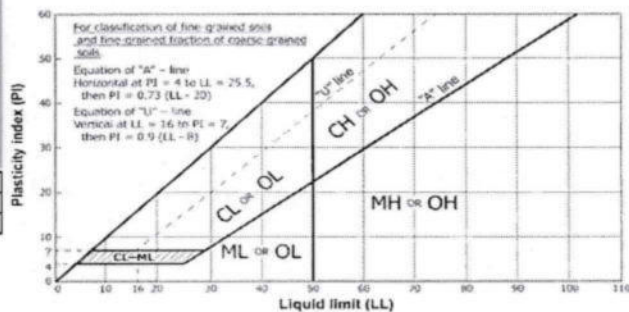
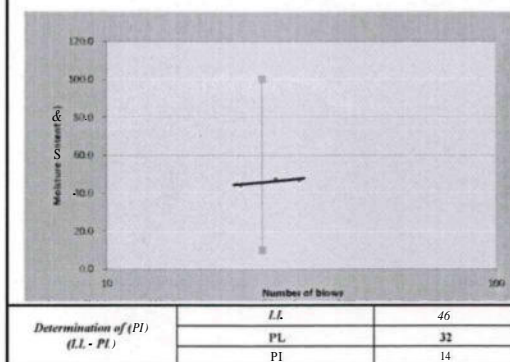




Represent Section	Mbewati class room	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1Pits
Material Description	Clayey Silt Soil	Test No	1

DETERMINATION OF LIQUID LIMIT & PLASTIC LIMIT OF SOIL
TEST METHOD: ASTM D4318


Determination		Liquid Limit			Plastic Limit			
Number of blows		25	27	30				
Test	No	1	2	3	1	1		
Container	No	1	2	7	1	2		
wt of wt soil	(g)	0.04	0.04	0.04	0.03	0.03		
Wt. of container + dry soil	(g)	0.07	0.05	0.06	0.055	0.05		
wt of container	(g)	0.04	0.03	0.04	0.04	0.03		
Wt. of water	(g)	0.01	0.01	0.01	0.01	0.01		
Wt. of dry soil	(g)	0.03	0.03	0.03	0.02	0.02		
Moisture content	(%)	4.7	4.0	4.0	5.0	5.0		
Average	(%)		4.00			5.0		



Remark

lab Eimincr	Material Eimincr
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 OPAL soil investigation center			
Represent Section		Mbcwati class room	Date Sampled
owner		UNOPS	Date Tested
Type of Material	foundation material	Sample No	I Pits
Material Description	Clayey Silt Soil	Test No	1

Specific gravity ASTM 854-90 Oven dried

S/no	Description	Determination number	
		1	2
1	Temperature in °c	31	31
2	Weight of bottle (w1) in g	18.42	18.23
3	Weight of bottle +dry soil (W2)in g	28.96	28.85
4	Weight of bottle +soil + water (W3) in g	90.82	90.22
5	Weight of bottle + water (W4) in g	85.3	83.9
6	Specific gravity $G = \frac{W2 - W1}{(W4 - W1) - (W3 - W2)}$	2.09960159	2.46977
7	Average G at 31 °c	2.28468452	
8	corrected G at 27° = $G \times (\text{relative density of water at room temprature} / \text{density of water at 27°c})$	2.28199528	

relative density of ewater at room
temprature=0.995369

relative density of water at 27°C=0.996542





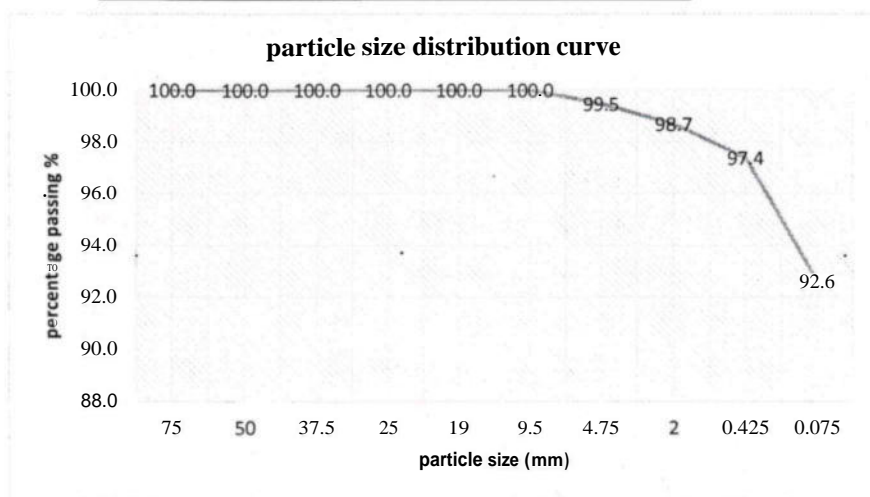
OPAL soil investigation center

Represent Section	Mbewati Toilet Area	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1 Pits
Material Description	Clayey SILT Soil	Test No	2

Particle Size Distribution of Sieve Analysis ASTM D422

Sieve Size (mm)	weight Retained	% Retained	% pass	Comm Retained
75	0	0	100.0	0
50	0	0	100.0	0
37.5	0	0	100.0	0
25	0	0	100.0	0
19	0	0	100.0	0
9.5	0	0	100.0	0
4.75	8	0.52287582	99.5	8
2	12	1.30718954	98.7	20
0.425	20	2.61437908	97.4	40
0.075	73	7.38562092	92.6	113
Pan	1417	100	0.0	1530
Total	1530			

gravel %	sand %	finer (silt/clay) %
1.307	1.307	97.39



lab Engineer	Material Engineer



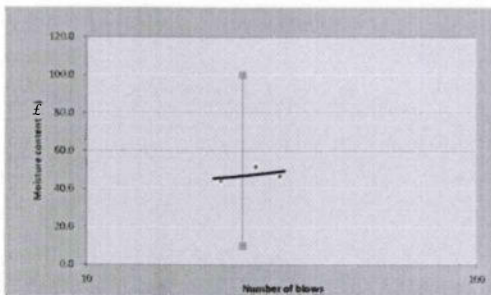


OPAL soil investigation center

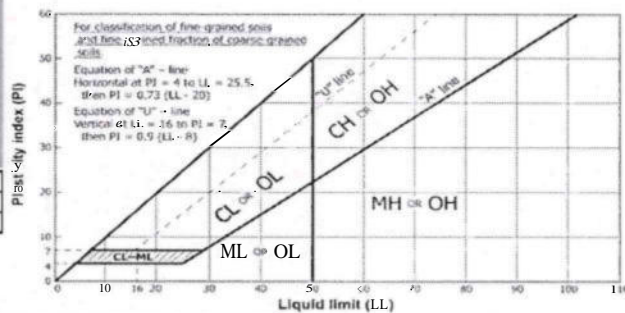
Represent Section	Mbewati Toilet Area	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1 Pits
Material Description	Clayey SILT Soil	Test No	2

DETERMINATION OF LIQUID LIMIT & PLASTIC LIMIT OF SOIL
TEST METHOD: ASTM D-4318

Determination		Liquid Limit				Plastic Limit			
Number of blows		31	27	22					
Test	No	1	2	3		1	1		
Container	No	1	2	7		1	2		
wt of wt soil	(g)	0.04	0.04	0.04		0.03	0.03		
Wt. of container + dry soil	(g)	0.07	0.05	0.06		0.055	0.05		
wt of container	(g)	0.04	0.03	0.04		0.04	0.03		
Wt. of water	(g)	0.01	0.01	0.01		0.01	0.01		
Wt. of dry soil	(g)	0.03	0.03	0.03		0.02	0.02		
Moisture content	(%)	16.7	32.0	44.0		30.0	34.0		
Average	(%)		48.00				32.0		



Determination of (PI) (LL - PL)	LL	48
	PL	32
	PI	16



Remark

Lab Engineer

Material Engineer





OPAL soil investigation center

Represent Section	Mbcwati Toilet Area	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	IPits
Material Description	Clayey SILT Soil	Test No	2

Specific gravity ASTM 854-90 Oven dried

S/no	Description	Determination number	
		1	2
1	Temperature in °c	31	31
2	Weight of bottle (w1) in g	18.42	18.23
3	Weight of bottle +dry soil (W2)in g	28.98	28.96
4	Weight of bottle +soil + water (W3) in g	90.82	90.22
5	Weight of bottle + water (W4) in g	85.3	85.3
6	Specific gravity $G = \frac{W2 - W1}{(W4 - W1) - (W3 - W2)}$	2.0952381	1.84682
7	Average G at 31 °c	1.97102697	
8	corrected G at 27° = $G \times (\text{relative density of water at room temprature} / \text{density of water at 27°c})$	1.96870693	

relative density of water at room
temprature=0.995369

relative density of water at 27°C=0.996542





Kisad Gaba PS – Test Pit No.1



Kisad Gaba PS – Test Pit No.2



Gelewsa Test Pit No.1



Gelewsa Test Pit No.2



Seregna PS Test Pit No.1



Seregna PS Test Pit No.2



Meswaety PS – Test Pit No.1



Meswaety – Test Pit No.2