

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 Outpatient Department (OPD), Staff Residence and Toilets for construction at Semret Health Post – Endhamoni Woreda.

Beneficiaries: The Project will cover conflict-affected communities in Ethiopia. However, this assignment is specific to beneficiaries in Tigray Region Selected Woreda in Tigray Regional State

- Endmahoni Woreda, South Zone; and

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 silty clayey soil to considerable depth exceeding of 5m 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 proposed location of the outpatient department 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 200 KPa to be used for Semret Health Post with a safety factor of 4.0. This report comprises information on the location of the test pits, pictures, log report and results of the laboratory analysis.

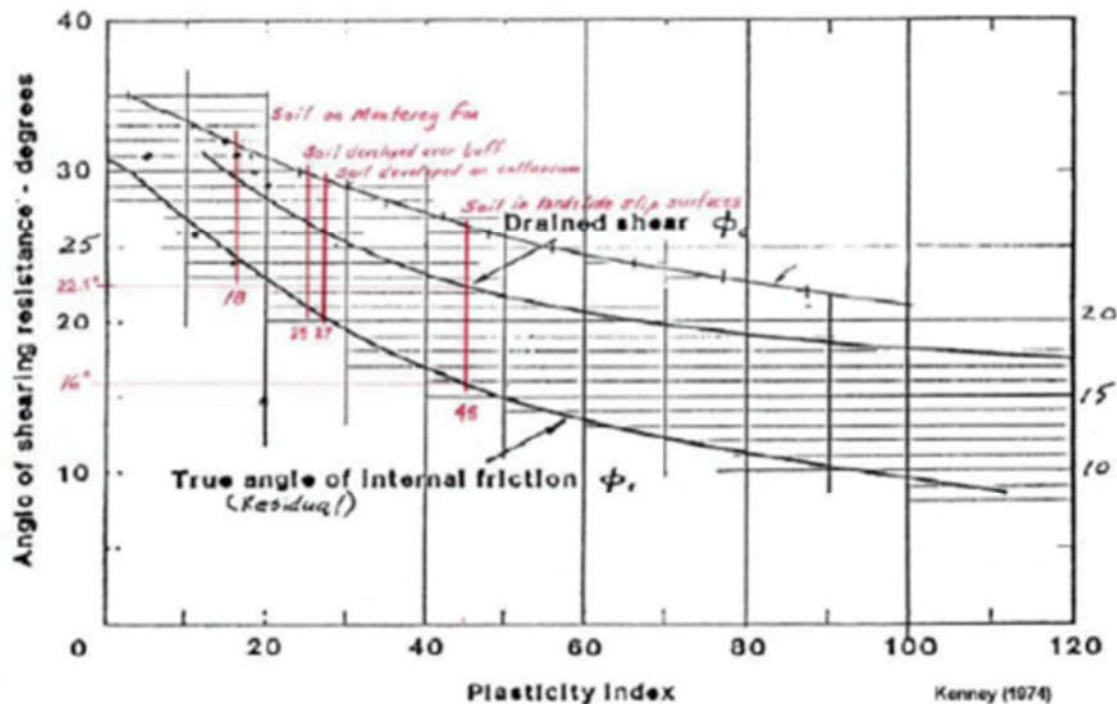
Geo-technical Investigation

Respons-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 toilet, outpatient department building and staff resident at existing health post 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 the health post. 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)
Semret Health Post	T.P.No. 01	SM- Non- Plastic silty CLAY with traces of sand	20	22.5	16
	T.P.No.02	SM- Non- Plastic silty CLAY with traces of sand	11	27	7

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:

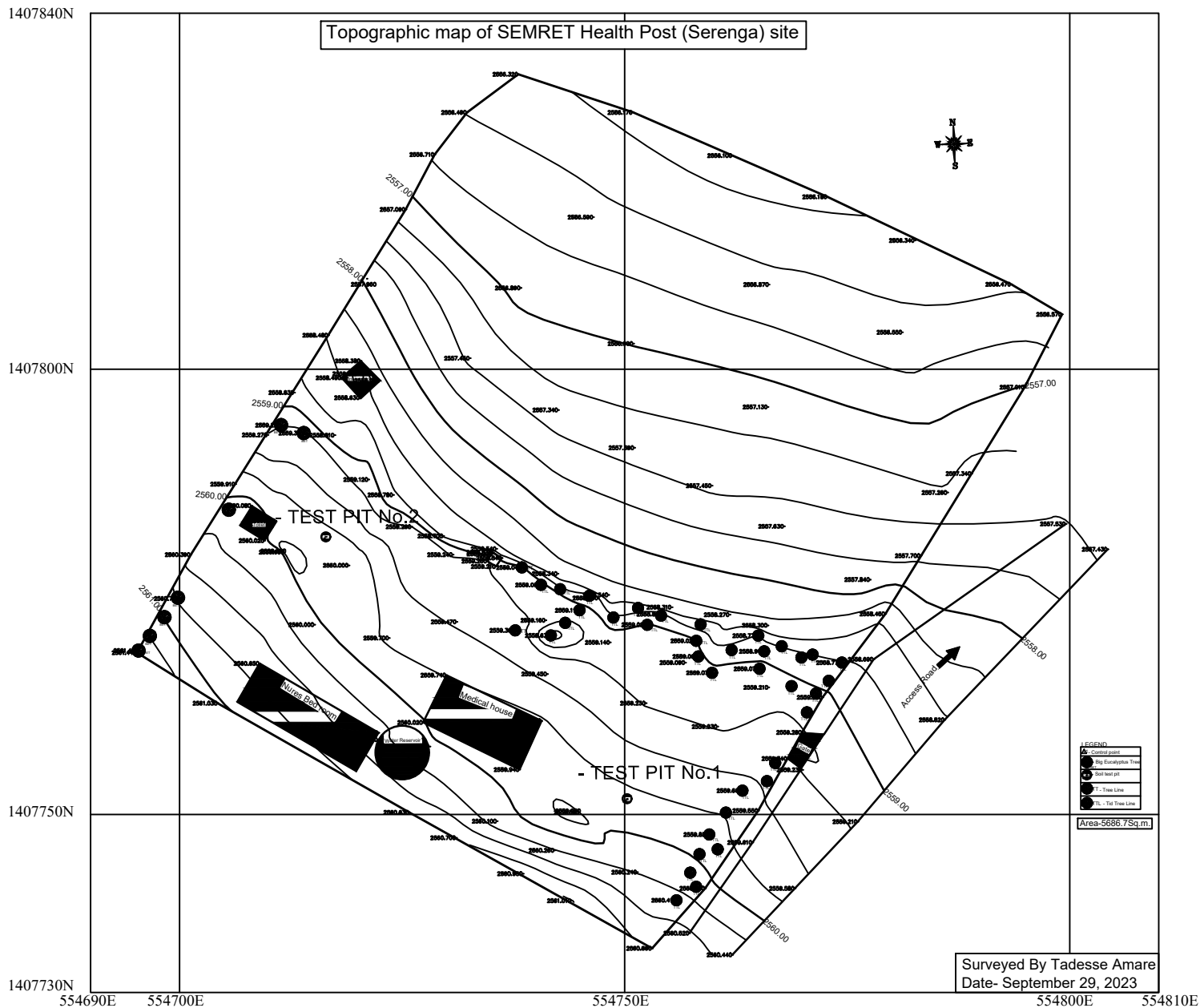
Sites	Friction angle (Degrees)	Cohesion (c) KPa	B (m)	D (m)	Nc	Nq	Ng	Ultimate Bearing Capacity Qu(Kpa)
Semret Health Post	22.5	16	1.0	2.0	21.4	10.0	7.4	858.4
	27	7	1.0	2.0	29.9	16.6	13.7	968.3

Considering a Safety Factor (SF) = 4.0, 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)
Semret Health Post	858.4	214.6

A recommended value of 200 KPa will be provided to the structural engineer for the design of foundations to Semret Health Post.

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





OPAL soil investigation center

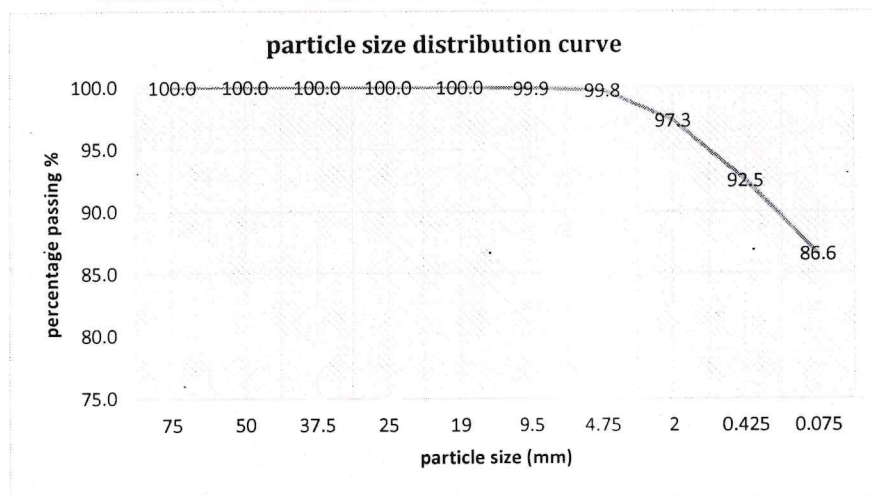
Represent Section	Simret health post Clinic Area	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1Pits
Material Description	brown clay soil	Test No	1

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	0	0	100.0	0
25	0	0	100.0	0
19	0	0	100.0	0
9.5	1	0.08064516	99.9	1
4.75	2	0.24193548	99.8	3
2	30	2.66129032	97.3	33
0.425	60	7.5	92.5	93
0.075	73	13.3870968	86.6	166
Pan	1074	100	0.0	1240
Total	1240			

gravel %	sand %	fines (silt/clay) %
2.661	4.839	92.5



lab Engineer

Material Engineer



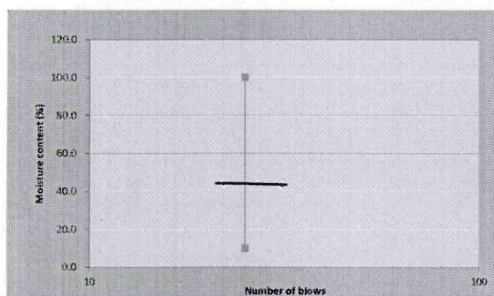


OPAL soil investigation center

Represent Section	Simret health post Clinic Area	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1Pits
Material Description	brown clay soil	Test No	1

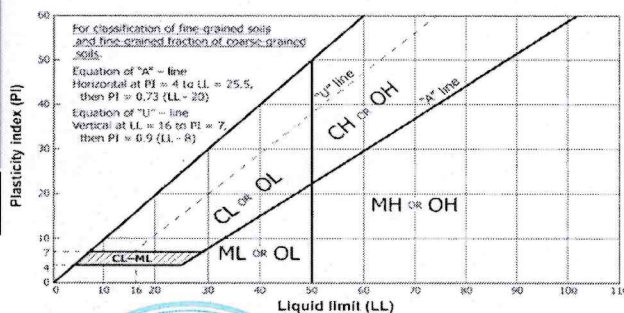
DETERMINATION OF LIQUID LIMIT & PLASTIC LIMIT OF SOIL TEST METHOD: ASTM D4318

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)	0.04	0.04	0.04	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	0.01	0.00	0.00		
Wt. of dry soil,	(g)	0.03	0.03	0.03	0.02	0.02		
Moisture container,	(%)	43.3	44.0	44.0	24.0	23.5		
Average	(%)	43.78				23.8		



Determination of (PI)
(LL - PL)

LL	44
PL	24
PI	20



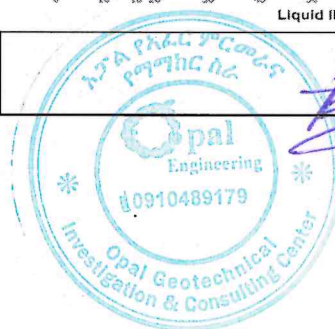
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Lab Engineer

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Material Engineer

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OPAL soil investigation center

Represent Section	Simret health post Clinic Area	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	18.57	18.5
3	Weight of bottle +dry soil (W2)in g	28.12	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 $G = \frac{W2-W1}{(W4-W1)-(W3-W2)}$	2.75216138	2.74521
7	Average G at 31 "c	2.74868343	
8	corrected G at 27" = $G * (\text{relative density of water at room temprature/density of water at 27" c})$	2.74544804	

relative density of ewater at room
temprature=0.995369

relative density of water at 27"C=0.996542



 OPAL soil investigation center			
Represent Section	Simret health post Clinic Area	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1 Pits
Material Description	brown clay 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,	15.4	15.3
Vk = Volume of the soil specimen read		
from the graduated cylinder containing kerosene,	10	10
Free swell index = $(V_d - V_k) / V_k \times 100 (\%)$	54	53
Average Free swell index	53.5 %	





OPAL soil investigation center

Represent Section	Simret health post toilet	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1Pits
Material Description	brown clay soil	Test No	1

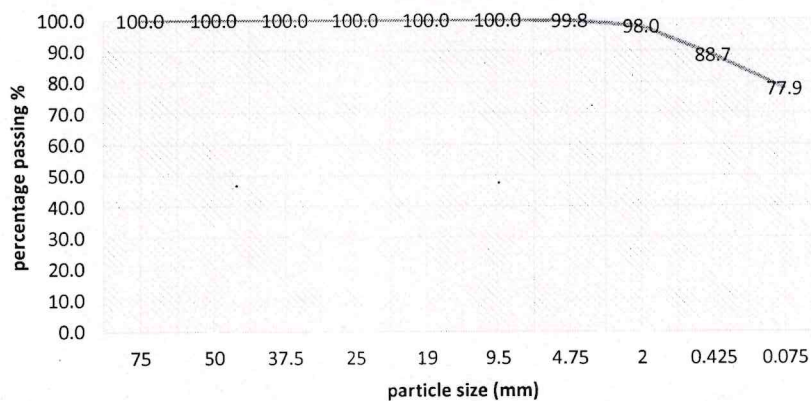
Particle Size Distribution of Sieve Analysis

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	0	0	100.0	0
19	0	0	100.0	0
9.5	0	0	100.0	0
4.75	2	0.17621145	99.8	2
2	21	2.02643172	98.0	23
0.425	105	11.277533	88.7	128
0.075	123	22.1145374	77.9	251
Pan	884	100	0.0	1135
Total	1135			

gravel %	sand %	fines (silt/clay) %
2.026	9.251	88.72

particle size distribution curve



lab Engineer

Material Engineer



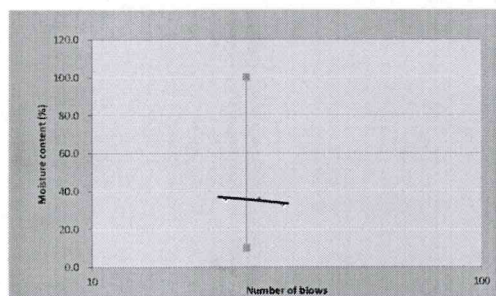


OPAL soil investigation center

Represent Section	Simret health post toilet	Date Sampled	
owner	UNOPS	Date Tested	
Type of Material	foundation material	Sample No	1 Pits
Material Description	brown clay soil	Test No	1

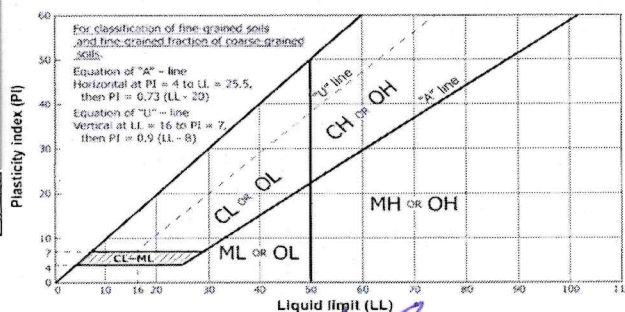
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Container	No	1	2	7		2		
wt of wt soil	(g)	0.04	0.03	0.03	0.03	0.03		
Wt. of container + dry soil	(g)	0.07	0.05	0.06	0.053	0.05		
wt of container	(g)	0.04	0.03	0.04	0.04	0.03		
Wt. of water	(g)	0.01	0.01	0.01	0.01	0.01		
Wt. of dry soil	(g)	0.03	0.03	0.03	0.02	0.02		
Moisture container	(%)	33.0	36.0	36.0	25.0	25.0		
Average	(%)	36.00				25.0		



Determination of (PI)
(LL - PL)

LL	36
PL	25
PI	11




Remark

lab Engineer

Material Engineer



 OPAL soil investigation center			
Represent Section		Simret health post toilet	Date Sampled
owner		UNOPS	Date Tested
Type of Material	foundation material	Sample No	1 Pits
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
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3	Weight of bottle +dry soil (W2)in g	28.56	28.52
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5	Weight of bottle + water (W4) in g	84.74	83.85
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7	Average G at 31 °c	2.65009635	
8	corrected G at 27° = $G \times (\text{relative density of water at room temprature} / \text{density of water at 27°c})$	2.646977	

relative density of ewater at room
temprature=0.995369

relative density of water at 27°C=0.996542



 OPAL soil investigation center			
Represent Section	Simret health post toilet		Date Sampled
owner	UNOPS		Date Tested
Type of Material	foundation material	Sample No	IPits
Material Description	brown clay 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,	13.2	14.9
Vk = Volume of the soil specimen read		
from the graduated cylinder containing kerosene,	10	10
Free swell index = $(Vd - Vk / Vk) \times 100 (\%)$	32	49
Average Free swell index	40.5 %	

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Semret HP– Test Pit No.1



Semret HP – Test Pit No.2