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SUBSURFACE INVESTIGATION REPORT

1435 & 1453 BELCOURT BLVD, OTTAWA, ON, K1C 1M1

Abstract

This report presents the findings of a Subsurface Investigation completed at the 1435 & 1453 Belcourt Blvd parcels, in the City of Ottawa, ON, K1C 1M1. The investigation included field and laboratory testing tailored to confirm the existence of sensitive marine clay known to exist within the proximity of the slopes around the nearby Billberry Creek and to measure its sensitivity. It was found that the site is underlain by silty clay and that the silty clay is sensitive at about 7.2 m depth and up to 20 m depth of investigation. The site location is shown in fig.1 in page 6 and the cased hole locations, elevations and depths are shown in figure 2 in page 8. The information reviewed also includes readily available geologic information from the Geological Survey of Canada (GSC).

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Report number: 91-BPG-R0[1]
April 15, 2026

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[1] For the account of Bearbrook Property Group (BPG).

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1 Introduction

Sensitive marine clay deposits are present within significant portions of the City of Ottawa (Cof O). Slopes in these deposits are susceptible to retrogressive slides. Retrogressive slides are ground slides that can spread over large areas. Retrogressive slides can be triggered by erosion, precipitation, earthquakes and development. The C of O, in partnership with Conservation Authorities (CAs) are seeking mitigation of the risks associated with retrogressive slides by delineating the extent of the risk and limiting development. In lieu of a finished guideline, in order to confirm the extent of the risk, the C of O and the CAs are using the following means:

1. Some available information suggesting the presence of sensitive clays;
2. A definition of the geometry of a slope or an escarpment, which renders a geotechnical investigation required for confirmation;
3. A preliminary definition of the extent of the risk
4. The minimum geotechnical investigation requirements to either confirm or deny the presence of the risk;
5. A process to approve the scope of proposed investigations;
6. The criteria rendering the site as risky;

The details of the delineation and the minimal geotechnical investigation requirements are in the "Technical Guidance on Slope Stability Assessment Requirements for Development Applications with Sensitive Marine Clays," which is provided to developers proposing development within the preliminary delineation.

The scope of the investigation here reported has been subject to the process in item 5, which rendered the scope as "Scope of work is sufficient to determine if the soil conditions on site would meet criteria for retrogressive landslide susceptibility." in an RVCA letter dated February 23, 2026, and distributed via email.

Part I

Investigation

2 Sampling and Testing

The field and laboratory program set out in our proposal is guided by the following standards:

- ASTM D 420-98 Standard Guide to Site Characterization for Engineering Design and Construction Purposes,

Figure 1: Key Plan

- ASTM D5434 - 12 Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock,
  - A sampling hole (at 0.76 m intervals) and a shear vane hole (at 1 m intervals) were advanced to 20 m and logged in the field. For the purpose of this report, the report borehole logs attached to this report are 3 borhole logs labeled BH1A, BH1B and BH1C. BH1A presents the parameters sought from this investigation (namely, the liquidity index and the remoulded shear strength at the natural water content), BH1B only adds the plastic limit to the information in BH1A, and BH1C focuses on the undisturbed shear strength, which is the more useful parameter for the purpose of development. This responds to the variation of ranges for each parameter, making the logs appear "cluttered" and difficult to read.
- ASTM D1586 - 11 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils,
  - The ASTM D1586 tests were completed using an "auto safety" hammer rated at 85% energy.
- ASTM D2573 - 08 Standard Test Method for Field Vane Shear Test in Cohesive Soil.
  - Shear vanes were completed using a "Roctest" "Vane Borer Model M-1000" (M-1000). The Instruction Manual can be found in the appendices. The M-1000 lacks sufficient resolution for the lower range of remoulded shear strengths in sensitive clays. An M & A engineer followed the tracing of records produced by the M-1000 to ensure proper identification of key components of the record, including the presence, or lack thereof, of a traceable value of remoulded shear

strength. The record was then labelled immediately with the letters, SV# and “PEAK” to denote the Shear Vane number and the peak of the remoulded shear strength (when visible) to ensure proper reading at a later time. Other meaningful labels were added to the record when judged as necessary. These records are presented in the appendices.

- AASHTO T 265-15 Laboratory determination of moisture content of soil;
- ASTM D1587 - 08(2012)e1 Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes,
  - Upon extraction of Shelby tubes, the tip of the sample was reviewed to ascertain the type of materials sampled.
- IS : 2720 (Part 5) - 2006, section 4 Test For the determination of liquid limit by cone penetration method;
- Tanzen, R. (2016). Determination of Plastic Limit using Cone Penetrometer
- S. Hansbo, Proc. Roy. SGI 14, 7-48 (1957): Use of Hansbo’s equation for the estimation of undrained shear strength based on cone penetration test data.
  - M-1000 remoulded shear strength measurements were sought to determine the K constant in Hansbo’s equation for greater accuracy and calibration of the laboratory test program. This was not realized within the tests program due to numerous limitations involving varying materials within the profile.

The elevation of the boreholes is estimated based on topographic surface elevations and their location.

Part II

Findings

3 Physical Settings, Strata and Topography

The site is a developed residential subdivision (detached dwellings) on land sloping downward (± 4.5 %) to the north. It is located to the east of Ottawa, ON as shown in Fig.1 in page 6. Its shortest distance to the Bilberry Creek is ± 215 m.

Figure 2 in page 8 shows a plan view of the site displaying the approximate test hole locations, elevations and depth.

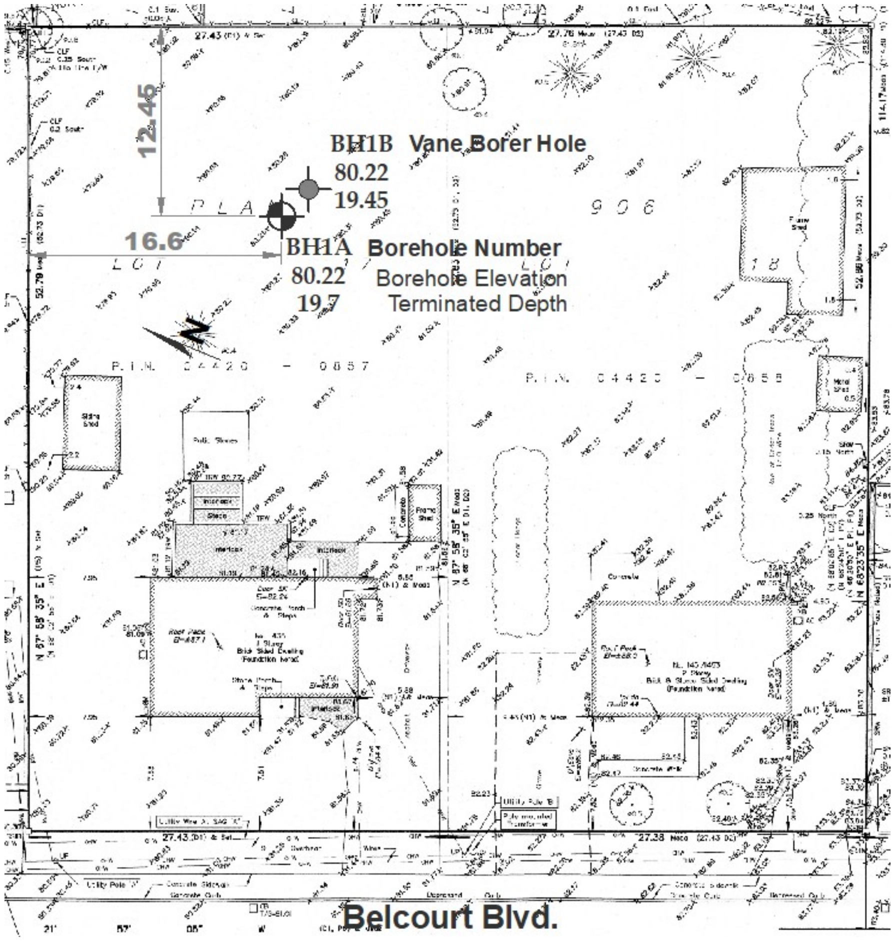

Figure 2: Test hole Locations Plan

It can be seen in the testhole logs in Appendix A that the site is a deep, stiff, silty clay deposit. The typical crust of very stiff silty clay that overlays the deposit is ± 4.8 m thick based on stiffnesses greater than 100 kPa above that elevation. The water table is interpreted to be at this same depth. The deposit extends to depths greater than the 20 m depth of investigation, as suggested by the geology database by Belanger (1998).

The geology data base by Belanger J. R. 1998 suggests 25 to 50 m of overburden soils underlain by shale bedrock at this site.

Part III

Geotechnical Assessments

The totality of tests completed can be described as follows:

- 1 Fall Cone Test (FC) completed for each of 23 Shelby tubes extracted at 0.75 m intervals to a maximum depth of 20 m;
- 2 moisture contents for each of the above Shelby tube samples;
- 2 field shear vane tests at each of 1 m intervals of 18 m starting at 2.4 m depth in a vane borer hole for this purpose only. One shear vane test in undisturbed clay and one remoulded shear strength at each vane testing depth. The M-1000 resolution for very low remoulded shear strengths did not yield measurements at many test depth locations.

The totality of data points and plots for the fall cone tests, the table of results, the labelled vane testing records and a classification via a plasticity chart are presented in the appendices. The materials are classified as silts and clays of high plasticity in general.

Only the table of results is presented within the body of the report for ease of reference.

Given the limitations in the resolution of the low values of shear strength of the M-1000, the interpretation of remolded shear strength is based solely in fall cone tests.

4 General Requirements

As a general requirement, “a clay is classified as susceptible to retrogressive landslides if the liquidity index (LI) (as determined from the prescribed investigation program) exceeds 1.0 ($IL - fc > 1.0$) and the remoulded shear strength is less than 1.6 kPa ($Sur - fc < 1.6$ kPa)”. While as written, it is 2 requirements, in essence is only one. This is because the shear strength (calculated from Hansbo’s equation) at the liquid limit, calculated from the penetration at the liquid limit, is 1.6 kPa (regardless of the standard used). One could thus say that the requirement is $IL - fc > 1.0$.

The definition of index properties from the fall cone test has many advantages over the Casagrande method, as one can rely on various configurations of the fall cone apparatus to obtain comparable results, albeit with similar workload demands for both methods.

Both results, the liquidity index and the shear strength at the natural water content, are calculated in this report.

4.1 Fall Cone Testing

The fall cone test equipment is the Indian type, having a 30-degree tip extending 30 mm in height and weighing 148 g (1.45 N). There is always a fall cone test result at the exact natural water content as tested immediately at the time of the extraction of the sample.

4.1.1 Normalization

The results are normalized to the British cone having a 30-degree tip extending 30 mm in height and weighing 80 g (0.78 N). After normalization, the fallcone used correlates at 4 mm and 27 mm penetration for the plastic limit and liquid limit respectively. The normalization is via Hansbo's equation. The British cone correlates at 2 mm and 20 mm penetration for the plastic limit and liquid limit respectively.

4.1.2 Limitations

The highest bound limit penetration depth of any fallcone is the height of the tapered portion of the cone. Measurements higher than this limit cannot be relied upon as the failure mechanics are different once the tapered portion is passed. For the fallcone used the limiting depth of penetration is 30 mm. What this means is that the minimum measurable shear strength for our test program is 1.3 kPa which is the strength calculated for the 30 mm penetration depth. Hence, for any natural water content for which the penetration is greater than 30 mm, our table of results show < 1.3 kPa.

For sensitive clays, the strength can be rendered as zero in our view as the behaviour is that of a sludge. Perhaps it is more of a problem of viscosity.

4.1.3 Plots

The test data points are fitted to a line based on a statistical regression automated via a computer algorithm. The liquid and plastic limits are picked automatically at penetrations of 27 and 4 mm, respectively. The calculation of shear strength based on the penetration at the soil's natural water content is completed and shown directly on the plot. All the results associated with each plot are shown on each plot.

Part IV
Results

5 Fall Cone Tests Results

The table below presents the results of Fall Cone Testing.

It can be seen in the table that below ST-10 at 7.2 m depth, all samples have a natural water content (wn(%)) greater than the liquid limit and thus, a shear strength less than 1.7 kPa.

The LI at ST-7 greater than 1 represents an outlier in the set, which may indicate measurement errors or experimental variability.

Variability in the determination of index properties of clays is a well-known issue in geotechnical engineering. Overall, however, the tests capture representative behaviour of the materials encountered at this site.

Table: Fall Cone Test Results

ID	wn (%)	LL (%)	PL (%)	PI (%)	LI	τ
ST-3	38.5	53.	32.7	20.3	0.28	72.6 kPa
ST-4	38.8	57.6	35.5	22.1	0.14	72.6 kPa
ST-5	53.5	63.3	33.1	30.2	0.68	8.1 kPa
ST-6	56.2	69.5	40.4	29.1	0.54	8.1 kPa
ST-7	78.5	73.6	38.8	34.7	1.14	2.4 kPa
ST-8	73.5	77.6	50.	27.6	0.86	2.2 kPa
ST-9	72.4	79.5	41.4	38.2	0.82	2.4 kPa
ST-10	71.1	71.4	42.2	29.2	0.98	1.7 kPa
ST-11	68.3	65.8	41.5	24.4	1.1	1.5 kPa
ST-12	70.4	67.7	31.5	36.2	1.08	1.4 kPa
ST-13	71.8	68.1	23.9	44.2	1.08	1.4 kPa
ST-14	74.3	80.4	10.5	69.9	0.92	1.6 kPa
ST-15	72.5	59.1	45.	14.1	1.96	< 1.3 kPa
ST-16	72.2	59.2	16.7	42.5	1.3	< 1.3 kPa
ST-17	74.	51.1	35.	16.1	2.42	< 1.3 kPa
ST-18	68.8	55.5	33.3	22.2	1.6	< 1.3 kPa
ST-19	69.4	51.4	41.6	9.8	2.84	< 1.3 kPa
ST-20	69.6	51.7	39.7	12.	2.5	< 1.3 kPa
ST-21	72.7	44.	34.3	9.7	3.96	< 1.3 kPa
ST-22	74.	61.7	16.8	44.9	1.28	< 1.3 kPa
ST-23	64.	50.	31.8	18.2	1.76	< 1.3 kPa
ST-24	69.7	54.8	30.7	24.1	1.62	< 1.3 kPa
ST-25	68.7	54.5	32.6	21.9	1.64	< 1.3 kPa
ST-26	65.7	52.4	33.3	19.0	1.7	< 1.3 kPa

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Part V

Appendices

A Borehole Logs

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Project: **Proposed Low Rise Residential Buildings**

M&A Mendez & Associates Ltd.

Location: **1435 Belcourt Blvd.**

Client: **Bearbrook Property Group**

Test Hole No.: BH1A of 1

Job No.: **91-BPG**

Test Hole Type: **Cased Hole and Vane Borer Hole**

Date: **3/11/2026**

"3" ID Casing"

SPT Hammer Type: **Safety auto hammer**

Logged By: **Yuri Mendez**

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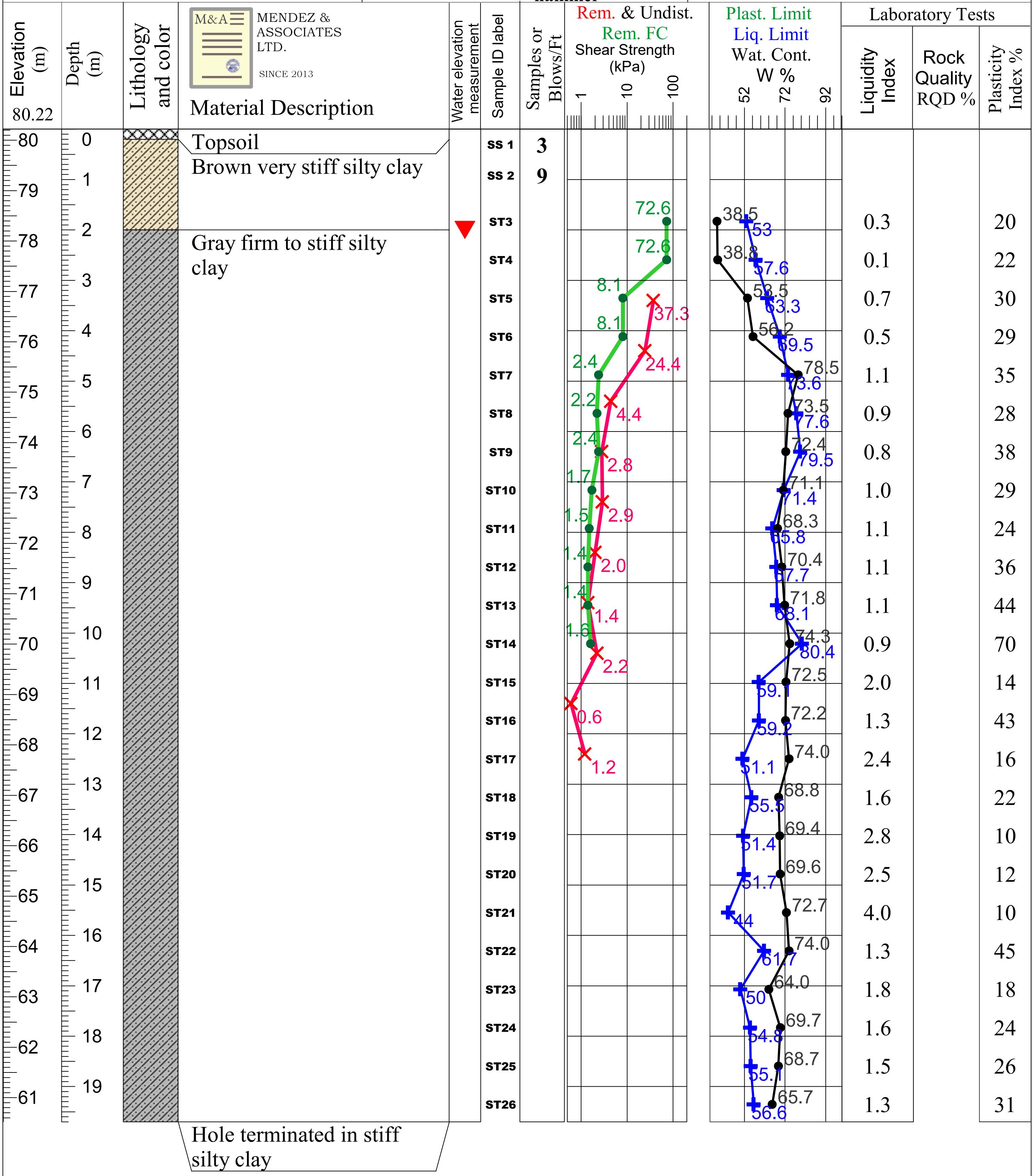


Material Description

Topsoil

Brown very stiff silty clay

Gray firm to stiff silty clay

Hole terminated in stiff silty clay

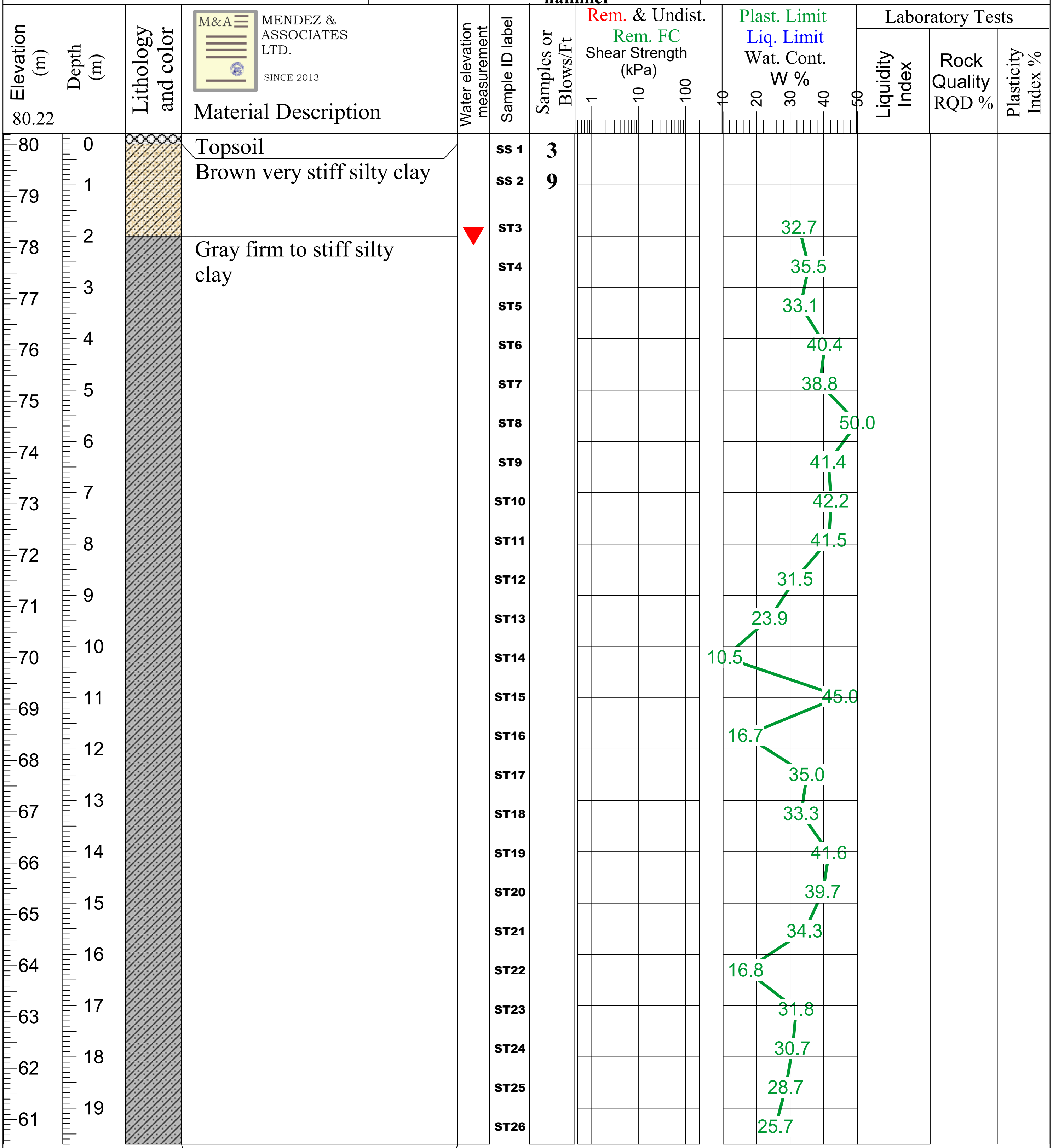
Laboratory Tests

Sample ID label	Samples or Blows/Ft	Liquidity Index	Rock Quality RQD %	Plasticity Index %
SS 1	3			
SS 2	9			
ST3		0.3		20
ST4		0.1		22
ST5		0.7		30
ST6		0.5		29
ST7		1.1		35
ST8		0.9		28
ST9		0.8		38
ST10		1.0		29
ST11		1.1		24
ST12		1.1		36
ST13		1.1		44
ST14		0.9		70
ST15		2.0		14
ST16		1.3		43
ST17		2.4		16
ST18		1.6		22
ST19		2.8		10
ST20		2.5		12
ST21		4.0		10
ST22		1.3		45
ST23		1.8		18
ST24		1.6		24
ST25		1.5		26
ST26		1.3		31

S = Sample for lab review and moisture content

▼ Water Elevation Estimated

Project: **Proposed Low Rise Residential Buildings**		M&A Mendez & Associates Ltd.
Location: **1435 Belcourt Blvd.**	Client: **Bearbrook Property Group**	**Test Hole No.: BH1B of 1**
Job No.: **91-BPG**	Test Hole Type: 8 1/4" OD	Date: **3/11/2026**
"3" ID Casing"	SPT Hammer Type: **Safety auto hammer**	Logged By: **Yuri Mendez**



Material Description	Sample ID label	Samples or Blows/Ft	Wat. Cont. W %
Topsoil	SS 1	3	
Brown very stiff silty clay	SS 2	9	
	ST3		32.7
Gray firm to stiff silty clay	ST4		35.5
	ST5		33.1
	ST6		40.4
	ST7		38.8
	ST8		50.0
	ST9		41.4
	ST10		42.2
	ST11		41.5
	ST12		31.5
	ST13		23.9
	ST14		10.5
	ST15		45.0
	ST16		16.7
	ST17		35.0
	ST18		33.3
	ST19		41.6
	ST20		39.7
	ST21		34.3
	ST22		16.8
	ST23		31.8
	ST24		30.7
	ST25		28.7
	ST26		25.7

Hole terminated in stiff silty clay

S = Sample for lab review and moisture content

▼ Water Elevation Estimated

Project: **Proposed Low Rise Residential Buildings**

M&A Mendez & Associates Ltd.

Location: **1435 Belcourt Blvd.**

Client: **Bearbrook Property Group**

Test Hole No.: BH1C of 1

Job No.: **91-BPG**

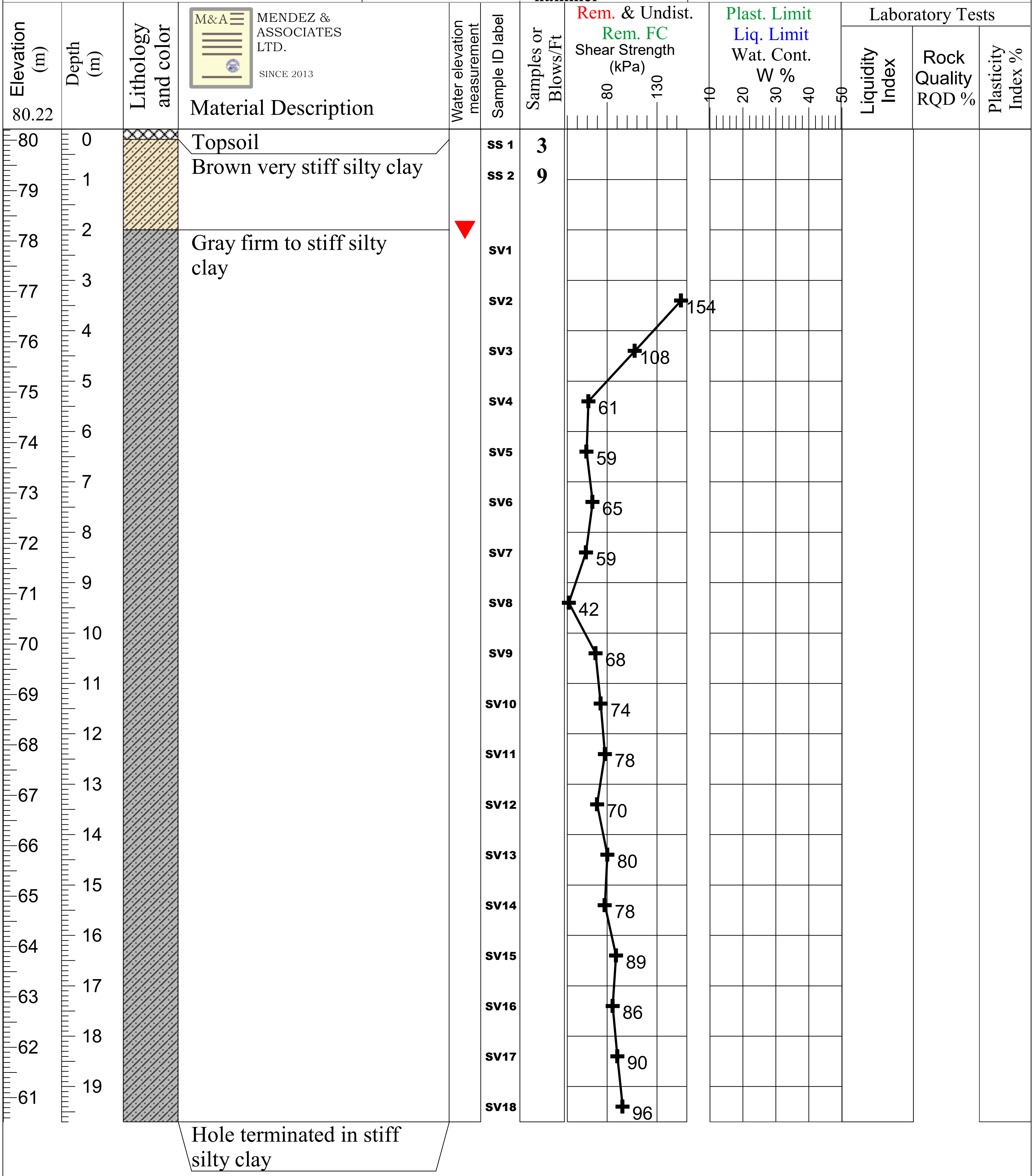
Test Hole Type: **Cased Hole and Vane Borer Hole**

Date: **3/11/2026**

"3" ID Casing"

SPT Hammer Type: **Safety auto hammer**

Logged By: **Yuri Mendez**



Topsoil

Brown very stiff silty clay

Gray firm to stiff silty clay

Hole terminated in stiff silty clay

SS 1	3	
SS 2	9	
SV1		
SV2		154
SV3		108
SV4		61
SV5		59
SV6		65
SV7		59
SV8		42
SV9		68
SV10		74
SV11		78
SV12		70
SV13		80
SV14		78
SV15		89
SV16		86
SV17		90
SV18		96

S = Sample for lab review and moisture content

▼ Water Elevation Estimated

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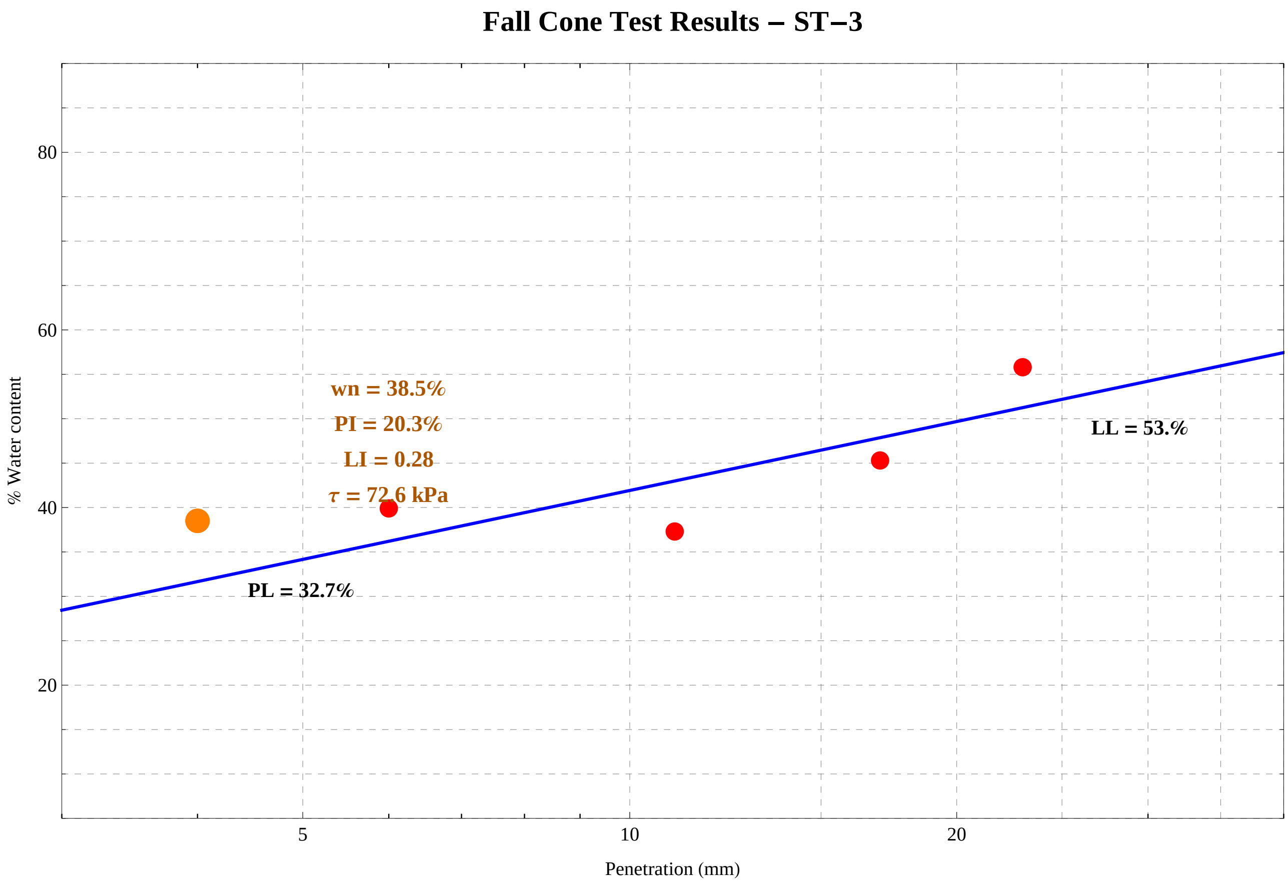
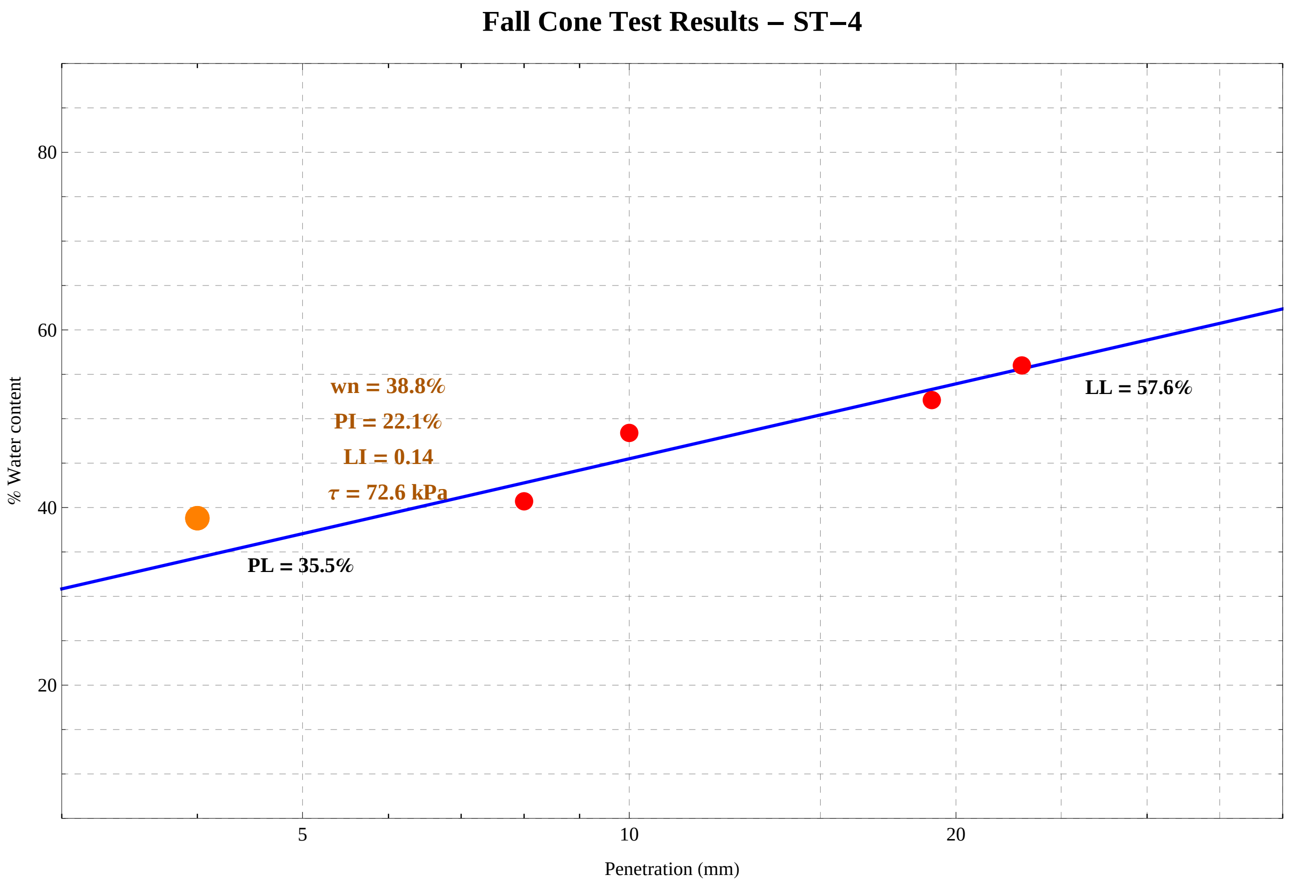
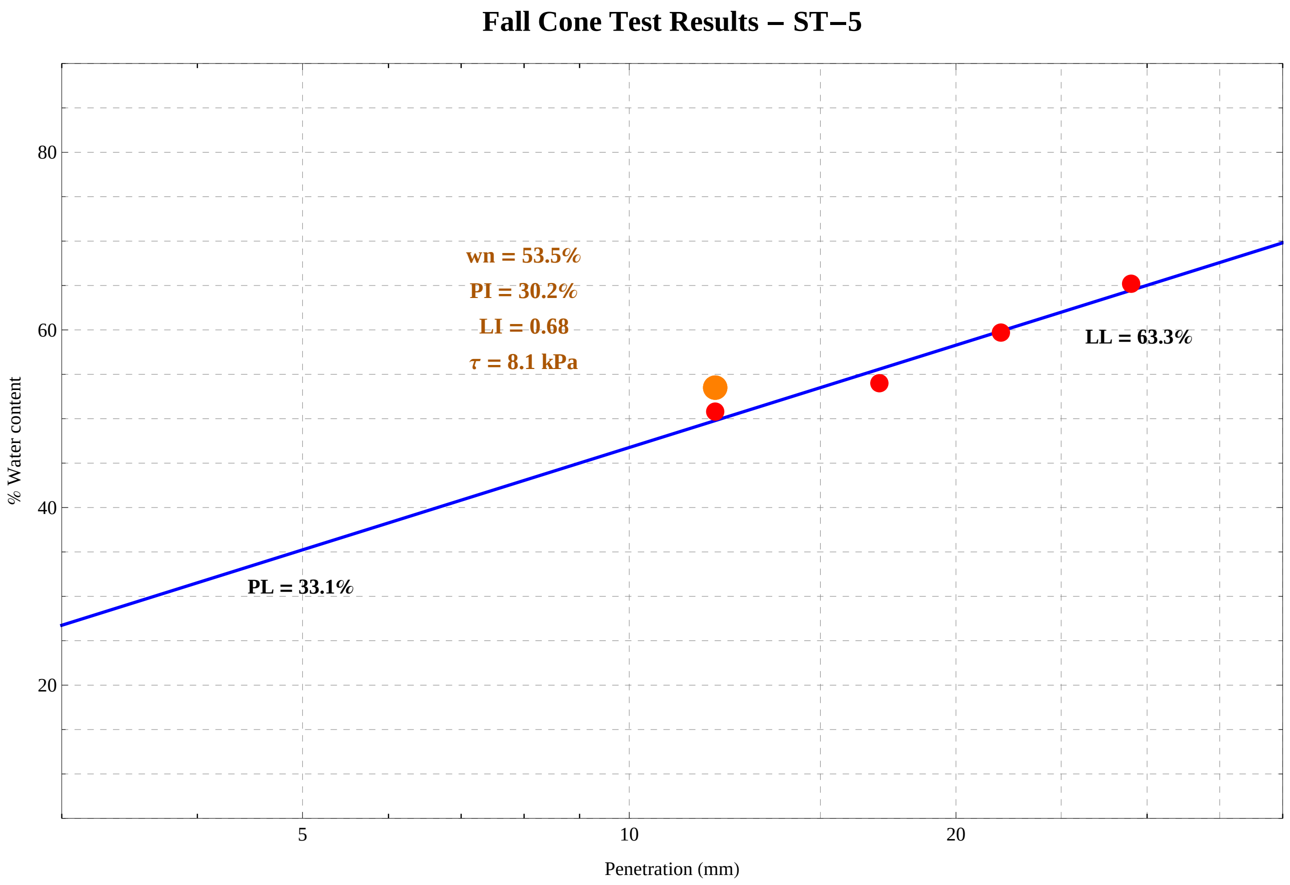
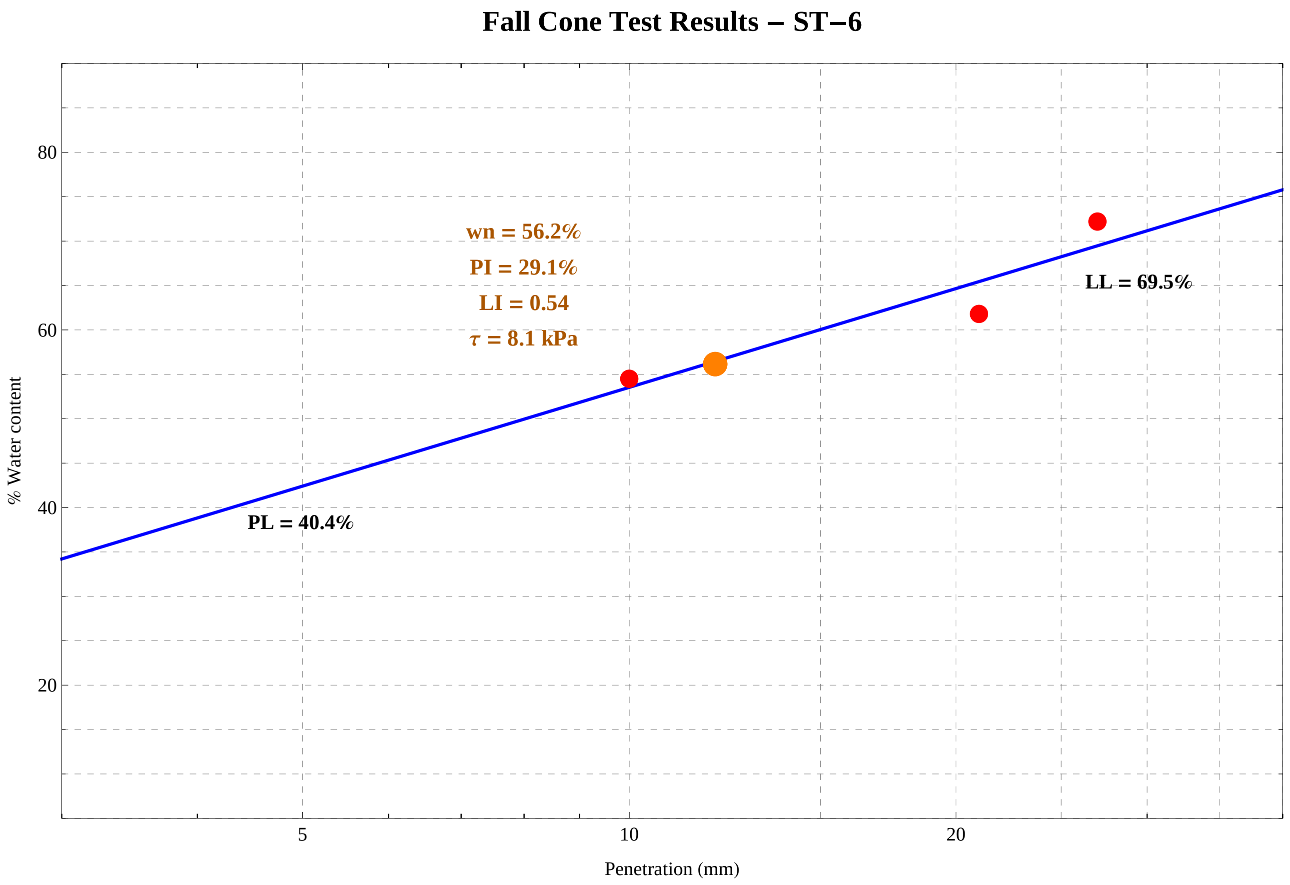
Appendix

B Fall Cone Data, Results, Plots and Plasticity Chart

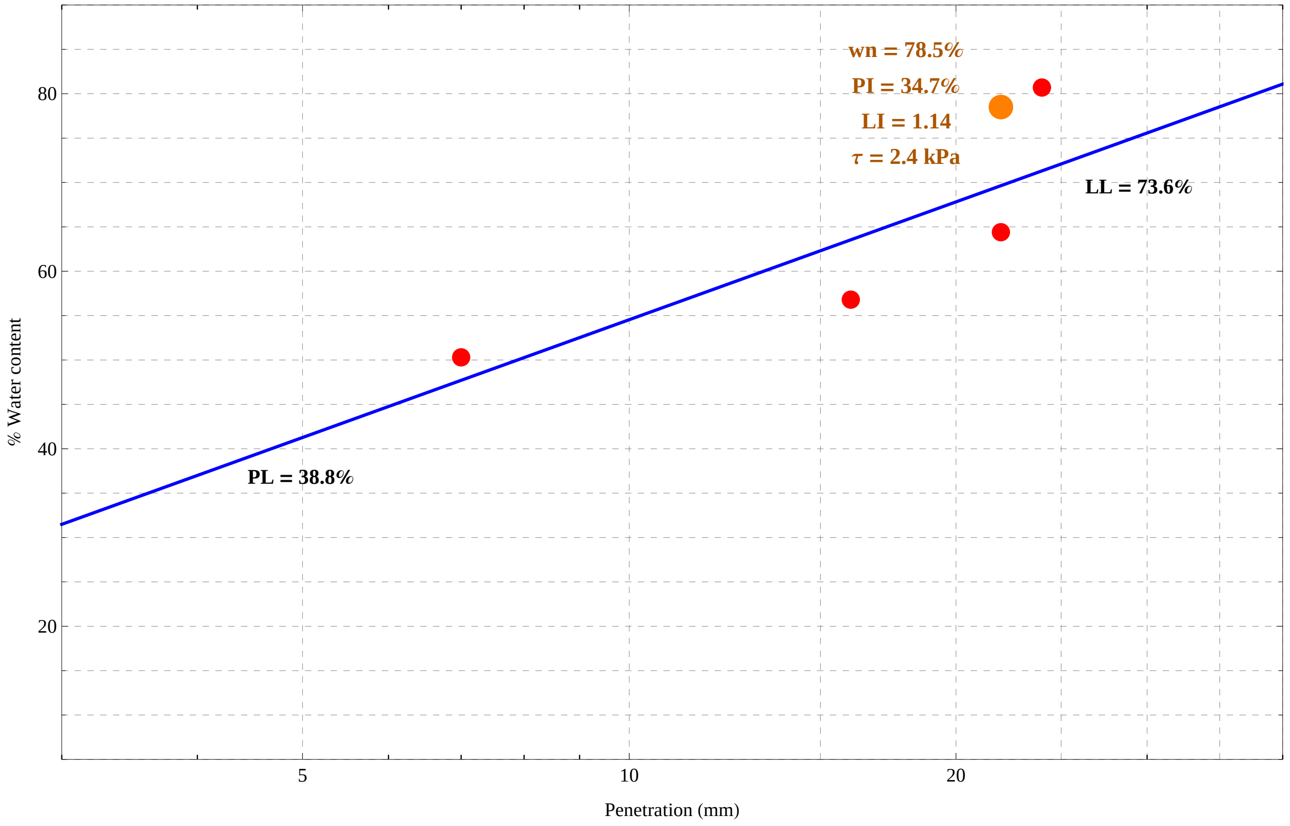

Fall Cone Test Results – ST–3
80
60
40
20
% Water content
5
10
20
Penetration (mm)
wn = 38.5%
PI = 20.3%
LI = 0.28
τ = 72.6 kPa
LL = 53.%
PL = 32.7%

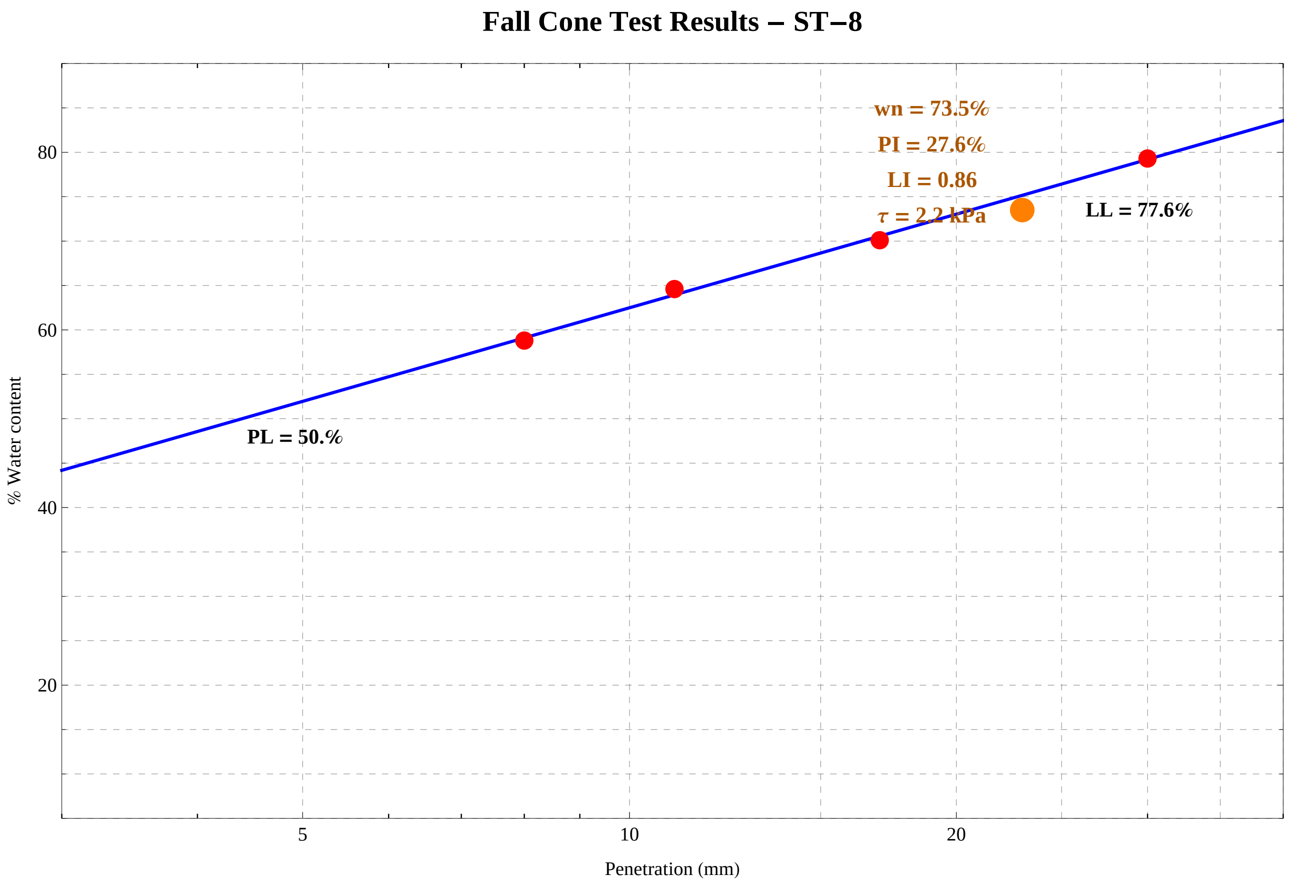

Fall Cone Test Results – ST–4
80
60
40
20
% Water content
5
10
20
Penetration (mm)
wn = 38.8%
PI = 22.1%
LI = 0.14
τ = 72.6 kPa
PL = 35.5%
LL = 57.6%

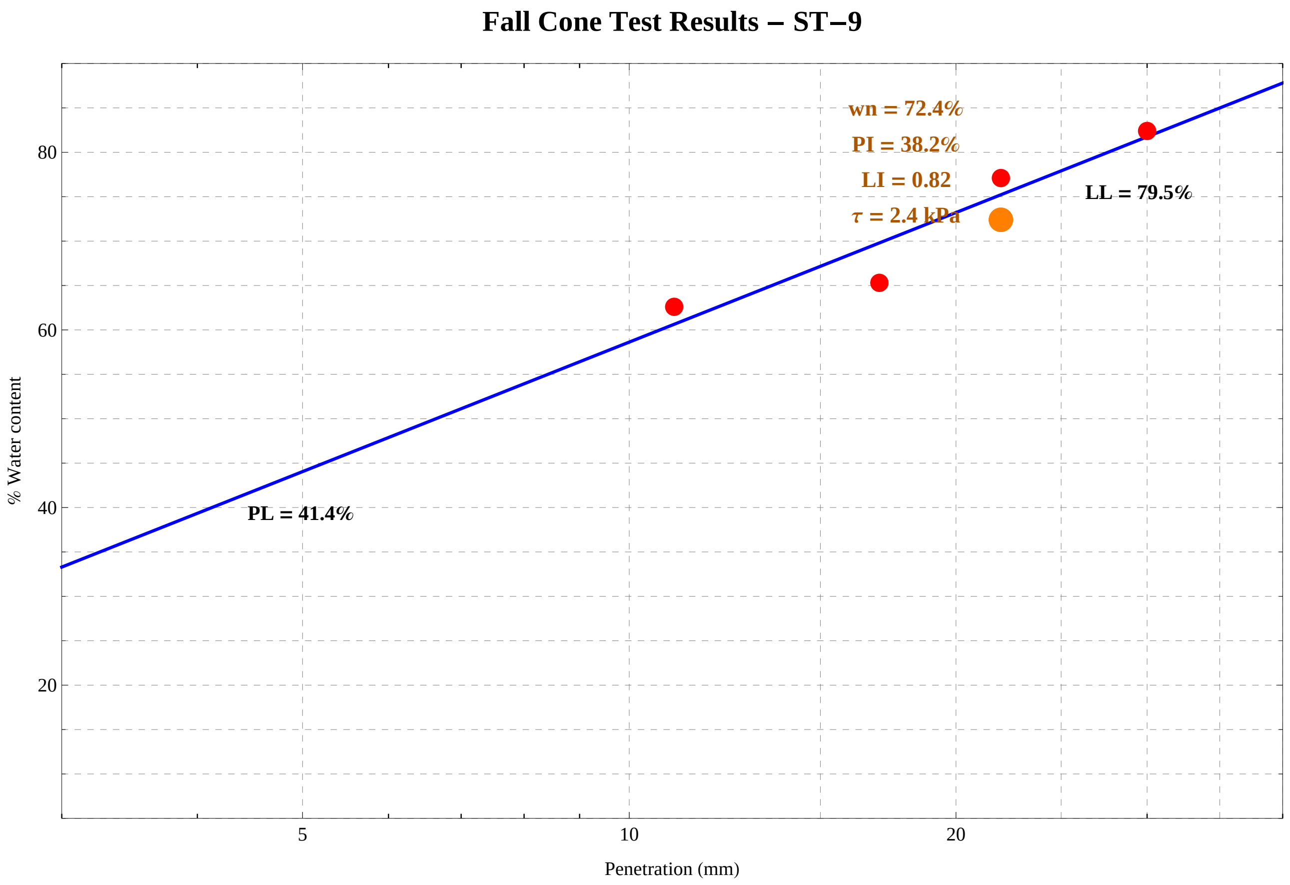

Fall Cone Test Results – ST–5
wn = 53.5%
PI = 30.2%
LI = 0.68
τ = 8.1 kPa
LL = 63.3%
PL = 33.1%
% Water content
80
60
40
20
5
10
20
Penetration (mm)

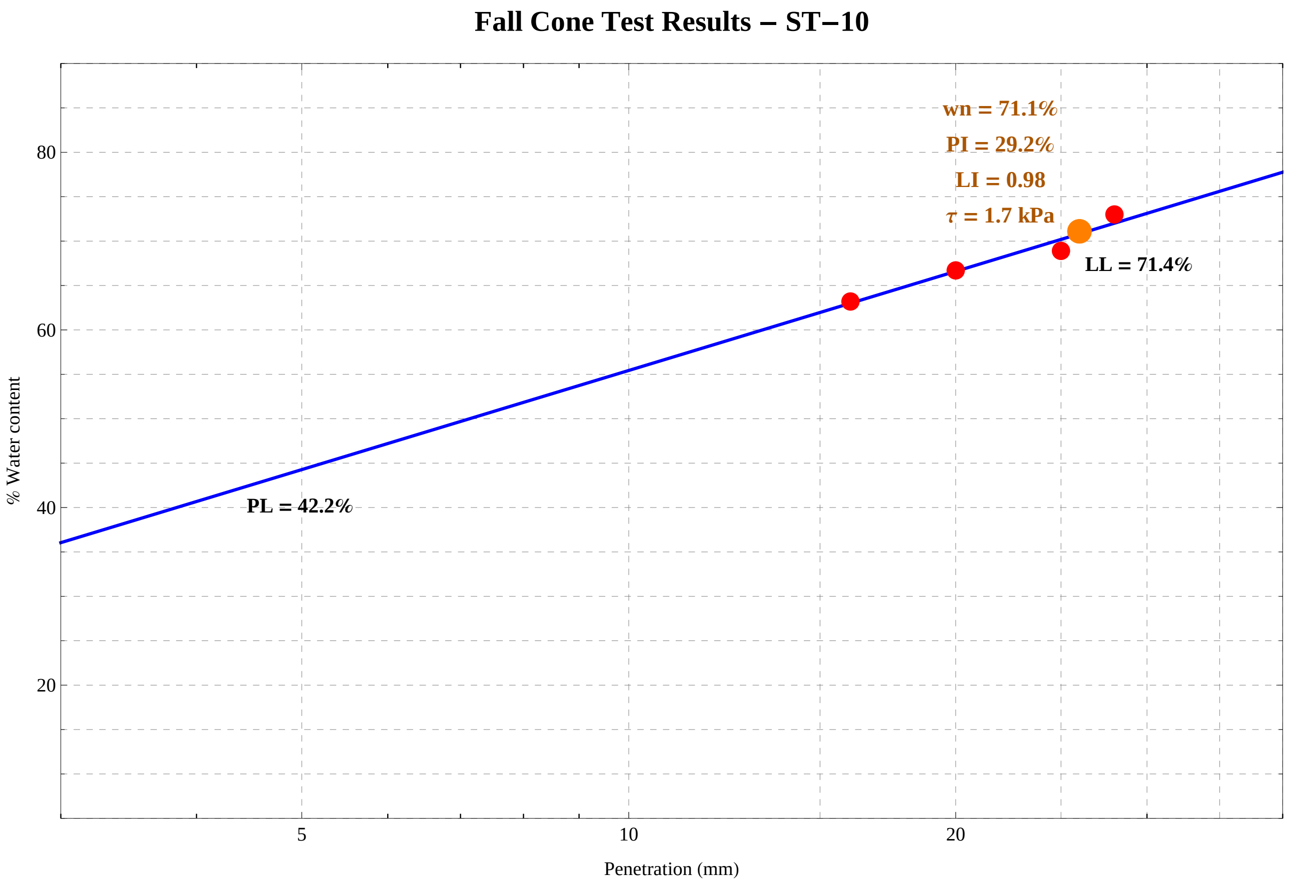

Fall Cone Test Results − ST−6
wn = 56.2%
PI = 29.1%
LI = 0.54
τ = 8.1 kPa
LL = 69.5%
PL = 40.4%
% Water content
80
60
40
20
5
10
20
Penetration (mm)

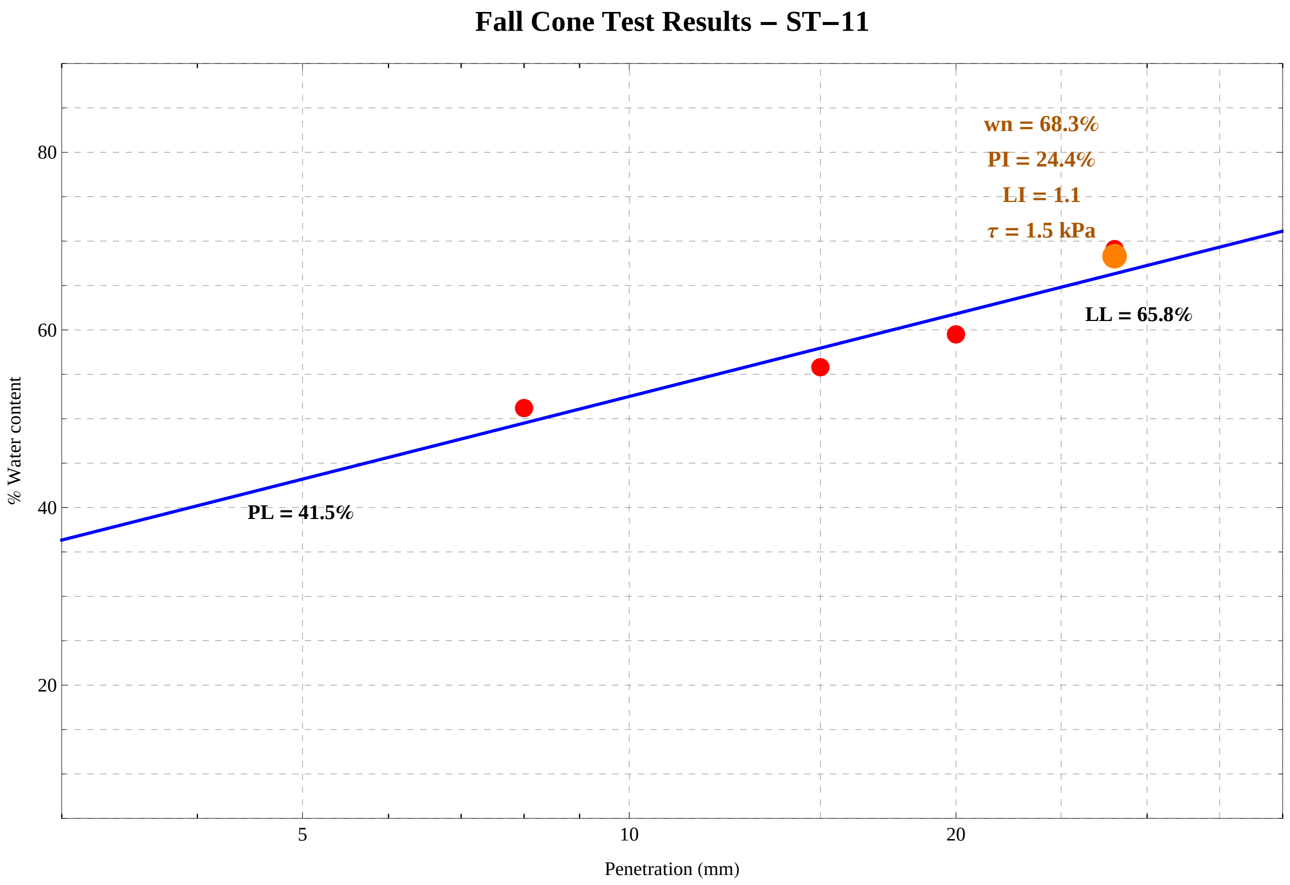
Fall Cone Test Results – ST–7

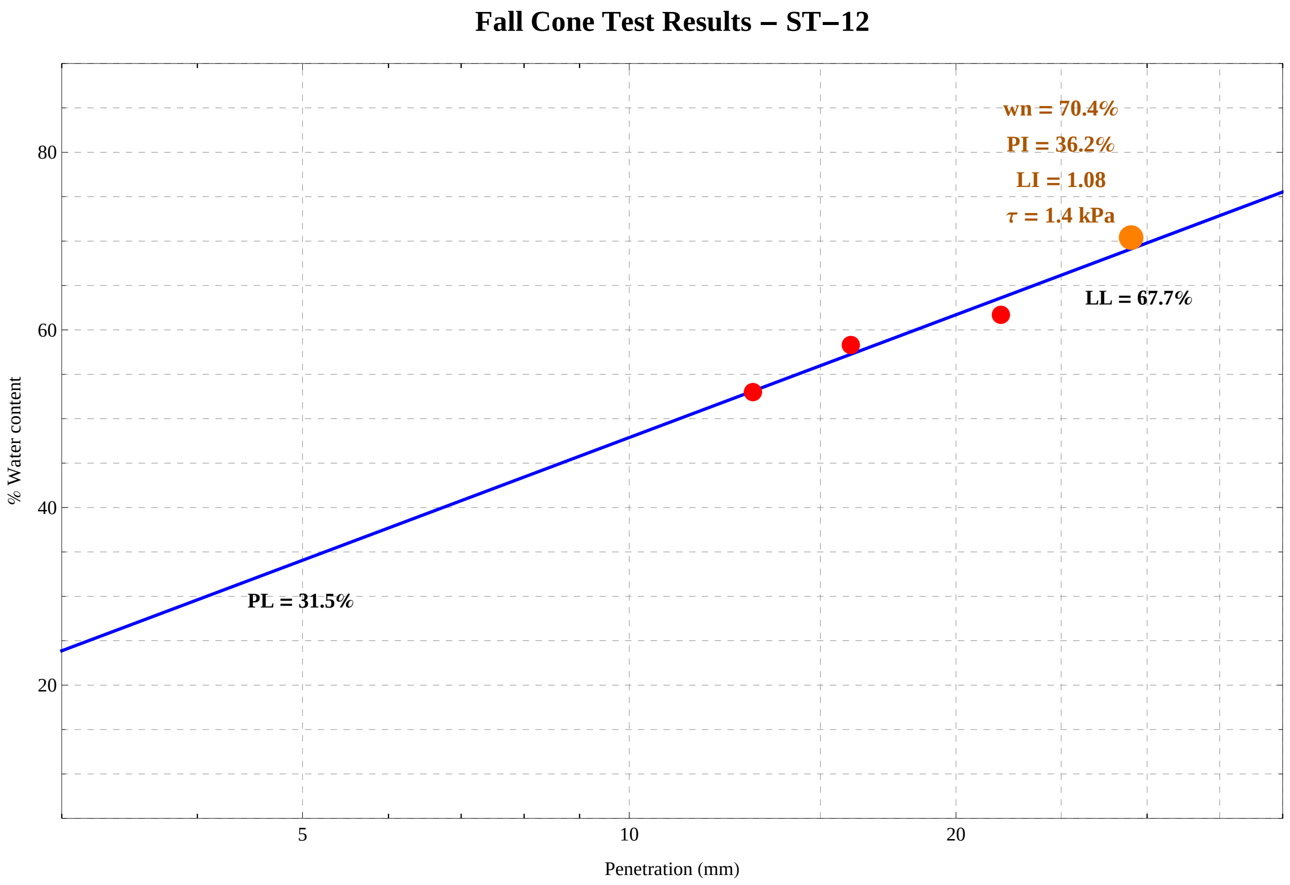



Fall Cone Test Results – ST–8
wn = 73.5%
PI = 27.6%
LI = 0.86
τ = 2.2 kPa
LL = 77.6%
PL = 50.%
80
60
40
20
% Water content
5
10
20
Penetration (mm)

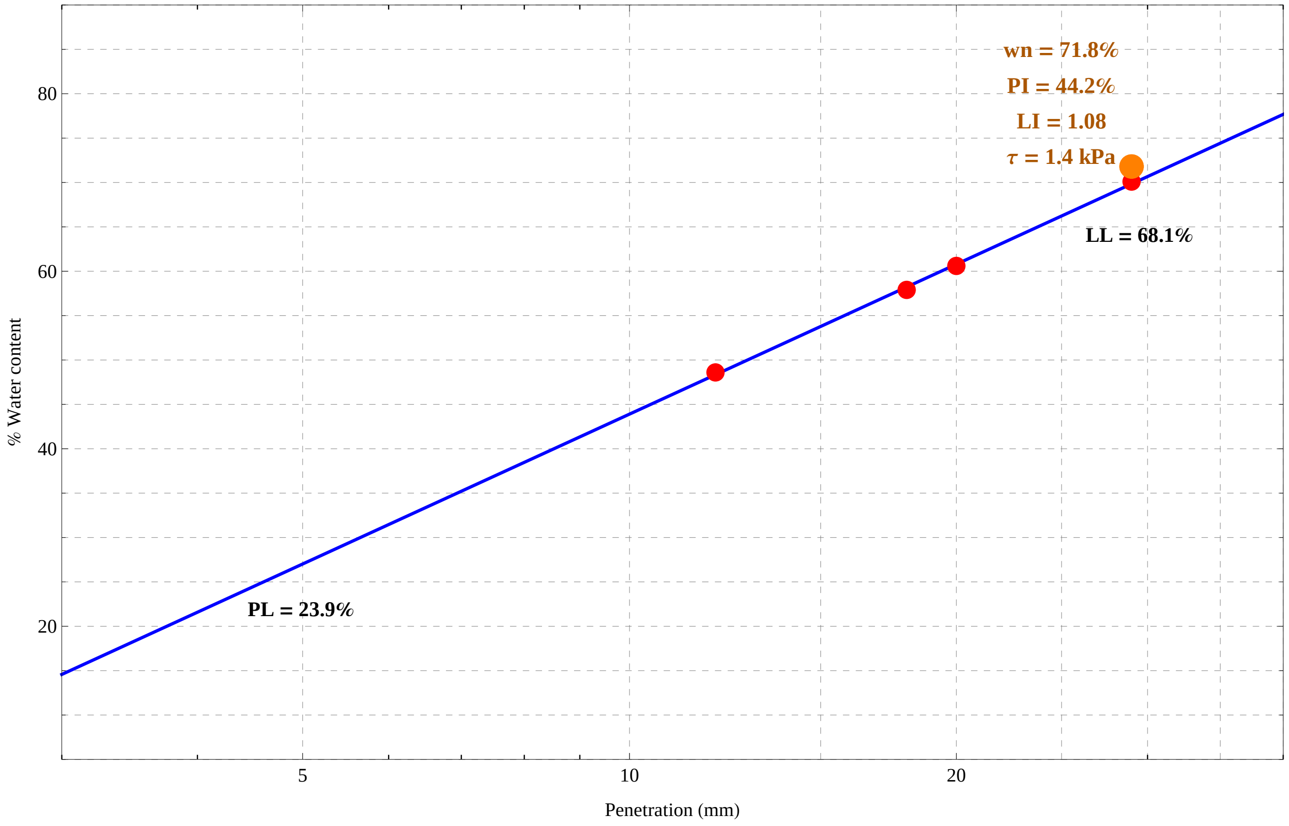

Fall Cone Test Results – ST–9
wn = 72.4%
PI = 38.2%
LI = 0.82
τ = 2.4 kPa
LL = 79.5%
PL = 41.4%
% Water content
20
40
60
80
5
10
20
Penetration (mm)

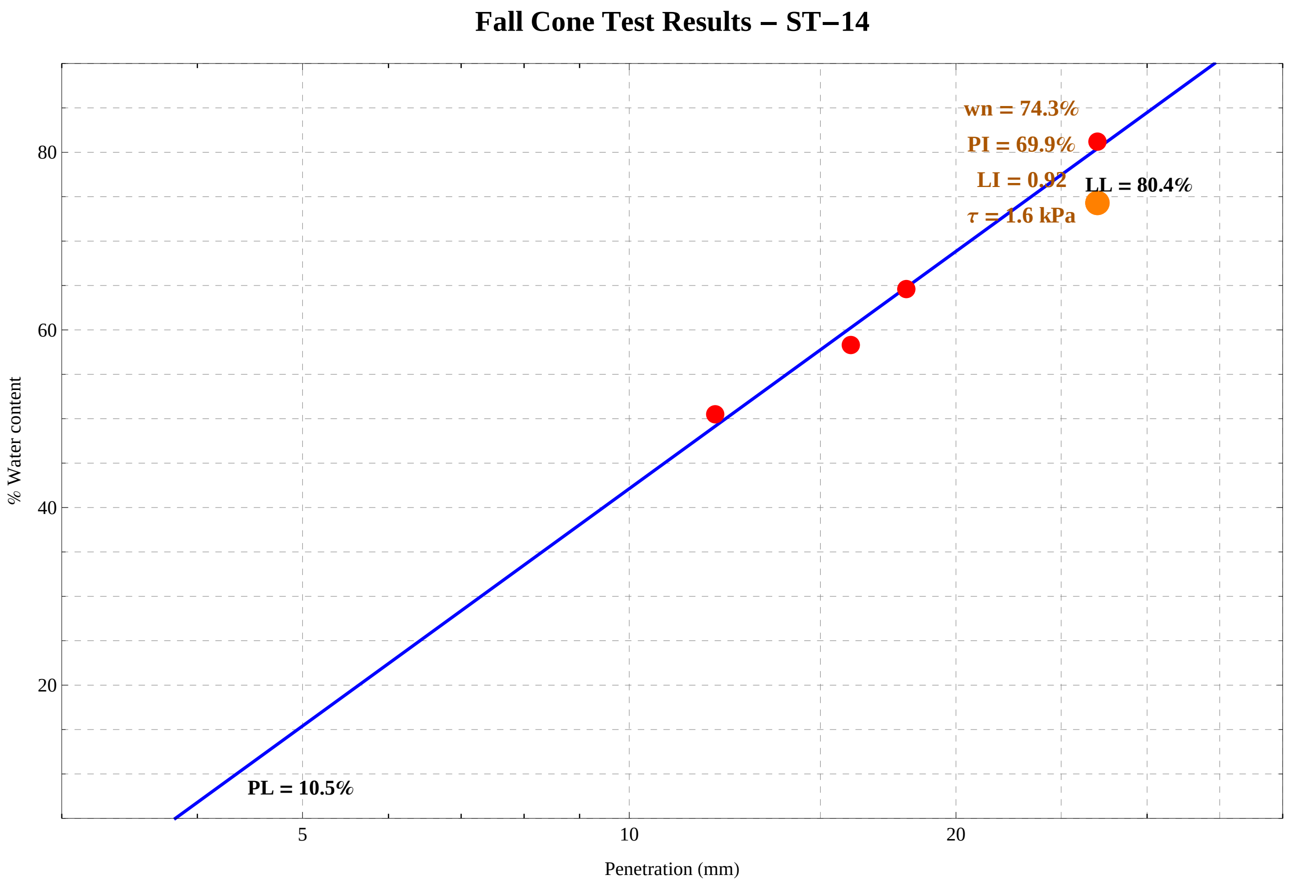

Fall Cone Test Results – ST−10
wn = 71.1%
PI = 29.2%
LI = 0.98
τ = 1.7 kPa
LL = 71.4%
PL = 42.2%
80
60
40
20
% Water content
5
10
20
Penetration (mm)

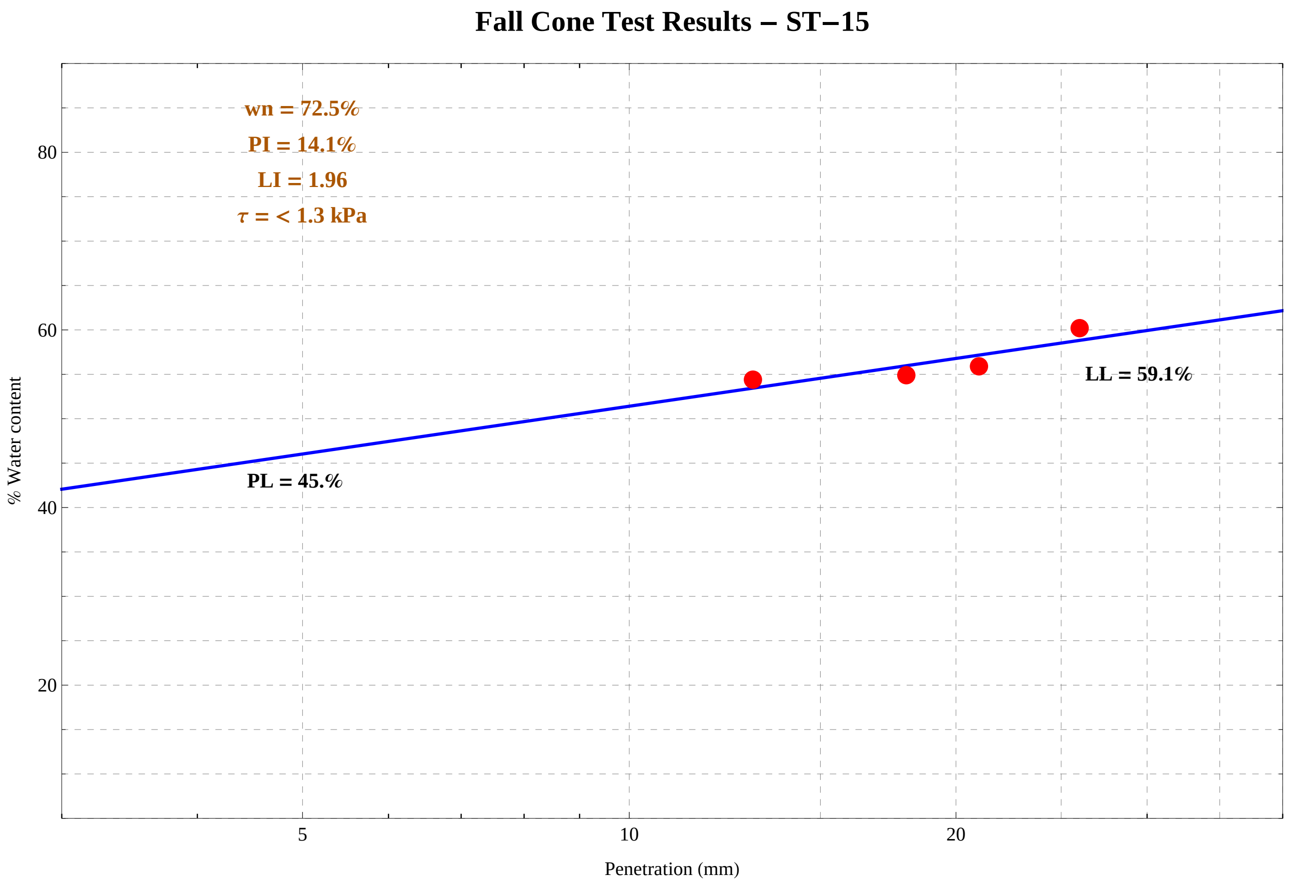

Fall Cone Test Results – ST–11
wn = 68.3%
PI = 24.4%
LI = 1.1
τ = 1.5 kPa
LL = 65.8%
PL = 41.5%
% Water content
80
60
40
20
5
10
20
Penetration (mm)

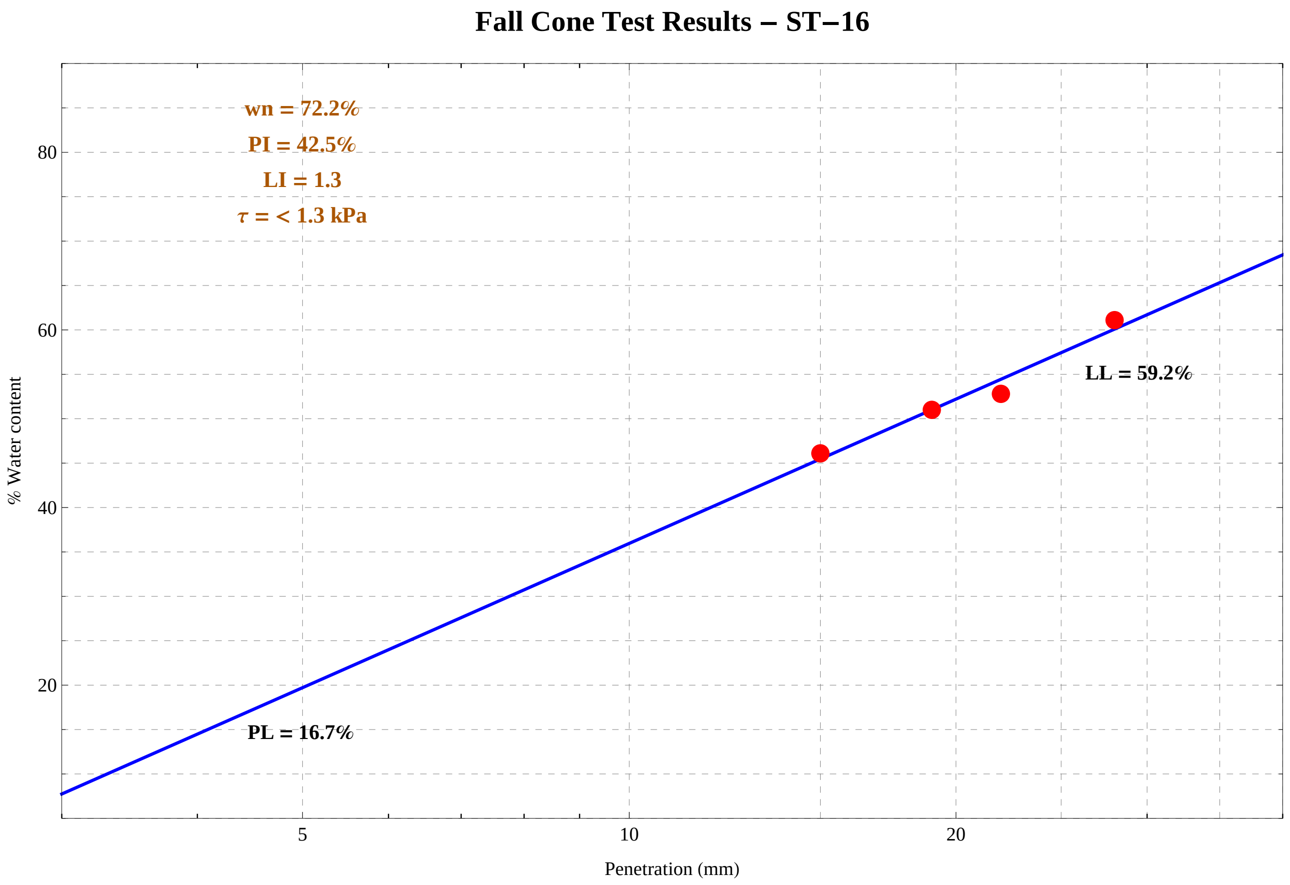

Fall Cone Test Results – ST−12
wn = 70.4%
PI = 36.2%
LI = 1.08
τ = 1.4 kPa
LL = 67.7%
PL = 31.5%
% Water content
80
60
40
20
5
10
20
Penetration (mm)

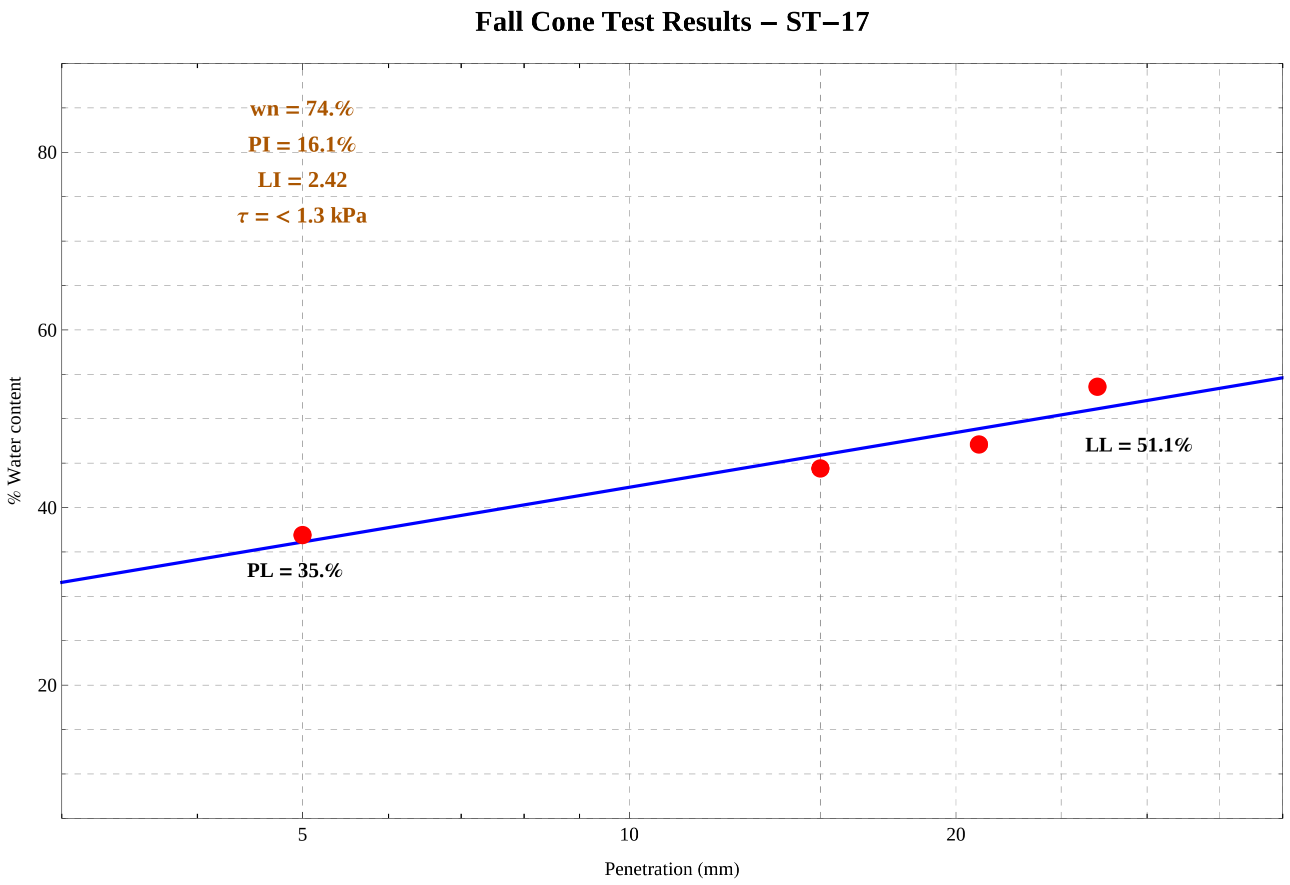
Fall Cone Test Results – ST–13

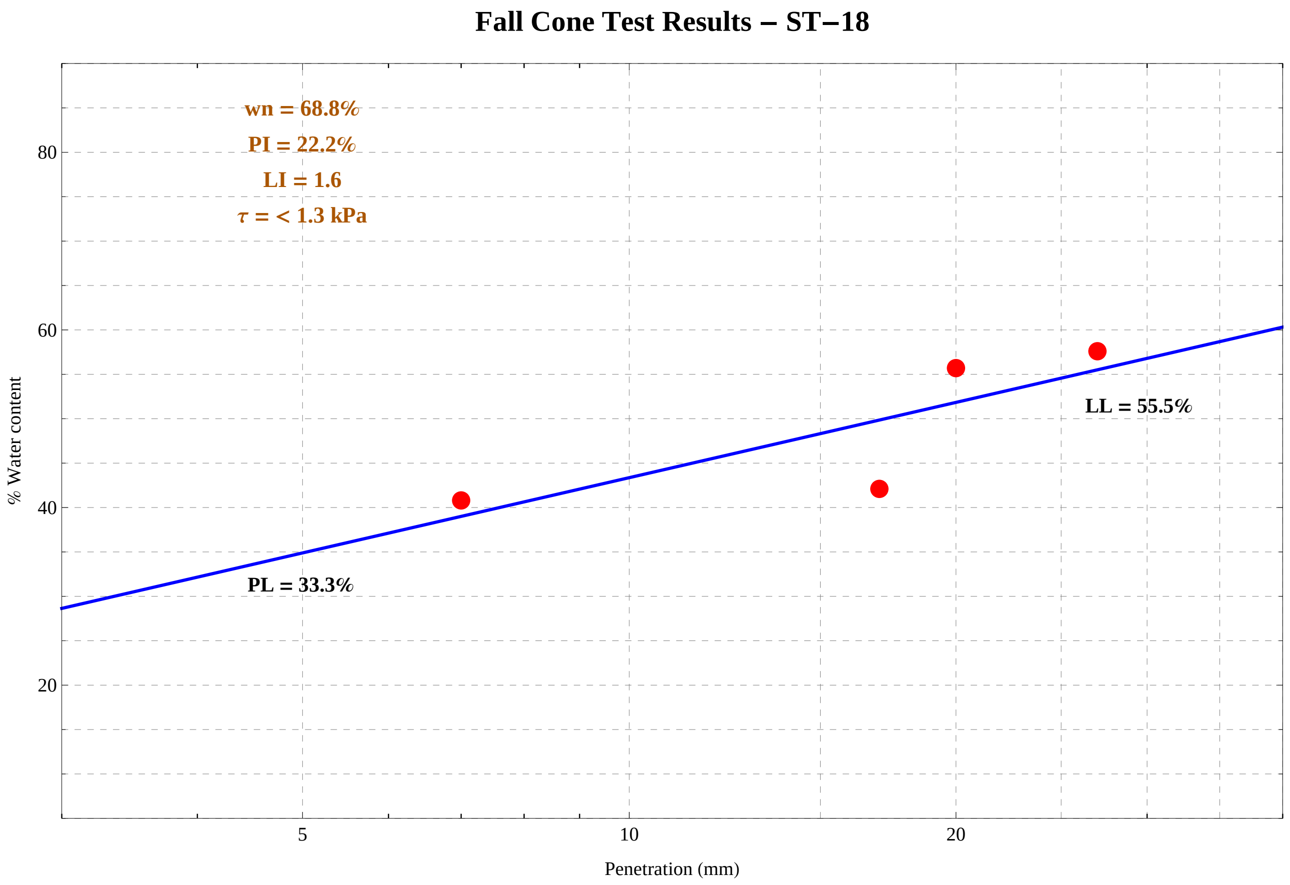


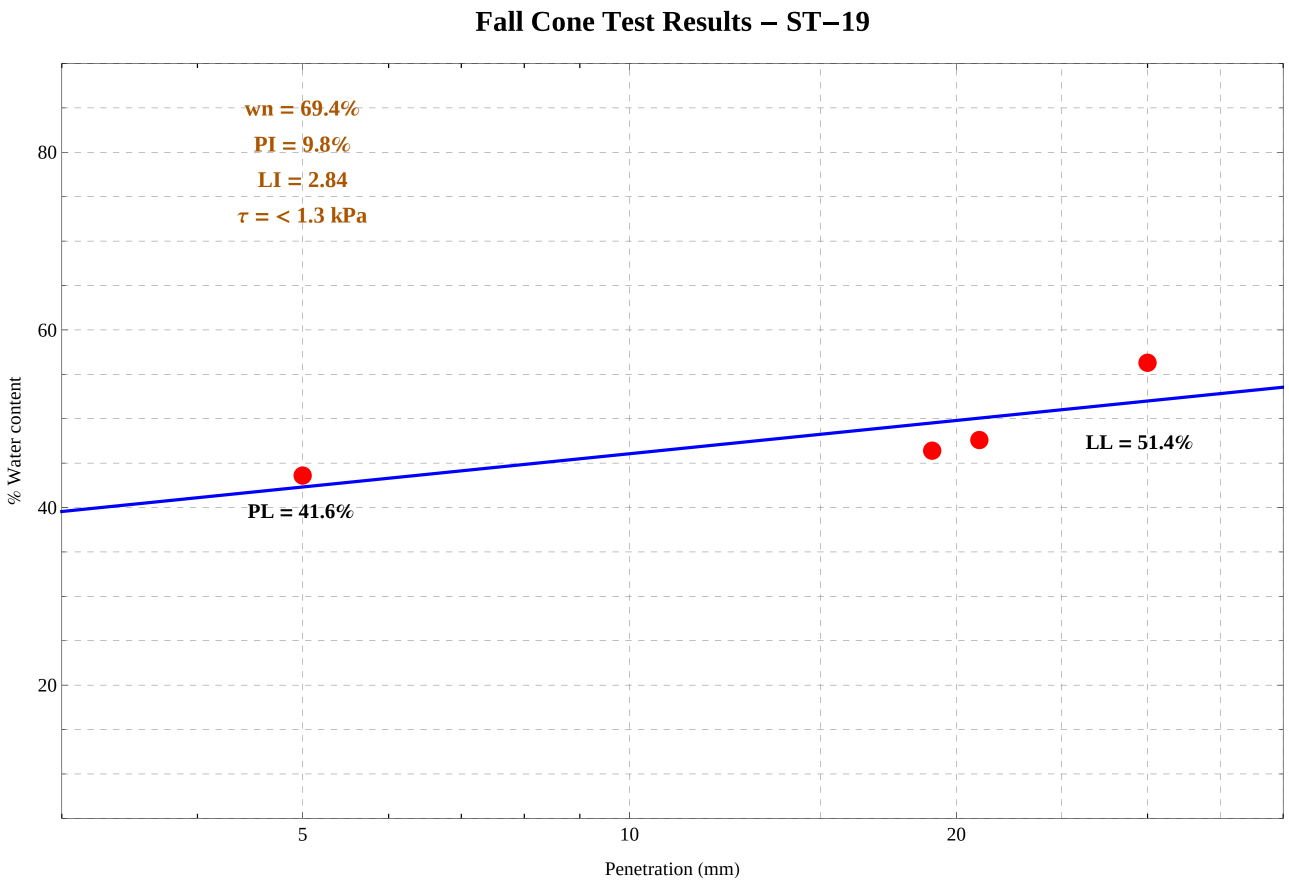

Fall Cone Test Results – ST−14
wn = 74.3%
PI = 69.9%
LI = 0.92
τ = 1.6 kPa
LL = 80.4%
PL = 10.5%
% Water content
20
40
60
80
5
10
20
Penetration (mm)

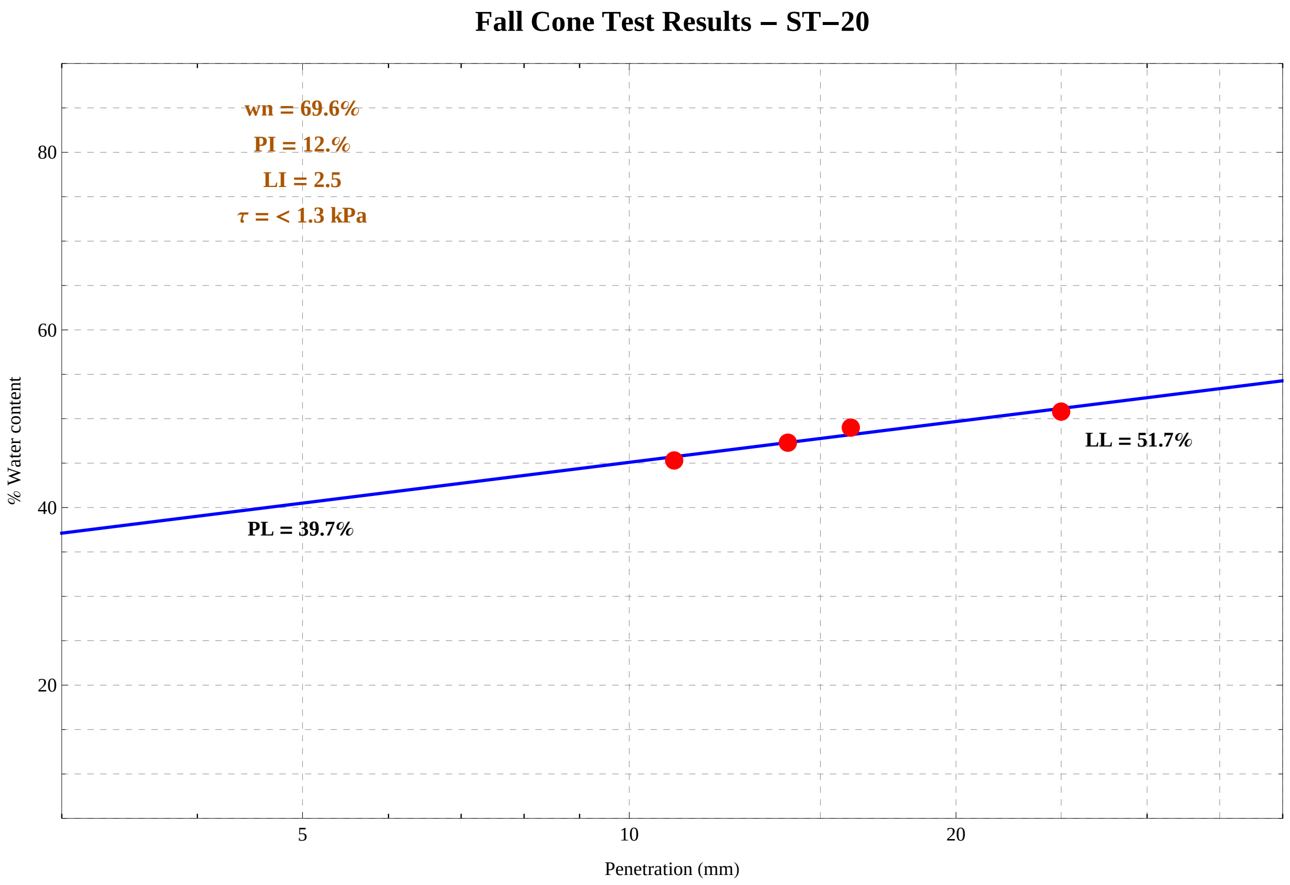

Fall Cone Test Results – ST–15
wn = 72.5%
PI = 14.1%
LI = 1.96
τ = < 1.3 kPa
LL = 59.1%
PL = 45.%
% Water content
80
60
40
20
5
10
20
Penetration (mm)

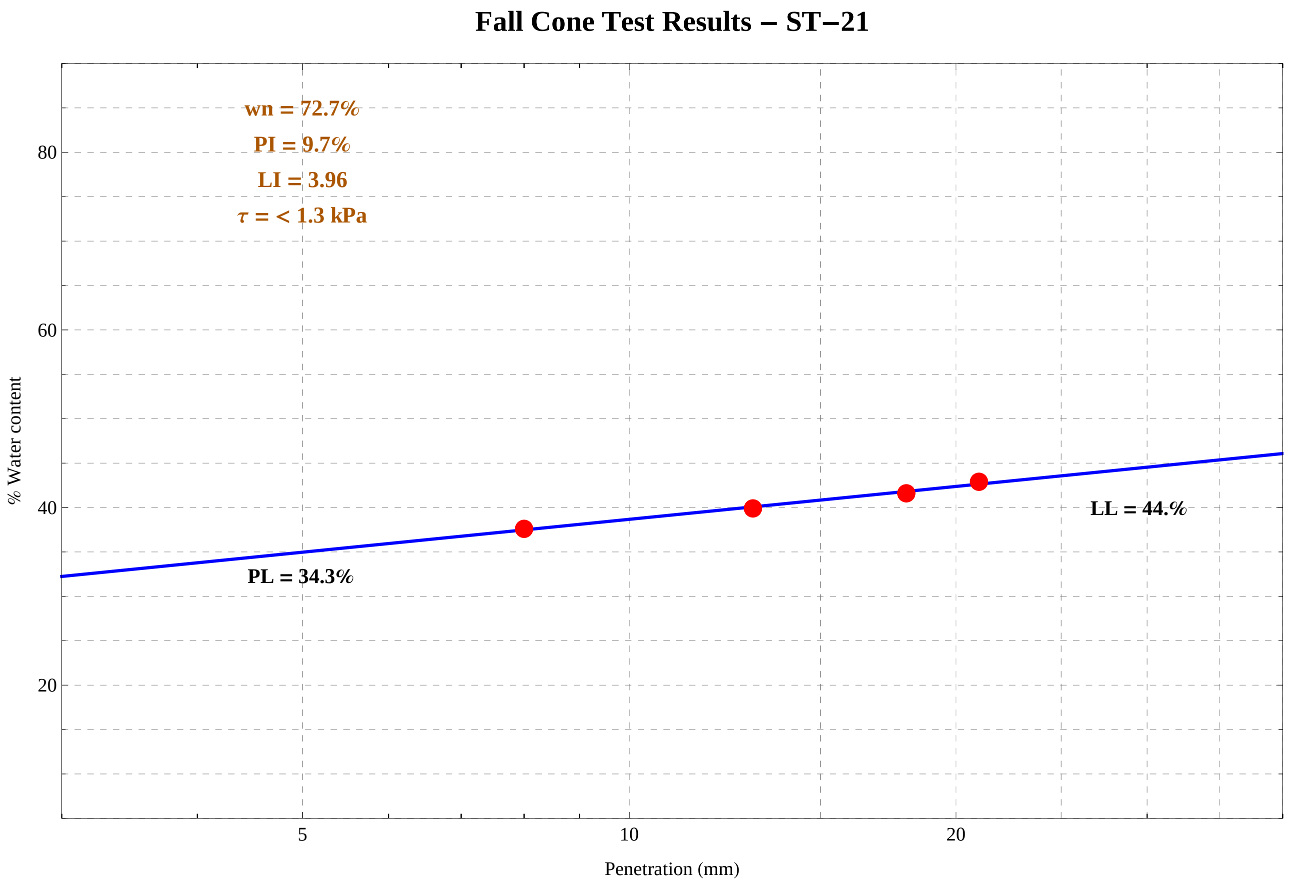

Fall Cone Test Results – ST−16
wn = 72.2%
PI = 42.5%
LI = 1.3
τ = < 1.3 kPa
LL = 59.2%
PL = 16.7%
% Water content
80
60
40
20
5
10
20
Penetration (mm)


Fall Cone Test Results – ST–17
wn = 74.%
PI = 16.1%
LI = 2.42
τ = < 1.3 kPa
PL = 35.%
LL = 51.1%
% Water content
80
60
40
20
5
10
20
Penetration (mm)

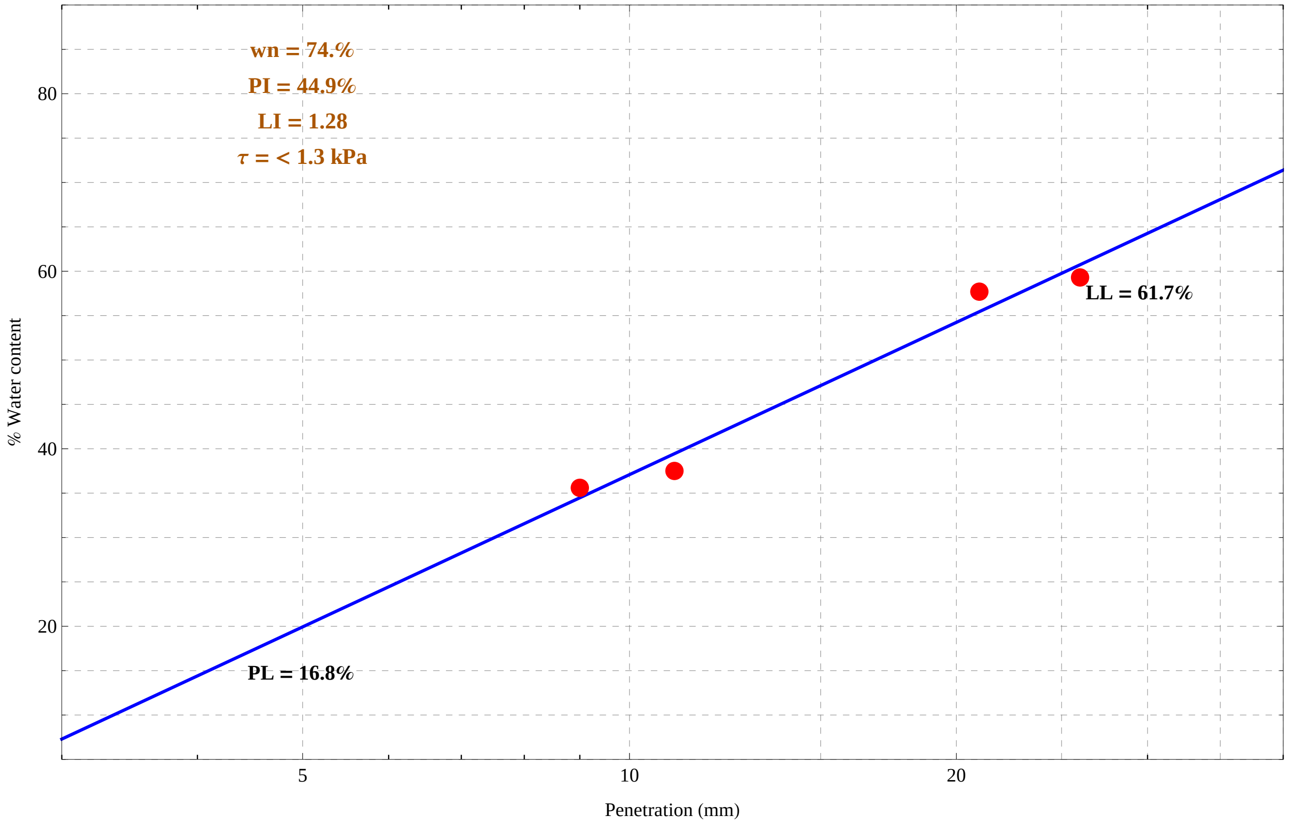

Fall Cone Test Results – ST–18
wn = 68.8%
PI = 22.2%
LI = 1.6
τ = < 1.3 kPa
LL = 55.5%
PL = 33.3%
80
60
40
20
% Water content
5
10
20
Penetration (mm)

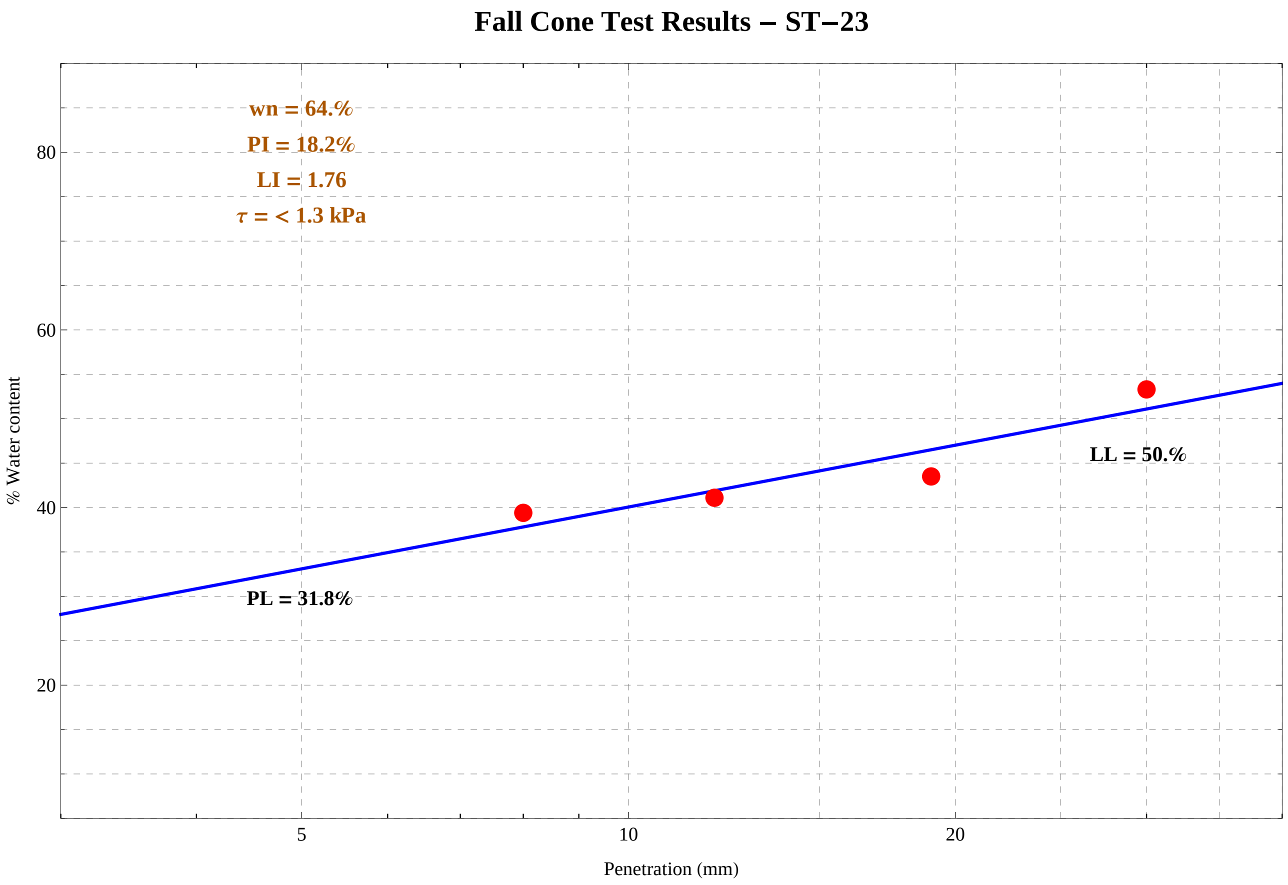

Fall Cone Test Results – ST–19
wn = 69.4%
PI = 9.8%
LI = 2.84
τ = < 1.3 kPa
LL = 51.4%
PL = 41.6%
% Water content
80
60
40
20
5
10
20
Penetration (mm)

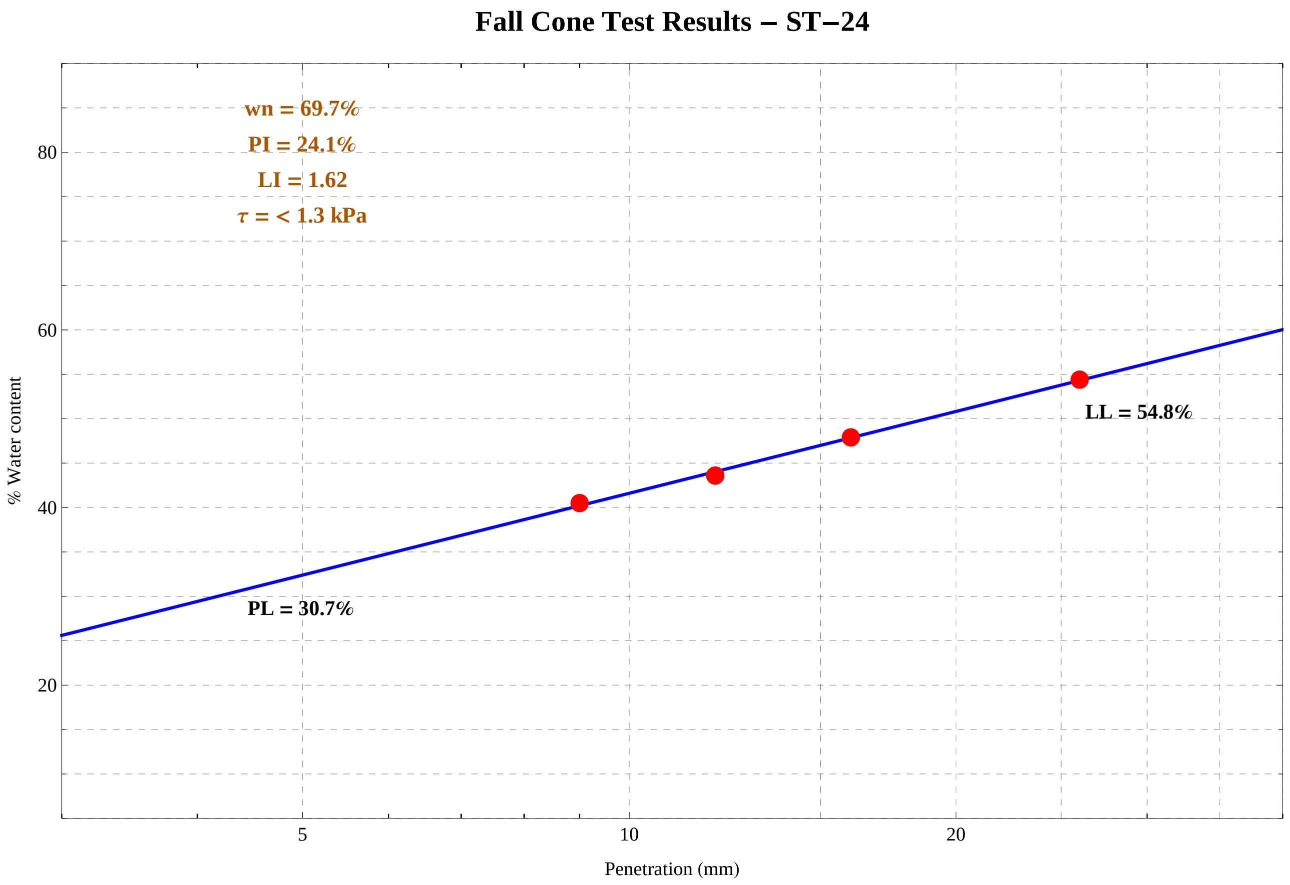

Fall Cone Test Results – ST−20
wn = 69.6%
PI = 12.%
LI = 2.5
τ = < 1.3 kPa
LL = 51.7%
PL = 39.7%
80
60
40
20
% Water content
5
10
20
Penetration (mm)

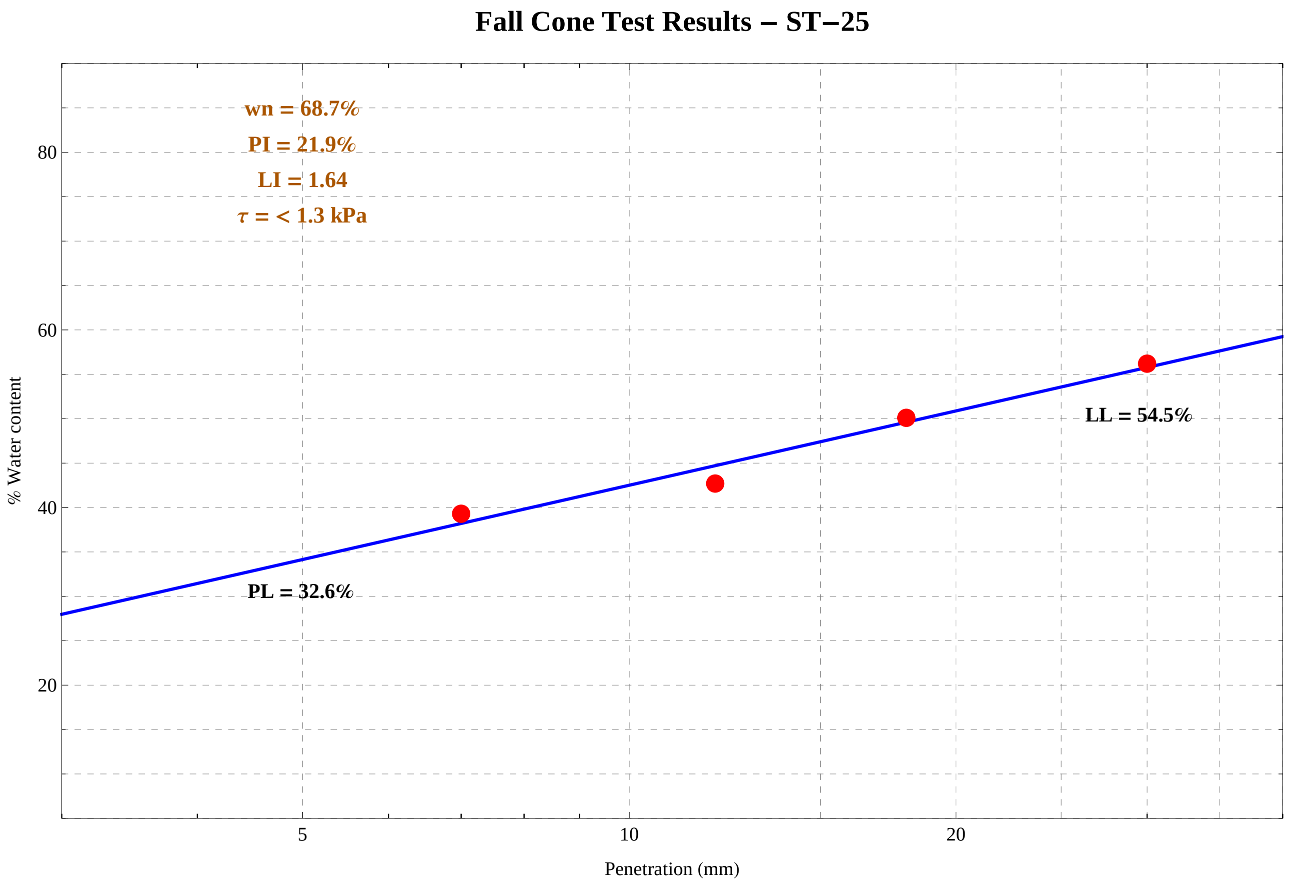

Fall Cone Test Results – ST–21
wn = 72.7%
PI = 9.7%
LI = 3.96
τ = < 1.3 kPa
LL = 44.%
PL = 34.3%
% Water content
80
60
40
20
5
10
20
Penetration (mm)

Fall Cone Test Results – ST−22




Fall Cone Test Results – ST–23
wn = 64.%
PI = 18.2%
LI = 1.76
τ = < 1.3 kPa
LL = 50.%
PL = 31.8%
80
60
40
20
5
10
20
% Water content
Penetration (mm)


Fall Cone Test Results – ST–24
wn = 69.7%
PI = 24.1%
LI = 1.62
τ = < 1.3 kPa
LL = 54.8%
PL = 30.7%
% Water content
80
60
40
20
5
10
20
Penetration (mm)


Fall Cone Test Results – ST–25
wn = 68.7%
PI = 21.9%
LI = 1.64
τ = < 1.3 kPa
LL = 54.5%
PL = 32.6%
% Water content
20
40
60
80
5
10
20
Penetration (mm)

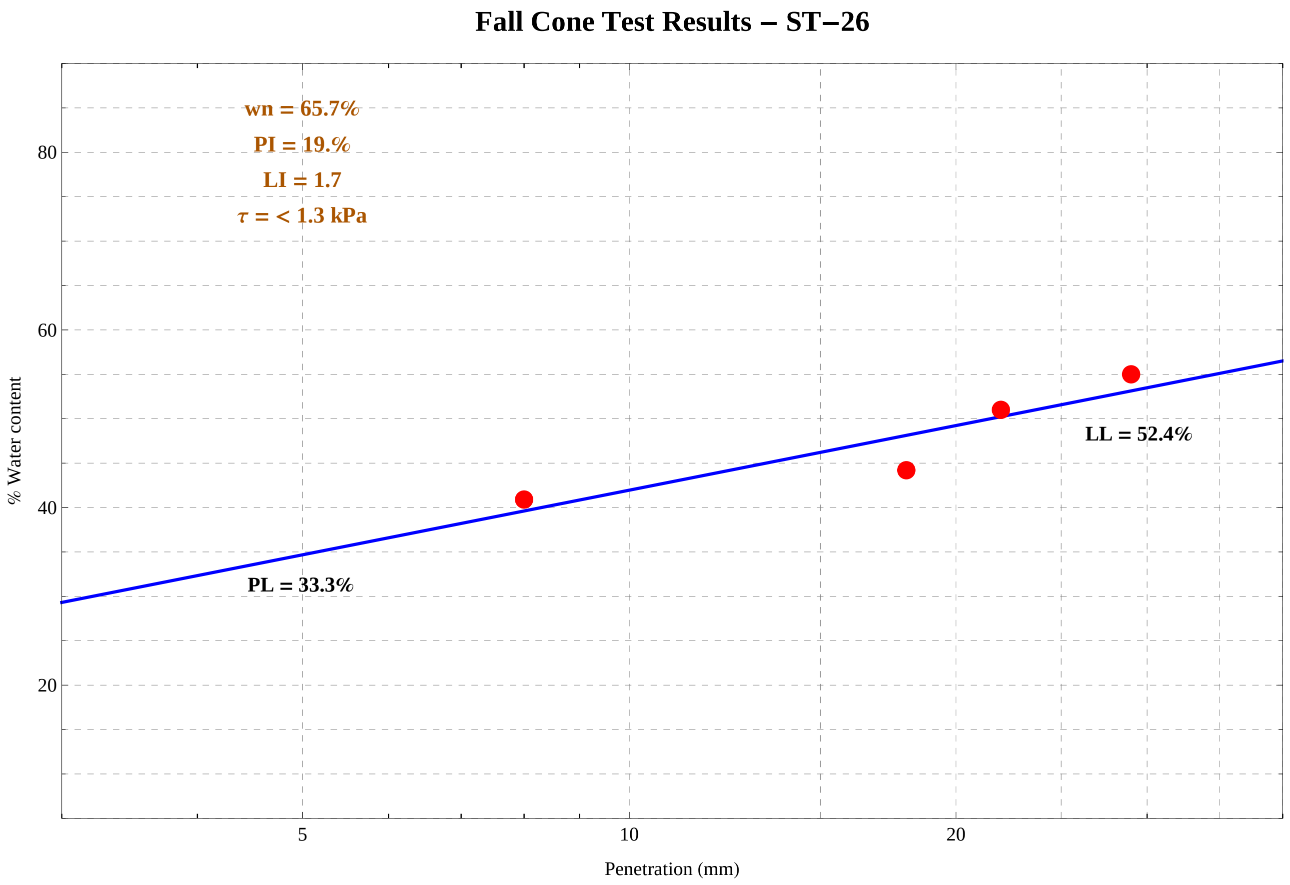


Table: Data Points

ID	w1	w2	Avg wn (%)	Nat (P,W)	Flow Points
ST–3	38.1	38.8	38.5	4., 38.5	{6., 39.9} {11., 37.3} {17., 45.3} {23., 55.8}
ST–4	32.6	44.9	38.8	4., 38.8	{8., 40.7} {10., 48.4} {19., 52.1} {23., 56.}
ST–5	57.1	50.	53.5	12., 53.5	{12., 50.8} {17., 54.} {22., 59.7} {29., 65.2}
ST–6	56.5	55.8	56.2	12., 56.2	{10., 54.5} {12., 56.4} {21., 61.8} {27., 72.2}
ST–7	78.1	78.9	78.5	22., 78.5	{7., 50.3} {16., 56.8} {22., 64.4} {24., 80.7}
ST–8	73.5	73.5	73.5	23., 73.5	{8., 58.8} {11., 64.6} {17., 70.1} {30., 79.3}

```
ST-9    72.4   72.4   72.4          22., 72.4    {11., 62.6} {17., 65.3}
                                                  {22., 77.1} {30., 82.4}

ST-10   76.5   65.7   71.1          26., 71.1    {16., 63.2} {20., 66.7}
                                                  {25., 68.9} {28., 73.}

ST-11   68.3   68.3   68.3          28., 68.3    {8., 51.2} {15., 55.8}
                                                  {20., 59.5} {28., 69.1}

ST-12   69.6   71.1   70.4          29., 70.4    {13., 53.} {16., 58.3}
                                                  {22., 61.7} {29., 70.1}

ST-13   71.8   71.8   71.8          29., 71.8    {12., 48.6} {18., 57.9}
                                                  {20., 60.6} {29., 70.1}

ST-14   74.6   74.    74.3          27., 74.3    {12., 50.5} {16., 58.3}
                                                  {18., 64.6} {27., 81.2}

ST-15   72.4   72.5   72.5          None, 72.5   {13., 54.4} {18., 54.9}
                                                  {21., 55.9} {26., 60.2}

ST-16   73.1   71.3   72.2          None, 72.2   {15., 46.1} {19., 51.}
                                                  {22., 52.8} {28., 61.1}

ST-17   74.4   73.6   74.           None, 74.    {5., 36.9} {15., 44.4}
                                                  {21., 47.1} {27., 53.6}

ST-18   69.    68.6   68.8          None, 68.8   {7., 40.8} {17., 42.1}
                                                  {20., 55.7} {27., 57.6}

ST-19   68.9   69.9   69.4          None, 69.4   {5., 43.6} {19., 46.4}
                                                  {21., 47.6} {30., 56.3}

ST-20   70.    69.2   69.6          None, 69.6   {11., 45.3} {14., 47.3}
                                                  {16., 49.} {25., 50.8}

ST-21   71.6   73.8   72.7          None, 72.7   {8., 37.6} {13., 39.9}
                                                  {18., 41.6} {21., 42.9}

ST-22   73.7   74.3   74.           None, 74.    {9., 35.6} {11., 37.5}
                                                  {21., 57.7} {26., 59.3}

ST-23   64.1   63.8   64.           None, 64.    {8., 39.4} {12., 41.1}
                                                  {19., 43.5} {30., 53.3}

ST-24   73.9   65.4   69.7          None, 69.7   {9., 40.5} {12., 43.6}
                                                  {16., 47.9} {26., 54.4}

ST-25   68.8   68.6   68.7          None, 68.7   {7., 39.3} {12., 42.7}
```

```
ST−25   68.8    68.6    68.7            None, 68.7   {7., 39.3} {12., 42.7}
                                                       {18., 50.1} {30., 56.2}

ST−26   66.     65.5    65.7            None, 65.7   {8., 40.9} {18., 44.2}
                                                       {22., 51.} {29., 55.}
```

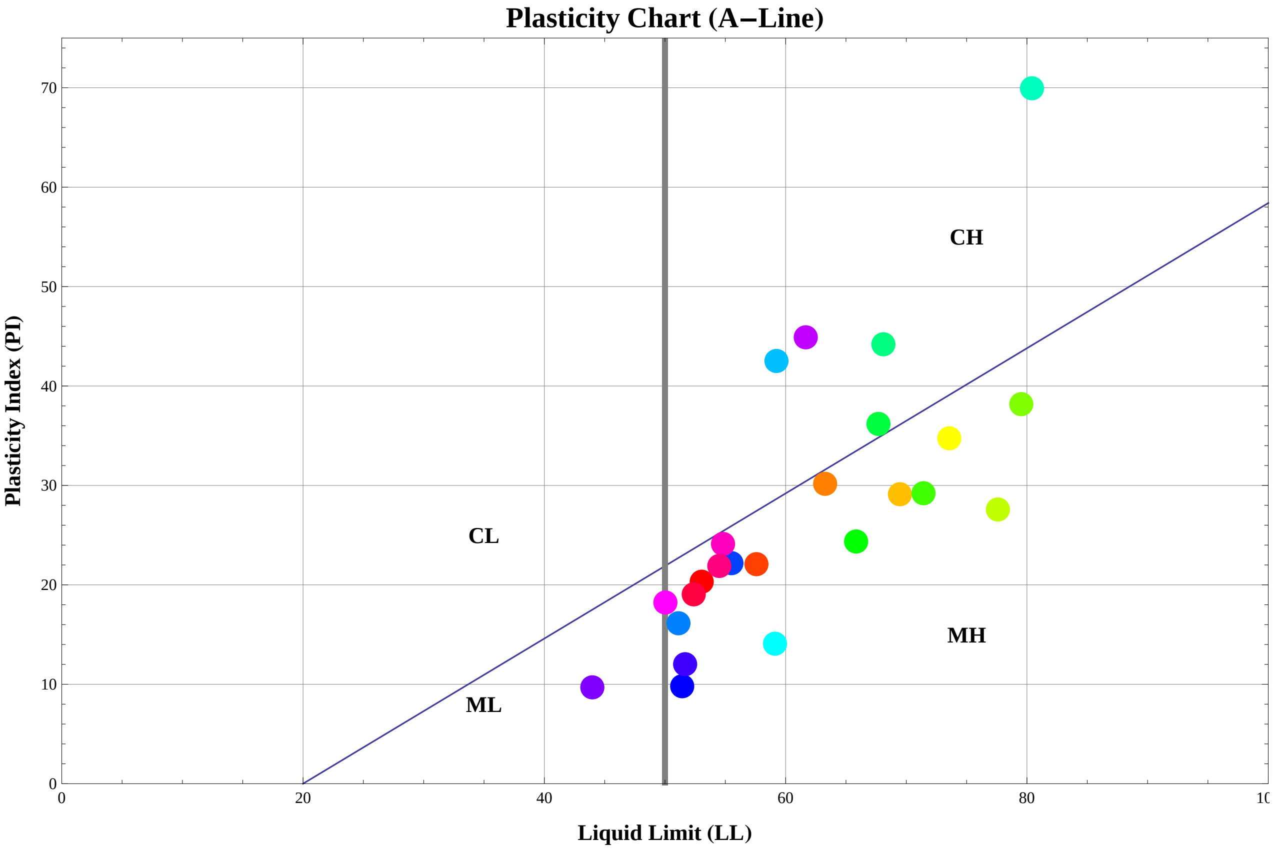
Table: Fall Cone Test Results

ID	**wn** (%)	**LL** (%)	**PL** (%)	**PI** (%)	**LI**	τ
ST–3	38.5	53.	32.7	20.3	0.28	72.6 kPa
ST–4	38.8	57.6	35.5	22.1	0.14	72.6 kPa
ST–5	53.5	63.3	33.1	30.2	0.68	8.1 kPa
ST–6	56.2	69.5	40.4	29.1	0.54	8.1 kPa
ST–7	78.5	73.6	38.8	34.7	1.14	2.4 kPa
ST–8	73.5	77.6	50.	27.6	0.86	2.2 kPa
ST–9	72.4	79.5	41.4	38.2	0.82	2.4 kPa
ST–10	71.1	71.4	42.2	29.2	0.98	1.7 kPa
ST–11	68.3	65.8	41.5	24.4	1.1	1.5 kPa
ST–12	70.4	67.7	31.5	36.2	1.08	1.4 kPa
ST–13	71.8	68.1	23.9	44.2	1.08	1.4 kPa
ST–14	74.3	80.4	10.5	69.9	0.92	1.6 kPa
ST–15	72.5	59.1	45.	14.1	1.96	< 1.3 kPa
ST–16	72.2	59.2	16.7	42.5	1.3	< 1.3 kPa
ST–17	74.	51.1	35.	16.1	2.42	< 1.3 kPa
ST–18	68.8	55.5	33.3	22.2	1.6	< 1.3 kPa
ST–19	69.4	51.4	41.6	9.8	2.84	< 1.3 kPa
ST–20	69.6	51.7	39.7	12.	2.5	< 1.3 kPa
ST–21	72.7	44.	34.3	9.7	3.96	< 1.3 kPa
ST–22	74.	61.7	16.8	44.9	1.28	< 1.3 kPa
ST–23	64.	50.	31.8	18.2	1.76	< 1.3 kPa
ST–24	69.7	54.8	30.7	24.1	1.62	< 1.3 kPa
ST–25	68.7	54.5	32.6	21.9	1.64	< 1.3 kPa
ST–26	65.7	52.4	33.3	19.	1.7	< 1.3 kPa

Table: Soil Classification

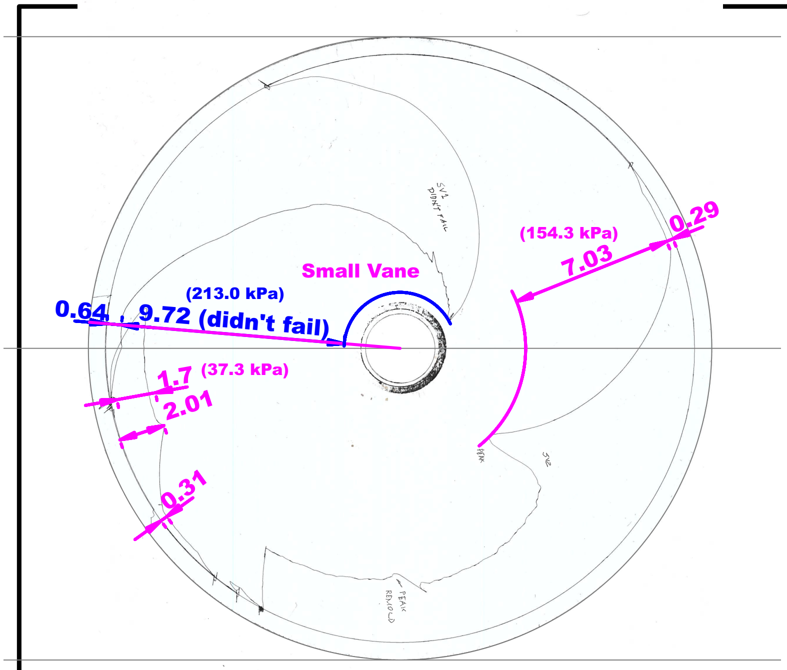
Sym	ID	LL	PL	PI	Class
●	ST–3	53.	32.7	20.3	MH
●	ST–4	57.6	35.5	22.1	MH
●	ST–5	63.3	33.1	30.2	MH
●	ST–6	69.5	40.4	29.1	MH
●	ST–7	73.6	38.8	34.7	MH
●	ST–8	77.6	50.	27.6	MH
●	ST–9	79.5	41.4	38.2	MH
●	ST–10	71.4	42.2	29.2	MH
●	ST–11	65.8	41.5	24.4	MH
●	ST–12	67.7	31.5	36.2	CH
●	ST–13	68.1	23.9	44.2	CH
●	ST–14	80.4	10.5	69.9	CH
●	ST–15	59.1	45.	14.1	MH
●	ST–16	59.2	16.7	42.5	CH
●	ST–17	51.1	35.	16.1	MH
●	ST–18	55.5	33.3	22.2	MH
●	ST–19	51.4	41.6	9.8	MH
●	ST–20	51.7	39.7	12.	MH
●	ST–21	44.	34.3	9.7	ML
●	ST–22	61.7	16.8	44.9	CH
●	ST–23	50.	31.8	18.2	MH
●	ST–24	54.8	30.7	24.1	MH
●	ST–25	54.5	32.6	21.9	MH
●	ST–26	52.4	33.3	19.	MH

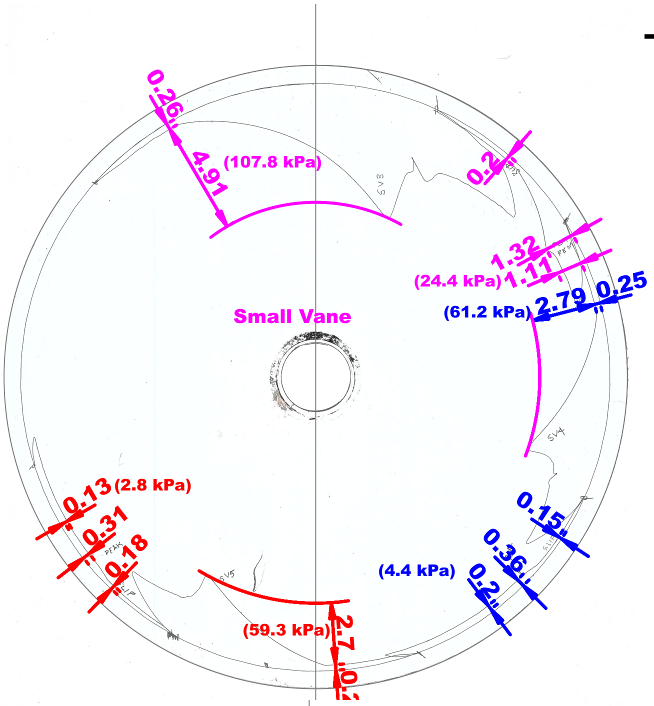
Plasticity Chart

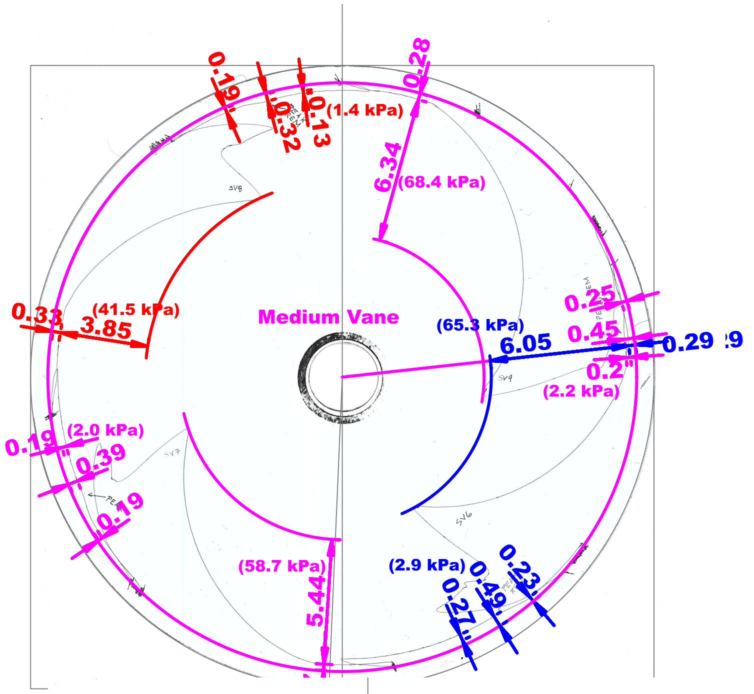


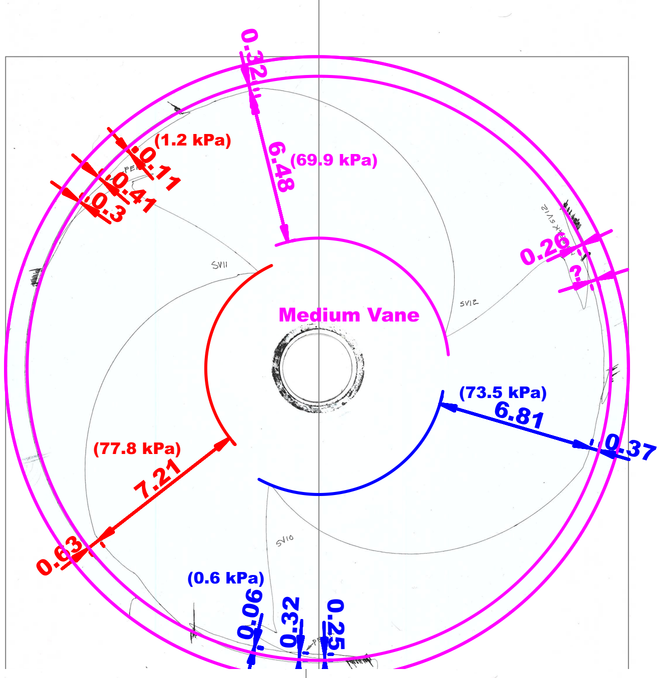
Appendix

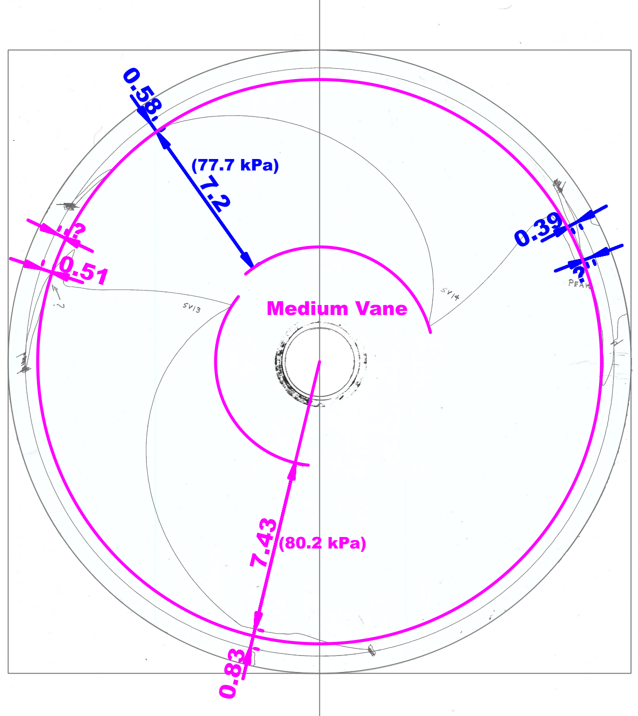
C Shear Vane Testing Labeled Records

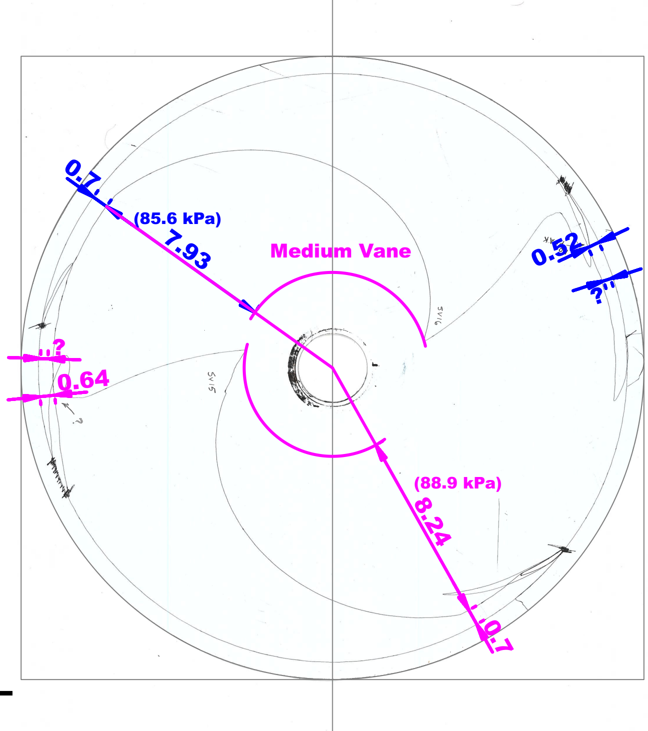

Small Vane
(213.0 kPa)
0.64
9.72 (didn't fail)
(154.3 kPa)
7.03
0.29
1.7
(37.3 kPa)
2.01
0.31
SV1 DIDN'T FAIL
SV2
PEAK
PEAK REMOLD

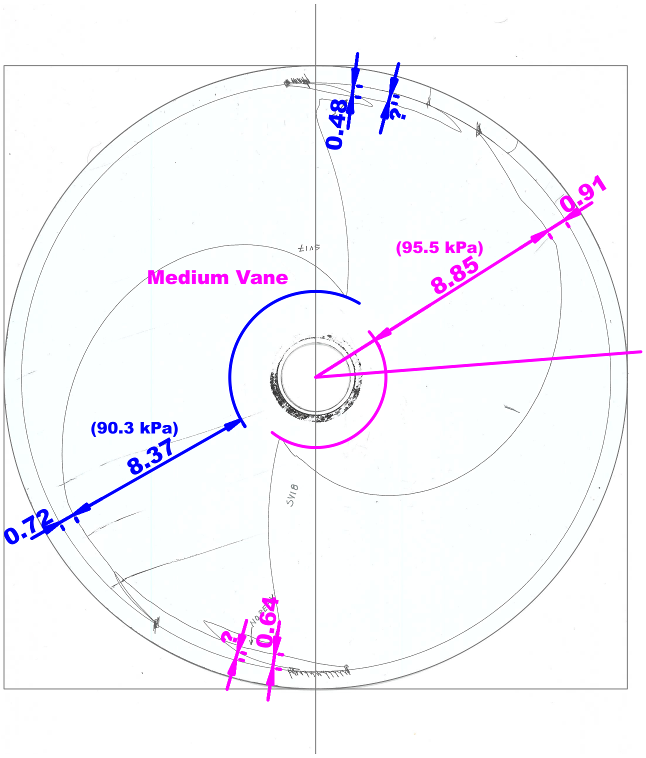

0.26
4.91
(107.8 kPa)
SV3
0.2
1.32
(24.4 kPa)
1.11
(61.2 kPa)
2.79
0.25
Small Vane
SV4
0.13
(2.8 kPa)
0.31
0.18
SV5
0.15
0.36
(4.4 kPa)
0.2
(59.3 kPa)
2.7


0.19
0.32
0.13
(1.4 kPa)
0.28
6.34
(68.4 kPa)
SV8
0.33
(41.5 kPa)
3.85
Medium Vane
(65.3 kPa)
6.05
0.25
0.45
0.29
0.2
(2.2 kPa)
SV9
0.19
(2.0 kPa)
0.39
0.19
SV7
(58.7 kPa)
5.44
(2.9 kPa)
0.49
0.23
0.27
SV6


0.32
(1.2 kPa)
0.11
0.41
0.3
6.48
(69.9 kPa)
SV11
0.26
?
SV12
Medium Vane
(73.5 kPa)
6.81
0.37
(77.8 kPa)
7.21
0.63
SV10
(0.6 kPa)
0.06
0.32
0.25


0.58
(77.7 kPa)
7.2
?
0.51
0.39
?
SV13
SV14
Medium Vane
7.43
(80.2 kPa)
0.83


0.7
(85.6 kPa)
7.93
Medium Vane
0.52
?
?
0.64
SV15
SV16
(88.9 kPa)
8.24
0.7


0.48"
?"
SV17
0.91
(95.5 kPa)
8.85
Medium Vane
(90.3 kPa)
8.37
0.72"
SV18
?"
0.64"

Report 91-BPG-R0
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Appendix

D Vane Borer M-1000 Manual

INSTRUCTION MANUAL

VANE BORER

Model M-1000

Tel. : 1.450.465.1113 • 1.877.ROCTEST (Canada, USA) • 33 (1) 64.06.40.80 (Europe) • www.roctest.com • www.telemac.com

E10046-180123

TABLE OF CONTENTS

1. DESCRIPTION

The M-1000 vane borer is an instrument for carrying out in-situ shear tests in cohesive soils. The test results appear graphically on a waxed paper disk that constitutes a permanent record. It is simple to use and has a very small relative vane volume displacement.

The instrument is normally mounted on a boring rig for testing at various depths without a drilled hole, or is mounted on the casing of a borehole using an adapter.

2. OPERATING INSTRUCTIONS WHEN USED WITH THE BORING RIG

1. The base-frame of the boring is fastened to the ground with the earth augers. These are screwed down with one of the crank handles of the boring rig, or with a power drill. Note that the base-frame must be sufficiently level to permit subsequent rod plumbing within the adjustment tolerances of the vertical frame.

2. Plumb the vertical frame and tighten the securing bolts.

3. Bolt the base clamp that accepts the torque-recording head to the top of the frame (2 bolts). Insert the instrument head and turn it so that the crank handle is in an unobstructed position. Lock the instrument head in the base clamp.

4. Place a paper disk in the instrument and turn it counter-clockwise once only, to scribe a zero line for visual reference during the testing. Make sure that the instrument's clutch is disengaged and is not gripping a rod, if any is passing through the head.

5. Assemble the vane and the slip coupling on the 80 cm starting rod. Tighten adequately. Hold the assembly under the instrument, thread a 100-cm rod through the head and tighten the 2 rods together. Add another rod to the top of the rod string just assembled.

6. **It is important to start the tip sounding with proper rod alignment.** Put the vane point against the ground surface so that the axis of the rod is vertical and parallel with the chain when the driving yoke is in its lowest position. If required, a shallow hole may first be dug for the vane. The torque instrument itself, with clutch disengaged, serves as an upper rod guide. After checking for rod plumbness, verify that all rod connections are tightly screwed.

   Note: The vane can sustain quite a heavy load but it is fairly brittle because of the hardening treatment. It must therefore not be subjected to excessive side pressure or crushing pressure. These forces can occur in stony fills, crushed brick layers and similar materials. In such cases a pilot hole should be bored prior to testing.

7. Insert the rod fork in the flats machined- on rods. The rod fork, for convenience, should be placed as high as possible along the rod. Press down the vane carefully until the desired test depth is attained.

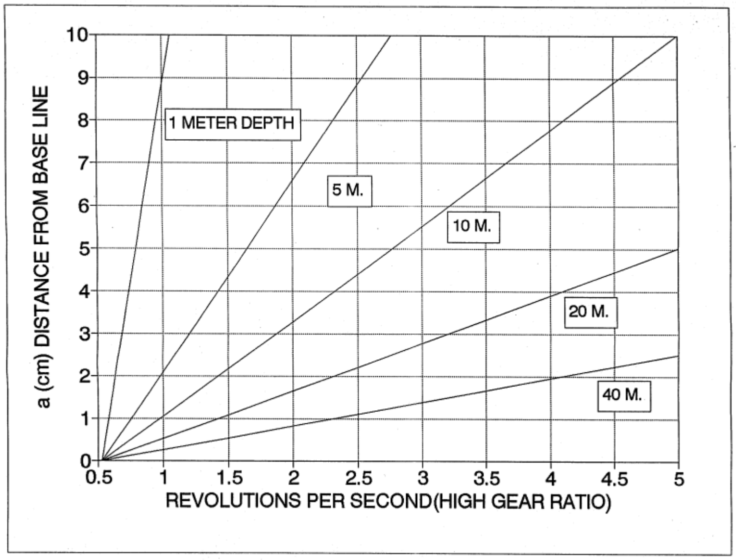
   Note: The mobile part of the clutch shall be in its lowest position when driving the rod. When ready to test, push the clutch in its uppermost position and turn it counterclockwise to firmly lock it on the rods.

8. With the vane in position, apply the torque to the vane at a rate that should not exceed 0.1°/s. This generally requires a time to failure of from 2 to 5 min., except in very soft clays where the time to failure may be as much as 10 to 15 min. In stiffer materials, which reach failure at small deformations, it may be desirable to

reduce the rate of angular displacement so that a reasonable determination of the stress-strain property is obtained. Record the maximum torque.
The vane is rotated by using one of the two axles that protrude on the side of the torque instrument. The axle located in the center of the hexagonal brass nut provides a high ratio of vane rotation to crank handle rotation. The other axle mounted at 90 degrees to the high gear ratio provides a low ratio of vane rotation to crank handle rotation. The gear ratio chosen is a matter of convenience. For the most uniform vane rotation, the high gear ratio is used. To engage the high gear ratio, the small gear ratio axle must be pulled outward (about 1 cm). To engage the small gear ratio, push the small gear ratio axle inward.

The charts below shows the rates of crank handle rotation in the high gear ratio vs "a" (radial distance in cm) required to rotate the vane at a rate of .1°/second (6°/minute).

The plots are shown for different rod lengths and take into account the rod twist. To remain within the ASTM D2573 specification, the rate of rotation of the crank handle in the high gear ratio should **not exceed** those shown.



As a general rule, the following table may serve as a guide for crank handle rotation.

Vane Test Depth Meters (ft)	High Gear Ratio	
	(RPMin)	(RPSec)
0 - 10 (32.8)	120	2
11 - 20 (65.6)	180	3
21 - 30 (98.4)	240	4

For rates exceeding approximately 3 RPM, it may be convenient to use the low gear with a 30: 1 high: low ratio.

9. After the test, the torque instrument is slowly loosened from the base clamp and the rod-gripping clutch is released. Do not release tension on the rods by cranking the handle counterclosewise. This will damage the equipment. A wrench is then used to rotate the rods and vane clockwise up to twenty times to insure

complete remolding. Immediately afterwards, the rods must be turned counterclockwise about 90 degrees to re-establish the free slip in the coupling. Care must be used not to turn too far counterclockwise to avoid loosening the rod joints. Ordinarily, the slip can be felt; just a few degrees may be sufficient. The end of the slip is usually noted by an abrupt increase in torque.

10. The remolded vane shear test should follow immediately (to avoid thixotropic effects). First, press in the small ratio axle to free the high ratio. Using the small ratio, the crank handle is then rotated with 1 to 2 rpm until the curve gets radial.

    Note: If the clay's shear strength during this test is so small that the vane cannot provide the reaction for the torque required to turn the slip coupling, corresponding to a torque of approximately 5 kg/cm, one does not obtain the free slip part of the test curve. The remolded strength then corresponds to a torque of less than 5 kg/cm (4.3 in. lb. (0.49 N/m).

11. The axle for the small gear ratio must be pulled out so that the high ratio can be used later, if desired.

12. Screw on the next rod and continue boring. Be sure joint tightness exceeds the torque to be applied later, to avoid joint slipping during a test. If tests have been made in the dry crust, you should pull up the vane and scrape it clean of clay from the dry crust before the vane is pushed down further into softer layers. Otherwise, if you happen to test just at the boundary between a very stiff dry clay crust and very soft underlying clay, the softer clay cannot scrape the vane clean of the much stiffer dry clay.

    While pressing the vane down to a greater depth for the next test, one re-establishes the slip angle between the rods and the vane because there is a slight pitch on the vane. The pitch of the vane blades is such that it develops approximately 15° of free slip during a 1-m depth increase. When testing at depth intervals less than 1 m, one should rotate the rod counterclockwise, before pressing from one testing depth to the next, to assure some free slip for the next test. Do not overturn, to avoid loosening rod and vane connections. This procedure can also be followed for test depth intervals of 1 m, thereby obtaining a larger and more certain free slip. The rod fork is used when pushing the vane to greater depth so that the rod does not undergo any rotation, which can remove or reduce the amount of free slip.

13. When the last vane test is finished and the rods and vane are to be withdrawn, the rod-cleaning equipment is fixed to the bottom of the rig. The wheel for depth recording (if in use) is removed first. Then the rubber wiper and its holder are passed over the rod and are held in place on the bottom beam of the rig with the forked end of the holder fastened to the 2 studs on the beam.

14. The rods are then pulled up and uncoupled. For convenience, use a 2-m rod-length by disconnecting each second rod. While pulling up, it is best to hold the rod with a clamp (lifting iron or ball cone clamp) which is fixed above the rig so that the rod does not sink each time one changes grip.

15. The vane and the slip coupling must be cleaned immediately. Make sure that the rubber around the connection has not been damaged. If damaged, it must be replaced (see instructions further on).

16. Oil the connection and the vane and make sure that the vane surfaces are smooth and not warped.

    Note 1: If a pause is taken while vane sounding, this must be done after a test and not after the vane has been pushed down to the next test depth. During a longer pause, i.e. a night, the rod must be pulled up a few meters before the pause. When the sounding is started again after a pause, the rod must be turned again approximately 10 revolutions and the rod pulled up and down so that the clay around the rod is properly disturbed. A pause taken while boring must be noted in the record. However, it is sometimes desirable to perform tests at the same depth after various rest-time intervals following remolding, in order to measure strength regain with time (thixotropic) effects. The free-slip feature also permits to take proper account of thixotropic effects along the rods.

Note 2: The condition of the slip coupling must occasionally be checked. This is done by fixing the vane in the ground surface and verifying the instrument to measure how great a torque is required to turn the slip coupling. This torque should not be greater than approximately 3 to 5 kg/cm (2.5 to 4.5 in. lbs.).

Note 3: When the recording pointer just reaches the cylindrical washer at the center, the vane-boring instrument must not be loaded further. If yielding does not occur in the clay at this load with the smallest vane, an undisturbed test cannot be made using the instrument. Instead, continue to the next test depth. With this sounding equipment, two men can press with a force of approximately 1500 to 2000 kg. The chain's breaking load is 4000 kg. The crank handles of the rig bend at a load corresponding to approximately 1000-kg penetration force per crank handle.

3. OPERATING INSTRUCTIONS IN A CASED HOLE

The vane borer can also be used in a drilled hole. The instructions pertaining to its use with the boring rig are slightly different. A casing adapter is used to mount the instrument head.

The vane, the slip coupling and the string of rods are assembled at the collar and lowered to the bottom of the hole. In casing depths greater than about 5 m, guide bushings are placed on the rods to center them inside the casing. They are placed at intervals of 5 - 10 m.

Once the vane and rod assembly reaches the bottom of the hole, the adapter is clamped onto the casing. The length of rod protruding above the casing must be about .6 meters greater than the proposed depth of shear testing below the bottom of the borehole. The chuck on the instrument head is unlocked and the instrument is then threaded over the rod and clamped on the adapter.

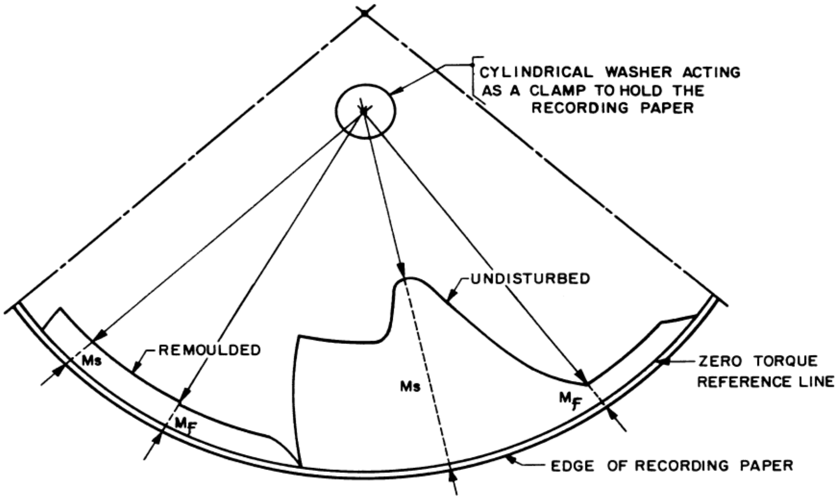
The rods are then pushed down with the fork, to the desired position of the vane below the casing bit. The clutch is locked on the rods. The test can be carried out as described in the previous section. In very soft clays, a swivel or rod clamp is used to support the vane-rod assembly during the test.

4. INTERPRETATION OF THE VANE BORING CURVE

The waxed paper chart record of a typical undisturbed and subsequent remolded vane shear test is shown below. The distance "a" to a point on the curve from the zero line, in the radial direction, is linearly proportional to the torque M applied to the aboveground end of the vane rod. The linear relationship between radial distance and torque is expressed by a calibration constant K for each instrument, or

$$\mathbf{M = K \times a}$$

Where: M = torque in kg • m
a = distance from zero torque reference line in cm
K = calibration constant for the torque recording head in kg •m / cm



Results of a vane shear test scribed on the waxed paper chart.

On the curve in the above figure, the torque required to rotate the rods plus the slip coupling corresponds to the torque M_f. The torque required to rotate the rods and the vane at yielding corresponds to the maximum moment M_s. The difference between M_s and M_f is equal to the torque M_v needed to turn only the vane at yielding. Note that the small torque required to perform the slip is thus conservatively neglected.

The torque M_f must be measured just before the breaking point of the curve, as shown on the figure. This is because the torque required to overcome rod friction sometimes decreases with continued remolding during the free slip angle, and its value at the break point is most representative of the desired value (at M_s). Any further decrease, after the break point, is neglected. The importance of such neglect can be checked by another slip-torque test immediately after yielding.

With the remolded test, one does not in certain cases get a distinct difference between M_f and M_s. The explanation is that the reaction torque from the remolded clay along the vane is so small that it is not sufficient to move the slip coupling. In other words, this means that the torque required to turn the vane is smaller than the torque needed to turn the slip coupling (3 to 5 kg/cm, 2.5 to 4.5 in. lb.).

The torque required to turn only the vane, M_v, is obtained as described. It is then converted to undrained shear strength s_u, in kg/cm^2 using the following relationships:

$$M_v = K (a_s - a_f)$$

$$S_u = M_v \times C$$

$$S_u = K (a_s - a_f) \times C$$

where M_v = the torque required to rotate the vane only in kg • m

a_s = distance in cm between the zero torque reference line to the peak of the curve

a_f = distance in cm between the zero torque reference line and the circular arc scribed during the first 15 degrees of rotation (corresponds to rod friction)

S_u = the undrained shear strength in kg/cm^2

C = vane form constant in $10^{-2} \times cm^{-3}$

K = calibration constant for the torque recording head in kg •m / cm (close to 1 typ.)

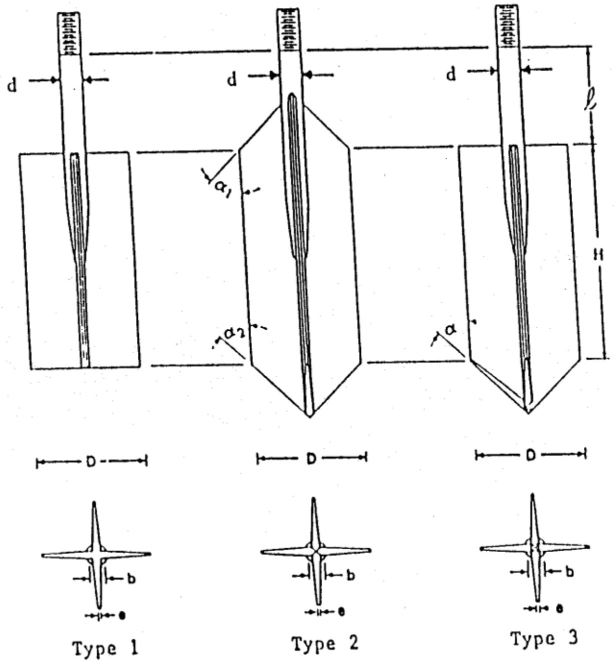
The vane constants for the “type 3” vanes are as follows:

Vane dimensions (cm)	**C (10^{-2} x cm^{-3})**
5 x 11	0.2
6.5 x 13	0.1
8 x 17.2	0.05
10 x 20	0.026

The vane constants can be determined from the formulae below.

In the above manner, one can obtain both the undisturbed and remolded shear strengths. Furthermore, the curve shows the strength of the soil immediately after yielding, which is of great importance when evaluating the effects of progressive strain. Also, the shape of the curve after yielding will show the character of the soil.

VANE FORM CONSTANTS



Type 1 $$C = \left[\pi D^2 H \left(\frac{1}{2} + \frac{D}{6H}\right)\right]^{-1}$$

Type 2 $$C = \left[\pi D^2 H \left(\frac{1}{2} + \frac{D}{12H\sin\alpha_1} + \frac{D}{12H\sin\alpha_2}\right)\right]^{-1}$$

Type 3 $$C = \left[\pi D^2 H \left(\frac{1}{2} + \frac{D}{12H} + \frac{D}{12H\sin\alpha}\right)\right]^{-1}$$

WHERE D = VANE DIAMETER IN CM.
H = HEIGHT OF CYLINDRICAL SECTION IN CM
α = ANGLE IN DEGREES
C = VANE CONSTANT IN $CM.^{-3}$ x 10^{-2}

In pure clays, the post-yielding part of the curve will be very smooth but, if there is silt or sand in the clay, this part of the curve will appear rugged.

Example

C = 0.05 x 10^{-2} x cm^{-3} (8 x 17.2 cm vane)
K = 1.1 kg x m / cm
a_s - a_f = 5 cm

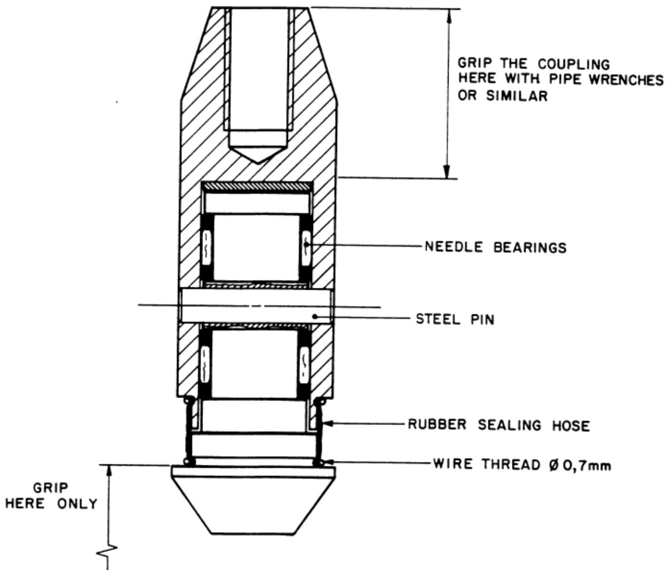
Then:

S_u = K (a_s - a_f) x C
S_u = 110 kg x cm / cm (5 cm) x (0.05 x 0.01 x cm^{-3})
S_u = 0.275 kg / cm^2 = 27 kPa

The slip coupling

Shown on Figure below is a section through the slip coupling.

It is important to keep the rods and vane tightly connected. Otherwise, there will be slippage in these joints and this unwanted behavior will remain undetected.



Cross-sectional view of the slip coupling

When loosening and fastening the vane, the slip coupling must not be gripped so as to damage the needle bearings. The coupling can be gripped as shown in the figure, either above the needle bearing or at the lower part of the coupling. To avoid damaging the surface of the coupling, use a pad with pipe wrenches or similar tools. Any damage should be smoothed with a file. To avoid excess rod torque and help assure that its value is nearly constant with slip, the surface of the coupling must always be kept free from rust and unevenness.

5. INSPECTION AND SERVICE

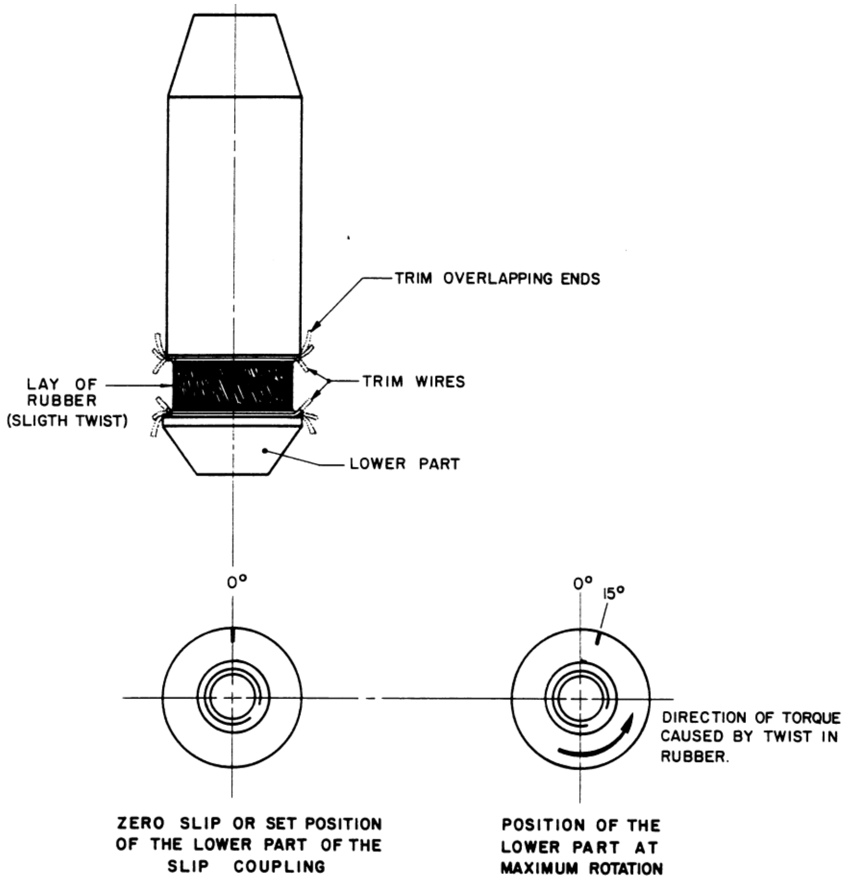
1. The M-1000 vane borer should be brought in annually for checking and calibration.
2. It is very important to occasionally check the condition of the slip coupling.
3. If the slip coupling is damaged or if too large, a torque (greater than 5 kg.cm or 4.5 in.lb) is required to turn the coupling; it should be sent for repair to the factory.

   In emergency, the repair can be done on site as follows:

   a) The rubber nose must be loosened and the pin approximately in the middle of the slip coupling should be knocked out with a punch.
   b) The connection is taken apart and the needle bearings taken out.
   c) The connection and the needle bearings must be thoroughly cleaned, in kerosene.
   d) The needle bearings must be embedded with waterproof grease and placed in position on the shaft of the coupling. The assembly is then pushed into the cylinder and the pin carefully driven in.

e) If possible, the pin and the coupling are to be sealed with solder. See to it that the temperature during soldering does not get too high.

f) The rubber hose is then cut to length approximately 1/2 inches. Slip the rubber over the tapered end of the coupling. Fasten the upper edge of the rubber sleeve using a double strand of wire to hold it in place. Rotate the free end of the rubber sleeve clockwise and fasten it using the wire. The twist in the rubber sleeve should provide sufficient torque to maintain the lower part of the coupling in a set position and allow 15 degrees of clockwise rotation between the upper and lower sections of the coupling.



Mounting of the rubber sleeve

6. ADDITIONAL NOTES ON THE OPERATION OF THE M-1000 VANE BORER SYSTEM

1. Check that the angle of play of the slip coupling is in the right direction before pressing down the rod for the final half-meter of depth.
2. Check that the rods are securely screwed together. Keep the threads clean.
3. Check that the rod chuck grips. Do not put any grease on the rods.
4. A **Quick Recording Head Diagnostic** can be done as follows:

a) Secure the recording head tightly. If possible use the casing clamp and attach the head to some king of bench or table

b) Put a sheath and a rod in the head. Engage the clutch.

c) Apply some torque on the rod and make sure the needle responds

d) Clamp vice grip pliers on the rod but with little compression. Hold the vice grip tightly and turn the handle on the head. The rod will slide in the vice grip.

e) Increase compression on the vice grip and make sure the needle responds properly

5. Check the slip coupling before starting in a new hole.
6. If the dry crust is tough, one should at first dig a hole with a spade in order that clay does not stick to the vane. If the vane is not clean, one will normally not get a clear break in the curve. It may sometimes suffice to run the vane up and down a few times in the dry crust.
7. The rod chuck is located at the base of the instrument head. Its purpose is to lock the instrument unto the rods. The following points are important:

   f) To lock the rods, turn the chuck slightly, from left to right, while pushing upward. Then turn in the opposite direction until the rods are squeezed tight.

   g) To unlock the rods, pull downward on the chuck while turning it from left to right.

   h) It is important not to unduly strain the spring.

7. The vane borer is mounted either on a boring rig or on the casing top of a drillhole.
8. For protection, the recording head is delivered with a little piece of cardboard underneath the needle. Keep this cardboard in place when carrying the equipment.

7. VANE BORER EQUIPMENT

Torque Recorder

1 - instrument head with clutch for rod and guide bushing
1 - crank handle
1 - Allen key type M4
1 - steel transport case

Torque Recorder Accessories

50 registration charts (waxed paper disc)
1 - base clamp

Standard vanes and slip coupling

1 - 5 x 11 cm
1 - 6.5 x 13 cm
1 - 8 x 17.2 cm
1 - slip coupling

Boring rig

1 - M-71 standard boring rig (2 ton capacity) or M-70 (1 ton capacity)
2 - crank handles
4 - earth anchors (extensions for deep anchoring optional)
4 - anchor lock plates
1 - /rod fork
Nec. 20.6 mm x 1 meter length rods
1 - 20.6 mm x .75 meter length starting rod
Nec. galvanized steel case for rods
2 - rod wrenches

8. PARTS LIST

M-100 Torque Recorder

Part No.	Description	Qty
M-101	Instrument housing	1
M-102	Cover, complete	1
M-103	Glass for cover	1
M-104	Fastening screw for cover	2
M-105	Stainless clutch	1
M-106	Center house	1
M-107	Center axle	1
M-108	Spring activator	1
M-109	Outer distance shim	1
M-110	Inner distance tube	1
M-111	Fastening plate (base clamp)	1
M-112	Measuring spring	1
M-113	Spring fastening	1
M-114	Spring pin	1
M-115	Axle	1
M-116	Wedge	1
M-117	Needle bearing	2
M-118	Screw, worm, large	1
M-119	Worm gear, large	1
M-120	Screw, worm, small	1
M-121	Worm gear, small	1
M-122	Seegerlocking	1
M-123	Axial bearing, small	1
M-124	Bronze bearing, hexagon	1
M-125	Axial bearing	1
M-126	Distance tube	2
M-127	Sprocket, large	1
M-129	Screw	2
M-130	Screw	3
M-131	Screw	3
M-132	Indicator plate	1
M-133	Screw	3
M-134	Ballbearing small	2
M-135	Indicator axle	1
M-136	Spring	1
M-137	Support plate for registration	
M-138	Screw F6S	4
M-139	Indicator	1
M-140	Ballbearing	1
M-141	Pressure center	1
M-142	Instrument crank, compl.	1
M-143	Handle for instrument crank	1
M-144	Instrument case	1
M-145	Chuck for instrument, compl.	1
M-146	Outer section to chuck	1
M-147	Inner section to chuck	1
M-148	Cylinder	3
	Spring	1
M-150	Screw, M4 x 15	1
M-151	Screw, M5 x 15	1
M-152	Registration paper	50
M-153	Angular slip coupling	1
M-154	Outer section for part 153	1
M-155	Inner section for part 153	1
M-156	Needle bearing half	4
M-157	Axial bearing	1
M-158	Protective rubber	
M-159	Lash wire	
M-160	Locking pin	1
M-161	Boring rod, 0,75 m	
M-162	Vane, 11 x 5 cm	
M-163	Vane, 13 x 6,5 cm	
M-164	Vane, 17,2 x 8 cm	
M-165	Screw, EC6S, M4 x 15	1
M-166	Screw, EC6S, M6 x 10	2
M-167	Screw, B6S, M6 x 15	3
M-168	Screw, B6S, M6 x 12	3
M-169	Locking screw, M3 x 10	

M-100 TORQUE RECORDER