



Full Day Seminar - Expanded Base Micropiles
Micropile Behavior Predictions using Advanced In-Situ Soil
Characterization - SDMT & CPTu
Full Scale In-Situ Load Tests: Compression, Uplift, Lateral, PDA



30/10/2025

Laterally Loaded Piles (LLP) using P-Y curves from DMT test results

Diego Marchetti diego@marchetti-dmt.it

Kaustav Das k.das@marchetti-dmt.it

Studo Prof. Marchetti – Rome Italy

www.marchetti-dmt.it

Presentation Outline

- Introduction
- P-Y curves for LLP applications
- Three methods for P-Y curves from DMT:
 - Gabr and Borden 1988
 - Robertson 1989
 - Marchetti 1991
- Case history Livorno LLP test (1991) analysis and validation of deflections
- Gatineau test site: Sample LLP analysis



Introduction

- Pile foundations are structural elements to transfer loads from superstructures to deeper, competent soil or rock strata
- Piles are commonly designed to resist axial loads (compression or tension), but sometimes also laterally loaded
- When a pile is laterally loaded, it deflects primarily in the loading direction, mobilizing soil resistance along its length
- The soil–pile interaction is nonlinear and depends on factors such as soil stiffness, strength, pile geometry and load magnitude
- The response is characterized by bending moments, shear forces and lateral deflections along the pile shaft, with maximum deformation typically occurring at shallow depths



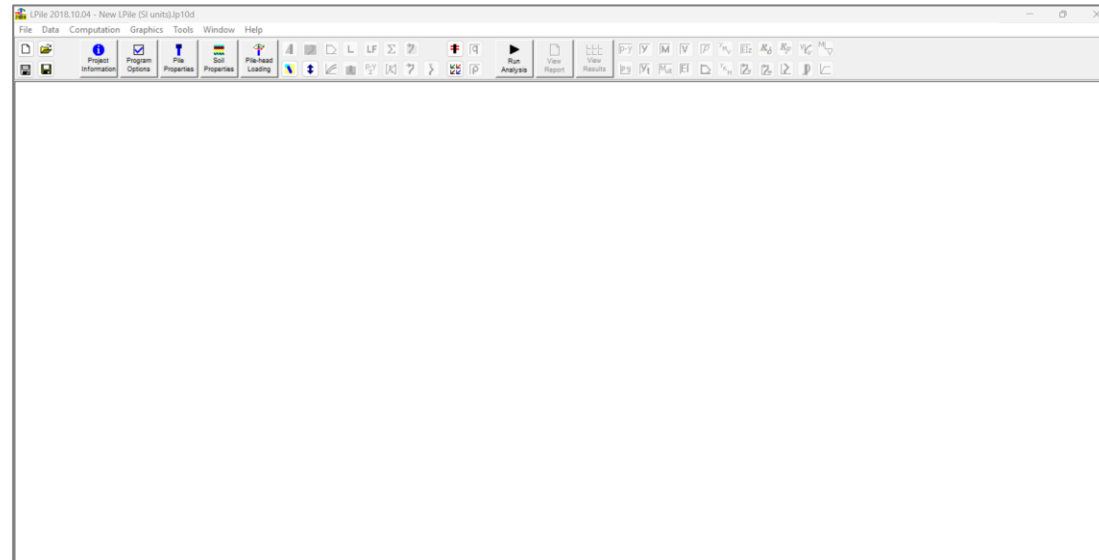
Introduction to LLP and P-Y Curves

- LLP analysis is generally more complex than for axially loaded piles, because of the nonlinear and heterogeneous nature of soil response
- Numerical or semi-empirical methods based on P-Y curve approach are widely adopted
- P-Y curves approach (Hetenyi 1946): soil is modeled with a series of independent and nonlinear springs (Winkler model), where the lateral soil reaction (P) at each depth is expressed as a function of the local lateral deflection (Y)
- Three main methods were developed to estimate P-Y curves from DMT results :
Gabr and Borden (1988), Robertson (1989), Marchetti (1991)
- Prediction of the two latter methods are compared with measured deflections in the case history LLP test site of Livorno (Italy 1991)



Software for LLP analysis using P-Y curves

- LLP analysis using Ensoft LPi 2018
- The freeware version of the software may be downloaded from <https://getintopc.com/software/ensoft-lpi-2018-free-download/>



Gabr and Borden (1988) method

$$\frac{P}{P_{ult}} = \tanh \left(\frac{E_{s1} y}{P_{ult}} \right)$$

Ultimate soil resistance P_{ult}

$$P_{ult} = N_p S_u d \quad N_p = 3 + \frac{\sigma'_{v0}}{S_u} + J \left(\frac{Z}{d} \right) \leq 9$$

N_p = non dimensional ultimate clay resistance coefficient

S_u = undrained shear strength from DMT

σ'_{v0} = effective vertical stress at depth Z

J = empirical coefficient; 0.5 for soft clay, 0.25 for stiff clay

Z = depth

d = pile diameter

Initial Tangent Modulus E_{s1}

$$E_{s1} = 6.5 \left(\frac{P_o - \sigma_{h0}}{b} \right) d$$

P_o first DMT reading

σ_{h0} in-situ horizontal at-rest pressure

b half blade thickness (7 mm)

d pile diameter



Gabr and Borden (1988) method

Comments:

- First method for P-Y curves from DMT data
- Developed specifically for stiff OC clay and tends to overpredict deflections in non OC clays
- E_{s1} based on P_0 , related to total horizontal stress and not to soil compressibility

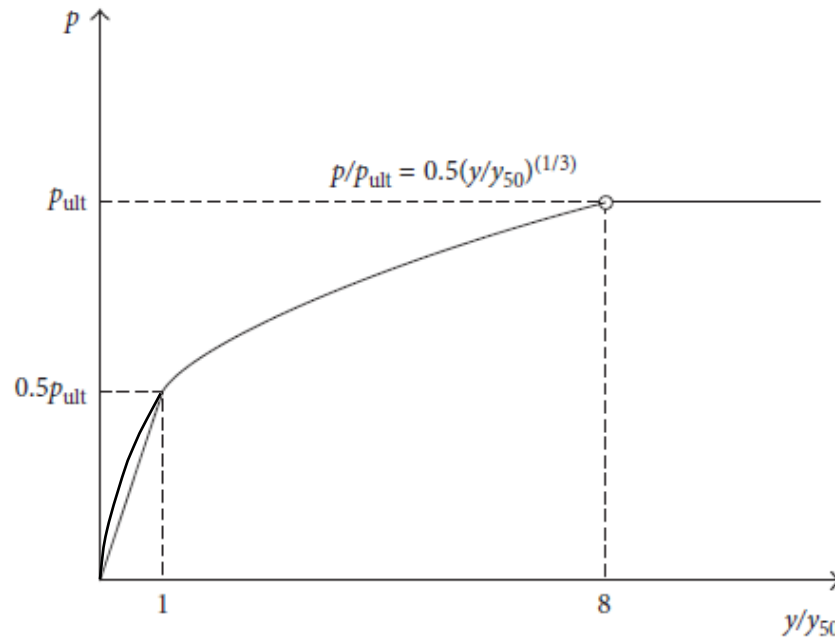


Robertson 1989 method for P-Y curves from DMT data

(for clay and sand)



Robertson 1989 method



Parameters:

p : soil reaction

y : pile deflection

p_{ult} : ultimate soil resistance

p/p_{ult} : ratio of soil resistance

y_{50} : pile deflection for $p = 50\% p_{ult}$

y/y_{50} : ratio of pile deflection

- Adaptation of early Matlock 1970 method: $y/y_{50} \geq 8 \rightarrow p/p_{ult} = 1$ (asymptot $p = p_{ult}$)
- Applicable in OC and NC clay and based on S_u
- Applicable in sand (based on φ)



Robertson 1989 method

$$\frac{P}{P_{ult}} = 0.5 \left(\frac{y}{y_{50}} \right)^{0.33}$$

Ultimate soil resistance (P_{ult})

$$P_{ult} = N_p S_u d \quad N_p = 3 + \frac{\sigma'_{v0}}{S_u} + J \left(\frac{Z}{d} \right) \leq 9$$

N_p = non dimensional ultimate clay resistance coefficient

S_u = undrained shear strength from DMT

σ'_{v0} = effective vertical stress at depth Z

J = empirical coefficient; 0.5 for soft clay, 0.25 for stiff clay

Z = depth

d = pile diameter

Reference pile deflection (y_{50})

$$y_{50} = \frac{23.67 k S_u (D^{0.5})}{F_c E_D}$$

F_c = 10 (empirical stiffness factor)

E_D = dilatometer modulus

S_u = undrained shear strength from DMT

k reduction factor to capture the effects of pile installation

$$k = \begin{cases} 1, & OCR \leq 1 \\ \frac{4}{3} - \frac{OCR}{3}, & 1 \leq OCR \leq 2 \\ \frac{2}{3}, & OCR > 2 \end{cases}$$



LLP Livorno case history with Robertson 1989 method

- DMT data exported from SDMT Pro (Z , σ'_{v0} , E_D , S_u , OCR)
- Evaluate all other parameters (k , N_p , P_{ult} , Y_{50})

Pile Length [m]	18							
d [m]	0.5							
Fc	10							
Z	σ'_{v0}	E_D	S_u	OCR	k	N_p	P_{ult}	Y_{50}
[m]	[kPa]	[MPa]	[kPa]	[]	[]	[]	[kN/m]	[m]
0.8	14	6.2	38	2.40	0.67	4.17	52.80	0.00684
1	17	5.6	37	2.10	0.67	4.46	55.28	0.00741
1.2	20	5.3	37	1.90	0.70	4.74	61.39	0.00818
1.4	24	5.5	33	1.70	0.77	5.13	64.86	0.00770
1.6	27	4.0	29	1.50	0.83	5.53	66.83	0.01011
1.8	30	2.4	28	1.50	0.83	5.87	68.50	0.01627
2	33	3.4	34	1.50	0.83	5.97	84.58	0.01395
2.2	37	3.7	44	1.60	0.80	6.04	106.32	0.01592
2.4	40	6.0	49	1.60	0.80	6.22	121.84	0.01093
2.6	43	5.1	35	1.30	0.90	6.83	107.55	0.01034
2.8	47	3.1	32	1.20	0.93	7.27	108.55	0.01613
3	50	3.0	29	1.00	1.00	7.72	112.00	0.01618
3.2	53	2.8	25	0.93	1.00	8.32	104.00	0.01494
3.4	56	1.7	22	0.82	1.00	8.95	98.40	0.02166
3.6	59	1.5	21	0.77	1.00	9.00	94.50	0.02343
3.8	62	0.9	22	0.76	1.00	9.00	99.00	0.04091
4	65	0.6	21	0.73	1.00	9.00	94.50	0.05858
4.2	66	1.1	20	0.69	1.00	9.00	90.00	0.03043
4.4	67	0.8	21	0.70	1.00	9.00	94.50	0.04394
4.6	68	0.8	21	0.70	1.00	9.00	94.50	0.04394
4.8	69	1.3	20	0.68	1.00	9.00	90.00	0.02575
5	70	1.1	21	0.68	1.00	9.00	94.50	0.03195



LLP Livorno case history with Robertson 1989 method

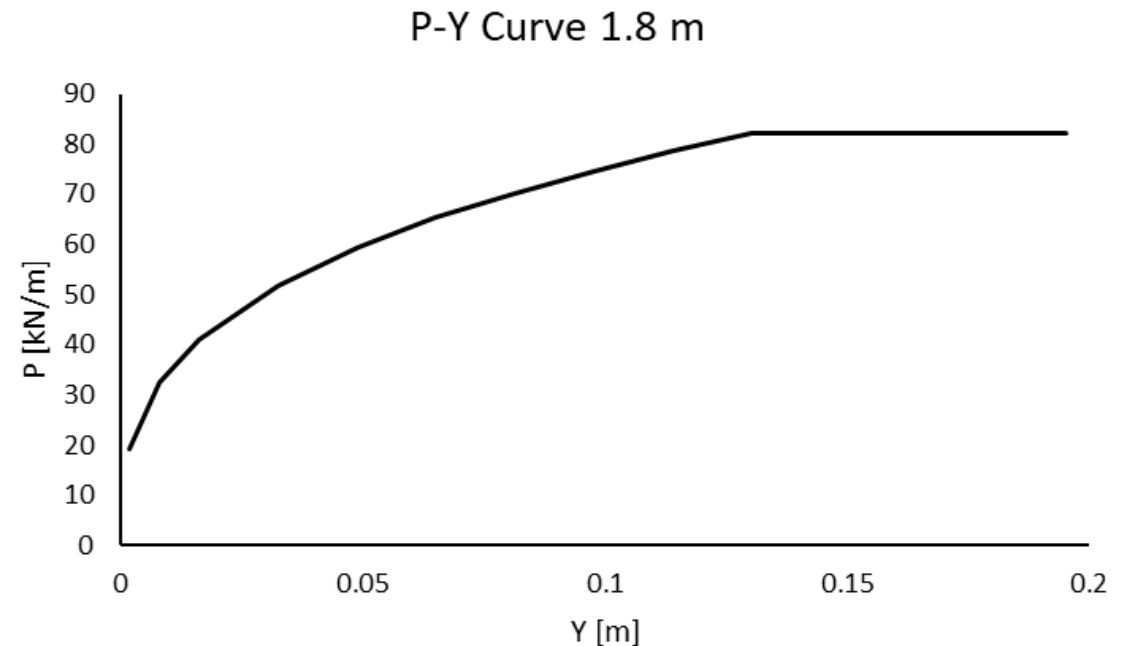
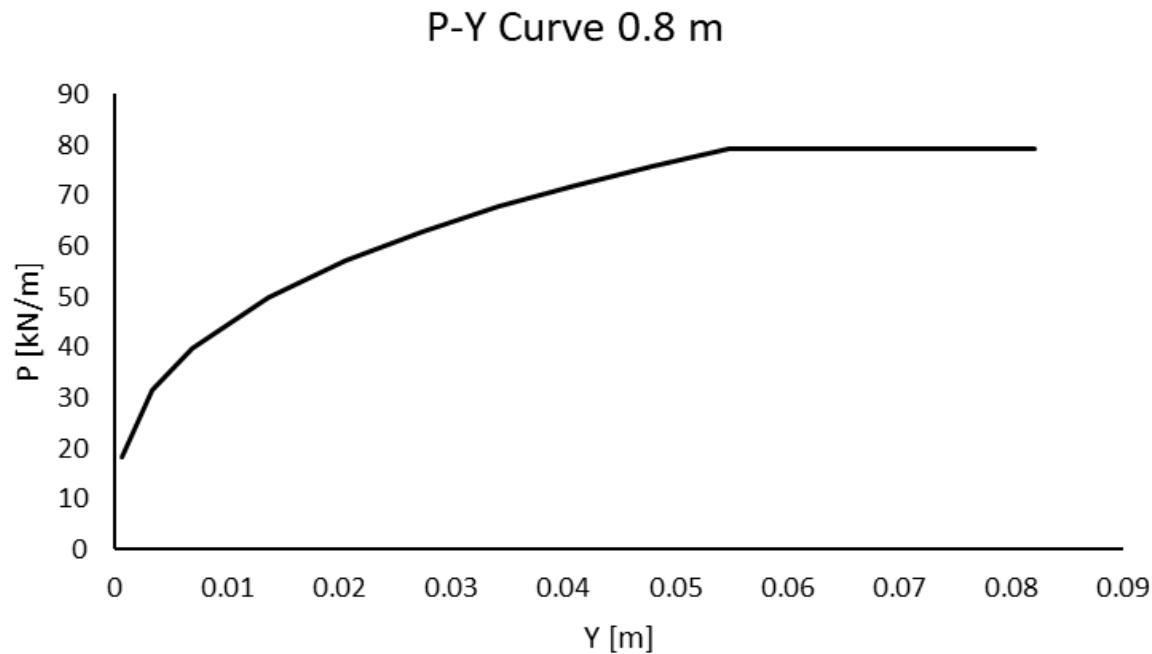
Evaluate P-Y values: calculation every 1 m depth and selection of Y/Y50 as in the table below

P-Y Graph										
Depth [m]	Y/Y50	y [m]	P/Pu	P [kN/m]		Depth [m]	Y/Y50	y [m]	P/Pu	P [kN/m]
0.8	0.1	0.00068	0.23	18.38		1.8	0.1	0.00163	0.23	19.08
	0.5	0.00342	0.40	31.43			0.5	0.00814	0.40	32.62
	1	0.00684	0.50	39.60			1	0.01627	0.50	41.10
	2	0.01368	0.63	49.89			2	0.03254	0.63	51.78
	3	0.02052	0.72	57.11			3	0.04882	0.72	59.28
	4	0.02736	0.79	62.86			4	0.06509	0.79	65.24
	5	0.03419	0.85	67.72			5	0.08136	0.85	70.28
	6	0.04103	0.91	71.96			6	0.09763	0.91	74.68
	7	0.04787	0.96	75.75			7	0.11391	0.96	78.62
	8	0.05471	1	79.20			8	0.13018	1	82.20
	9	0.06155	1	79.20			9	0.14645	1	82.20
	10	0.06839	1	79.20			10	0.16272	1	82.20
	11	0.07523	1	79.20			11	0.179	1	82.20
	12	0.08207	1	79.20			12	0.19527	1	82.20



LLP Livorno case history with Robertson 1989 method

Optional plots of P-Y curves every 1 m



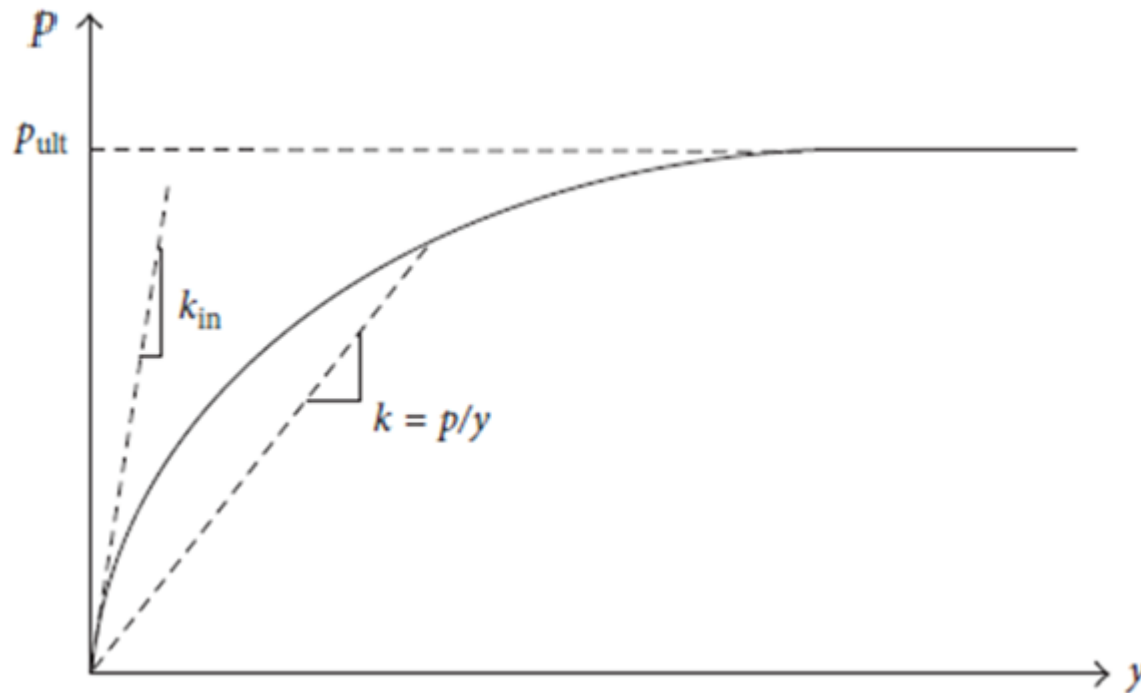
Marchetti 1991 method for P-Y curves from DMT data

(for clay only)



Marchetti 1991 method

This method simplifies previous methodologies and improves them by adopting tangent hyperbolic curve (Gabr and Borden 1988) and DMT compressibility parameter E_D (Robertson 1989)



Parameters:

- p : soil reaction
- y : pile deflection
- p_{ult} : ultimate soil resistance



Marchetti 1991 method

$$\frac{P}{P_{ult}} = \tanh \left(\frac{E_{s1} y}{P_{ult}} \right)$$

Ultimate soil resistance (P_{ult})

$$P_{ult} = \alpha K1 (P_0 - U_0) d$$

$$\alpha = \text{reduction factor} = \frac{1}{3} + \frac{2}{3} \left(\frac{Z}{7d} \right) \leq 1$$

$$K1 = 1.24$$

Z = depth, d = pile diameter

P_0 = Corrected DMT-A reading

U_0 = in-situ hydrostatic pressure

Initial Tangent Modulus (E_{s1})

$$E_{s1} = \alpha K2 E_D$$

E_{s1} = initial tangent soil modulus,

$$K2 = 10 \left(\frac{d}{0.5} \right)^{0.5}$$

E_D = dilatometer modulus

y significant for $y/d \leq 4\%$



LLP Livorno case history with Marchetti 1991 method

- DMT data exported from SDMT Pro (Z , P_0 , U_0 , E_D)
- Evaluate or input all other parameters ($K_1=1.24$, K_2 , α , P_u , E_{s1})

Pile Length [m]	18					
d [m]	0.5					
K1	1.24					
K2	10					
Z [m]	P_0	U_0	E_D	α	P_{ult}	E_{s1}
[m]	[kPa]	[kPa]	[MPa]	[]	[kN/m]	[kPa]
0.8	206	0	6.2	0.49	62.04	30114
1	211	0	5.6	0.52	68.52	29333
1.2	223	0	5.3	0.56	77.69	29781
1.4	207	0	5.5	0.60	77.00	33000
1.6	194	0	4.0	0.64	76.75	25524
1.8	192	0	2.4	0.68	80.49	16229
2	225	0	3.4	0.71	99.64	24286
2.2	285	0	3.7	0.75	132.95	27838
2.4	317	0	6.0	0.79	155.36	47429
2.6	243	0	5.1	0.83	124.83	42257
2.8	231	0	3.1	0.87	124.12	26867
3	216	0	3.0	0.90	121.17	27143
3.2	196	0	2.8	0.94	114.58	26400
3.4	178	0	1.7	0.98	108.26	16676
3.6	173	0	1.5	1.00	107.26	15000
3.8	179	0	0.9	1.00	110.98	9000
4	179	0	0.6	1.00	110.98	6000
4.2	173	2	1.1	1.00	106.02	11000
4.4	179	4	0.8	1.00	108.50	8000
4.6	184	6	0.8	1.00	110.36	8000
4.8	183	8	1.3	1.00	108.50	13000
5	188	10	1.1	1.00	110.36	11000



LLP Livorno case history with Marchetti 1991 method

Evaluate P-Y values: calculation every 1 m depth and selection of Y/D as in the table below

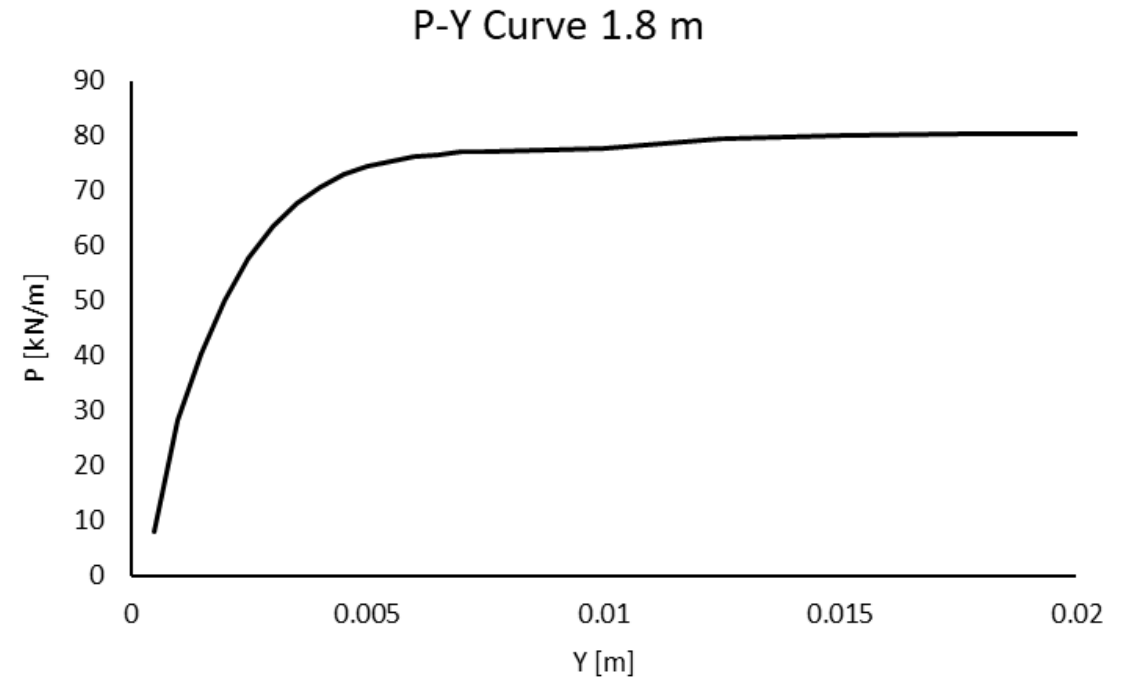
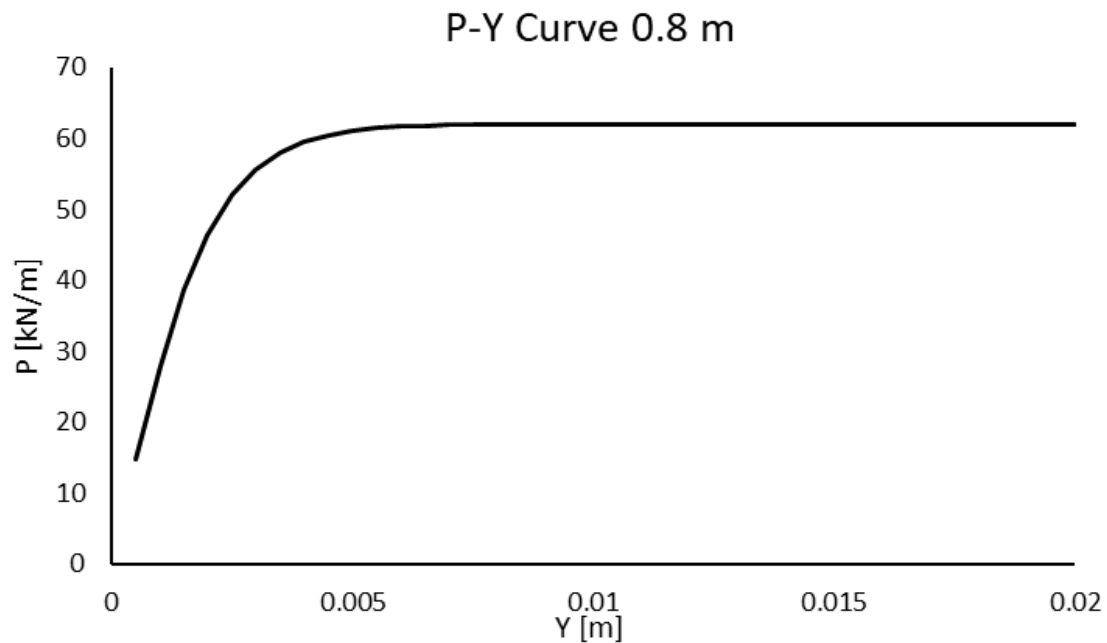
P-Y Graph			
Depth [m]	Y/D [%]	y [m]	P [kN/m]
0.8	0.1	0.0005	14.77
	0.2	0.001	27.95
	0.3	0.0015	38.58
	0.4	0.002	46.47
	0.5	0.0025	51.97
	0.6	0.003	55.64
	0.7	0.0035	58.02
	0.8	0.004	59.53
	0.9	0.0045	60.48
	1	0.005	61.08
	1.1	0.0055	61.44
	1.2	0.006	61.67
	1.3	0.0065	61.81
	1.4	0.007	61.90
	1.5	0.0075	61.95
	2	0.01	62.03
	2.5	0.0125	62.03
	3	0.015	62.04
	3.5	0.0175	62.04
	4	0.02	62.04

Depth [m]	Y/D [%]	y [m]	P [kN/m]
1.8	0.1	0.0005	8.09
	0.2	0.001	16.01
	0.3	0.0015	23.63
	0.4	0.002	30.81
	0.5	0.0025	37.45
	0.6	0.003	43.51
	0.7	0.0035	48.94
	0.8	0.004	53.74
	0.9	0.0045	57.94
	1	0.005	61.57
	1.1	0.0055	64.69
	1.2	0.006	67.34
	1.3	0.0065	69.58
	1.4	0.007	71.46
	1.5	0.0075	73.03
	2	0.01	77.69
	2.5	0.0125	79.46
	3	0.015	80.11
	3.5	0.0175	80.36
	4	0.02	80.4431



LLP Livorno case history with Marchetti 1991 method

Optional plots of P-Y curves every 1 m

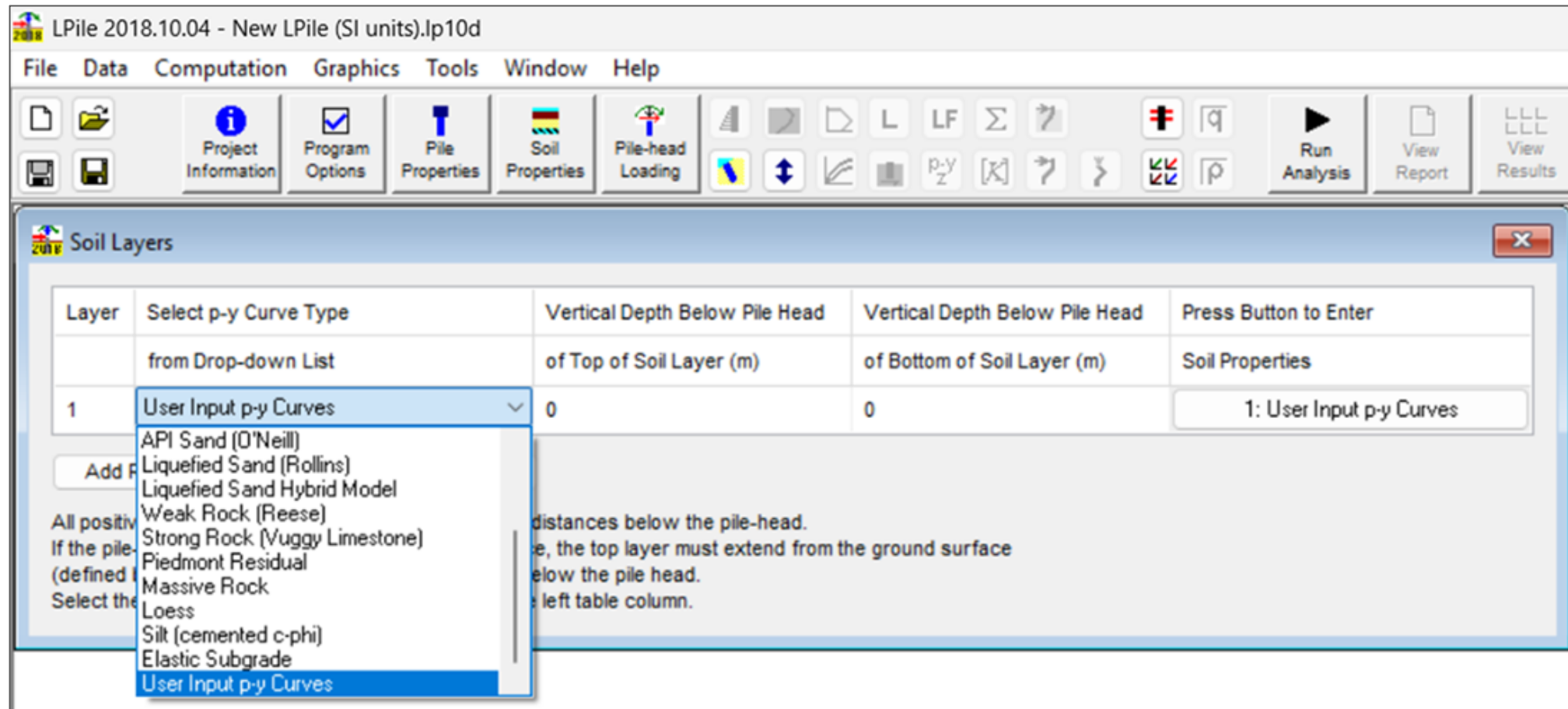


Ensoft Lpi 2018 software for LLP - Input and Processing



Input P-Y curves in Ensoft Lpi 2018 software

Step 1 Create the subsoil profile by using user input P-Y curves



Input P-Y curves in Ensoft Lpi 2018 software

Step 2 Create layers starting from first test depth (generally 1.0 m interval – max 20 layers)

LPile 2018.10.04 - New LPile (SI units).lp10d

File Data Computation Graphics Tools Window Help

Project Information Program Options Pile Properties Soil Properties Pile-head Loading

Run Analysis View Report View Results

Soil Layers

Layer	Select p-y Curve Type	Vertical Depth Below Pile Head of Top of Soil Layer (m)	Vertical Depth Below Pile Head of Bottom of Soil Layer (m)	Press Button to Enter Soil Properties
1	User Input p-y Curves	0.8	1.8	1: User Input p-y Curves

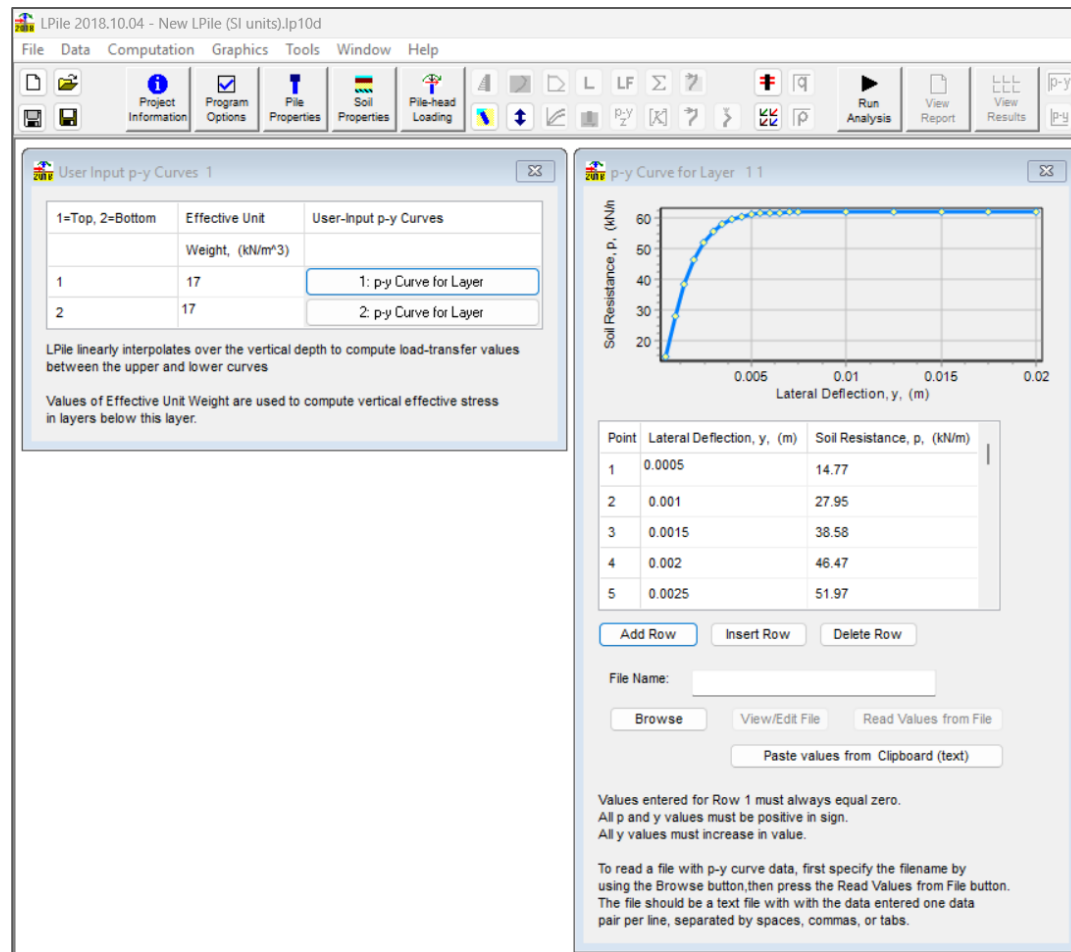
Add Row Insert Row Delete Row

All positive depth coordinates are defined as vertical distances below the pile-head.
If the pile-head is embedded below the ground surface, the top layer must extend from the ground surface (defined by a negative vertical depth) to some point below the pile head.
Select the p-y soil type using the drop-down list in the left table column.



Input P-Y curves in Ensoft Lpi 2018 software

Step 3 For each layer, input unit weight for top and bottom depth of layer and P-Y curves

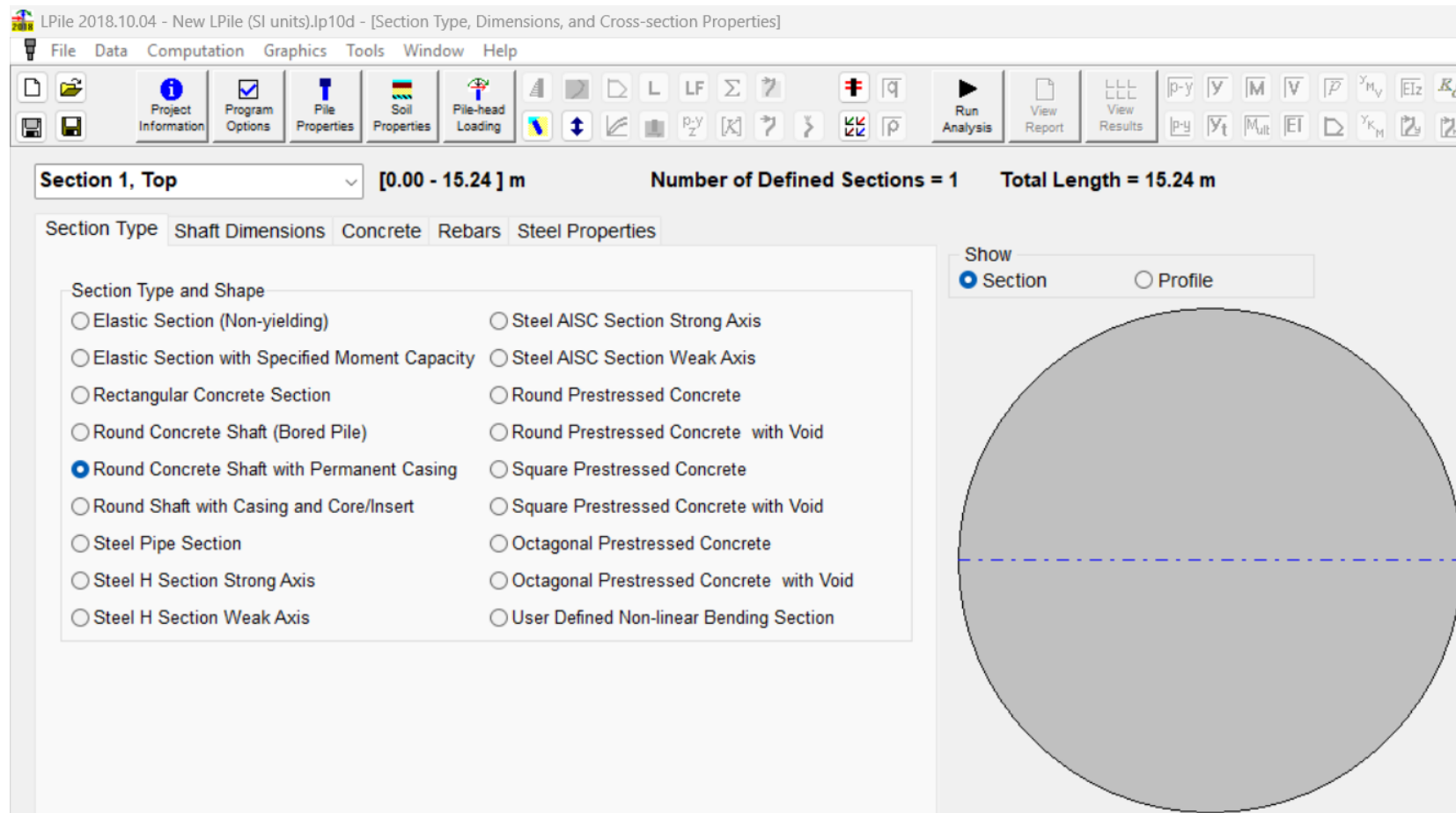


P-Y Graph			
Depth [m]	Y/D [%]	y [m]	P [kN/m]
0.8	0.1	0.0005	14.77
	0.2	0.001	27.95
	0.3	0.0015	38.58
	0.4	0.002	46.47
	0.5	0.0025	51.97
	0.6	0.003	55.64
	0.7	0.0035	58.02
	0.8	0.004	59.53
	0.9	0.0045	60.48
	1	0.005	61.08
	1.1	0.0055	61.44
	1.2	0.006	61.67
	1.3	0.0065	61.81
	1.4	0.007	61.90
	1.5	0.0075	61.95
	2	0.01	62.03
	2.5	0.0125	62.03
	3	0.015	62.04
	3.5	0.0175	62.04
	4	0.02	62.04



Input Pile properties in Ensoft Lpi 2018 software

Step 4 Choose pile type from the list



Input Pile properties in Ensoft Lpi 2018 software

Step 5 Input shaft dimensions

LPIle 2018.10.04 - New LPIle (SI units).lp10d - [Section Type, Dimensions, and Cross-section Properties]

File Data Computation Graphics Tools Window Help

Project Information Program Options Pile Properties Soil Properties Pile-head Loading Run Analysis View Report View Results

Section 1, Top [0.00 - 5.35] m Number of Defined Sections = 1 Total Length = 5.35 m

Section Type Shaft Dimensions Concrete Rebars Steel Properties

Elevation Dimensions

Length of Section (m) 5.35

Elastic Section Properties:

Structural Shape Select Shape

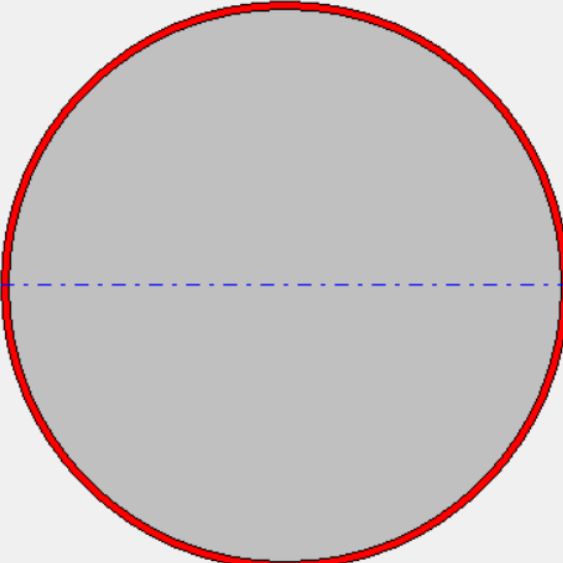
	At Top	At Bottom
Elastic Sect. Width (mm)	0	0
No data required (mm)	0	0
Area (mm ²)	0	0
Mom. of Inertia (mm ⁴)	0	0
Plas. Mom. Cap. (m-kN)	0	0
Shear Capacity (kN)	0	0

Cased Drilled Shaft Section Dimensions:

Casing Outside Diam. (mm)	508
Casing Wall Thickness (mm)	6.3
Section Width (mm)	0
Section Depth (mm)	0
Corner Chamfer (mm)	0
Core Void Diameter (mm)	0
Core Wall Thickness (mm)	0
Flange Thickness (mm)	0
Web Thickness (mm)	0
Elastic Mod. (kN/m ²)	0

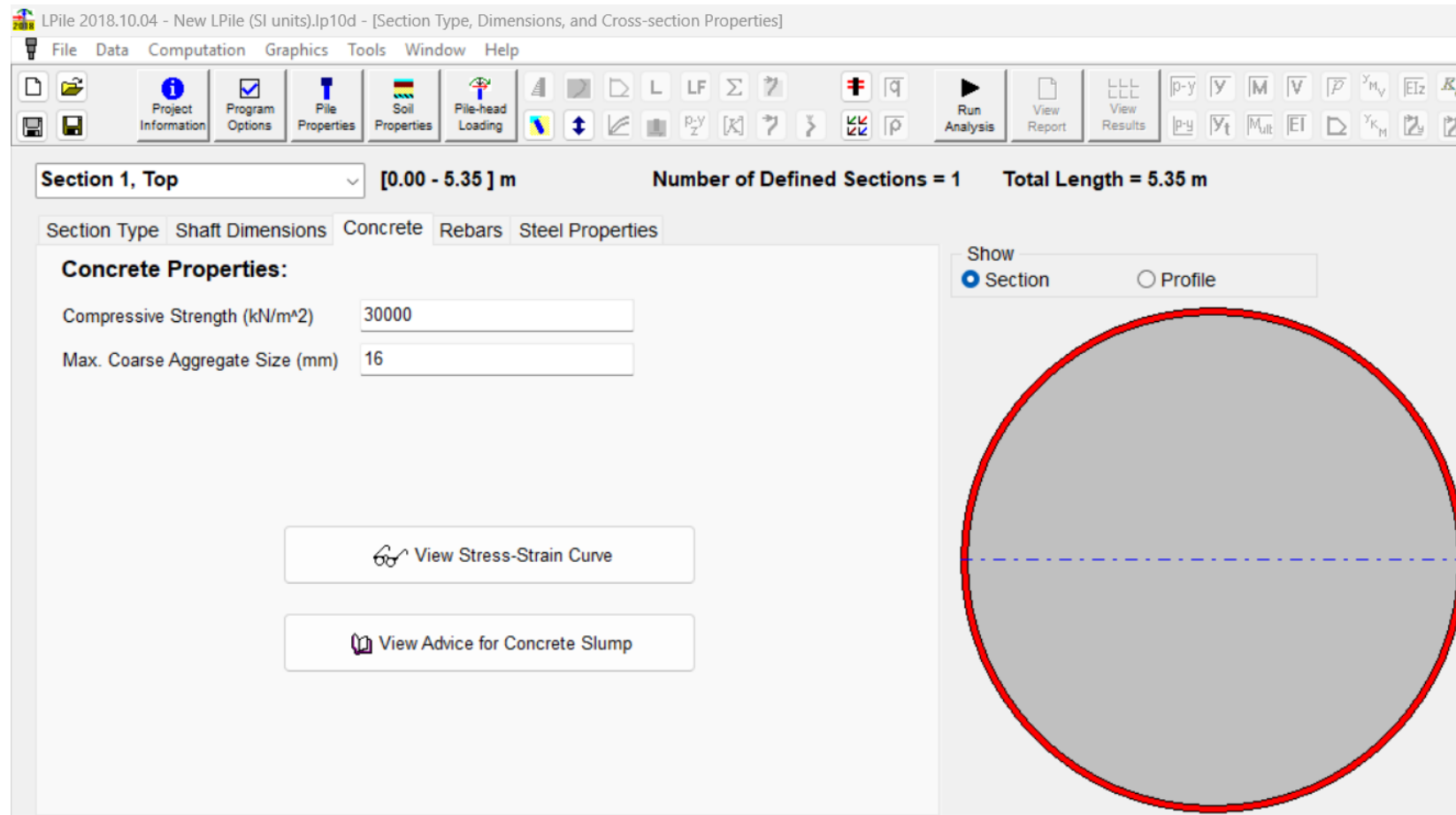
Show ☒ Section ☐ Profile

Compute Mom. of Inertia and Areas and Draw Section Copy Top Properties to Bottom



Input Pile properties in Ensoft Lpi 2018 software

Step 6 Input concrete properties, Max. coarse aggregate size of the employed concrete



Input Pile properties in Ensoft Lpi 2018 software

Step 7 Input reinforcing bar properties

LPI 2018.10.04 - New LPI (SI units).lp10d - [Section Type, Dimensions, and Cross-section Properties]

File Data Computation Graphics Tools Window Help

Project Information Program Options Pile Properties Soil Properties Pile-head Loading Run Analysis View Report View Results

Section 1, Top [0.00 - 5.35] m Number of Defined Sections = 1 Total Length = 5.35 m

Section Type Shaft Dimensions Concrete Rebars Steel Properties

Reinforcing Bar Properties:

Yield Stress (kN/m²) 413685.4733709 Elastic Modulus (kN/m²) 199947978.7959

☐ Continue Rebar Pattern and Size from Section Above

Bar Size 24 mm

Bar Area (mm²) 452.3893421169

Number of Bars 20

Bar/Bundle Options

- ☒ Single Bars
- ☐ 2-Bar Bundles
- ☐ 3-Bar Bundles

Concrete Annulus to Edge of Bar (mm) 50

☒ Automatically position bars in circle

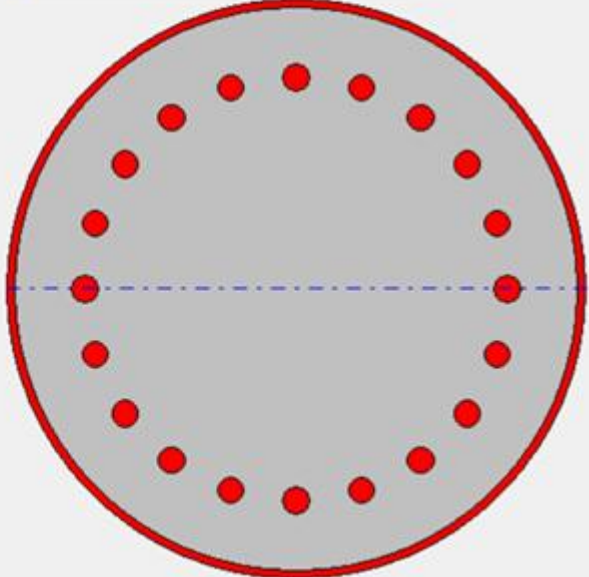
☐ Offset Reinforcement Pattern from Centroid of Section

Offset (mm) 0

Rebar Size/Number Options

Edit Bar Positions

Show ☒ Section ☐ Profile



The diagram shows a circular cross-section of a pile. The outer boundary is a thick red circle. Inside, 20 red dots represent the reinforcing bars, arranged in a circular pattern. A horizontal dashed blue line passes through the center of the circle, representing the centroid.



Input Pile properties in Ensoft Lpi 2018 software

Step 8a In section 'Pile Head Loading', select condition 1 for free head and input loads

LPile 2018.10.04 - New LPile (SI units).lp10d

File Data Computation Graphics Tools Window Help

Project Information Program Options Pile Properties Soil Properties Pile-head Loading

Pile-Head Loadings and Options

Load Case	Pile-Head Loading Condition	Condition (1) for Loading Type	Condition (2) for Loading Type	Axial Load (p-delta) (kN)	Compute Top y vs. L?
1	(1) Shear [lb or kN] and (2) Moment [in-lb or kN-m]	100	0	0	Yes
2	(1) Shear [lb or kN] and (2) Slope [rad]	180	0	0	Yes
3	(1) Shear [lb or kN] and (2) Rotational Stiff. [M/rad]	220	0	0	Yes
4	(1) Displ. [inch or meter] and (2) Moment [in-lb or kN-m]	260	0	0	Yes

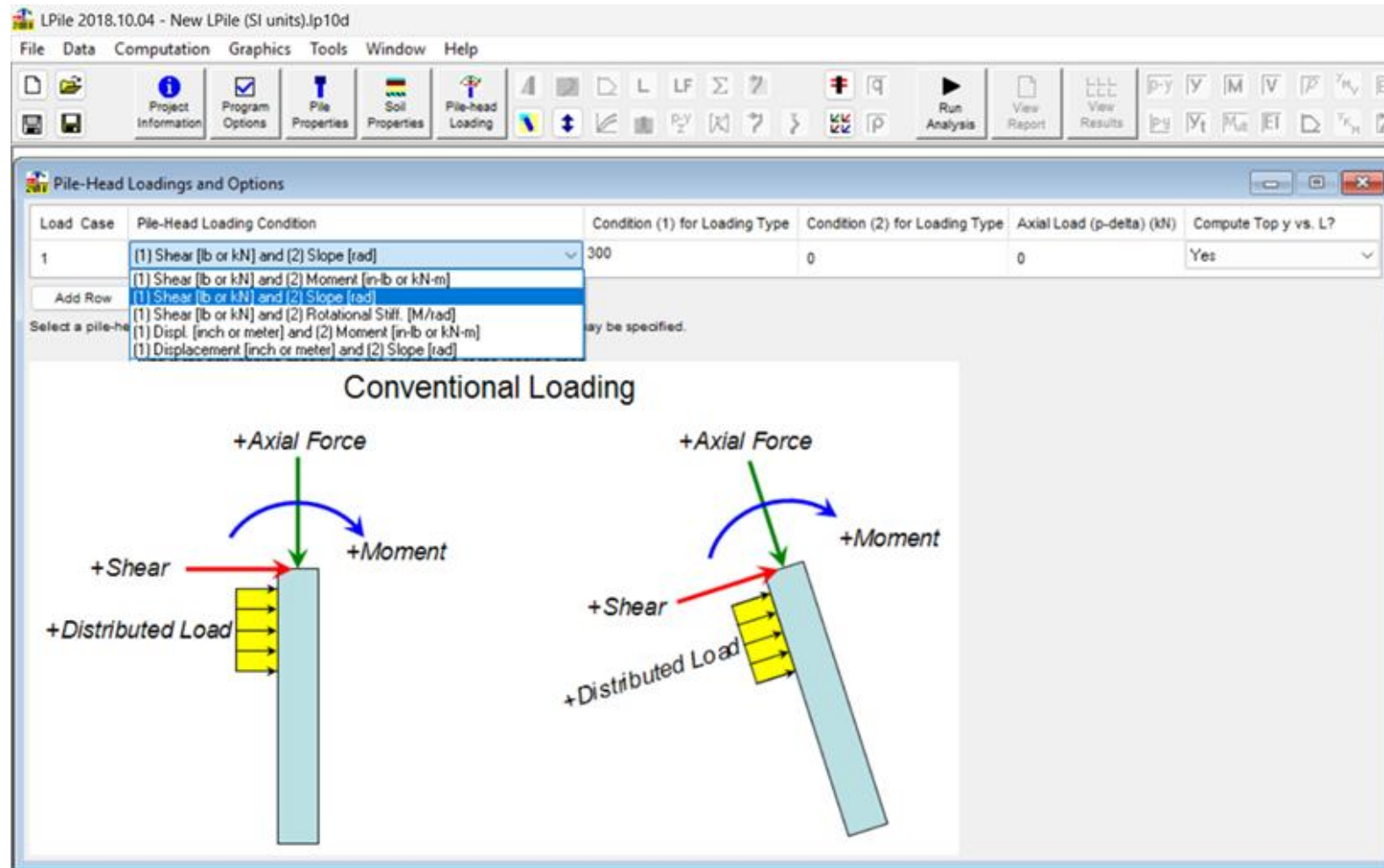
Add Row Insert Row Delete Row

Conventional Loading



Input Pile properties in Ensoft Lpi 2018 software

Step 8b In section 'Pile Head Loading', select condition 2 for fixed head and input loads



Details of LLP case history in Livorno (CH clay)

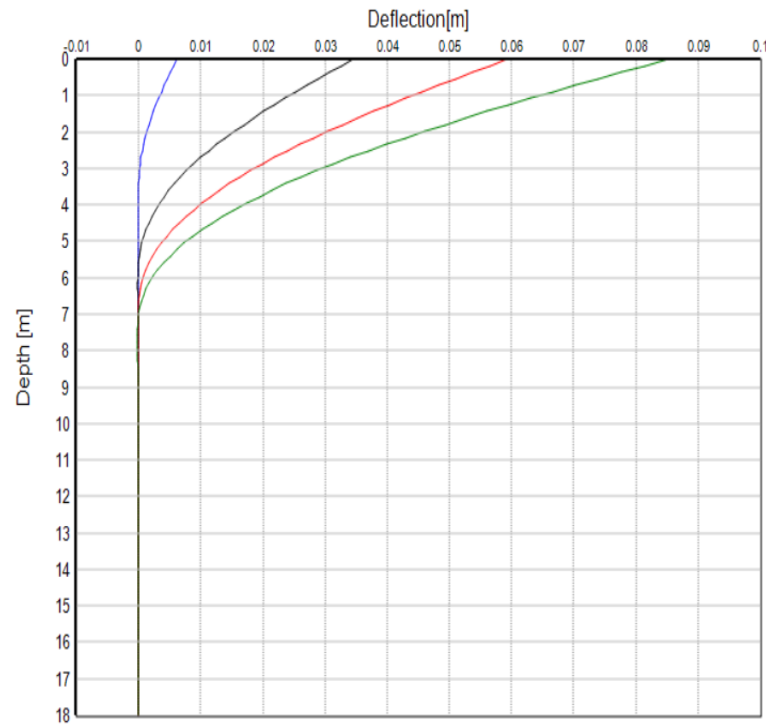
- Pile diameter = 0.5 m
- Pile length = 18 m
- Two different pile conditions:
 - Free head loading (kN): 100, 180, 220, 260
 - Fixed head loading (kN): 50, 100, 140, 180, 220, 260, 300
- Pile casing: OD = 508 mm, ID = 495.4 mm
- Compressive strength of concrete = 30 MPa
- Reinforcement steel:
 - 20 bars Φ 24 mm up to depth 5.35 m
 - 8 bars Φ 24 mm from depth 5.35 m to 18 m



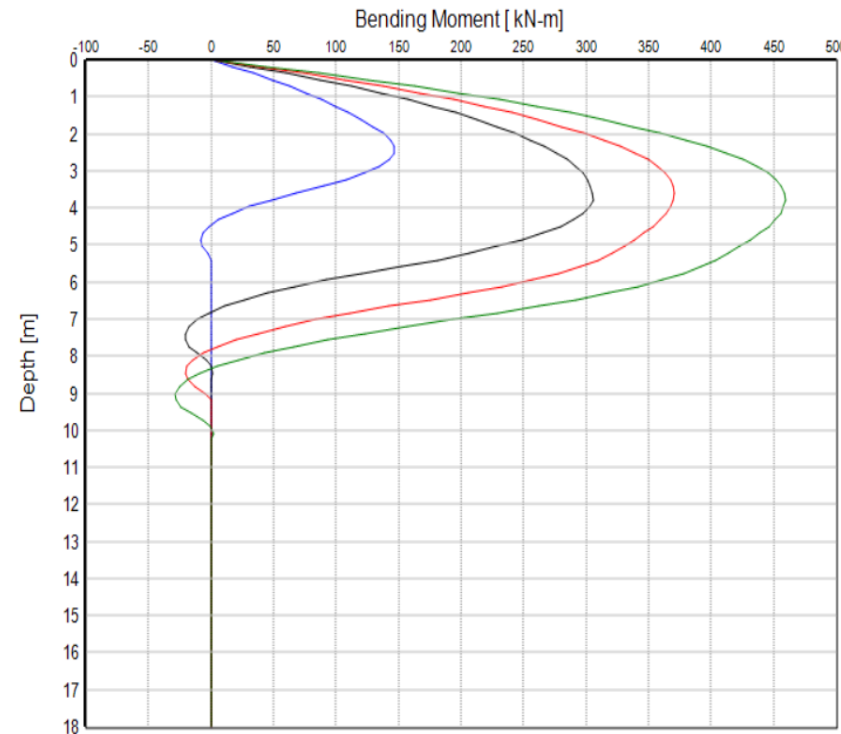
LLP analysis output P-Y curves Robertson 1989

LLP Livorno case history free head condition

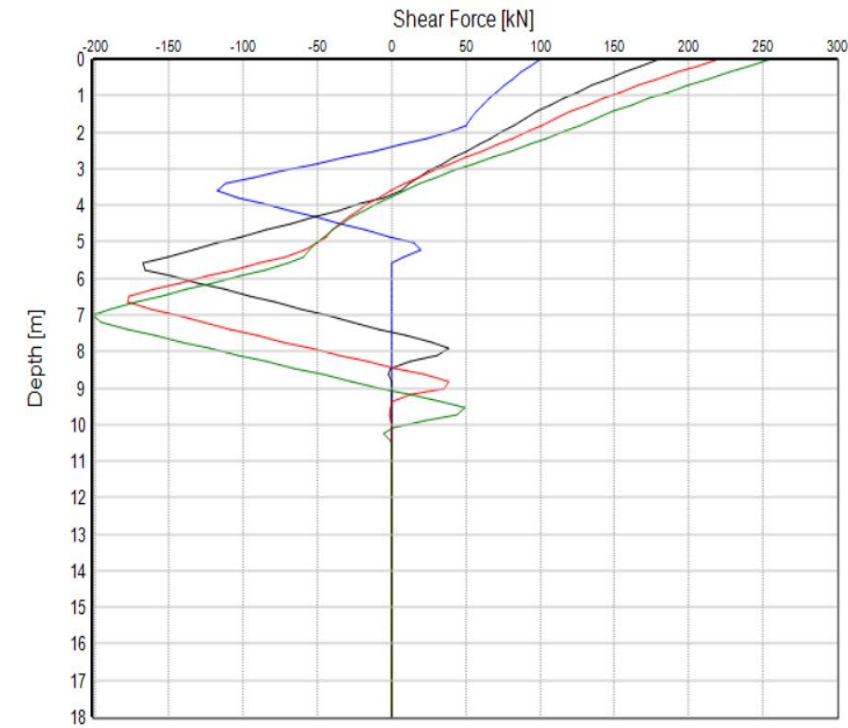
Lateral Deflection vs. Depth



Bending Moment vs. Depth



Shear Force vs. Depth



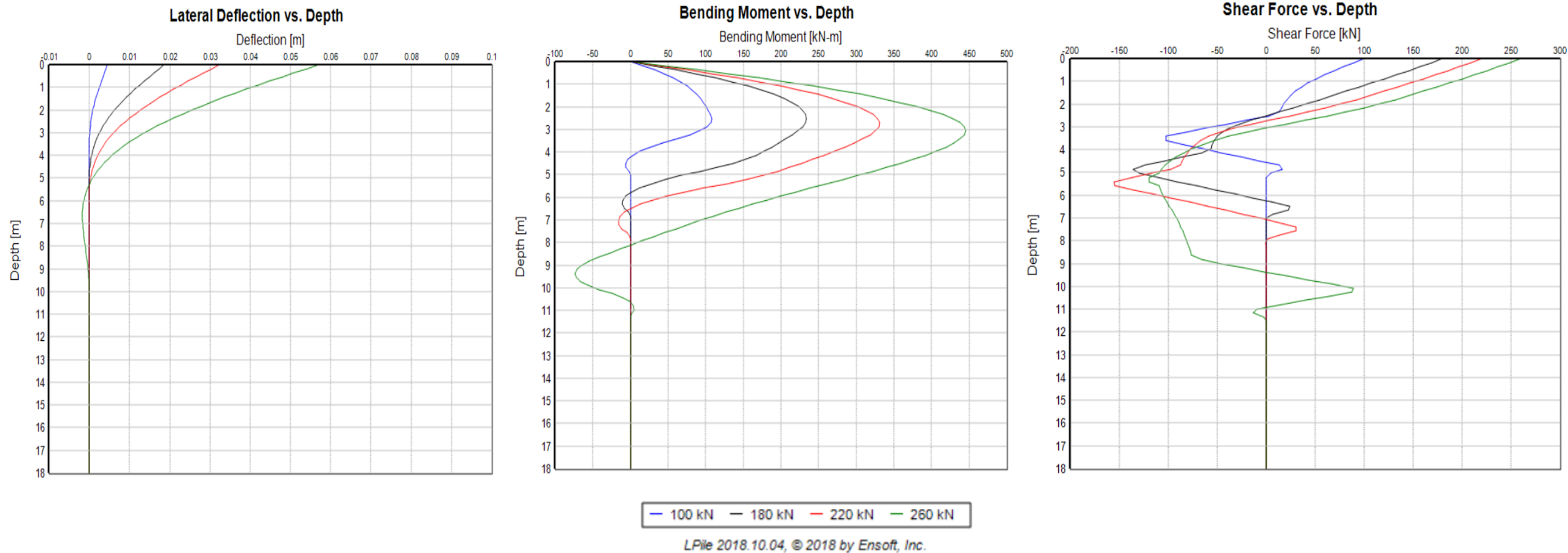
— 100 kN — 180 kN — 220 kN — 260 kN

LPile 2018.10.04, © 2018 by Ensoft, Inc.



LLP analysis output P-Y curves Marchetti 1991

LLP Livorno case history free head condition



LLP Livorno case history: validation of Robertson 1989, Marchetti 1991 compared with field test measurements

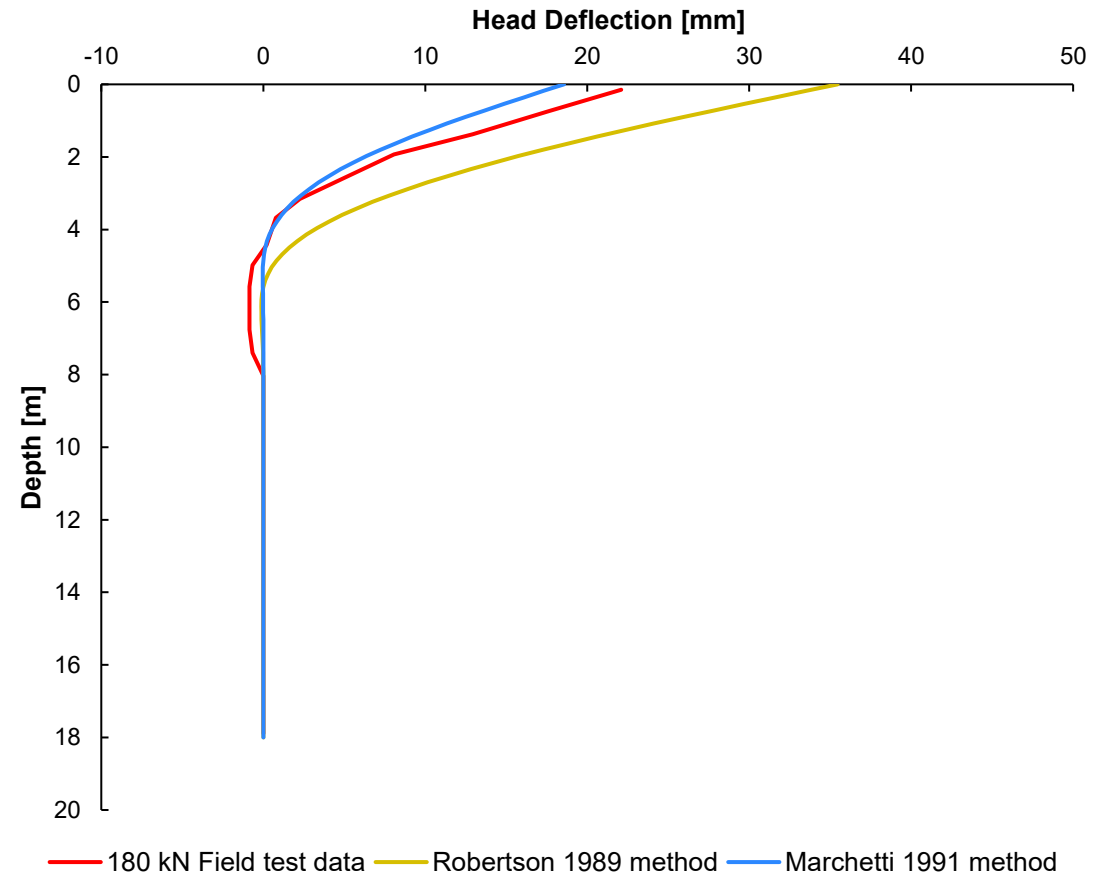
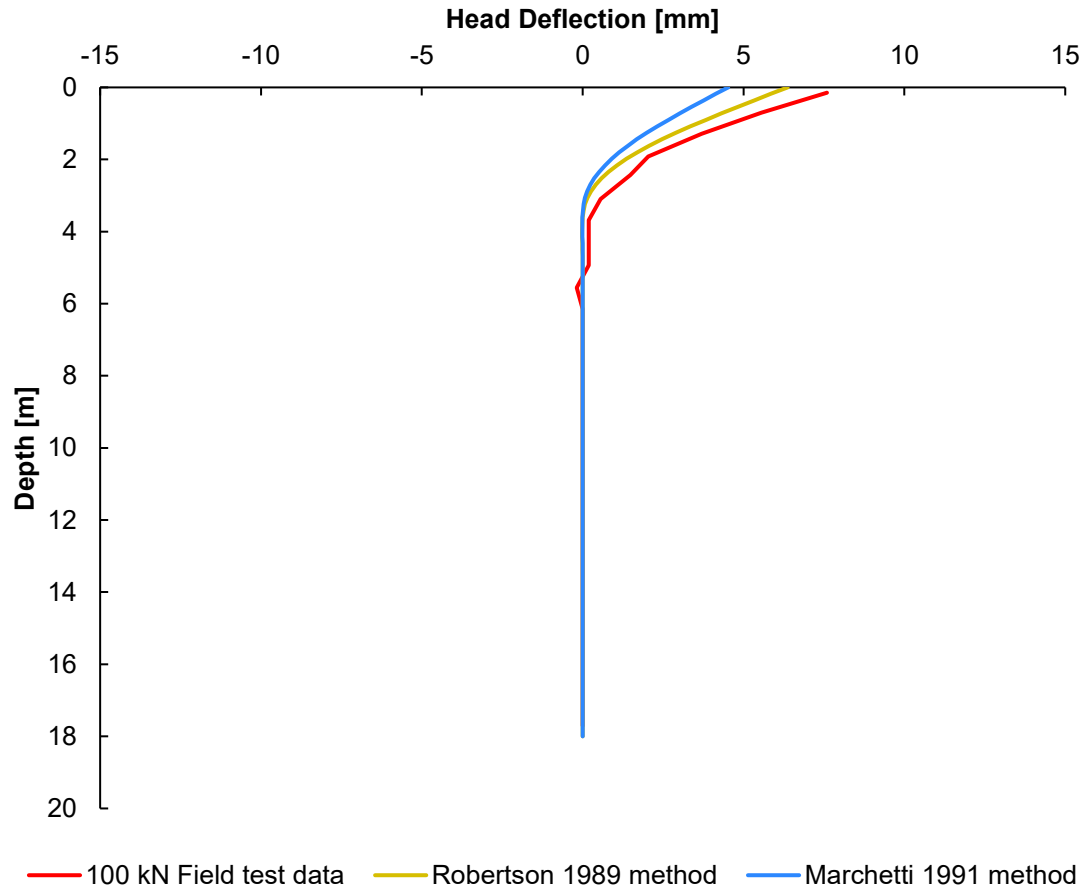


Free Head Pile Robertson 1989 - Marchetti 1991 - measured

100 kN horizontal load

LLP tests Livorno

180 kN horizontal load

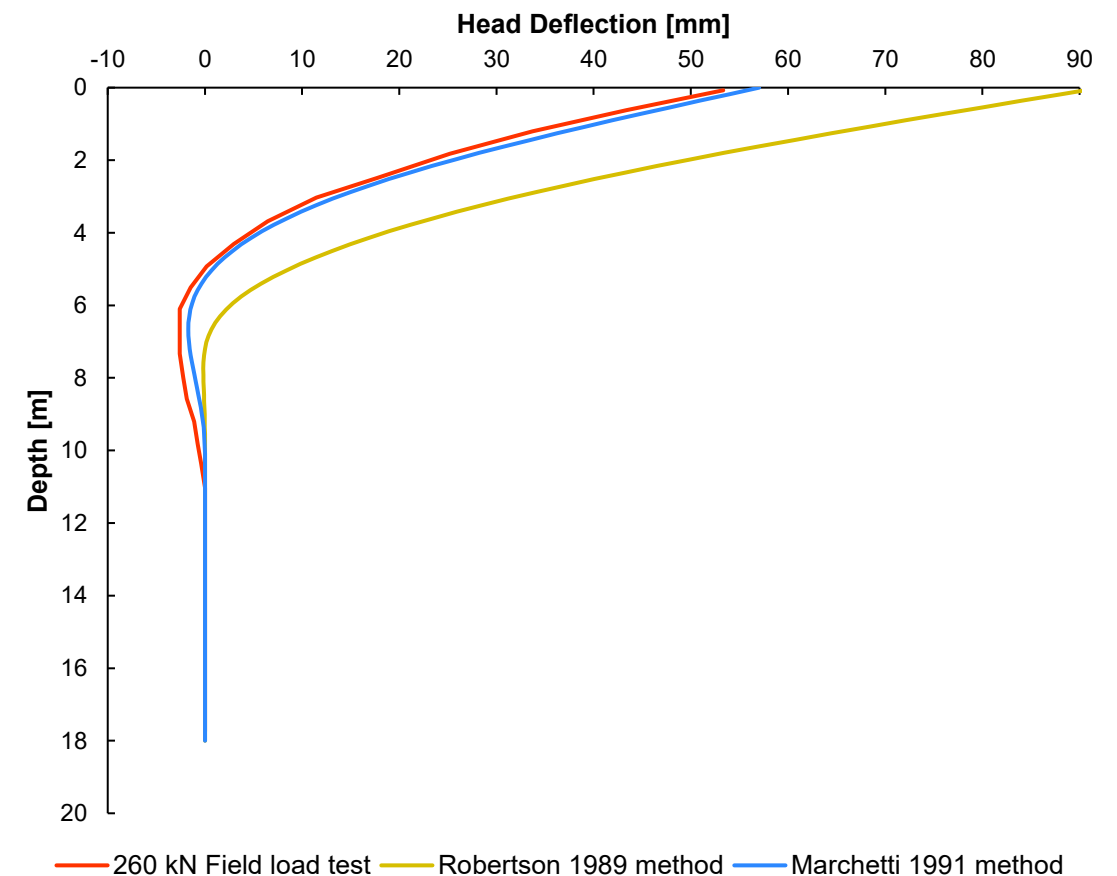
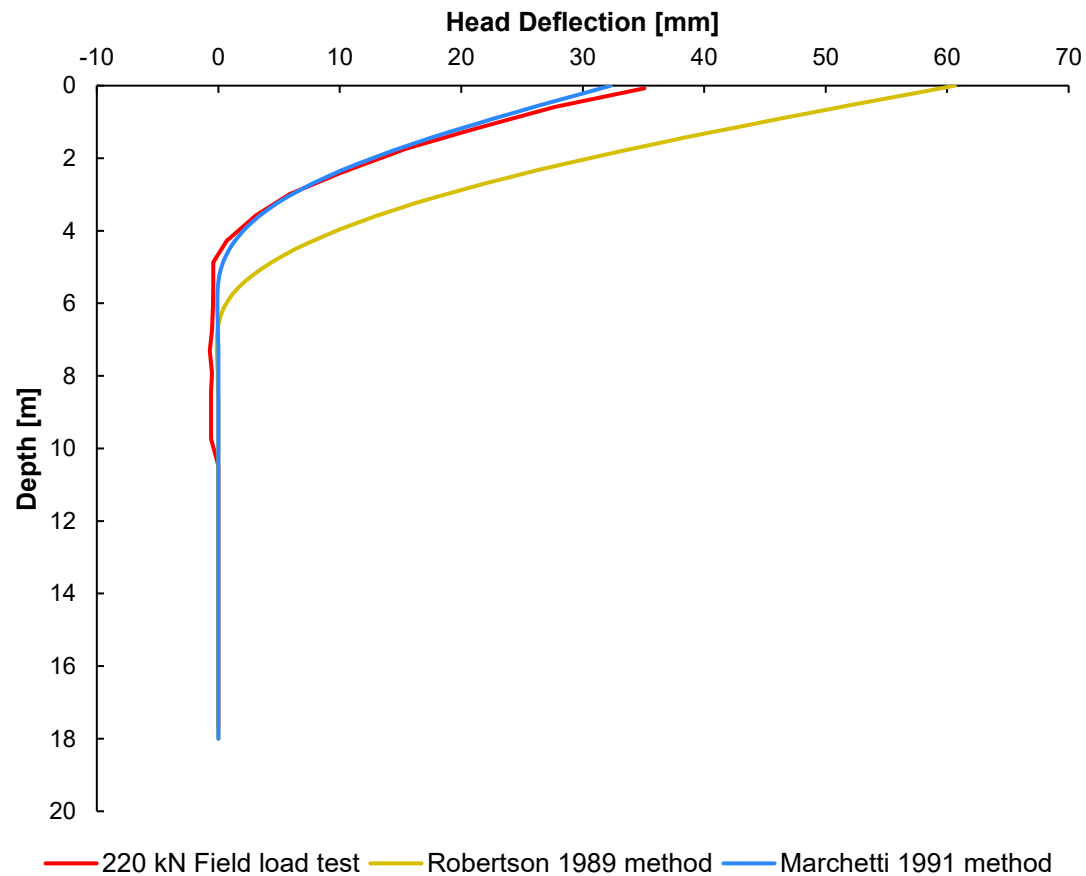


Free Head Pile Robertson 1989 - Marchetti 1991 - measured

220 kN horizontal load

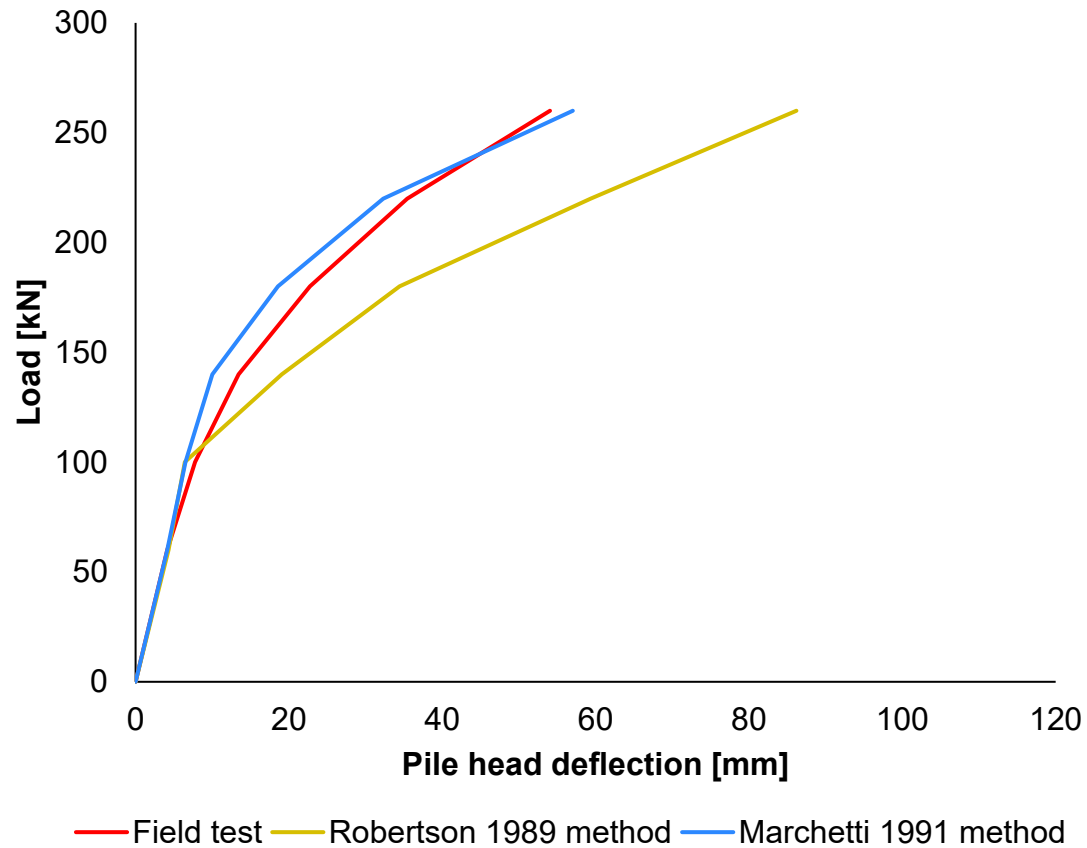
LLP tests Livorno

260 kN horizontal load



Free Head Pile Robertson 1989 - Marchetti 1991 - measured

LLP tests Livorno



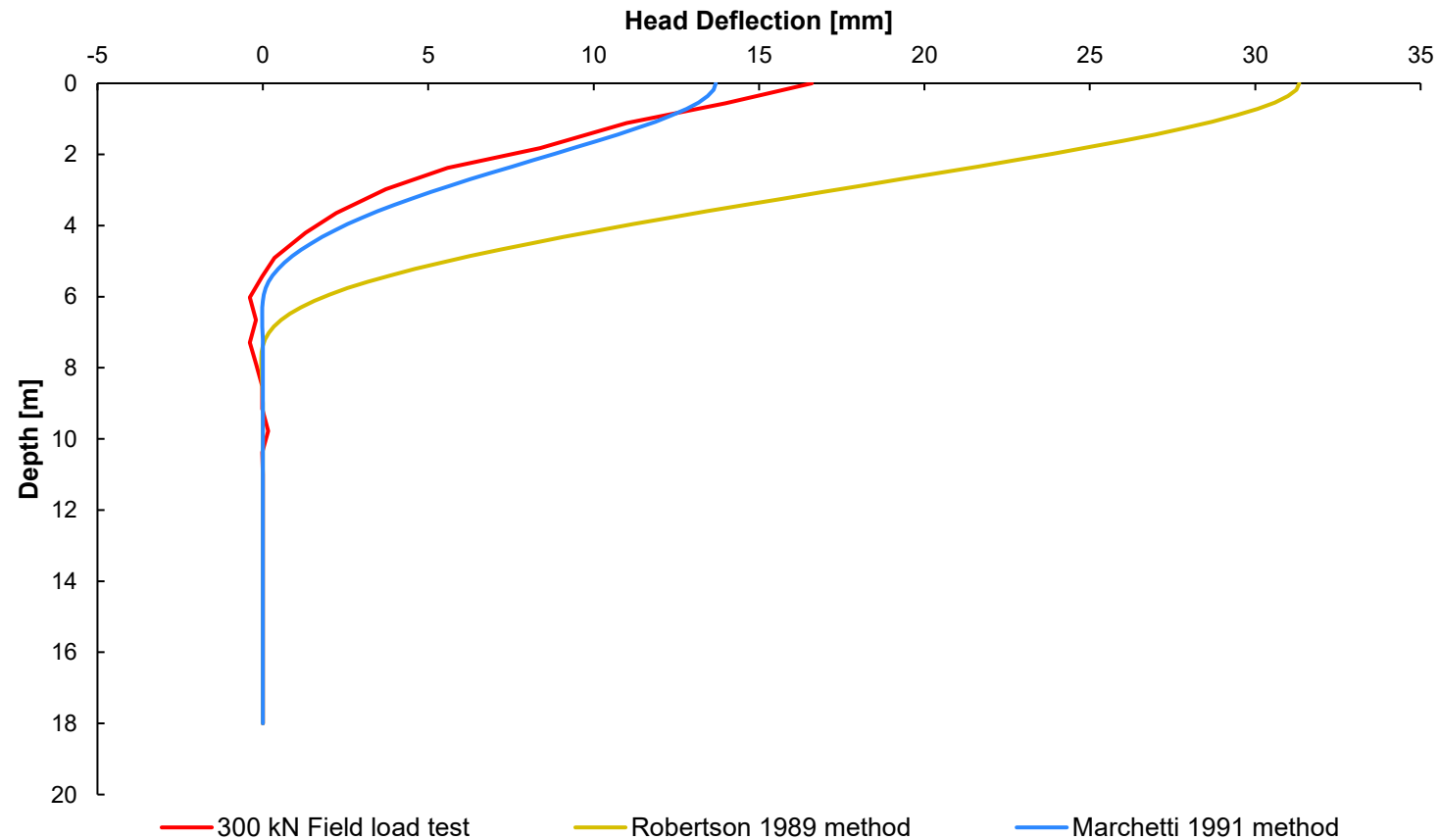
Applied Load	Field measure	Robertson (1989)	Error Robertson	Marchetti (1991)	Error Marchetti
[kN]	[mm]	[mm]	[%]	[mm]	[%]
0	0	0	0	0	0
60	4	4	0	4	0
100	8	6	-25	7	-13
140	13	19	46	10	-23
180	23	34	48	19	-17
220	35	59	41	32	-9
260	54	86	59	57	5



Fixed Head Pile Robertson 1989 - Marchetti 1991 - measured

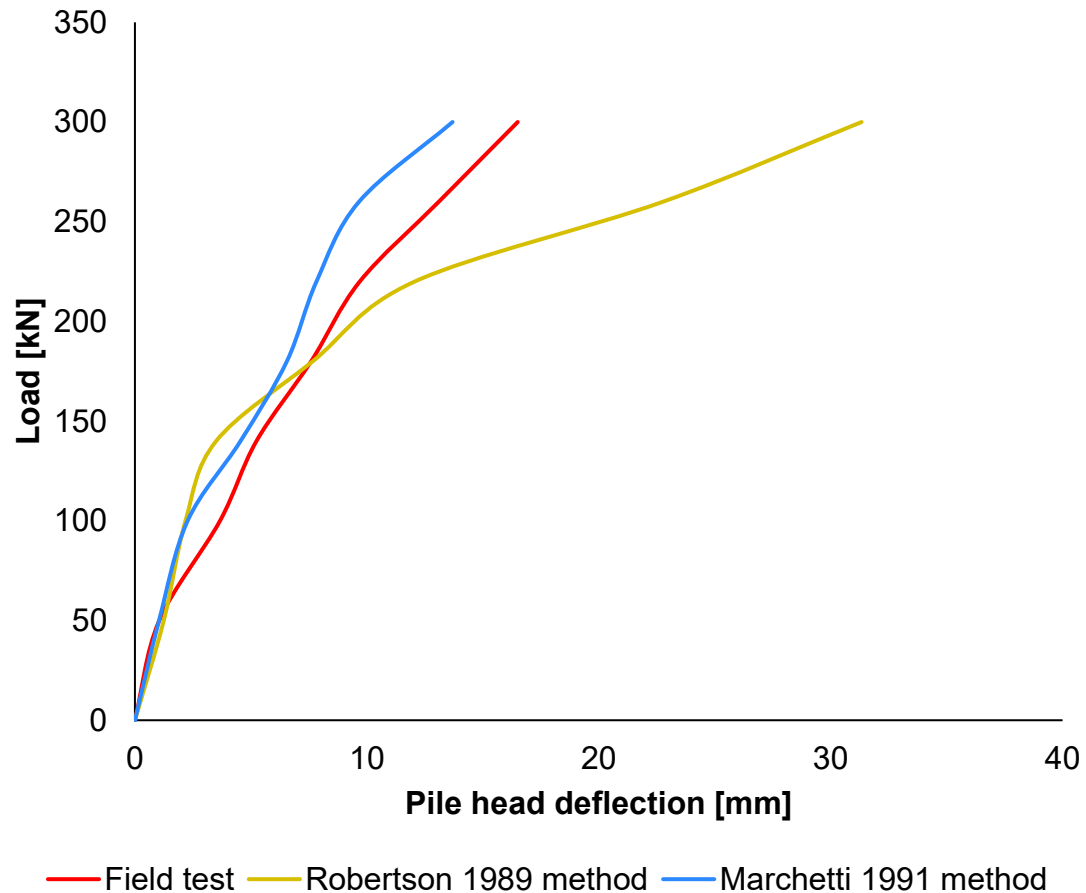
LLP tests Livorno

300 kN horizontal load



Fixed Head Pile Robertson 1989 - Marchetti 1991 - measured

LLP tests Livorno



Applied Load	Field measure	Robertson (1989)	Error Robertson	Marchetti (1991)	Error Marchetti
[kN]	[mm]	[mm]	[%]	[mm]	[%]
0	0	0	0	0	0
50	1	1	0	1	0
100	4	2	-50	2	-50
140	5	4	-20	5	0
180	8	8	0	7	-13
220	10	12	20	8	-25
260	13	23	76	10	-23
300	17	31	82	14	-18



LLP test in Livorno (1991)

Comments on Robertson (1989) and Marchetti (1991) performance:

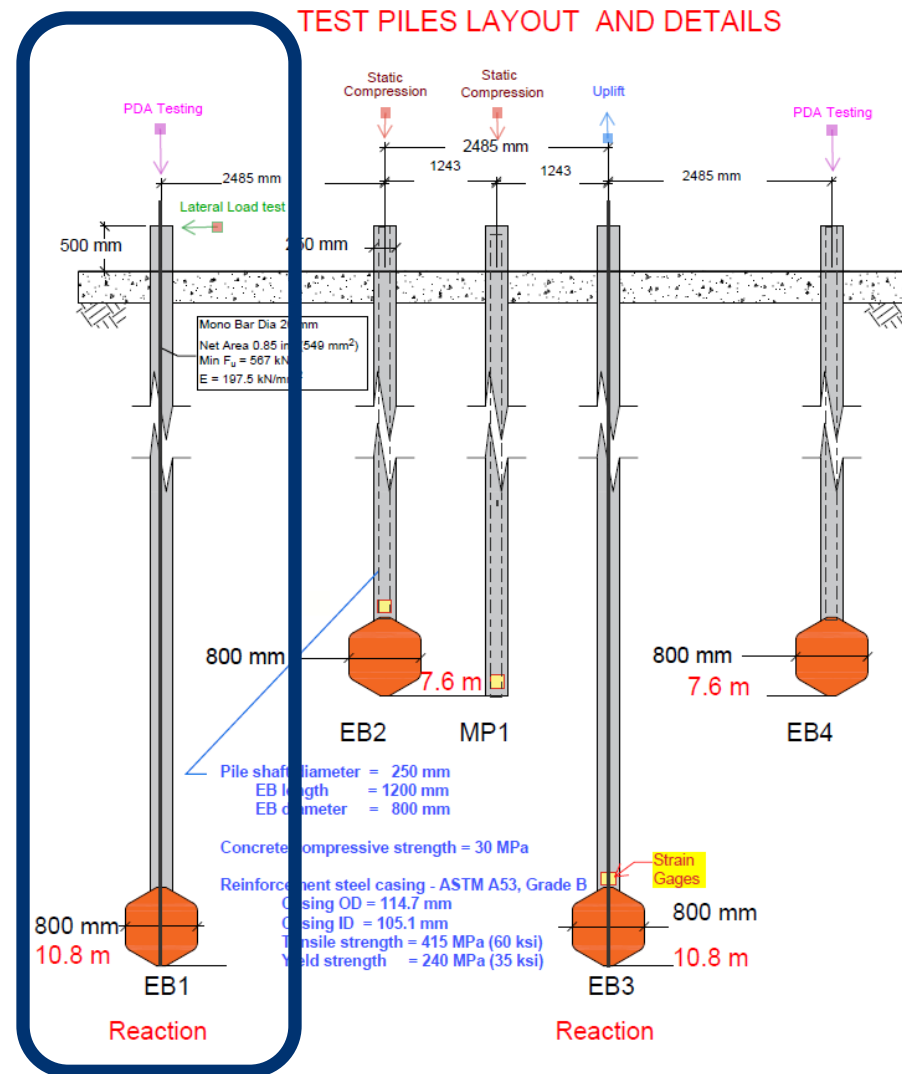
- At the lowest load, where initial tangent modulus is estimated by E_D , Robertson method provides good prediction
- At medium to high loads, Robertson method overpredicts deflections. Possible reason: $p = p_{ult}$ only for $y/y_{50} \geq 8$, too conservative !!
- Marchetti method (tanh function) provides very good predictions at all loads in the LLP test of Livorno



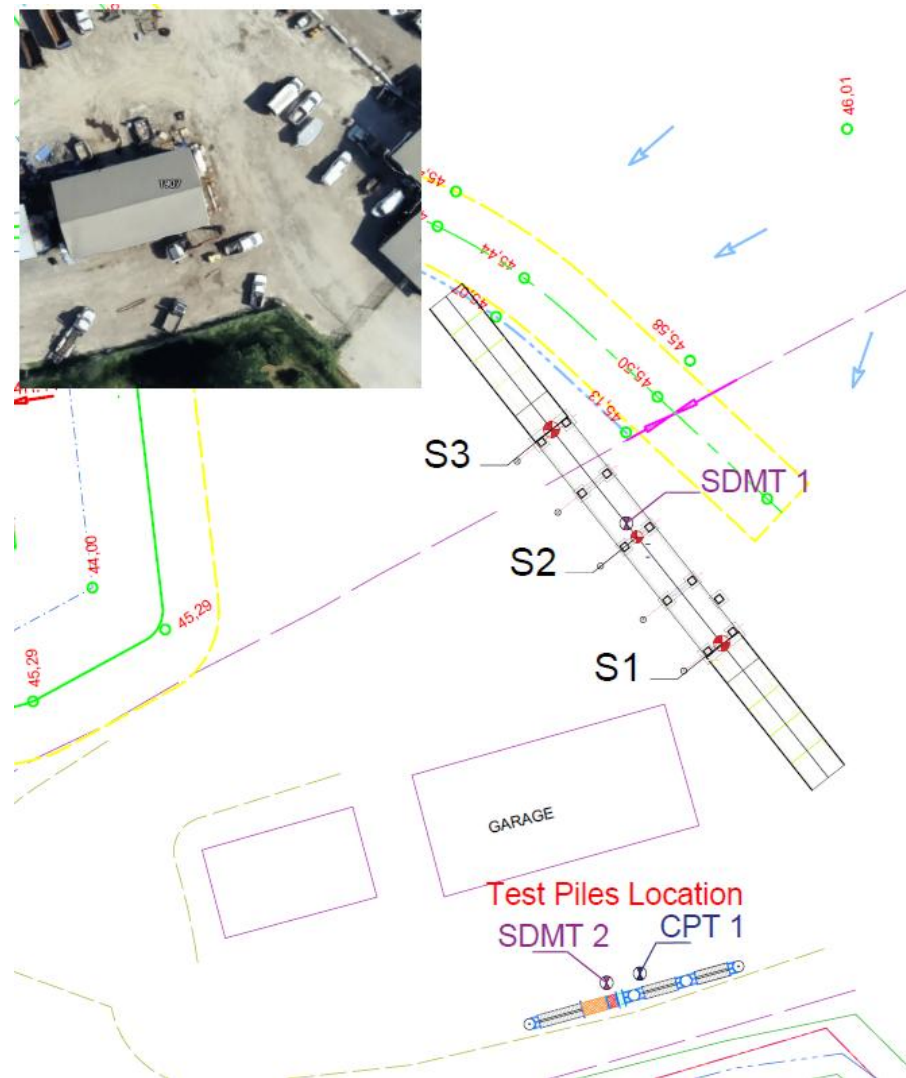
LLP tests in Gatineau (2025)



Pile testing Specifications for the Gatineau Pile Testing Event (2025)



Site characterization tests for the Gatineau Pile Testing Event (2025)



Summary of information for the LLP prediction in Gatineau

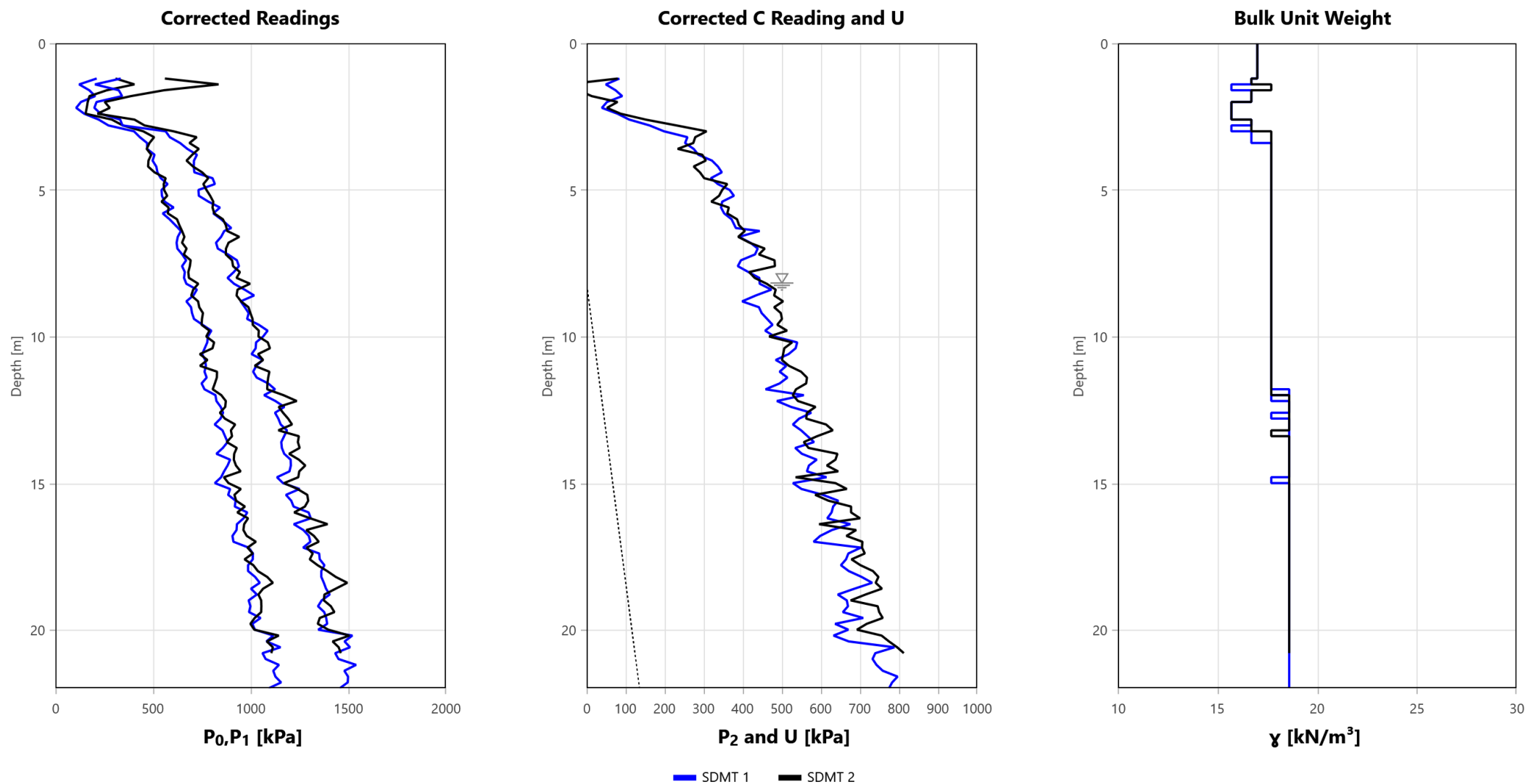
- DMT (CPT and Boreholes) detect mostly a stiff silty clay subsoil
- Robertson 1989 and Marchetti 1991 are both applicable
- Pile EB1: LLP with expanded base (pile toe geometry assumed irrelevant)
- Pile diameter 0.25 m
- Pile reinforcement: 4 inch steel pipe (101.9 mm)
- The concrete and grout compressive strength is 30 MPa
- Steps discussed in the previous slides will be adopted for the LLP simulation



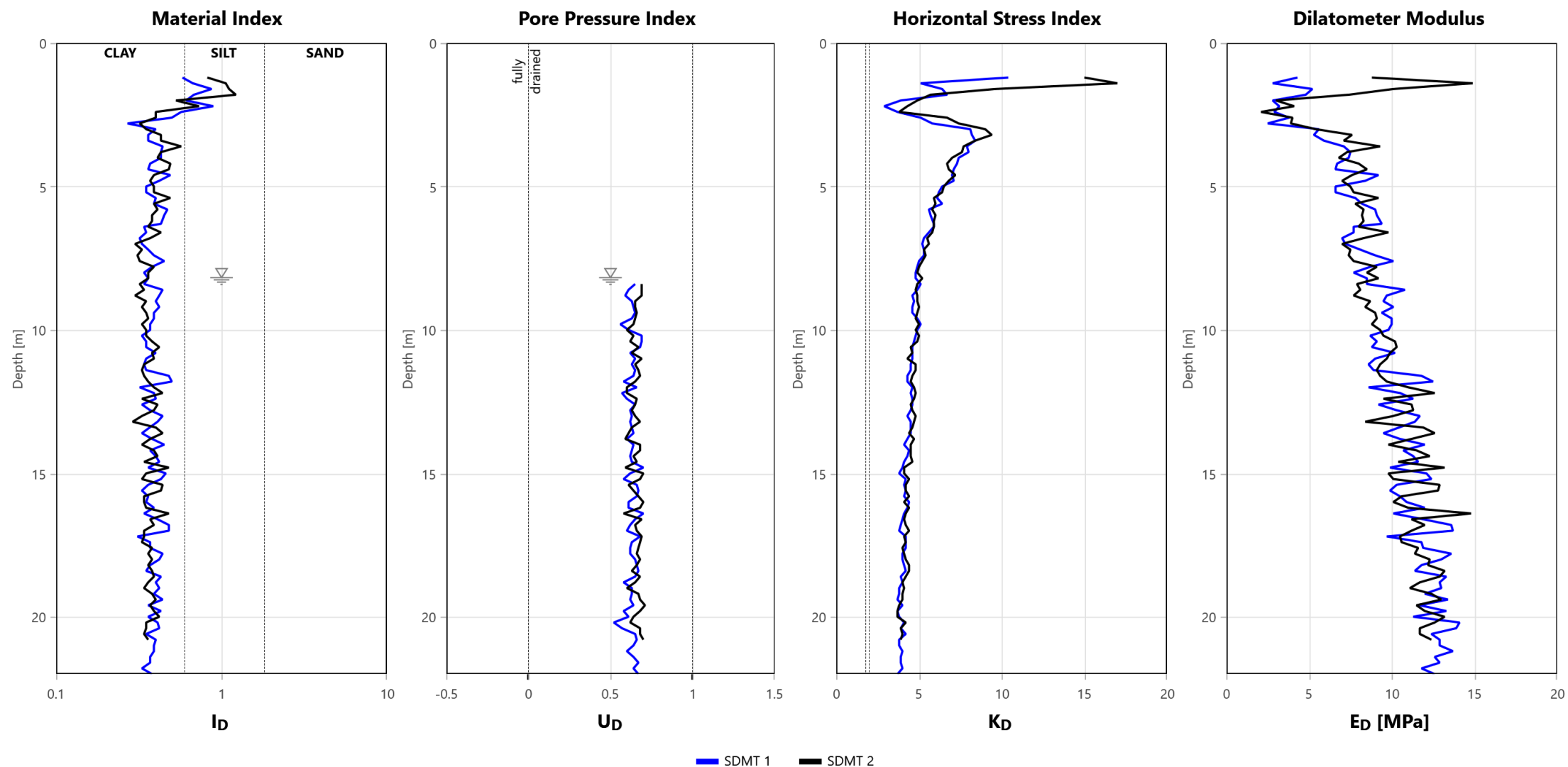
Gatineau LLP test site (September 2025): DMT test results



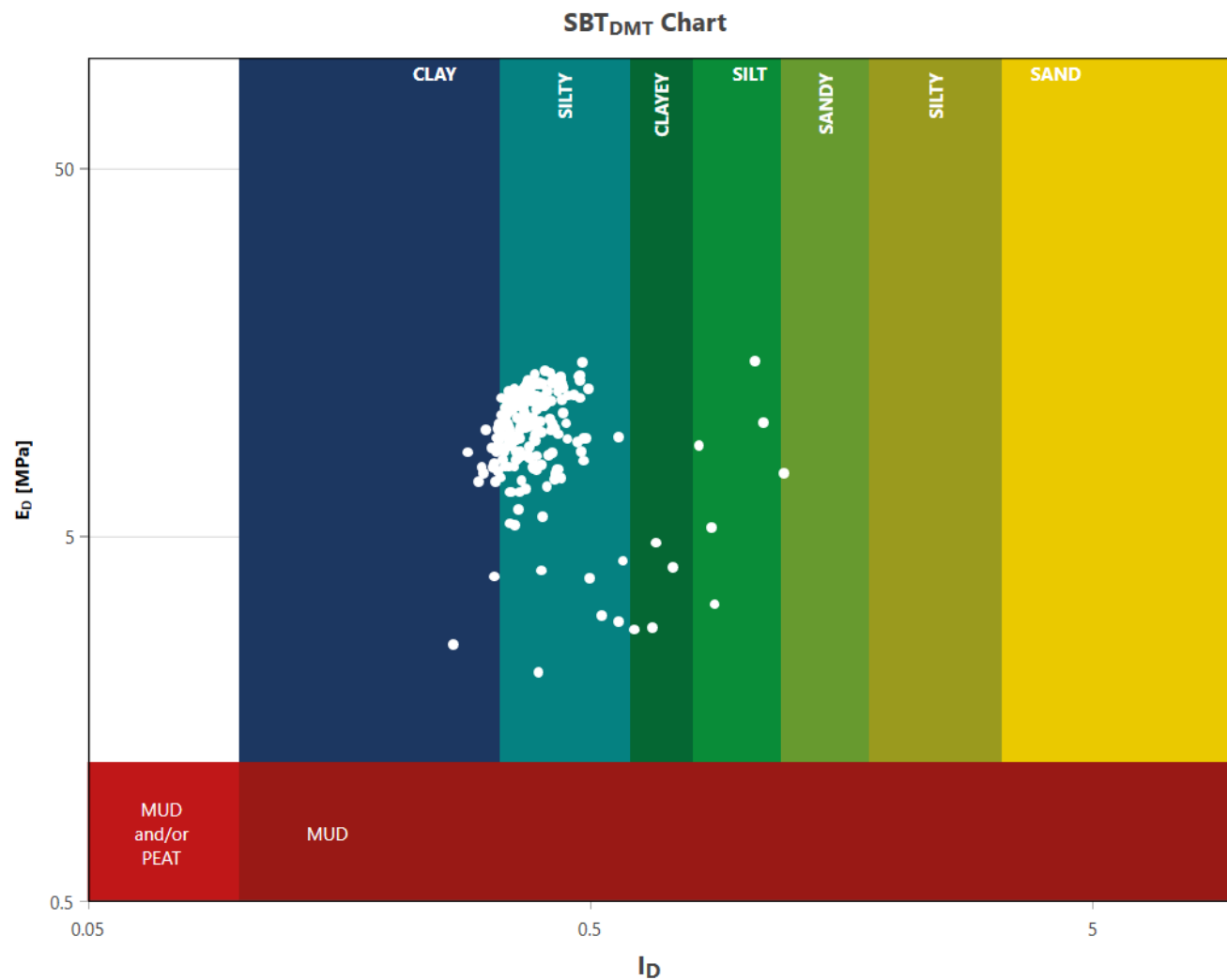
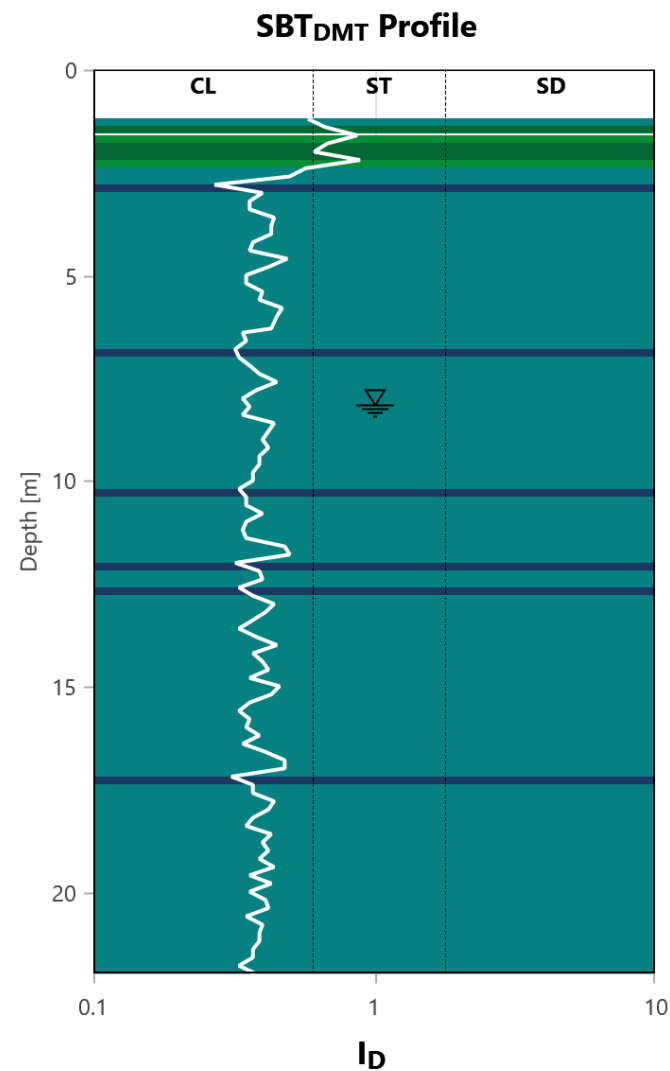
Medusa DMT tests results in Gatineau (2025/9)



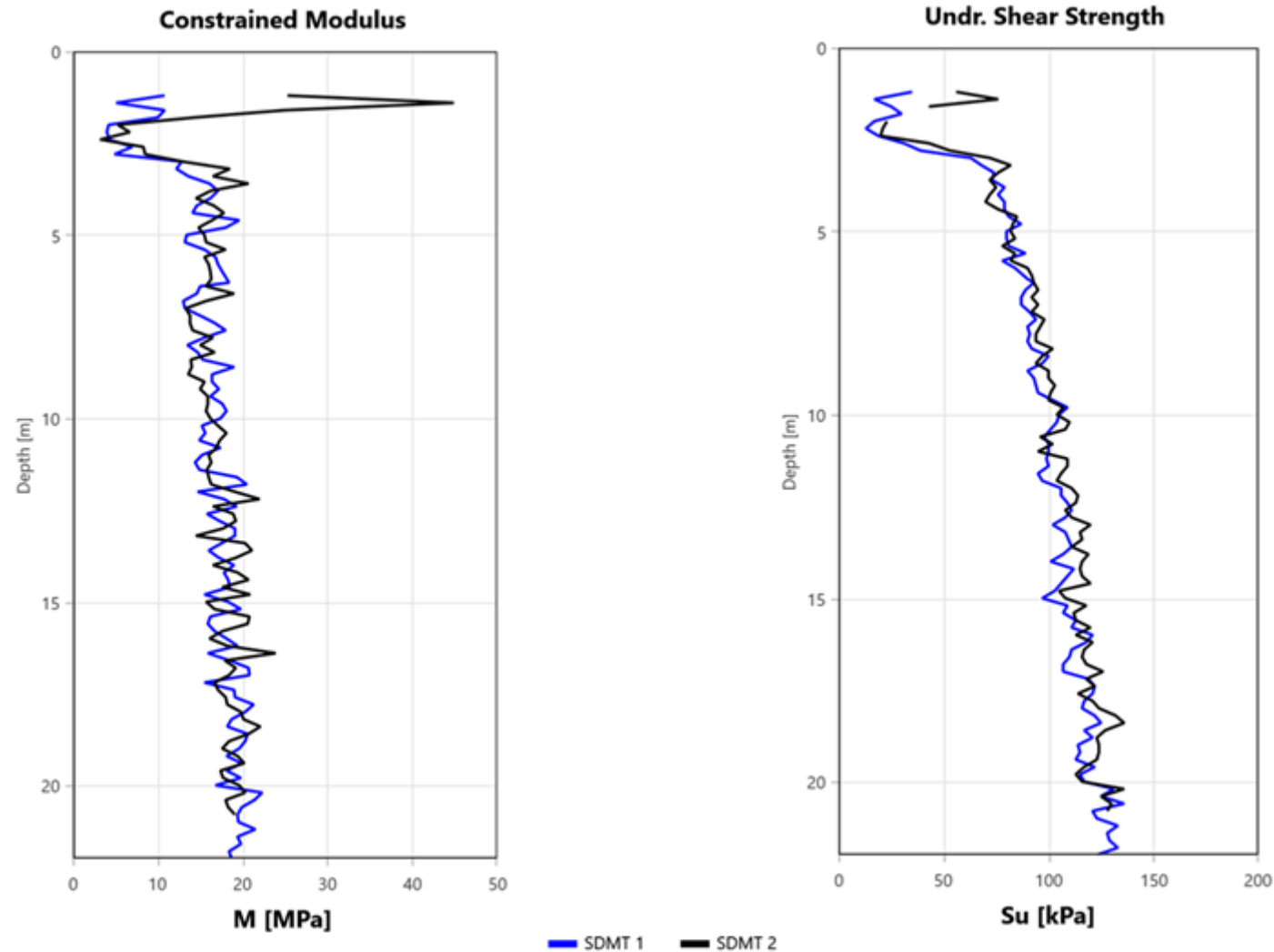
Medusa DMT tests results in Gatineau (2025/9)



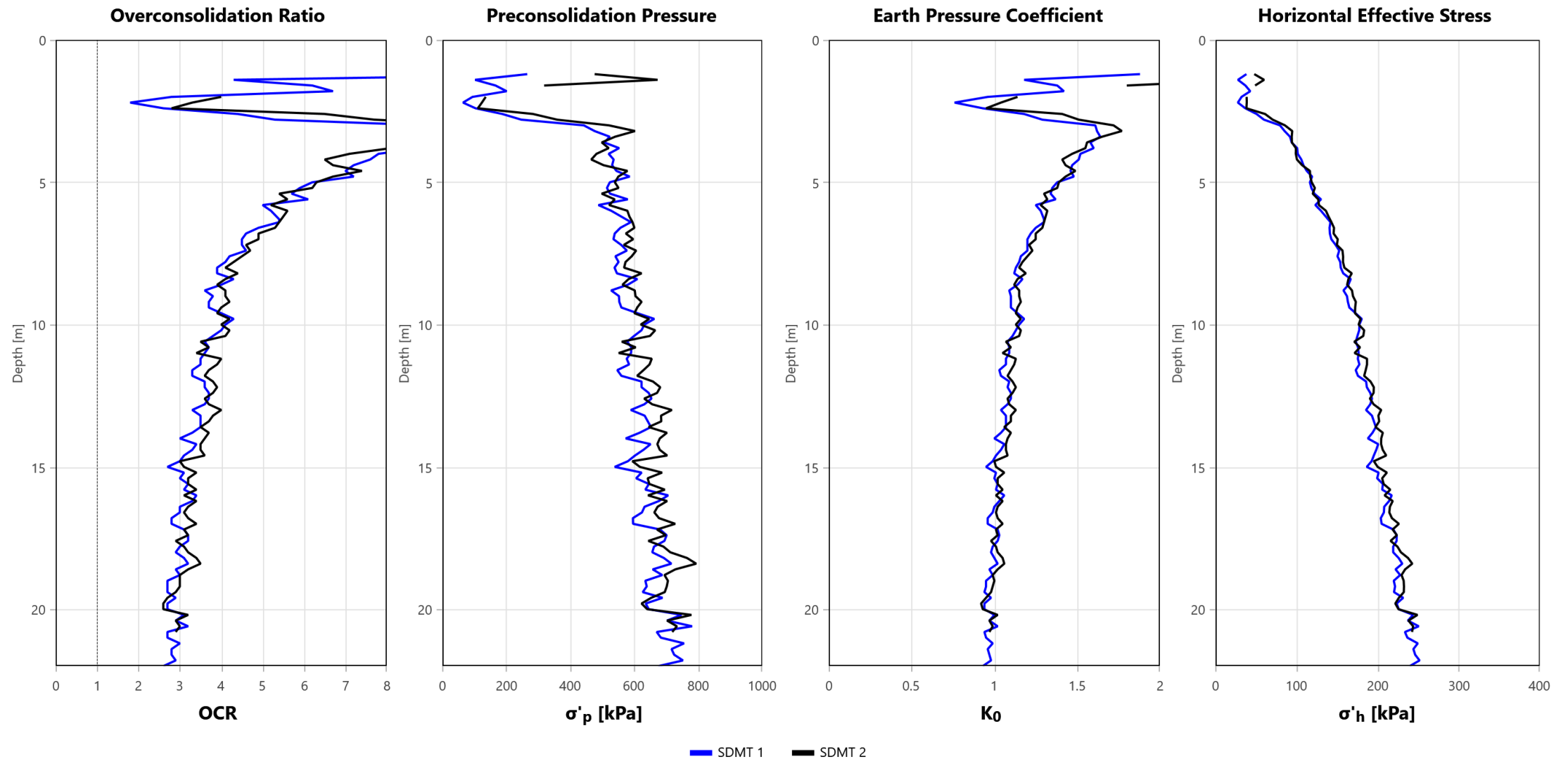
Medusa DMT tests results in Gatineau (2025/9)



Medusa DMT tests results in Gatineau (2025/9)



Medusa DMT tests results in Gatineau (2025/9)



Input LL Pile properties in Ensoft Lpi 2018 software (Gatineau 2025)

Section 1, Top [0.00 - 10.50] m Number of Defined Sections = 1 Total Length = 10.50 m

Section Type Shaft Dimensions Concrete Rebars Steel Properties

Elevation Dimensions

Length of Section (m) 10.5

Elastic Section Properties:

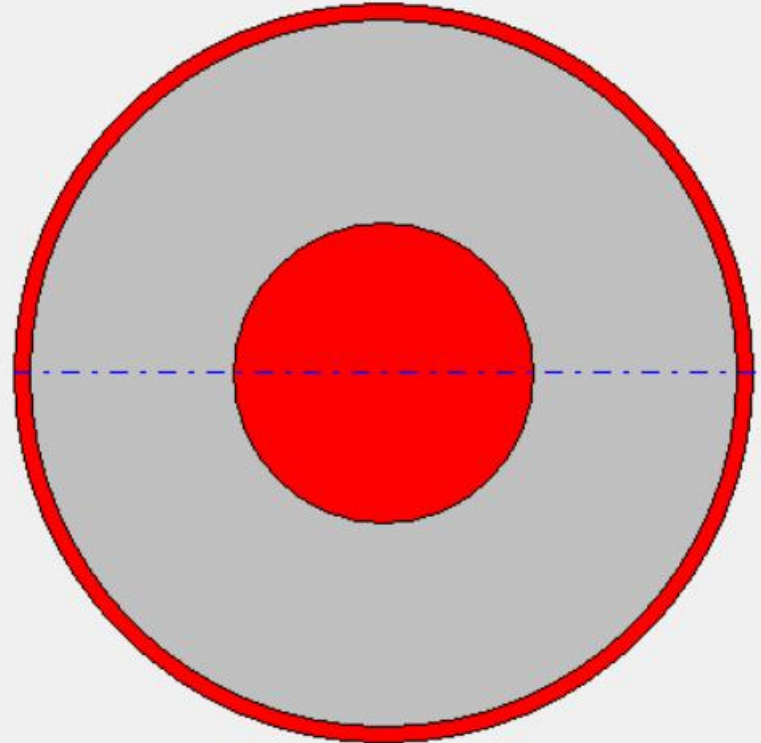
Structural Shape Select Shape

	At Top	At Bottom
Elastic Sect. Width (mm)	0	0
No data required (mm)	0	0
Area (mm^2)	63500	0
Mom. of Inertia (mm^4)	12900000000	0
Plas. Mom. Cap. (m-kN)	0	0
Shear Capacity (kN)	0	0

Cased Drilled Shaft Section Dimensions:

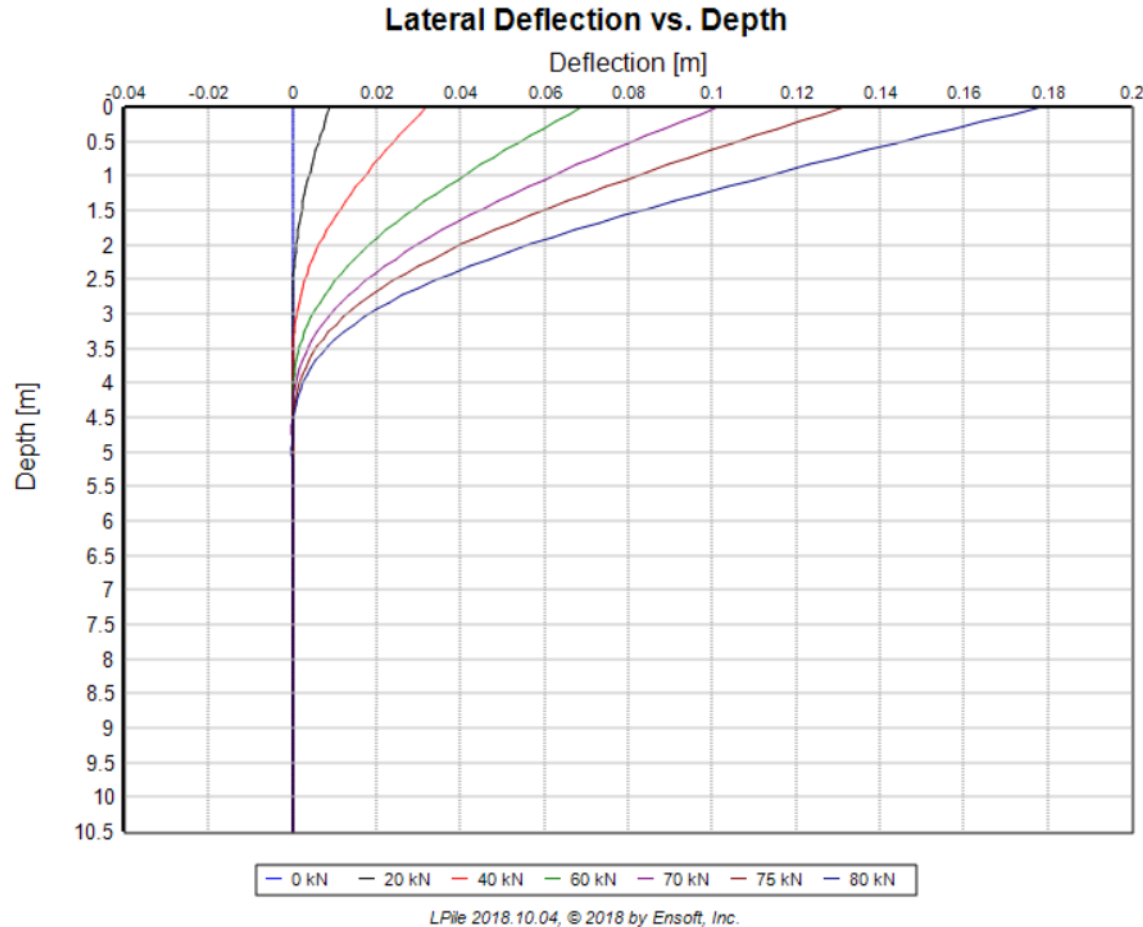
Casing Outside Diam. (mm)	250
Casing Wall Thickness (mm)	4.8
Section Width (mm)	404
Section Depth (mm)	1120
Corner Chamfer (mm)	0
Core Void Diameter (mm)	0
Core Wall Thickness (mm)	0
Flange Thickness (mm)	45
Web Thickness (mm)	26.2
Elastic Mod. (kN/m^2)	0

Show ☒ Section ☐ Profile

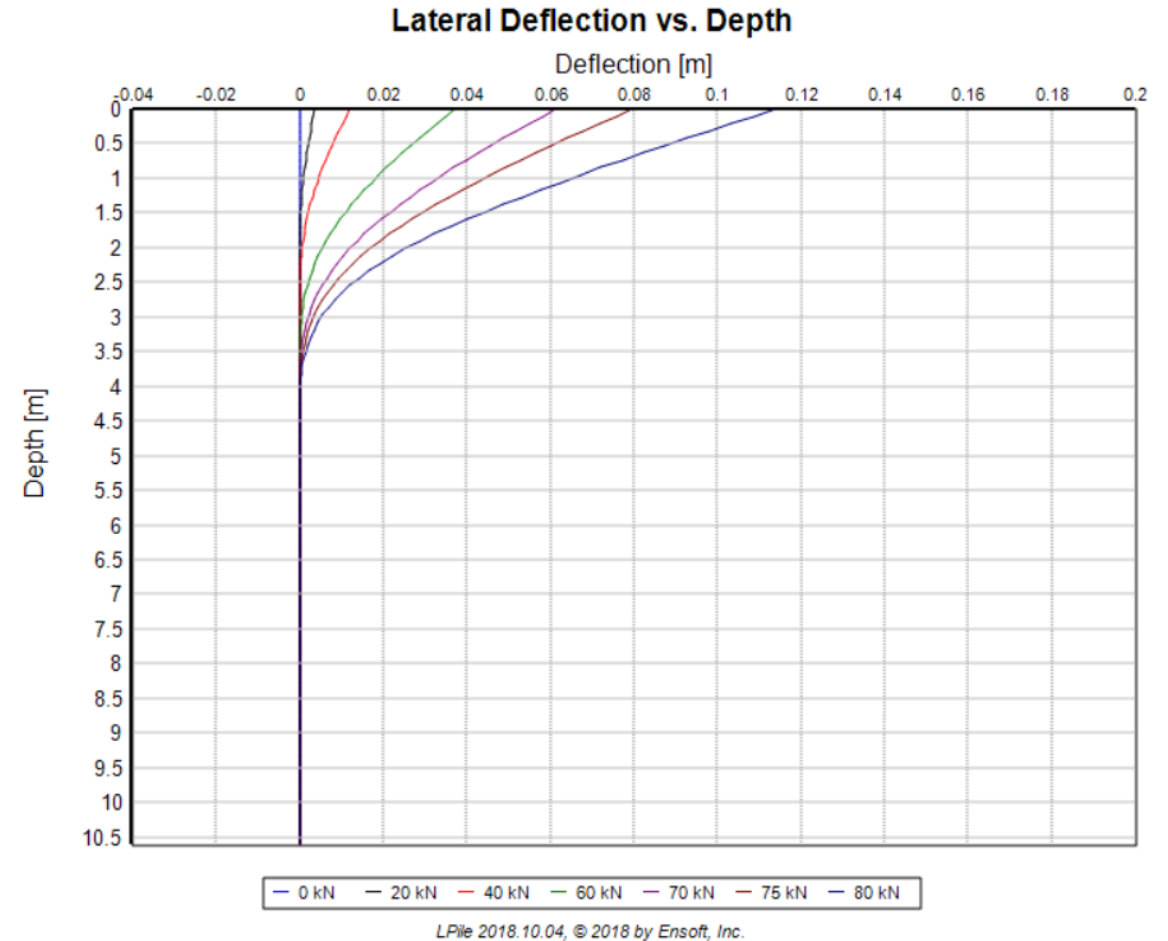


Compute Mom. of Inertia and Areas and Draw Section Copy Top Properties to Bottom

EP1 Free Head LLP pile deflection using Ensoft Lpi 2018



Robertson 1989 method

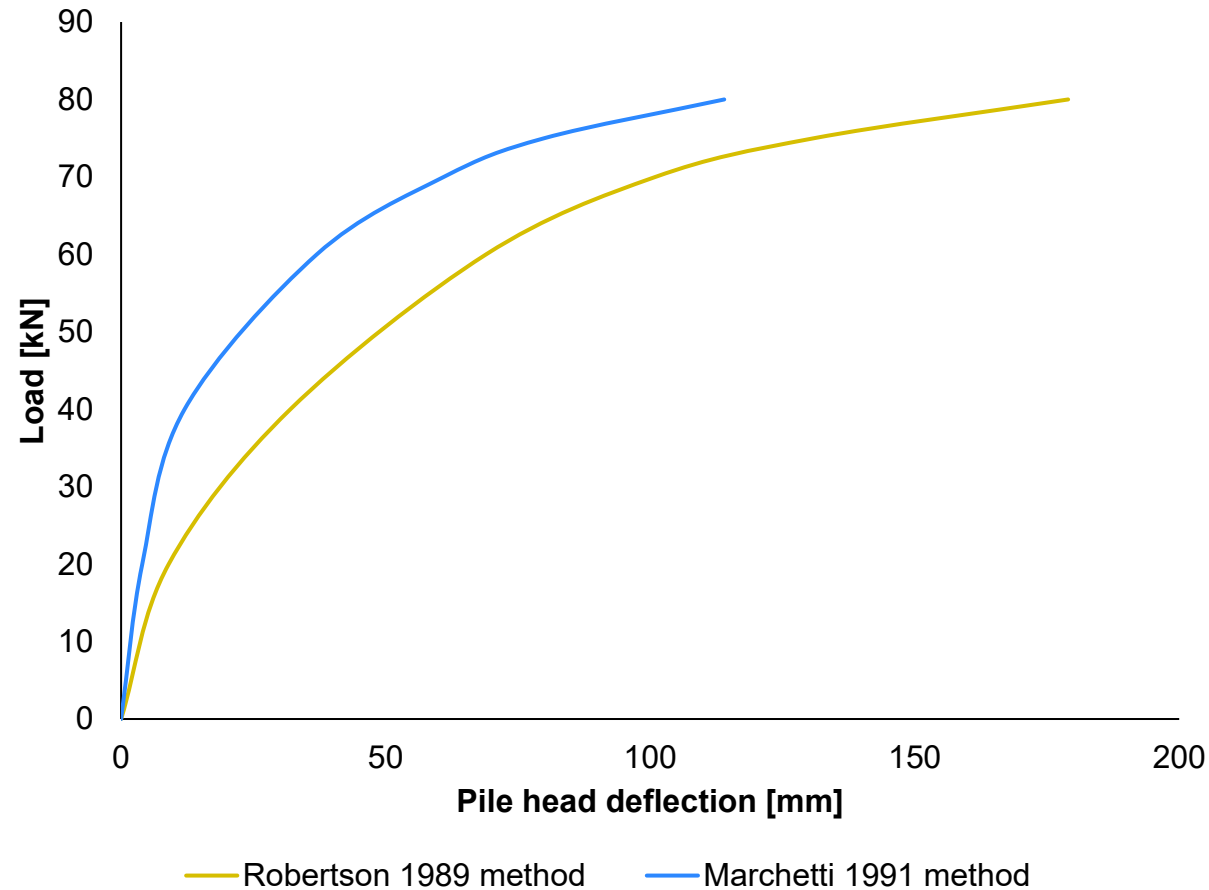


Marchetti 1991 method



EP1 Free head Sample LL Pile prediction (Gatineau 2025)

warning: assumed pile conditions may be different from final pile test conditions !



Applied Load	Robertson (1989)	Marchetti (1991)
[kN]	[mm]	[mm]
0	0	0
20	9	4
40	32	12
60	69	37
70	101	61
75	131	80
80	179	114



Summary-Conclusions-Discussion

- Gabr & Borden (1988): first method with hyperbolic expression, but ignoring E_D
- Robertson (1989): introduced E_D for initial tangent modulus, cubic parabola
- Several comparisons and case histories (Robertson (1989), Briaud, J.-L. et al. (2018), Auburn University / B-424–2 style report and FHWA / DOT(2024)) concluded Robertson 1989 method underestimates soil reaction (p-values) with overprediction of pile-head deflection
- In Livorno LLP test case history
 - Robertson 1989 prediction overestimated measured deflections
 - Marchetti 1991 prediction agreed with measured deflections



Summary-Conclusions-Discussion

- Differences Robertson 1989 vs Marchetti 1991 (P–Y relationship)
 - Robertson 1989
 - non-hyperbolic, soil stiffness too low in small-medium strain range, ‘delaying’ ultimate resistance p_{ult}
 - p approaches p_{ult} only after very large displacements $= 8y_{50}$
 - Excess computed deflection, mostly in the pre-yield regime
 - Marchetti 1991
 - Hyperbolic tangent captures smooth transition from initial stiffness to ultimate resistance
 - Soil nonlinearity more realistic
 - Achieves $p/p_{ult} \approx 1$ at smaller more reasonable displacements



Summary-Conclusions-Discussion

- Ensoft Lpi 2018 software simple tool for processing pile behavior (including LLP)
- Pile properties must be corresponding to in situ conditions (important as P-Y curves)
- Gatineau LLP test predictions valuable for additional validation

Special thanks to Robert Edde and all event organizers

