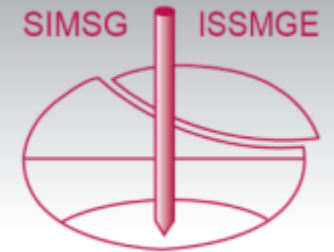




3° C.F.P.B.
3° CONGRESO - SEMINARIO INTERNACIONAL
DE FUNDACIONES PROFUNDAS
DEL 27 AL 29 DE ABRIL DE 2017



B.E.S.T. The Bolivian Experimental Site for Testing Piles

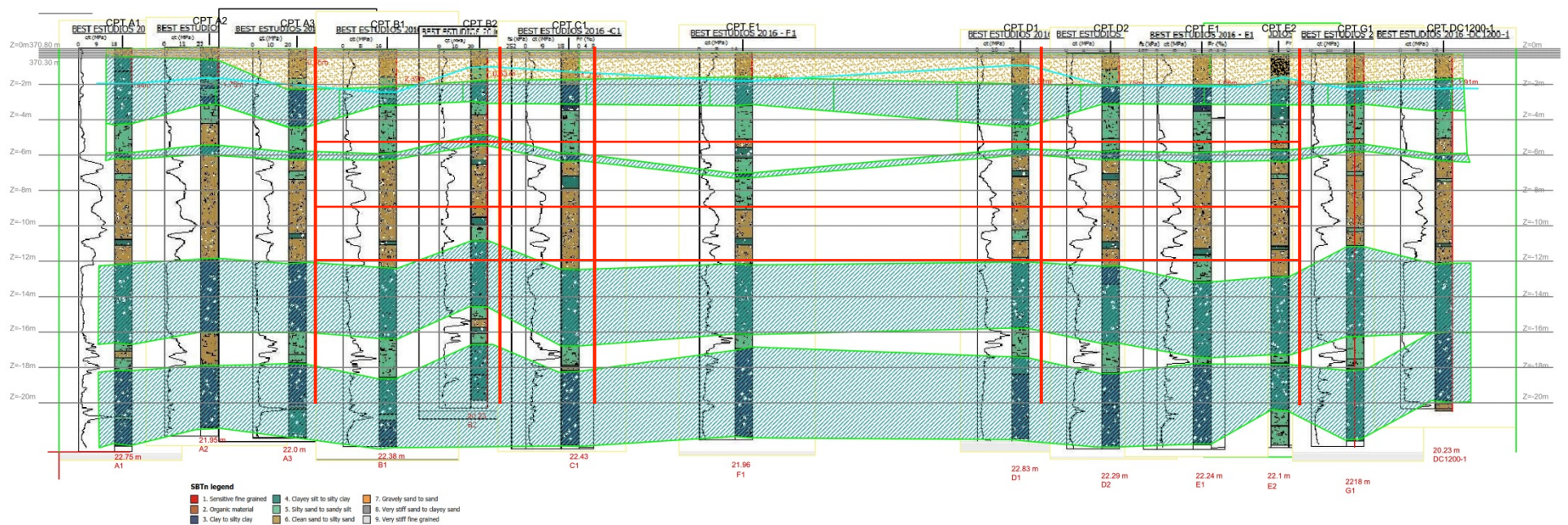
Memorial Session in Honour of Prof. Silvano Marchetti

Soil investigation results : PMT

Roger Frank
ENPC, Paris

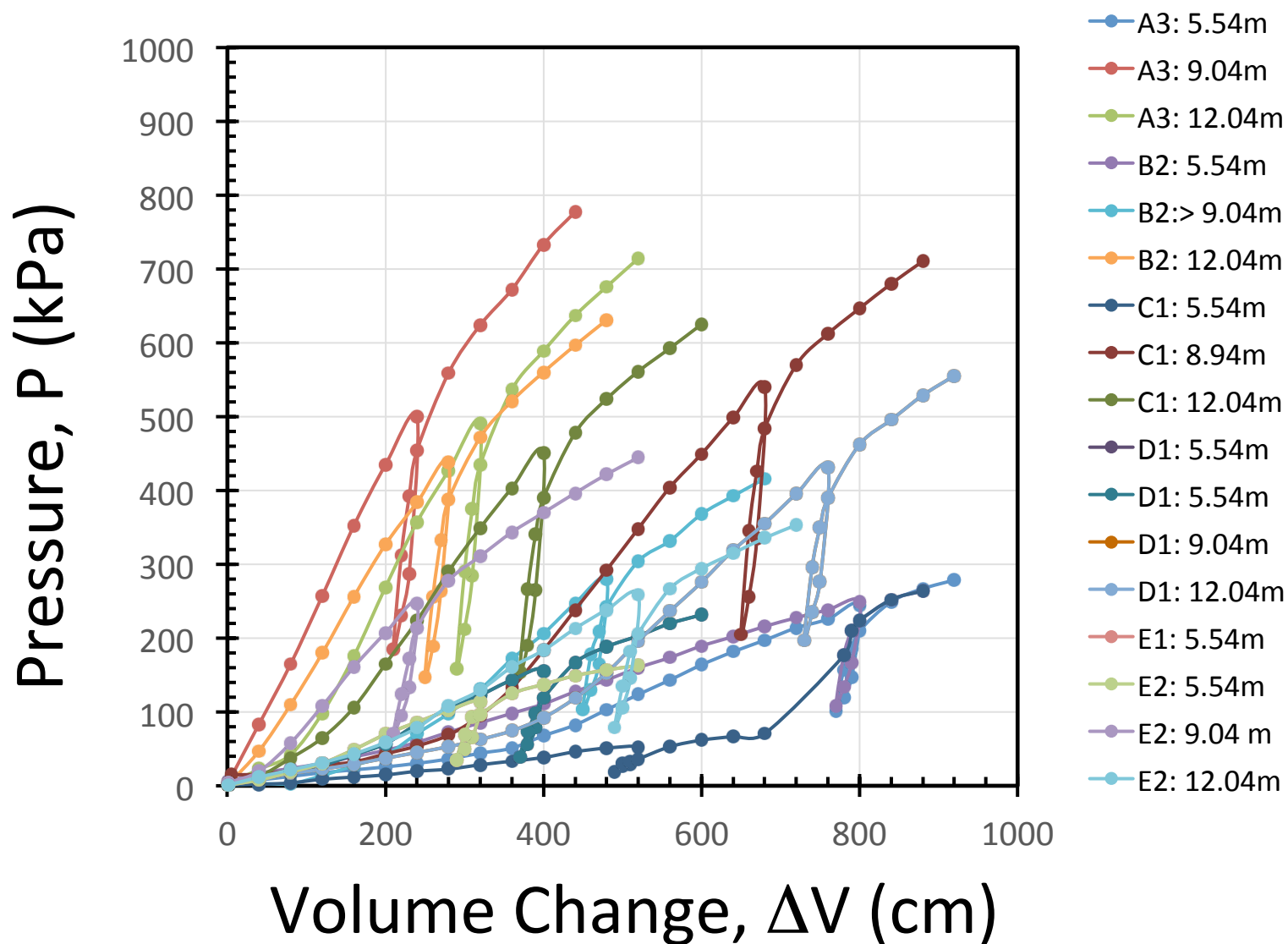
76.7 m

B.E.S.T. ESTIMATED PROFILE



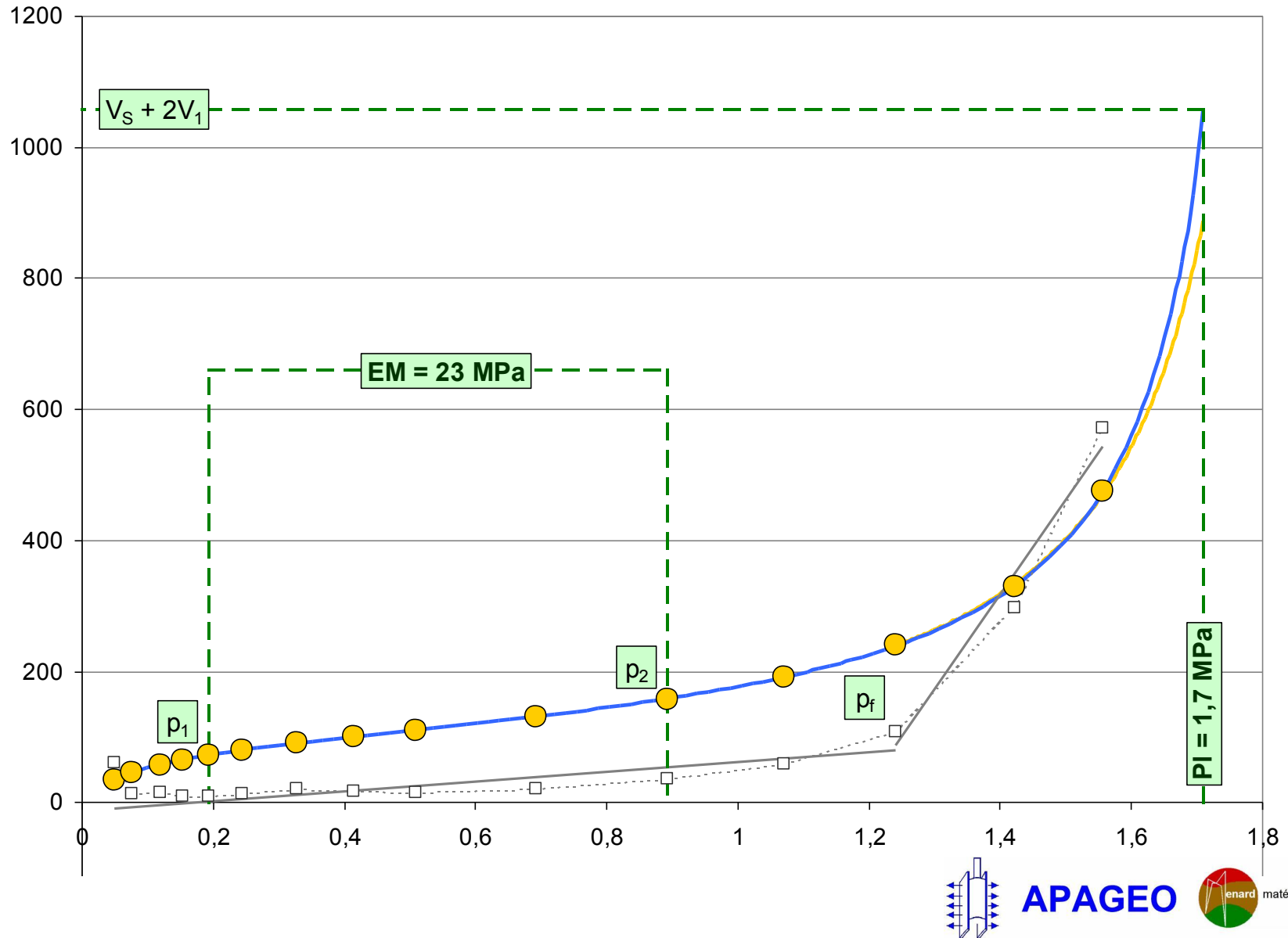
R Frank BEST PMT results, 3° C.F.P.B., Santa Cruz, 27-29 April 2017

B.E.S.T. - PMTs

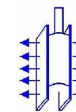


R Frank BEST PMT results, 3° C.F.P.B., Santa Cruz, 27-29 April 2017

P. Mayne (2017)

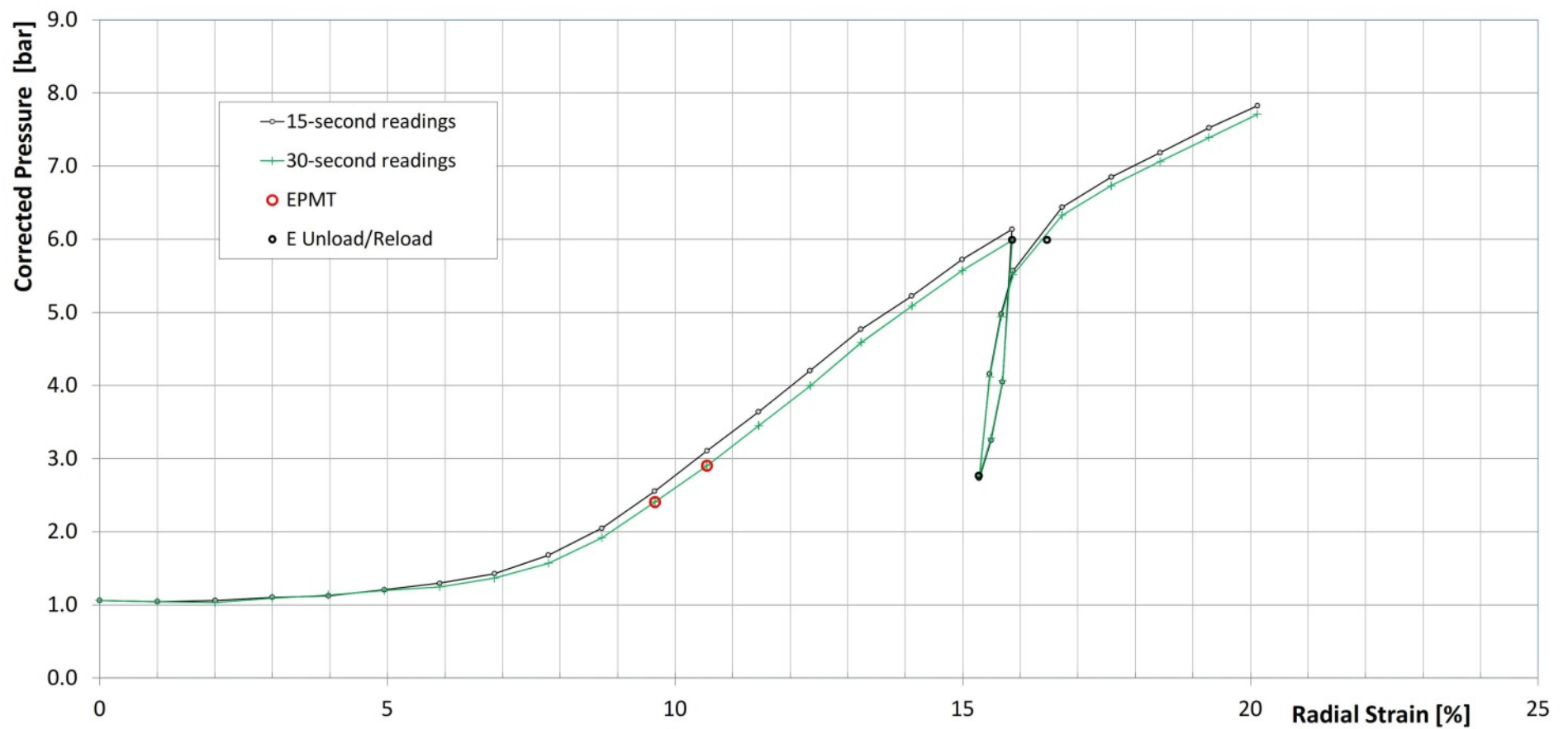


R Frank BEST PMT results, 3° C.F.P.B., Santa Cruz, 27-29 April 2017



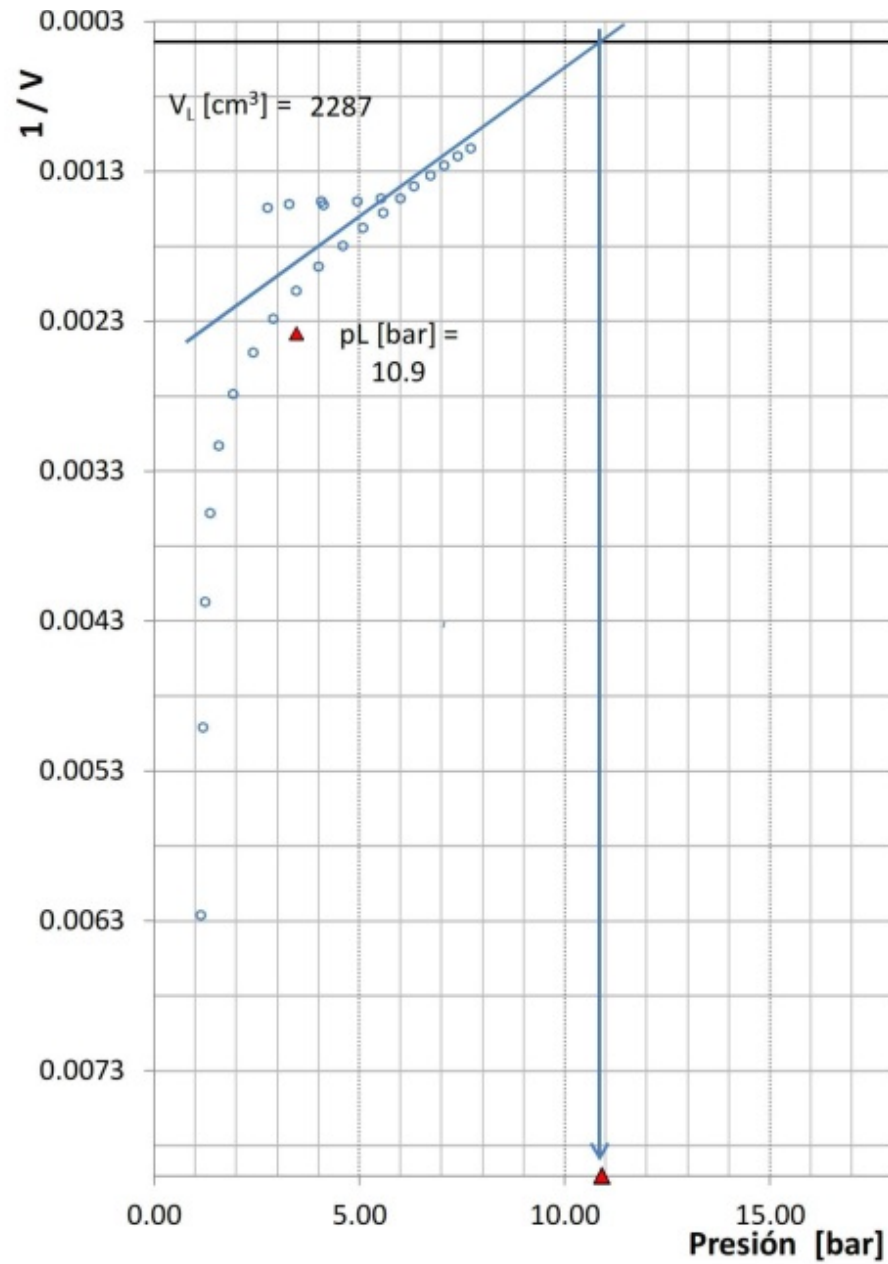
APAGEO





B.E.S.T. C1-2 PMT

R Frank BEST PMT results, 3° C.F.P.B., Santa Cruz, 27-29 April 2017



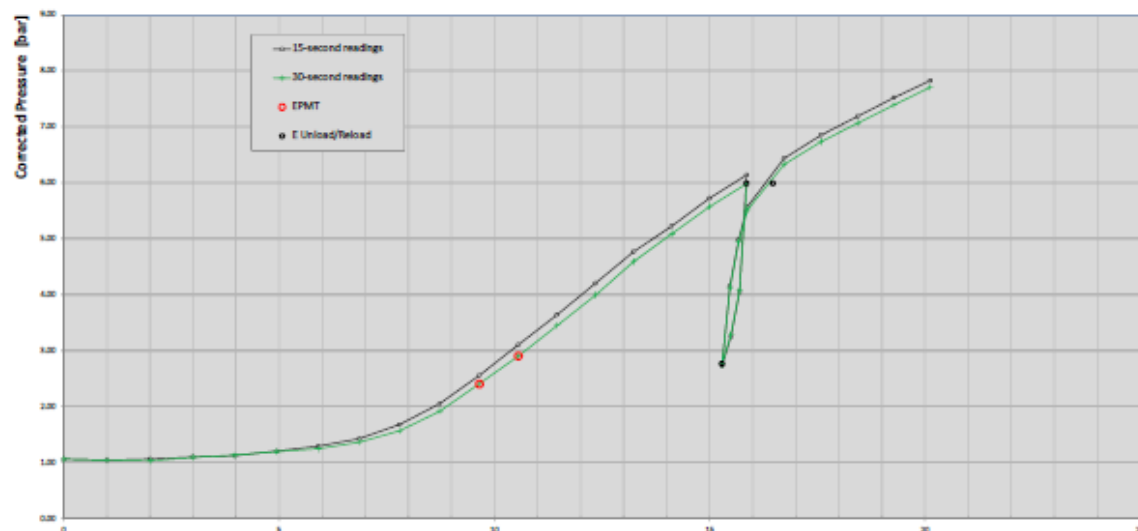
Determination of Limit Pressure p_L at $V_L = 2(V_0 + V_c)$

R Frank BEST PMT results, 3° C.F.P.B., Santa Cruz, 27-29 April 2017

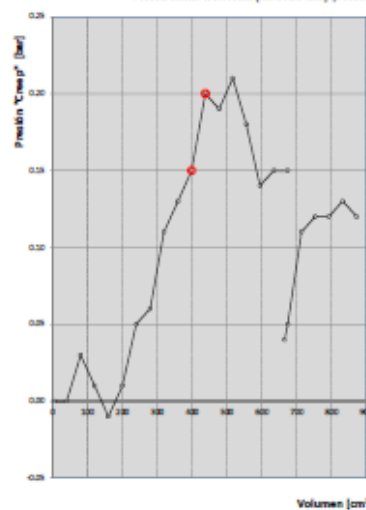
B.E.S.T. C1-2 PMT

Field Test Data (uncorrected)			Corrected Test data						Creep		Auxiliary Data	
Volume [cm ³]	Pressure [bar]		15-second readings			30-second readings			Volume [cm ³]	ΔP (kPa)	30 sec	
	15 sec	30 sec	Pressure [bar]	Volume [cm ³]	ΔP% [N]	Pressure [bar]	Volume [cm ³]	ΔP% [N]			Pressure [bar]	1/V
5	0.15	0.15	1.06	5	0.00	1.06	5	0.00	5	0.00	1.06	0.00019
40	0.16	0.16	1.04	36.8	1.01	1.04	36.8	1.01	36.8	0.00	1.04	0.002612
80	0.21	0.18	1.06	76.8	2.01	1.03	76.8	2.01	76.8	0.03	1.03	0.01263
120	0.38	0.27	1.15	118.7	3.00	1.08	118.7	3.00	118.7	0.01	1.08	0.00936
160	0.53	0.34	1.12	158.8	3.96	1.13	158.8	3.96	158.8	-0.01	1.13	0.00887
200	0.44	0.43	1.41	189.4	4.95	1.40	189.4	4.95	189.4	0.01	1.40	0.00714
240	0.55	0.50	1.30	229.4	5.91	1.26	229.4	5.91	229.4	0.06	1.26	0.00794
280	0.70	0.64	1.43	279.2	6.86	1.37	279.2	6.86	279.2	0.06	1.37	0.00736
320	0.87	0.85	1.80	319.9	7.80	1.57	319.9	7.80	319.9	0.11	1.57	0.00637
360	1.04	1.02	2.08	360.0	8.73	1.74	360.0	8.73	360.0	0.13	1.74	0.00575
400	1.27	1.22	2.68	399.9	9.64	2.41	399.9	9.65	399.9	0.18	2.41	0.00502
440	2.43	2.23	3.10	437.1	10.55	2.90	437.4	10.56	437.4	0.20	2.90	0.00448
480	2.86	2.78	3.54	476.5	11.45	3.45	476.7	11.46	476.7	0.19	3.45	0.00405
520	3.46	3.24	4.30	515.8	12.35	3.90	516.1	12.35	516.1	0.21	3.90	0.00361
560	4.12	3.94	4.77	555.2	13.23	4.55	555.4	13.24	555.4	0.18	4.55	0.00320
600	4.58	4.44	5.23	594.6	14.11	5.09	594.8	14.12	594.8	0.14	5.09	0.00288
640	5.08	4.93	5.70	634.0	14.99	5.57	634.2	14.98	634.2	0.15	5.57	0.00258
680	5.90	5.35	6.14	673.5	15.86	5.96	673.7	15.86	673.7	0.15	5.96	0.00240
720	3.41	3.43	4.06	669.0	15.69	4.07	669.0	15.69	4.07	0.00150		
760	2.81	2.84	3.35	665.9	15.49	3.36	665.9	15.49	3.36	0.00150		
800	2.04	2.12	2.73	647.5	15.39	2.76	647.5	15.39	2.76	0.00154		
840	3.52	3.48	4.18	665.9	15.47	4.12	665.9	15.47	4.12	0.00152		
880	4.34	4.30	4.95	664.2	15.57	4.84	664.2	15.57	4.95	0.00150		
920	4.34	4.35	4.95	674.2	15.57	4.94	674.2	15.57	4.95	0.00146		
960	5.81	5.70	6.44	713.2	16.72	6.33	713.3	16.73	6.33	0.00140		
1000	6.24	6.12	6.85	752.7	17.58	6.73	752.8	17.58	6.73	0.00133		
1040	6.59	6.47	7.19	792.2	18.43	7.07	792.4	18.43	7.07	0.00126		
1080	6.93	6.80	7.52	831.6	19.28	7.39	832.0	19.28	7.39	0.00120		
1120	7.24	7.12	7.83	871.5	20.12	7.71	871.8	20.12	7.71	0.00115		

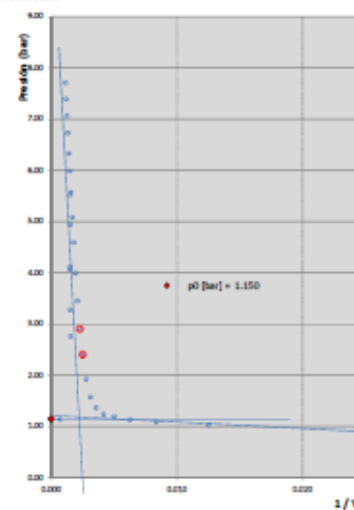
Interpreted PMT Test Results			
(30-second readings)		volume	scale strain
		[cm ³]	[N]
P ₀	1.15 [bar]	160	4.0
P _L	10.00 [bar]		
P ₁	9.75 [bar]		
P _V	2.41 [bar]	398	9.8
E _{avg}	80 [bar]	437	10.8 [9.65-10.96 %]
E _{avg} / P ₁	8.2		
E _{unload}		648	15.3
E _{reload}	421 [bar]		



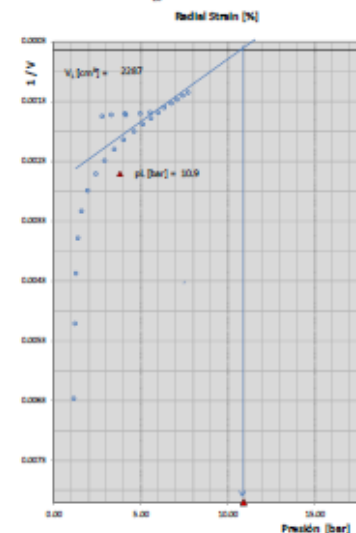
Pressuremeter test results (corrected data) pressure vs radial strain



Pressure difference from 15 to 30 sec. readings Δp [15-30 sec]

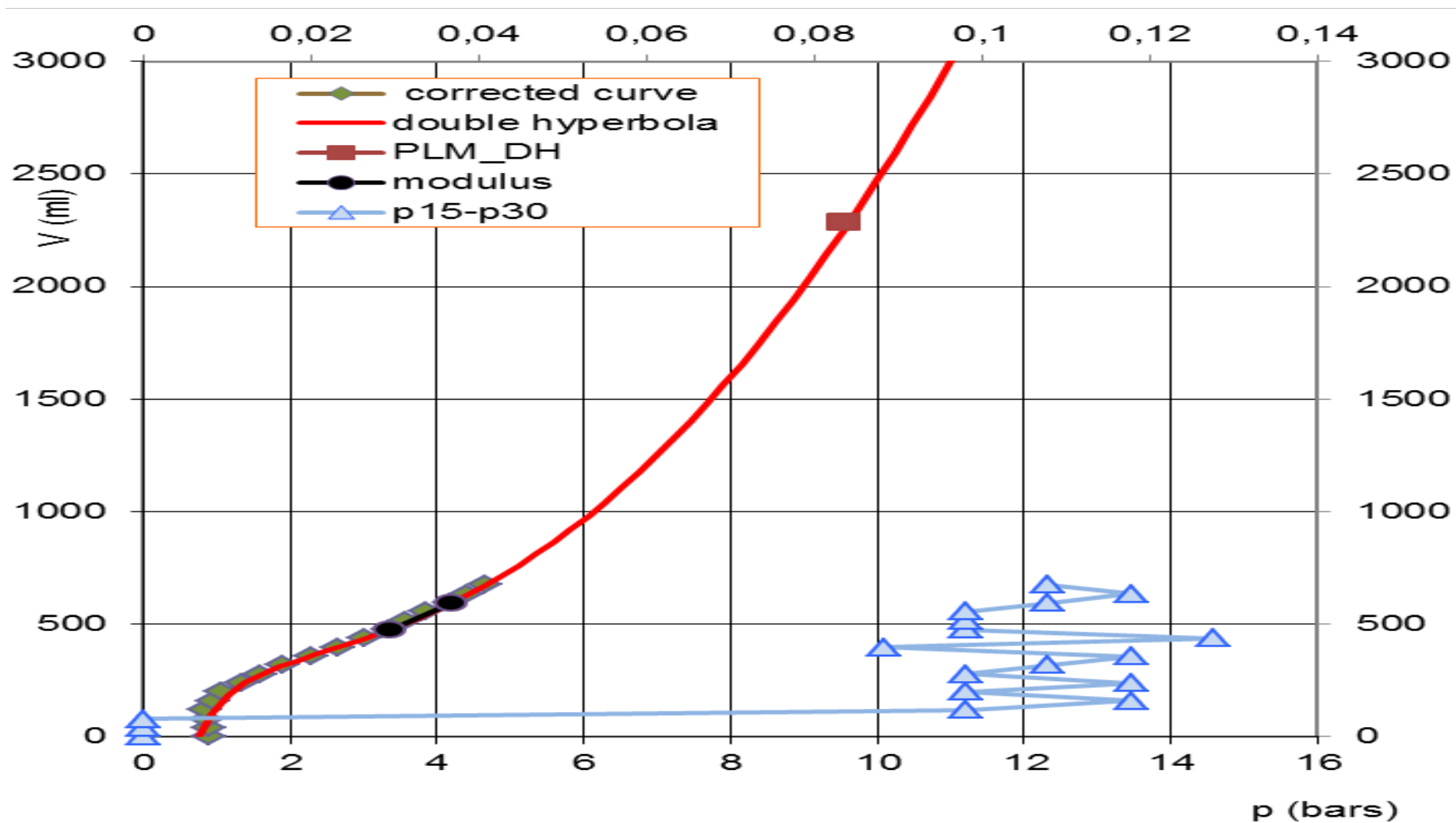


Determination of total correct pressure p₀

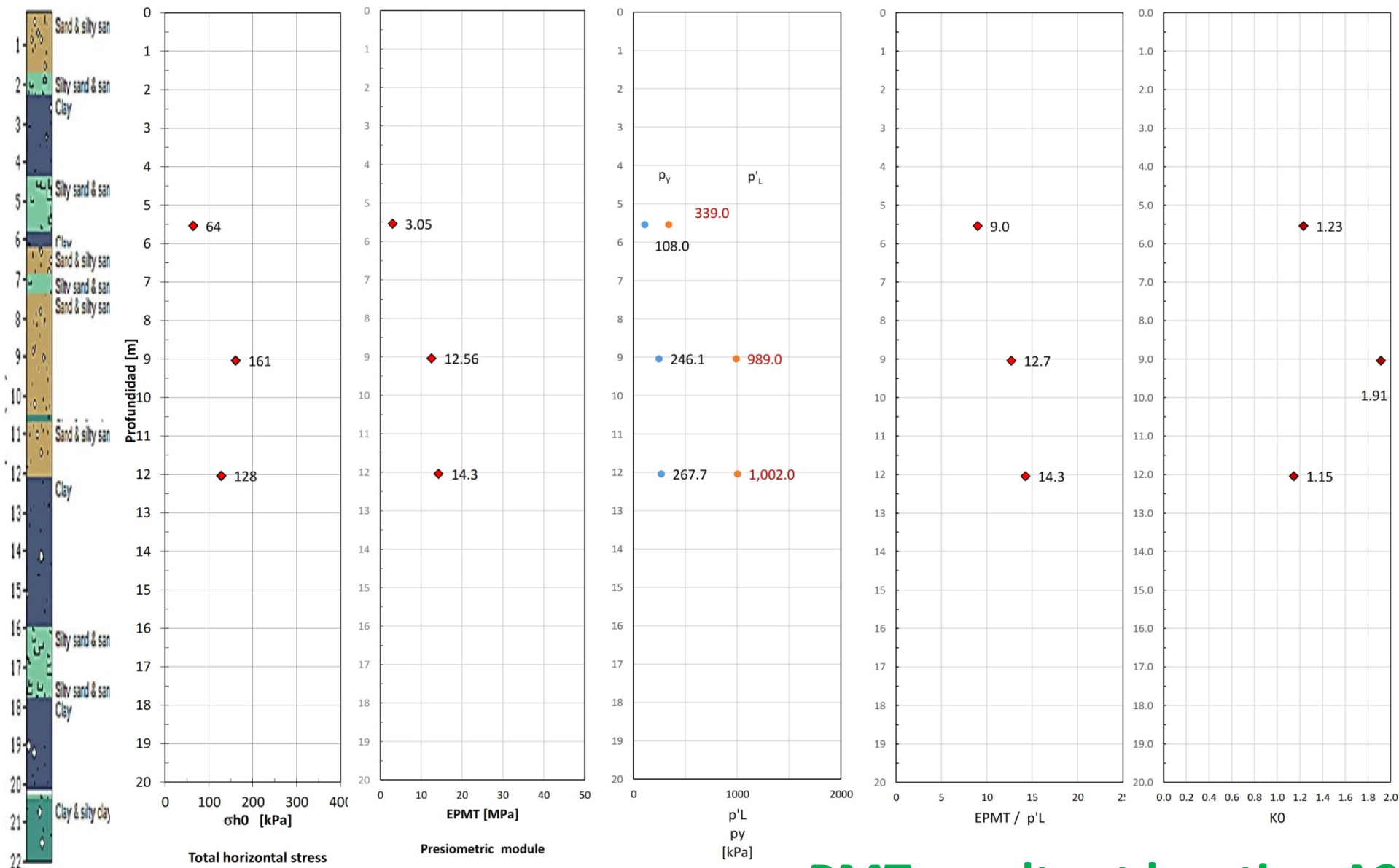


Determination of Limit Pressure p_L at V_L = 2(V₀ + V_c)

Pressuremeter Equipment: TEXAM Model	Probe Designation: N1 Probe (76 mm ID)	Drilling Method: Mud/rotary Drilling	Test Date: 23-12-16	Project: B.E.S.T.	TEST PMT No.: 2
Pressuremeter Calibration: as per ASTM D1470	Probe Size: 76mm	Drilling Bit: Long bit	Test Depth (m): 8.94 (middle of the probe)	Client: Incolec No. Project	Borehole No.: C1
Method B	Calibration Record N: 2	Test Duration: 15 minutes			
Volume Increment: 40 cm ³	Tubing Length: 50 [m]	Technician: Miguel Rodriguez			
Maximum Volume: 1400 cm ³	Probe Length: 0.46 [m]	Engineer: J. J. M. M. M.			
Maximum Pressure: 100 bar	Probe Initial Volume: 1260 cm ³	Drilling company: SEICOCRUZ			

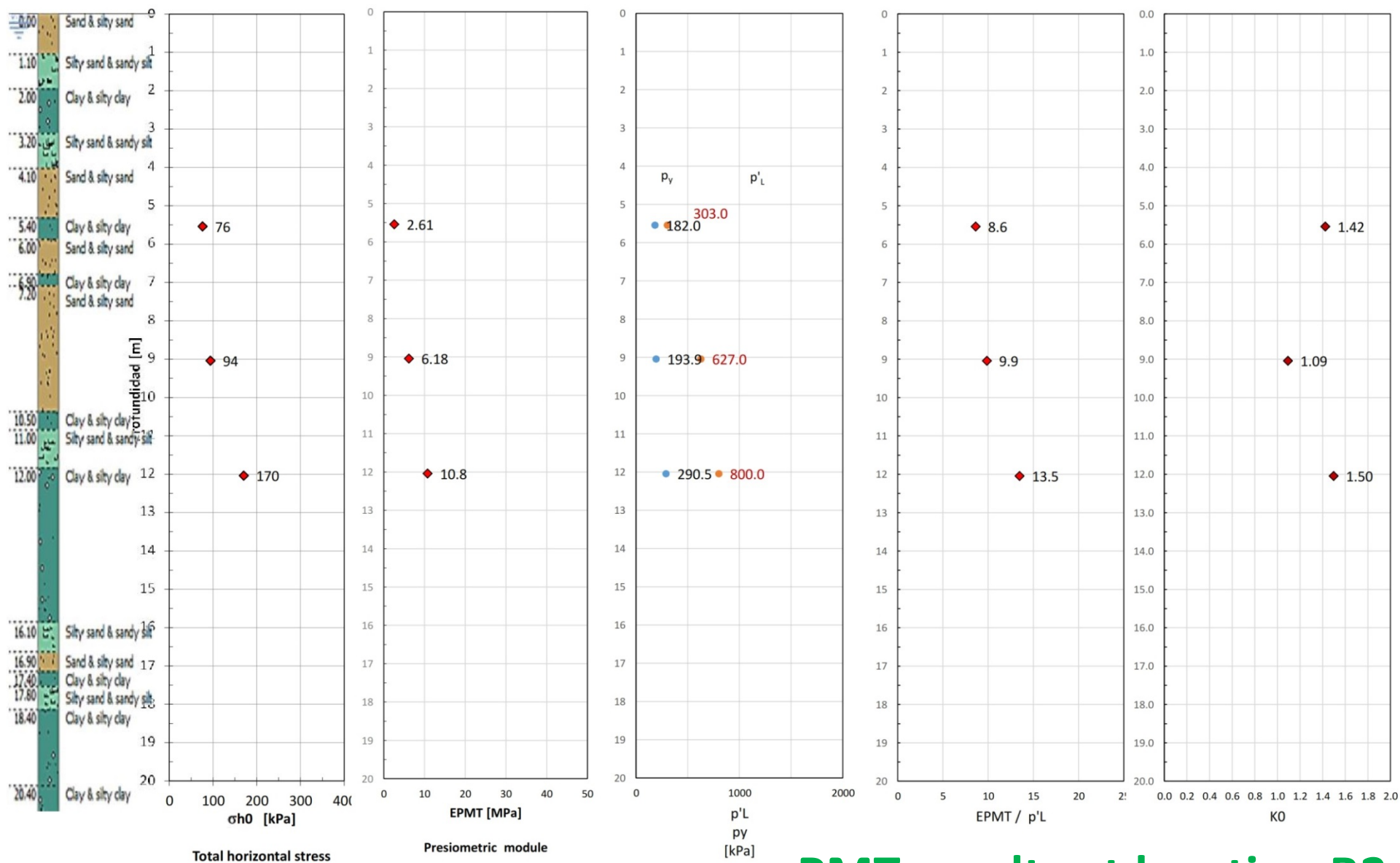


B.E.S.T. B2-2 PMT



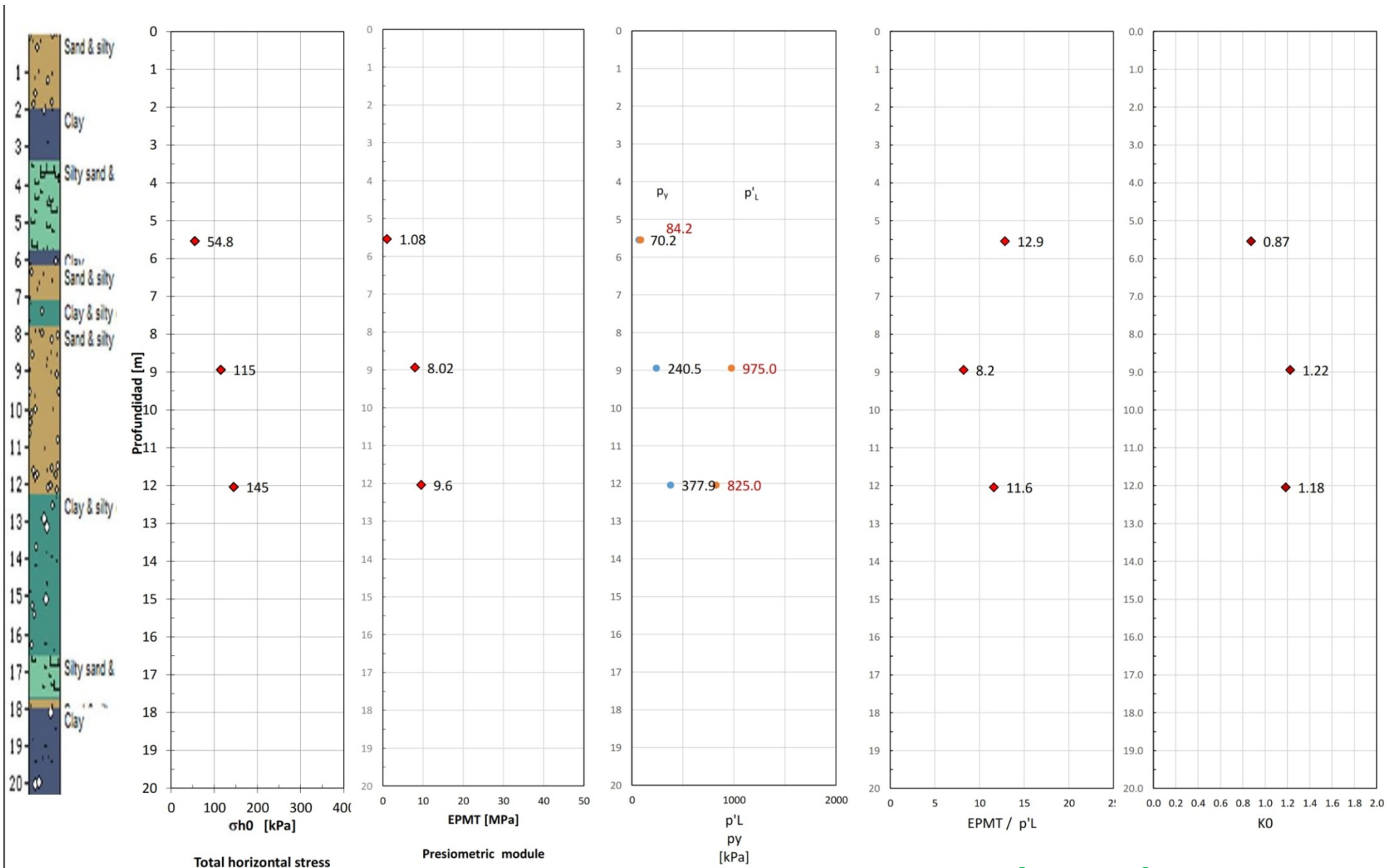
PMT results at location A3

Project: B.E.S.T.	BoreHole A3-PMT	 
Resume of PMT results	R Frank BEST PMT results, 3° C.F.P.B., Santa Cruz, 27-29 April 2017	
Date: December, 2016	Register No.: 30/2016	



PMT results at location B2

Project: B.E.S.T.	BoreHole B2-PMT	 
Resume of PMT results	R Frank BEST PMT results, 3° C.F.P.B., Santa Cruz, 27-29 April 2017	
Date: December, 2016	Register No. 20/2016	



PMT results at location C1

Project: B.E.S.T.

BoreHole C1-PMT

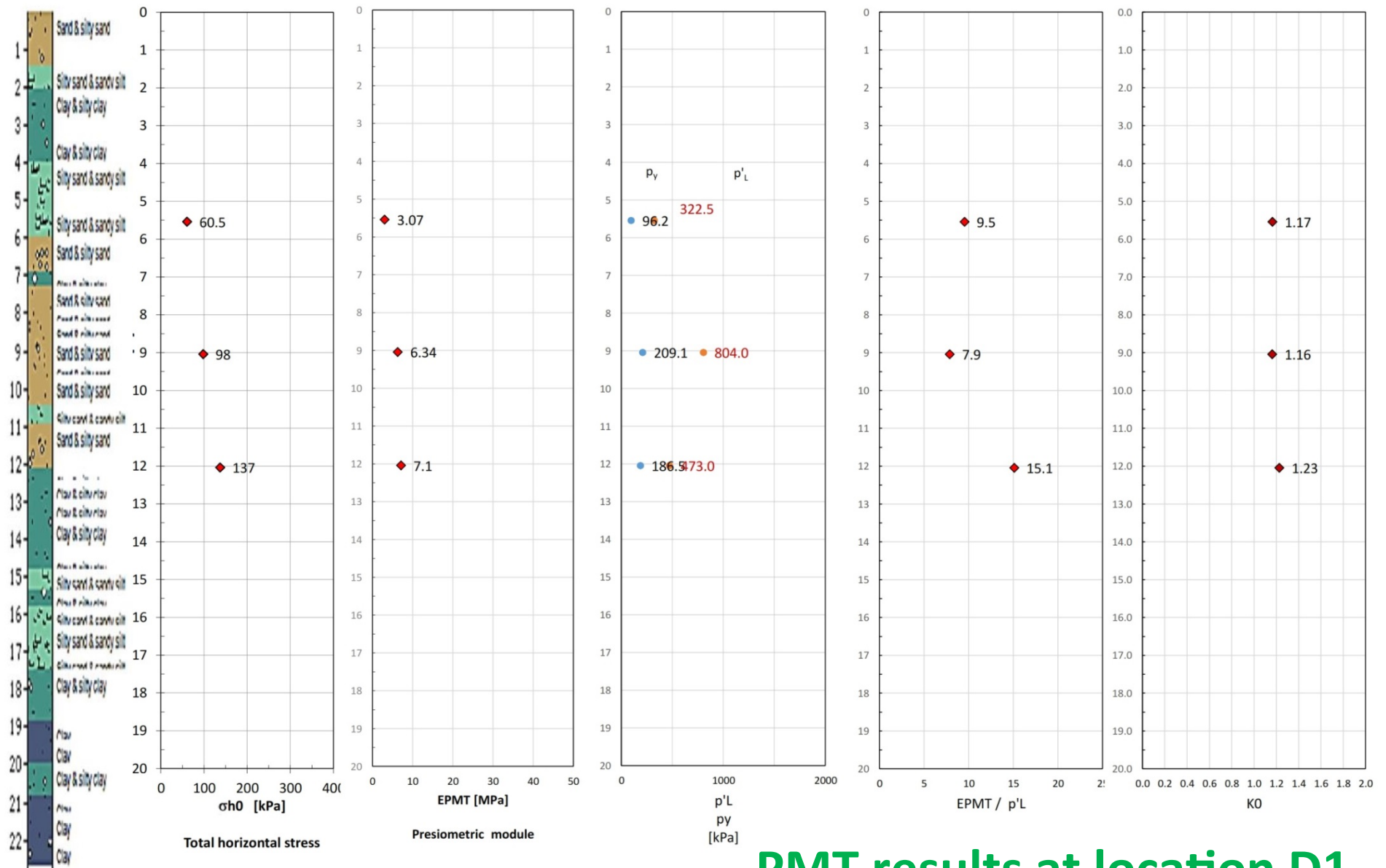
Resume of PMT results

Date: December, 2016

R Frank BEST PMT results 3° C.F.P.B., Santa Cruz, 27-29 April 2017

Register No.: 30/2016

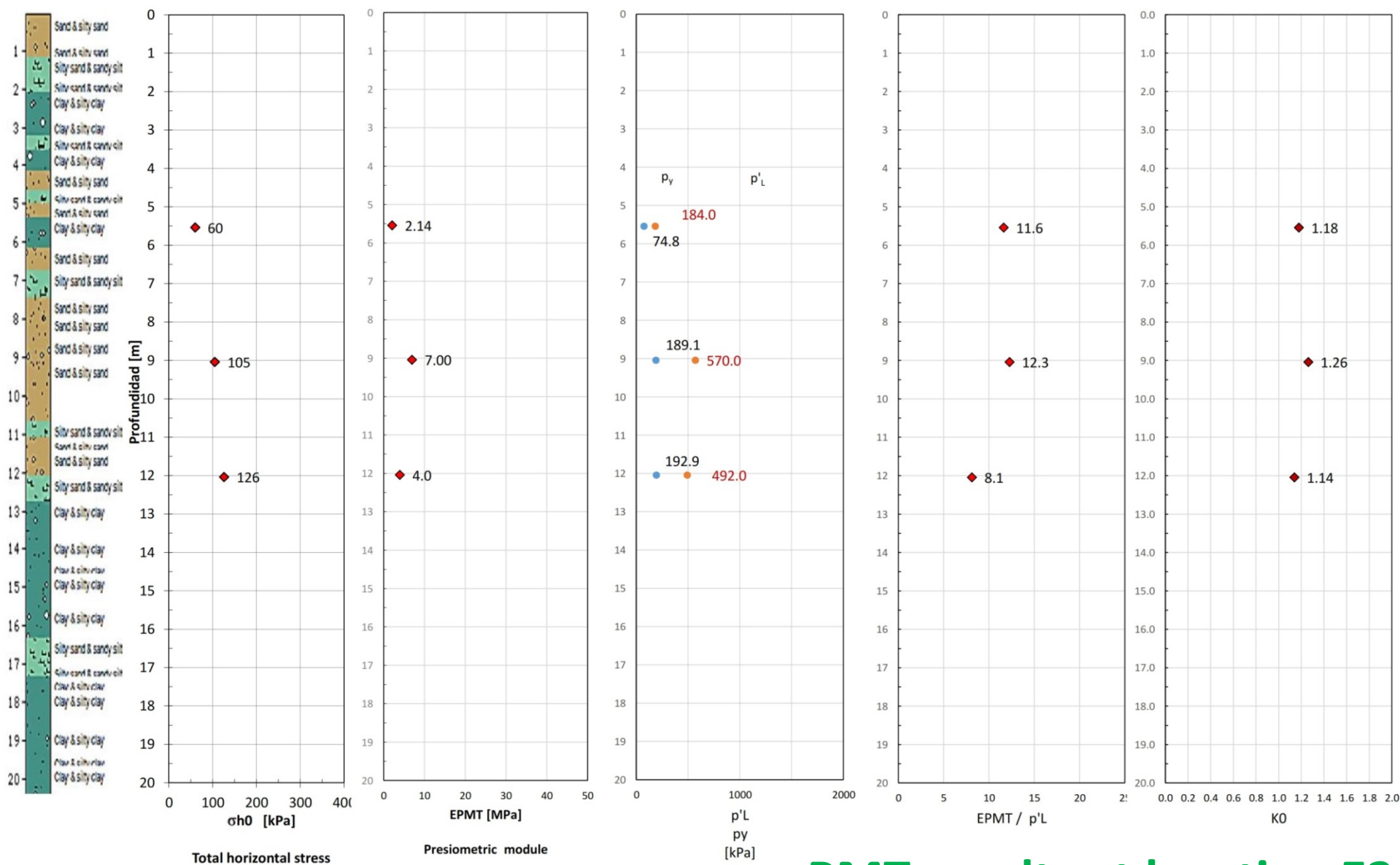




PMT results at location D1

Project: B.E.S.T.	BoreHole D1-PMT	 
Resume of PMT results		
Date: December, 2016		

R Frank BEST PMT results, 3° C.F.P.B., Santa Cruz, 27-29 April 2017



PMT results at location E2

Project: B.E.S.T.	BoreHole E2-PMT	 
Resume of PMT results	R Frank BEST PMT results, 3° C.F.P.B., Santa Cruz, 27-29 April 2017	
Date: December, 2016	Register No. 30/2016	

Analysis of some results

- 9 m depth : all in the sand layer,
 $670 \text{ kPa} < p_L < 990 \text{ kPa}$, and $7 < E_M/p_L < 11 \rightarrow$ medium dense sands

- 5.5 m and 12 m depth, either:
 - predominantly sand layer
 - silty sand and sandy silt layer

A3, C1 and D1, at 5.5 m depth :

$140 \text{ kPa} < p_L < 400 \text{ kPa} \rightarrow$ very loose to loose sands or silts?

$7.7 < E_M/p_L < 8.1 \rightarrow$ stiffer soils?

- at the interface of these two layers, or
- at the interface of one of these two layers and a clay layer

E2 clay at 5.5 m depth? (but very near sand and silty sand)

$p_L = 240 \text{ kPa}$ and $E_M/p_L = 8.6 \rightarrow$ very soft clay

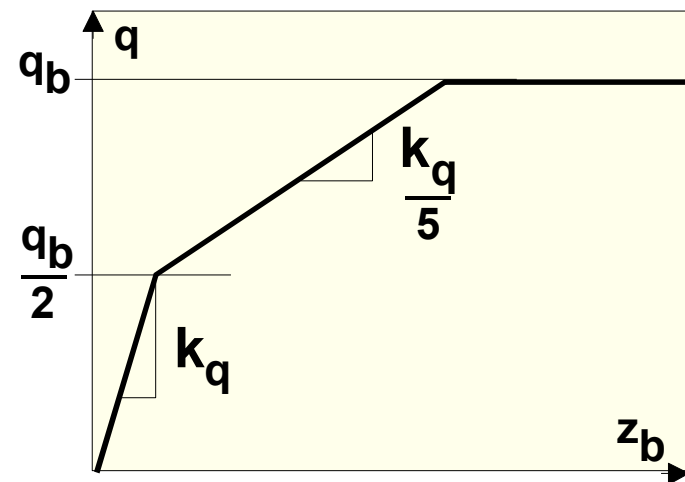
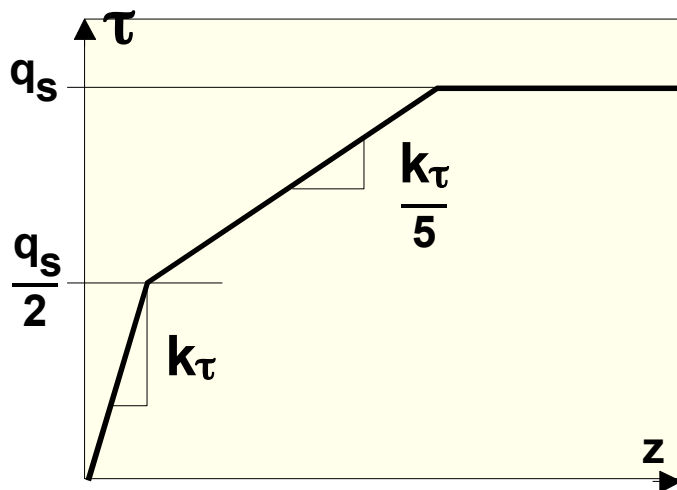
$p_L = 240 \text{ kPa} \rightarrow$ loose sand, but E_M/p_L is too high...

Design of piles with PMT results

- Ménard pressuremeter tests provide:
 - a deformation parameter, $E_M \rightarrow$ displacement assessment
 - a failure parameter $p_L \rightarrow$ capacity assessment
 - These parameters, used with simple rules, charts or softwares (for t-z or p-y approaches) can solve most of current problems of shallow and deep foundations
 - This vision is fully compatible with Eurocode 7...
- The rest is a matter of engineering judgement !

Load-settlement curves for piles from PMT results

t-z curves from Ménard pressuremeter modulus E_M
(laws of Frank-Zhao, 1982)



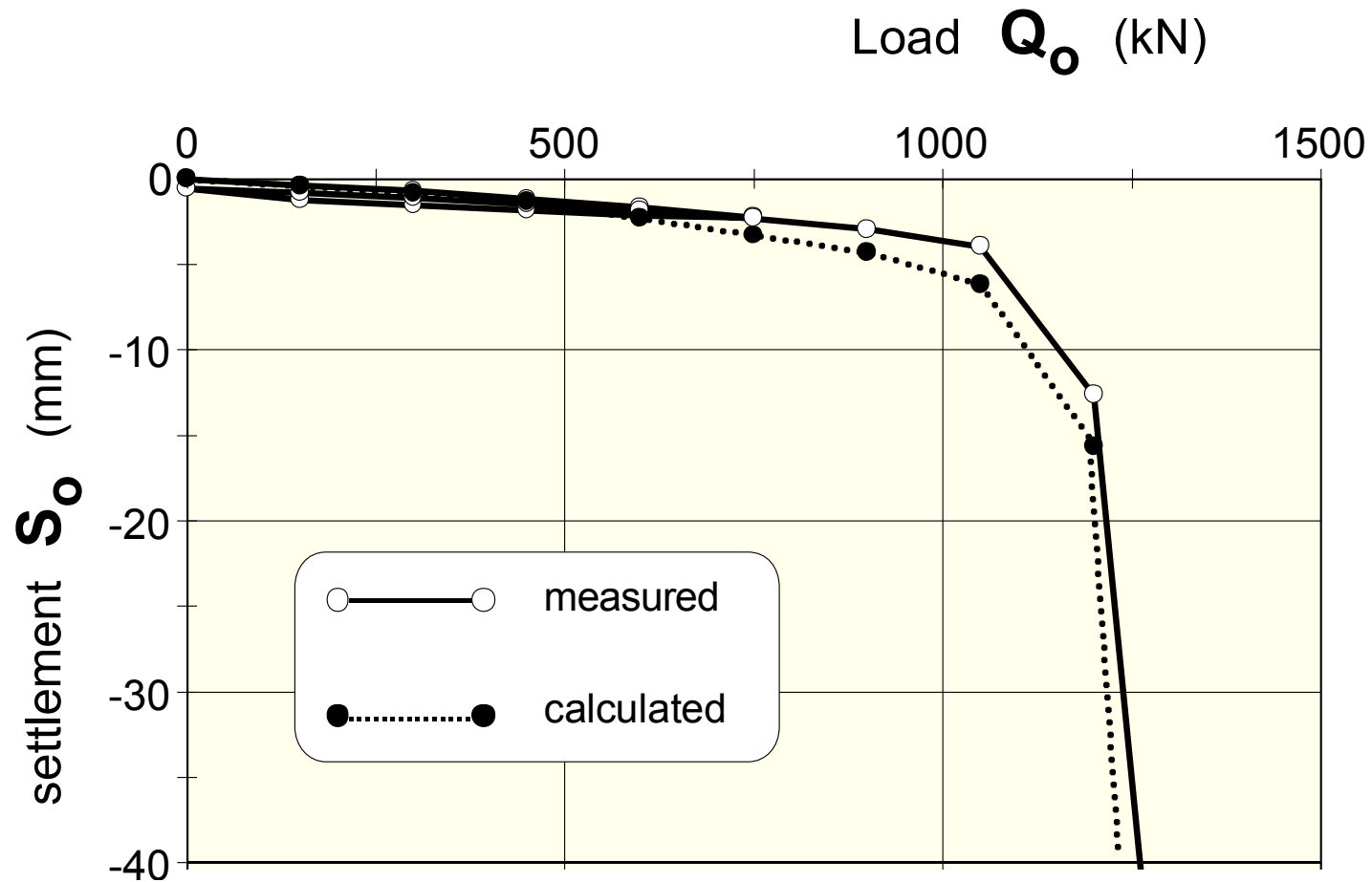
for fine grained soils :

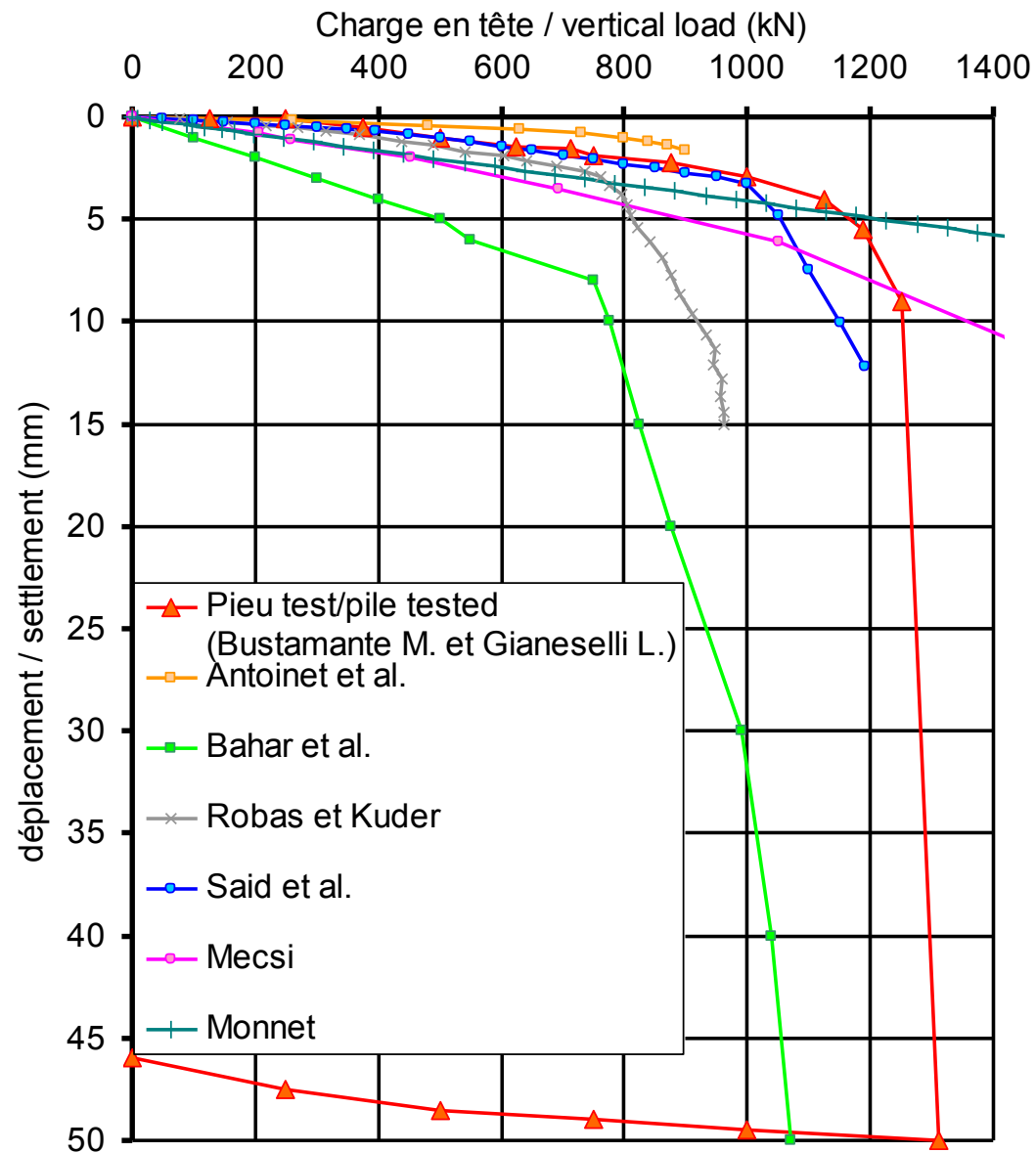
$$k_\tau = 2.0 E_M/B \text{ and } k_q = 11.0 E_M/B$$

for granular soils :

$$k_t = 0.8 E_M/B \text{ and } k_q = 4.8 E_M/B$$

1st example : cased screw pile in Ypresian clay (Belgium)







B.E.S.T. The Bolivian Experimental Site for Testing Piles

Thank you for your attention !