Universität Stuttgart

IGS

Institut für Geotechnik

Boden- und Felsmechanik,
Erd- und Grundbau, Felsbau,
Spezialtiefbau, Tunnelbau,
Umweltgeotechnik

Univ.-Prof. Dr.-Ing. habil. Chr. Moormann

Hochschule für Technik Stuttgart

Fakultät B,
Fachgebiet Geotechnik
Prof. Dr.-Ing. Th. Benz
Prof. Dr.-Ing. C. Vogt-Breyer

Stuttgarter Geotechnik-Seminar

Monday, 16 November 2020

Applications of Dilatometer (DMT) and Seismic Dilatometer (SDMT) in Geotechnical Engineering

Eng. Diego Marchetti

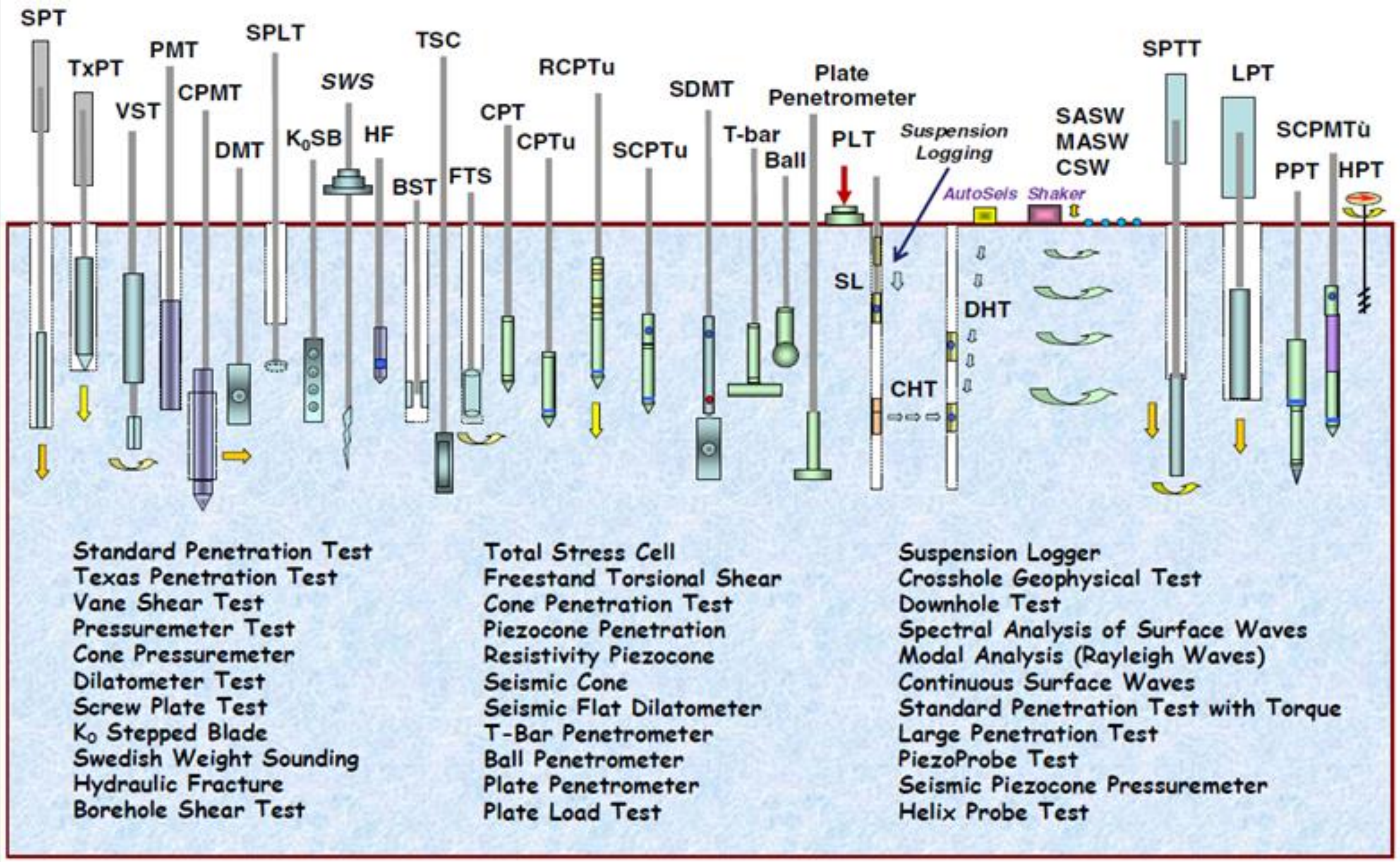
Studio Prof. Marchetti

Italy

MARCHETTI DILATOMETER

www.marchetti-dmt.it

Many different tools for site investigation..



"Soil borings … laboratory testing … SPT … pressuremeter (PMT) … vane (VST) … crosshole (CHT) … All of these are valid and suitable … yet at considerable cost in time and money …"   Mayne 2009

Direct Push Technology: SCPT & SDMT increasing leadership in penetrable soils:

Direct Push Technology:

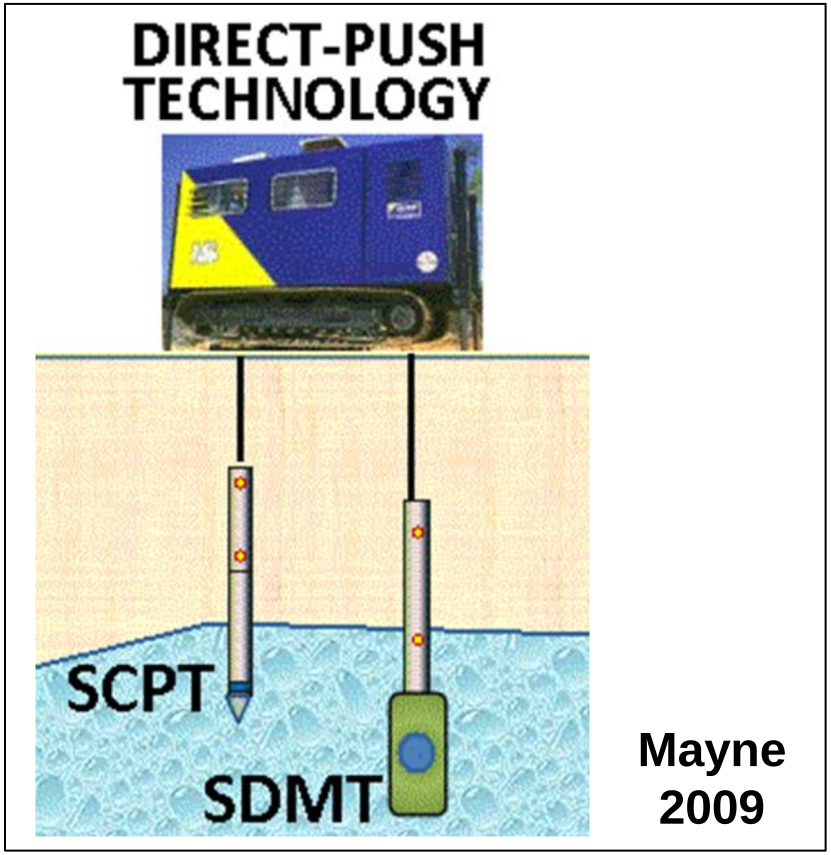
✓ simple

✓ fast

✓ repeatable

✓ continuous soil profile

✓ results real time



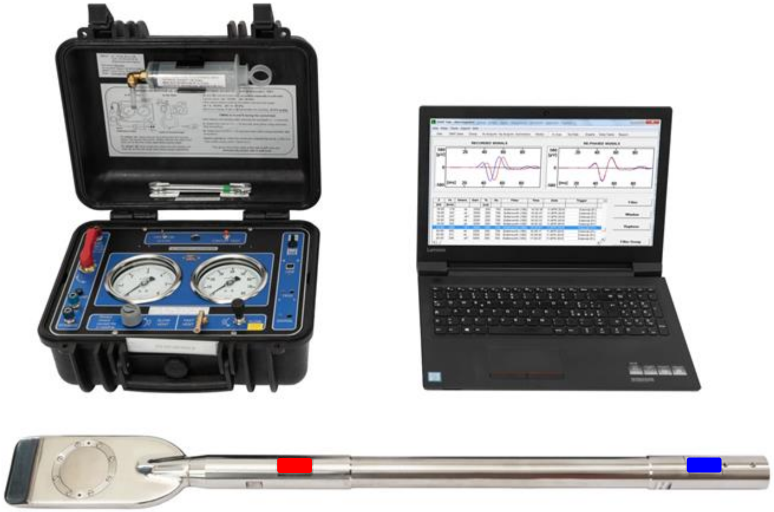
Sands:

recovering undisturbed samples very difficult

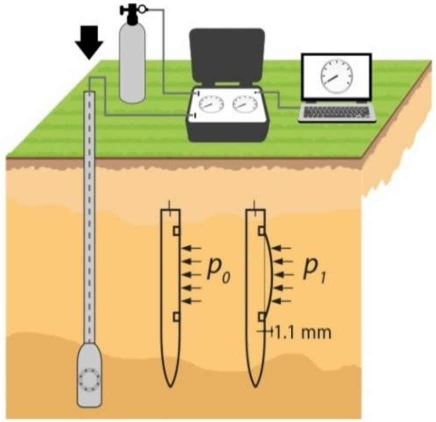
→ Direct Push Technology is the state-of-practice

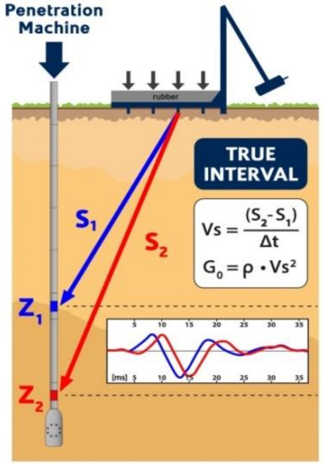
Seismic Dilatometer (S + DMT)

Seismic Dilatometer (SDMT)



Flat Dilatometer 1980



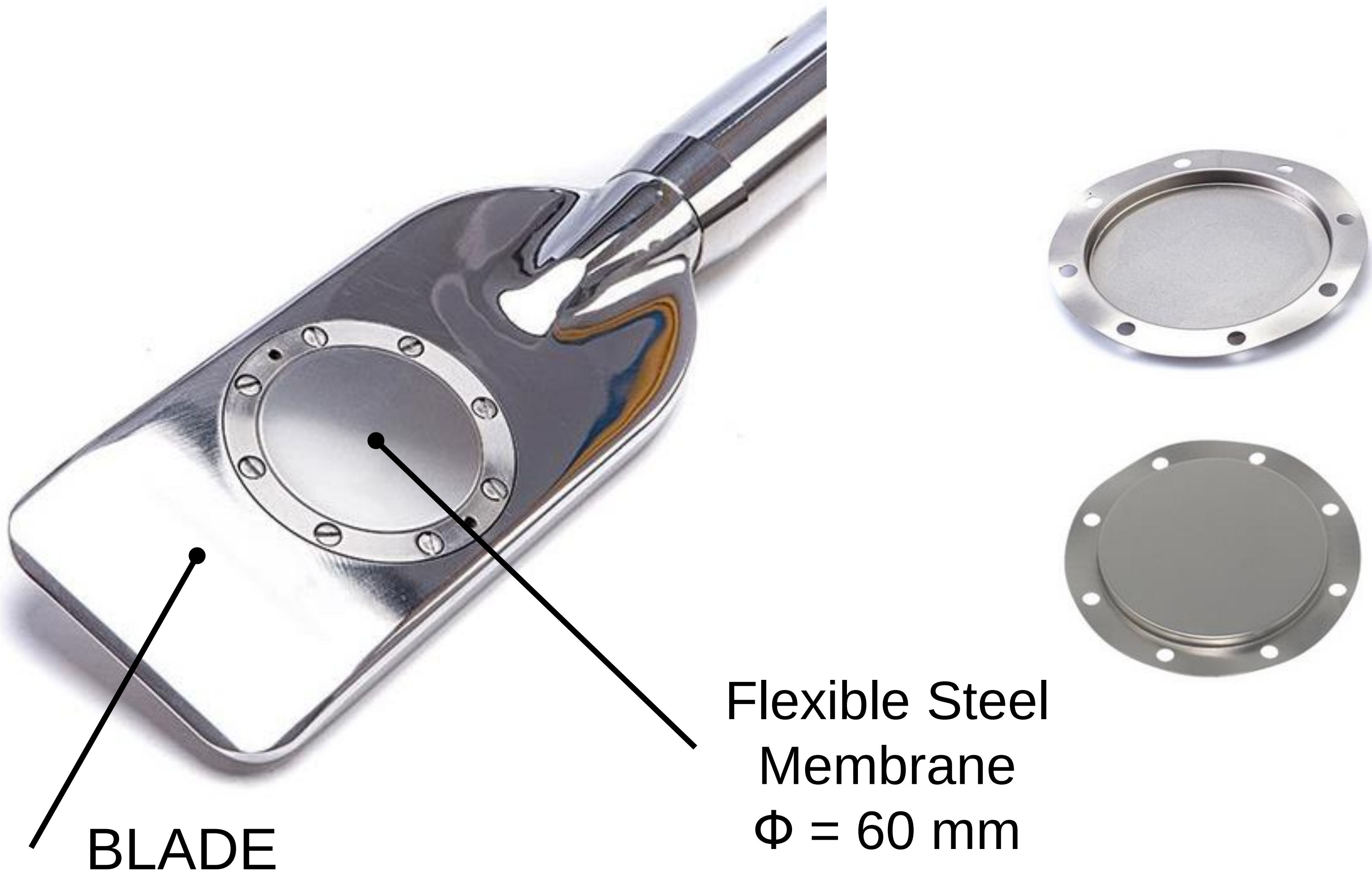


Seismic Module 2004

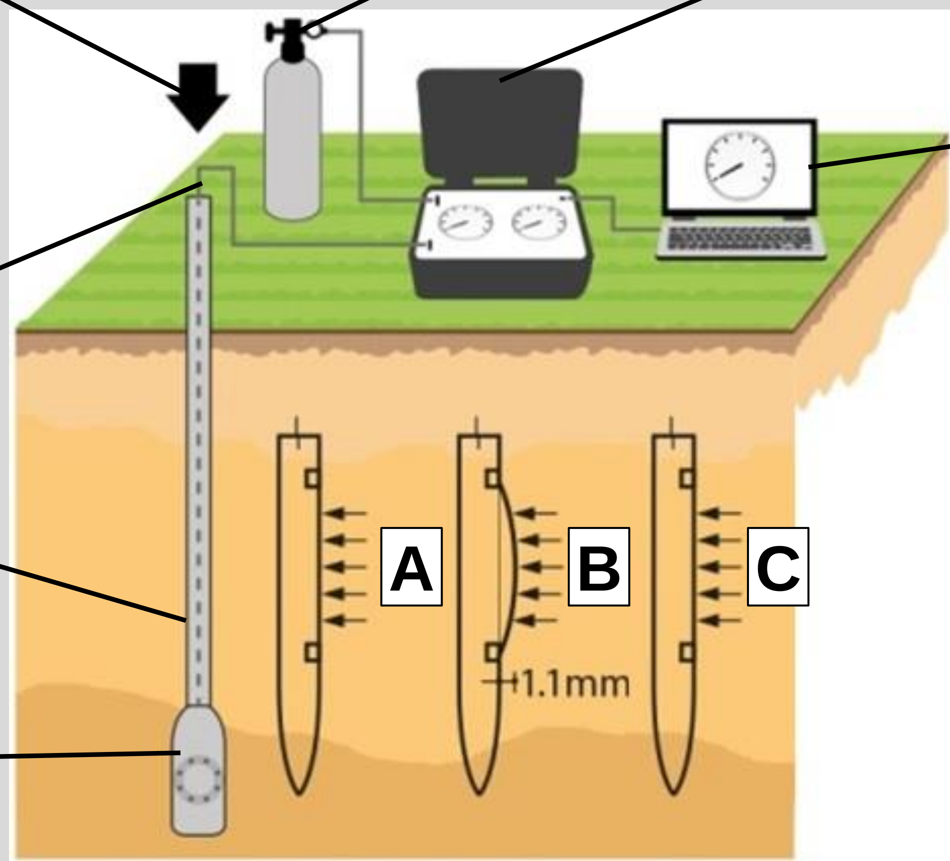
Prof. Silvano Marchetti (1943 – 2016)

inventor of the Flat Dilatometer (1974)

Flat Dilatometer (DMT)



DMT Test Layout



<u>Test Procedure</u>

stop every 20 cm

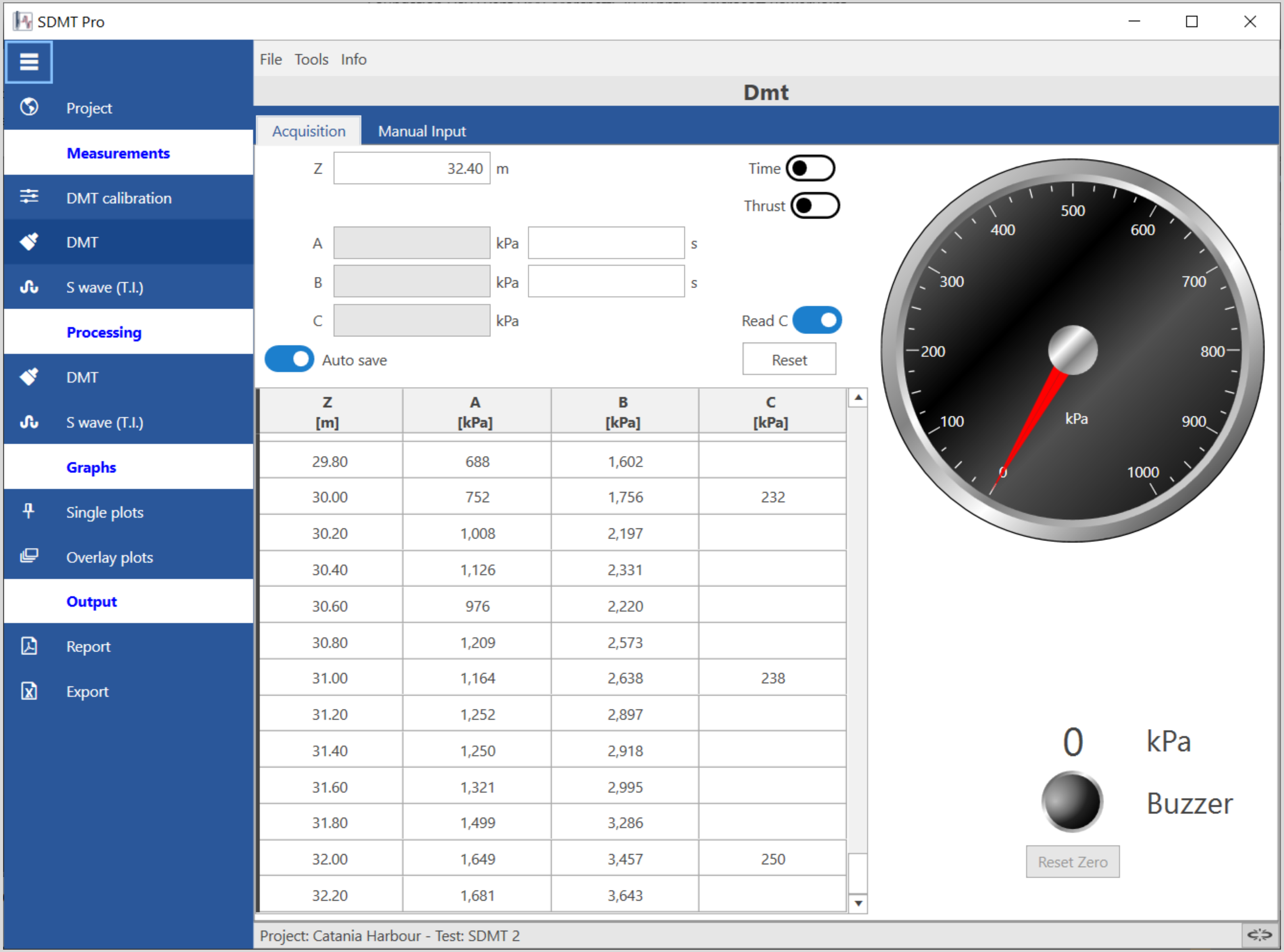
A : Lift-off pressure

B : Pressure for 1.1 mm expansion

Deflate after B

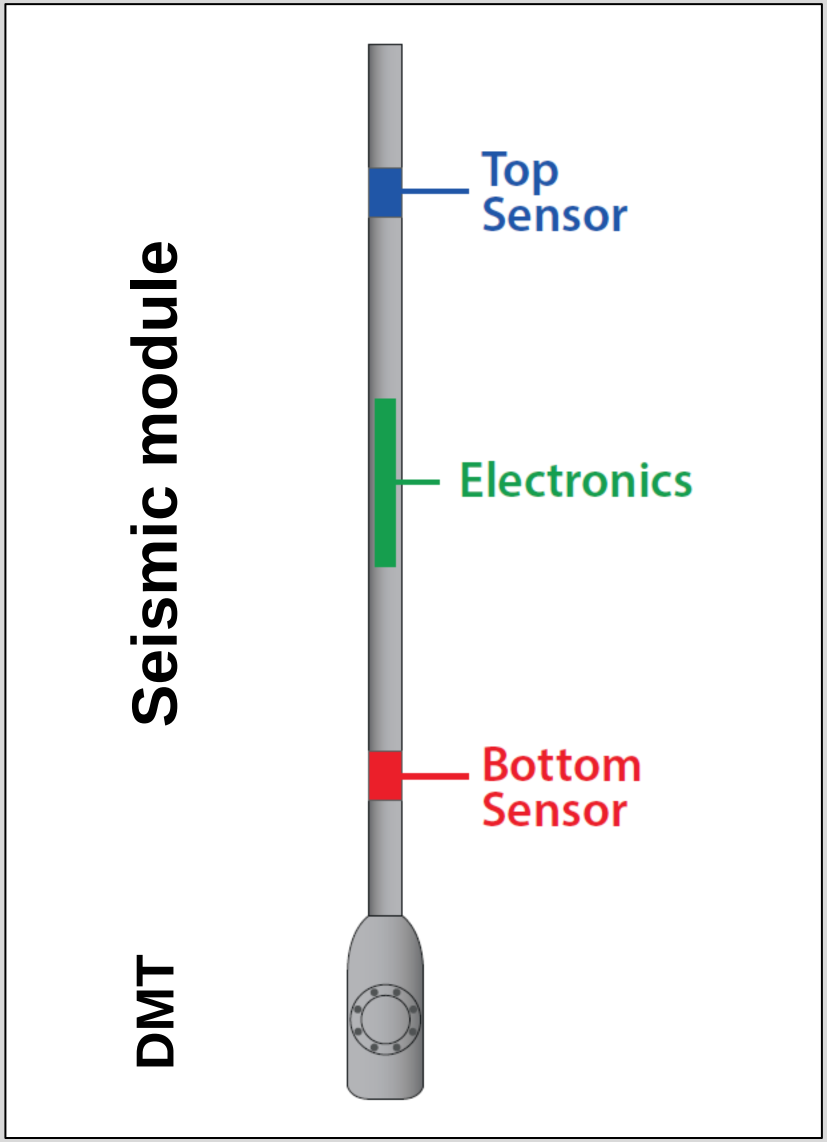
C : Closing pressure

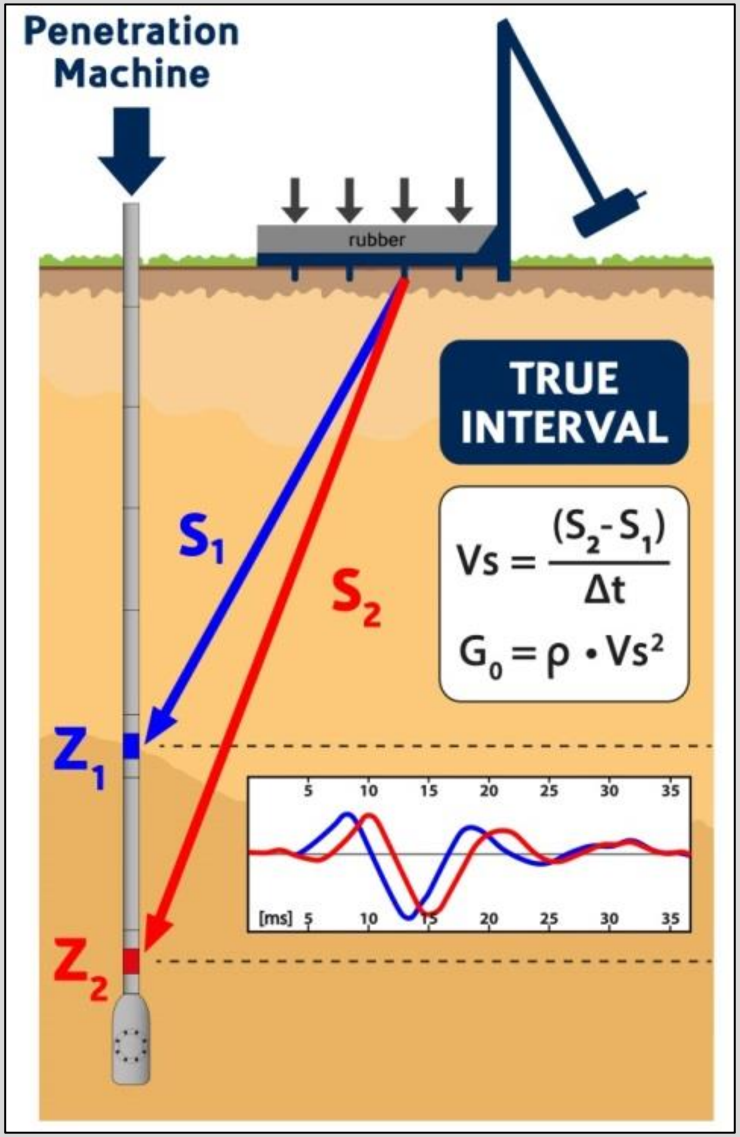
DMT Data: A, B and C with depth (Z)



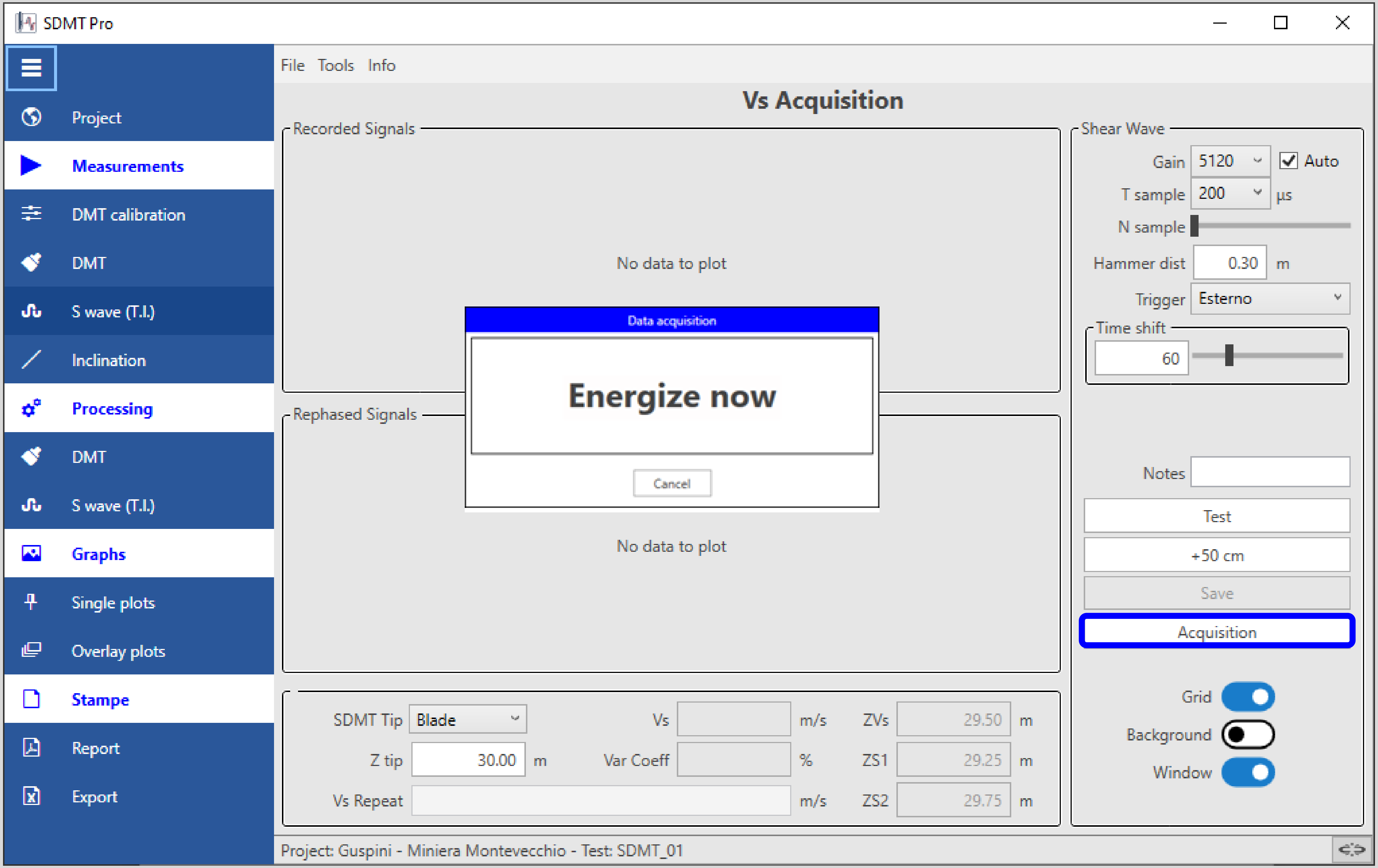
Z [m]	A [kPa]	B [kPa]	C [kPa]
29.80	688	1,602	
30.00	752	1,756	232
30.20	1,008	2,197	
30.40	1,126	2,331	
30.60	976	2,220	
30.80	1,209	2,573	
31.00	1,164	2,638	238
31.20	1,252	2,897	
31.40	1,250	2,918	
31.60	1,321	2,995	
31.80	1,499	3,286	
32.00	1,649	3,457	250
32.20	1,681	3,643	

SDMT – Test Layout



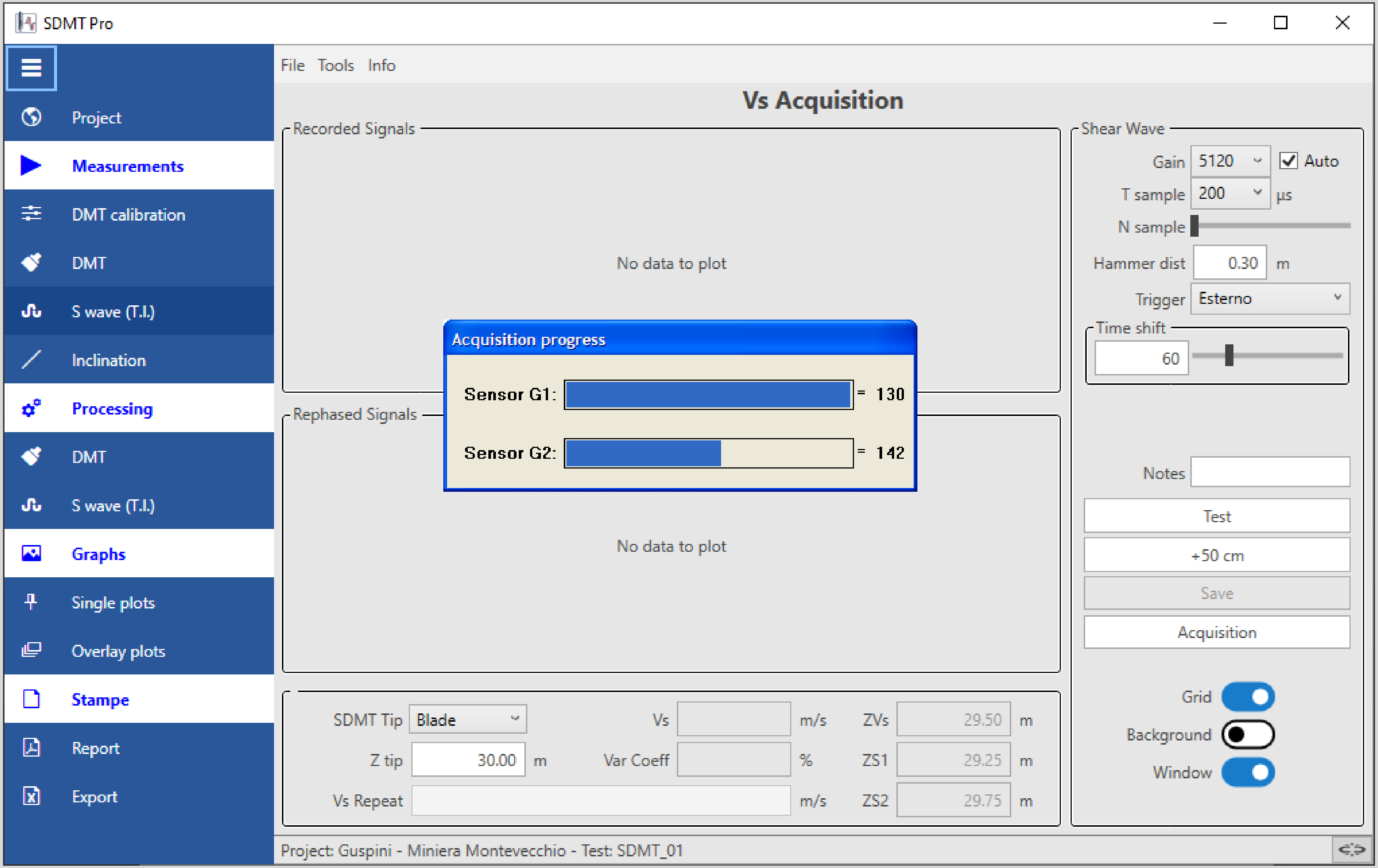


Shear wave velocity measurement

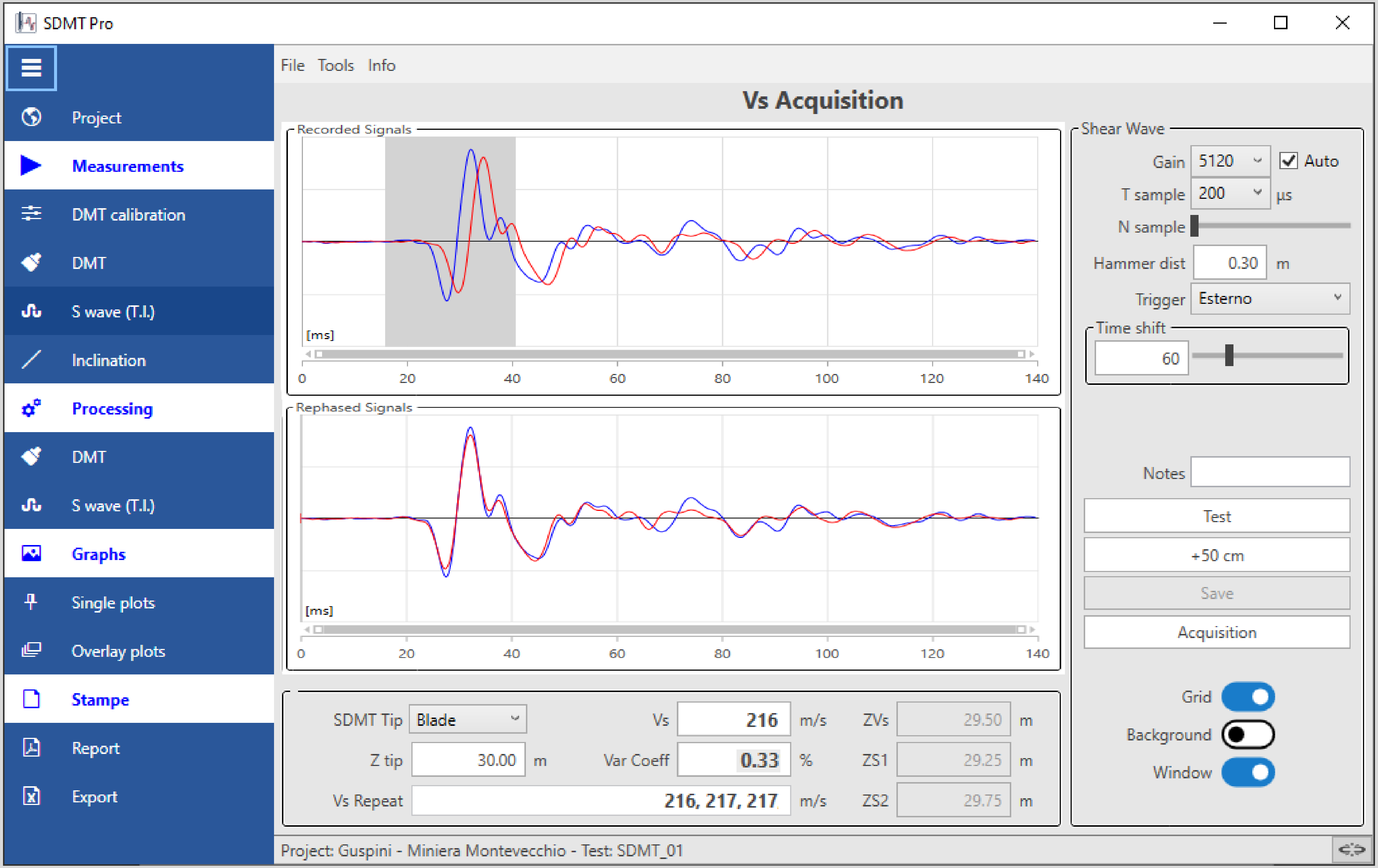


Generate S-wave at surface

Data transfer of seismic wave (≈ 5 sec)

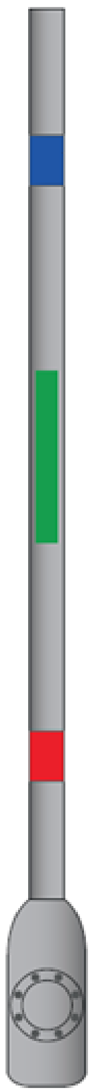


Vs available real time



SDMT main features

SDMT



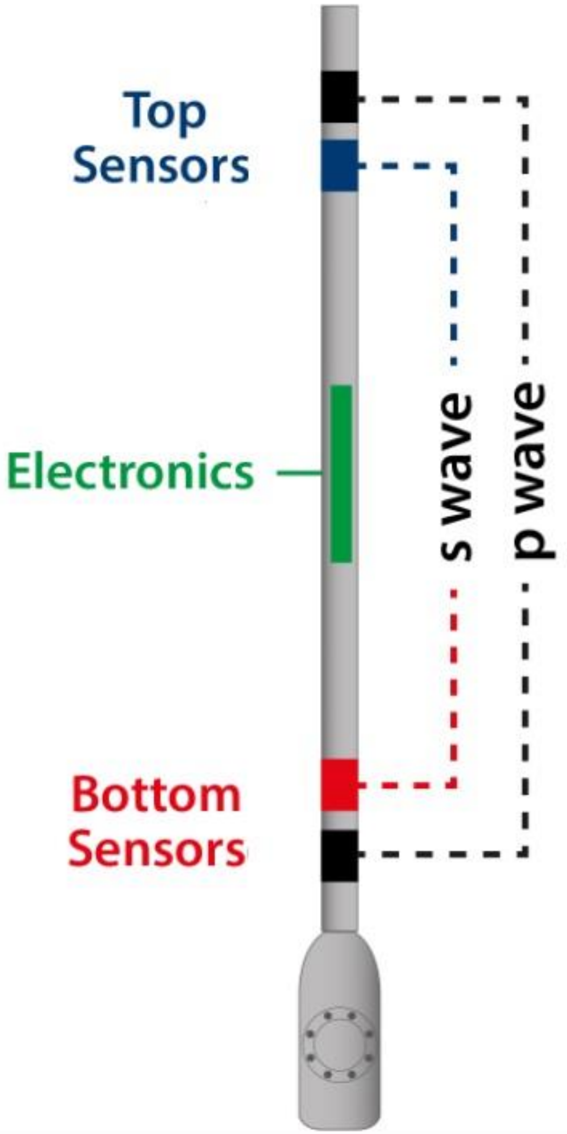
- Test execution is rapid
  - no hole (if soil is penetrable)
  - no wait time for cementation (e.g. crosshole, downhole)

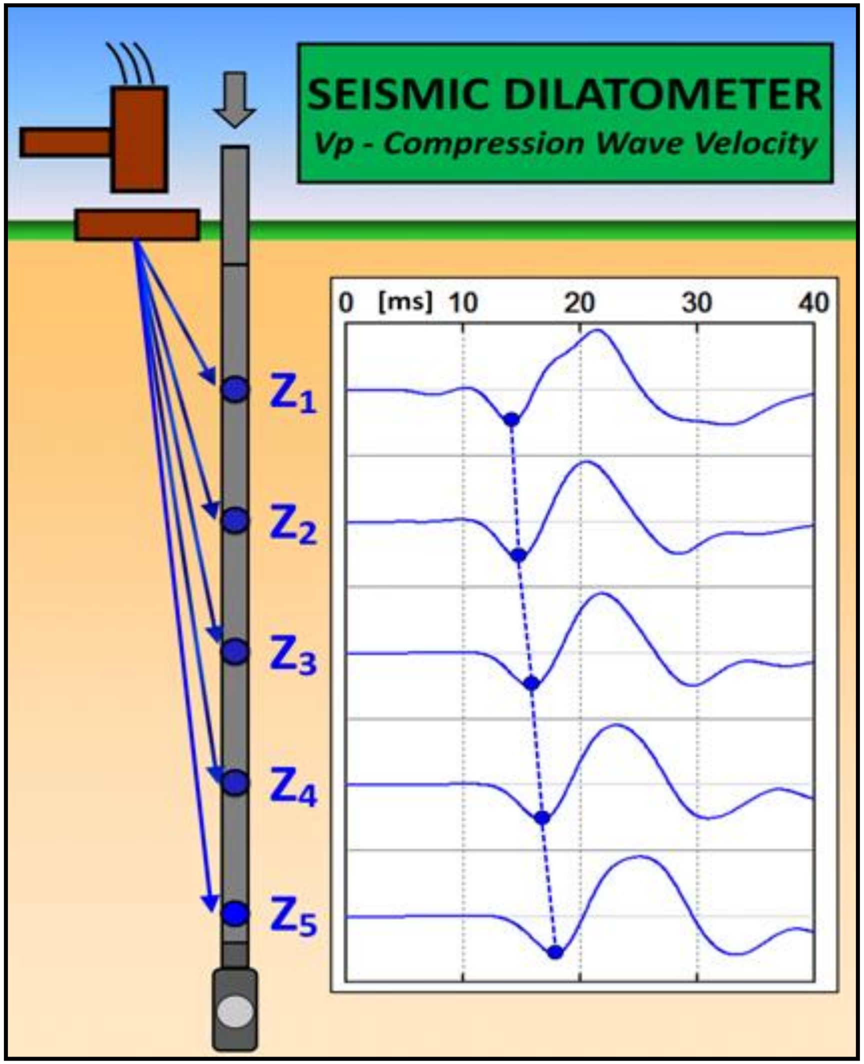
- Vs interpretation
  - Automatic
  - operator independent
  - real time

Accuracy of delay (Δt) calculation

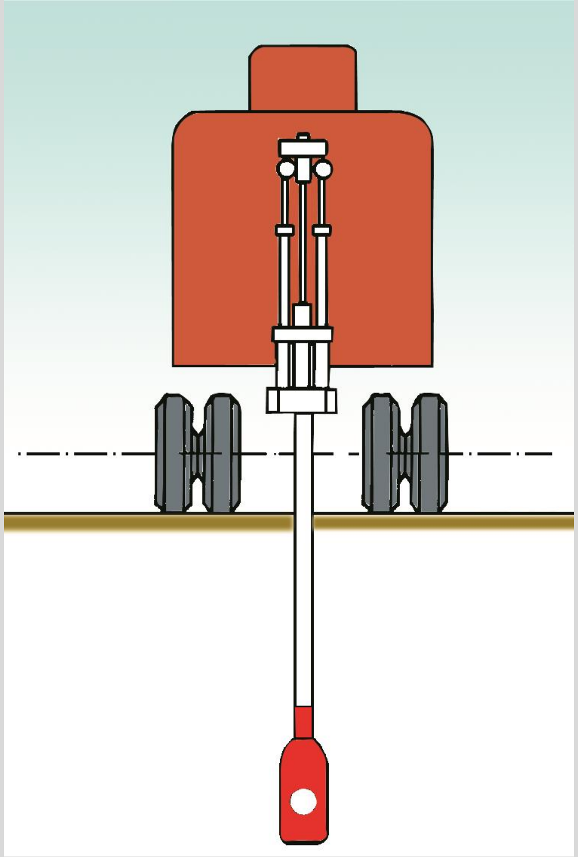
- Signals are amplified and digitized in depth → clean waves → delay Δt very clear
- True-interval (2 receivers) vs Pseudo-interval (1 receiver)
  - Trigger offset <u>no influence</u> on Δt calculation
  - Same wave to both receivers

SPDMT for compression wave velocity



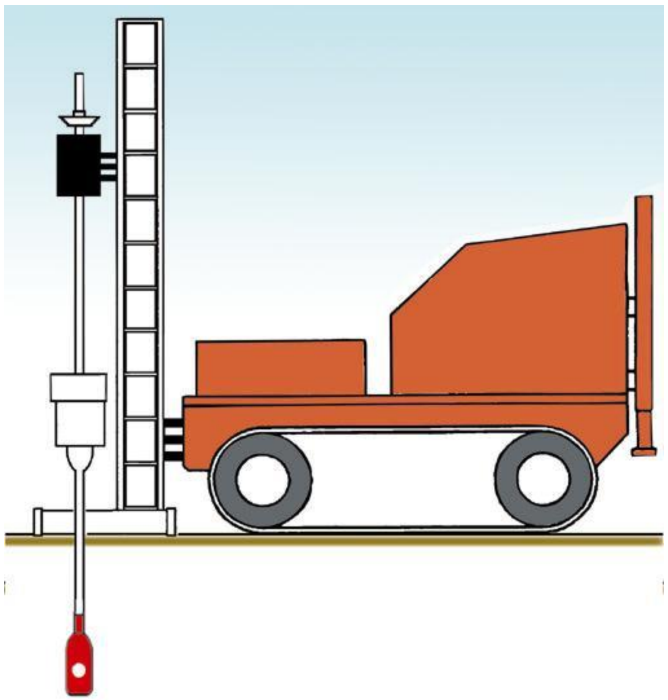


Heavy Truck Penetrometer – most efficient



Able to push 20+ tons without lateral instability

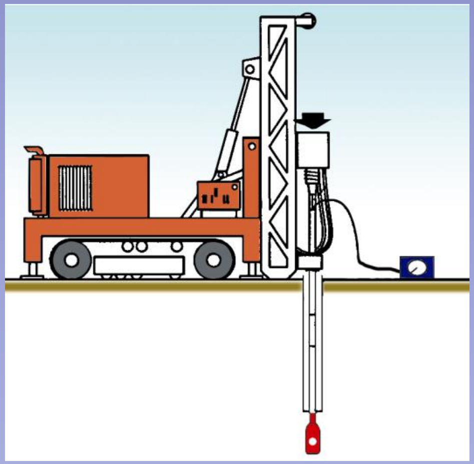
Light Penetrometer – cost effective



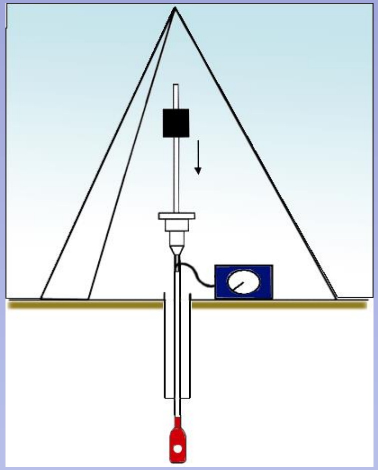
Juan Santamaria Airport , Costarica

Economical and easy to transport, but requires anchoring

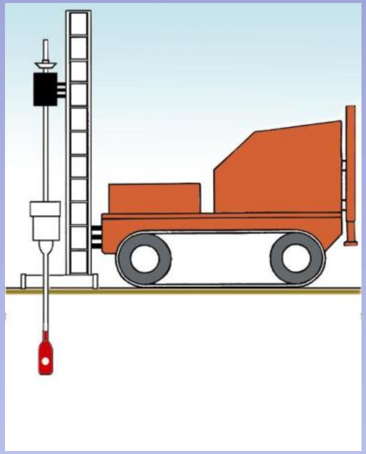
Many ways for advancing the DMT blade



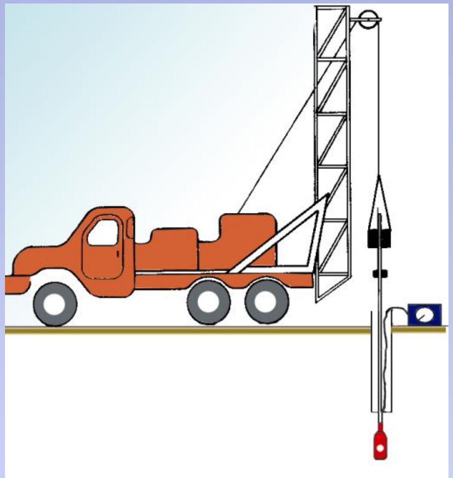
Pushed by drill rig



Driven by Spt tripod



Driven or pushed by light penetrometer



Driven by drill rig

Soils testable by DMT/SDMT

DMT

- ALL SANDS, SILTS, CLAYS
- **Very soft soils (Su = 2-4 kPa, M=0.5 MPa)**
- **Hard soils/Soft Rock (Su = 1 MPa, M=400 MPa)**
- **Blade robust (safe push 25 ton)**

SDMT

- **All penetrable soils (like DMT above)**
- **Also in non penetrable soils like gravel, very dense sand, etc: inside a backfilled borehole (Totani et al 2009)**

Max depth: 135 m in L'Aquila (2009)

Interpretation of the Results

Corrected readings:

to account for membrane rigidity (calibration)

DMT Field Readings

- **A**
- **B**
- **C**

→

Corrected Readings

- P_0: Corrected A reading
- P_1: Corrected B reading
- P_2: Corrected C reading

DMT Intermediate parameters

Corrected Readings

- P_0
- P_1
- P_2

Intermediate Parameters

- I_D: Material Index
- K_D: Horizontal Stress Index
- E_D: Dilatometer Modulus
- U_D: Pore Pressure Index

I_D, K_D, E_D, U_D are definitions, not correlations !!!

Interpreted Geotechnical Parameters

Intermediate Parameters

- I_D
- E_D
- K_D
- U_D

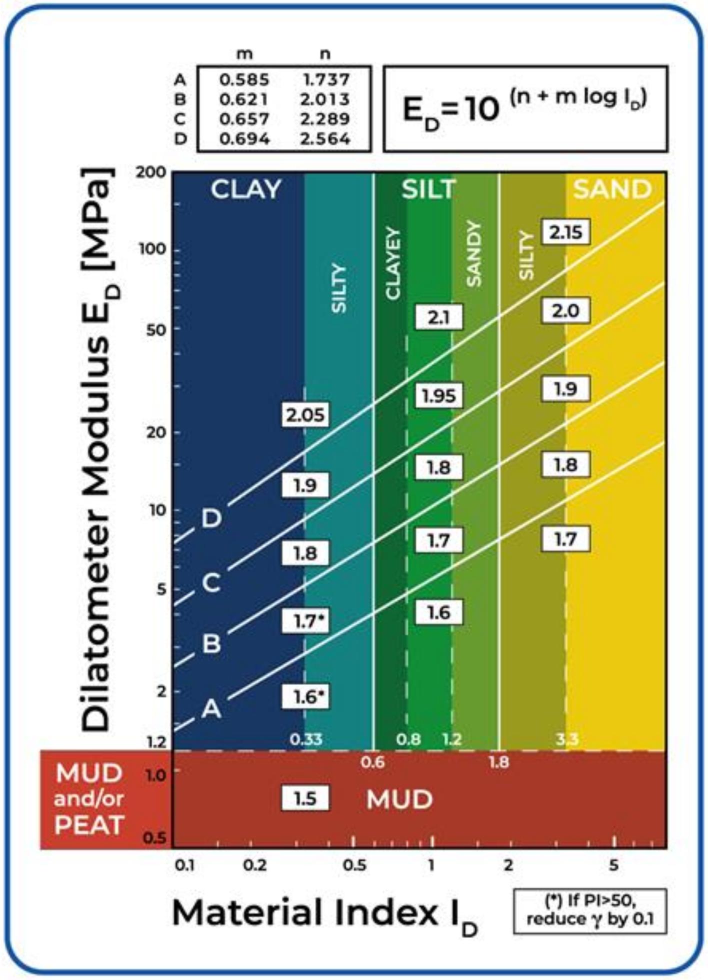
Interpreted Geotechnical Parameters

- M: Constrained Modulus
- Cu: Undrained Shear Strength (clay)
- K_0: Earth Pressure Coeff (clay)
- OCR: Overconsolidation Ratio (clay)
- Φ: Safe floor friction angle (sand)
- γ : Unit weight and description
- U : Pore pressure (sand)
- Drained vs Undrained behaviour

DMT Formulae (1980 - today)

	SYMBOL	PARAMETER NAME	FORMULA /DESCRIPTION	
Field Readings	A	First Reading	Membrane lift-off pressure	
	B	Second Reading	Pressure for 1.1 mm membrane expansion	
	C	Third Reading	Membrane closing pressure	
	ΔA	Membrane Calibration (A in free air)	Suction as positive pressure	
	ΔB	Membrane Calibration (B in free air)	Inflation as positive pressure	
	[T, A]	Dissipation Test Readings	A-readings with time (at specific depth)	
Corrected Readings	P_0	Corrected First Reading	$P_0 = 1.05 (A + \Delta A) - 0.05 (B - \Delta B)$	
	P_1	Corrected Second Reading	$P_1 = B - \Delta B$	
	P_2	Corrected Third Reading	$P_2 = C + \Delta A$	
Intermediate Parameters	I_D	Material Index	$I_D = (P_1 - P_0) / (P_0 - U_0)$	
	K_D	Horizontal Stress Index	$K_D = (P_0 - U_0) / \sigma'_{v0}$	
	E_D	Dilatometer Modulus	$E_D = 34.7 (P_1 - P_0)$	
	U_D	Pore Pressure Index	$U_D = (P_2 - U_0) / (P_0 - U_0)$	
	T_{Flex}	Dissipation Flex Point		
Interpreted Geotechnical Parameters	γ	Unit weight	see unit weight chart	
	K_0	Earth Pressure Coefficient	$K_{0\ DMT} = (K_D / 1.5)^{0.47} - 0.6$	$I_D \le 1.2$
	OCR	Overconsolidation Ratio	$OCR_{DMT} = (0.5\ K_D)^{1.56}$	$I_D \le 1.2$
	Su	Undrained Shear Strength	$Su_{DMT} = 0.22\ \sigma'_{v0}\ (0.5\ K_D)^{1.25}$	$I_D \le 1.2$
	Φ	Friction Angle	$\Phi_{safe\ DMT} = 28 + 14.6 \log K_D - 2.1 \log^2 K_D$	$I_D > 1.8$
	M	Vertical Drained Constrained Modulus	$M_{DMT} = R_M\ E_D$	
			If $(I_D \le 0.6)$ $R_M = 0.14 + 2.36 \log K_D$	
			If $(I_D \ge 3)$ $R_M = 0.5 + 2 \log K_D$	
			If $(0.6 < I_D < 3)$ $R_M = R_{M0} + (2.5 - R_{M0}) \log K_D$	
			$R_{M0} = 0.14 + 0.15 (I_D + 0.6)$	
			If $(K_D > 10)$ $R_M = 0.32 + 2.18 \log K_D$	
			If $(R_M < 0.85)$ set $R_M = 0.85$	
	C_h	Coefficient of Consolidation	$C_{h\ DMT} = 7\ cm^2 / T_{Flex}$	
	K_h	Coefficient of Permeability	$K_{h\ DMT} = C_{h\ DMT}\ \gamma_w / M_h \quad (M_h \approx K_{0\ DMT}\ M_{DMT})$	
	U_0	Equilibrium Pore Pressure	$U_0 \approx P_2$ for drained layers only	

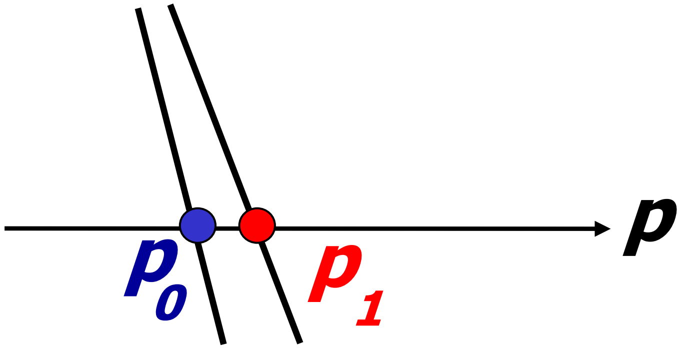
SBT chart and (γ / γ_w)



The Flat Dilatometer Test (DMT) in Soil Investigations (2001) – A Report by the ISSMGE Committee TC16. Proceedings, Int. Conf. on In-Situ Measurement of Soil Properties and Case Histories, 95–131. Parahyangan Catholic University, Bandung, Indonesia.

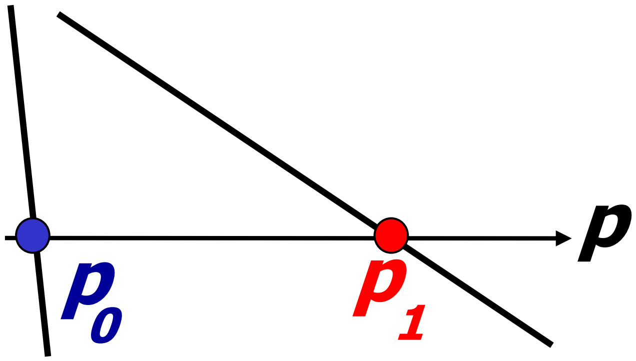
I_D contains information on soil type

CLAY



$$\frac{P_1}{P_0} \approx 1.1\text{-}1.3$$

SAND



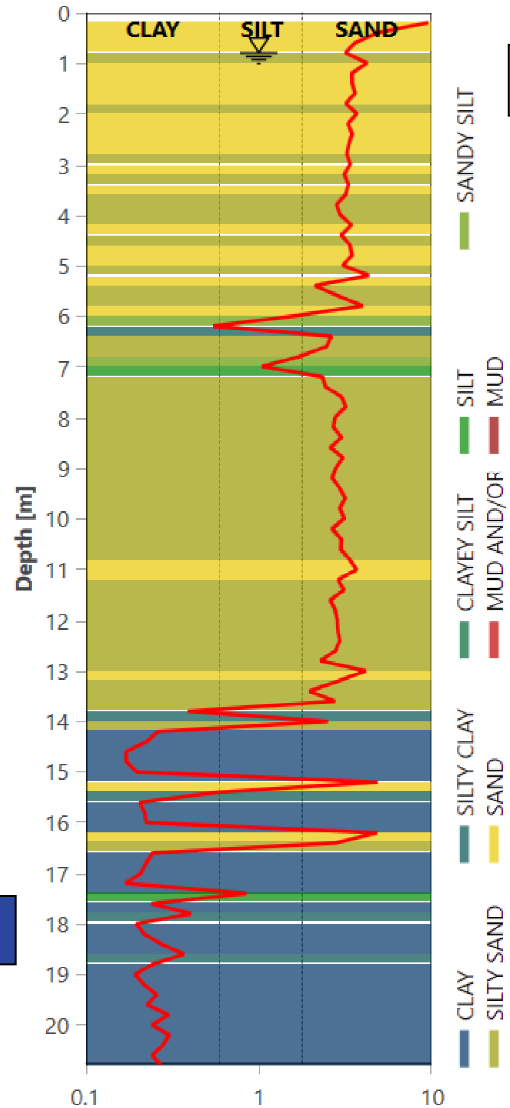
$$\frac{P_1}{P_0} \geq 2.5$$

SILT falls in between

Definition: $I_D = \dfrac{(P_1 - P_0)}{(P_0 - U_0)}$

I_D contains information on soil type

Material Index



SAND

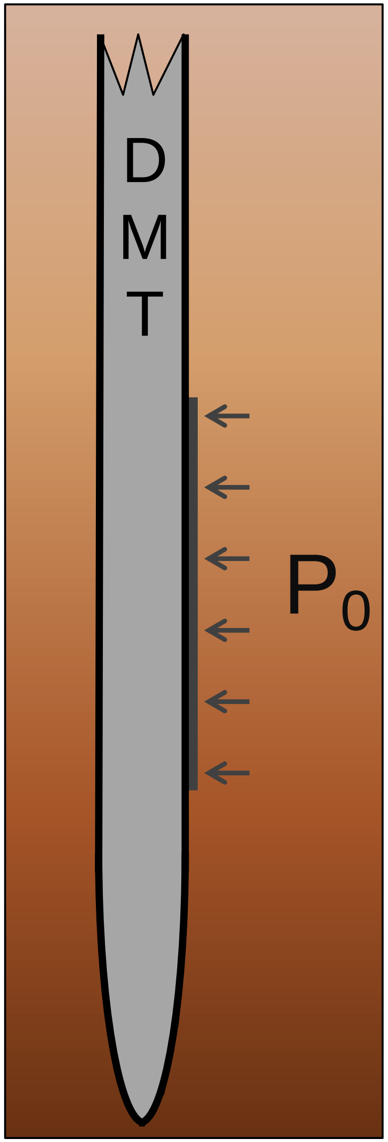
Z [m]	P_0 [bar]	P_1 [bar]
…	…	…
2.0	2.61	11.90
2.2	2.78	11.55
2.4	2.68	11.53
2.6	2.64	10.90
2.8	3.06	12.40
3.0	3.08	12.90
…	…	…

CLAY

Z [m]	P_0 [bar]	P_1 [bar]
…	…	…
19.0	5.86	6.65
19.2	5.91	6.80
19.4	5.90	6.95
19.6	6.01	6.95
19.8	6.04	7.30
20.0	6.00	7.02
…	…	…

Fiumicino 2005

K_D contains information on stress history



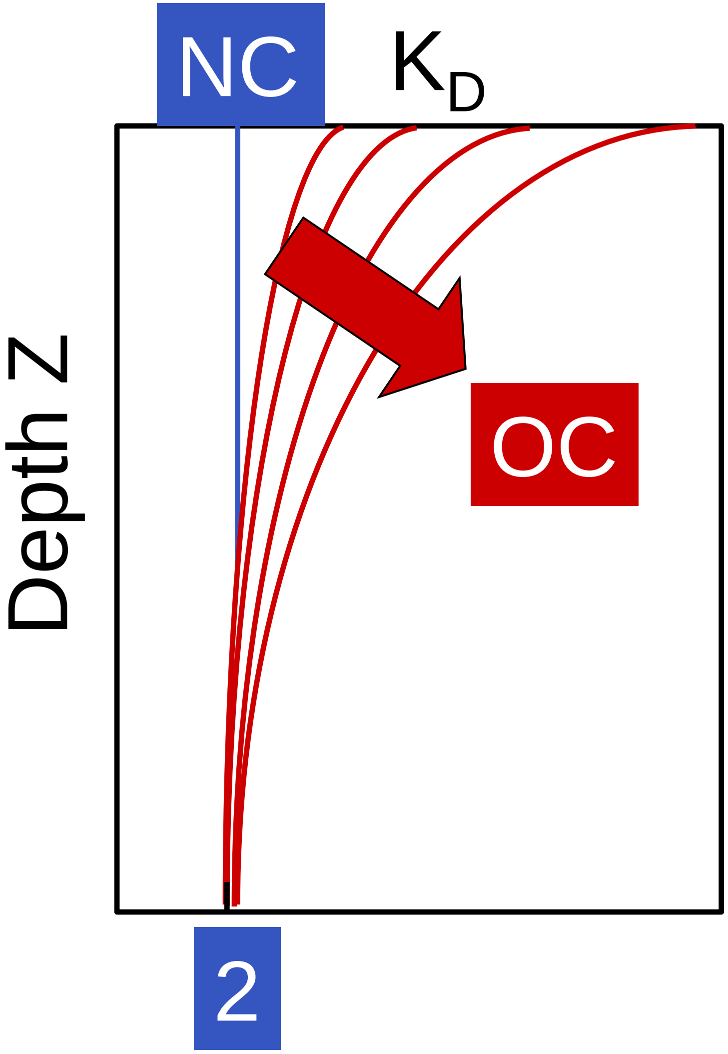
$$K_D = \frac{(P_0 - U_0)}{\sigma'_v}$$

same formula as K_0: $(P_0 – U_0) \rightarrow \sigma'_h$

K_D is an '*amplified*' K_0, because $(P_0 - U_0)$ is an '*amplified*' σ'_h, due to penetration

K_D well correlated to K_0 & OCR (clay)

K_D contains information on stress history



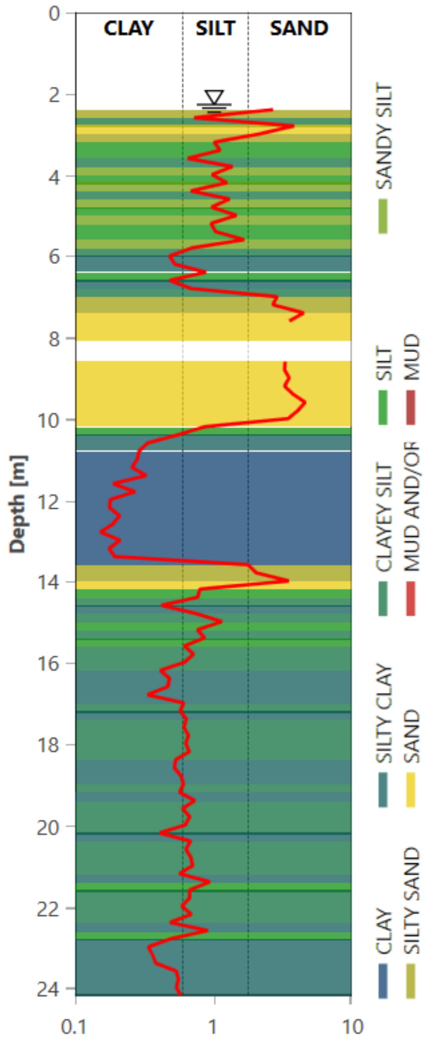
$K_D = 2$ in NC clay (OCR = 1)

KD > 2 in OC clay (OCR > 1)

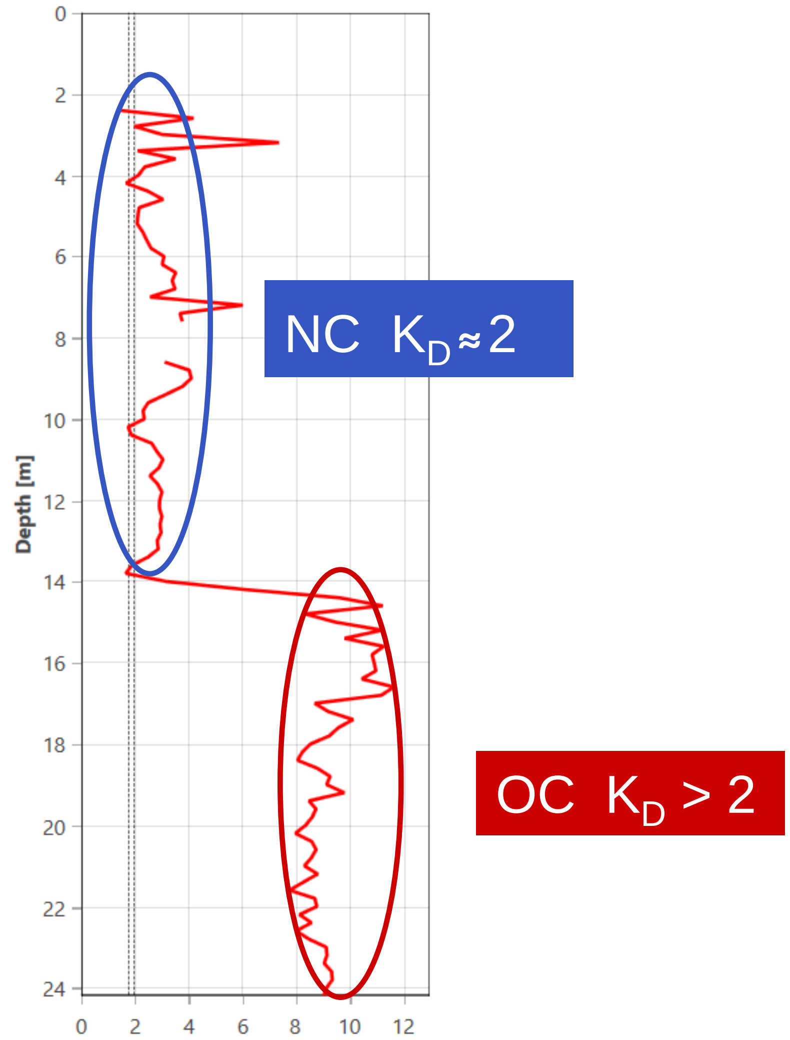
K_D stress history index

K_D contains information on stress history

Material Index



Horizontal Stress Index



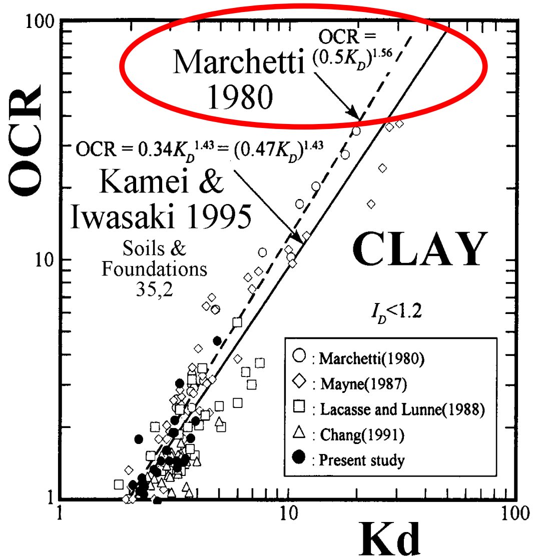
Taranto 1987

CLAY: K_D correlated to OCR

$$OCR = \left(0.5 \cdot K_D\right)^{1.56}$$ Marchetti 1980 (experimental)

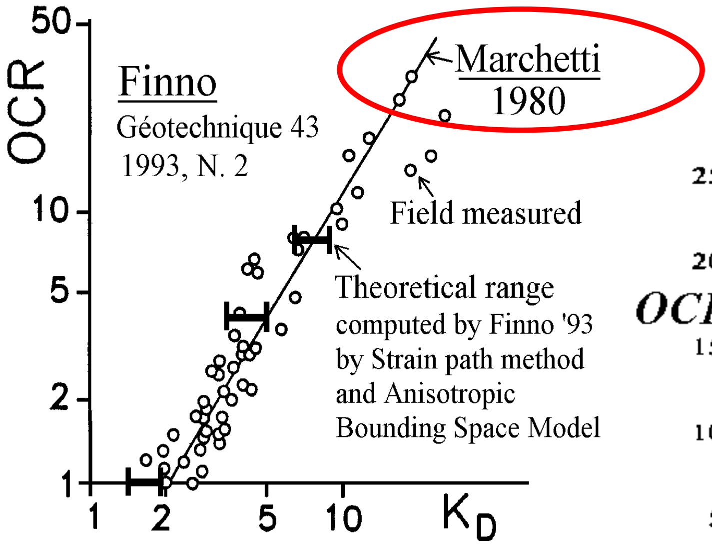
Experimental

Kamei & Iwasaki 1995



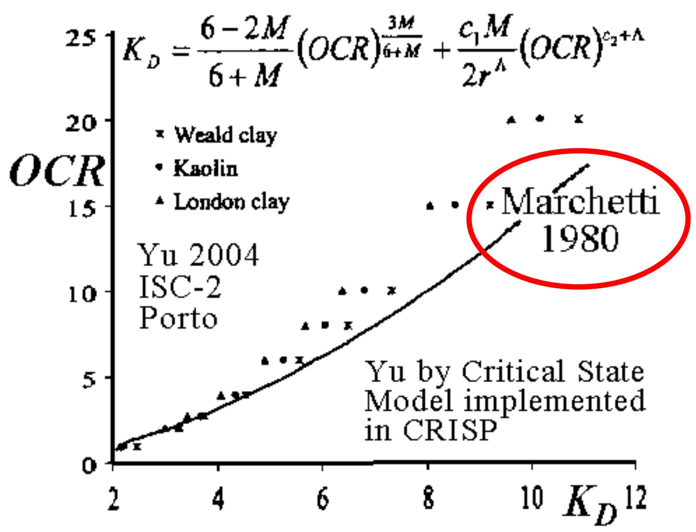
Theoretical

Finno 1993



Theoretical

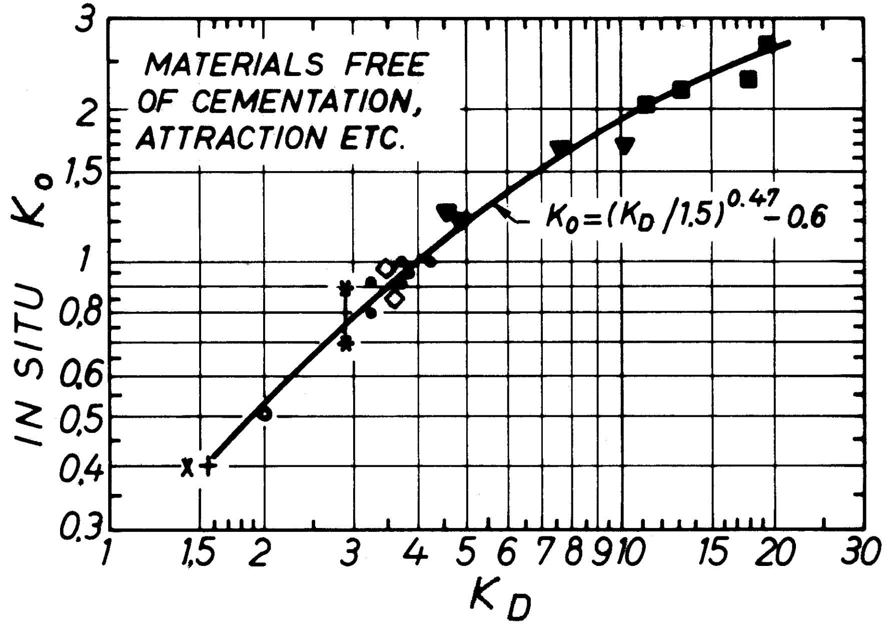
Yu 2004



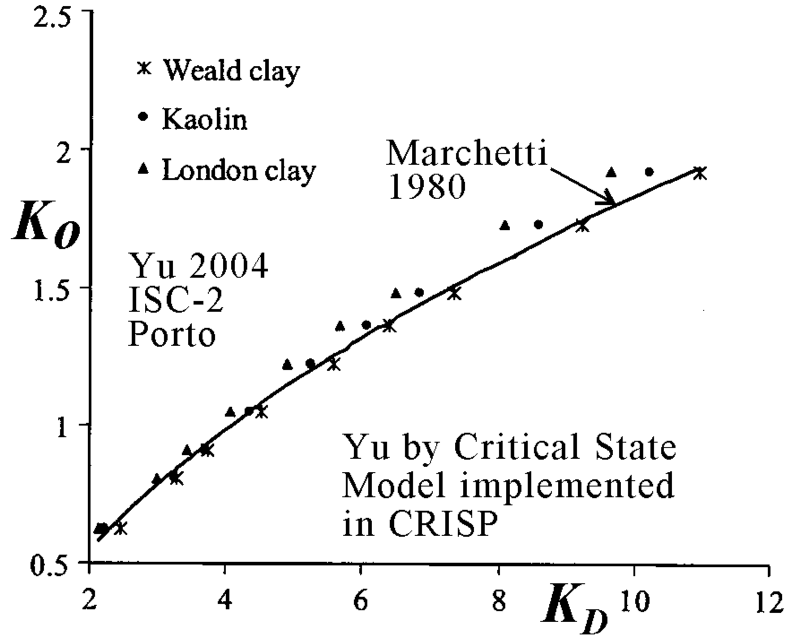
CLAY: K_D correlated to K_0

$$K_0 = \left(\frac{K_D}{1.5}\right)^{0.47} - 0.6$$ Marchetti 1980 (experimental)

Experimental
Marchetti (1980)

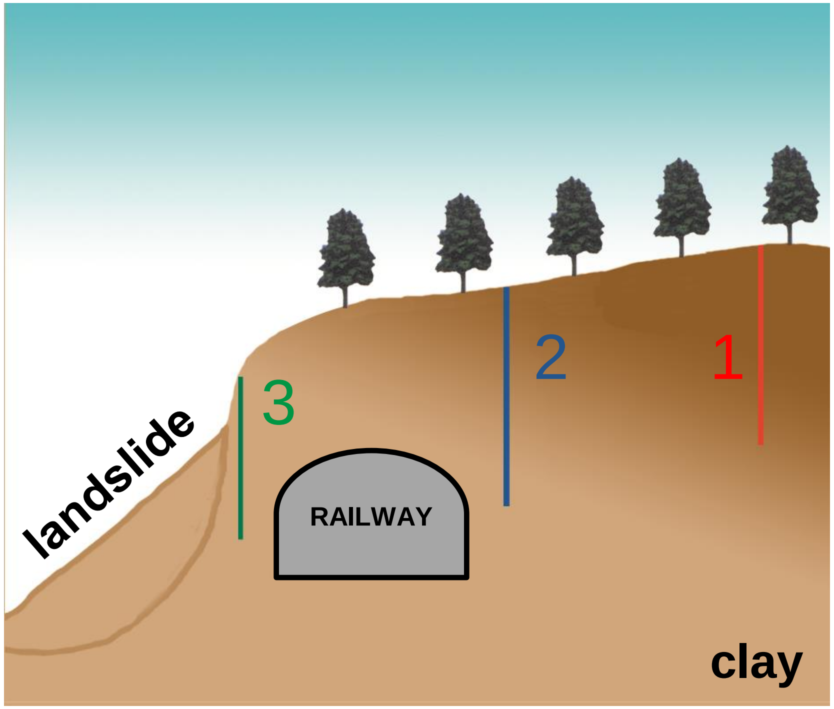


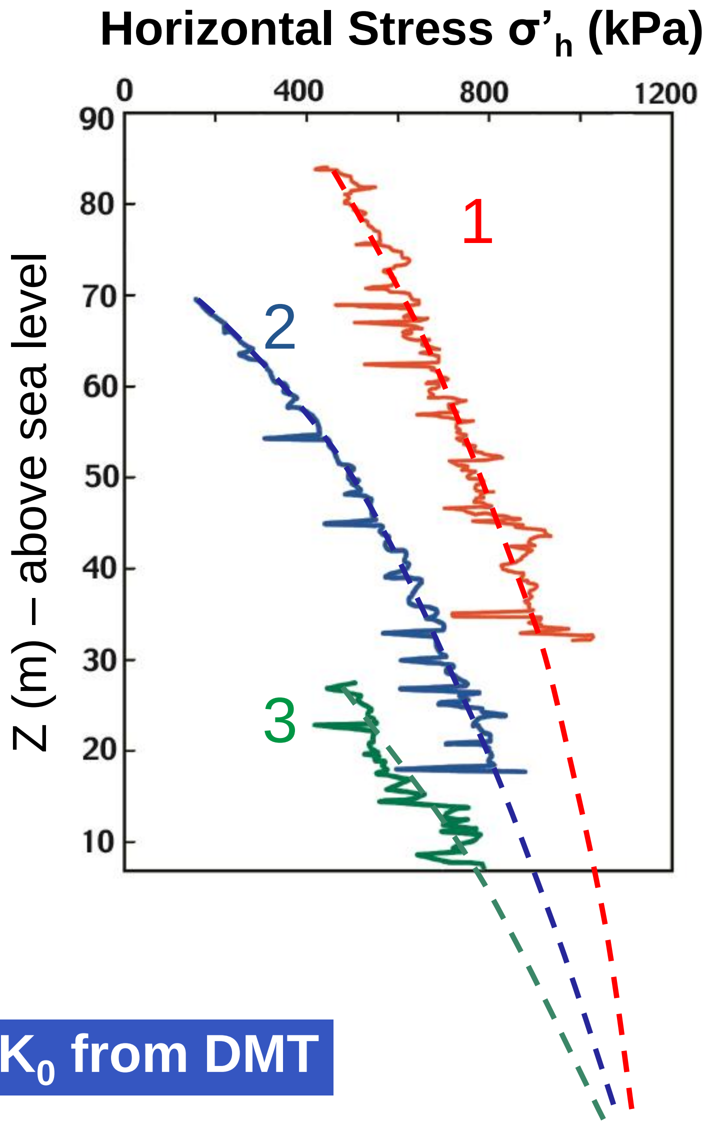
Theoretical
2004 Yu



Example: σ'$_h$ relaxation behind a landslide (K_0)

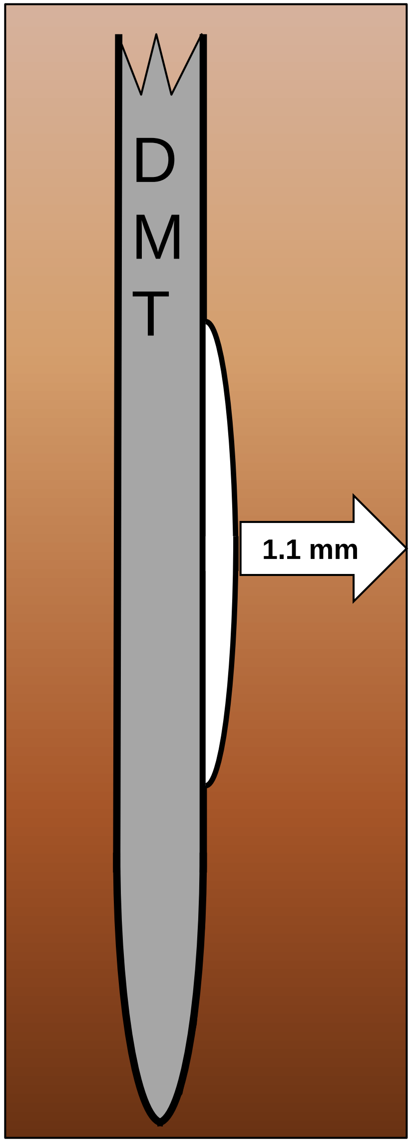
Case History (2002):
Landslide in Milazzo, Sicily





σ'$_h$ obtained using K_0 from DMT

E_D contains information on deformation



Theory of elasticity:

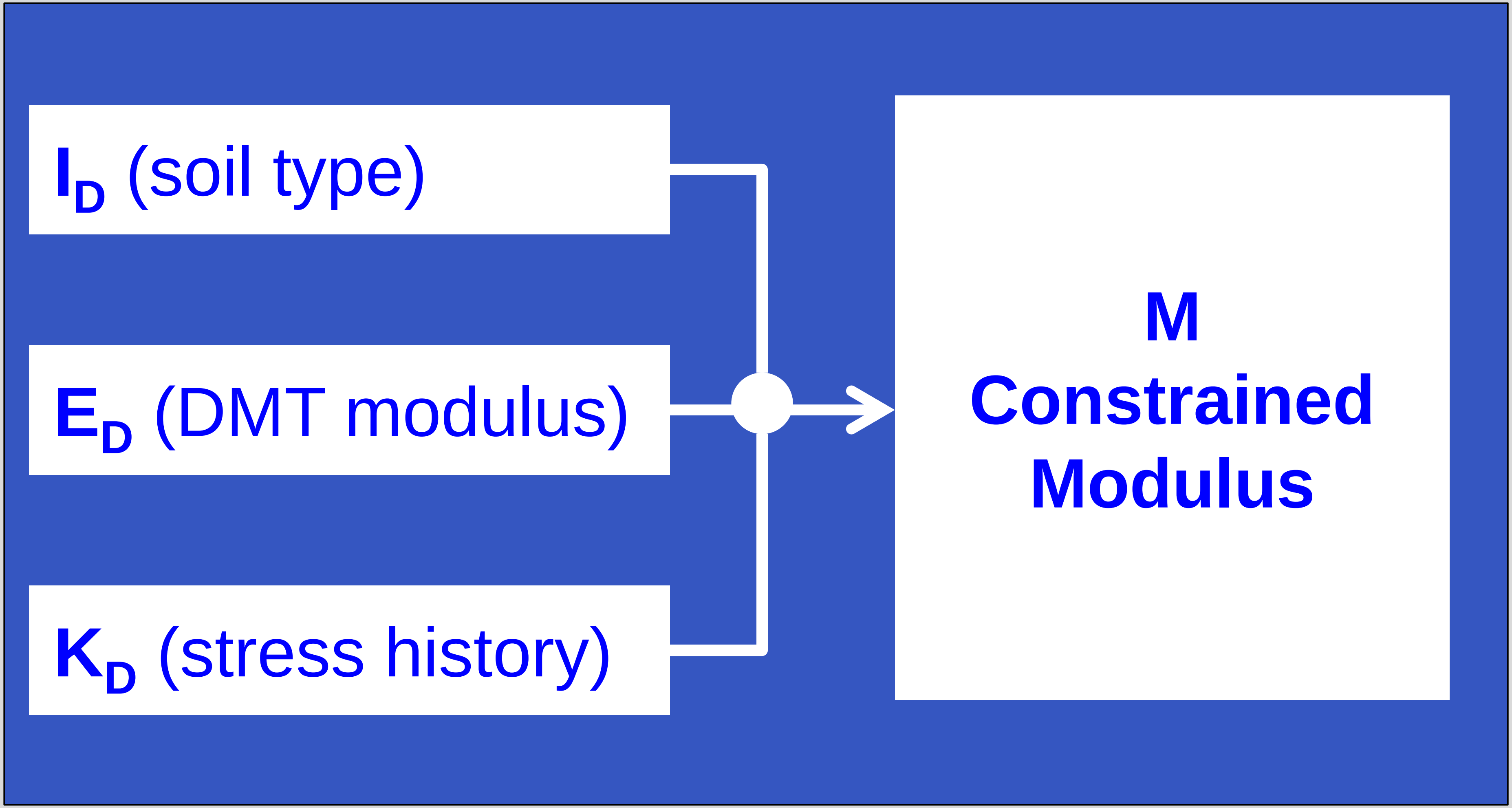
E_D = elastic modulus of the horizontal load test performed by the DMT membrane (D = 60mm, 1.1 mm expansion)

$$E_D = 34.7 \cdot (P_1 - P_0)$$

Gravesen S. "Elastic Semi-Infinite Medium bounded by a Rigid Wall with a Circular Hole", Danmarks Tekniske Højskole, No. 11, Copenhagen, 1960, p. 110.

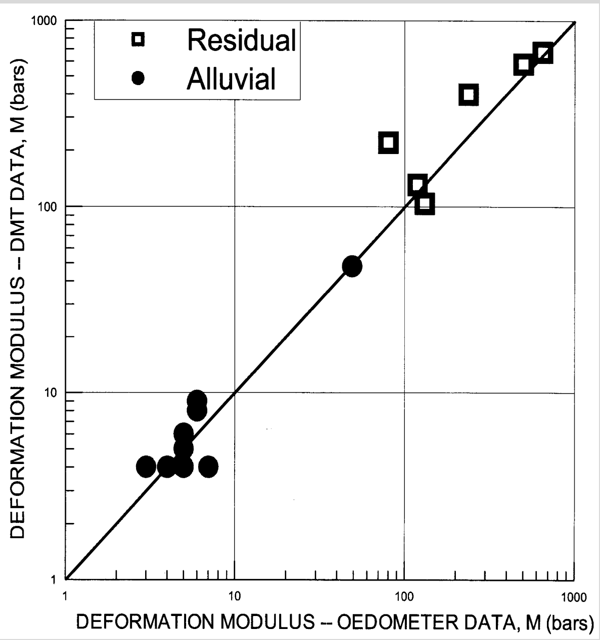
E_D not directly usable → corrections (penetration,etc)

M obtained from E_D using information on soil type I_D and stress history K_D



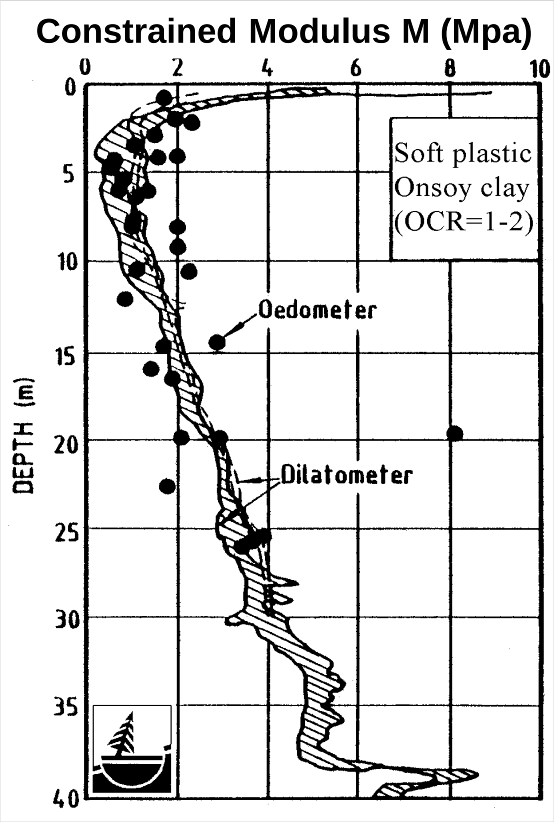
M Comparison from DMT and from Oedometer

Virginia - U.S.A.



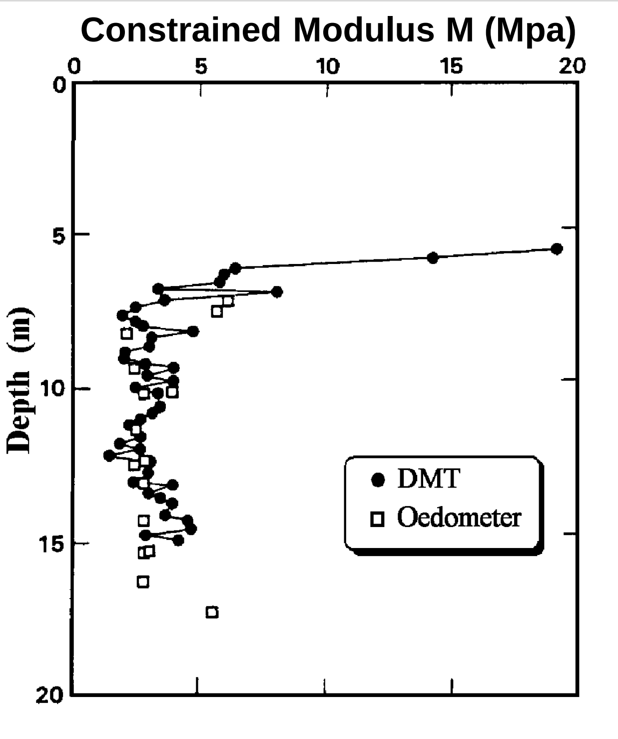
Failmezger, 1999

ONSOY Clay - NORWAY



Norwegian Geotechnical Institute (1986). "In Situ Site Investigation Techniques and interpretation for offshore practice". Report 40019-28 by S. Lacasse, Fig. 16a, 8 Sept 86

Tokyo Bay Clay - JAPAN



Iwasaki K, Tsuchiya H., Sakai Y., Yamamoto Y. (1991) "Applicability of the Marchetti Dilatometer Test to Soft Ground in Japan", GEOCOAST '91, Sept. 1991, Yokohama 1/6

Su in clay (Ladd 1977 Tokyo)

Ladd: *best Su measurement not from TRX UU !!*

best Su: oedometer → OCR → SHANSEP

$$\left(\frac{Su}{\sigma'_v}\right)_{OC} = \left(\frac{Su}{\sigma'_v}\right)_{NC} \cdot OCR^{m}$$

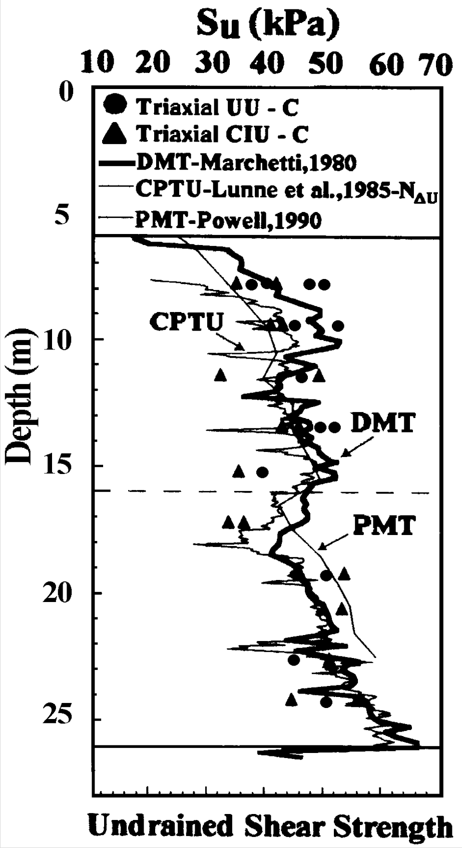
$$OCR = \left(0.5 \cdot K_D\right)^{1.56}$$

Using m ≈ 0.8 (Ladd 1977) and $(Su/\sigma'_v)_{NC} \approx 0.22$ (Mesri 1975)

$$Su = 0.22\,\sigma'_v \left(0.5 \cdot K_D\right)^{1.25}$$

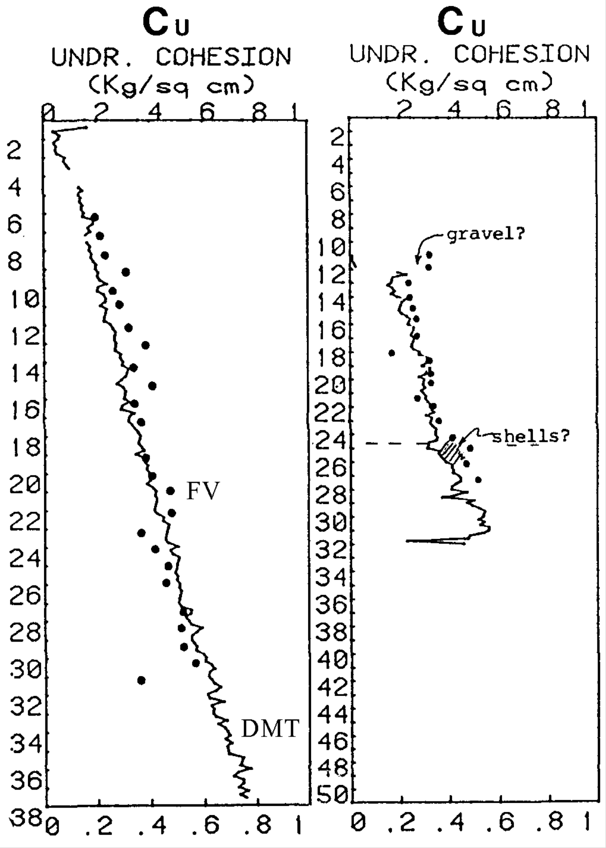
Su comparisons from DMT and from other tests

Recife - Brazil



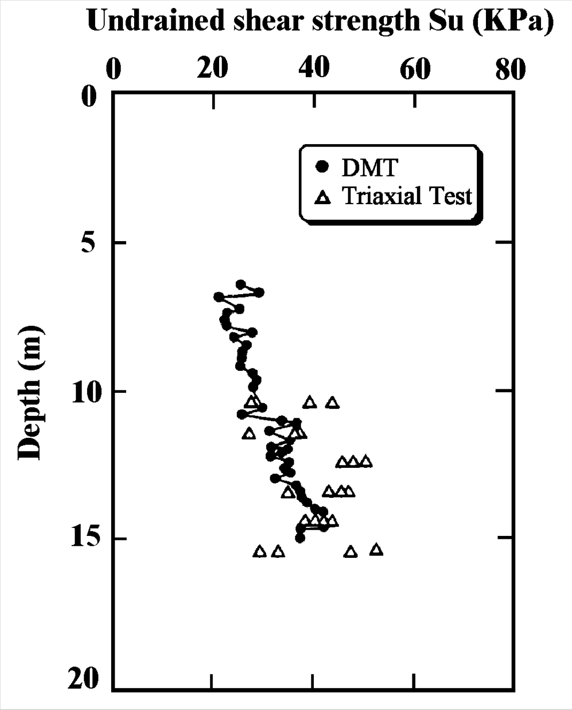
Coutinho et al., Atlanta ISC'98

Skeena Ontario – Canada



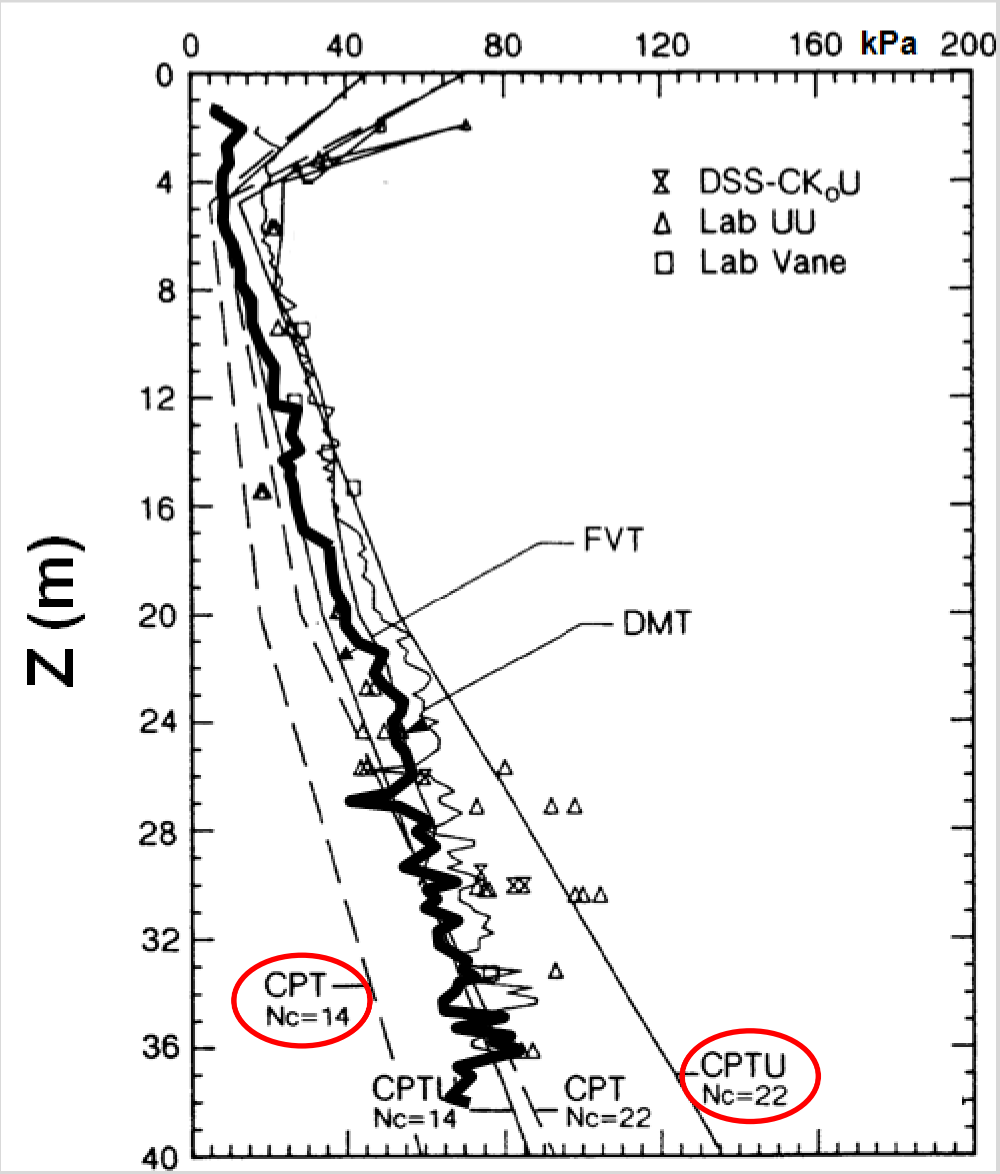
Mekechuk J. (1983). "DMT Use on C.N. Rail Line British Columbia",
First Int.Conf. on the Flat Dilatometer, Edmonton, Canada, Feb 83, 50

Tokyo Bay Clay - Japan



Iwasaki K, Tsuchiya H., Sakai Y., Yamamoto Y. (1991) "Applicability of the Marchetti Dilatometer Test to Soft Ground in Japan", GEOCOAST '91, Sept. 1991, Yokohama 1/6

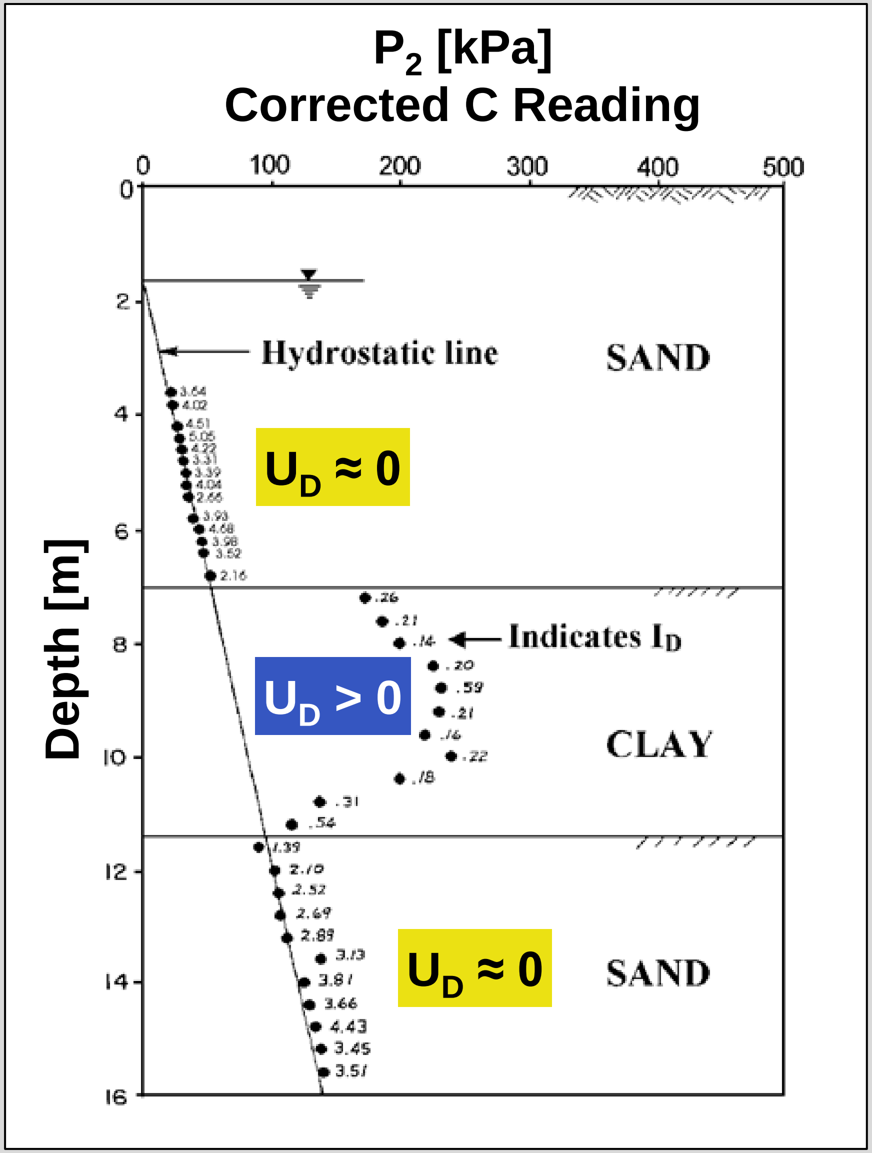
Su at National Site FUCINO – ITALY



CPT: different profiles according to Nc (=14-22)

A.G.I., 10th ECSMFE Firenze 1991
Vol. 1, p. 37

Pore water pressure: C Readings (P_2)



Schmertmann 1988 (DMT Digest No. 10, May 1988, Fig. 3)

SAND: $P_2 \approx U_0$
drainage (≈ piezometer)

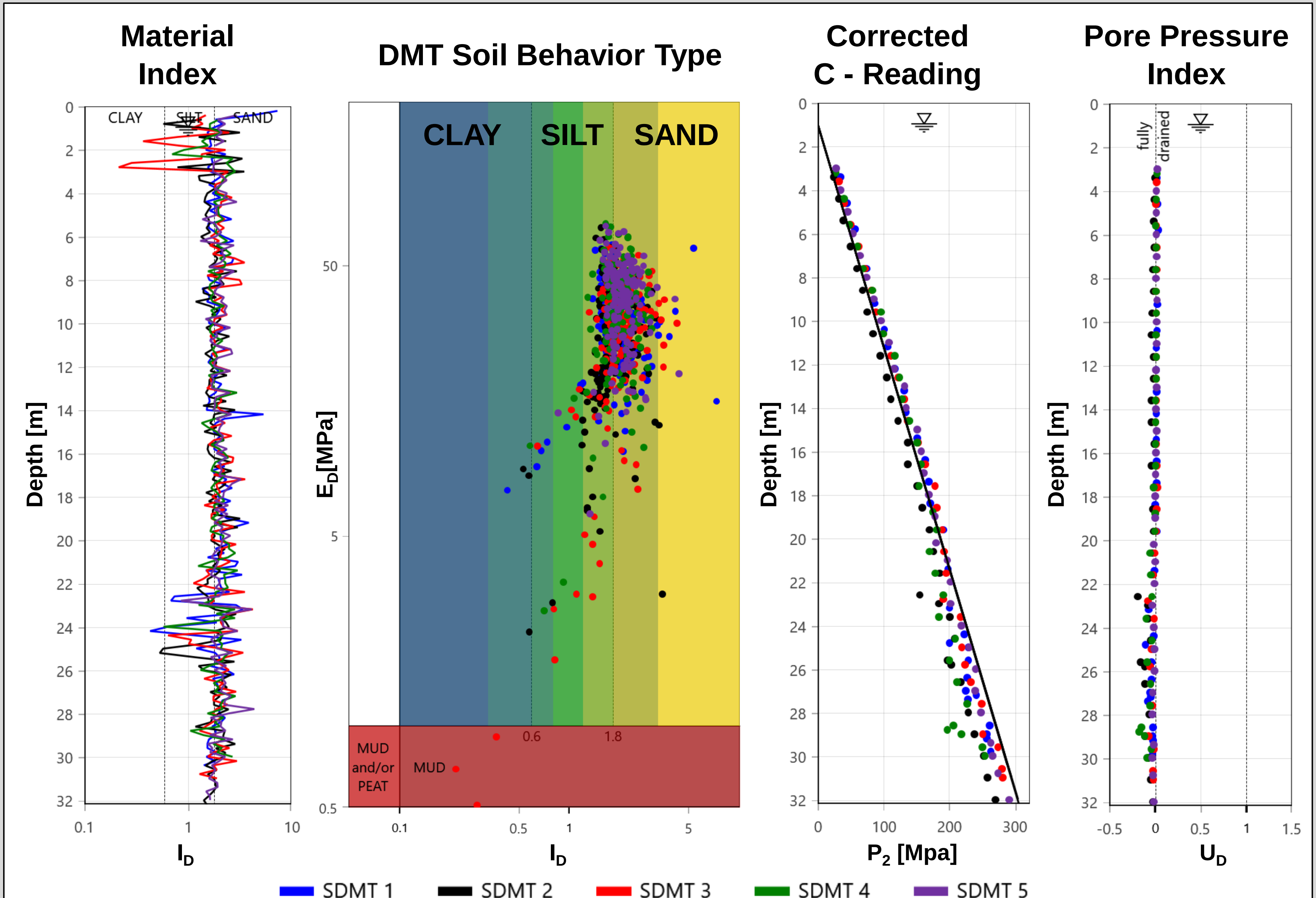
CLAY: $P_2 > U_0$
no drainage (≈ highlights Δu)

Definition: $U_D = \dfrac{(P_2 - U_0)}{(P_0 - U_0)}$

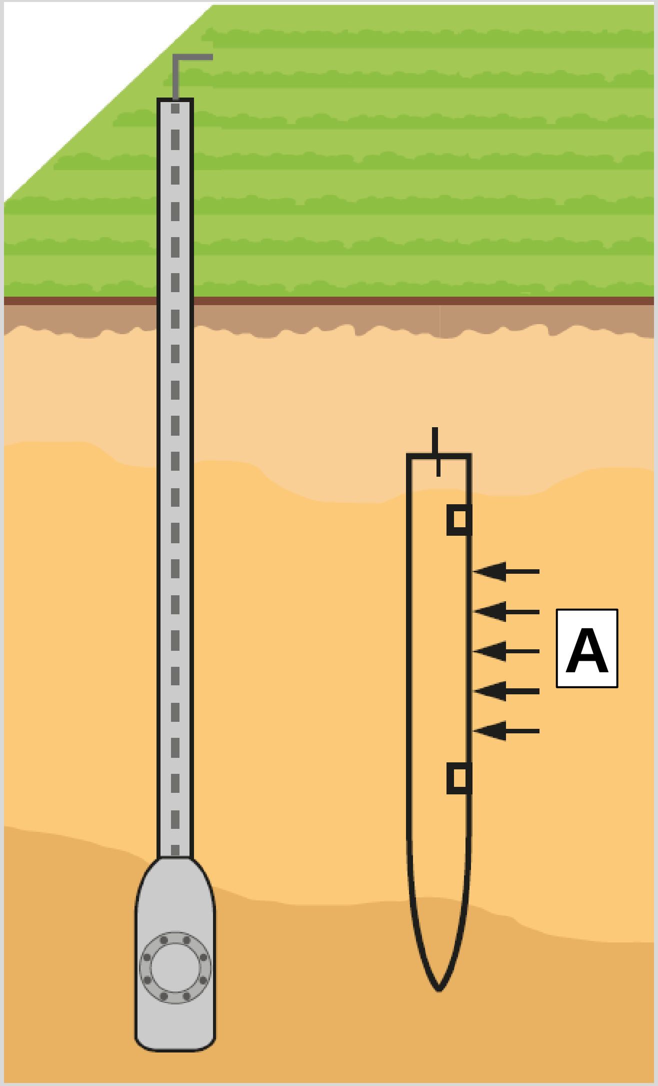
EXAMPLE OF SDMT TESTS IN SAND

Catania Harbour - 2012

SDMT TESTS IN SAND (Catania 2012)



DMT Dissipation Test



Test procedure:

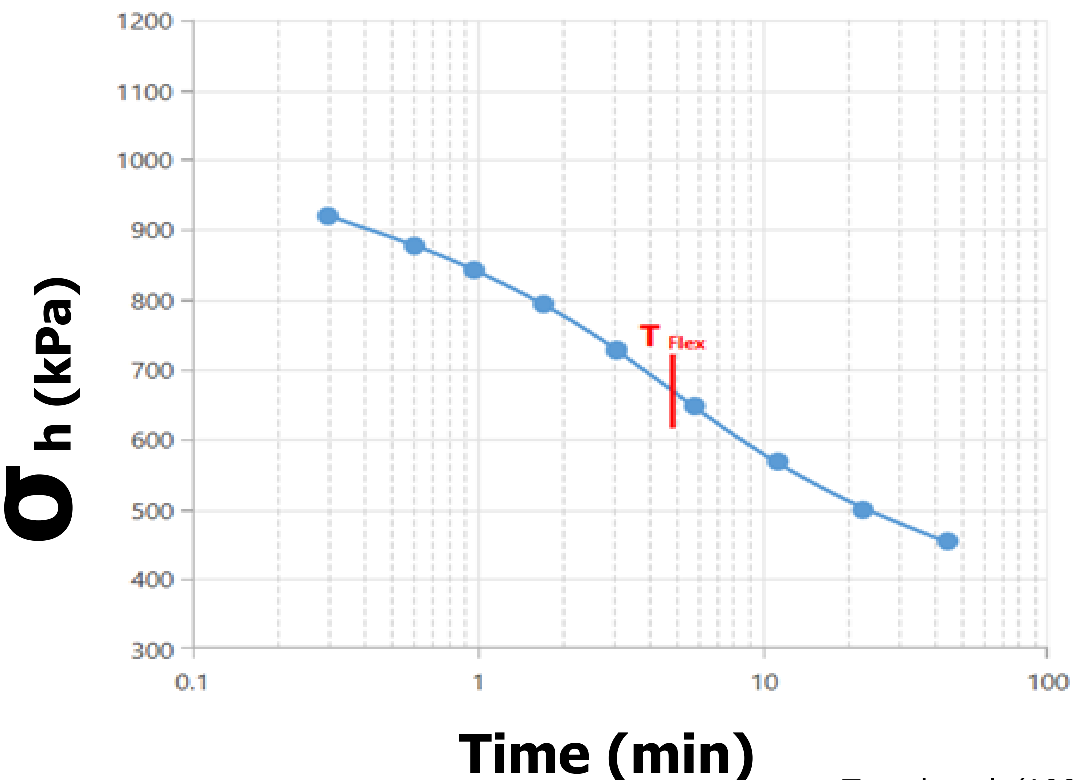
- *Stop penetration (origin T = 0 s)*
- *Repeat only A readings (deflate)*

NO MEMBRANE EXPANSION

T [min]	A [kPa]
0.280	1,040
0.600	966
0.870	921
1.350	868
2.430	776
4.600	674

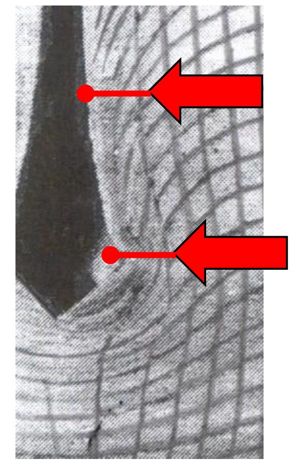
Dissipation test in cohesive soils
estimate *coefficient consolidation & permeability*

$$C_h \cong \frac{7\ cm^2}{T_{flex}} \qquad k_h = \frac{C \times \gamma_w}{M}$$

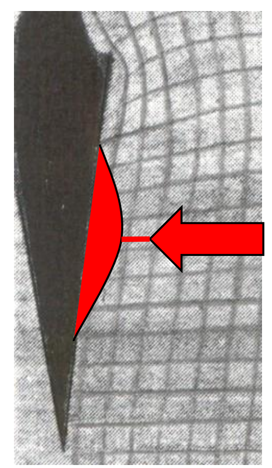


Totani et al. (1998)

wedge vs cone (dissipation)



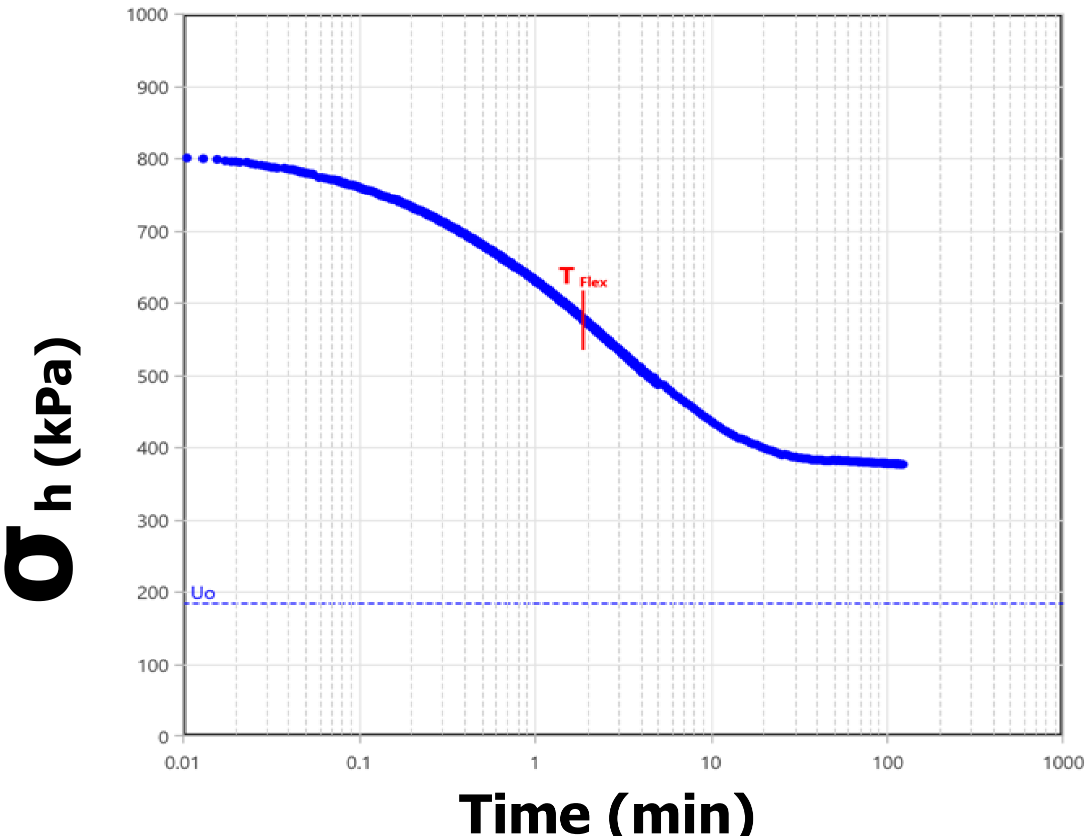
cone
From u(t) in a singular highly disturbed point



wedge
From a ≈ mini embankment
Larger volume in a less disturbed zone

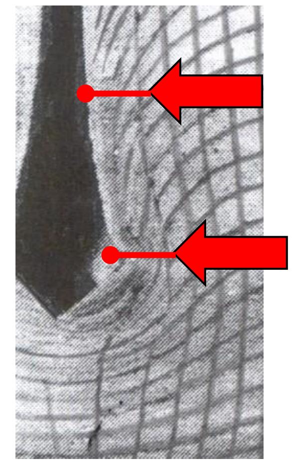
Dissipation test in cohesive soils
estimate *coefficient consolidation & permeability*

$$C_h \cong \frac{7\ cm^2}{T_{flex}} \qquad k_h = \frac{C \times \gamma_w}{M}$$

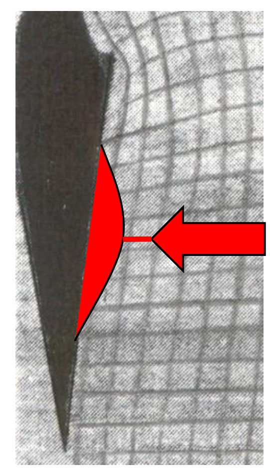


Totani et al. (1998)

wedge vs cone (dissipation)



cone
From u(t) in a singular highly disturbed point



wedge
From a ≈ mini embankment
Larger volume in a less disturbed zone

International Standards

***EUROCODE 7* (2007).** Standard Test Method, European Committee for Standardization, Part 3: Design Assisted by Field Testing, Section 9: Flat Dilatometer Test (DMT), 9 pp.

***ISO* (2017).** ISO/TS 22476-11, Geotechnical investigation and testing - Field testing Part 11: The Flat Dilatometer Test, 9 pp

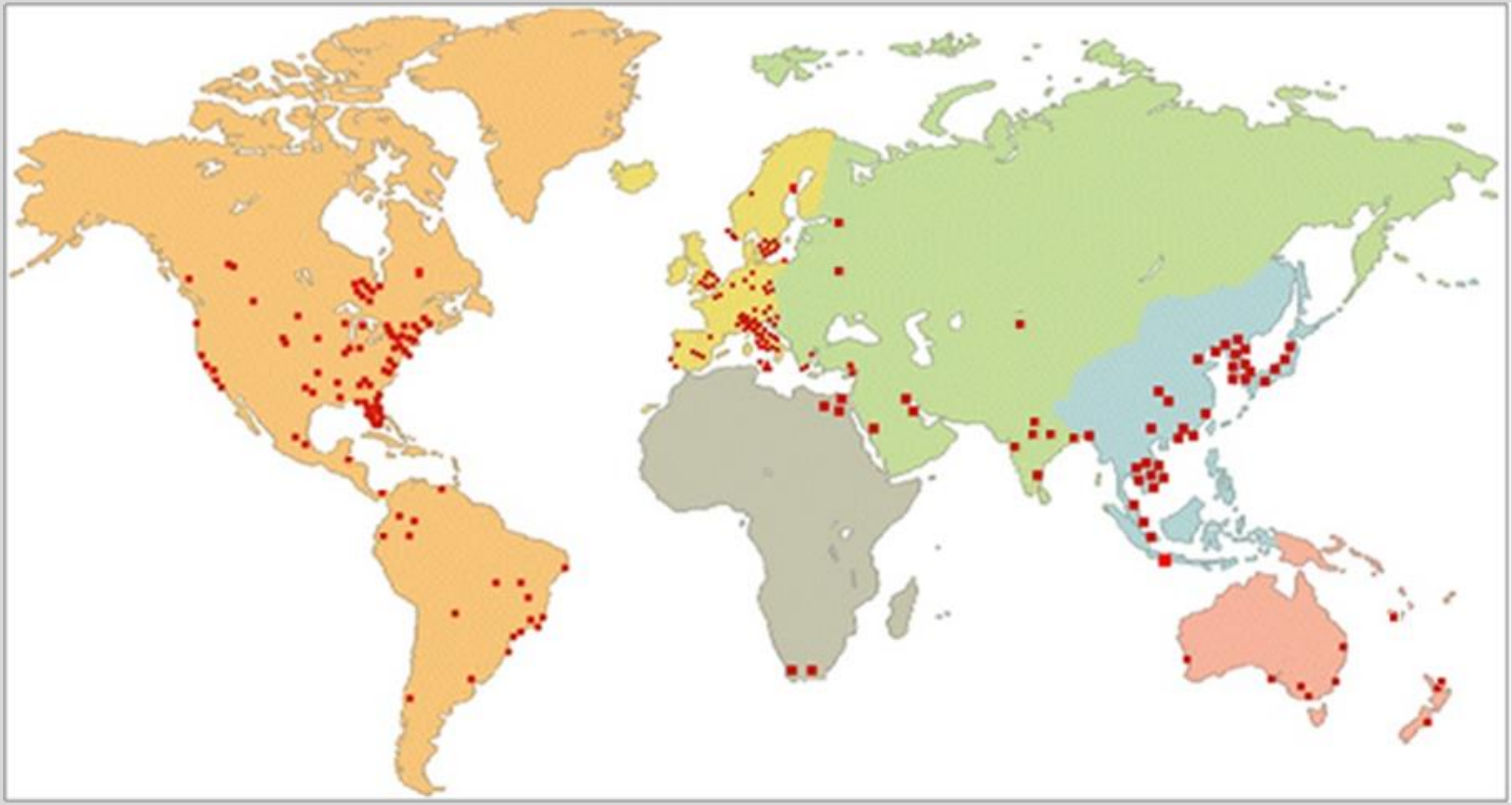
***ASTM (2016)*.** Standard Test Method D6635-15, American Society for Testing and Materials. Standard test method for performing the Flat Dilatometer Test (DMT), 14 pp.

***TC16 / TC102 (2001)*.** "The DMT in soil Investigations", ISSMGE Technical Committee on Ground Property, Characterization from in-situ testing, 41 pp.

NATIONAL STANDARDS:

- **Italy: Consiglio Superiore Lavori Pubblici (2009), Protezione Civile (2008)**
- **Sweden: Swedish Geotechnical Society SGF report (1994)**
- **France: ISO/TS 22476-11:2005(F)**
- **China: TB10018 (2003), GB50021 (2003), DGJ08-37 (2012)**
- **..**

SDMT used in over 80 countries (°)



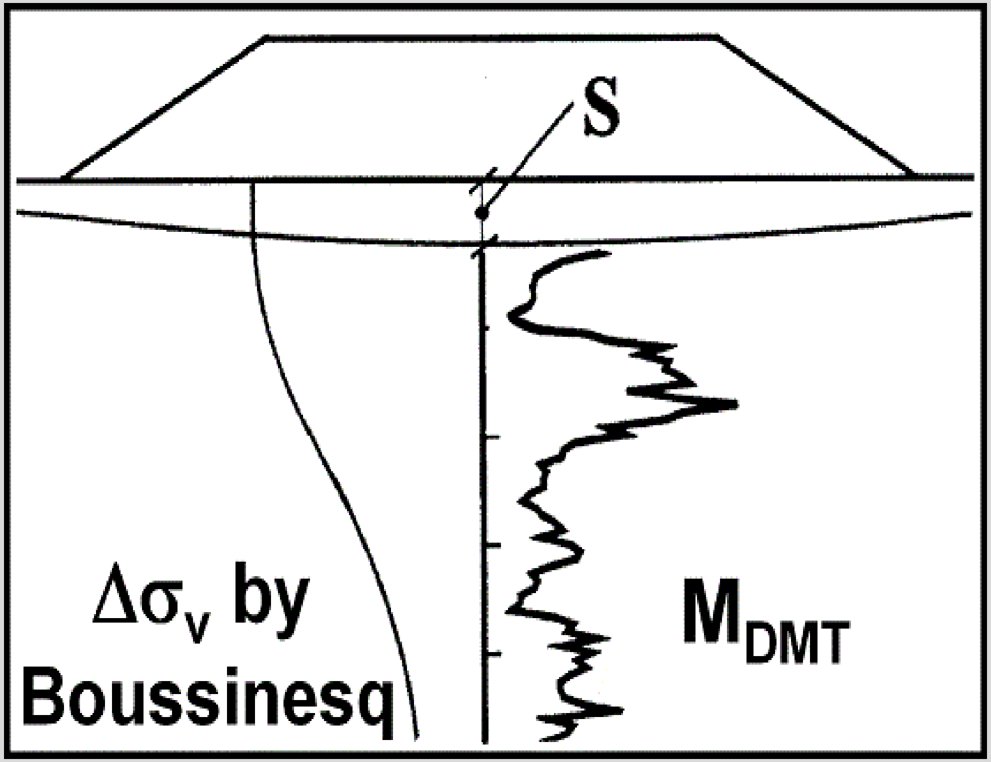
(°) Algeria, Angola, Argentina, Australia, Austria, Bahrain, Bangladesh, Belgium, Bolivia, Bosnia, Brazil, Bulgaria, Canada, Czech Republic, China, Chile, Cyprus, Colombia, Costa Rica, Croatia, Denmark, Ecuador, Egypt, United Arab Emirates, Estonia, Finland, France, Germany, Greece, Guadalupe, Guatemala, Honduras, Hong Kong, Hungary, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Kazhakstan, Korea, Kosovo, Kuwait, Lithuania, Malaysia, Mauritius, Mexico, Myanmar, Netherland, New Zealand, Norway, Oman, Panama, Peru, Paraguay, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Serbia, Singapore, Slovenia, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Taiwan, Thailand, Tunisia, Turkey, United Kingdom, United States of America, Venezuela, Vietnam.

Main SDMT applications

- **Settlements of shallow foundations**
- **In situ G-γ decay curves**
- **QA of soil improvement**
- **Slip surface detection in OC clay**
- Liquefaction resistance (CRR)
- Laterally loaded piles (P-y curves)
- Diaphragm walls (springs model)
- FEM input parameters (es. Plaxis)
- Vs for soil sample quality assessment

Settlements Prediction (Modulus)

SETTLEMENTS PREDICTION



LOAD → Boussinesq → $\Delta\sigma_v$

SOIL → DMT → M

$$S = \sum \frac{\Delta\sigma_v}{M} \Delta z$$

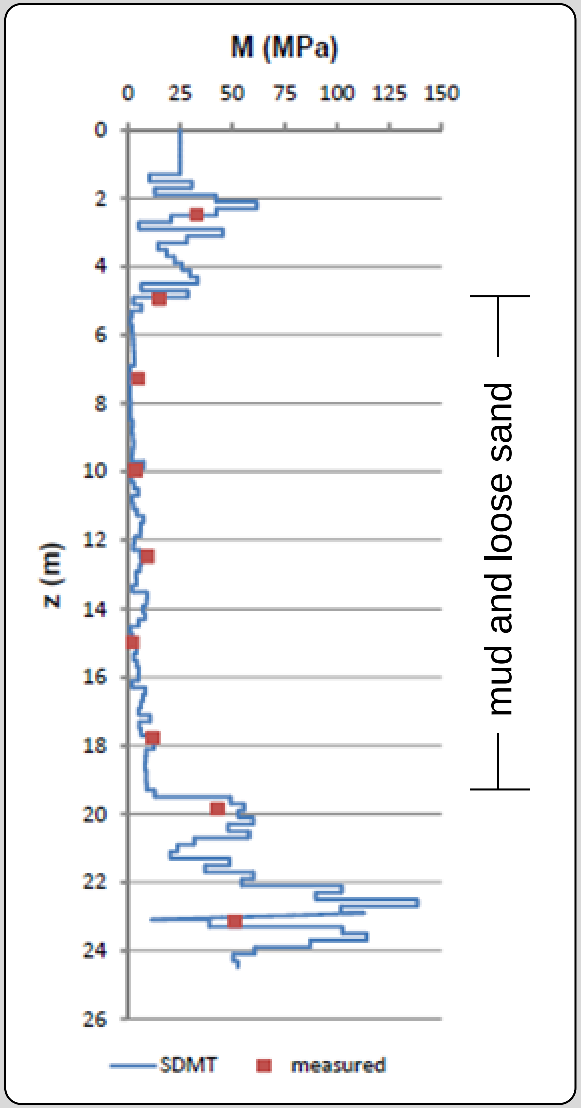
- <u>1-D approach</u> (classic Terzaghi)
- Primary settlement at working loads (Fs ≈ 2.5-3 to b.c.)

Many publications & case histories of good agreement between measured and DMT-predicted settlements / moduli:

- ***Failmezger*** *(2020)*
- ***Godlewski*** *(2018)*
- ***McNulty & Harney*** *(2014)*
- ***Berisavijevic*** *(2013)*
- ***Vargas*** *(2009)*
- ***Bullock*** *(2008)*
- ***Monaco*** *(2006)*
- ***Lehane & Fahey*** *(2004)*
- ***Mayne*** *(2001, 2004)*
- ***Failmezger*** *(1999, 2000, 2001)*
- ***Crapps & Law Engineering*** *(2001)*
- ***Tice & Knott*** *(2000)*
- ***Woodward*** *(1993)*
- ***Iwasaki et al.*** *(1991)*
- ***Hayes*** *(1990)*
- ***Mayne & Frost*** *(1988)*
- ***Schmertmann*** *1986,1988)*
- ***Steiner*** *(1994)*
- ***Leonards*** *(1988)*
- ***Lacasse*** *and* ***Lunne*** *(1986)*
- ..
- ..

Observed vs. Predicted Settlements by DMT

Silos on Danube Bank (Belgrade)



Silo founded on mat 100 m x 23 m, with qnet = 160 kPa

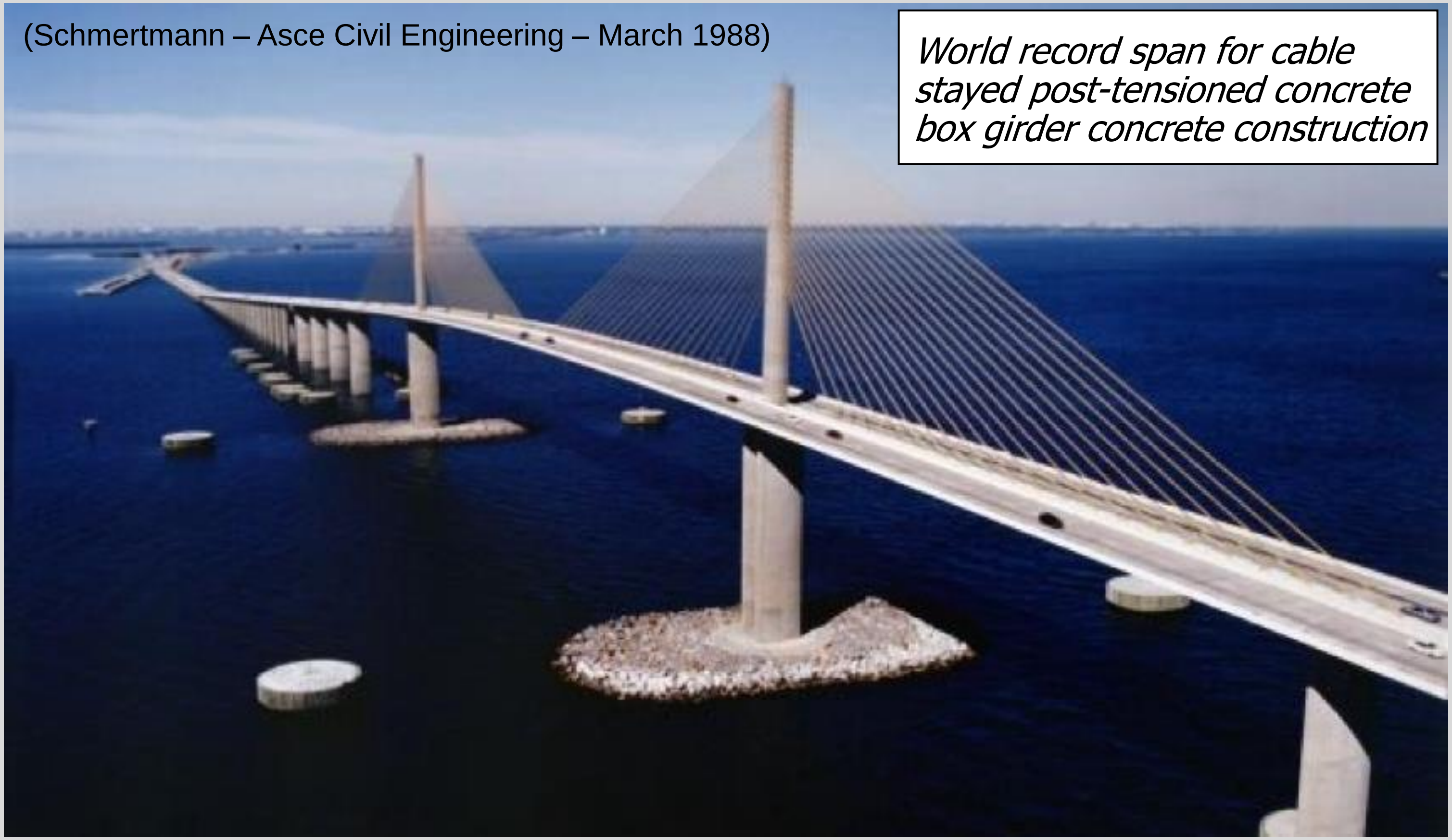
DMT Settlement prediction: 77 cm

Measured Settlement: 63 cm

DMT +22%

D. Berisavijevic, 2013

Sunshine Skyway Bridge – Tampa Bay – Florida



M from DMT ≈ **200** MPa (≈ 1000 DMT data points)

M from laboratory: M ≈ **50** MPa

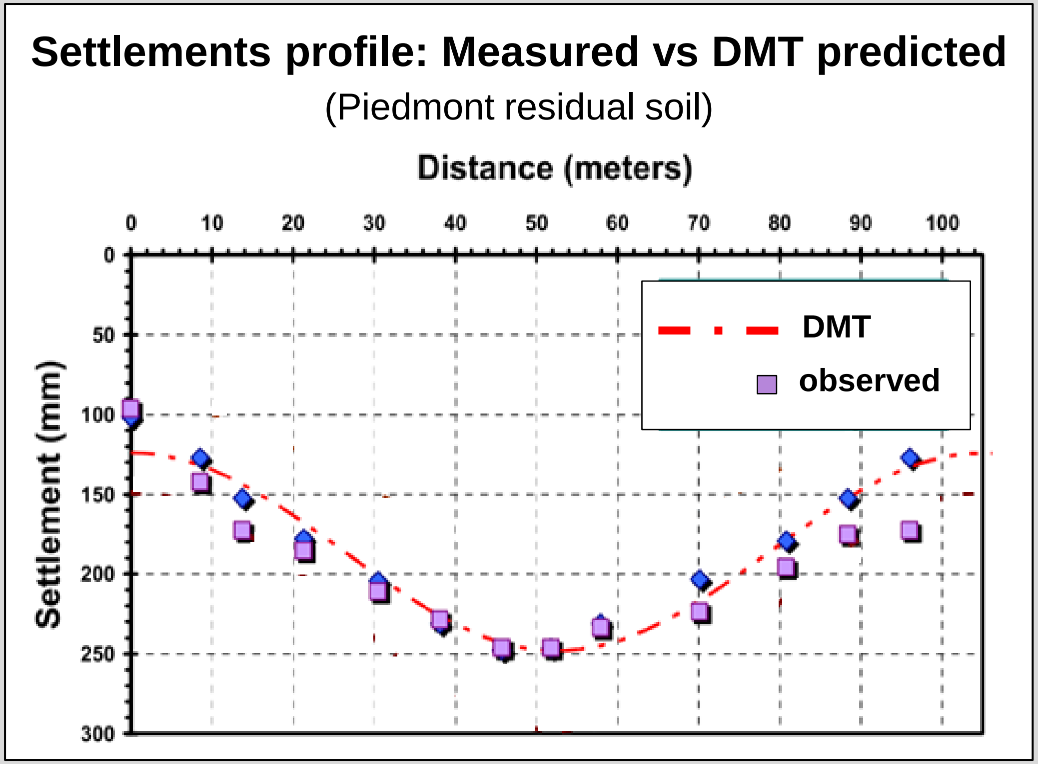
M from observed settlements: M ≈ **240** MPa

→ DMT good estimation of M in this site

Observed vs. Predicted Settlements by DMT

Dormitory Building 13 storeys (Atlanta - USA)

Mayne, 2005



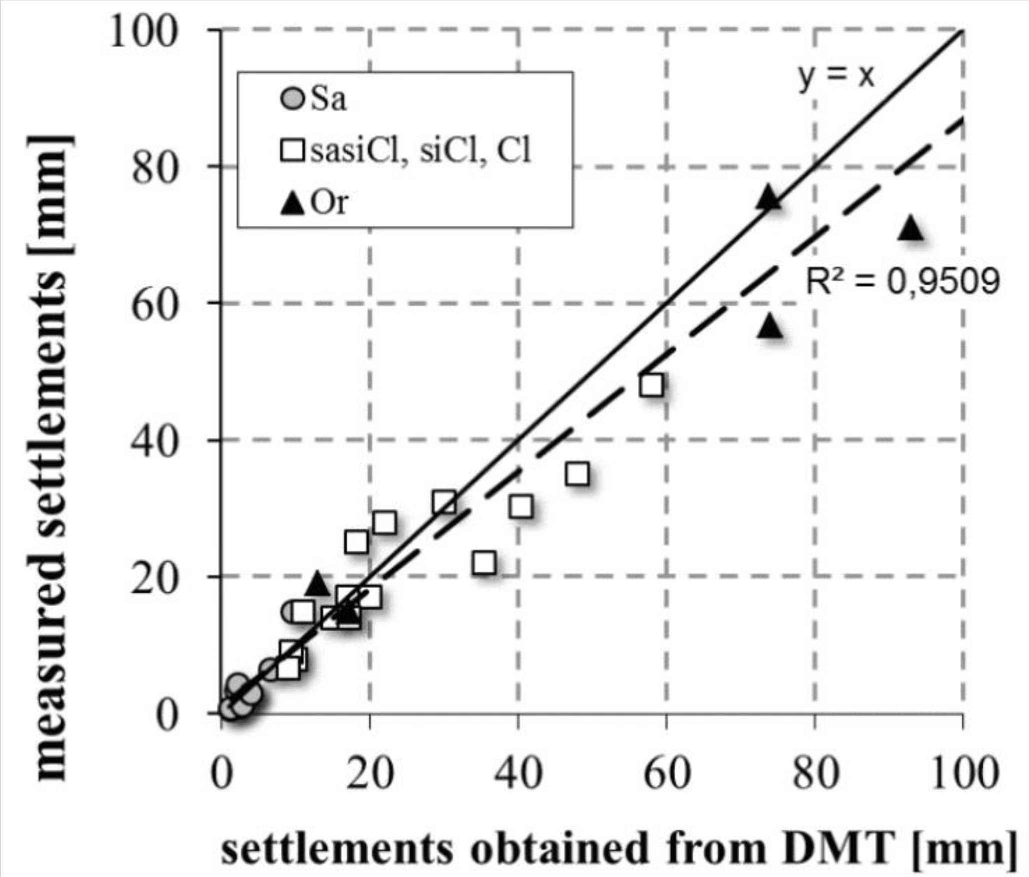
SPT Settlement prediction: 46 mm

DMT Settlement prediction: 250 mm

Observed Settlement: 250 mm

SPT → error is large and unsafe !!!

28 Projects: observed vs. predicted by DMT



Different soil types

Godlewski, 2018

*"..comparison of settlement values measured at the structures with respect to those obtained by dilatometer data and observations (**28 structures**). It should be added that the given set of buildings was limited to structures with **shallow foundation**.."*

Example of SDMT measurements and a ‘real time’ Settlements Prediction at a demonstration site for a workshop

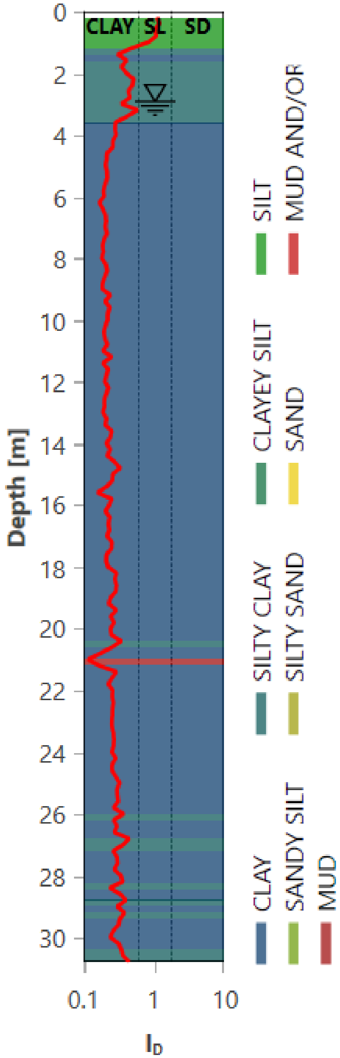
Bogotà (Colombia - 2015)

Example of SDMT tests in Clay

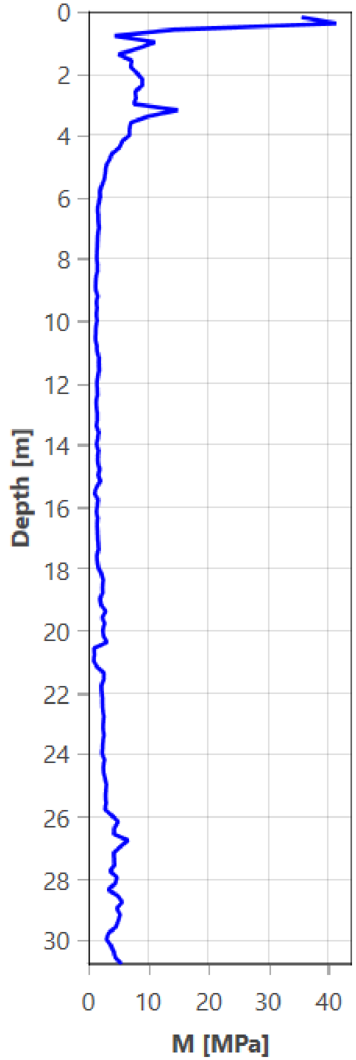
SDMT Workshop in Colombia (May 2015, Bogotà)

SDMT Escuela Colombiana 9 May 2015

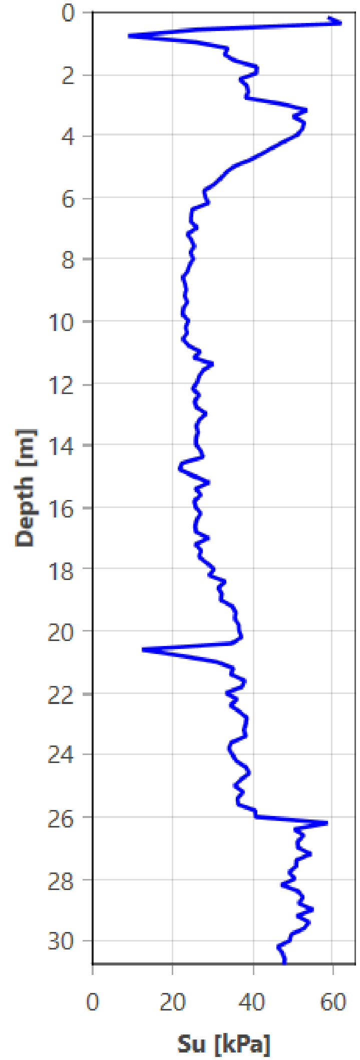
Material Index



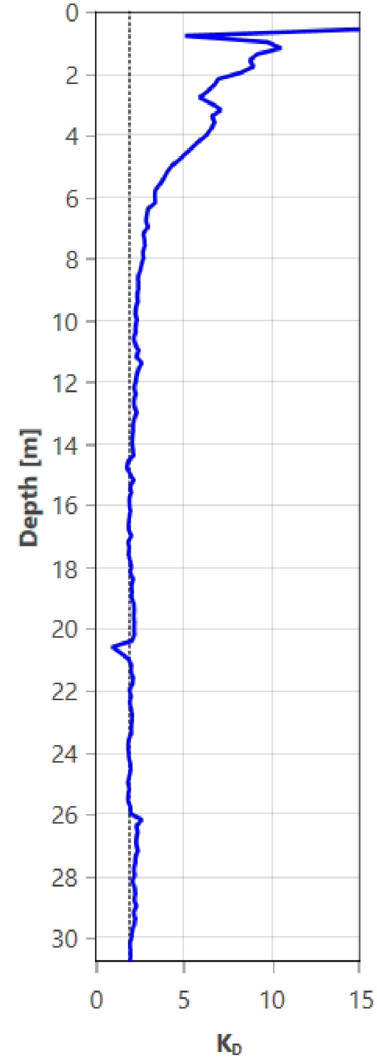
Constrained Modulus



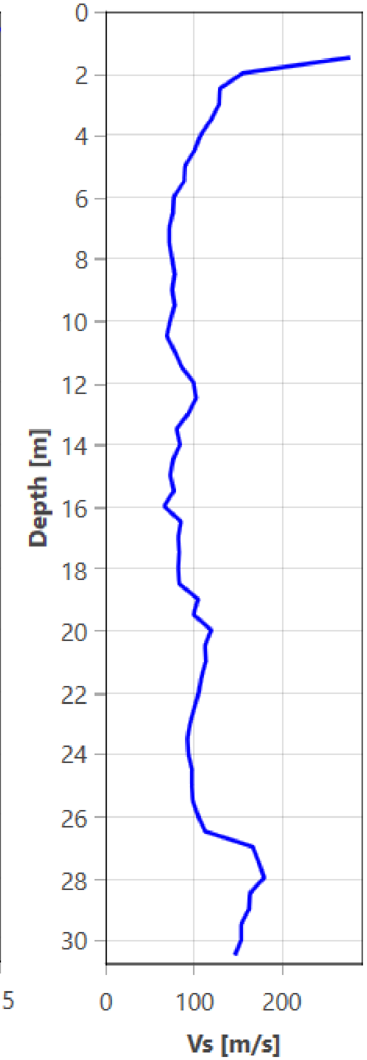
Undrained Shear Strength



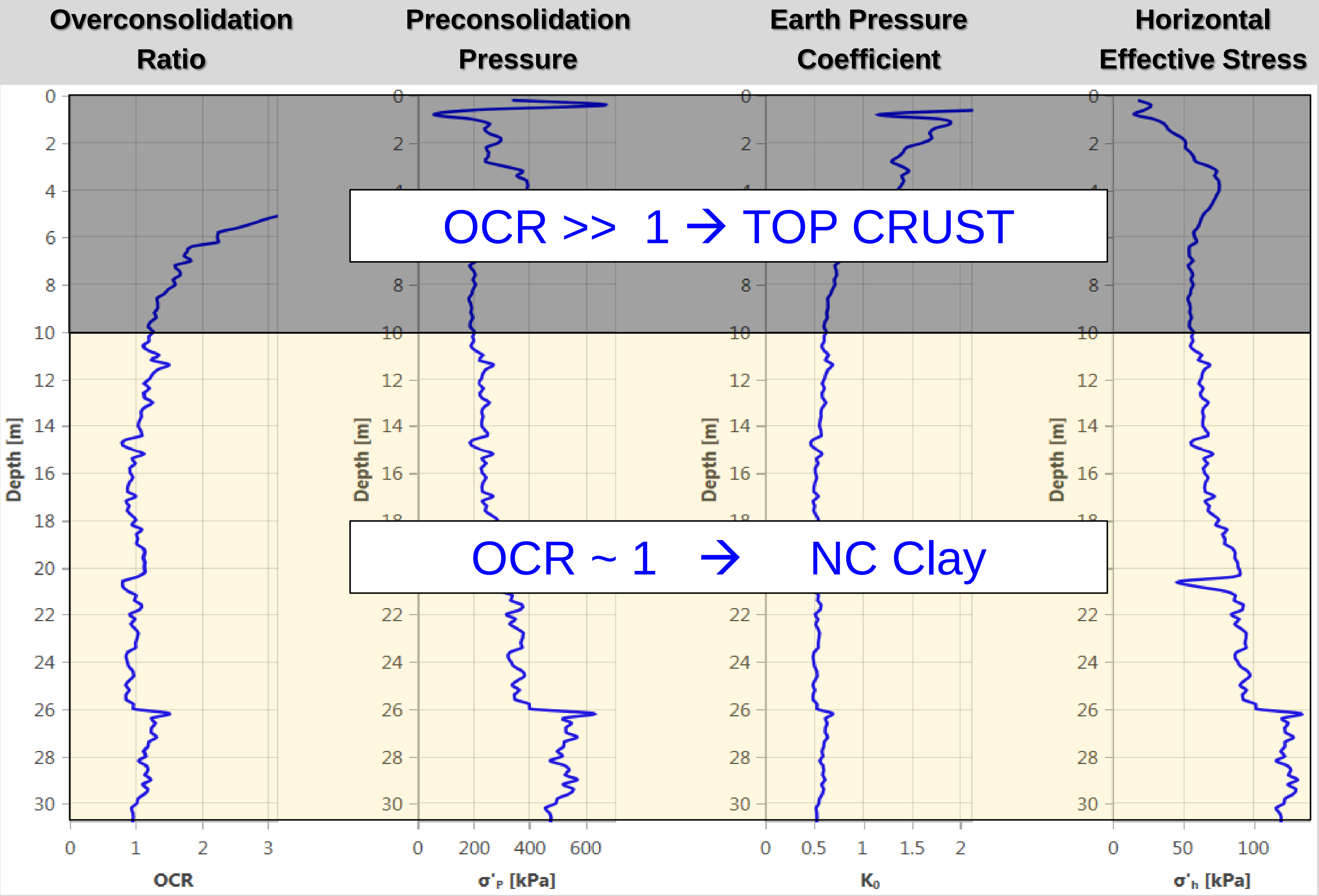
Horizontal Stress Index



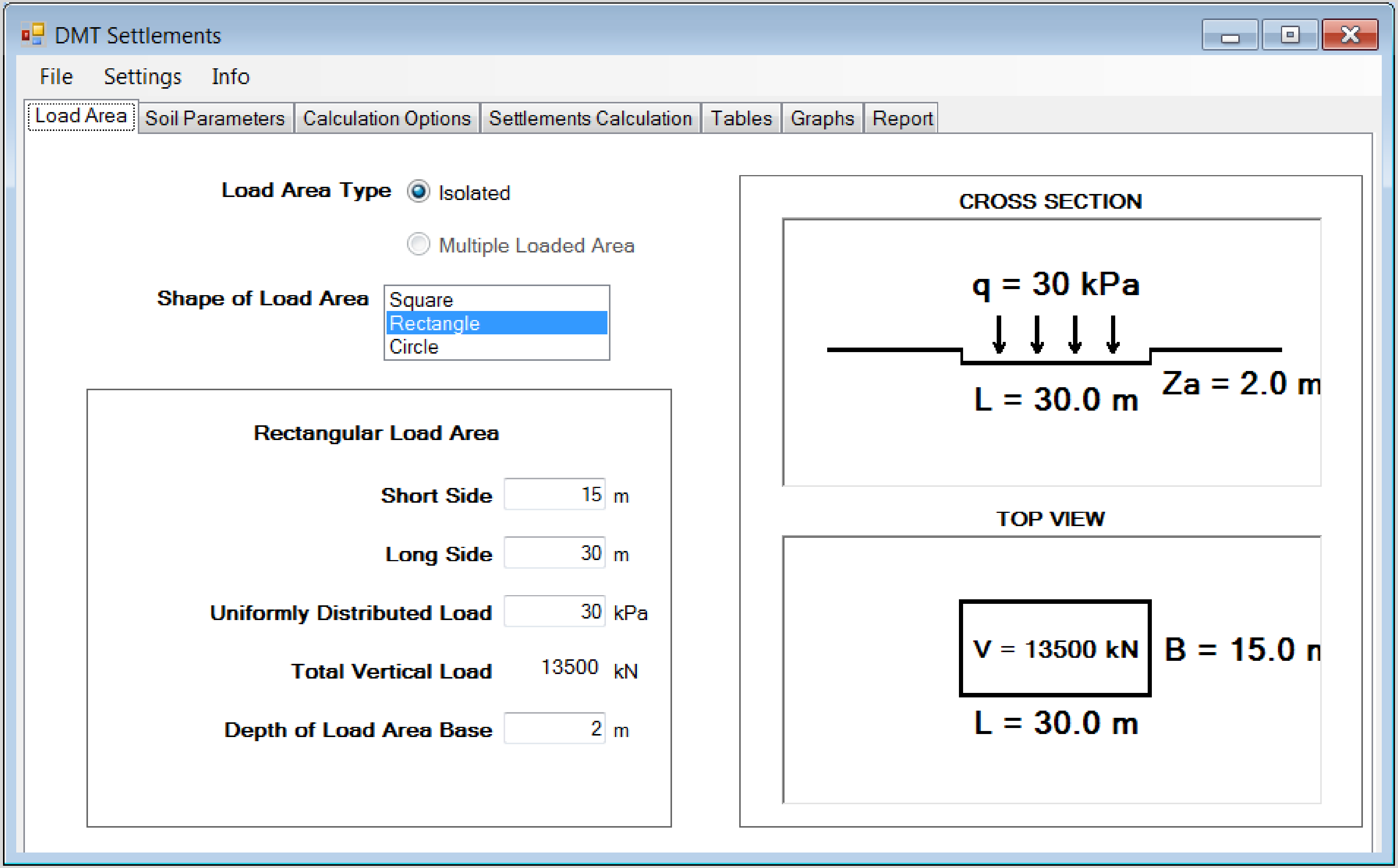
Shear Wave Velocity



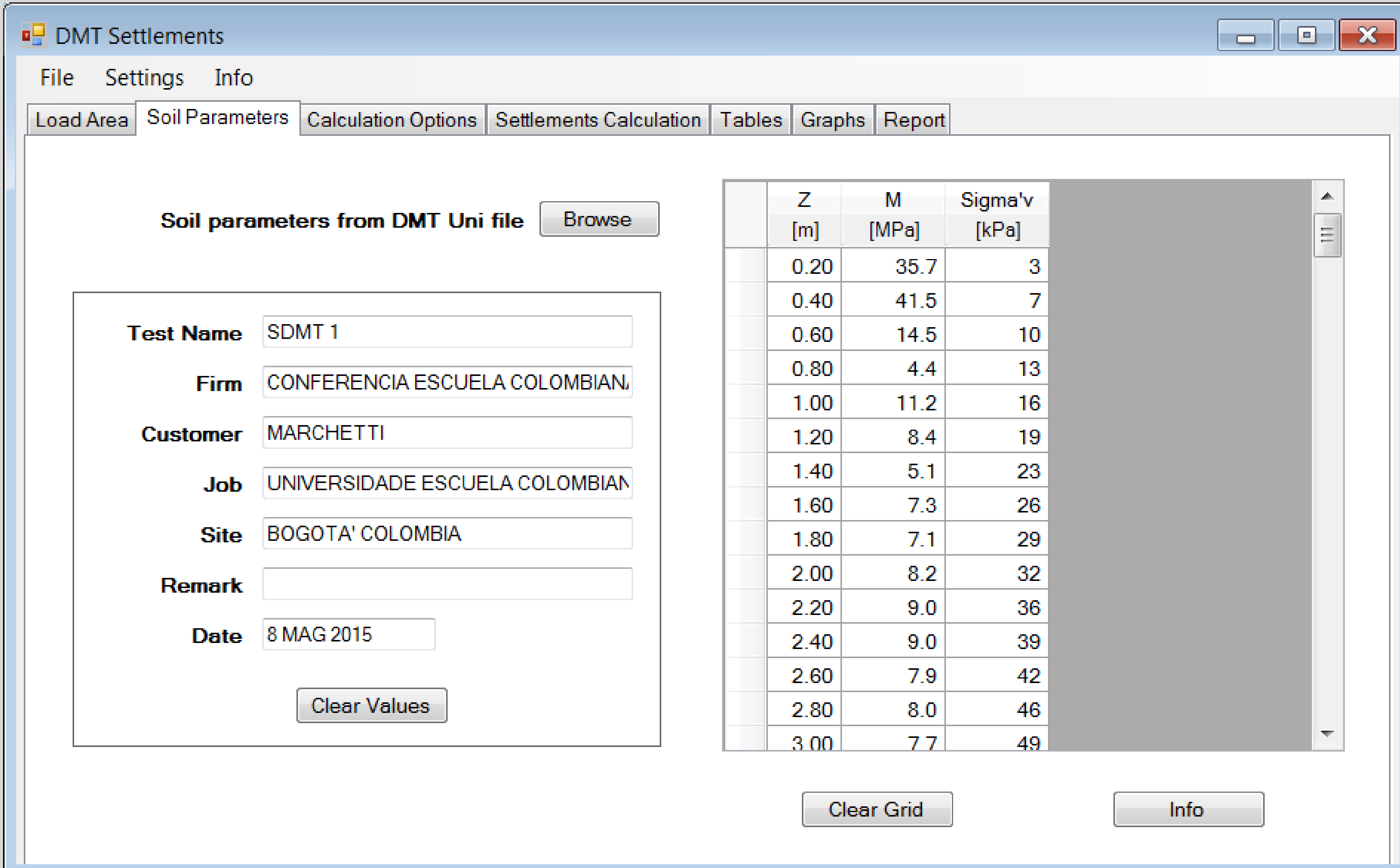
STRESS HISTORY PARAMETERS



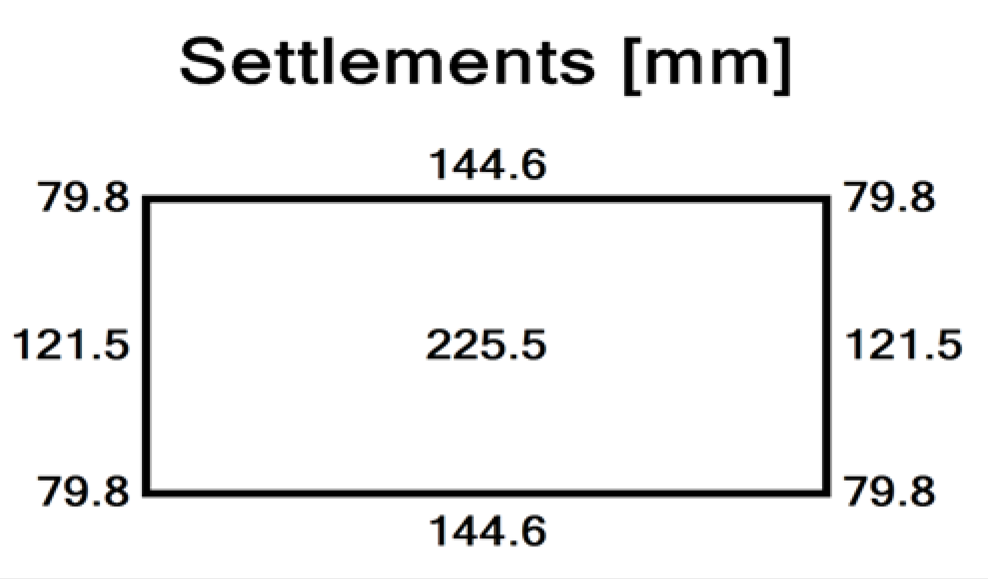
Settlements Calculation: Load information



Settlements Calculation: Soil information

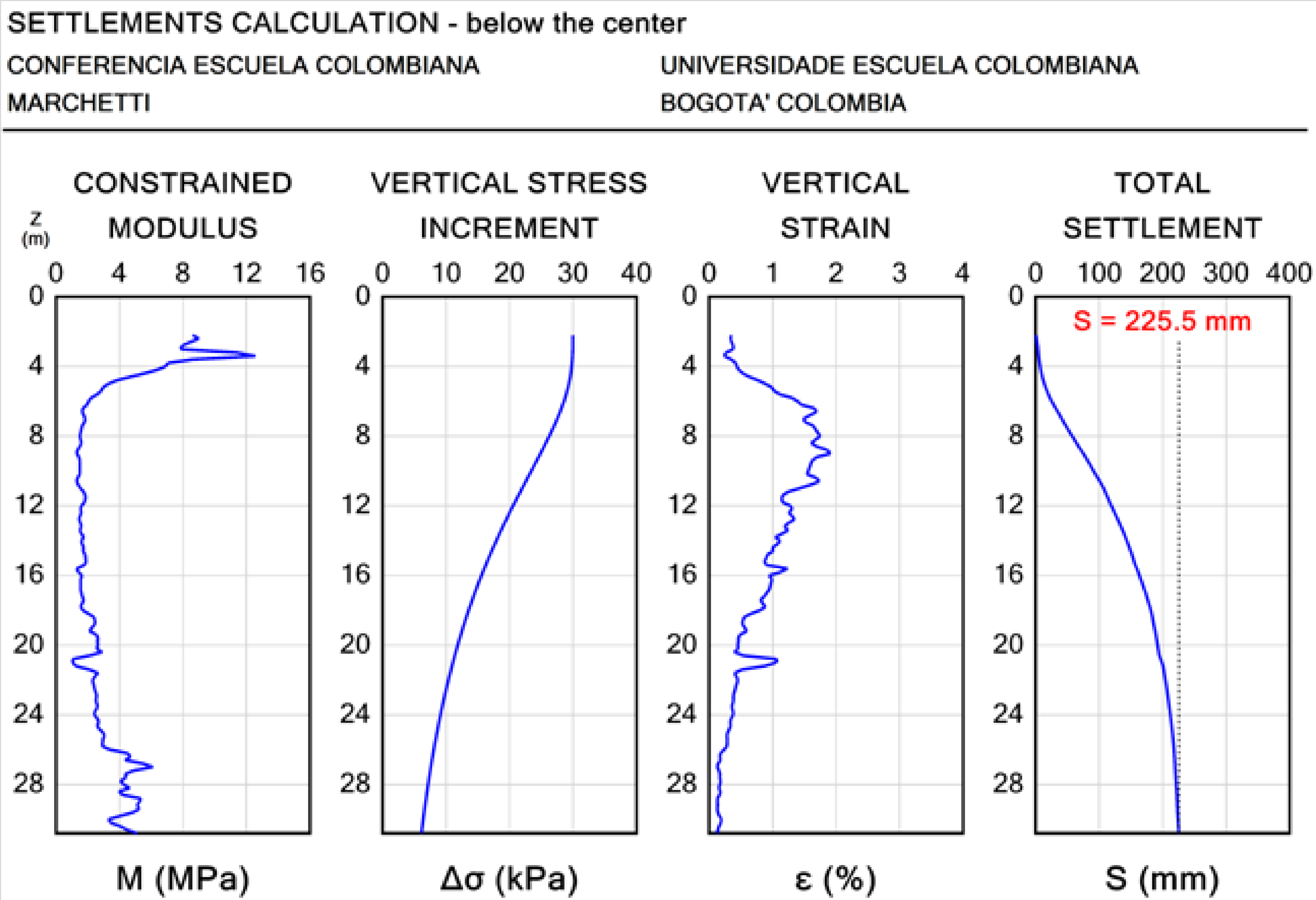


Settlements Calculation



	Settlements Calculation Point	Settlements [mm]	Z Stop [m]	Δσ/σ'v
▶	below the center	225.5	30.80	0.027
	below the corner	79.8	30.80	0.017
	below the median point of short side	121.5	30.80	0.019
	below the median point of long side	144.6	30.80	0.024

Settlements: graph below center of load



Main differences CPT-DMT

1. Flexibility in penetration

CPT – measurements performed at fix penetration rate of 2 cm / sec

→ penetrometer required

→ penetration rate may influence results

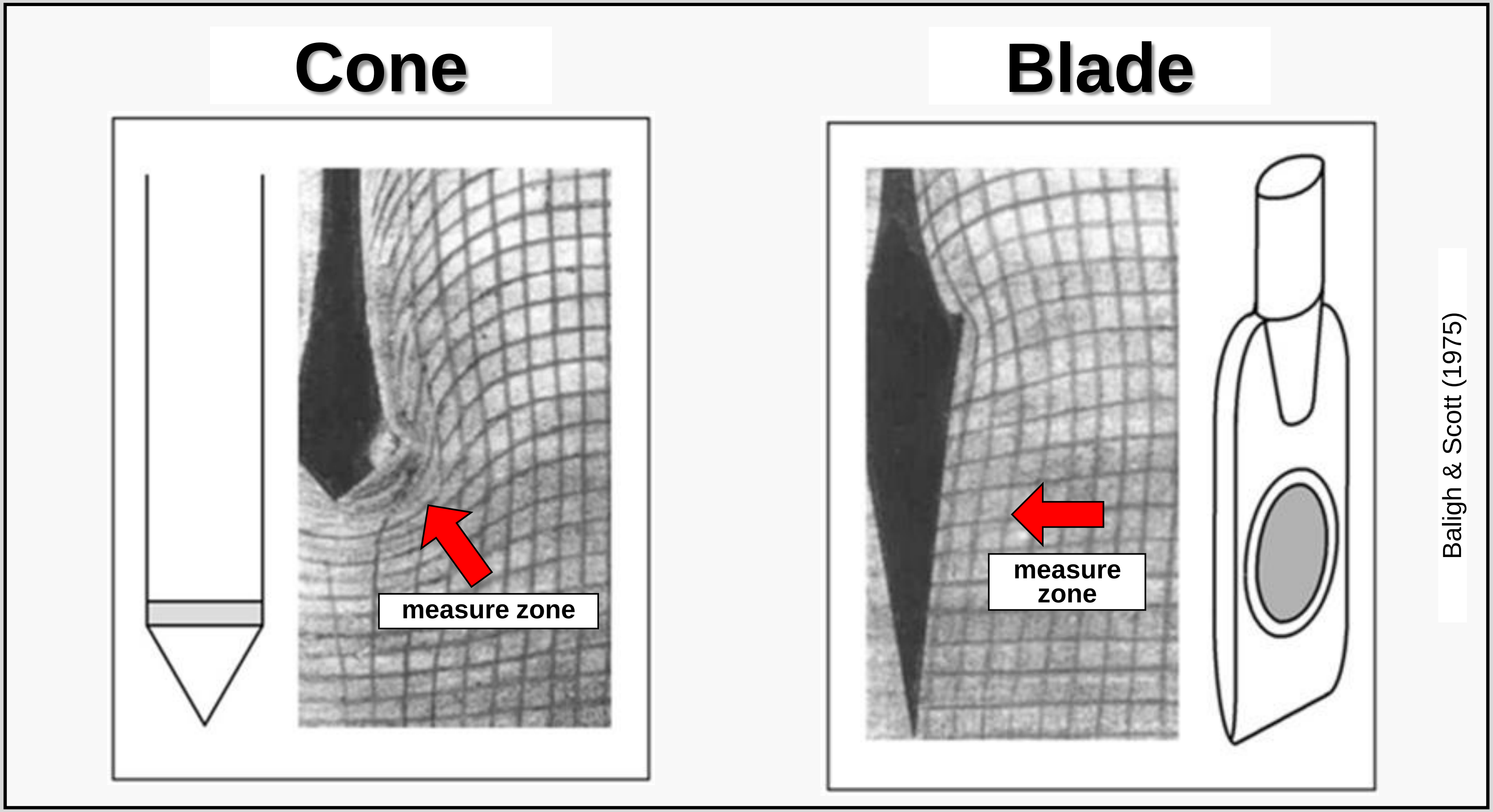
DMT – no requirement on penetration rate.

Measurements when blade is not moving.

→ penetrometer, drill rig, floating barge, etc

→ measurements independent of penetration rate

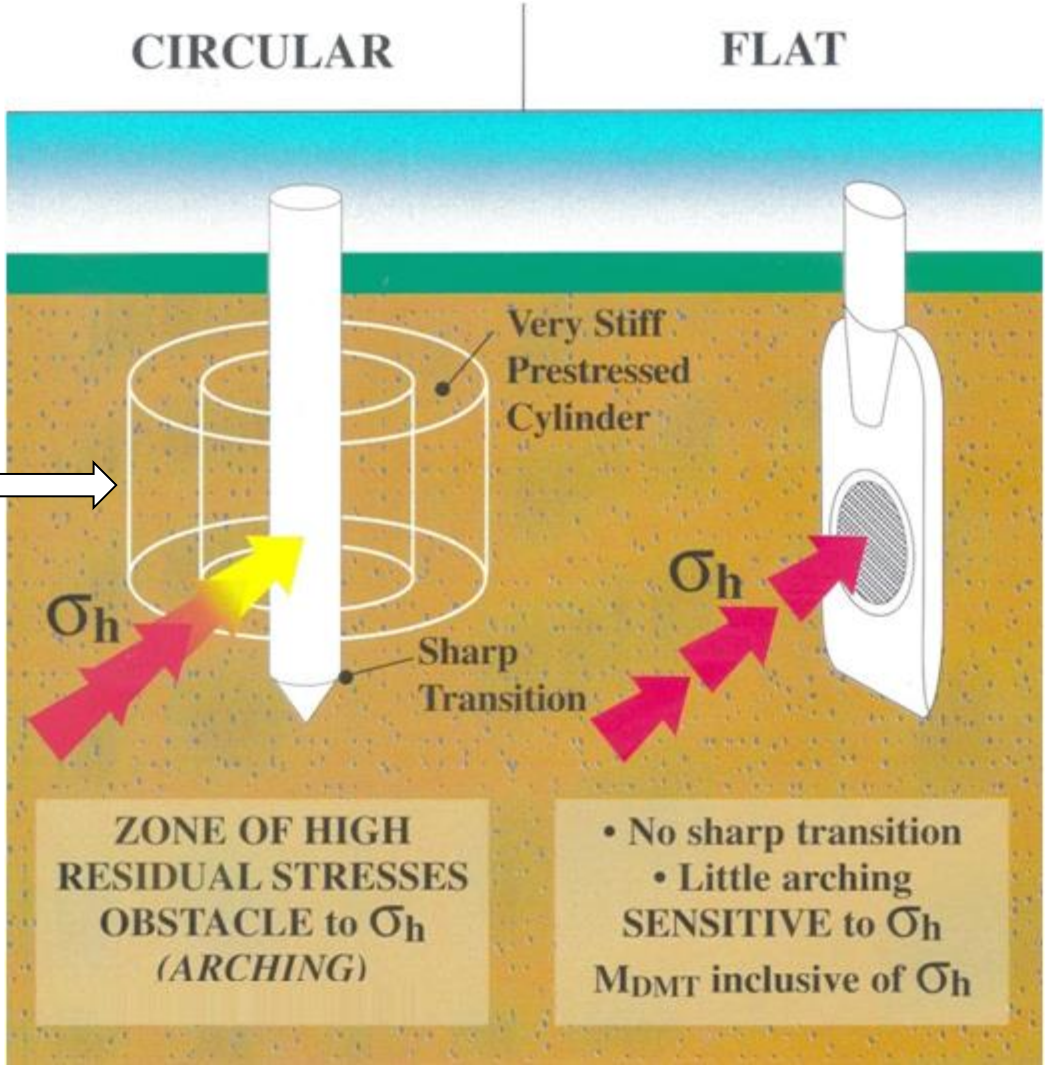
2. Probe shape and soil distortion



Blade penetration causes less distortion than cone penetration, preserving the original state of the soil → less disturbance

3. Sensitivity to σ_h of CPT(SPT) and DMT

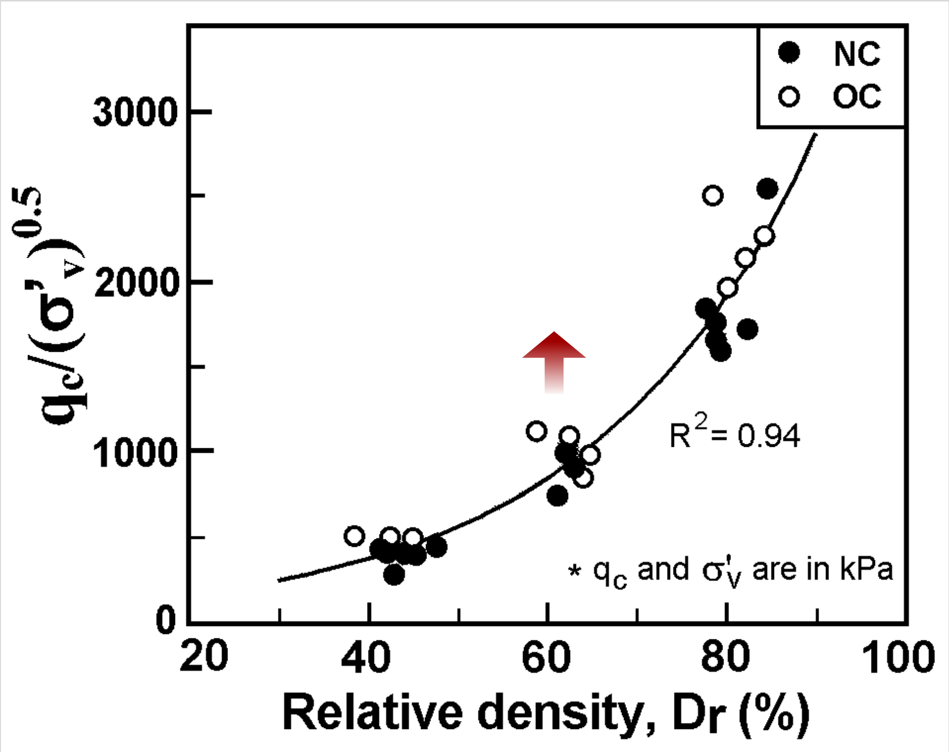
Arching effect



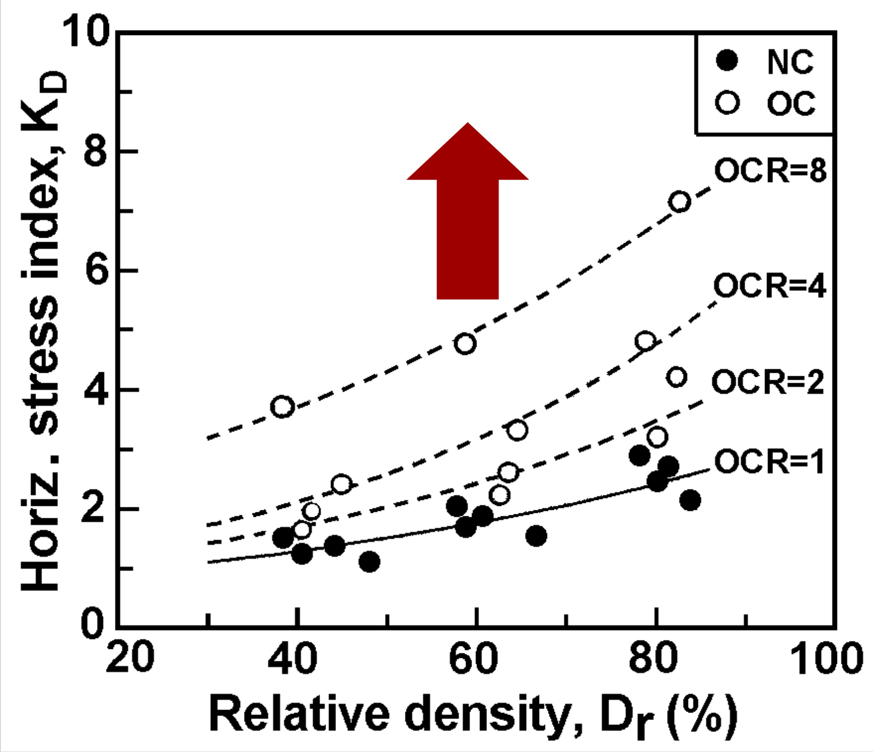
Hughes & Robertson (*Canadian Journal August 1985)*

4) SANDS: Stress History effects ON CPT & DMT

Effect of SH on normalized Q_c (CPT)



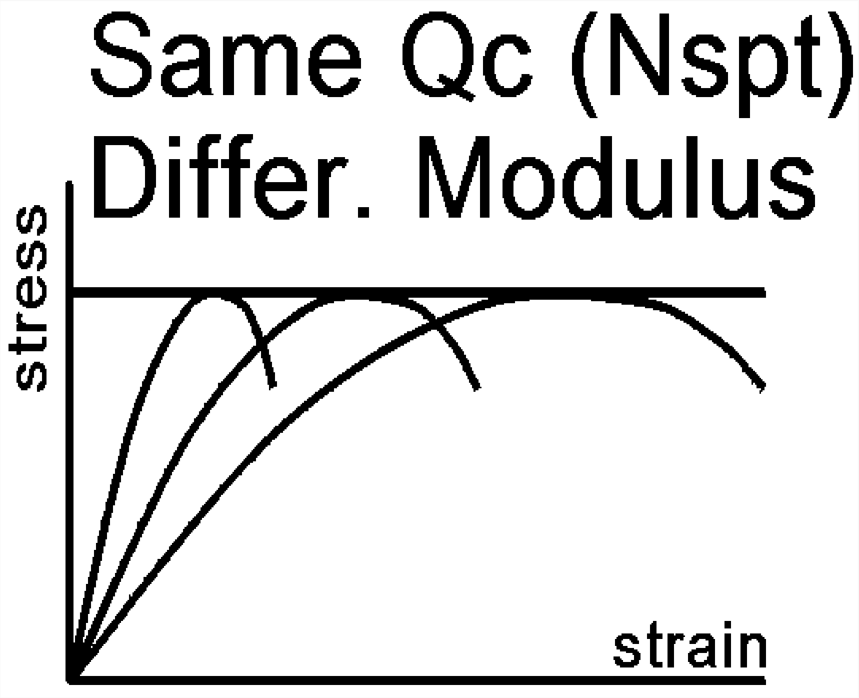
Effect of SH on K_D (DMT)



Lee 2011, Eng. Geology – CC in sand

K_D sensitive to Stress History

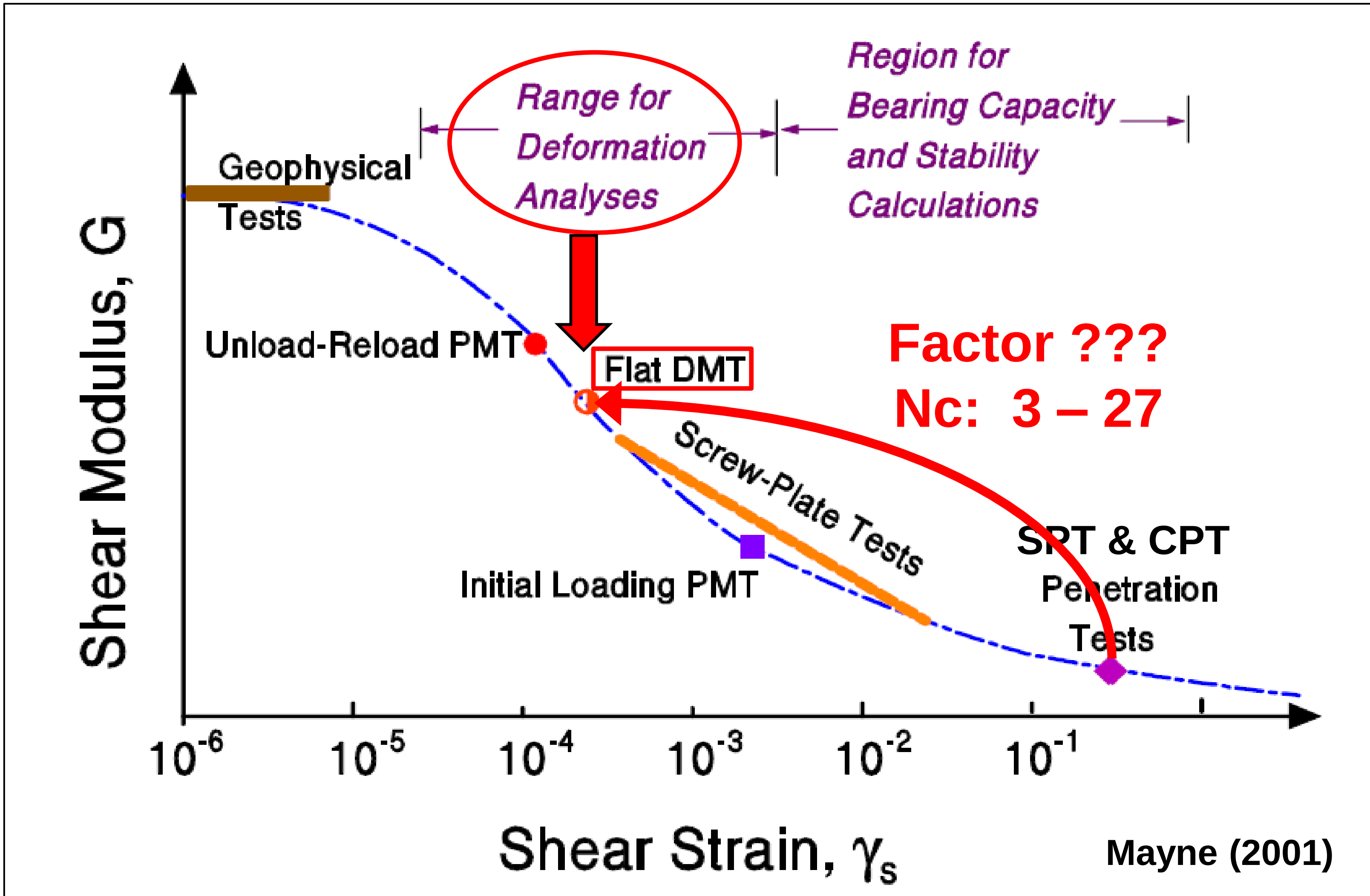
5. DMT (like PMT): Modulus direct measurement



Stiffness ≠ Strength

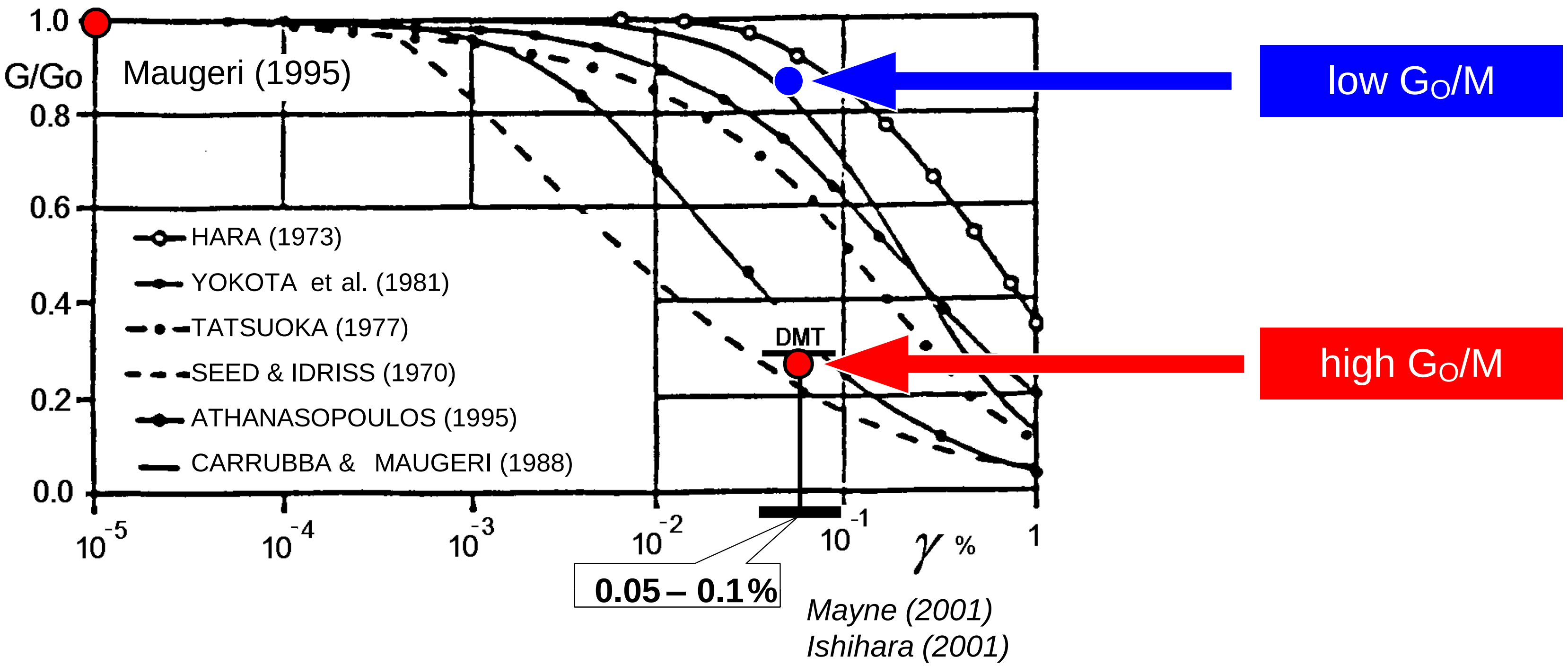
CPT (SPT) measures resistance and correlates to stiffness with a factor ranging significantly: ~ (3 – 27)

6. DMT: direct measurement of modulus in the soil loaded at the strain level for deformation analysis



G-gamma decay curves (in situ)

G_o and M_{DMT} on the G - γ decay curve



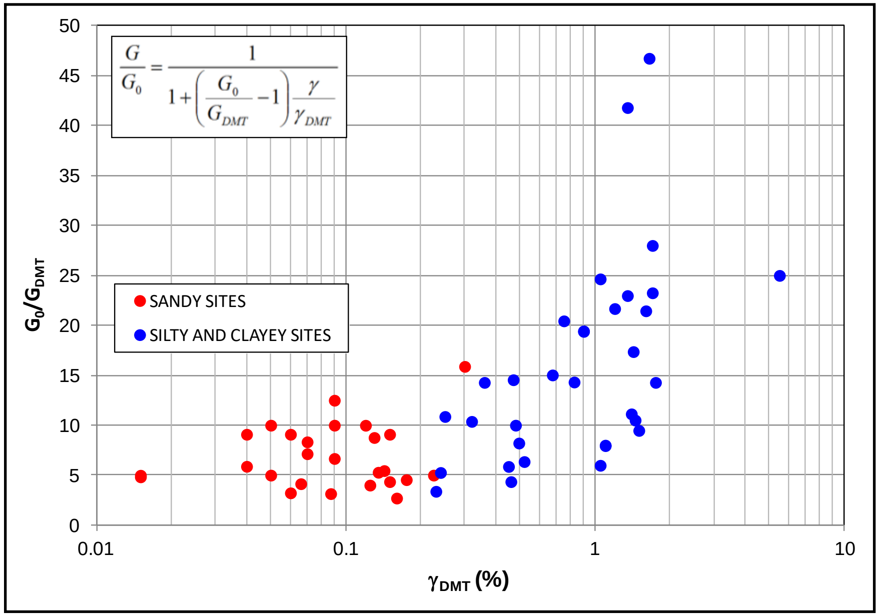
SDMT ➡ G_0 - *small strain modulus (from Vs)*

two points M_{DMT} - *working strain modulus* (γ = 0.05 – 0.1 %)

G_0 / M_{DMT} may provide an in situ estimate of the G-γ decay curve

Pubblications: Rodriguez et al (2019), Amoroso et al (2012, 2014), Marchetti et al (2008), Lehane & Fahey (2004) Porto ISC-2 – non linear settlement analysis from in situ tests

Tentative estimation of G - γ decay curve

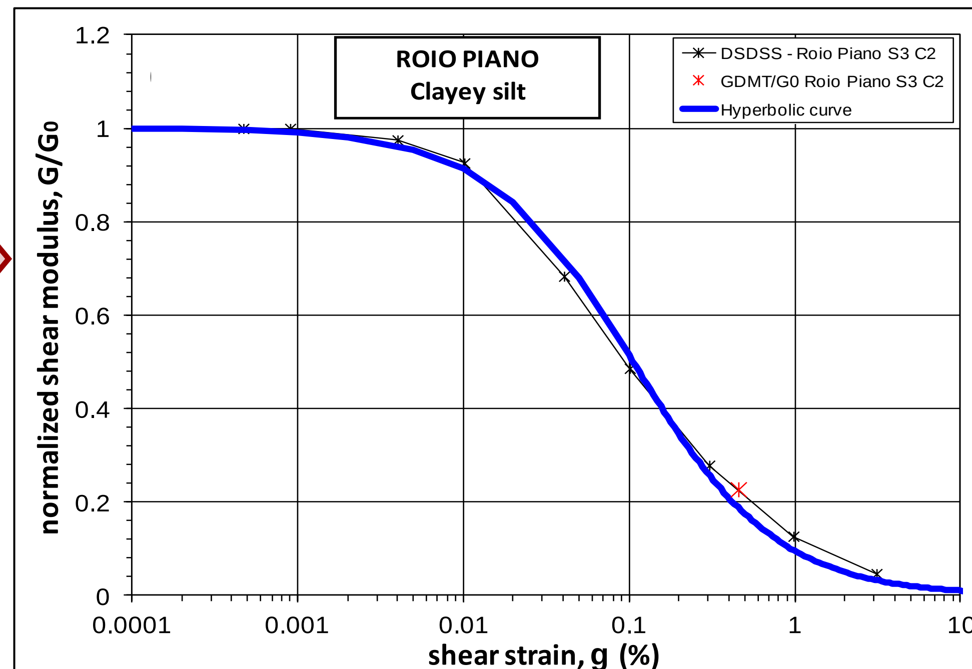


SDMT experimental data used to assist the construction of a **hyperbolic equation**

$$\frac{G}{G_0} = \frac{1}{1 + \left(\frac{G_0}{G_{DMT}} - 1 \right) \frac{\gamma}{\gamma_{DMT}}}$$

Good agreement between hyperbolic SDMT estimation and laboratory stiffness decay curve

Amoroso et al. 2014



requires further validation

Quality Assessment of Soil Improvement

In the last decades the DMT has been increasingly used in compaction jobs to quantify the gain in soil improvement

Ground Reinforcement

- Stone Columns
- Soil Nails
- Micropiles
- Jet Grouting
- Ground Anchors
- Geosynthetics
- Fibers
- Lime Columns
- Vibro-Concrete Columns
- ..

Ground Improvement

- Surface Compaction
- Drainage/Surcharge
- Electro-osmosis
- Compaction grouting
- Blasting
- Dynamic Compaction
- ..

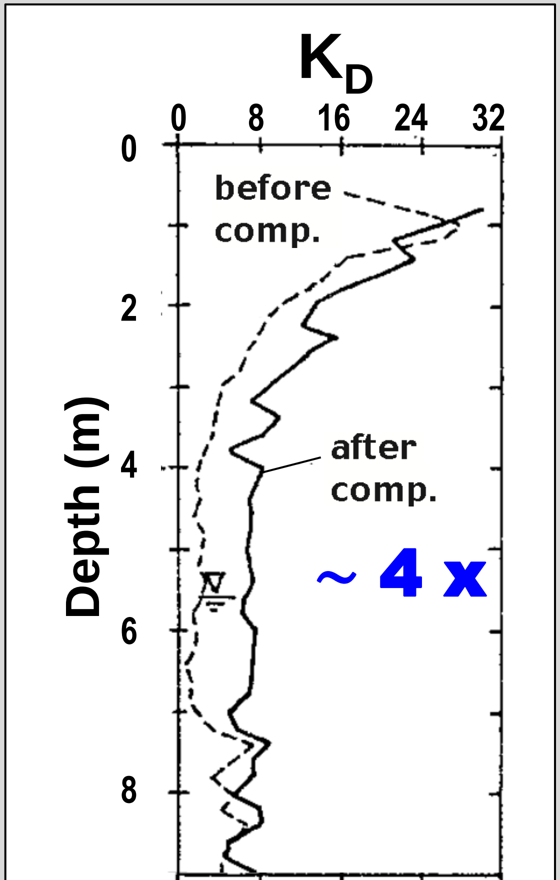
Ground Treatment

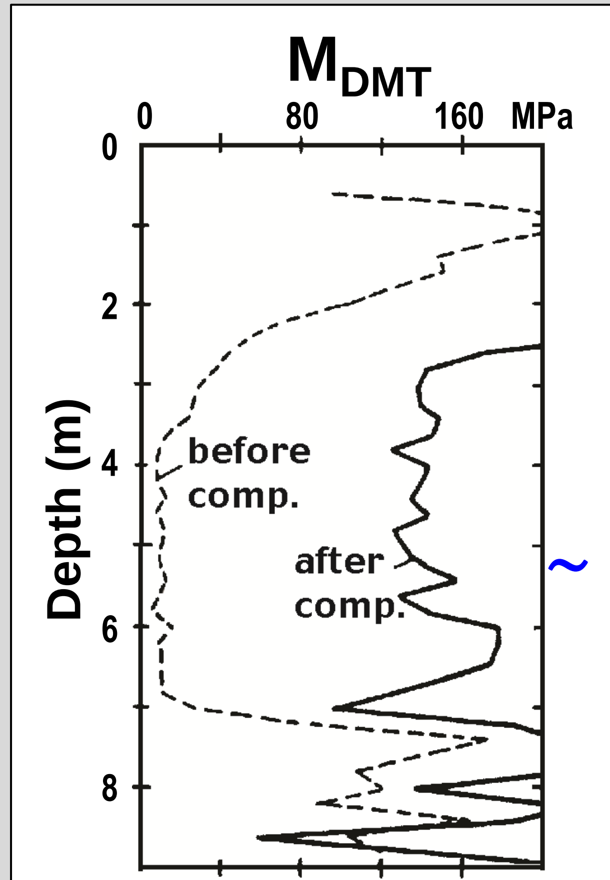
- Soil Cement
- Lime Admixtures
- Flyash
- Dewatering
- Heating/Freezing
- Vitrification
- ..

DMT for Compaction Control (case history 1)

Loose sandfill - container terminal in Belgium

Resonant vibrocompaction technique





~ 10 x

Van Impe, De Cock, Massarsch, Mengé - New Delhi (1994)

DMT for Compaction Control (case history 2)

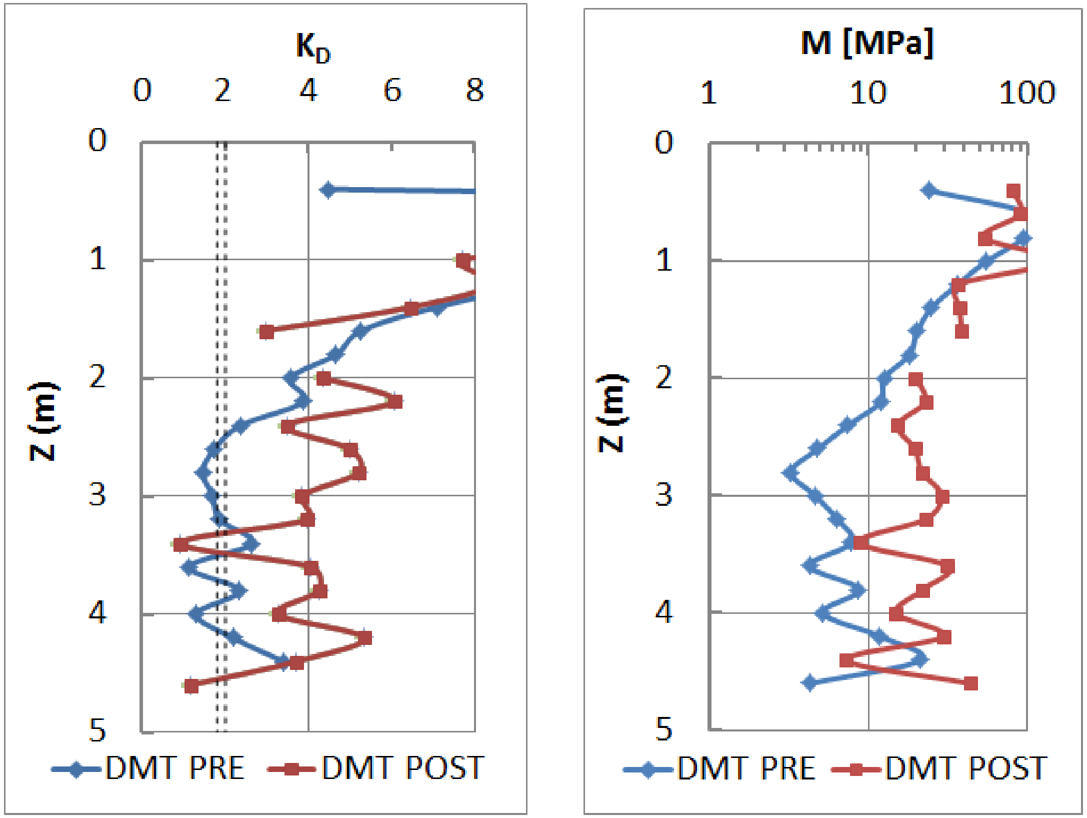


Figure 3

Resin Injection

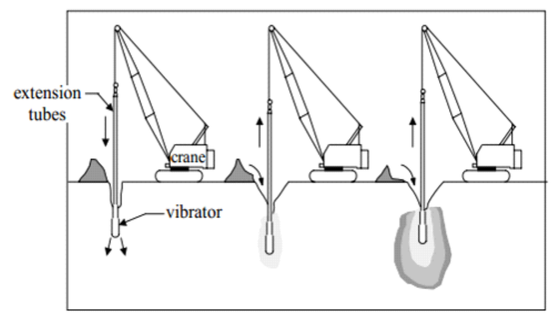
"The DMT tests were performed near the ground improvement and about 15 feet away from the improvement."

Grifton School Project USA (SAND)

"Figure 3 illustrates how well resin injections improved the soil and how well K_D and M detected such improvements" (Failmezger 2017)

DMT for Compaction Control - Palma Jumeirah Dubai

E. Sharif (2015)

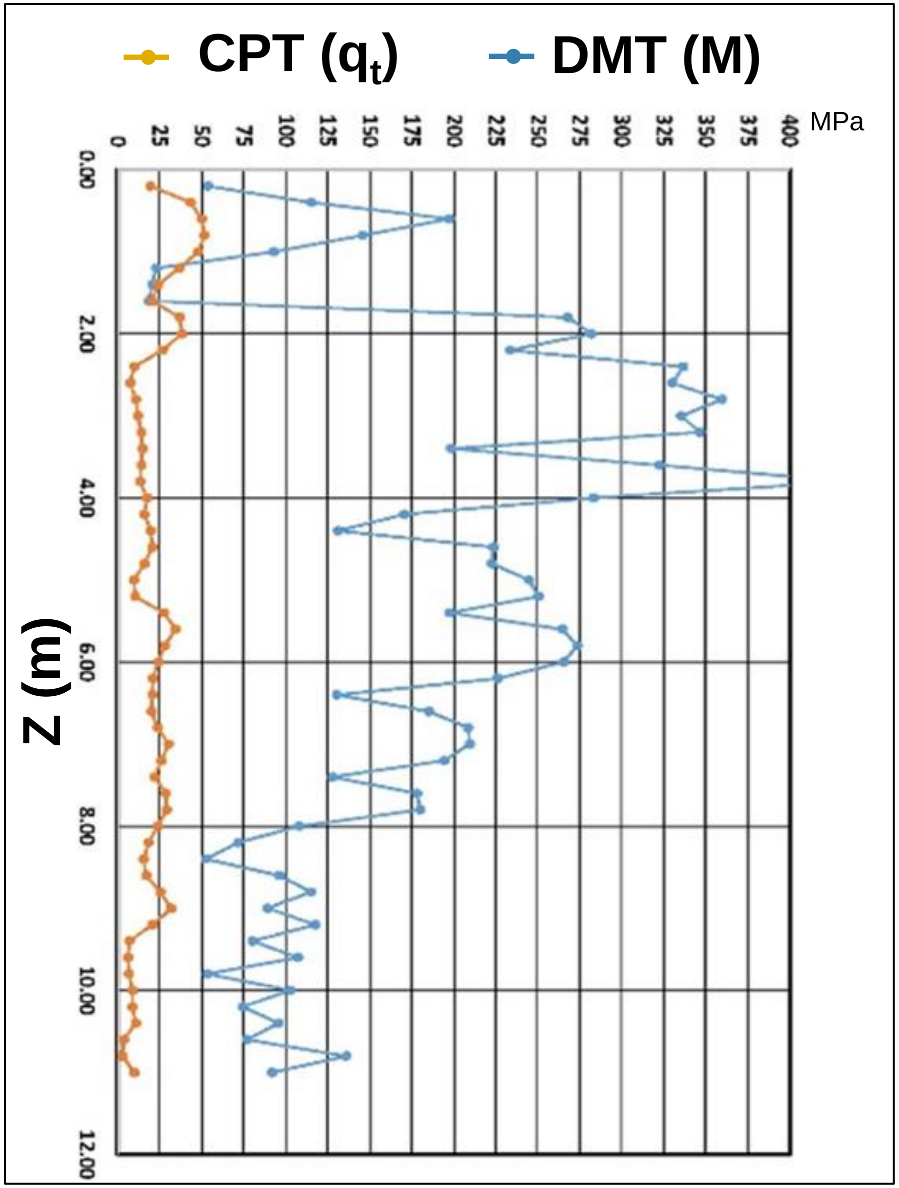


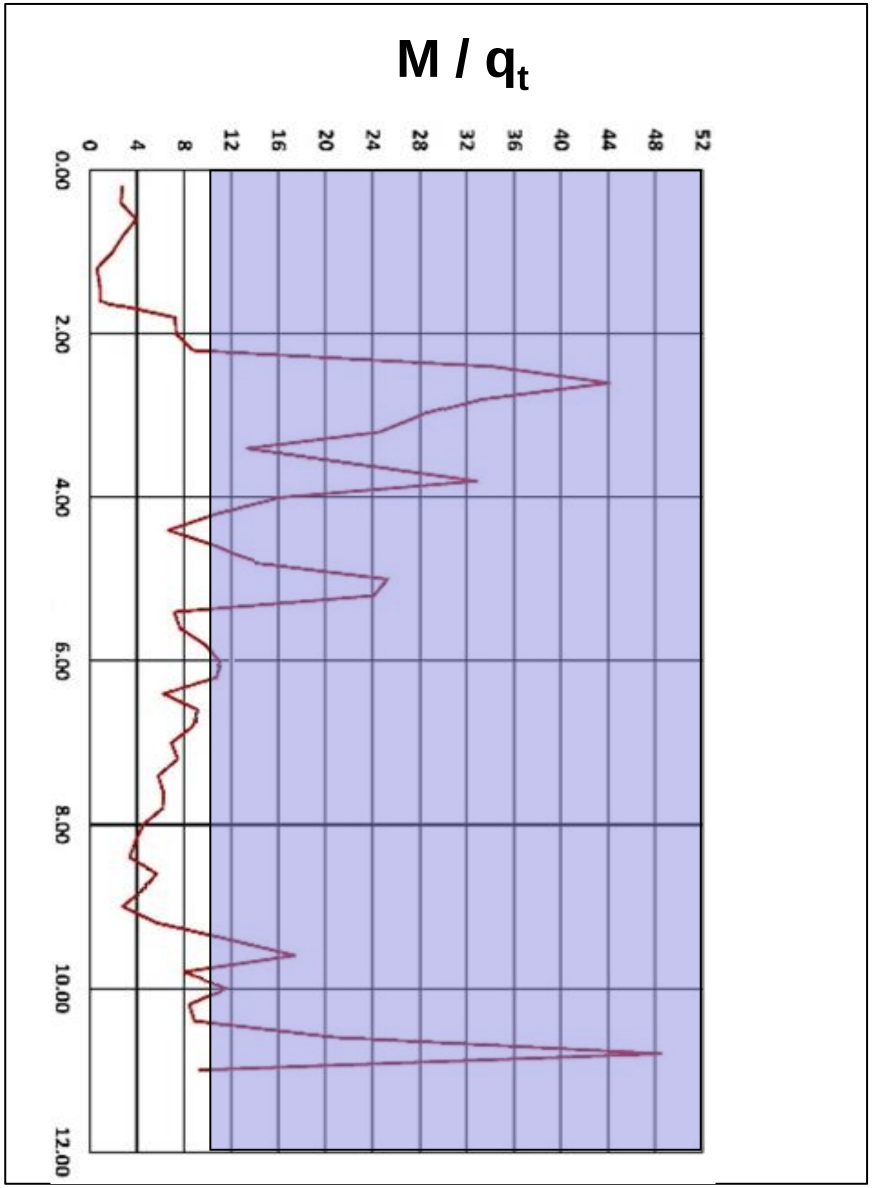
"..hydraulically filled silty fine calcareous sand dredged from sea bed, underlain by sedimentary rock of very weak sandstone and siltstone.."

Aim of DMT & CPT tests: to confirm OC of vibrocompaction, detected also by very high Vs (400-500 m/s)

DMT for Compaction Control - Palma Jumeirah Dubai

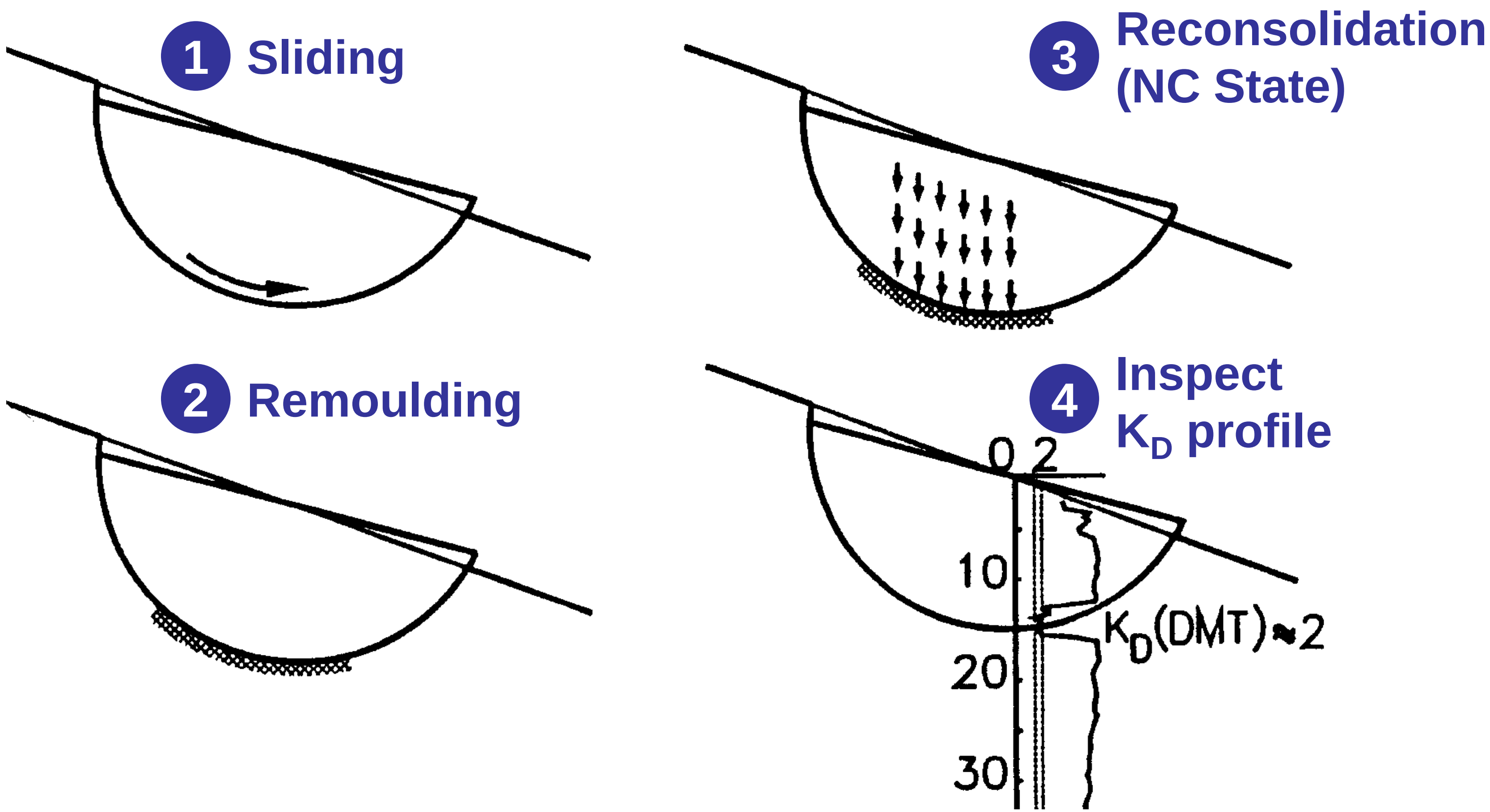
E. Sharif (2015)





Slip surface detection in OC clay slopes

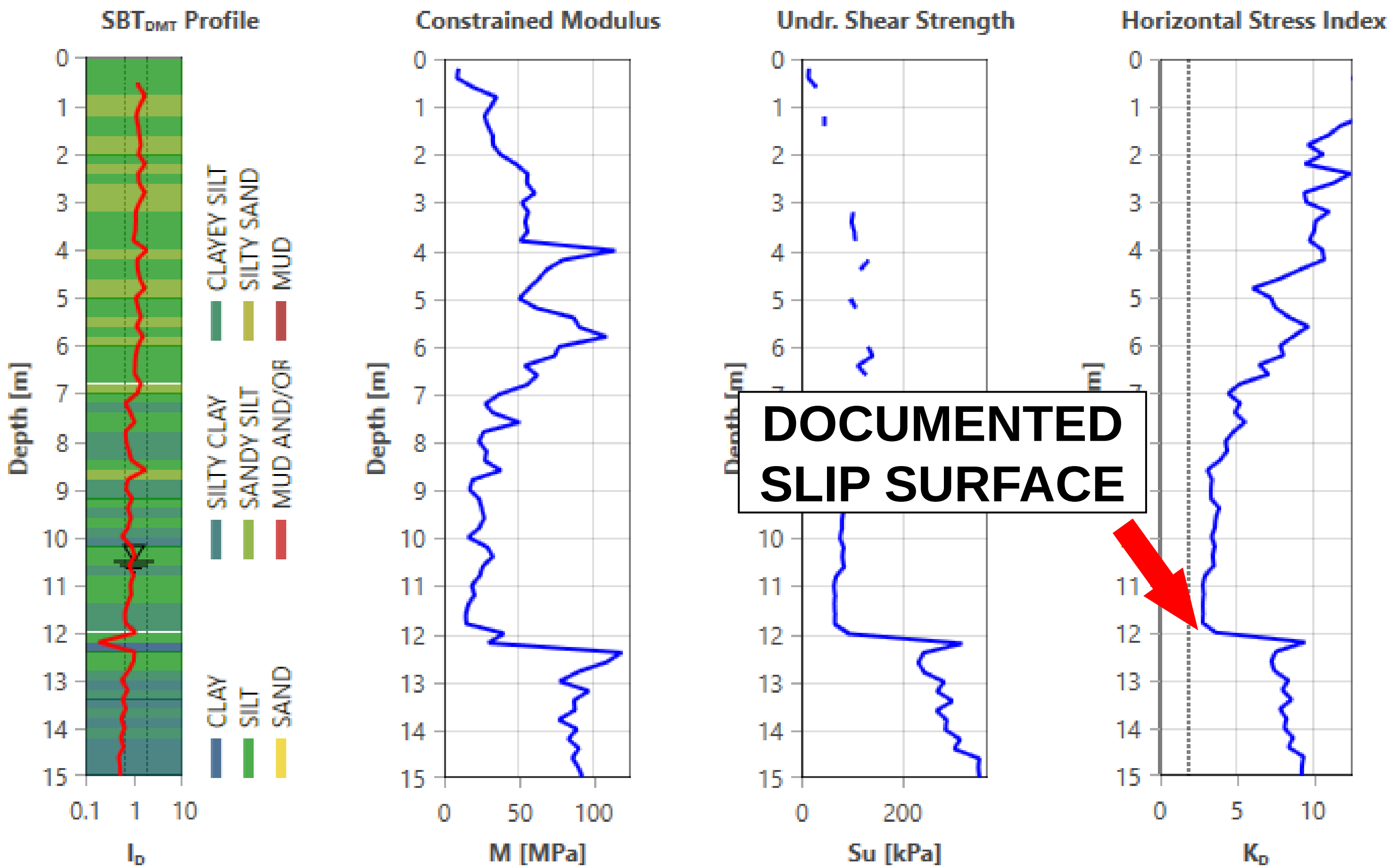
*DMT-K_D method ➡ Verify if an <u>OC clay slope</u> contains **active** (or old **quiescent**) slip surfaces*



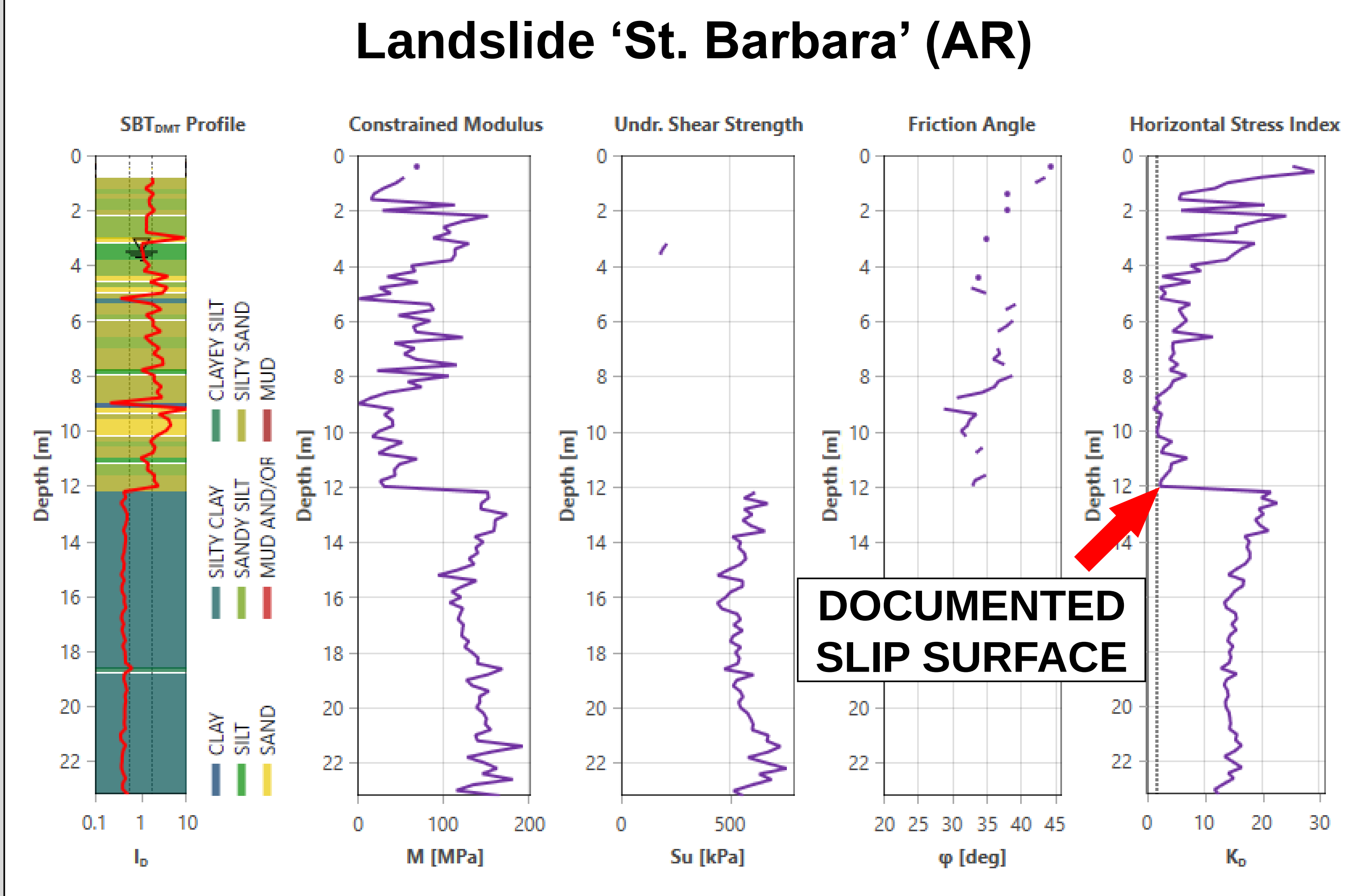
(Totani et al. 1997)

Validation of DMT-K_D method

Landslide "Filippone" (Chieti 1997)

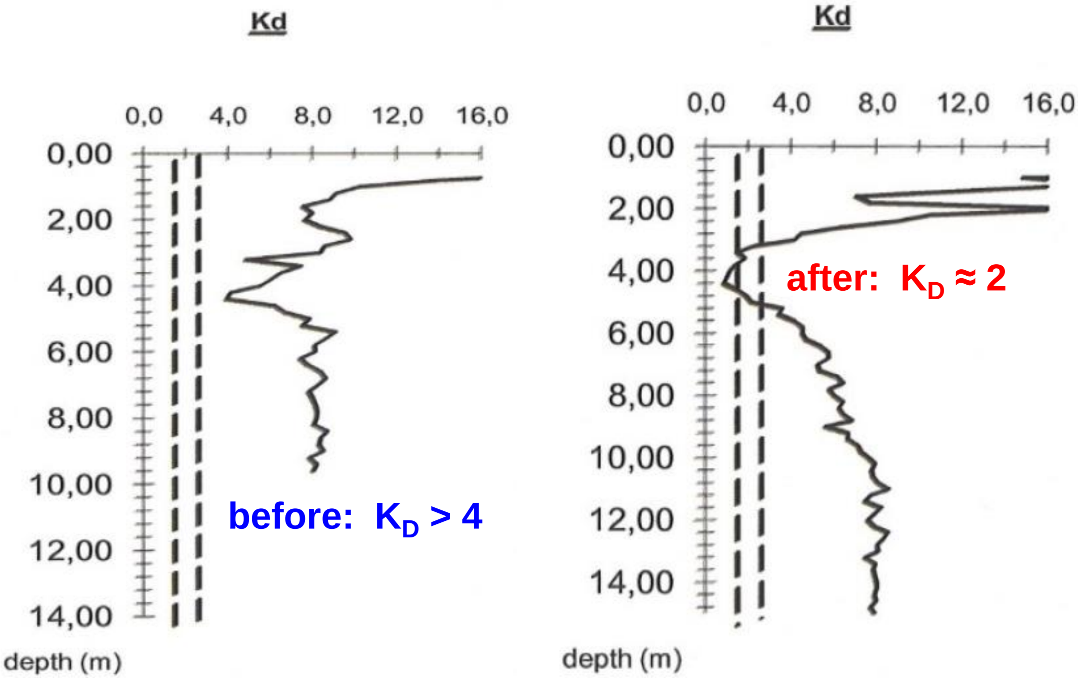


Validation of DMT-K_D method



K_D to detect slip surface

Inspection of K_D profile
before and after the landslide



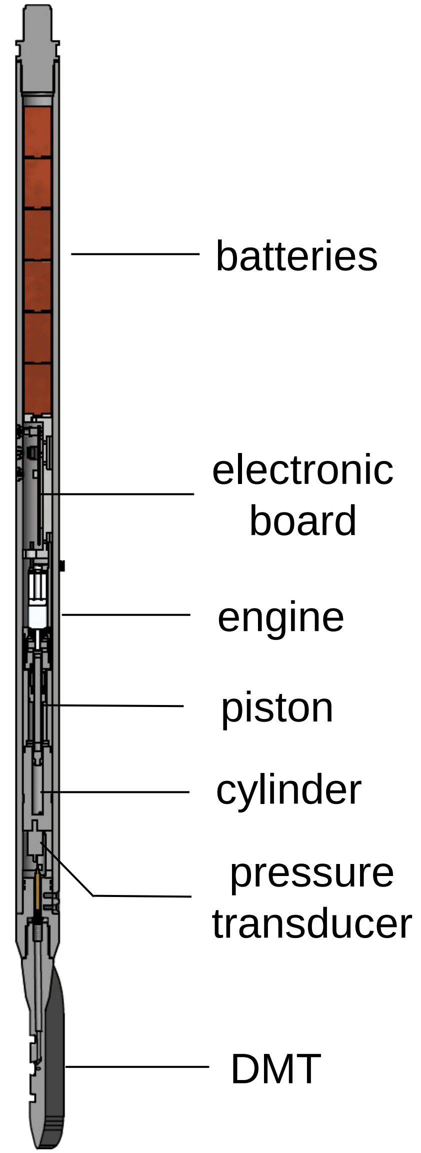
Peiffer, 2016 - ISC'5 Conf.

MEDUSA DMT

ONSHORE AND OFFSHORE SOIL TESTING

Medusa DMT: Automated Dilatometer

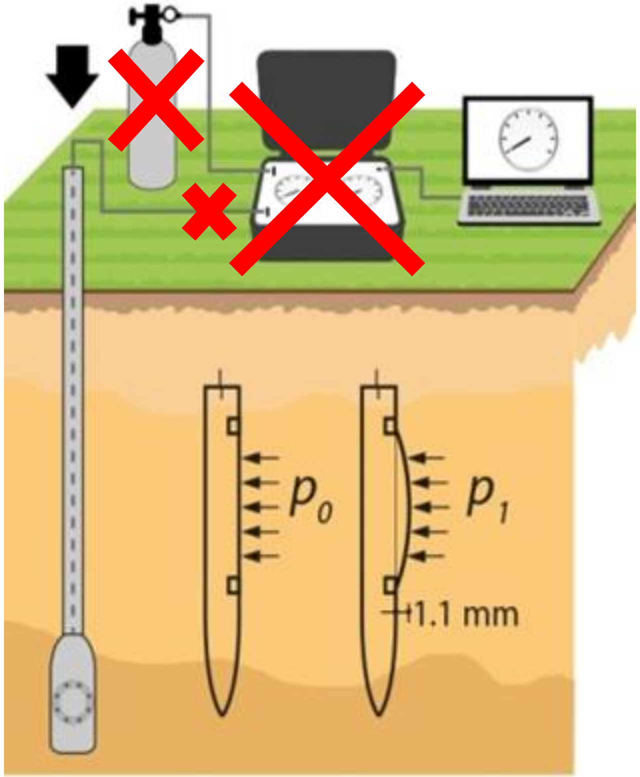
- **Battery Power Pack (24h operational)**
- **Electronic Board**
- **Hydraulic Motorized Syringe:**
  - **Electric Engine**
  - **Piston**
  - **Cylinder**
- **Pressure Transducer**
- **Blade with standard dimensions**



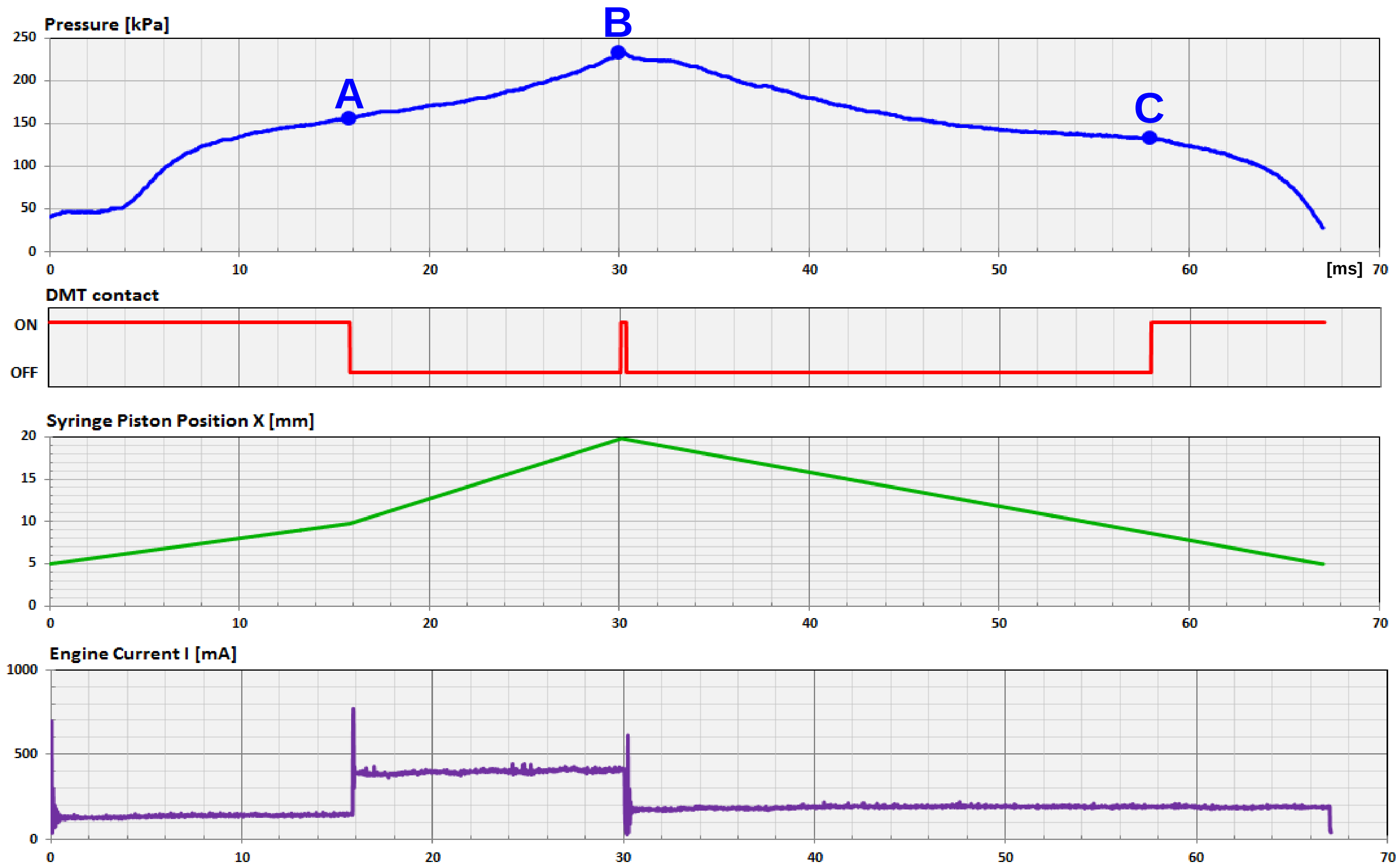
patent no. 18457.0137.US0000

Medusa DMT vs. Traditonal DMT

- ❑ No gas tank
- ❑ No control unit
- ❑ No pneumatic cable
- ❑ No operator required for inflation



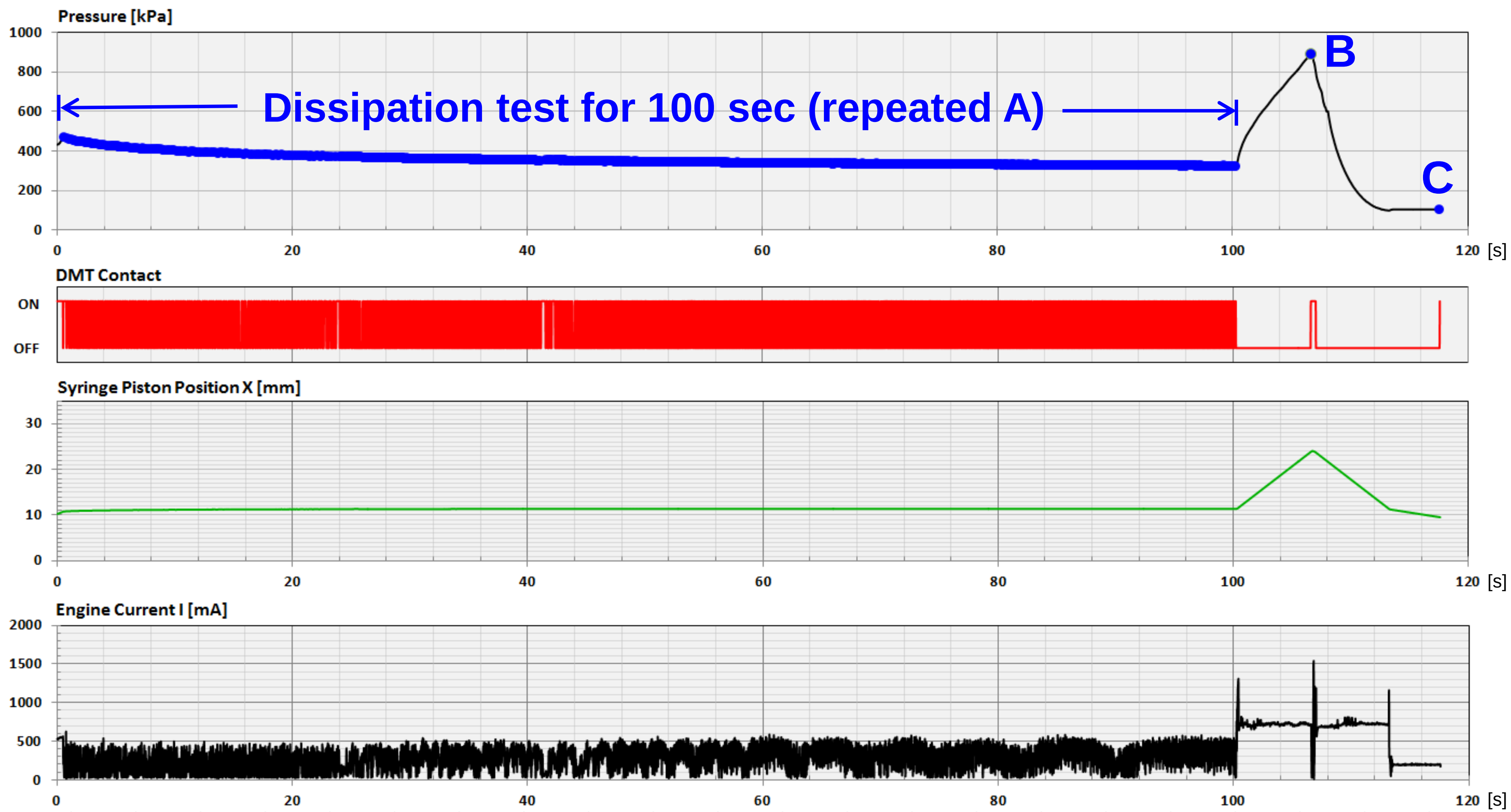
Medusa DMT: example of test cycle



T = 0 when penetration stops and test cycle begins

Dissipation test before membrane expansion

Motorized syringe able to maintain membrane in the A position → monitoring σ_h with time



Medusa DMT validation in a Tailing’s Dam

(Poland - November 2019)

Zelazny Most Tailings Dam – Poland

Main Characteristics:

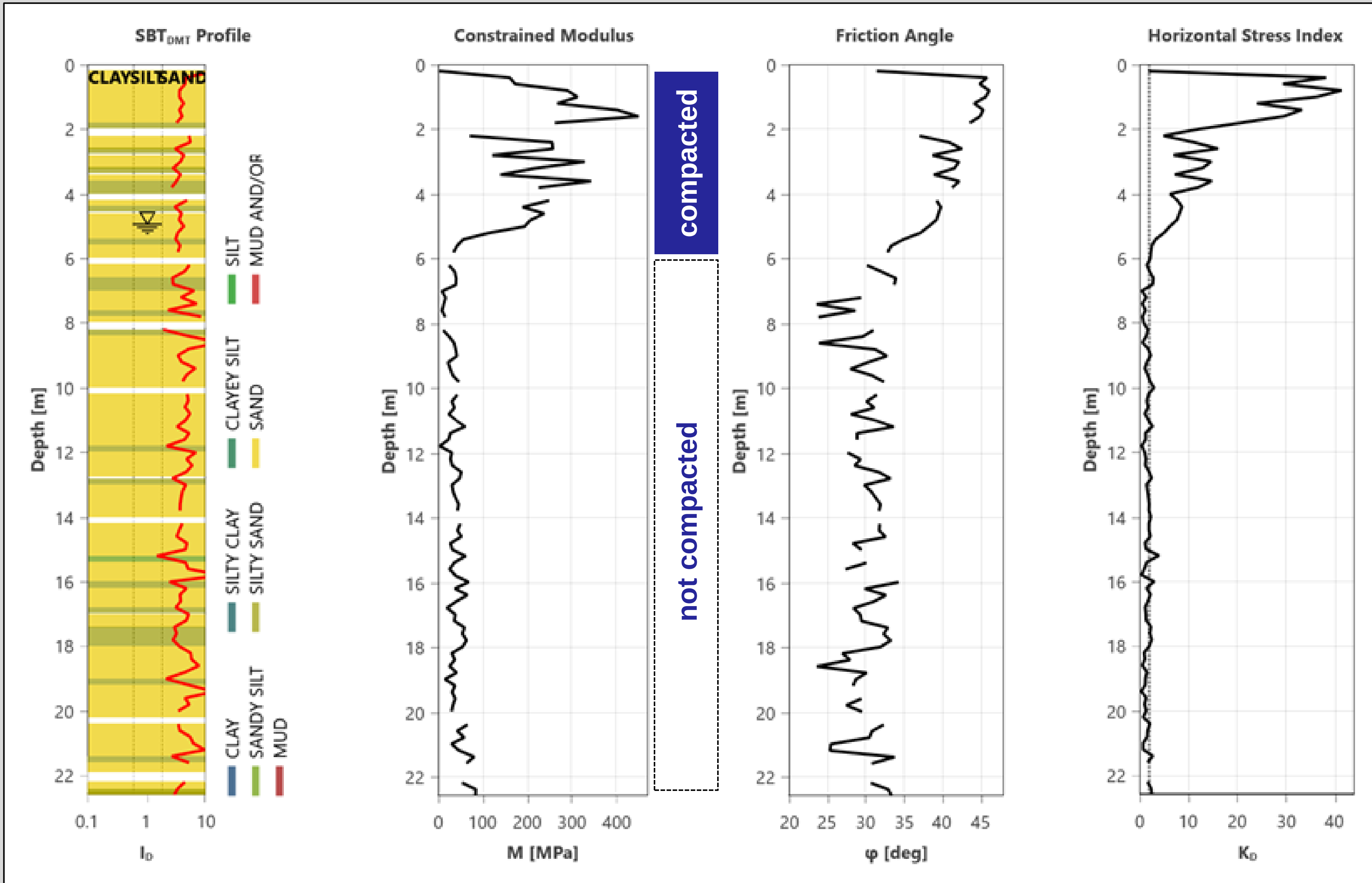
Geomaterial:	wastes copper mine
Maximum dam height:	66+ m
Total volume stored:	558x106 m^3
Storage rate:	29x106 m^3/year
Area covered:	14.0 km^2
Total Dam's length:	14.3 km
Operation time:	1977-2042

Medusa DMT validation in Zelazny Most

Zelazny Most Tailings Dam (Poland)
November 2019

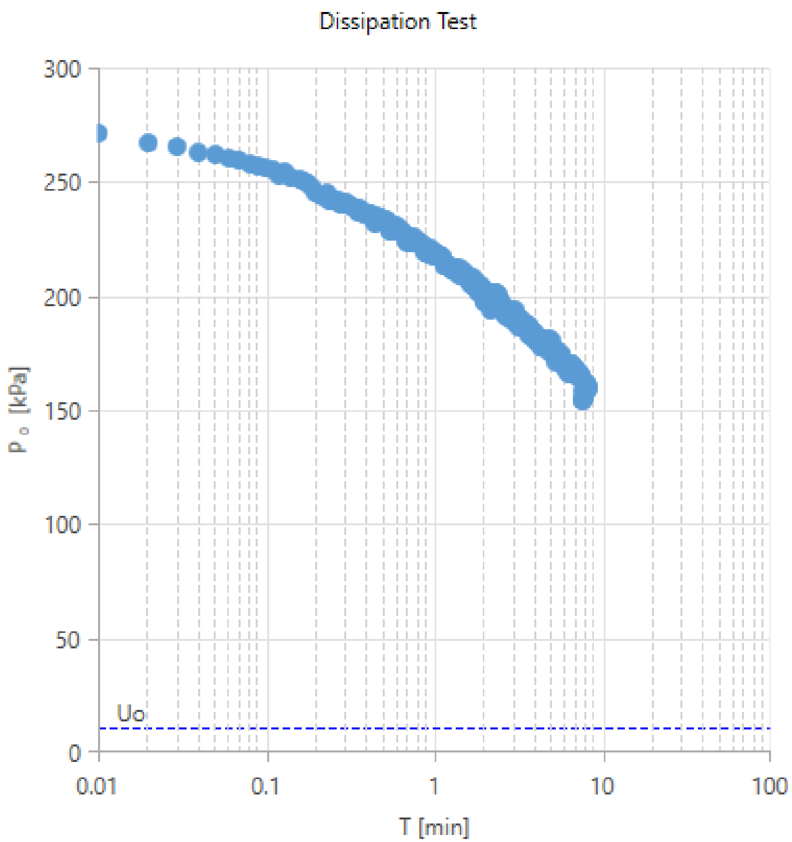
Medusa DMT at Zelazny Most – Poland

(November 2019)



Medusa DMT at Zelazny Most – Poland

(November 2019)



Partially Draining Layers (Niche Silts)

Significant dissipation during test execution:

→ Readings lower than expected

→ Readings require corrections

Medusa enables to detect this behaviour monitoring σ_h with time prior to standard DMT readings

F. Schnaid Mitchell Lecture for ISC'6 (delayed for COVID19)

Technical Questions

Email: diego@marchetti-dmt.it

Documentation

website: *www.marchetti-dmt.it*

Commercial Information

E-shop: *www.marchettidilatometershop.com*