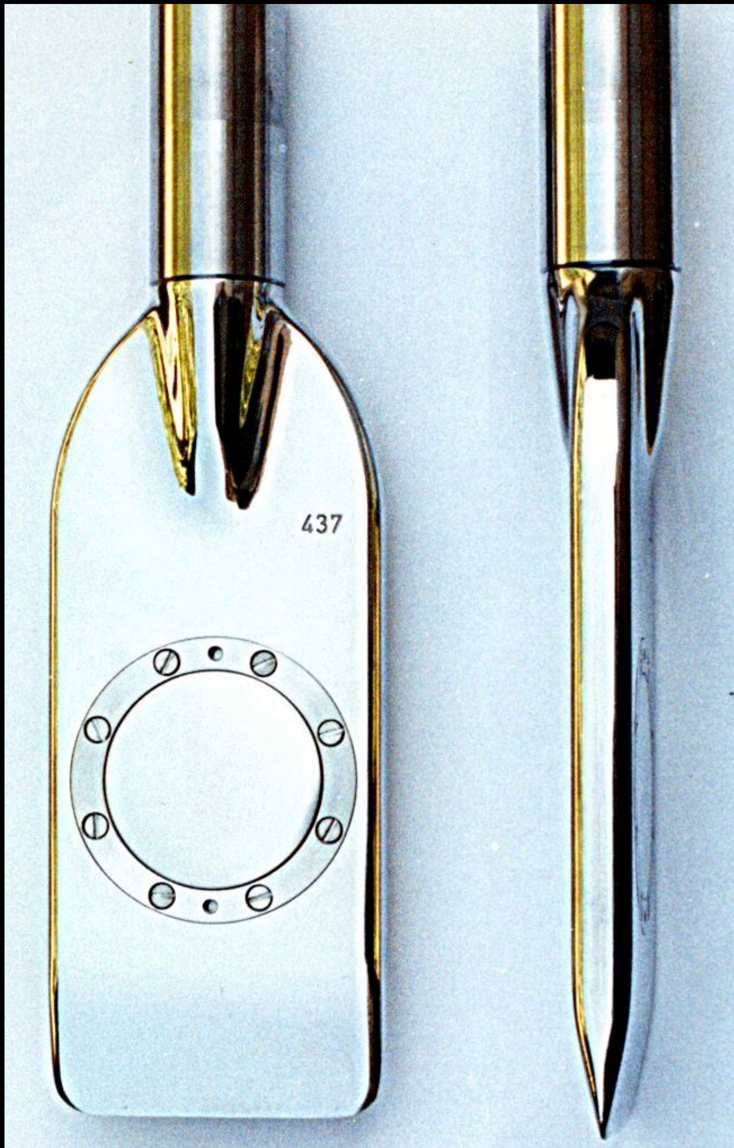
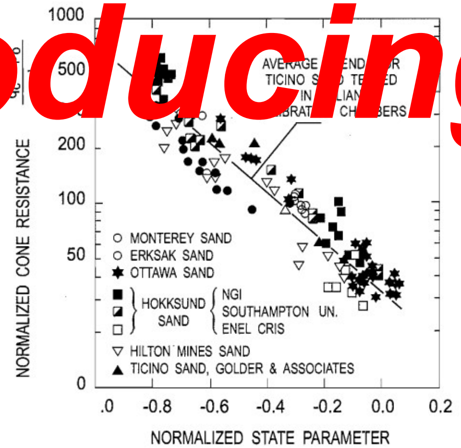


Marchetti’s Dilatometer (DMT)

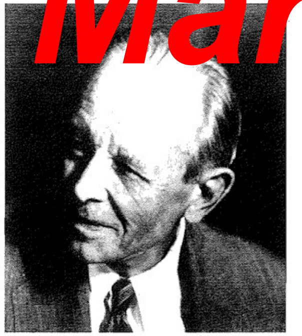
In situ 2001

In situ Testings and Soil Properties Correlations

Introducing Marchetti



$$\bar{\Psi} = \frac{\Psi}{e_{max} - e_{min}} = \frac{V_\lambda - \Gamma}{e_{max} - e_{min}}$$



in conjunction with

International Conference on In Situ Measurement of Soil Properties and Case Histories

Bali-Indonesia, May 21-24, 2001


International Site Characterisation Conference 2 (ISC’2)
Oporto, Portugal, Sept 2004
Introducing Marchetti

2nd International
Conference on the

FLAT

DILATOMETER

Introducing Marchetti

Washington DC

at the Arlington Hyatt Regency Hotel

April 2-5, 2006.

Details at

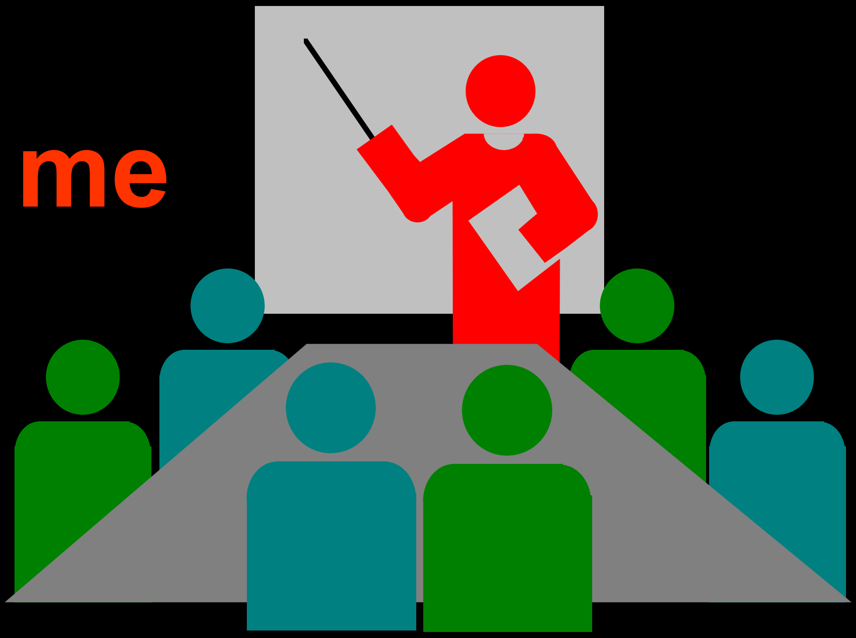
www.2006dmt.com

Silvano Marchetti

During My Presentation

- **Please ask questions**
- **Please make comments**

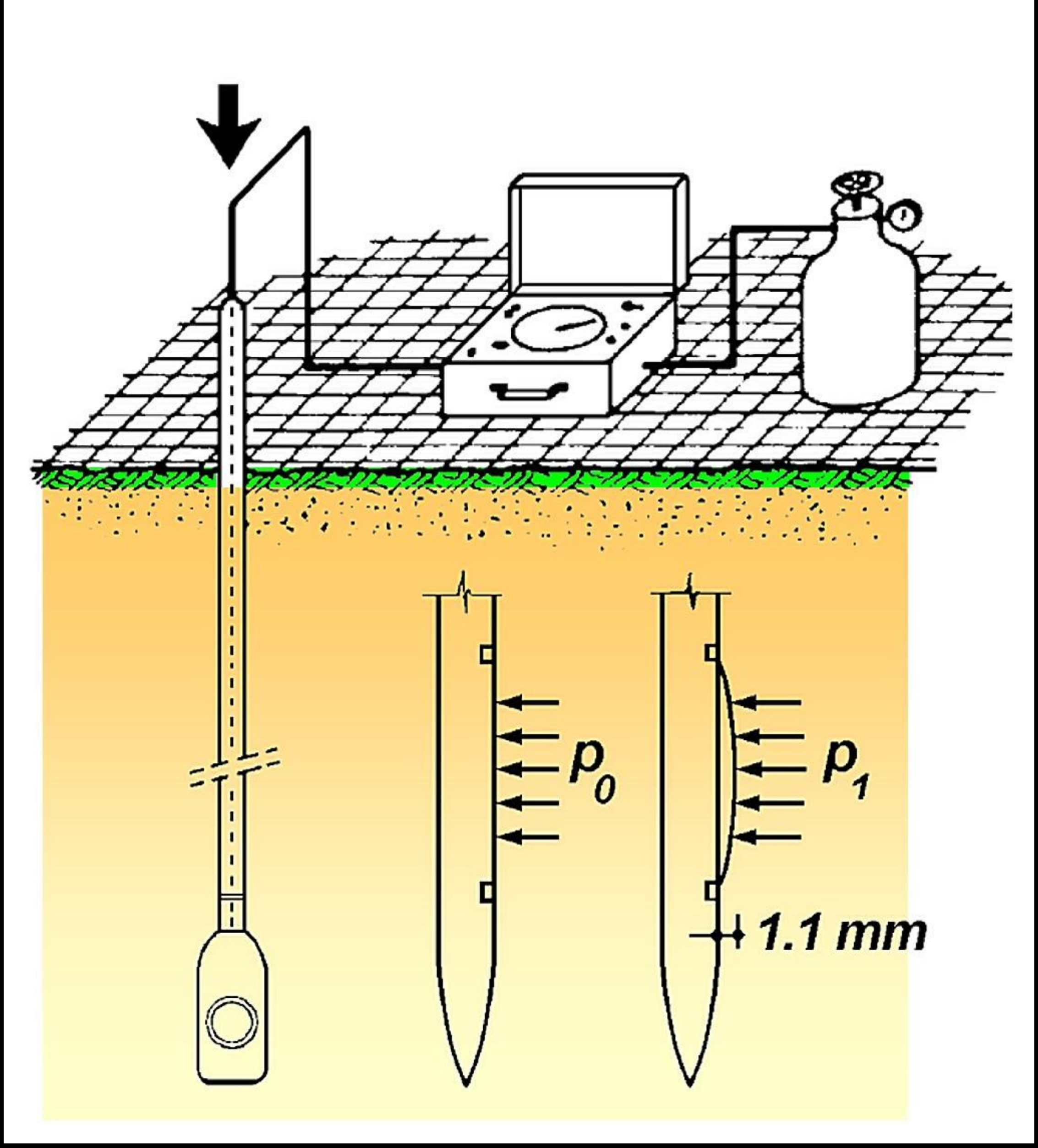
- **Please interrupt me**
- **Please enjoy**



July

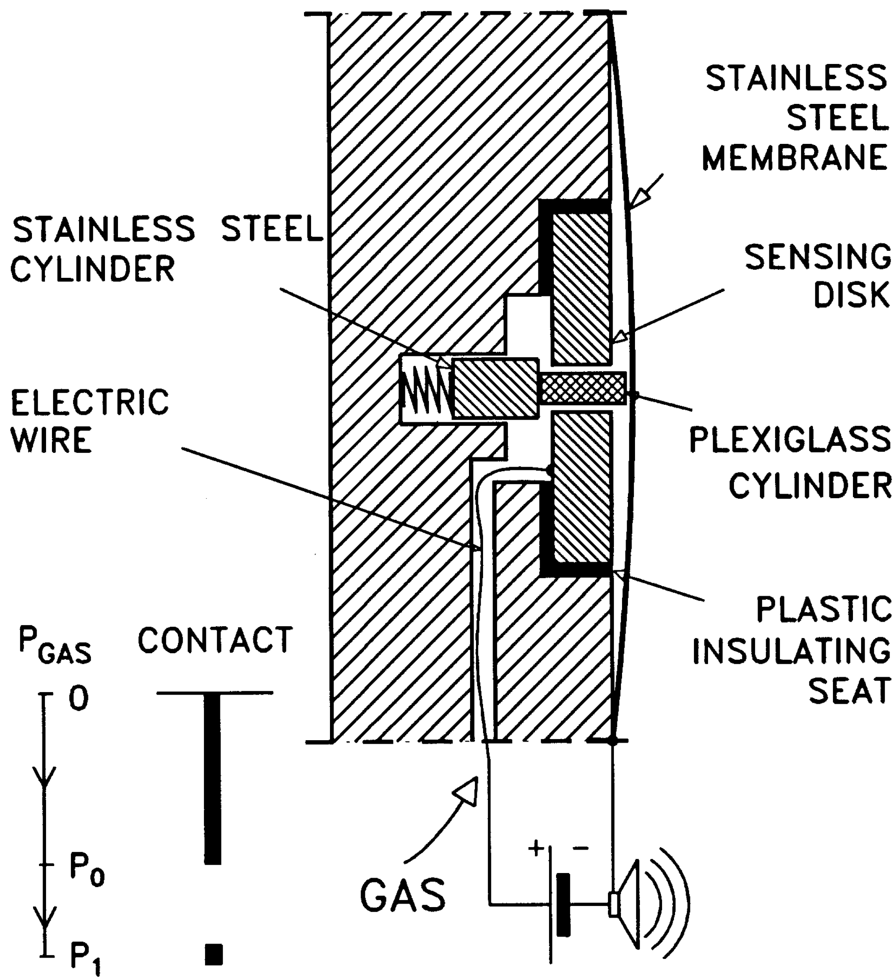
Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

2007



p_0
p_1
1.1 mm

WORKING PRINCIPLE



Only mechanical parts.

Fixed dimens. (± 0.01 mm).

Cannot be regulated.

Verify: only pressure (1.10 mm by construction)

BASIC (1980) REDUCTION FORMULAE

From A, B (p_0, p_1) :

Group	Symbol	Parameter	Formula
p_0 and p_1	p_0	Corrected First Reading	$p_0 = 1.05(A - Z_M + \Delta A) - 0.05(B - Z_M - \Delta B)$
	p_1	Corrected Second Reading	$p_1 = B - Z_M - \Delta B$
Inter-mediate parameters	I_D	Material Index	$I_D = (p_1 - p_0) / (p_0 - u_0)$
	K_D	Horizontal Stress Index	$K_D = (p_0 - u_0) / \sigma'_{vo}$
	E_D	Dilatometer Modulus	$E_D = 34.7\ (p_1 - p_0)$
Interpreted parameters	K_0	Coeff. Earth Pressure in Situ	$K_{0,DMT} = (K_D / 1.5)^{0.47} - 0.6$
	OCR	Overconsolidation Ratio	$OCR_{DMT} = (0.5\ K_D)^{1.56}$
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	γ	Unit Weight and Description	(see chart)
	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 $0.6 < I_D < 3$ $R_M = R_{M,0} + (2.5 - R_{M,0}) \log K_D$ where $R_{M,0} = 0.14 + 0.15(I_D - 0.6)$ If $K_D > 10$ $R_M = 0.32 + 2.18 \log K_D$ If $R_M < 0.85$ set $R_M = 0.85$
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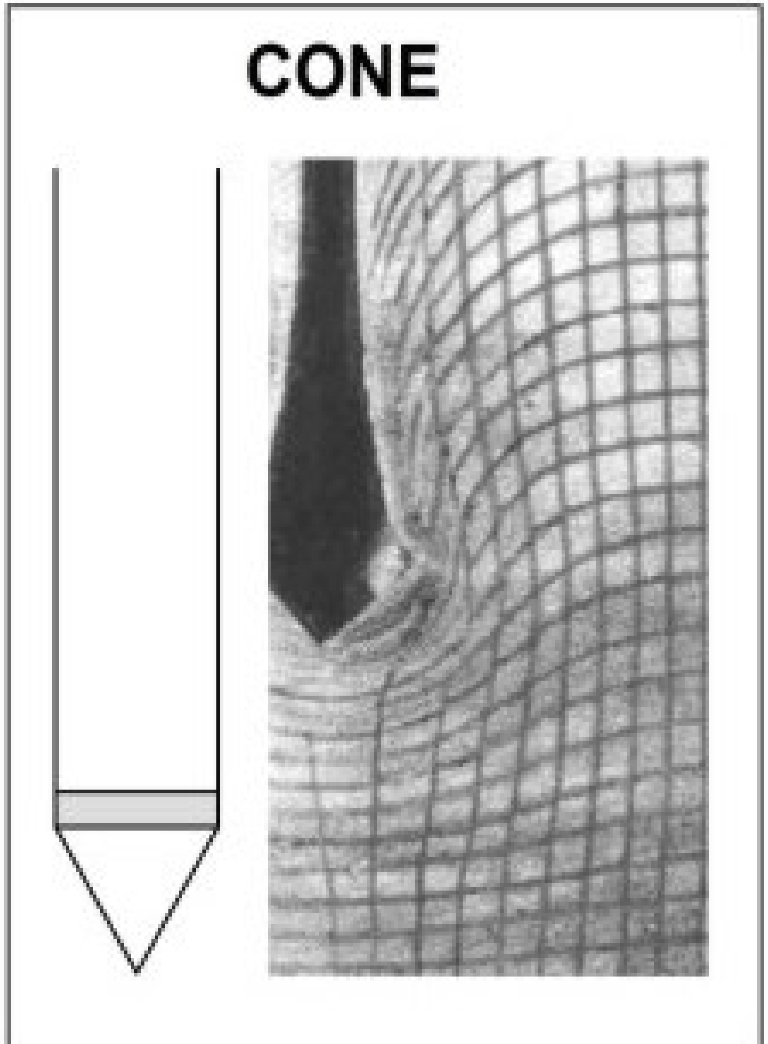
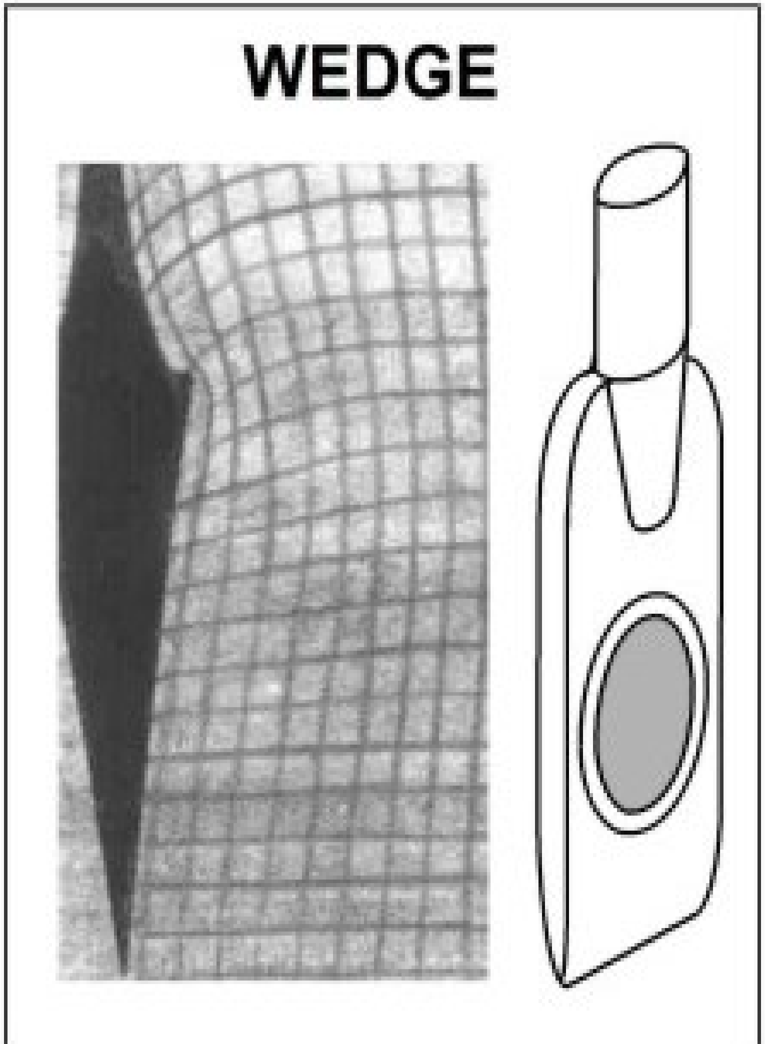
Kd : an amplified Ko

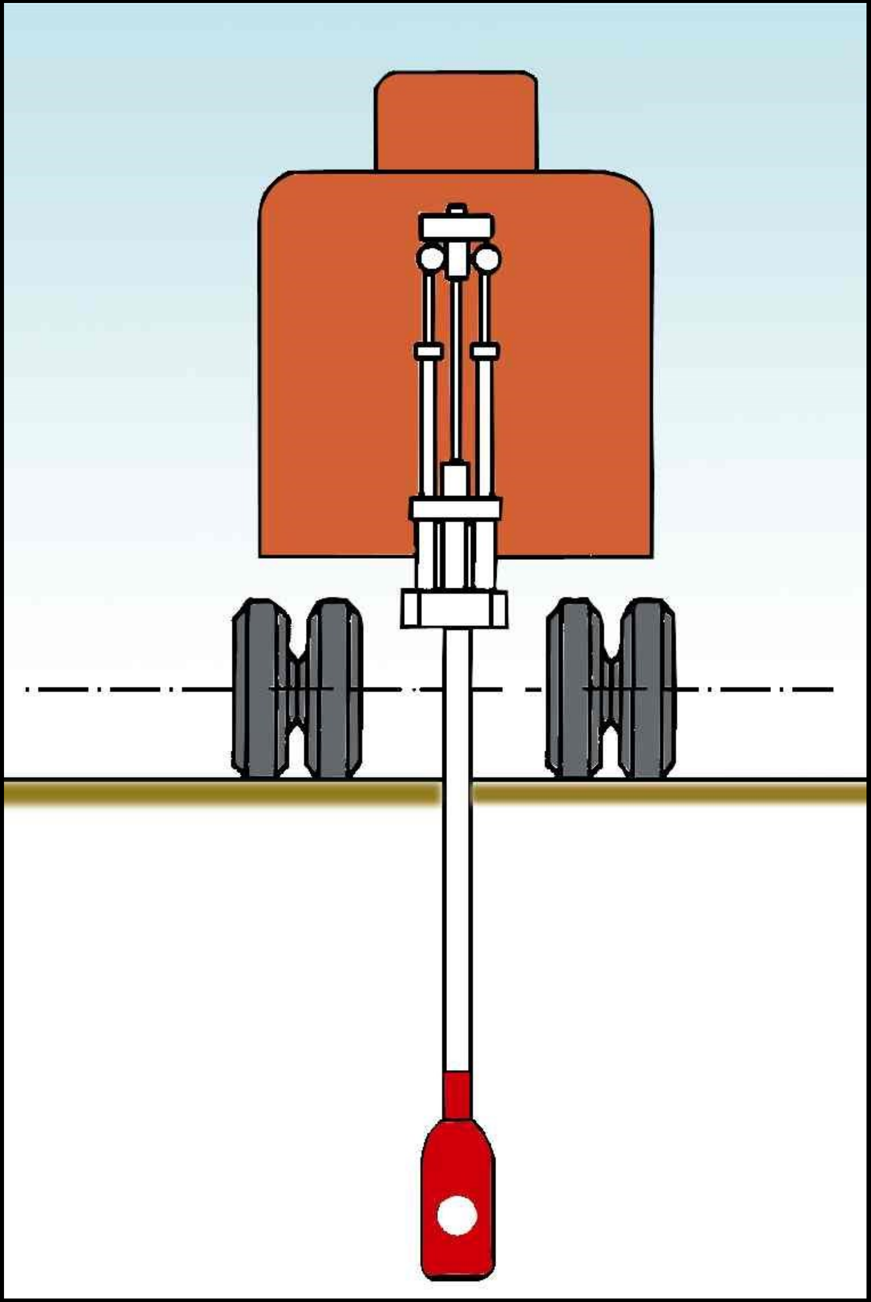
Theory of elasticity

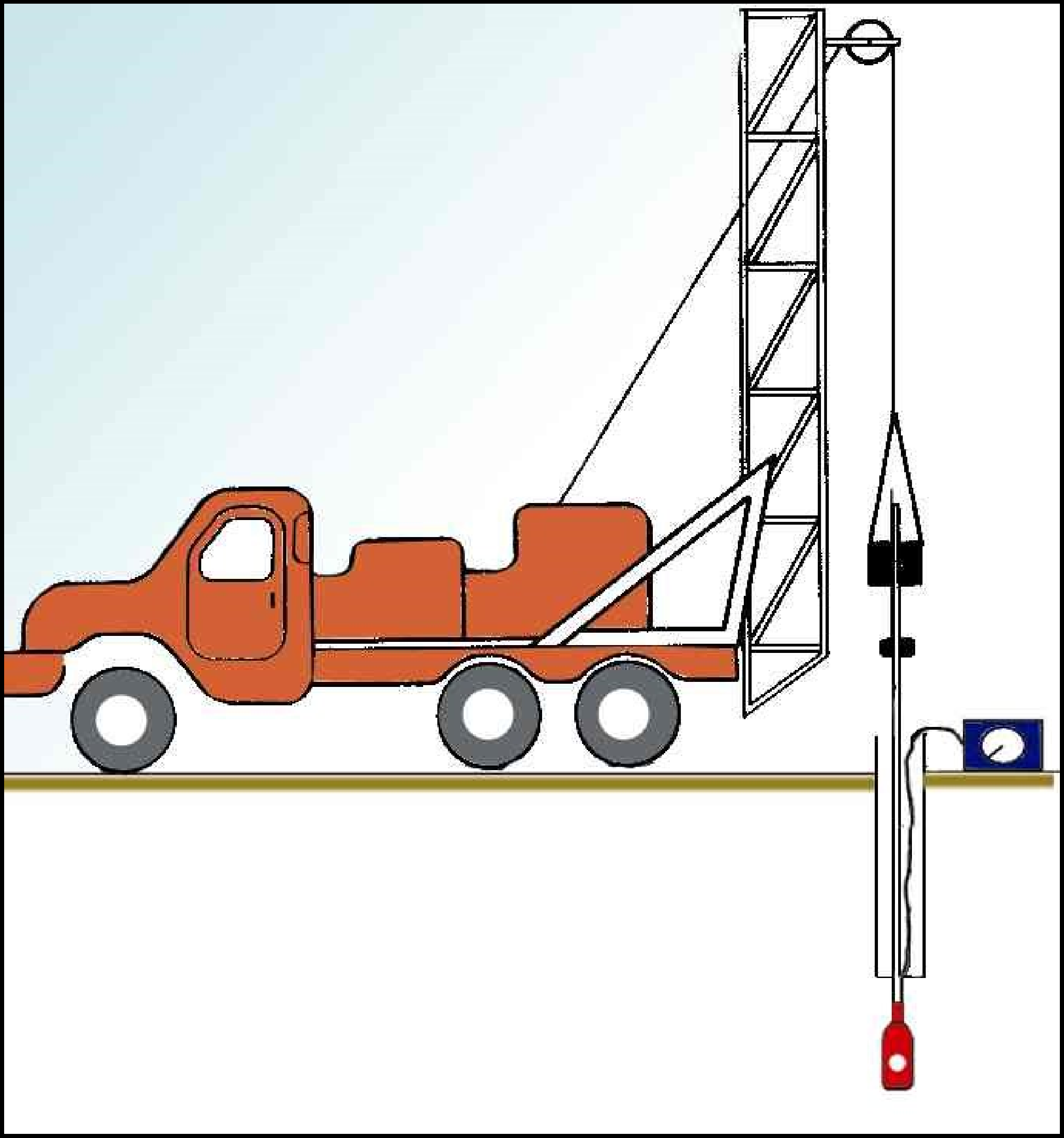
Rm=f(Kd,Id)
Distortion, Horiz to Vert Drained-undrained

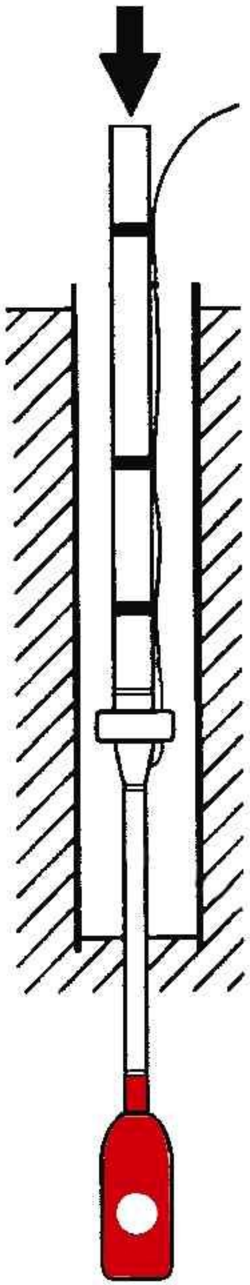
DISTORTIONS IN CLAY



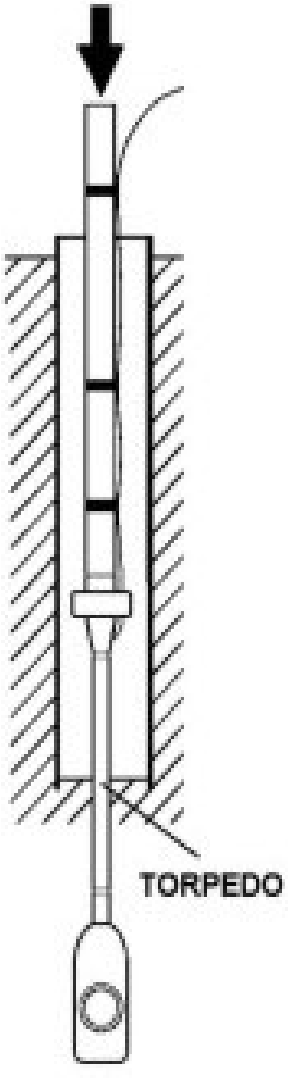


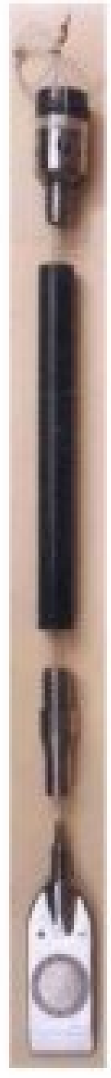






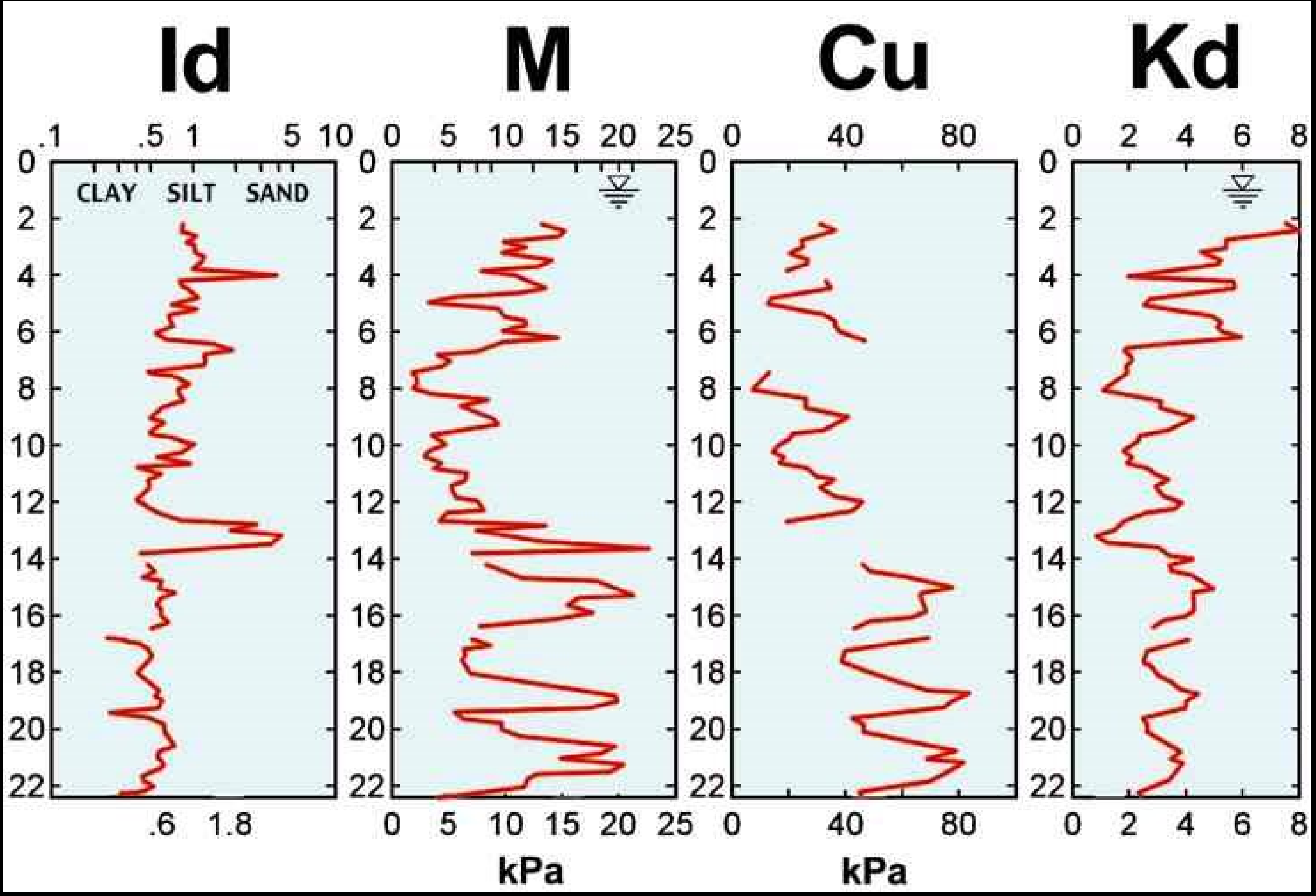
“TORPEDO” INSERTION METHOD





ASTM

INTERNATIONAL



Id
M
Cu
Kd
.1 .5 1 5 10
0 5 10 15 20 25
0 40 80
0 2 4 6 8
CLAY SILT SAND
0 2 4 6 8 10 12 14 16 18 20 22
.6 1.8
kPa
kPa

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Distortion, Horiz to Vert Drained-undrained

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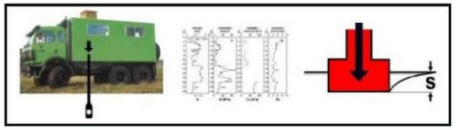
www.marchetti-dmt.it

Flat Dilatometer (DMT) downloadable papers.

by Prof. S. Marchetti marchetti@flashnet.it



Abstract : A dilatometer test consists of pushing a flat blade located at the end of a series of rods. Once at the testing depth, a circular steel membrane located on one side of the blade is expanded horizontally into the soil. The pressure is recorded at specific moments during the test. The blade is then advanced to the next test depth.
The main application of the DMT is to estimate **Settlements** and **Operative Moduli**, both in sands and clays.
Other design applications include: compaction control, detecting slip surfaces in slopes, liquefiability, laterally loaded piles and other geotechnical problems using the soil parameters for which the instrument provides estimates.

Distinctive features of DMT
Soil distortions. The dilatometer distorts the soil substantially less than any other penetration test.
Arching effect. The penetration of cylindrical probes creates a stiff soil ring surrounding the probe (Robertson & Hughes 1995). Such obstacle /parasitic screen reduces the sensitivity to σ_h (Huang 1994). Such arching effect is nearly nonexisting with the DMT flat blade (L/B ratio = 7), resulting in a higher sensitivity to σ_h.
Compaction control. The DMT is about twice as sensitive to compaction as other penetration tests (e.g. Schmertmann 1986, Jendeby 1992, Pasqualini 1993, De Cock-Van Impe-Peiffer 1993).

Key references (all downloadable – see list below):

- The **TC16 DMT Report by the ISSMGE (2001**) is a comprehensive document incorporating all the most important information on DMT.
- The **DMT Course Notes (2001)** by Marchetti and Monaco: usable as a "User's manual" by technicians actually performing DMT. Contains detailed figures on equipment, procedure, maintenance, tolerances and quality checks.
- **Manual of the software** DMT Elab.

Slide Show - General Information on (S)DMT (824 KB) (print version 2.6 MB)

Control Box and Blade	Test Layout	Machines for DMT Insertion
Examples of Results	Settlement-Moduli Comparisons	Cu comparisons

Interpretation Formulae	Database DMT sites in Italy	Soils testable by DMT
Working principle animation	Software: update, download ...	Transmit field data
Dmt Users Community	Quality Certification	Bibliography
Choice of Rig and Rods	Reading Hints	Field Data Sheets (Engl Ital)
Compaction	Plaxis Parameters	Settlements Calculation
Troubleshooting Hardware	Troubleshooting Interpretation	Troubleshooting Software

- **Second International Conference On the Flat Dilatometer Washington, D.C. April 2-5, 2006**
CALL FOR ABSTRACTS : Abstracts should be e-mailed to the conference editors: Roger Failmezger or Dr. Paul Bullock. Deadline for papers: Nov 1, 2005 (More info).
- **Monaco & Marchetti (2005) "Sand liquefiability assessment by Flat Dilatometer Test (DMT)", Proc. 16th ICSMGE Engineering, Osaka (pdf format 0.3 MB)**
- **Monaco & Marchetti(2004) "Evaluation of the coefficient of subgrade reaction for design of multi-propped diaphragm walls from DMT moduli", Proc. "Intnl Site Characterization" ISC'2 – Porto Portugal (pdf format 0.3 MB))**
- **SDMT - Seismic Dilatometer (2004), (SDMT Information 1.1 MB)**
- **Dmt Dissip (Dec 2002), Windows program for DMT Dissipations. (Sample Diagrams ,Info, Download)**
- **Dmt Elab (July 2002), Windows program for DMT. Dmt Elab also generates files *.uni used for settlements. (Sample Diagrams , Info , Download, Manual)**
- **Mayne, Martin, Schneider (1999) "Small- and Large-Strain Soil Properties from Seismic Flat Dilatometer Tests", Proc. Pre-failure Deformation Characteristics of Geomaterials, Jamiolkowski et al. editors, Torino. (pdf format 1 MB) [SDMT adds to the "standard" DMT the capability of determining Go. "E" and Go are then used combinedly to identify the modulus degradation curve]**
- **Devincenzi (2002) "El ensayo dilatométrico de Marchetti". Geotecnia 2002 (in Espanol) (pdf format 0.8 MB)**
- **Plaxis parameters (2002) "Hard Soil Model : E50,ref can be estimated from oedometer data (M)" (pdf format 0.1 MB)**
- **ASTM D6635-01 (2002) "Standard Test Method for Performing the Flat Plate Dilatometer". Book of Standards Vol. 04.09**

- **Marchetti S. (2001) "The Flat dilatometer", 18th CGT - Conferenze Geotecnica Torino, 56 pp. (pdf format 0.8 MB or doc format 1.1 MB) [Slides, in English]**
- **DMT Course Notes (2001) by Marchetti and Monaco, Bali Insitu 2001, 77 pp. (pdf format or doc format 4 MB). [Detailed figures on equipment, procedure, maintenance, tolerances and quality checks. A kind of "User's Manual", thought for technicians actually performing DMT]**
- **TC16 (2001) "The DMT in Soil Investigations", A Report by the ISSMGE Committee TC16, 41 pp. (pdf format or doc format 1 MB) ; (click here for the Italian version) [A comprehensive official reference covering in detail Field operations, Procedure, Interpretation, Applications].**
- **Powell, Lunne, Frank (2001) "Semi-Empirical Design Procedures for axial pile capacity in clays", Proc. XV ICSMGE, Istanbul 5 pp. (pdf format 0.05 MB) [New method by BRE-UK, NGI Oslo, LCPC Paris. Based on load tests on 60 driven or jacked piles at 10 clay sites in UK, Norway, France, Denmark. The Authors found that, for the piles in their study, the DMT-based method outperformed other methods for compression piles. A summary of the method can also be found in TC16 DMT 2001 (see Fig. 36)].**
- **Mayne P. (2001) "Settlements predicted by SPT and DMT vs settlement measured of a 13-story Dormitory Building for Georgia State University in Atlanta", Personal Communication.1 p. (htm format) [Prof. Mayne compares settlements predicted by SPT and DMT vs measured . "*The measured settlement was 9.8 inches. SPT had predicted 1 inch (in this case 1 order of magnitude lower). DMT + theory of elasticity gave essentially the correct answer*"].**
- **Totani, Marchetti, Monaco, Calabrese (2001) "Use of the Flat Dilatometer Test (DMT) in Geotechnical Design". IN SITU 2001, Intnl. Conf. On In situ Measurement of Soil Properties, Bali, Indonesia. (pdf format 0.2 MB) [Concentrated, 2001-updated, 6pp paper, summarizing main applications]**
- **ESSENTIALS (1-page) of the DMT (2001). A personal view by S. Marchetti (pdf format)**
- **Tice & Knott (2000) "Cape Hatteras Light Station Relocation" - ASCE Outstanding Civil Engineering achievement for 2000, Geo-Strata Oct. - 1p. summary from GPE-Florida (pdf format 40 KB) [Good agreement was observed between DMT-predicted and measured settlements at the sandy site under Cape Hatteras Light Station]**
- **Schnaid, Ortigao, Mantaras, Cunha, MacGregor (2000) "Analysis of self-boring pressuremeter (SBPM) and Marchetti dilatometer (DMT) tests in granite saprolites", Canad. Geot. Jnl. Vol. 37, 4, Aug 2000, 796-810 Abstract 1p. (pdf format 0.1 MB) [Compares parameters from SBPM and DMT]**
- **KCI Technologies, Md, Usa (2000): Webpage on DMT [By DMT "*a more cost effective design can result compared to using the SPT alone* (producing) *savings in construction cost*"]**
- **Failmezger R.(1998-2000) " (a) Describes his experience as a second engineer asked to reevaluate the first design (b) Designer liability for overdesign due non-state-of-the-art settlement predictions in USA (c) Differences in accuracy of settlements predicted by SPT and DMT" Pers. communication, 2p. (pdf format 10 KB)**
- **Failmezger R., Rom D., Ziegler S.B.(1999) "Behavioral Characteristics of Residual Soils. SPT?- A Better Approach to Site Characterization of Residual Soils using other In-Situ Tests", ASCE Geot. Special Pub. No. 92, Edelen, Bill, ed., ASCE, Reston, Virginia,158-175. (pdf format 70 KB) [5 case-histories comparing settlements predictions by SPT and DMT on pp.6-7-8. At Route 460 Blacksburg Bypass SPT predicted 100 mm settlements, while DMT predicted 27 mm (confirmed by oedometers)," leading to change in design and large savings". Generally SPT overpredicted settlements (in one case by a factor 10). Also of interest p.10: Settlement Probability Design; and p.15: Diagram comparing M_{DMT} - M_{oed}]**
- **Marchetti S.(1999) "On the calibration of the DMT membrane", L'Aquila University, Italy, Internal techn. note, 9 pp. (pdf format 0.2 MB) [Should be read by operators, especially important when testing in very soft soils]**
- **Pelnik, Fromme, Gibbons, Failmezger (1999)."Foundation Design Applications of CPTU and DMT Tests in Atlantic Coastal Plain Virginia", Transp. Res. Board, 78th Annual Meeting, Jan., Washington, D.C. Abstract 2 p. (pdf format 10 KB) [Case histories and Table comparing the relative ability of CPTU and DMT to predict settlements in Virginia sediments]**
- **Marchetti S. (1999) " The Flat Dilatometer and its applications to Geotechnical Design ", Lecture notes (90 pp) Intnl Seminar on DMT held at the Japanese Geot. Society, Tokyo, 12 Feb 1999 (pdf format 1.3 MB). Very detailed reference. Index: DMT equipment, Field equipment, Procedure, Derivation of parameters, Results, Distortions due to penetration, Comparisons with other tests, Coeff. of Consolidation & Permeability (clay), Settlements, *Operative* modulus, Detect slip surfaces in slopes, P-y curves for lat. loaded piles, Sand liquefaction, Compaction control, Pavement subgrade control, Subgrade Kh for anchored diaghrams, DMT for FEM.**
- **Totani, Marchetti, Monaco, Calabrese (1999) "Impiego della prova dilatometrica nella progettazione geotecnica", XX Convegno Ital. di Geotecnica, Parma, Sept. (In Italian). (pdf format 0.4 MB)**
- **Tanaka (1998)."Characterization of Sandy Soils using CPT and DMT", Soils and Foundations, Japanese Geot. Soc.,Vol. 38, 3 , 55-65. (pdf format 1.4 MB) [Comparisons with parameters determined on high quality frozen sand samples]**
- **Totani, Calabrese, Monaco (1998)."In situ determination of Ch by Flat Dilatometer (DMT)", Proc. First Intnl Conf. On Site Characterization ISC '98, Atlanta, Georgia (USA), 883-888. (pdf format 0.7 MB) [Illustrates case-histories comparing Ch by DMTA dissipations with Ch backfigured from real works observations. The rate of consolidation predicted by DMTA was 1 to 3 times slower than real]**
- **Milestones on LIQUEFACTION (1998) / RELATIVE DENSITY excerpts from: Tanaka 98 (11pp), Robertson 98 (1pp), Howy and Yu 97 (4pp), Jefferies 95 (2pp), Sladen 89 (10pp), Schmertmann 86 (4pp) (To download, click the Author !)**
- **Totani G., Calabrese M., Marchetti S. and Monaco, P. (1997). " Use of in situ flat dilatometer (DMT) for ground**

characterization in the stability analysis of slopes". Proc. XIV Intnl Conf. on Soil Mechanics and Foundation Engineering, Hamburg, Sept., Vol. 1, pp. 607-610. (doc format 0.4 MB) [About the Kd=2 method to verify the presence of sliding surfaces (active or quiescent) in an overconsolidated clay slope]

- **Marchetti S. (1997). "The Flat Dilatometer : Design Applications". Third Geotechnical Engineering. Conf. Cairo Univ. Jan. 1997, Keynote lecture, 26 pp. (pdf format 0.4 MB) [Comprehensive in depth detailed treatment]**
- **Eurocode 7, (1997) " Geotechnical Design. Part 3 : Design assisted by field tests, "Flat Dilatometer Test (DMT)". (pdf format 0.6 MB)**
- **Kamei T. and Iwasaki K. (1995) "Evaluation of undrained shear strength of cohesive soils using a Flat Dilatometer", Soils and Foundations, Vol. 35, 2, 111-116, June. (pdf format 0.6 MB) [Compares DMT's vs other tests' parameters from numerous distant geographical areas. Confirms the strong correlation in clays OCR-Kd, virtually similar to the 1980 original correlation]**
- **Sawada S. and Sugawara N. (1995) "Evaluation of densification of loose sand by SBP and DMT", Proc. 4th Int. Symp. On Pressuremeter, Sherbrooke, Canada, 17-19 May '95, Balkema, 101-107. (pdf format 0.8 MB) ["*SBP and DMT are valuable tools for estimating soil parameters on sandy soil and effectiveness of the treatment ... SBP is much time-consuming and too much expensive*"]**
- **Steiner W. (1994) "Settlement Behaviour of an Avalanche Protection Gallery Founded on Loose Sandy Silt", Settlement '94 ASCE Conf. at Texas A&M, Vol. 1, 207-221 - Abstract & Conclusions 2p. (pdf format 0.2 MB) [An earthfill on a loose sandy-silt produced settlements substantially higher than anticipated based on conventional soil borings. DMT were then performed. The DMT-predicted settlements agreed well with observed settlements]**
- **Massarsch K.R. (1994) "Settlement Analysis of Compacted Granular Fill", Proc. 13 ICSMFE New Delhi, Vol.1, 325-328. (pdf format 0.6 MB) [Emphasizes the necessity of considering the Sigmah increase due to compaction for settlement calculation. Massarsch notes "*attempts have been made to correlate directly tangent modulus M to Qc, but with limited success (Jamiolkowski et al.1988)*". Without consideration of stress history / OCR due to compaction, settlements could easily be overestimated by a factor > 3, as high lateral stresses reduce substantially settlement]**
- **Finno R. J. (1993) "Analytical Interpretation of Dilatometer Penetration Through Saturated Cohesive Soils", Geotechnique 43 No.2, 241-254. Abstract 2 p. (pdf format 0.22 MB) [Finds theoretically (Anisotropic Bounding Space Model) an OCR-Kd relation practically identical to the 1980 experimentally-established original correlation]**
- **Woodward, McIntosh (1993) "Case history : Shallow Foundation Settlement Prediction Using the Marchetti Dilatometer", ASCE Annual Florida Sec. Meeting - Abstract & Conclusions 3p.(pdf format 0.2 MB) [Reports good agreement between DMT-predicted and observed settlements at a sandy site. "*Use of modulus from DMT permitted considerable savings vs using data from SPT. SPT, for this project, underpredicted the modulus* " producing non-state-of-the-art settlement predictions]**
- **Wong J.T.F., Wong M.F. and Kassim K. (1993) "Comparison between Dilatometer and Other In-Situ and Laboratory Tests in Malaysian Alluvial Clay". 11th Southeast Asian Geot. Conf., 4-8 May 93, Singapore, 275-279. (pdf format 0.5 MB) []**
- **Geopac (1992) "Comparisons of settlements predicted by PMT and DMT in a silty-sandy soil in Quebec",. Pers. communication (pdf format 90 KB) [*...settlements predicted by PMT and DMT were very similar, but the time for testing quite different.*]**
- **Jendeby L. (1992) "Deep Compaction by Vibrowing", Nordic Geotechnical Meeting NGM-92, Vol. 1, 19-24 Abstract 2p. (pdf format 0.1 MB) [A sandfill compaction case. Mdmt reflected the compaction about twice more sensitively than Qc. The ratio M/Qc (before-compaction 8-10) increased, after compaction, to ca. 25. The ratio M/Qc possibly usable as a rough indicator of OCR]**
- **Iwasaki K. et. al (1991) "Applicability of the Marchetti Dilatometer Test to Soft Ground in Japan", GEOCOAST '91, Sept. 1991, Yokohama 1/6, 4 pp. (pdf format 0.4 MB) [Documents very good agreement between M and Cu by DMT and from high quality samples in Tokyo Bay]**
- **Reyna, F. & Chameau, J.L. (1991) "Dilatometer Based Liquefaction Potential of Sites in the Imperial Valley". 2nd Int. Conf. on Recent Advances in Geot. Earthquake Engrg. and Soil Dyn.. St. Louis. May, 7 pp. (pdf format 1.0 MB) []**
- **Hayes(1990) "The Marchetti Dilatometer and Compressibility", Southern Ontario Section of the Canad. Geotechn. Society. Seminar on "In Situ Testing and Monitoring". Introduction and 2 summary diagrams. (pdf format 0.2 MB) [Has diagrams with many datapoints showing good agreement between observed and DMT-predicted settlements and moduli]**
- **Marchetti & Totani (1989) "Ch Evaluations from DMTA Dissipation Curves", Proc. XI ICSMFE, Rio de Janeiro, Vol. 1: 281-286. (pdf format 0.7 MB) [Initial paper illustrating the proposed methodology for deriving Ch from Tflex of the DMTA dissipation curves]**
- **Powell, J.J.M. & Uglow, I.M. (1988) "The Interpretation of the Marchetti Dilatometer Test in UK Clays". ICE Proc. Penetration Testing in the UK. Univ. of Birmingham, Paper 34: 269-273. July. (pdf format 0.6 MB) []**
- **Leonards, G.A. & Frost, J.D. (1988) "Settlement of Shallow Foundations on Granular Soils". ASCE Jnl of Geotechn. Engineering, Vol. 114, No. 7: 791-809. July. Abstract 1 p. (pdf format 0.15 MB) [Deals with settlements predictions in sand by DMT. Emphasizes that "*In granular soils correlations between penetration resistance and soil modulus (Terzaghi & Peck 1967, Schmertmann 1970) seriously overestimate settlements if the deposits has been prestressed*". Ranks the usefulness of various in situ tests for predicting settlements in sand]**
- **Lutenegger, A.J. (1988) "Current Status of the Marchetti Dilatometer Test" Invited Lecture. Proc. ISOPT-1, Orlando, FL, Vol. 1: 137-155. Mar. (pdf format 2.2 MB) [State of the art of DMT in 1988]**

- **Robertson, P.K., Davies, M.P. & Campanella, R.G. (1987) "Design of Laterally Loaded Driven Piles Using the Flat Plate Dilatometer". Geotechnical Testing Jnl, Vol. 12, No. 1: 30-38. March (pdf format 1.0 MB) []**
- **Robertson, P.K.& Campanella, R.G. (1986) "Estimating Liquefaction Potential of Sands Using the Flat Plate Dilatometer". Geotechnical Testing Journal, Vol. 9, No. 1: 38-40. March (doc format 0.4 MB) []**
- **Schmertmann, J.H.et al.(1986) "CPT/DMT Quality Control of Ground Modification at a Power Plant". Proc. In situ '86 ASCE Spec. Conf. Virginia Tech, Blacksburg, VA, pp.985-1001. (pdf format 1.1 MB) [Compaction caused a % increase of Mdmt ca. double than the % increase of Qc,cpt. Schmertmann recommends issuing specifications in terms of modulus rather than (elusive) Dr]**
- **ASTM SUBCOMMITTEE 18.02,(1986) "J.H. Schmertmann, Chairman, "Suggested Method for Performing the Flat Dilatometer Test". ASTM Geotechn. Testing Journal, Vol. 9, 2, June, 93-101 (pdf format 1.2 MB) []**
- **Lacasse & Lunne (1986) "Dilatometer Tests in Sand". Proc. In Situ '86 ASCE Spec. Conf. Virginia Tech, Blacksburg, VA : 686-699. Abstract 1 p. (pdf format 0.1 MB) [Reports good agreement between DMT-predicted and measured settlements under a silos at a sandy site]**
- **First International Conference on the Flat Dilatometer, Mobile Augers and Research Ltd., Edmonton, Alberta (1983) (pdf format 5.6 MB) [Papers by Schmertmann, Hayes, Mekechuk, Burges & Campanella]**
- **Marchetti, S. (1982) "Detection of liquefiable sand layers by means of quasi static penetration tests". Proc. 2nd European Symp.on Penetration Testing, Vol. 2: 689-695. Amsterdam, NL. May. (doc format 0.6 MB) [Two stage Calibration Chamber tests to evaluate DMT sensitivity to pure prestrain - study aimed at detecting sand liquefiability]**
- **Marchetti, S. (1980) "In Situ Tests by Flat Dilatometer". Journal of the Geotechn. Engineering Division, ASCE, Vol. 106, No. GT3, Proc. Paper 15290, p. 299-321. (pdf format 2.0 MB) [Original 1980 paper on DMT. Derivation of the correlations]**

READING HINTS. For a general overview, see the following comprehensive documents:

Readers unfamiliar with DMT : Totani et al. 2001 Bali, 6 pages (in Italian : Totani et al. 1999 Parma).

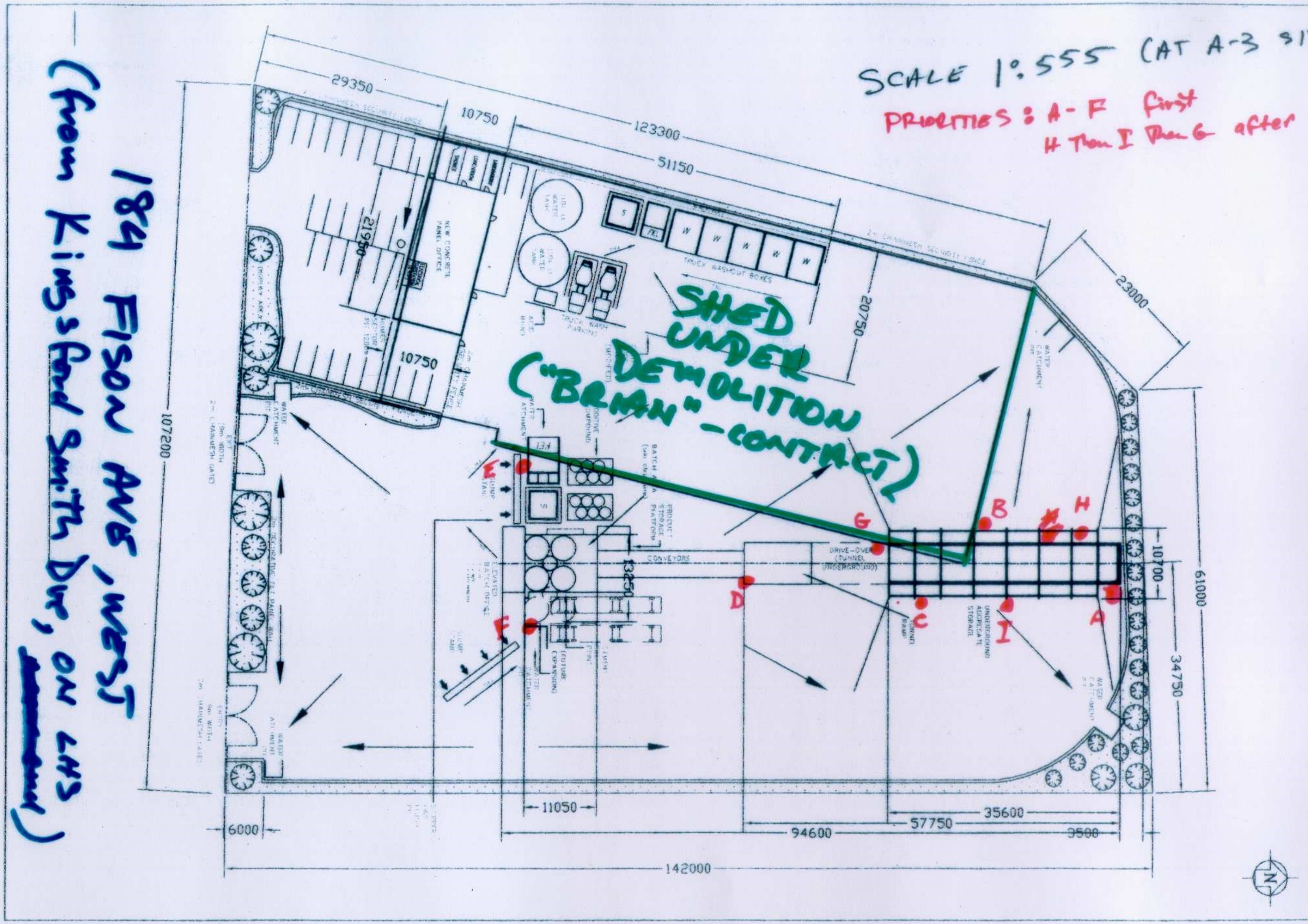
More detailed and extensive treatment : (a) In the form of paper : Marchetti 1997 Cairo and especially TC16 2001 Bali. (b) In the form of a series of slides: Marchetti 1999 Tokyo, Marchetti 2001 Torino. (c) In the form of Course Notes - User's Manual : Course Notes 2001 Bali

PAPERS (of the above list) GROUPED BY TOPIC - ALL DOWNLOADABLE
Settlements and compressibility : Schmertmann 86, Lacasse 86, Leonards 88, Hayes 90, Iwasaki 91, Geopac 92, Jendeby 92, Woodward 93, Steiner 94, Tanaka 98, Failmezger 98-2000, Failmezger et al. 99, Pelnik et al.99, Schnaid et al 2000, Tice & Knott 2000

PMT and DMT : Schmertmann 87 Digest 9, Geopac 92, Kalteziotis 91, Lutenegger 88 and 90, Wong 93, Sawada 95, Ortigao 96, Schnaid 2000

Ch and K by DMT : Robertson 88, Schmertmann 88, Marchetti 89, Totani 98

Liquefaction : Marchetti 82, Robertson 86 , Reyna 91, Tanaka 98, Milestones on liquefaction 98, TC16 2001


SCALE 1:555 (AT A-3 SIZE)
PRIORITIES: A - F first
H Then I Then G after
SHED UNDER DEMOLITION ("BRIAN" - CONTACT)
184 FISON AVE, WEST
(from Kingsford Smith Dr, ON LHS)
29350
10750
123300
51150
21950
20750
23000
10750
107200
TRUCK WASHOUT BOXES
NEW CONCRETE PANEL OFFICE
CONVEYORS
DRIVE-OVER (TUNNEL UNDERGROUND)
UNDERGROUND AGGREGATE STORAGE
ELEVATED BATCH DECK
PRODUCT STORAGE PLATFORM
WATER CATCHMENT PIT
13250
10700
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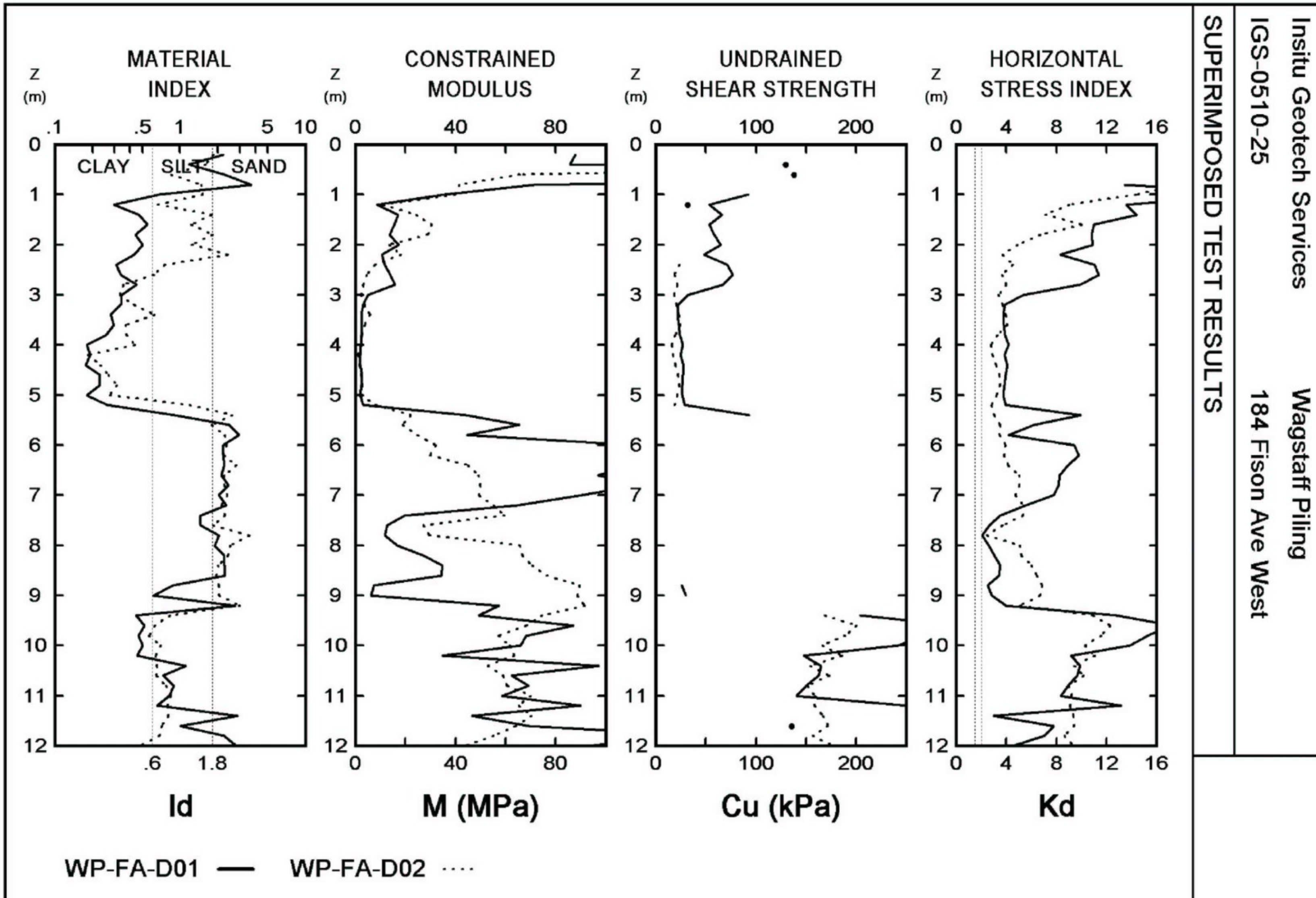
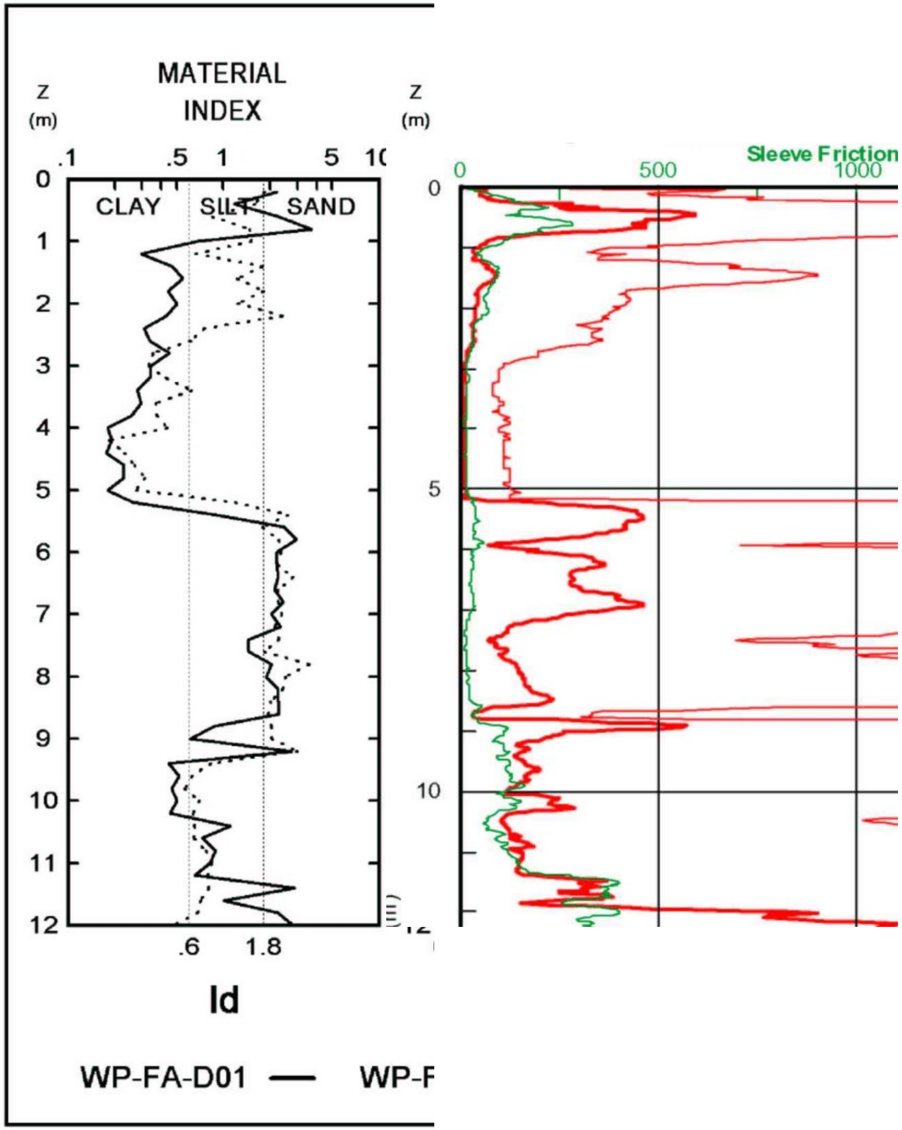
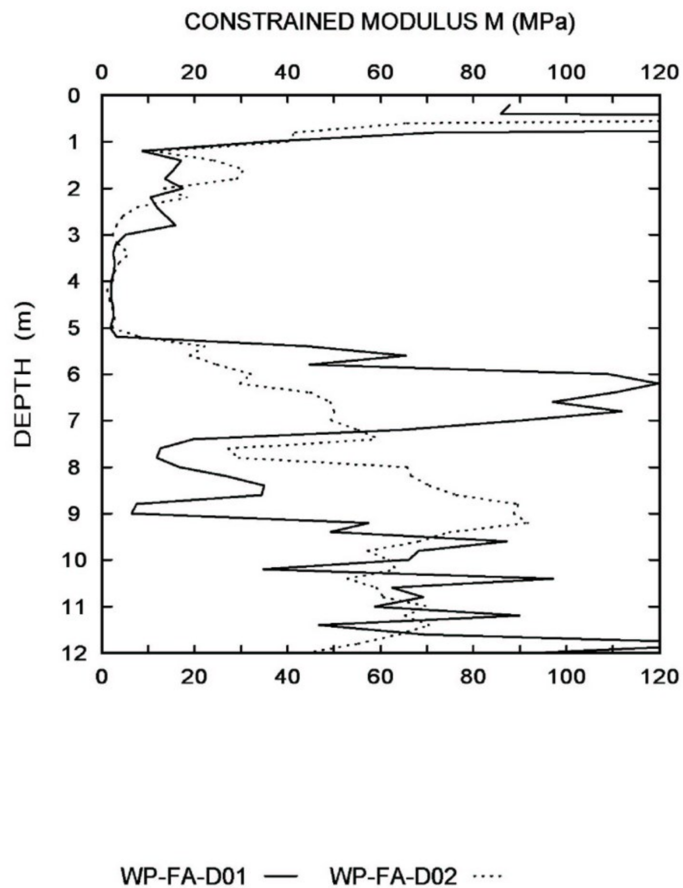


MATERIAL INDEX
CONSTRAINED MODULUS
UNDRAINED SHEAR STRENGTH
HORIZONTAL STRESS INDEX
Z (m)
CLAY
SILT
SAND
Id
M (MPa)
Cu (kPa)
Kd
WP-FA-D01
WP-FA-D02
Insitu Geotech Services
IGS-0510-25
SUPERIMPOSED TEST RESULTS
Wagstaff Piling
184 Fison Ave West


MATERIAL
INDEX
Z
(m)
.1 .5 1 5 10
CLAY SILT SAND
0 1 2 3 4 5 6 7 8 9 10 11 12
.6 1.8
Id
WP-FA-D01
Sleeve Friction
0 500 1000
0 5 10

Insitu Geotech Services	Wagstaff Piling
IGS-0510-25	184 Fison Ave West

SUPERIMPOSED TEST RESULTS



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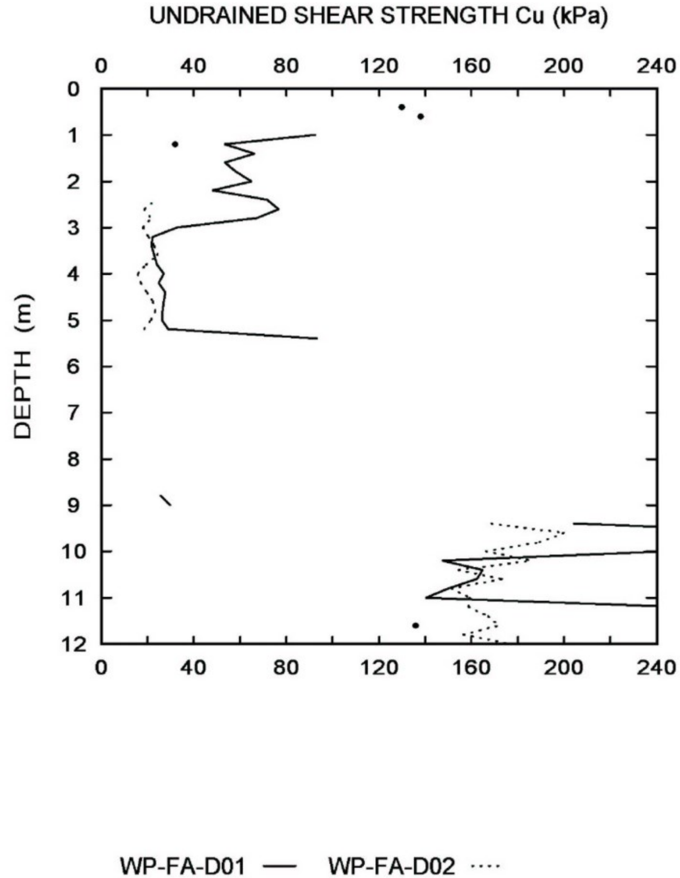
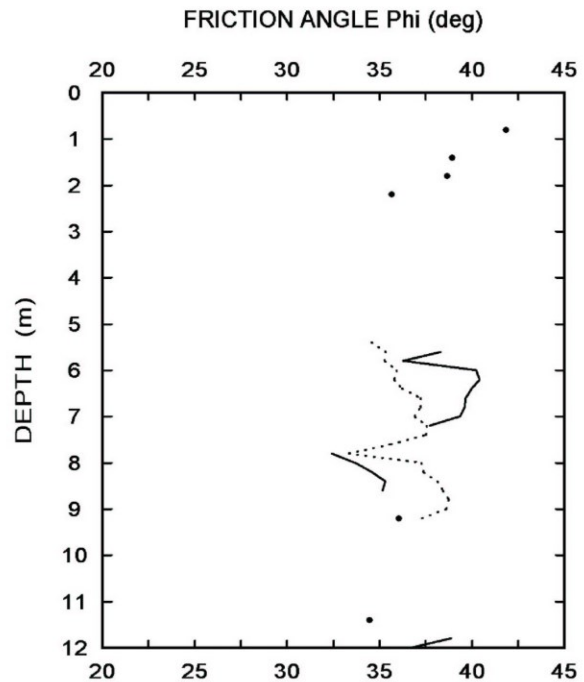
IGS-0510-25	184 Fison Ave West	
SUPERIMPOSED TEST RESULTS		



Insitu Geotech Services	Wagstaff Piling
IGS-0510-25	184 Fison Ave West

SUPERIMPOSED TEST RESULTS



WP-FA-D01 —— WP-FA-D02 ····

2nd International Conference on the

FLAT DILATOMETER

Washington DC

at the Arlington Hyatt Regency Hotel

April 2-5, 2006.

Details at

www.2006dmt.com

Dr Paola Monaco – L'Aquila University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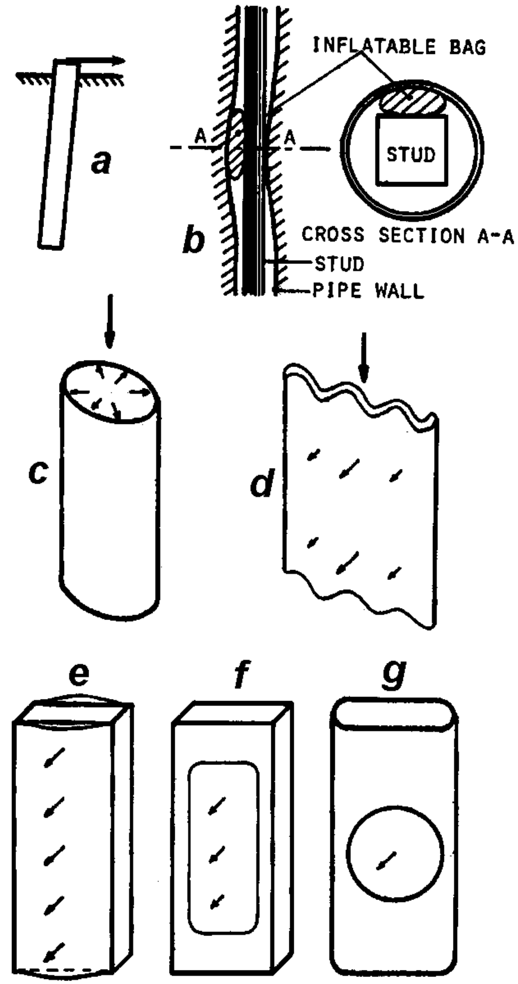
Background

Original stimulus for development of DMT ➡ tool for parameters for DESIGN of LATERALLY LOADED PILES

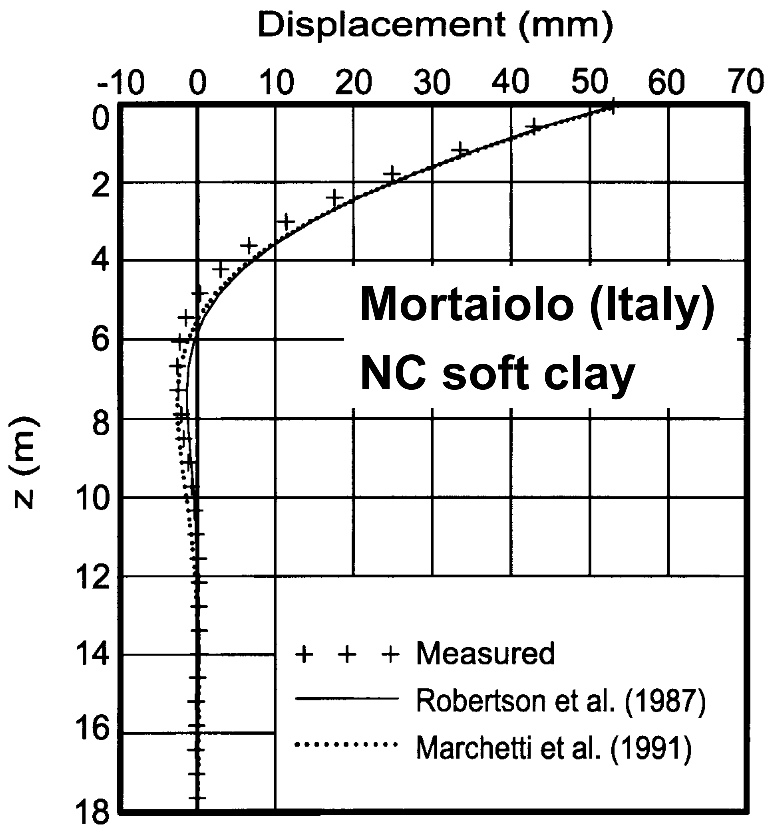


Similarity DMT – LL PILES

1. **Structural element installed in soil**
2. **LATERAL deformation**

MARCHETTI (1977) - "Devices for In Situ Determination of Soil Modulus Es"
Proc. 9th ICSMFE, Tokyo, Spec. Session No. 10.

Validations on full scale piles

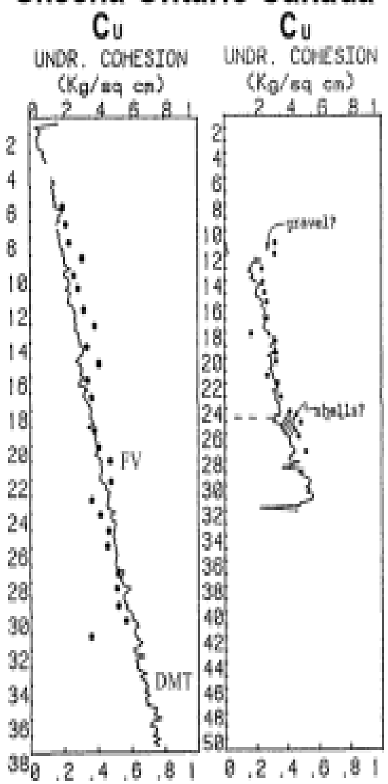


Marchetti et al. (1991) + **NGI (1998), Georgia Tech (1998)**

- **2 methods ➡ similar predictions**
- **<u>Very good agreement</u> PREDICTED vs OBSERVED behavior**

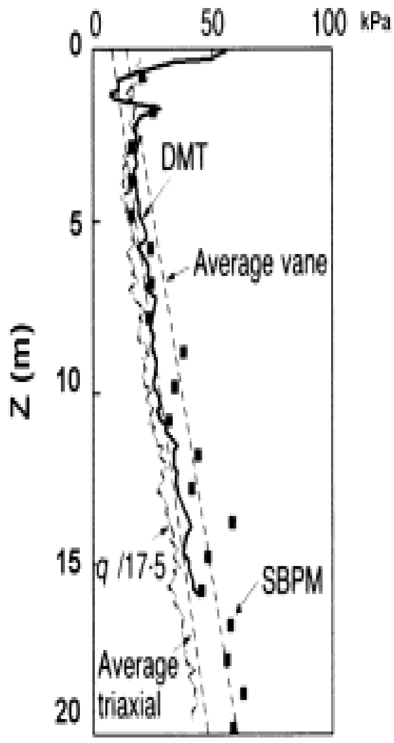
Cu comparisons

Field Vane at
Skeena Ontario Canada



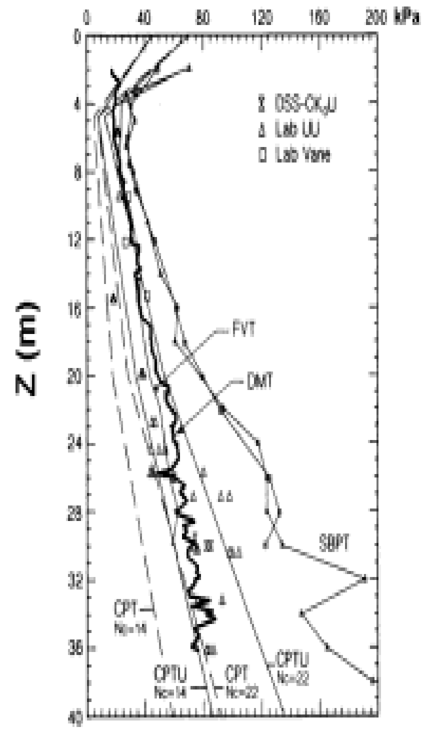
Mekechuk 1983

National Site
BOTHKENNAR UK



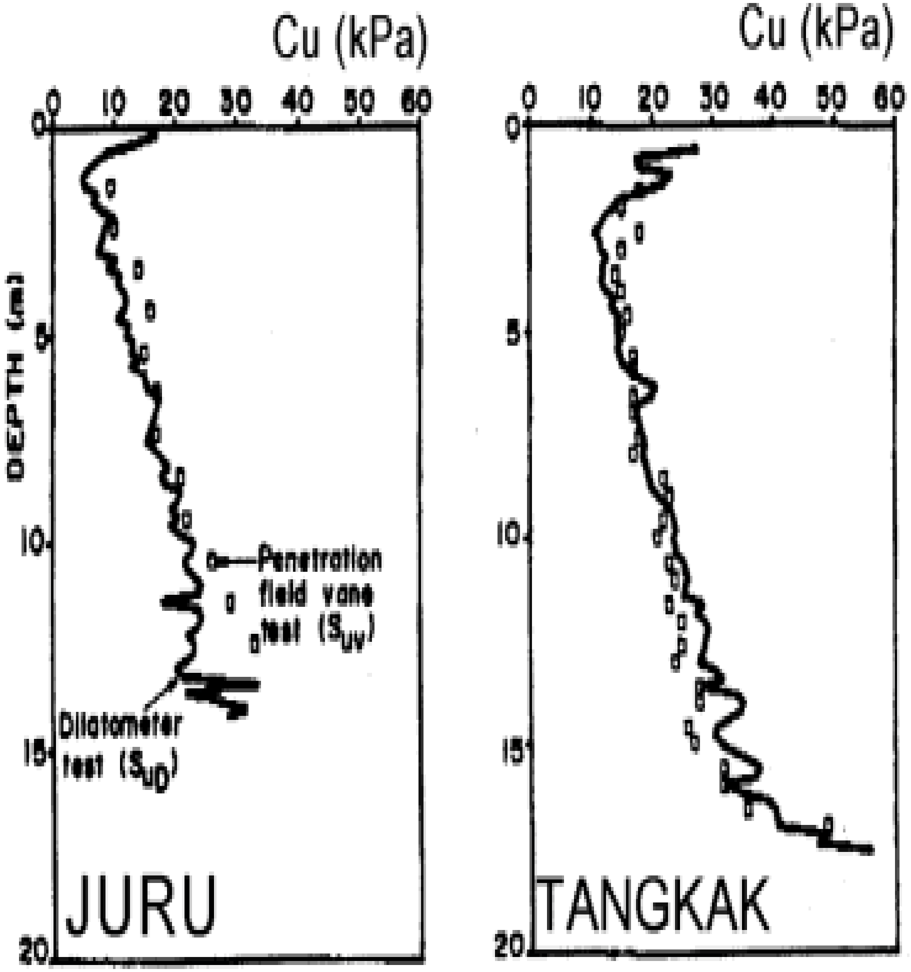
Nash et al., Géotechnique, June 1995, p. 173

National Site
FUCINO ITALY



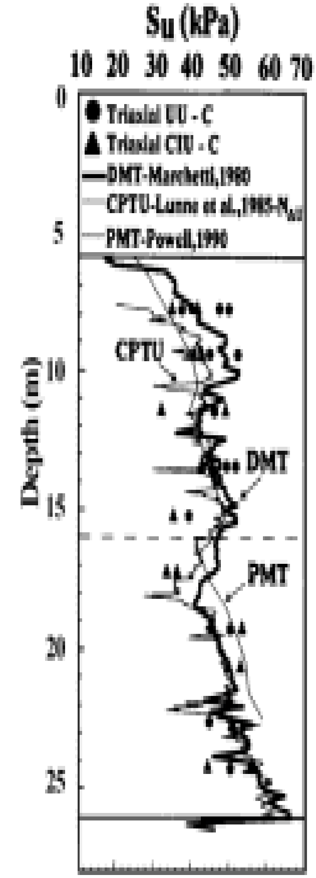
A.G.I., 10th ECSMFE Firenze 1991 Vol. 1, p. 37

Malaysian Clays



Wong, J.T.F. & Dobie, M.J.D. 1990

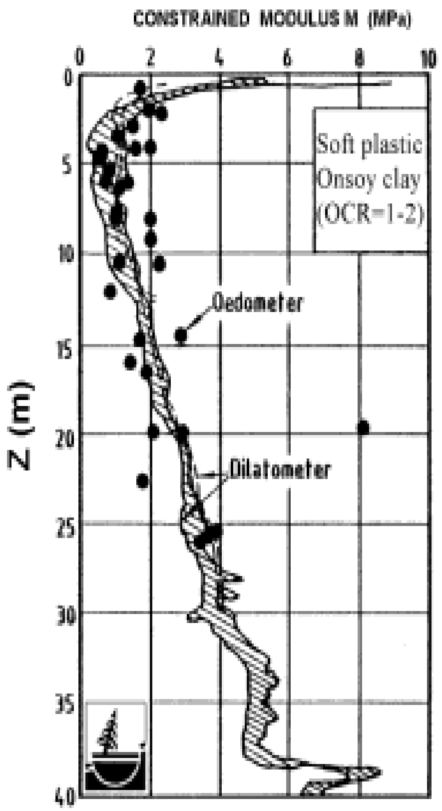
Cu in Recife Clay – Brazil
Univ. of Pernambuco Research Site 1



Coutinho et al., Atlanta ISC 1999

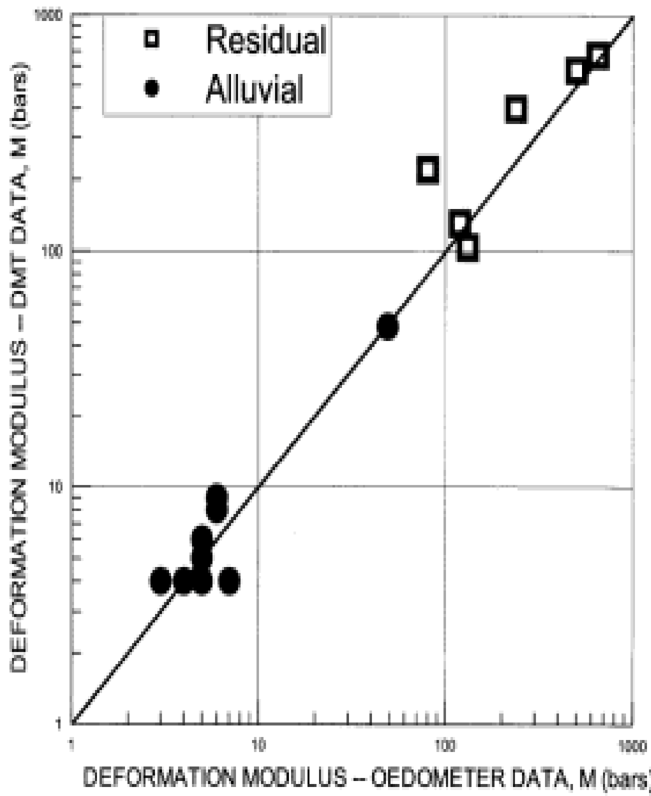
M comparisons

ONSOY Clay (NORWAY)



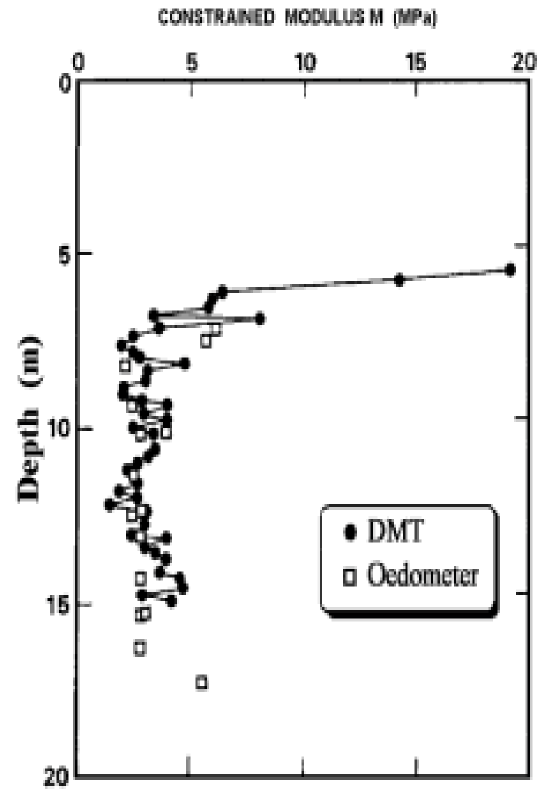
Norwegian Geotechnical Institute (1986).
"In Situ Site Investigation Techniques
and interpretation for offshore practice"
Report 40019-28 by S. Lacasse, Fig. 16a, 8 Sept 86

SITES IN VIRGINIA, U.S.A.



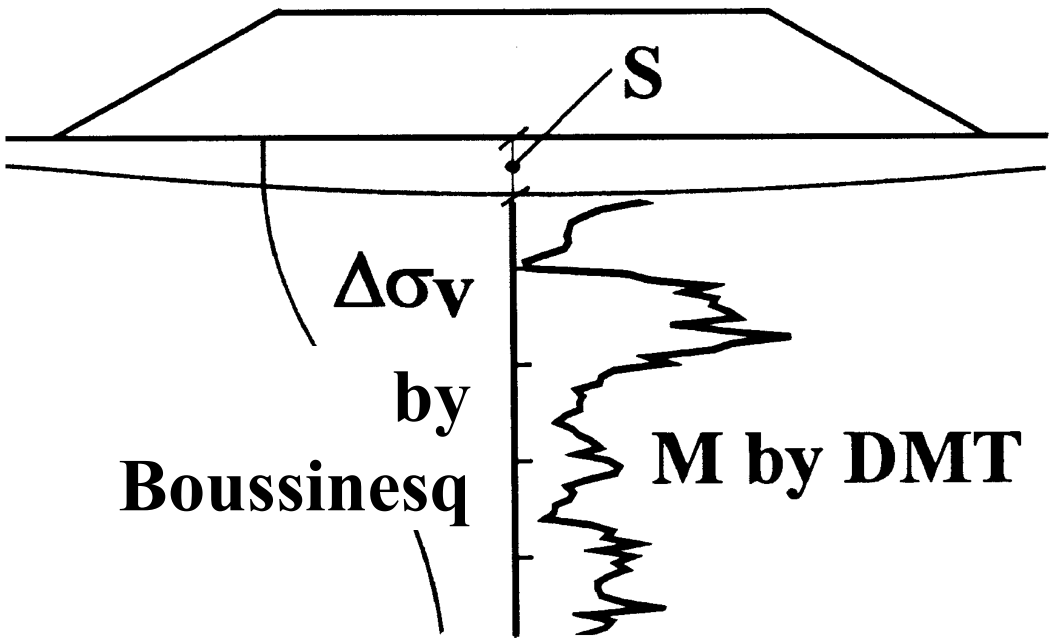
FAILMEZGER, 1999

M in Tokyo Bay Clay



Geotechnical Research Center
Kiso-Jiban Consultants Co., Tokyo

APPLICATION N° 1 SETTLEMENTS



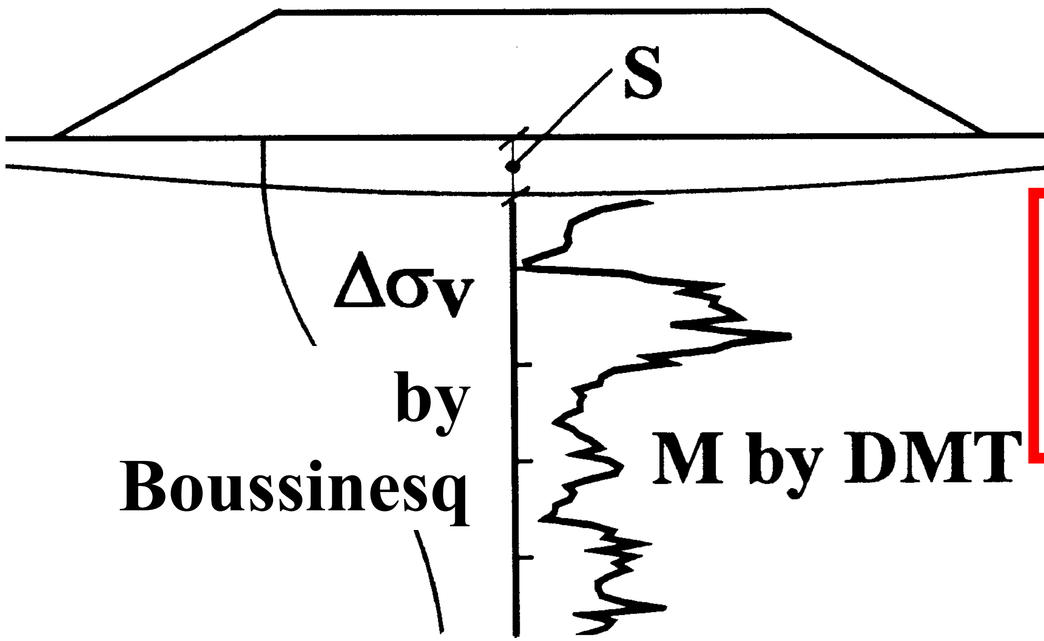
$$S = \sum \frac{\Delta \sigma_v}{M} \cdot \Delta Z$$

or 3-D (Hooke) with E ≈ 0.8 M ⇒ Similar Predictions
(Poulos : important is Modulus, not Formula!)

$$S_{3-D} = \Sigma \frac{1}{E} \cdot \left[\Delta\sigma_v - \nu \cdot \left(\Delta\sigma_x + \Delta\sigma_y \right) \right]$$

NOTE: Mdmt is just for primary. Mdmt must be treated as if obtained by oedometer

APPLICATION N° 1 SETTLEMENTS



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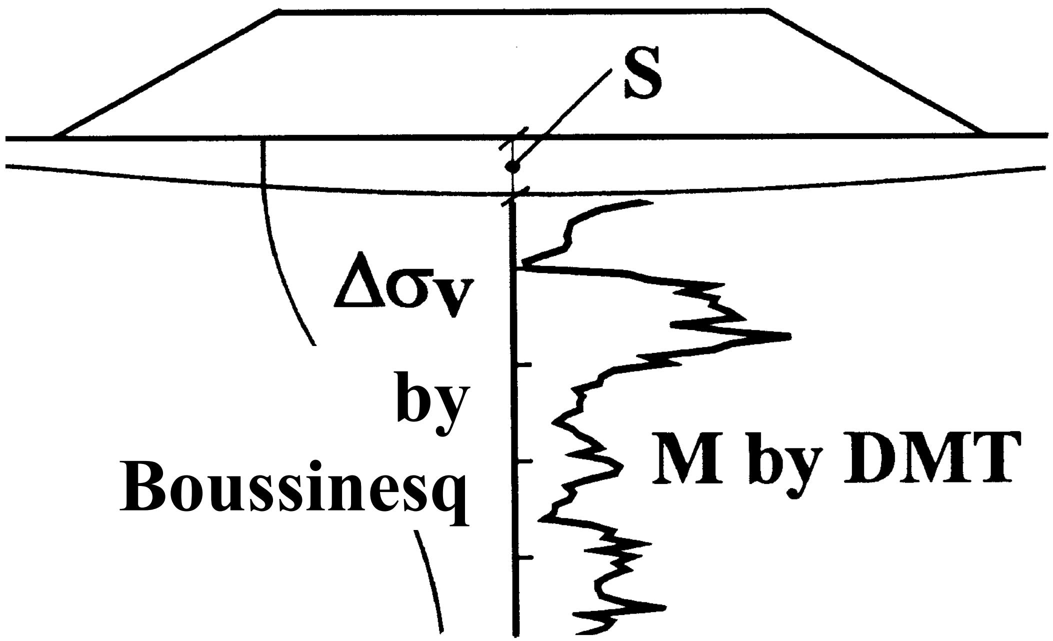

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NOTE: Mdmt is just for primary. Mdmt must be treated as if obtained by oedometer

Dr John Schmertman

Cape Hatteras Lighthouse

DMT-calculated vs observed SETTLEMENTS

SCHMERTMANN, 1986 - 16 CASE-HISTORY

Proc. In Situ '86 ASCE Spec. Conf. VIP, Blacksburg, p.303.

No	Location	Structure	Compressible soil	Settlement (mm)			Ratio DMT/ meas.
				DMT	**	meas	
1	Tampa	Bridge pier	HOC Clay	*25	b,d	15	1.67
2	Jacksonville	Power Plant	Compacted sand	*15	b,o	14	1.07 (ave.3)
3	Lynn Haven	Factory	Peaty sd.	188	a	185	1.02
4	British Columbia	Test embankment	Peat org. sd.	2030	a	2850	0.71
5a b c	Fredricton " "	Surcharge 3' plate building	Sand Sand Quick cl. Silt	*11 *22 *78	a a a	15 28 35	0.73 0.79 2.23
6a b	Ontario "	Road embankment building	Peat Peat	*300 *262	a,o a,o	275 270	1.09 0.97
7	Miami	4' plate	Peat	93	b	71	1.31
8a b	Peterborough "	Apt. bldg Factory	Sd. & si.	*58 *20	a, o a, o	48 17	1.21 1.18
9	"	Water tank	Si. clay	*30	b,o	31	0.97
10a b	Linkoping "	2x3 m plate 1.1x1.3m plate	Si. sand Si. sand	*9 *4	a,o a,o	6.7 3	1.34 1.33
11	Sunne	House	Silt & sand	*10	b,o	8	1.25

-30%
+50%

DMT-CALCULATED vs OBSERVED. Ave : 1.18

DMT-calculated vs observed SETTLEMENTS

SCHMERTMANN, 1986 - 16 CASE-HISTORY

Proc. In Situ '86 ASCE Spec. Conf. VIP, Blacksburg, p.303.

No	Location	Structure	Compressible soil	Settlement (mm)			Ratio DMT/ meas.
				DMT	**	meas	
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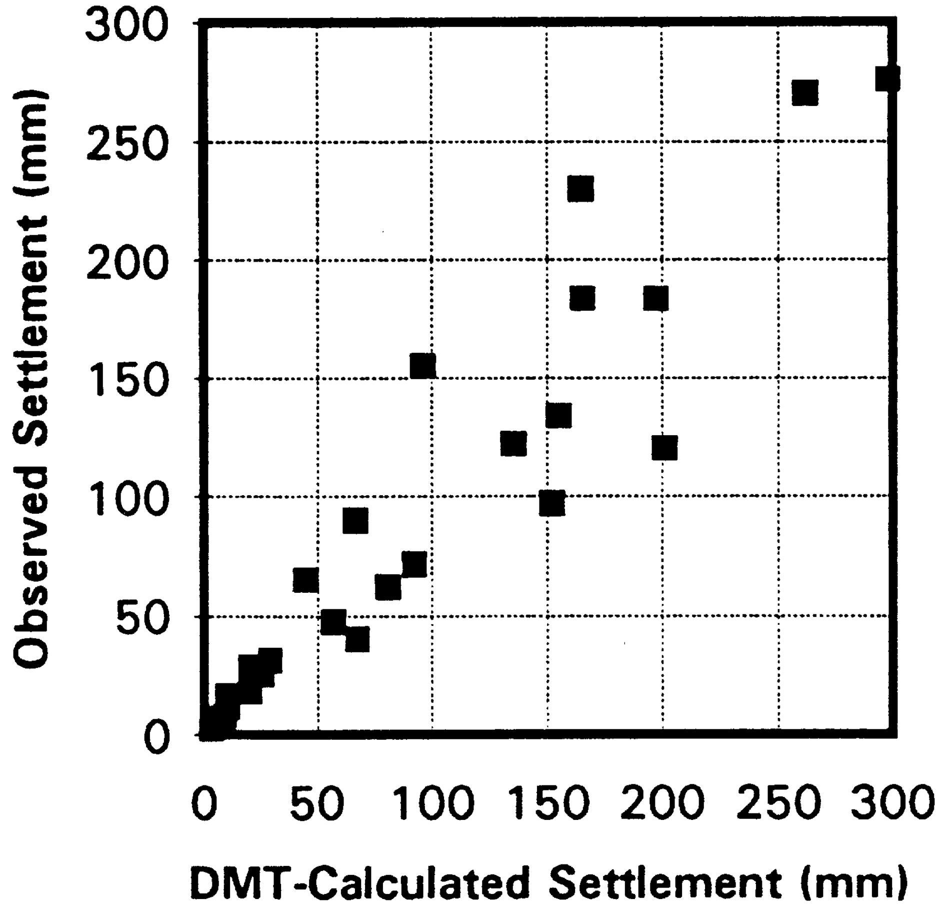
3	Lynn Haven	Factory	Peaty sd.	188	a	185	1.02
4	British Columbia	Test embankment	Peat org. sd.	2030	a	2850	0.71
5a b c	Fredricton " "	Surcharge 3' plate building	Sand Sand Quick cl. Silt	*11 *22 *78	a a a	15 28 35	0.73 0.79 2.23
6a b	Ontario "	Road embankment building	Peat Peat	*300 *262	a,o a,o	275 270	1.09 0.97
7	Miami	4' plate	Peat	93	b	71	1.31
8a b	Peterborough "	Apt. bldg Factory	Sd. & si.	*58 *20	a, o a, o	48 17	1.21 1.18
9	"	Water tank	Si. clay	*30	b,o	31	0.97
10a b	Linkoping "	2x3 m plate 1.1x1.3m plate	Si. sand Si. sand	*9 *4	a,o a,o	6.7 3	1.34 1.33
11	Sunne	House	Silt & sand	*10	b,o	8	1.25

-30%
+50%

DMT-CALCULATED vs OBSERVED. **Ave : 1.18**

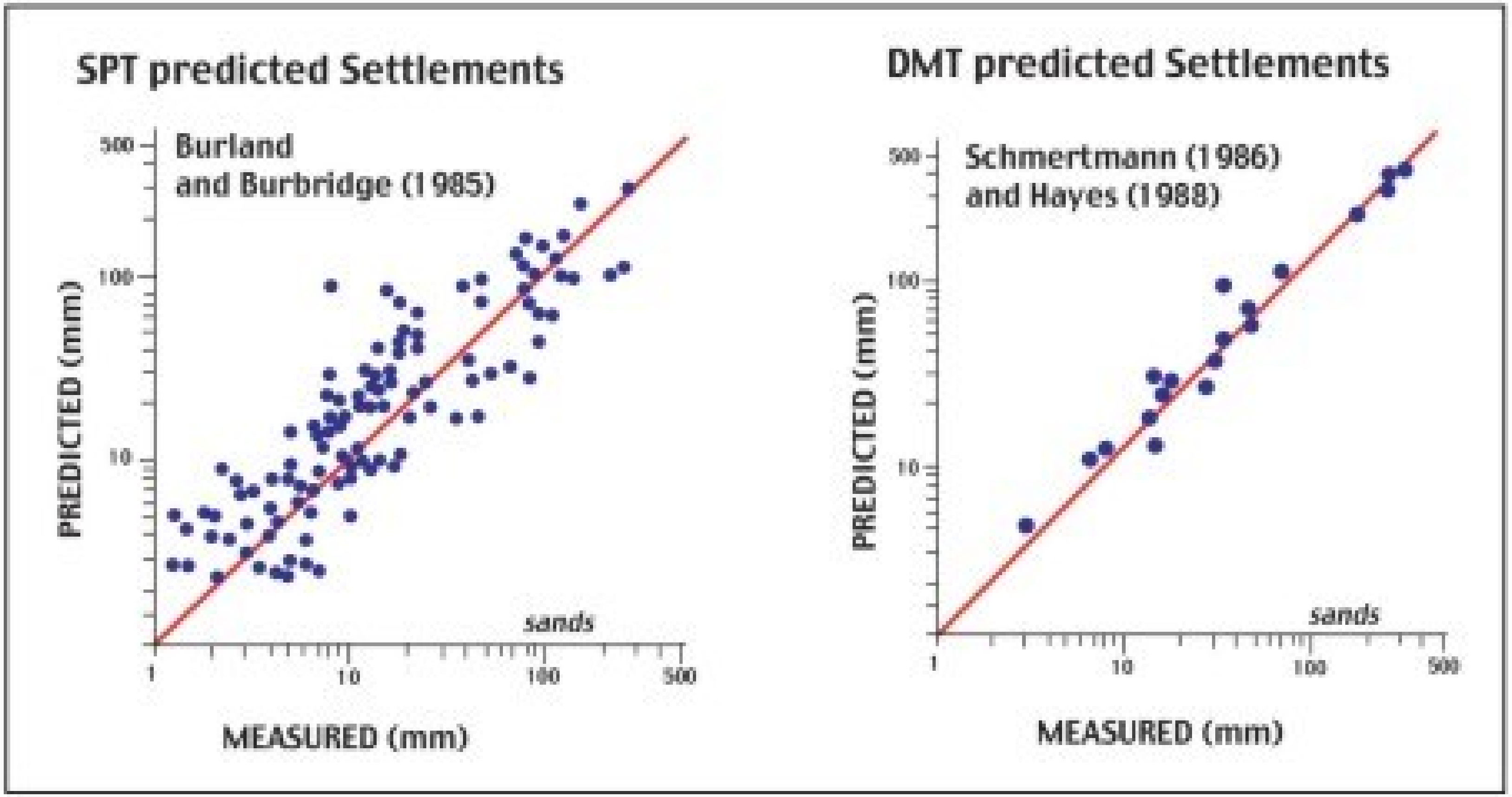
DMT-calculated vs observed SETTLEMENTS



HAYES, 1990

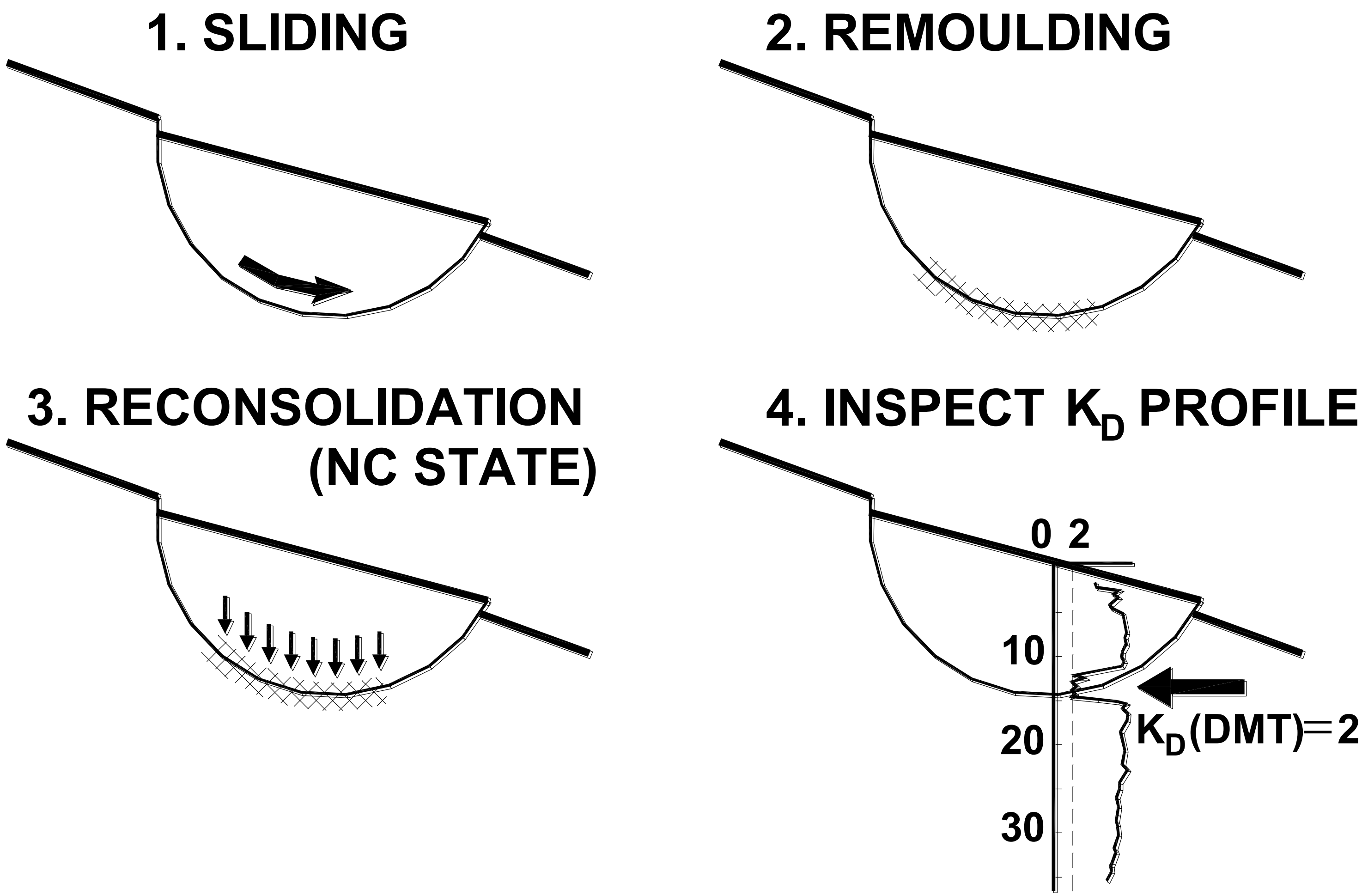
HAYES J.A. (1990). "The Marchetti Dilatometer and Compressibility". Paper to Southern Ontario Section of Canad. Geot. Soc. Seminar on "In Situ Testing and Monitoring". Sept.

SETTLEMENT PREDICTION



Bullock & Failmezger (Porto 2004)

Verify if an OC clay slope contains ACTIVE (or old QUIESCENT) SLIP SURFACES



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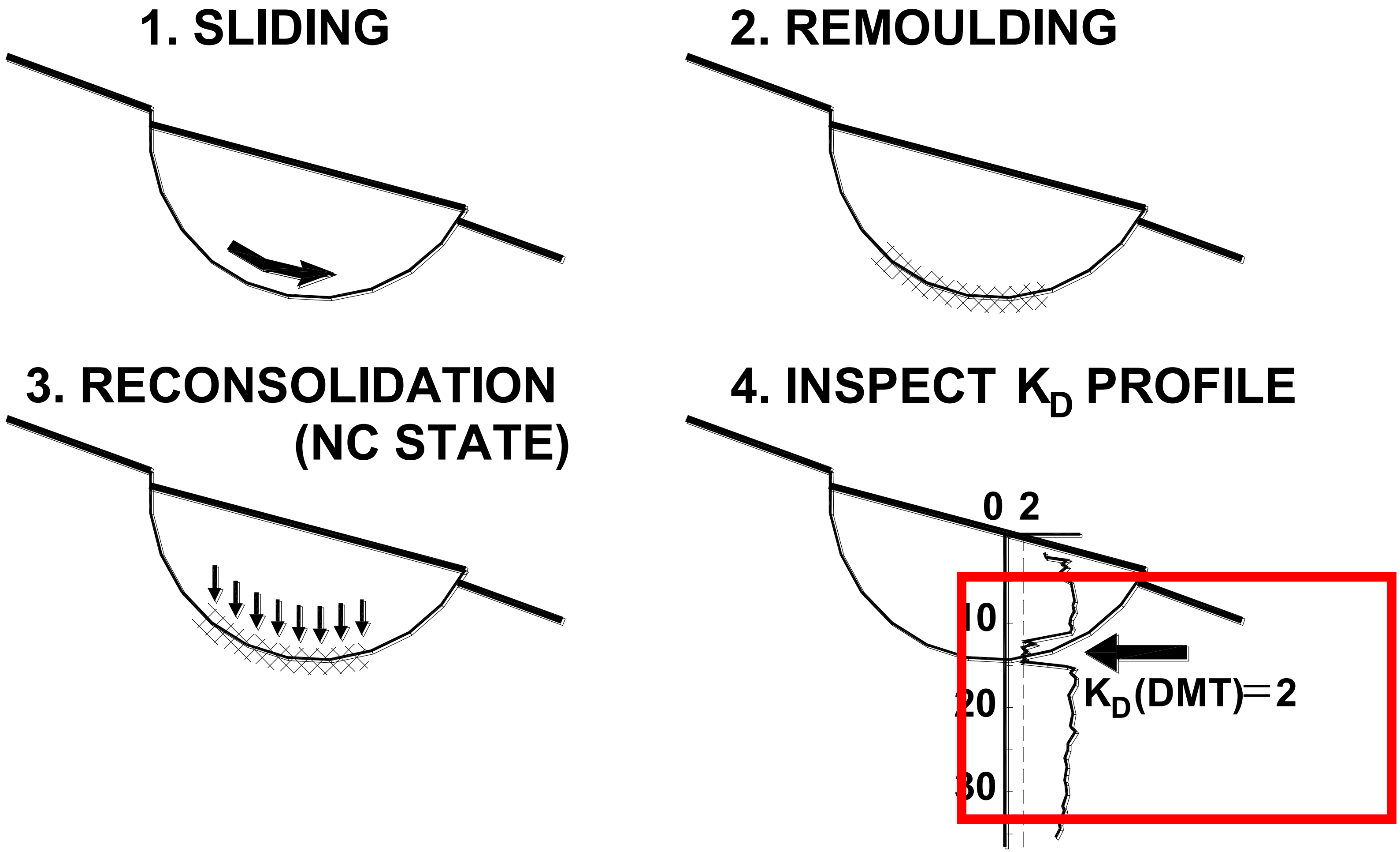
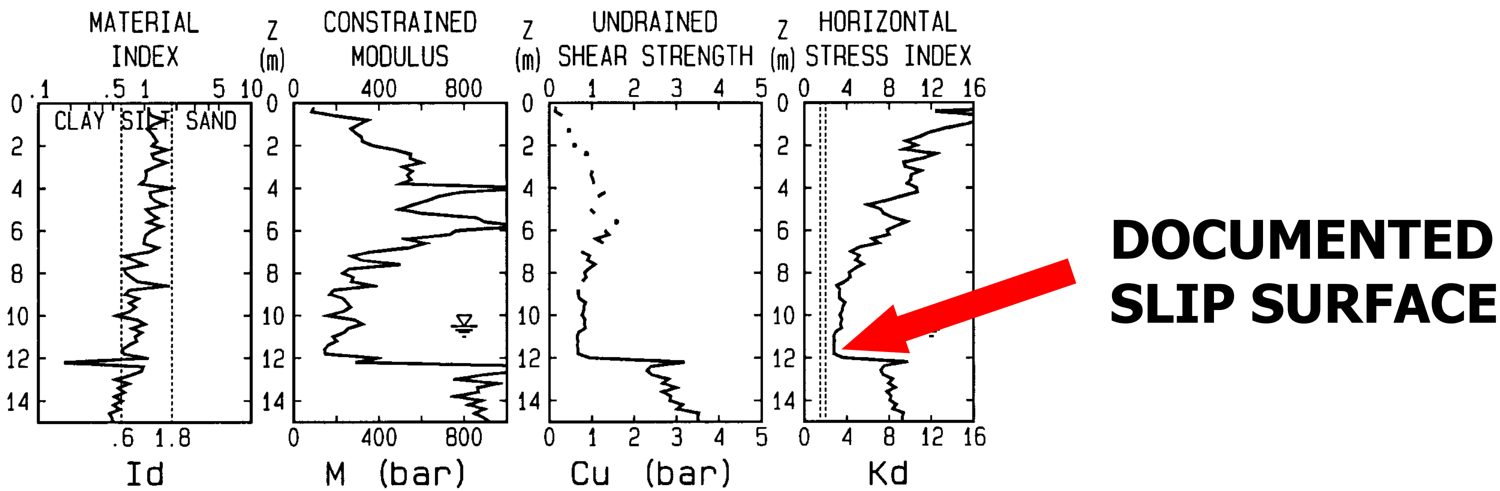
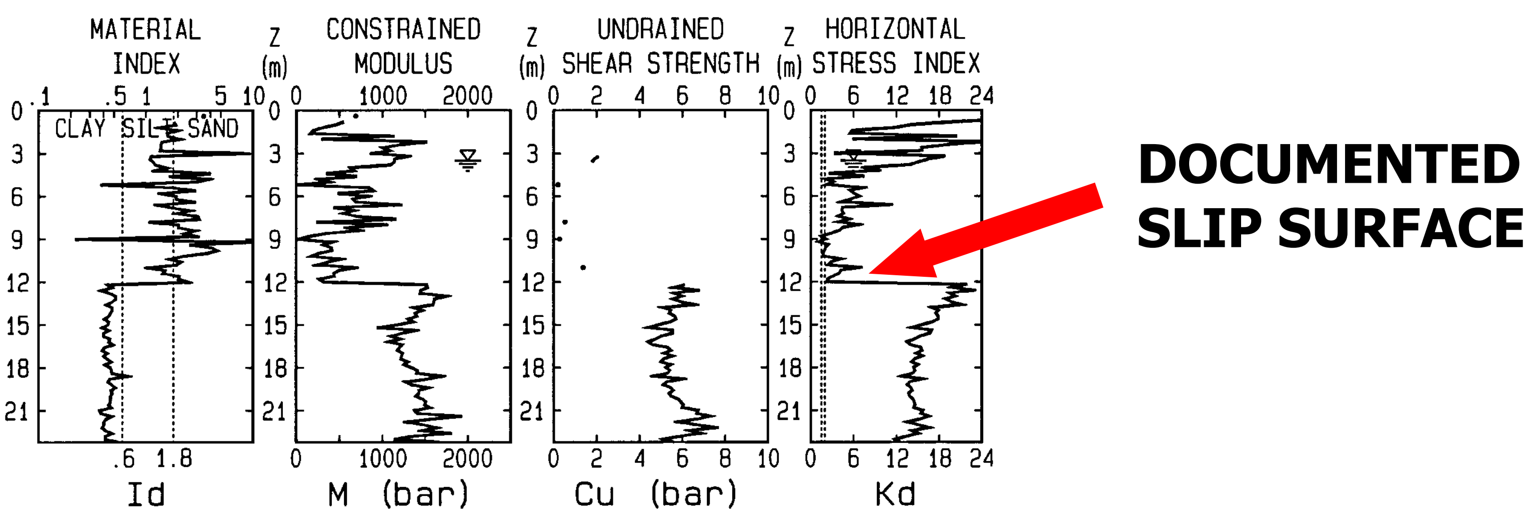


Examples of $K_D \approx 2$ in slip surfaces

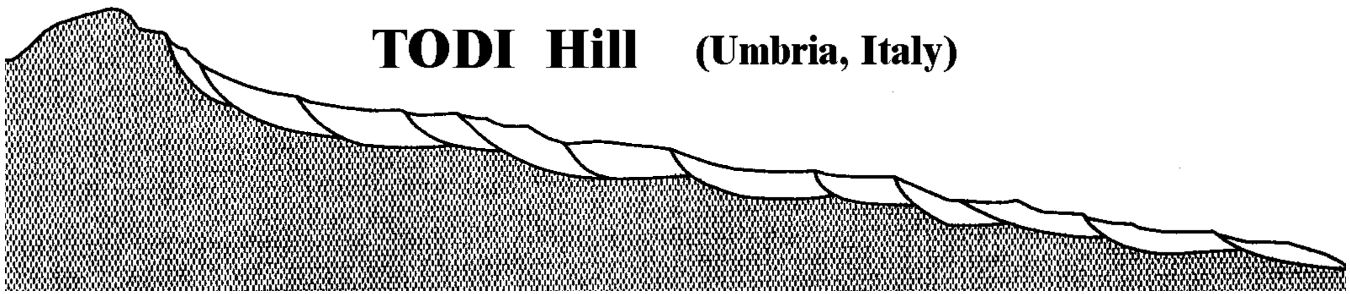
LANDSLIDE "FILIPPONE" (Chieti)



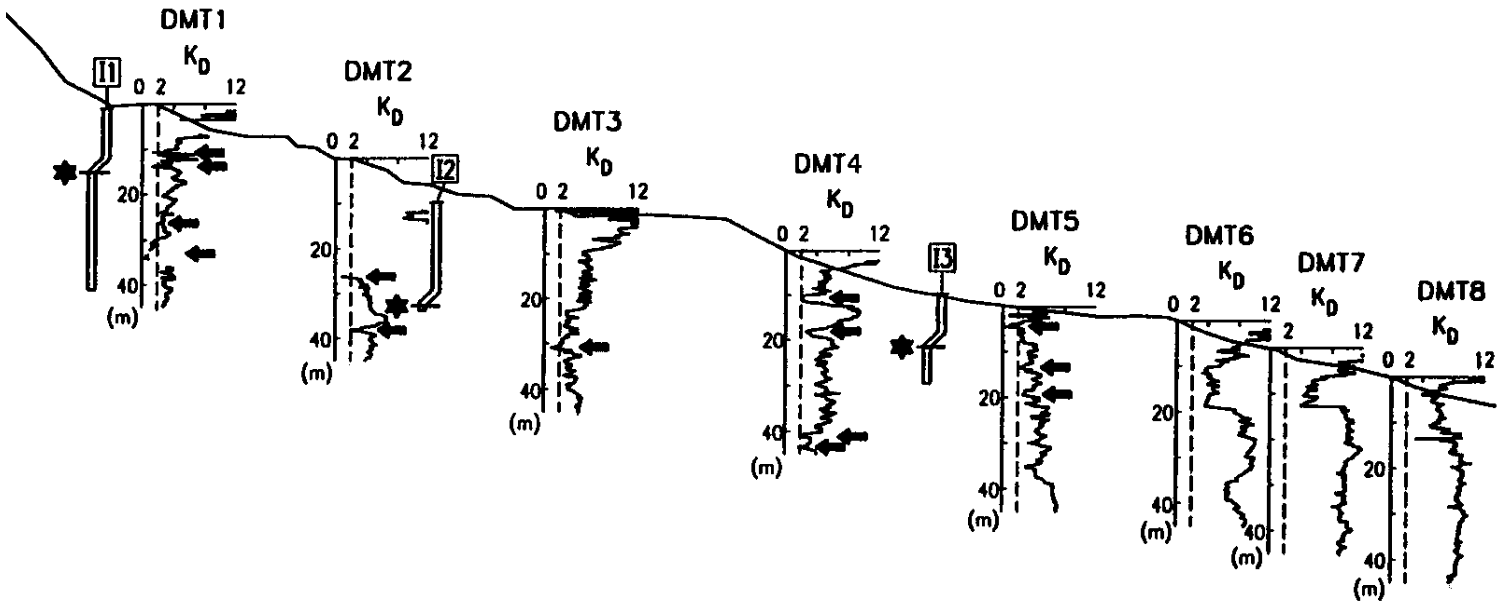
LANDSLIDE "CAVE VECCHIE" (S. Barbara)



Todi Hill landslide (Italy)

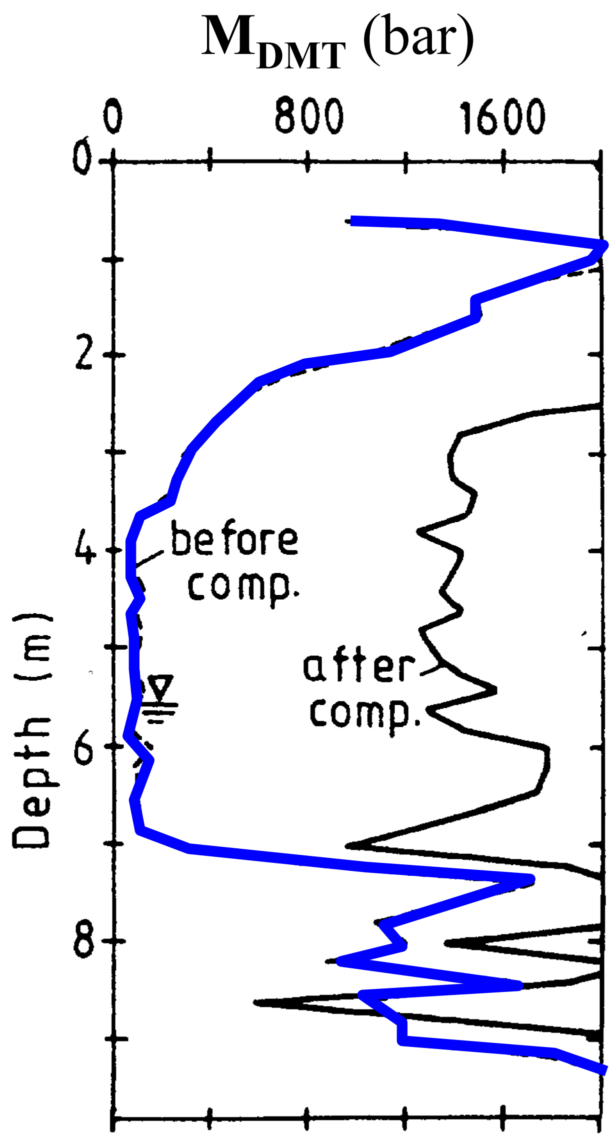


Qualitative reconstruction (Tonnetti 1978)



$K_D \approx 2$ layers correspond to SLIP SURFACES by INCLINOMETERS

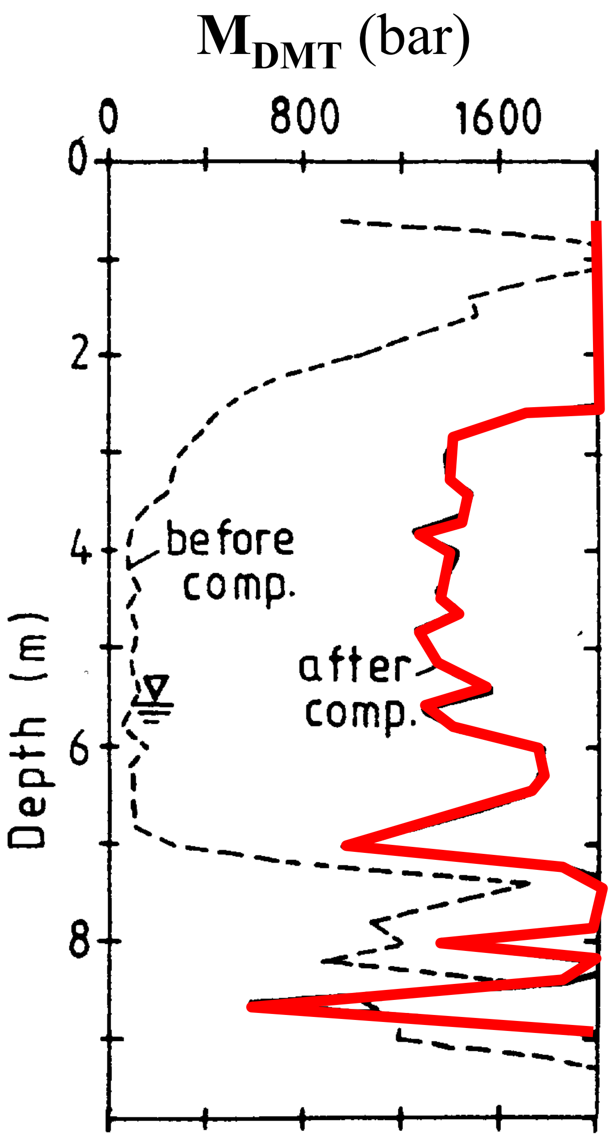
DMT before-after for Compaction Control



Resonant vibrocompaction technique

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

DMT$_{before-after}$ for Compaction Control



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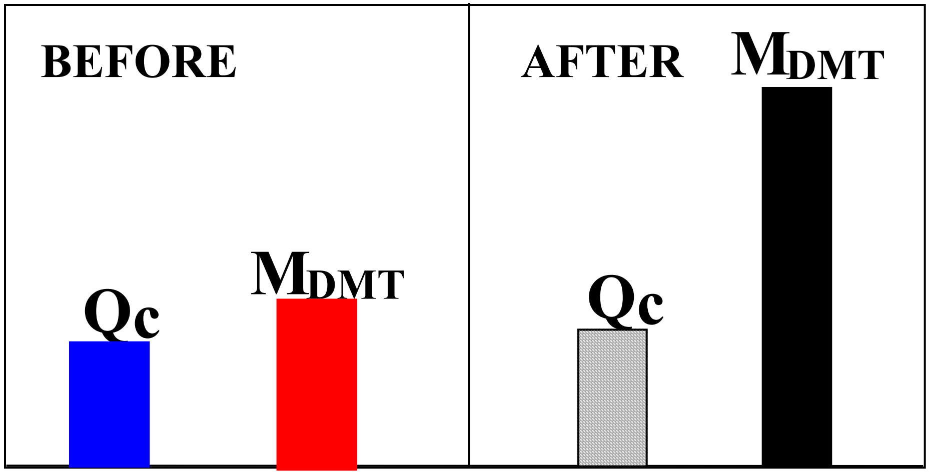
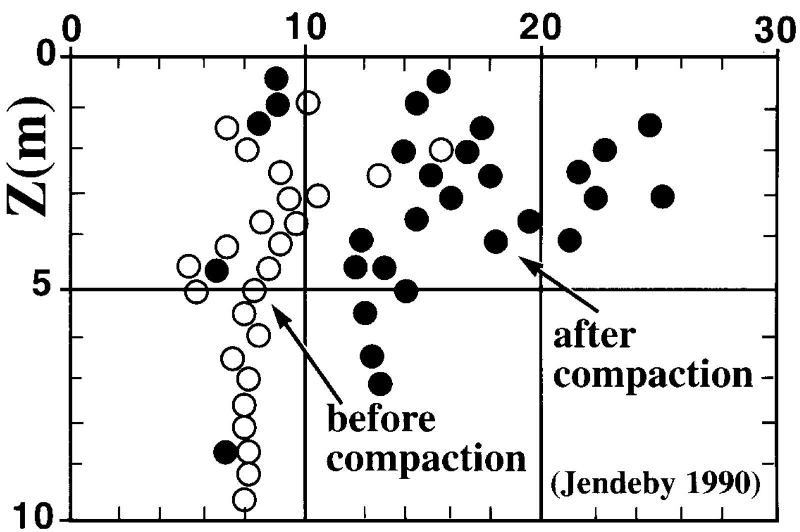
FLAT SHAPE MORE REACTIVE TO STRESS HISTORY

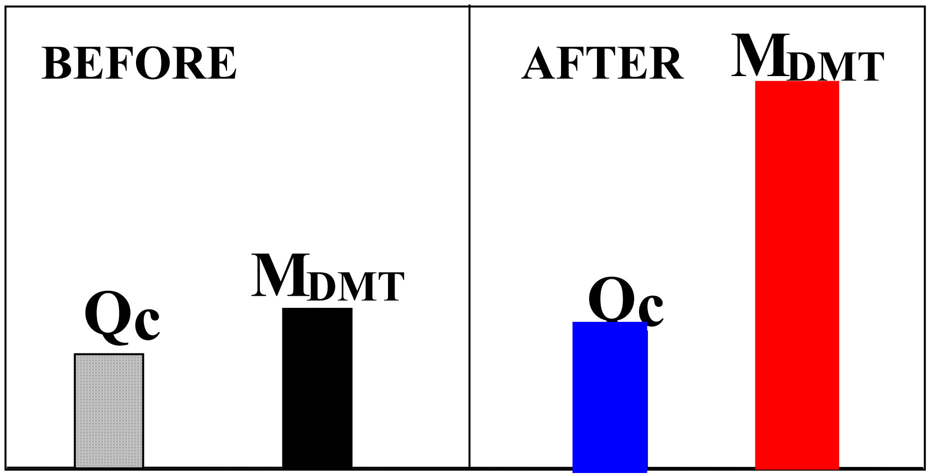


Jendeby 92 measured Qc & Mdmt before and after compaction of a loose sandfill

Ratio M_{DMT}/Q_C



FLAT SHAPE MORE REACTIVE TO STRESS HISTORY



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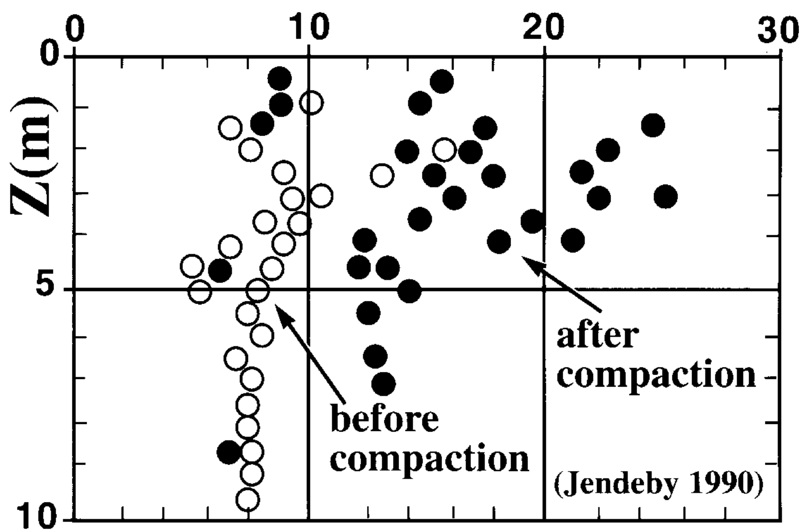
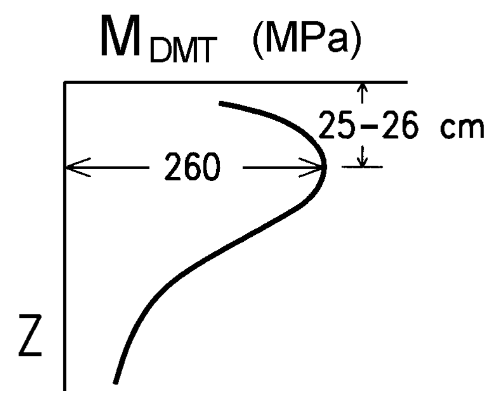


Bangladesh Subgrade Compaction Case History
90 Km Road Rehabilitation Project

As an alternative to specs [Proctor-CBR-Eplate] an acceptance Mdmt profile was fixed and used as an economical production method for quality control of compaction, with only occasional verifications

This was the acceptance profile. Almost invariabile the max of the profile was found at 25-26 cm



One way of using DMT : convert Ed to CBR (Borden 86) but physical mis-matching. A more direct alternative : calculate pavement using moduli

DMT BEST APPLICATIONS

- **M and Cu profiles**
- **Estimating settlements, deformation**
- **Monitoring soil improvement**
- **Recognize soil type**
- **Verify if a clay slope contains active/old slip surfaces**

Useful information also on:

- **OCR and Ko in clay**
- **Coefficient of consolidation/permeability**
- **P-y curves for laterally loaded piles**
- **Sand liquefiability**
- **Friction angle in sand**
- **(Some info OCR and Ko in sand)**

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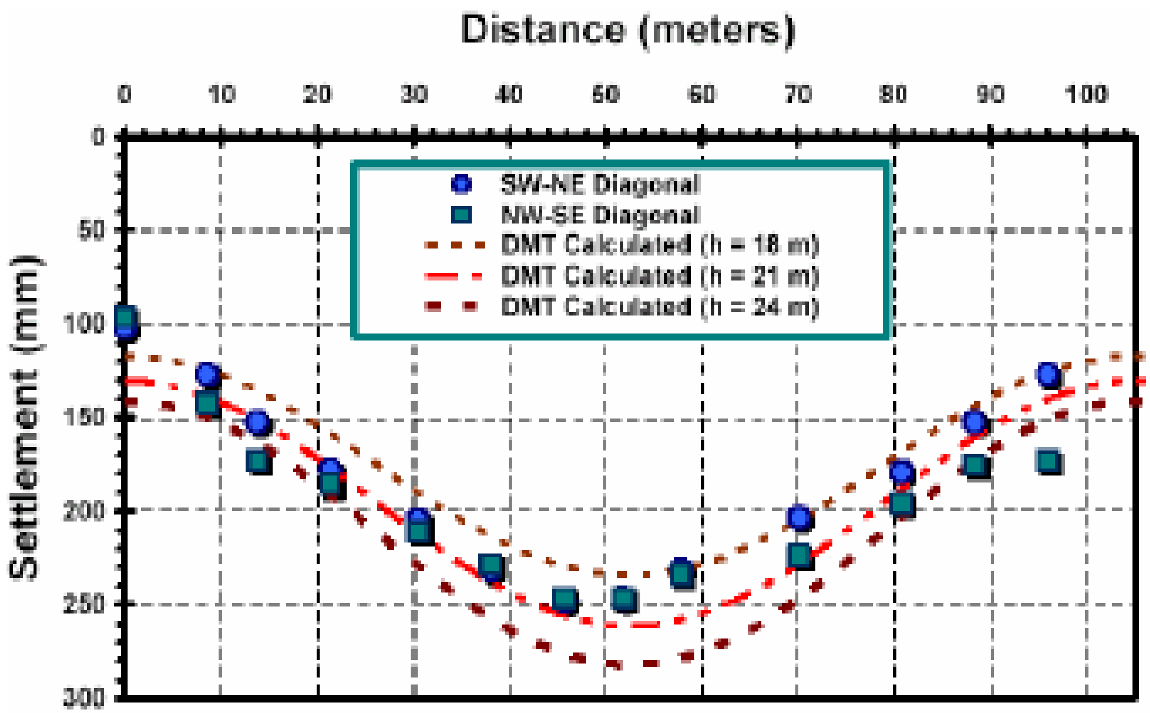


Fig. 7. Measured vs DMT-calculated settlement profiles along the diagonal axes of the mat foundation of a 13-story dormitory building in Atlanta, Georgia (Mayne 2005)

thicknesses are in excellent agreement with measured settlement profiles (Fig. 7). If carried out before, such calculations would have given essentially the correct answer and warned the designers of excessive displacements.

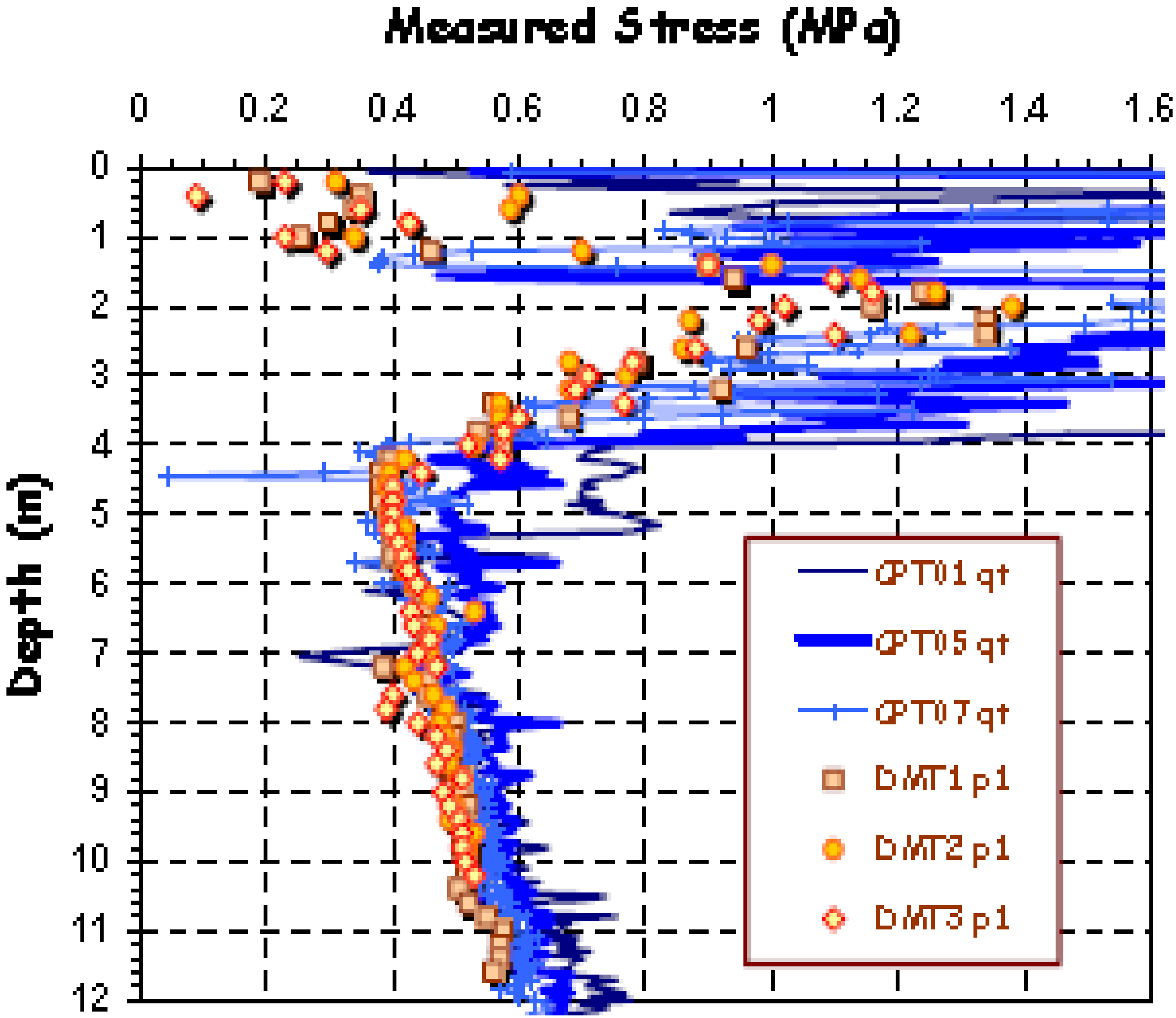
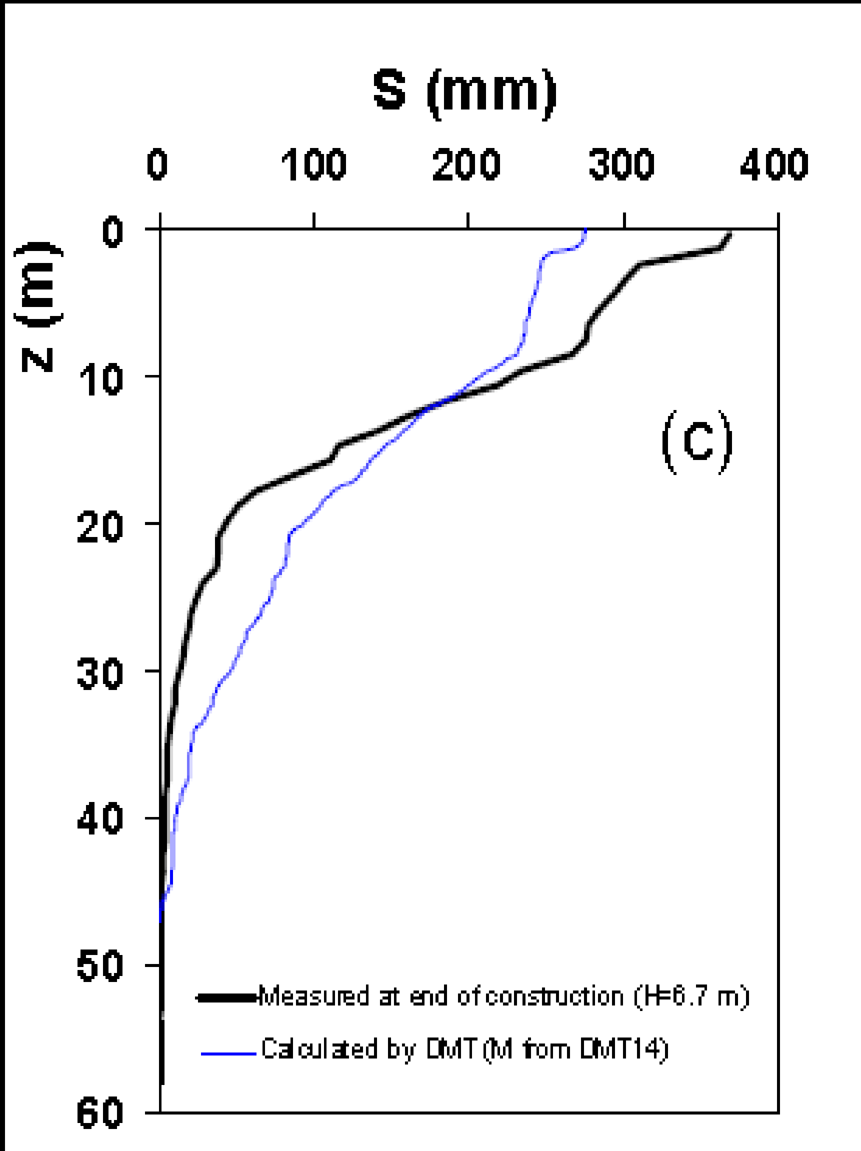


Figure 4. DMT p_1 and CPT q_t at Amherst NGES, MA.


FULLIN



9 CONCLUSIONS

A full-scale instrumented test embankment (40 m in diameter, 6.70 m high, applied load 104 kPa) was built at the site of Treporti, typical of the silty deposits in the Venice lagoon area.

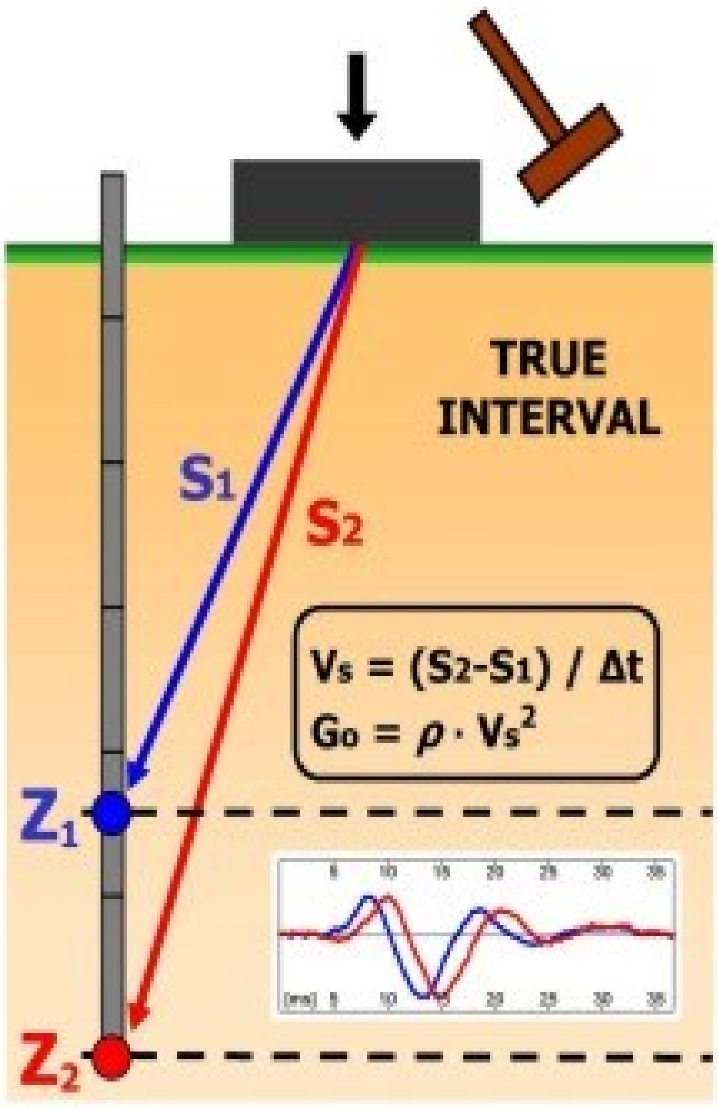
The most significant results obtained from comparison of DMT results with the in situ observed embankment behavior, presented in this paper, are:

(a) The settlement predicted by DMT at the end of construction (net of secondary developed during construction) is in good agreement with the measured settlement.

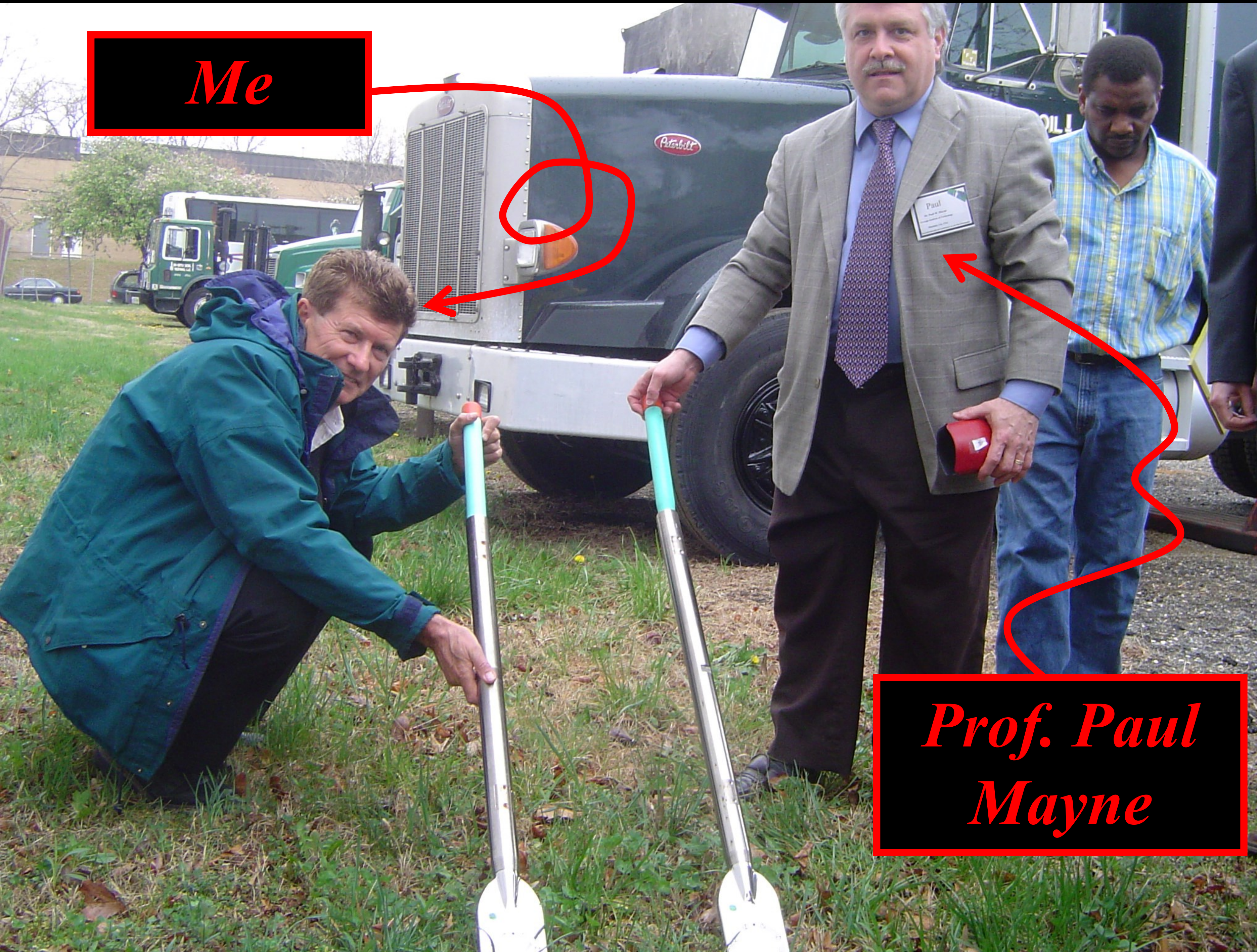
(b) The comparison of the profiles of moduli *M* obtained from DMT and backcalculated from local vertical strains measured every 1 m depth under the center of the embankment, at the end of construction, shows an overall satisfactory agreement.

Company & Base	In Situ Tests Offered	Comment
GeoPave, Melbourne	CPT, CPTu, DMT	Division of VicRoads, truck rig
NewSyd, Newcastle (research & contracting)	CPT, CPTu, Seismic CPT, Conductivity Cone	Collaboration between University of Newcastle and Sydney University, truck rig
Insitu Geotech Services (IGS), Brisbane	CPT, CPTu, DMT, Vane Shear (2006), Seismic DMT (2006)	All-terrain balloon tyred testing machine
Cone Penetration Testing Services (CPTS), Brisbane	CPT, CPTu, Seismic CPT, Vane Shear	Truck rig and all-terrain track rig

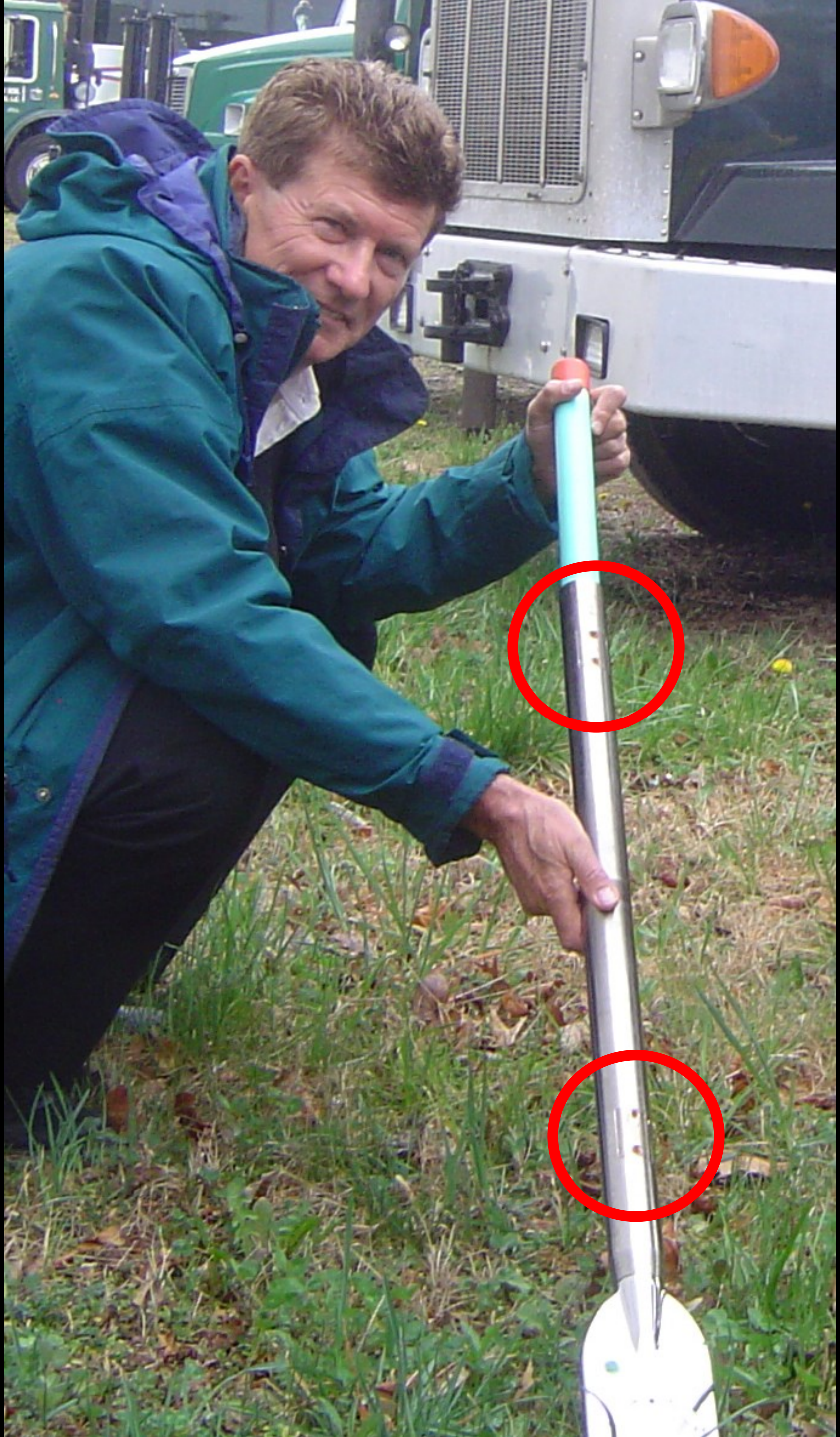
SEISMIC DILATOMETER



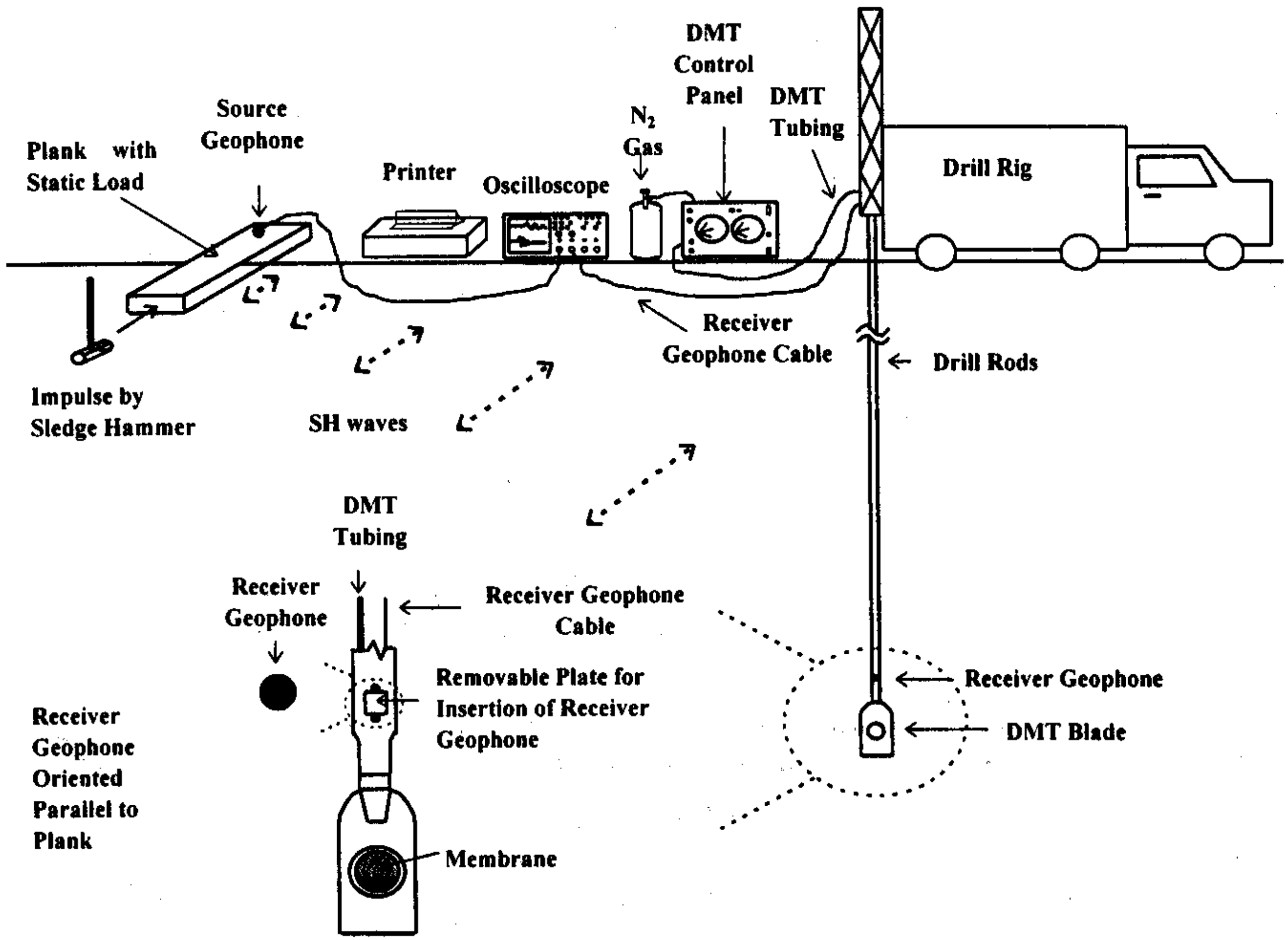

Paul
Prof. Paul Mayne


Me
Peterbilt
Paul
Prof. Paul Mayne


two
geophones

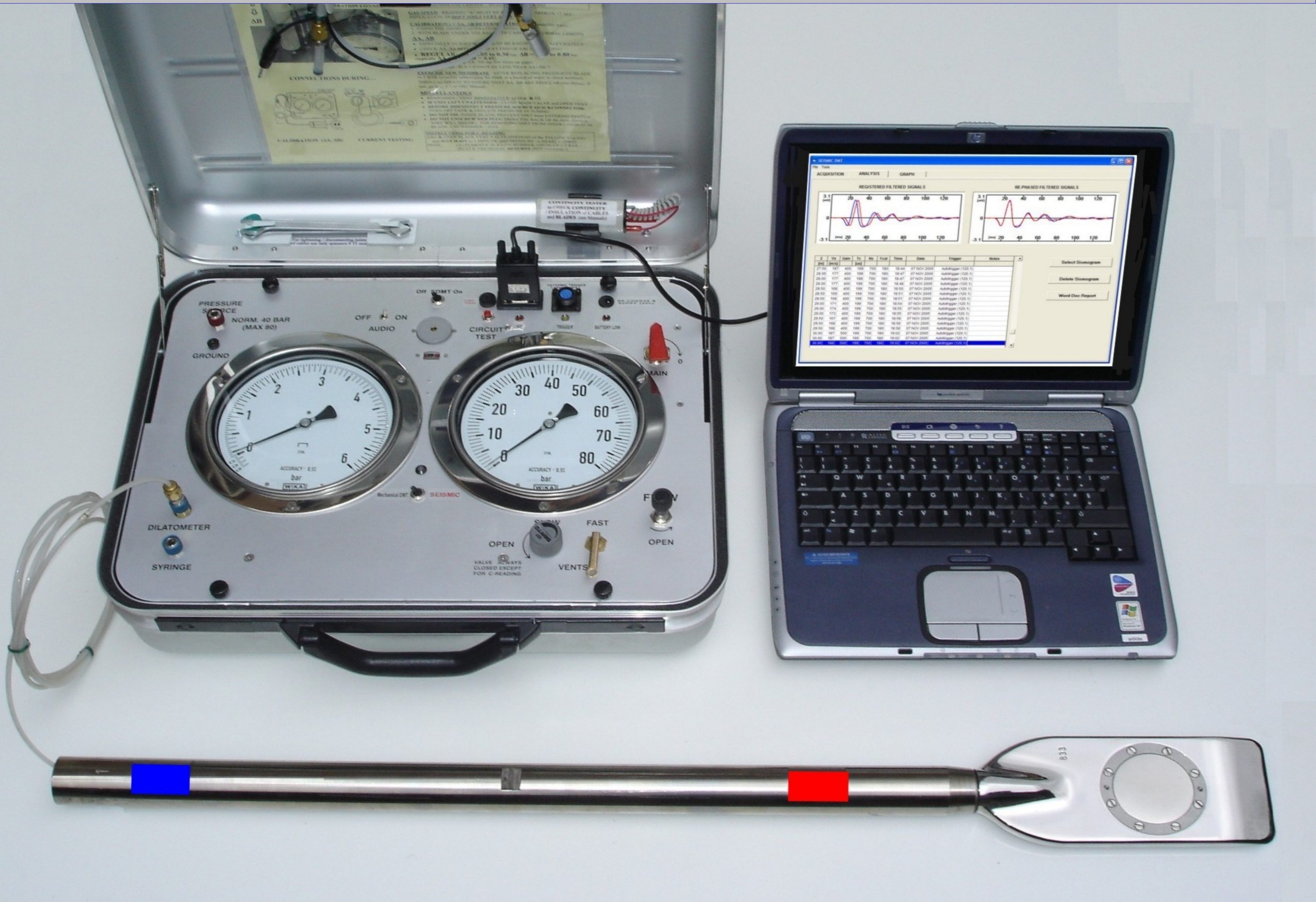


SDMT Test Setup



Mayne & Martin (1998). "Seismic flat dilatometer in Piedmont residual soils", ISC '98, Atlanta .

Seismic Dilatometer (SDMT)



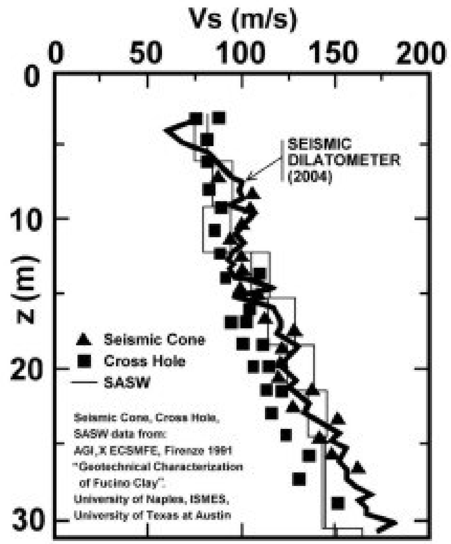
SDMT REPEATABILITY

Each Vs corresponds to a single blow of the hammer

Differences of Vs: 1 m/s

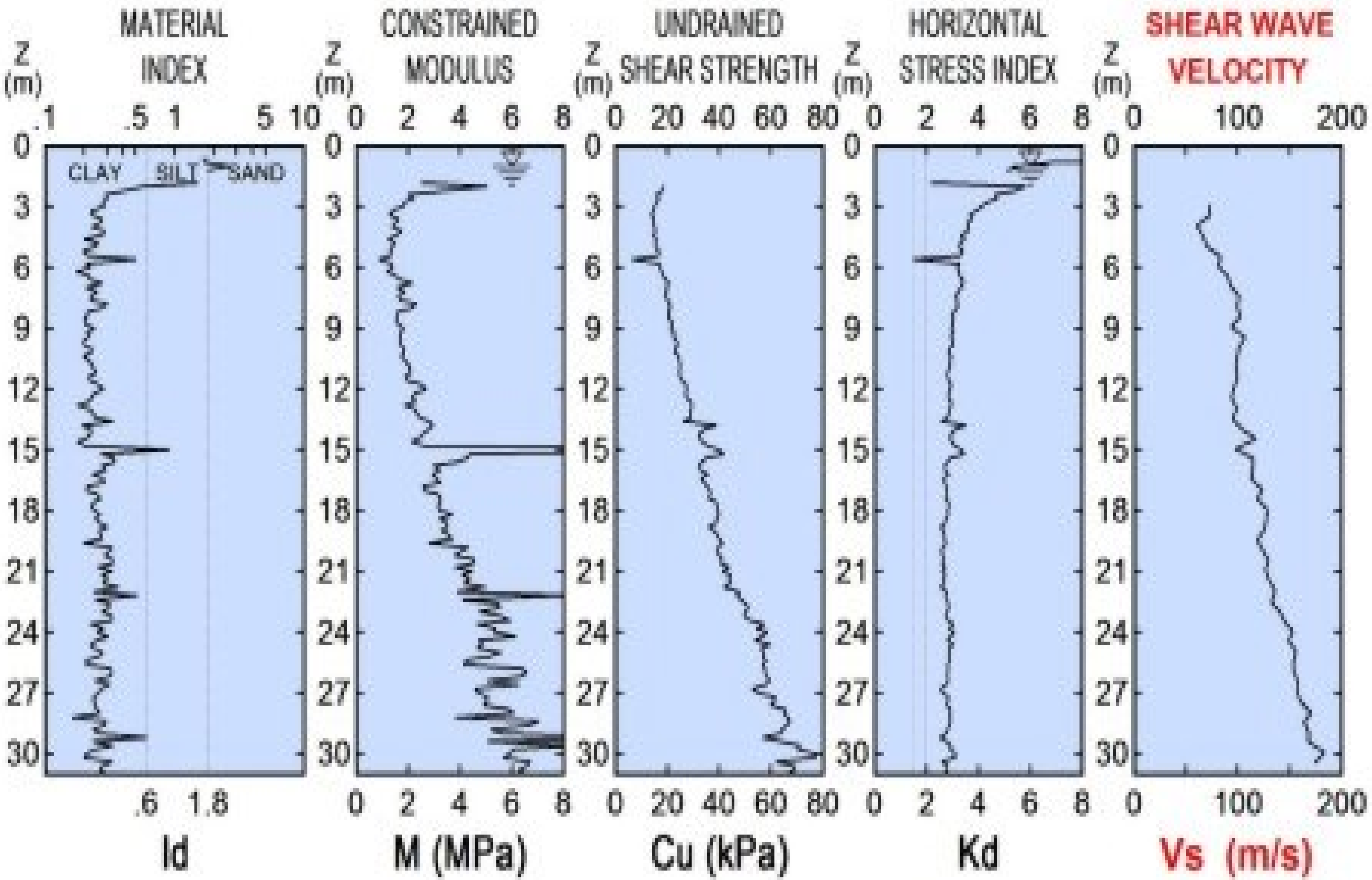
Z [m]	Vs [m/s]		
10.0	101	101	
10.5	99	99	
11.0	98	98	
11.5	99	100	
12.0	97	96	
12.5	94	94	
13.0	99	99	
13.5	95	95	
14.0	103	103	
14.5	117	117	117
15.0	98	98	98
15.5	115	115	
16.0	114	114	
16.5	113	113	
17.0	122	123	
17.5	119	119	
18.0	128	128	
18.5	127	127	
19.0	125	125	
19.5	119	119	
20.0	124	124	124

VALIDATION

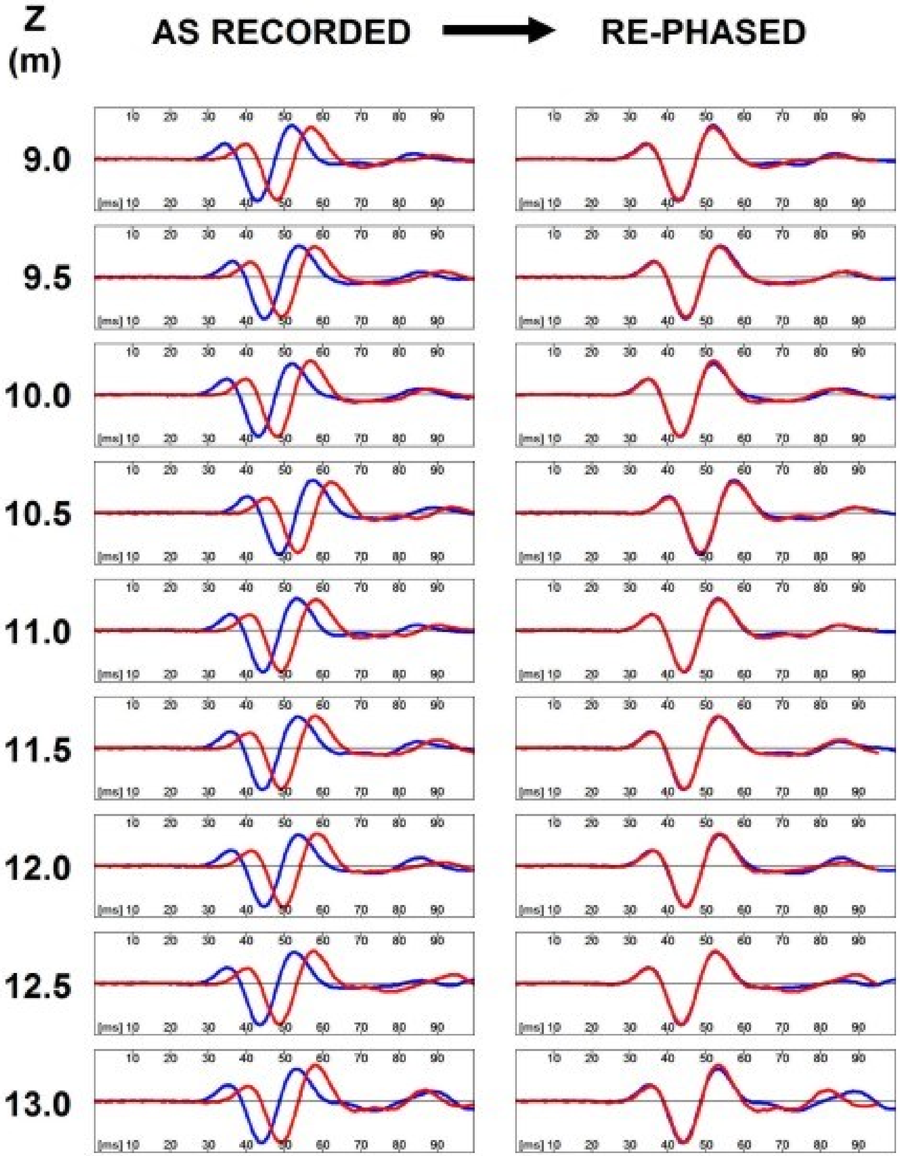


SDMT at FUCINO Research Site June 2004

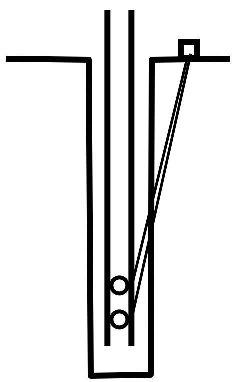
SDMT TEST RESULTS

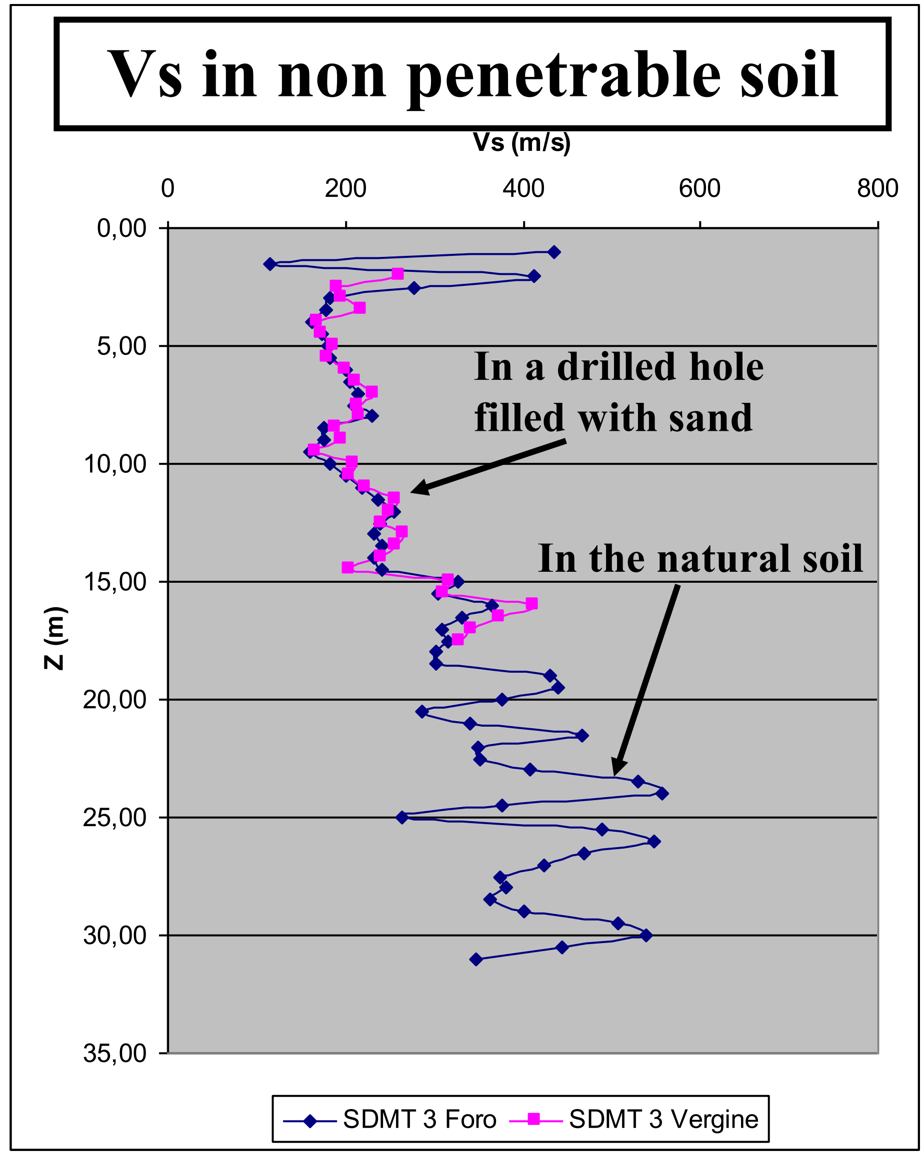


SDMT SISMOGRAMS



Drill a hole
Fill it with sand
Do SDMT (no DMT)



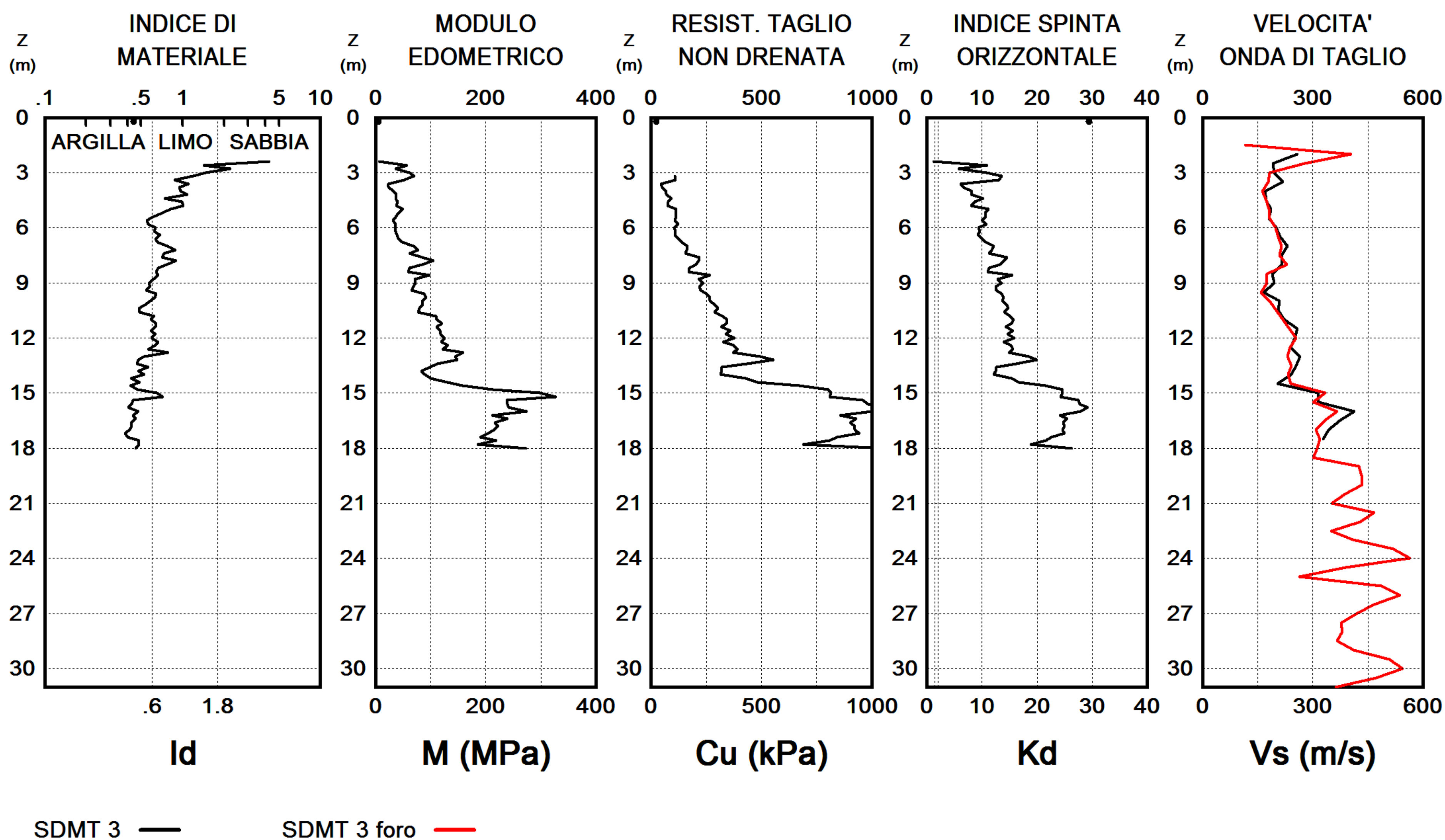


STUDIO PROF. MARCHETTI

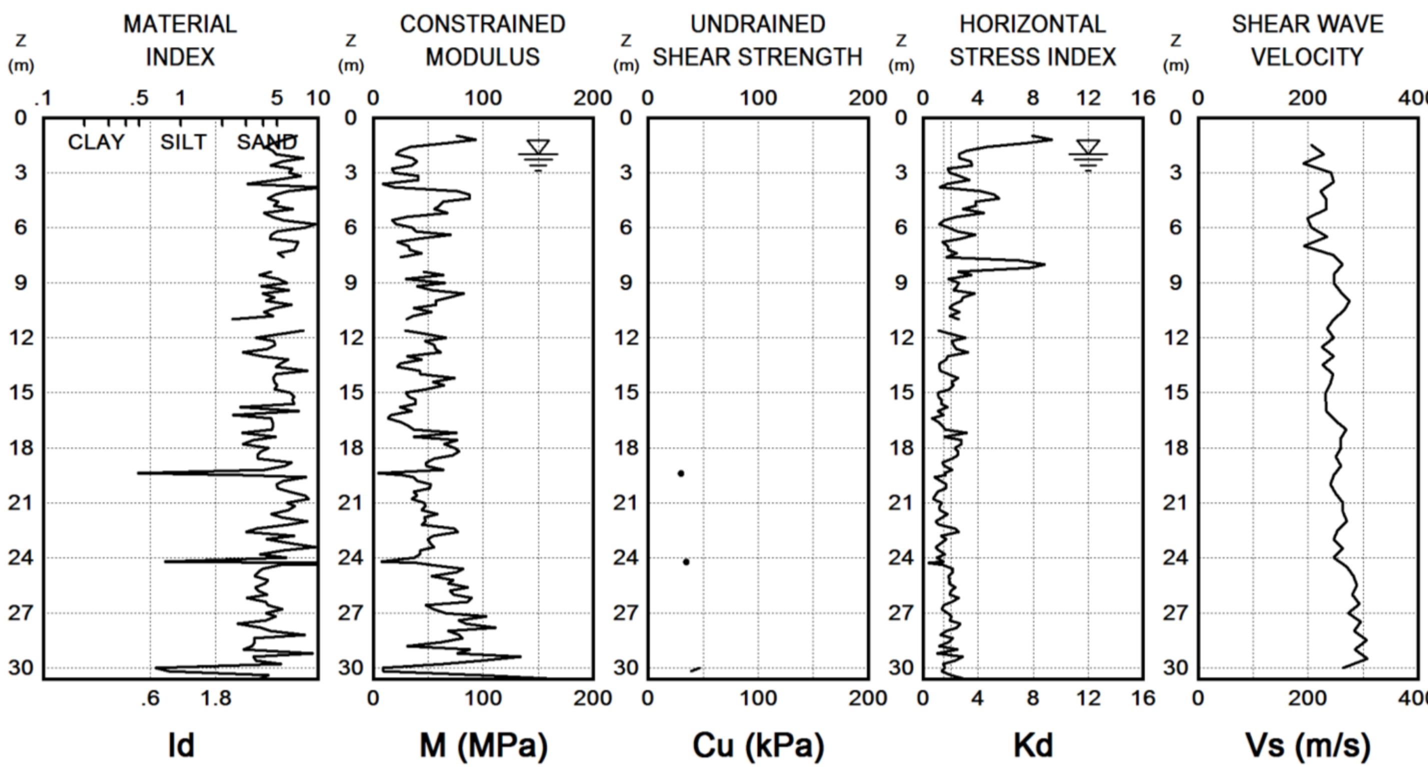
UNIV. SANNIO - DIP. INGEGNERIA

Acquedotto San Giuliano

Montescaglioso - Ginosa (Matera)



Zelazny Most – Poland



Zelazny Most – Repeatability of Vs

Z	Vs	Vs values	Std Deviation
[m]	[m/s]	[m/s]	[%]
7.00	179	178,178,180,180,180,179,179,180,180,180	0.50
7.50	231	234,232,232,230,229,231,232,229,230	0.68
8.00	225	227,225,224,225,225,225,226,226,225,224,224	0.40
8.50	276	276,276,280,273,275,273,271,273,287,281	1.68
9.50	248	244,251,250,247,250,249,250,249,242,248	1.11
10.00	292	292,289,290,293,289,292,289,-,292,296,295,293	0.79
10.50	320	321,323,320,325,323,325,316,314,308,321	1.61
11.00	291	293,291,293,291,291,290,290,291,290,290	0.38
11.50	321	324,320,320,322,320,322,319,319,320,320	0.48
12.00	309	311,307,311,309,309,311,309,309,307,311	0.50
12.50	286	287,285,285,285,287,285,285,287,287,287	0.35
13.00	265	264,265,265,265,264,265,265,265,266,265,266,264	0.24
14.00	312	313,312,312,322,310,312,310,310,310,312	1.10
14.50	298	301,298,299,299,298,296,299,298,299,298	0.44
15.00	309	307,309,307,309,309,309,309,309,309,309	0.29

Today SOA is a few m/sec scatter

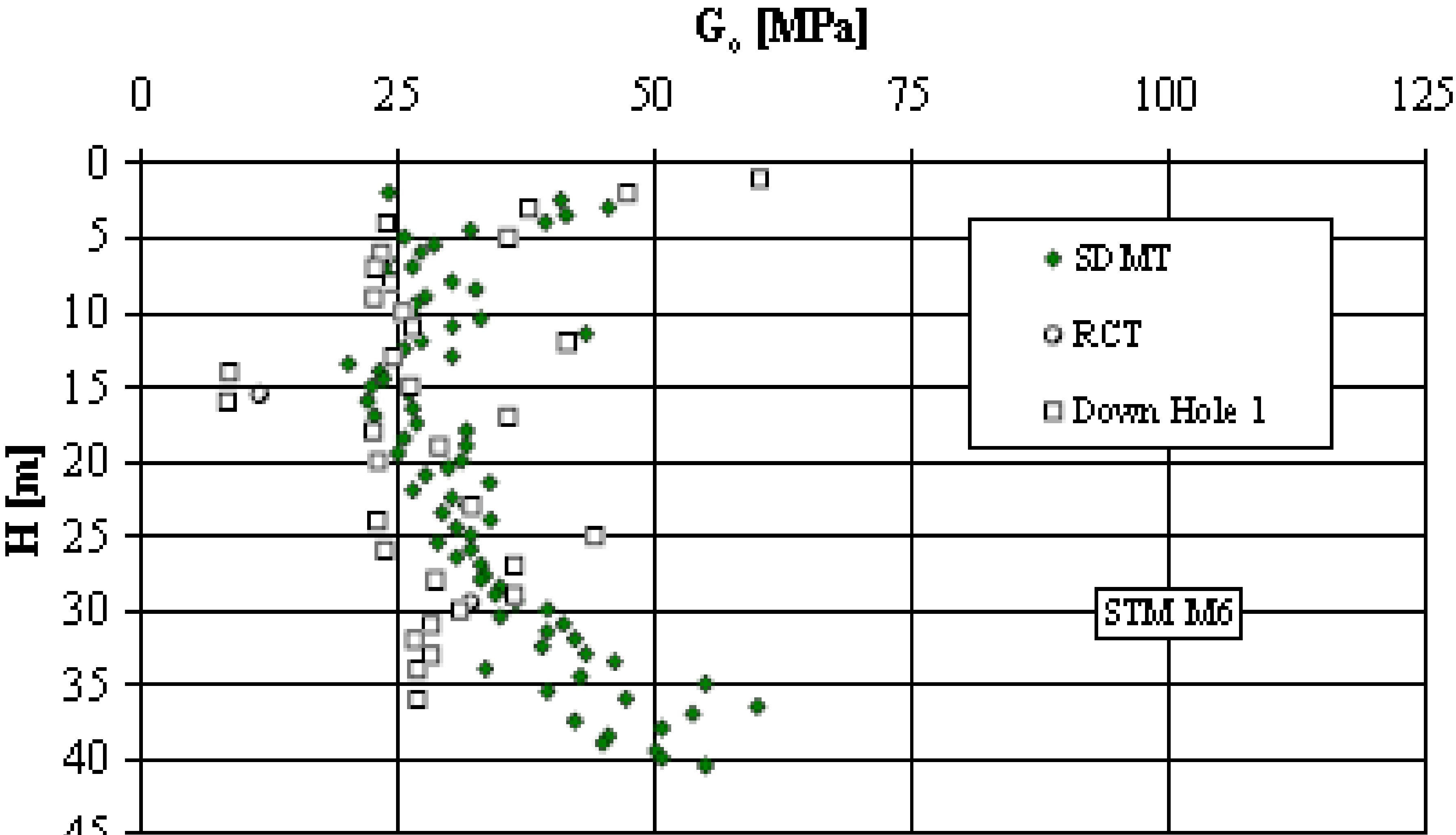


Figure 6. G_o from laboratory and in situ tests.

4 CONCLUSIONS

A site characterization for seismic response analysis has been presented in this paper. On the basis of the data shown it is possible to draw the following conclusions:

- SDMT were performed up to a depth of 42 meters. The results show a very detailed and stable shear wave profile. The shear wave profiles obtained by SDMT compare well with laboratory tests;


the
end