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DIGEST #10 May, 1988

10.A ISOPT-1 Papers

The First International Symposium on Penetration Testing was held at Walt Disney World, Orlando, from 21-24 March 1988. All the full registrants received the two-volume set of the PROCEEDINGS, distributed at the time of registration. Volume 1 contains 13 papers and Volume 2 an additional paper with major reference to the DMT and they are listed below according to page number, along with abstract-comments by this editor. Copies of the ISOPT-1 PROCEEDINGS may be ordered from A. A. Balkema, P.O. Box 1675, NL-3000 BR, Rotterdam, The Netherlands at a cost of \$115 US for both volumes.

Professor M. Jamiolkowski organized and led Specialty Session 2. at ISOPT-1 on the DMT. The session approximately followed the attached proposed schedule. There will be no Proceedings from the Session.

- A.1 "Current Status of the Marchetti Dilatometer Test" by A. Lutenegger (pp. 137-155): A mini-SOA review of the DMT.
 All users of the DMT should review this paper. The author emphasizes the broad variety of actual applications for which the DMT has been used, the broad variety of soils in which it has been used, and the general growth of the use of the test. He introduces some new concepts and also suggests expanded use of the DMT for pore pressure measurements.
- A.2 "New Correlations of Penetration Tests for Design Practice", by M. Jamiolkowski, V. Ghionna, R. Lancellotta and E. Pasqualini (pp. 263-296): A mini-SOA on the subject. It includes tabular details of 2 DMT soundings in hard clays, as well as K_0 , M, and \emptyset prediction comparisons vs. results from the large scale Italian chamber testing. The authors also show data to suggest a G_0 (low strain modulus)/E_D correlation.
- A.3 "Penetration Testing of a Dessicated Clay Crust" by G. Bauer and A. Tanaka (pp. 477-488): The DMT results in a stiff, fissured clay crust were consistent and repeatable. The K_D, E_D, and c_u values all strongly sensed the presence of the crust. The DMT-predicted c_u values agreed well with those obtained by triaxial testing.

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A.4 "Some Experience with the Dilatometer Test in Singapore" by M-F Chang (pp. 489-496): Two marine clays investigated by 4 DMT soundings. The author investigated OCR (DMT too high), su (DMT within +/- 40% of field vane) and M profiles (DMT very close to the recompression index). Also, the DMT clearly reflected the non-equilibrium condition of an underconsolidated clay. Author recommend more routine use of the DMT. Contraction of the second

- A.5 "Analysis of Load Deflection Response of Laterally Loaded Piers Using DMT" by M. Jabr and R. Warden (pp. 513-520): Authors propose a method for determining the coefficient of lateral subgrade reaction based on DMT data, applicable to drilled shafts/bored piles. Comparisons made with 3 field tests.
- A.6 "CPT and DMT Evaluation of Blast-Densification of Sand" by R.
 Hryciw and C. Dowding (pp. 521-526): E_D and K_D profiles to
 9 meters at a test area on the Atlantic coastline. Both reduced with blasting, which agreed with parallel CPT q_c data. The DMT data suggested anisotropic K-conditions after the blasting.
- A.7 "DMT-Cross hole Shear Correlations" by R. Hyrciw and R. Woods (pp. 527-532): Field tests in a dry, glacially overconsolidated silty sand deposit showed good correlation between the small strain shear modulus Go and Ko determined from the DMT.
- A.8 "Calibration of Dilatometer Correlations" by S. LaCasse and T. Lunne (pp. 539-548): Presents results from a 4 year research program. Soil property comparisons include OCR, modulus, undrained shear strength, and effective friction angle. The authors comment on the remarkable reproducibility of DMT data and its simplicity and cost-effectiveness. They feel comfortable with using the DMT in Norwegian clays, but look for more experience with silts and sands.
- A.9 "Dilatometer C-reading to Help Determine Stratigraphy", A. Lutenegger and M. Kabir (pp. 549-554): The authors provide data to demonstrate that the recontact pressure (C-reading, or p₂) measures the penetration pore pressure in some cohesive soils and that p₂ dissipation tests in such soils should provide a basis for estimating the horizontal coefficient of consolidation. They also propose a pore pressure index, U_D, that includes p₂ and should help site stratigraphy.

- A.10 "Marchetti Dilatometer Testing in UK Soils" by J. Powell and I. Uglow (pp. 555-562): The authors found that the DMT results correlate well with various properties of UK soils, but sometimes with considerable changes required vs. the Marchetti 1980 correlations, particularly in stiff, overconsolidated clays. They note that p_2 dissipation tests have the potential of assessing the coefficient of horizontal consolidation. But, they caution that p_2 values in stiff clays may include important variability due to differences in the p_0 - p_1 - p_2 technique.
- A.11 "Excess Pore Pressures On-a Flat Dilatometer Test" by P. Robertson, R. Campanella, D. Gillispie and T. By (pp. 567-576): The authors provide data showing that p2 measures afterpenetration pore pressure in both sands (no excess equilibrium) and some clays (with excess). They also show that p2-dissipation can be used to determine a horizontal coefficient of consolidation and they present a tentative method.
- A.12 "Basic Interpretation Procedures of Flat Dilatometer Tests" by R. Roque, N. Janbu and K. Senneset (pp. 577-587): The authors report on research in a medium-stiff, medium sensitivity, Norwegian clay. The Marchetti 1980 correlation did not work well at this research site and the authors discuss various reasons why, using effective stress bearing capacity and cavity expansion theories.
- A.13 "Site Assessment and Settlement Evaluation of Firm Alluvial Sands and Clays With the Marchetti Dilatometer" by S. Saye and A. Lutenegger: (pp. 589-596): The authors present and discuss data from one site in Omaha, Nebraska, and conclude that the DMT provided valuable stratigraphic information and proved suitable for preliminary estimates of settlements under surcharge fills.
- A.14 "CPT and DMT testing of highway pavements in Florida" by
 K. Badu-Tweneboah, D. Bloomquist, B. Ruth and W. Miley
 (Vol. 2, pp. 627-633): The authors tested 12 existing asphalt pavements and investigated correlations vs. resilient moduli by other methods for the base, subbase and subgrade layers. The CPT correlated with R² ranging from 0.71-0.92, and the DMT between 0.72 and 0.89.

10.B Estimating c and k from p₂ dissipation tests

As noted in the item 10.A abstracts for papers A.9, A.10, A.11 and A.12 and in previous DIGESTS, the discovery that p_2 measures pore pressures in soils ranging from sands to soft-medium clays has stimulated researchers to evaluate the coeff. of consolidation and permeability insitu. The editor has prepared the enclosed draft paper, distributed as a handout at the DMT Specialty Session 2. at ISOPT-1. Since then we have obtained another excellent example site showing how p_2 accurately measures equilibrium pore pressures in sand with $I_D>2$. Figure 10 presents this example, which shows no difference between pushed and hammer-driven insertion methods.

10.C New DMT Manuals Available

As part of the work product for a PennDOT research project, Schmertmann & Crapps, Inc. and In-Situ Research Ltd. (3861 W. 27th Ave., Vancouver BC, Canada V6S 1R4, Vol. II by Robertson & Campanella), prepared new DMT and CPT manuals: They are briefly listed on the attached p. 1 from Vol. I, and are available from GPE at (prices): I(\$20), II(\$50), III(\$35), IV(\$35), all(\$100). You may also get Vol. II from In-Situ Research Ltd.

10.D Updated DMT Bibliography

Our latest DMT bibliography of March 1988 now lists over 100 papers. You may obtain a copy at no charge by simply requesting one. Vol. I in item 10.C also includes this bibliography.

10.E DMT Membrane Memo

The enclosed memo briefly discusses a possible problem that has developed with the "H" membranes and our recommended temporary solution.

10.F Gas Tank Test Safety Reminder

The gas pressure tanks used with the DMT require qualified visual inspection yearly and hydro-test checking every five years. These precautions are federal DOT regulations which will help insure the safety of the tank and the quality of the contents. Your gas supplier or local SCUBA shop can provide these services. Visual inspection typically costs about \$5 and the hydro test runs \$15-20.

John H. Schmertmann, Editor

Draft of paper prepared for a 1988 Geotechnical Conference sponsored by the Pennsylvania Dept. of Transportation (PennDOT). For preliminary distribution at ISOPT-1.

THE COEFFICIENT OF CONSOLIDATION OBTAINED FROM p2 DISSIPATION IN THE DMT By: John H. Schmertmann March, 1988

1. INTRODUCTION

1.1 The Coefficient of Consolidation

Rate often has equal importance with magnitude in geotechnical engineering problems. For example, when determining the importance of settlement, say the settlement of an embankment, the rate at which the settlement will occur usually determines the seriousness of any problems with settlement. Settlement that continues well after construction may for example mean negative skin friction on piles, a settlement discontinuity at a bridge abutment and the more rapid deterioration of pavement structure and riding quality. Because the coefficient of consolidation represents the key soil property that controls many rate of settlement problems, geotechnical engineers often have a special interest in any test that provides a value for this coefficient. The DMT has now become such a test.

Engineers typically use equation (1) to evaluate rate of consolidation settlement.

 $T = \frac{ct}{H^2}$ (1)

- Where T = a dimensionless time factor associated with a particular degree of consolidation, depending on the geometry of the drainage pattern involved.

 - t = the time since the beginning of consolidation.

H = the length of a drainage path representative of a problem, usually the longest path.

When using eqn. (1) to calculate the rate of consolidation settlement one must know the coefficient of consolidation, c.

1.2 The Marchetti Dilatometer Test (DMT)

Schmertmann & Crapps, Inc. first introduced the DMT into the USA in 1979, courtesy of its Italian inventor, Professor Silvano Marchetti. Because of its relative newness some engineers still do not know much about the DMT. Briefly, the test consists of pushing a penetrometer blade with a sharp cutting edge into the soil, stopping and then using gas pressure to expand a circular steel membrane horizontally into the surrounding soil. The operator measures the pressure required to just begin to move the membrane into the soil, referred to as the A-reading, and then the larger pressure required to move the membrane 1 mm into the soil, referred to as the B-reading. After correcting for membrane stiffness these readings become po and pl, respectively. Marchetti and others have established various correlations to predict the insitu engineering soil properties that existed prior to the disturbance of the soil displacements associated with inserting the DMT blade penetrometer. The interested reader can find many other references describing the DMT in more detail. For example, ASTM (1986) describes in more detail the DMT equipment, the performance of the test, and the data reduction.

1.3 The C-reading and p₂

In the last approximately five years research directed towards evaluating the importance of pore pressures to the DMT results has resulted in giving the DMT user an important new tool of special importance to the subject of this paper. This research has resulted in the discovery that a controlled pressure release or venting of the gas after the B-reading produces another important point in the cycle of membrane inflation-deflation -- namely the gas pressure at which the returning membrane again reaches its initial A-reading liftoff position. We now refer to this as the C-reading and give the symbol p2 to the C-reading corrected for membrane stiffness. The next section discusses the importance of p2.

2. P2 APPROXIMATELY MEASURES PORE PRESSURE

The writer introduced this subject in a previous paper to the 1986 PennDOT Geotechnical Conference in Harrisburg (Schmertmann, 1986). The following constitutes a review and an update.

2.1 In Sands

Campanella and Robertson (1985) first obtained data that indicated p_2 closely measured the total water pressure in high-permeability soils such as sands. They obtained the data reproduced here in <u>Figure la</u>. In a specially instrumented research DMT blade they followed the pressure required to produce the full inflation-deflation cycle and simultaneously measured the pore water pressure at the center of the moving membrane. As shown, they found that the load-unload cycle produced essentially no excess hydrostatic pore pressure and the closing p_2 matched the pre-insertion equilibrium water pressure, u_0 .

Schmertmann (DMT DIGEST #7A, 1986) explored the lower limit of permeability, in terms of the DMT material index I_D, for which insertion- and test-generated excess pore pressures remained essentially zero. <u>Figure 2</u> shows his results. This figure appears to show clearly that when I_D equals or exceeds 2.0, then p_2 = approximately u₀ (taken as hydrostatic in these data). Others have since confirmed this finding, for example see <u>Figures 3 and 4b</u>. Note that with the I_D-based soil identification system proposed by Marchetti (1980) an I_D of 2.0 represents a silty sand.

Although the writer does not know exactly why p_2 from the DMT appears to successfully measure ambient pore pressure in sands, he and others (Lutenegger, 1988) believe that a small cavity probably forms behind the deflating membrane, which fills with water at the ambient pressure. A very rapid deflation, such as the previously typical sudden release of the gas pressure after the B-reading when performing the DMT without obtaining a C-reading, probably causes very high pore pressures gradients and unstable soil conditions behind the suddenly deflating membrane. Research has also shown that a subsequent A-reading after a sudden release usually gives a second p_0 significantly higher than p_2 had the deflation been controlled, perhaps because unstable sand collapses against the membrane and thus adds soil pressure to the second p_0 .

2.2 <u>Clays</u>

At the same time as Campanella and Robertson presented Figure la, they

presented the similar <u>Figure 1b</u> obtained in a clay. This time they found very high excess hydrostatic pressures resulting from performing the DMT. However, their data in clay again shows that the p₂ closure pressure approximately equals the pore pressure on completion of the DMT. The total pore pressure included a large component of excess ambient pore pressure (often referred to as "excess hydrostatic", but this correct only if the ambient pore pressure equals the hydrostatic from a known phreatic surface). <u>Figure 2</u> also shows that with I_D in the clay range (less than 0.6) the p₂ values can exceed the ambient hydrostatic by large ratios in compressible clays. <u>Figure 3</u> presents an example log of p₂ illustrating how p₂ tracks hydrostatic in the sand layers but greatly exceeds hydrostatic in the clay layers.

Further research has continued to support the empirical observation that P2 approximately equals the total DMT-generated pore pressure. For example, included as <u>Figure 4</u> herein are data from Robertson <u>et. al.</u> (1988) that show the p2 value approximately equaling test pore pressures in both sand and clays. <u>Figure 5</u> presents data from another researcher showing how well p2 matched pore pressures determined by a parallel DMT sounding with a special DMT blade containing a piezometer at the same location as the DMT membrane.

The writer does not know the reason p₂ in clays approximately matches pore pressure.^{*} This may only happen in soft and medium clays, not highly overconsolidated (probably indicated by a low K_D, as in <u>Figure 4a</u>). Other researchers have noted a similar behavior with the pressuremeter test in soft/weak soils where deflation closure pressures have also approximately matched pore pressures in sands and clays (DMT DIGEST #5A, 1985). <u>Caution</u>: Uglow and Powell (1988) have shown that p₂ did not correctly measure pore pressure in the highly OC, stiff clays they tested and that p₂ in such clays depended on DMT procedures such as testing time and the extent of any overexpansion past the B-reading. *one reason: When eff. stress very small due to insertion disturbance.

3. P2 DISSIPATION WITH TIME

3.1 pp Dissipation Matches Pore Pressure Dissipation

The initial work by Boghrat (1987) showed that when performing DMTs in clay soils ($I_D < 0.6$) only 10% or less of the excess pore pressure generated had dissipated after 1 minute from stopping the blade penetration. <u>Figure</u> <u>6(a)</u> shows his results, all involving the dissipation of negative pore pressures in stiff, HOC clays. Lutenegger and Kabir (1988) recently obtained the data in <u>Figure 6(b)</u> that confirms the 10% finding in softer clays that dissipated positive pore pressure. That leaves at least 90% of the excess pore pressure still to dissipate and subject to being measured and analyzed. Initially, researchers merely observed that such dissipation curves, and also the dissipation curves from successive P_0 readings, had shapes similar to those already predicted theoretically and measured experimentally in the much more extensive CPT pore pressure dissipation research and literature as noted subsequently.

Figure 7 from Lutenegger (1988) shows a comparison between CPTU-determined pore pressure dissipation, DMT pore pressure dissipation and p2 dissipation. Note that although the curves have a displacement on the time scale, they all have the same shape. Figure 8 from Robertson <u>et.al.</u> (1988) shows another example of a comparison between DMT pore pressure dissipations and p2 dissipation. The first example involves parallel tests in a uniform clay, the second comparison comes from different measurements during the same DMT. The above comparisons tend to confirm the reasonable expectation that if P2 approximately measures total ambient plus excess ambient pore pressures then the dissipation of P2 with time should approximately track the dissipation of the total pore pressure with time.

One might also reasonably expect that once the first cycle of p_0-p_2 membrane expansion and deflation opens a water-filled small cavity in the soil next the the membrane, and <u>if</u> this cavity remains open with time and therefore does not require periodic reopening, that subsequent p_0 readings will track the u dissipation. This would avoid the need for successive p_0-p_2 cycles and make the tracking easier and faster and perhaps also produce smoother data. Professor R. Campanella suggested and has had his students try this method and reports (personal communication) good results at one site.

One might further expect in soils wherein p_0 results almost entirely or mostly from pore pressure that the dissipation of the p_0 readings only would also track the u dissipation. Marchetti reports (personal communication, Oct. 1987) that such p_0 dissipation data produces approximately the same t50 as actual pore pressure or p_0-p_2 cycle data. He prefers to use such p_0 dissipation curves and the resulting t50 values in a qualitative sense to decide <u>relative</u> coeff. of consolidation values as an aid to decisions such as whether or not to use artificial drainage. The writer prefers to at least attempt quantitative determinations despite the uncertainties involved, as discussed subsequently. Then the user can decide how conservatively to use the results in any particular problem situation.

3.2 CPTU Dissipation Theory Applied to DMT

A number of researchers have in the last ten years investigated theoretically the problem of the generation and dissipation of excess pore pressures around a penetrating cone penetrometer, for example Torstensson (1977), Baligh (1980), Gupta (1983) and Baligh and Levadoux (1986). The problem remains complex and each had to make simplifying assumptions. Each

presented his results in terms of a dimensionless time factor that includes the square of the radius of the cone penetrometer, the geometrical position of the pore pressure sensing element on the cone tip, and the ratio of modulus to strength of the soil penetrated. We have early indications that the time factor curves presented by Gupta best fit field data (Lutenegger, Saye and Kabir, 1988). However, Baligh and Levadoux (1986) have recently confirmed that the calculated coefficient of consolidation applies primarily to the horizontal direction and to an unloading or a recompression behavior. Thus, estimating field coefficients of consolidation in the vertical direction, and for other than unloading or recompression, requires correction factors as discussed subsequently in Section 3.3.

When applying the CPT theory to the DMT one must use an additional factor to account for the difference in shape between the circular cone penetrometer and the rectangular DMT blade with its length-width ratio of 6.3. A possible simple way to handle this involves using an equivalent radius for the DMT blade instead of the radius of the cone in the definition of time factor for the CPT theory. A 10 square cm cone has a radius of 17.8 mm. A circle with the same cross sectional area as the DMT blade would have a radius of approximately 22 mm. However, both the writer's experience and that of Lutenegger and Kabir (1987) (also Lutenegger, Saye and Kabir (1988)) suggests that an equivalent radius of 24 mm would produce approximately the same results for c_h when using either CPTU-dissipation or DMTC-dissipation tests in the same cohesive soils. The method suggested herein therefore uses $r^2 = 600$ mm².

3.3 Example Data and Calculation

Figure 8 presents the data sheet with a worked example for calculating test and field values for ch. Part (a) lists the field data consisting of a sequence of C-readings taken at successive times after stopping the DMT blade penetration and thus starting the pore pressure dissipation that results primarily from this penetration (Figure 1b shows only small additional pore pressure resulting from the 1 mm membrane expansion after the penetration). Part (b) shows these data plotted on a square root of time scale, which the writer considers most convenient for making the two time extrapolations required -- the first for p2 at zero time and the second for p2 at equilibrium (theoretically infinite) time. For zero time the writer recommends a linear backward extrapolation, which matches approximately with the aforementioned dissipation theories and which is conservative (produces a greater $t_{c,50}$) vs. the probably more correct continuing flat curvature. The infinite extrapolation reaches the ambient equilibrium pore pressure -- which might be known from other data, for example, a hydrostatic condition from a known phreatic surface. If not known, then a curve fitting or mathematical

extrapolation to an asymptotic value is required. After making these extrapolations the user can determine the time at 50% C-reading dissipation (or 30% if more convenient) as also shown in the (b) part of <u>Figure 8</u>. He or she then enters this time into the part (c) equation for the test c_h , along with the applicable time factor obtained from the Gupta time factor curves shown. This determines the c_h value applicable to this DMT. It probably does not apply directly to the insitu soil for a loading situation.

A correction needs to be applied to account for whether the field loading will produce virgin compression, recompression or some combination. Tentatively, the writer suggests the following empirical factors by which to divide the test c_h to obtain the applicable insitu c_h : 7 if the applicable field compression is virgin compression, 5 if recompression and then virgin, 3 if recompression and 1 if recompression in a highly overconsolidated cohesive soil.

One may need to apply still another correction to account for a different vertical vs. horizontal coefficient of consolidation. Equation (2) gives the equation for this coefficient in terms of the soil coefficient of permeability, k, and the 1-D compression modulus, M.

$c = \frac{k \lambda_{er}}{M} \dots \dots$	(2)
$c_{h} = \frac{k_{h}}{M_{h}} \cdots $	(2a)
$c_{\nabla} = \frac{k_{\nabla} M_{\sigma}}{M_{\nabla}} \cdot $	(2b)
M _h = K M _v	.(3)

Permeability usually has the greatest anisotropic variation. <u>Table 1</u> provides a rough guide for estimating a (k_h/k_v) ratio. Analysis of DMT data includes the routine prediction of the insitu M_v . The writer suggests estimating M_v by assuming it varies proportionally with the anisotropic effective stress condition, namely the K value as shown by eqn. (3) and which the DMT also routinely predicts. <u>Figure 9</u> also includes the calculations for c_v and k_h and k_v using an assumed anisotropic permeability ratio of 4 in this layered soil and the average DMT- predicted values of K = 1.1 and $M_v = 95$ bar at this site.

<u>TABLE 1</u> - Typical Anisotropic Permeability Ratios (from Baligh and Levadoux, 1986)

Nature of Low-k Soil (clay)	k <u>h</u> k _v	
No evidence of layering	1.2 <u>+</u> 0.2	
Slight layering, e.g., sedimentary clays with occasional silt dustings to random lenses	2.5	
Varved clays in northeastern U.S.	10 <u>+</u> 5	

3.4 Field Comparisons

The writer now has found five field cases, including two from PennDOT Research Project 84-24, comparing c_h and c_v values determined from DMT and/or CPTU measurements vs. backfigured values from field settlement or pore pressure dissipation behavior. <u>Table 2</u> includes these comparisons. The reader can see from the general good agreement between predicted and measured behavior that the DMT and CPT c_h and c_v prediction method looks very promising and appears to predict the coefficient of consolidation with an accuracy perhaps equal to that achieved from laboratory consolidation tests.

The laboratory determination has the advantage of using a good test model and consolidation theory for analysis, but a test takes a long time and uses a very small and always partly disturbed sample. The DMTC and CPTU method performs the test very quickly and relatively economically on a larger volume of insitu soil, but uses a semi-empirical analysis method.

4. CONCLUSIONS

Extensive, but new and therefore preliminary research data indicate that:

4.1 The DMT P2 reading measures ambient pore water pressures in sands and ambient plus excess ambient pore water pressures in soft-medium cohesive soils with OCR < 3. For clays, P. Robertson (personal communication, 1988) has suggested the limits $I_{\rm D} < 0.6$ and $K_{\rm D} \leq 3.0$.

4.2 P2 dissipation curves closely match excess ambient pore pressure dissipation curves in soft-medium cohesive soils with OCR < 3.

4.3 Dissipation curve theories developed for the CPTU and known to be only approximate because of the many theoretical problems involved, also have an approximate applicability to p₂ dissipation data.

4.4 The available comparisons between DMT-p2 and CPTU dissipation-predicted values of the coefficient of consolidation and field performance indicate a prediction accuracy comparable to that obtained from usually more costly, and always more time consuming, sampling and laboratory consolidation testing.

4.5 The writer believes the theory, documentation and level of practice are now adequate to begin to include these CPTU and DMTC c_v and c_h methods in site investigations for design purposes.

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-			1 1			avg. (ft ² /day)**				"error"		
Site	Soil	Soil	CPT	DMT	c _h	۹	CPT/DMT	meas.	how	No.	(DMT-Meas)	Notes
A	NC Boston blue clay	x			x		0.11 0.09	settlement oed. tests	c.10 4	9%	*** Baligh & Levadoux (86) Research embankment site	
В	NC N.Y. sensitive marine clay		X	x		0.016		pore pressures oed. tests	<u>4</u> <u>7</u> 	0%	wick drain research Lutenegger et.al. (88)	
C	Penn. cohesive embankment	X			x	0.17 <u>1.15</u> 0.66	·		2		S&C Inc. file 586-5	
							0.49 <u>1.0</u> <u>0.75</u> 1.9	pore pressures oed. tests	2 loca. 2	12%	entire embankment fill	
D	Penn. OC,layered, silt-clay	X	x		X X	<u>0.74</u> 0.99×	<u> </u>	settlement oed. tests (2 labs)	$-\frac{6}{7^{X}}$ $-\frac{3}{10}$ samp	- <u>34%</u>	S&C Inc. file 586-3 range 0.17 to 2.7 from 29 time curves	
E	Canada, BC NC, organic clayey silt	x		X			0.9	settlement	c. <u>10</u>	-44%	wick drain research under test embankment Robertson et.al. (88)	

TABLE 2 - COEFFICIENT OF CONSOLIDATION COMPARISONS: CPTU & DMTC Method* vs. Backfigured from Field Measurements

* Using combined method shown on example data sheet x See Fig. 9 for an example from these data ** ft $^{2}/d \times (1.08 \times 10^{-6}) = m^{2}/s$ *** Part of data used to develop the * combined method

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OF THE MEMBRANE

(Campanella <u>et al</u>. 85)



FIGURE 2 P2 - HYDROSTATIC RATIO COMPARED WITH MATERIAL INDEX







(dissipation of - pore pressures)

Boghrat, 1983)

(from Lutenegger, ISOPT-1, 1988)



FIGURE 8 REPEATED A, B AND C-READINGS (CORRECTED FOR MEMBRANE STIFFNESS) USING STANDARD DMT COMPARED WITH DMT PORE PRESSURE DISSIPATION (MCDONALD FARM SITE) (Robertson, et al., 1988)







FIGURE 10 - FOUR DMT P_2 SOUNDINGS IN A FLORIDA, MARINE, SLIGHTLY SHELLY, CLEAN TO SILTY, FINE TO MEDIUM SP SAND, WITH ALMOST ALL I_D BETWEEN 2.5 AND 4. SHOWS THAT P_2 COMPARES ALMOST EXACTLY WITH COMPUTED HYDROSTATIC WATER PRESSURE AND THAT INSERTION BY HAMMER PENETRATION DID NOT AFFECT P_2

ISOPT-I - SPECIALTY SESSION ON DMT PROPOSED SCHEDULE

- PROF. M. JAMIOLKOWSKI (ITALY) SESSION LEADER INTRODUCTION (5')
- P<u>ROF. C.P. WROTH</u> AND DR. G. HOULSBY (UK) INFLUENCE OF HORIZONTAL STRESS ON THE DILATOMETER TEST IN SAND (15')
- DR. S. LACASSE, <u>DR. T. LUNNE</u> AND DR.T. BY (NORWAY) ESTIMATE OF K₀ FROM DILATOMETER TEST (10')
- DR. MING-FANG CHANG (SINGAPORE) DMT VERSUS CPTU INTERPRETED STRESS HISTORY OF CLAY DEPOSITS (10')
- PROF. J. SCHMERTMANN (USA) THE C-READING AND PORE PRESSURES" (15')
- <u>PROF. S. MARCHETTI</u> (ITALY) C_h EVALUATION FROM DMT-A(t) DISSIPATION CURVES (15')
- DR. P.W. MAYNE (USA) PENETRATION PORE PRESSURES AND LATERAL STRESSES IN CLAYS BY DMT (10')
- DR. R. BORDEN (USA) USE OF DMT FOR THE DESIGN OF LATERALLY LOADED DEEP FOUNDATIONS (10')

DISCUSSION (25')

CLOSURE BY SESSION LEADER (5')

attachment for 10.A

attachment for 10.C

GUIDELINES FOR USING THE CPT, CPTU AND MARCHETTI DMT FOR GEOTECHNICAL DESIGN

VOLUME I - SUMMARY

1. INTRODUCTION

1.1 Objective and Scope

In June 1985 Schmertmann & Crapps began Research Project 84-24 for PennDOT titled "CORRELATION STUDY FOR THE FLAT PLATE DILATOMETER AND ELECTRICAL DUTCH CONE PENETROMETER". It had the multiple objectives of improving, and expanding if possible, the correlations between the insitu tests involved, namely the static Cone Penetration Test (CPT) and the Marchetti Dilatometer Test (DMT), and the soil engineering properties of interest to DOT engineers, to demonstrate their utility at appropriate sites in Pennsylvania, to work directly with PennDOT engineers and technicians to further familiarize them with these relatively new insitu test methods, and to produce current written CPT and DMT user and design "Guidelines" for all interested DOT engineers. <u>Table 1</u> lists the field sites and testing done for this project.

The final work product from this project consists of the following four volumes, all under the same general title of GUIDELINES FOR USING THE CPT, CPTU AND MARCHETTI DMT FOR GEOTECHNICAL DESIGN.

Vol. I - SUMMARY (78 pp. incl. CPT & DMT bibliographies)
Vol. II - USING CPT AND CPTU DATA (235 pp., by Robertson & Campanella)
Vol. III - DMT TEST METHODS AND DATA REDUCTION (183 pp.)
Vol. IV - DMT DESIGN METHODS AND EXAMPLES (135 pp.)

The present Volume I serves as a combination introduction to and summary of the following three that present many more details. This Volume I briefly describes capabilities, with some details. For quick reference we have

GPE. INC. -Geotechnical Equipment -----

GPE DILATOMETER MEMORANDUM

"H" MEMBRANE SPACER GASKET 26 Feb 88

The hardened "H" style membranes have dramatically increased the damage resistance and usability of the DMT membrane. Unfortunately, the high strength steel from which they are made does not conform itself to the shape of each individual blade as well as the softer metal of the earlier membranes. Though within practical machine tolerances, the variation in blade and membrane dimensions may further impair (or possibly improve) the match between membrane and blade. Because of this mismatch, some "H" membrane users have experienced difficulty with leakage (leak check to 5 bars required) and with obtaining reasonable calibration values. In many cases, proper membrane exercise techniques and re-tightening of the membrane retaining ring screws will alleviate these problems.

In spite of the difficulty, GPE Inc. recommends that DMT operators continue to use the "H" membranes to take advantage of their cost efficiency and superior strength. As a temporary solution, we have found that adding a "spacer" gasket beneath the membrane gasket now used seems to work consistently well. These 0.1 mm thick gaskets are available from GPE Inc. and are currently distributed at no extra cost with all "H" membrane orders. However, we emphasize that operators should continue to use the exercise procedure to properly seat the membrane and stabilize its calibrations.

Both GPE Inc. and Dr. Marchetti are currently exploring various practical solutions to this problem which we hope will be corrected in the near future. Please bear with us until that time and make use of the spacer gasket if needed.

attachment for 10.E

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