GPE, INC.
Geotechnical Equipment

DMT DIGEST NO. 7
March, 1986

7A. PennDOT Paper Update

The enclosed Appendix A preprint of a paper prepared for a PennDOT-ASCE geotechnical conference in April, 1986, constitutes the bulk of this DIGEST. The editor prepared this paper to also provide an update for readers of this DIGEST.

7B: Marchetti CPT-linked K_o and ϕ in Sands

As noted in Section 2a. of the 7A. PennDOT paper, Marchetti has developed a new and simplified procedure for evaluating K and friction angle in uncemented sands — provided the user has representative CPT q_c data available. The q_c refers to the electric tip and mechanical tip data needs to be converted. His published discussion for XI ICSMFE describes his method in more detail. He bases it primarily on the results from extensive Italian chamber testing (paper [8] in 7A. PennDOT paper) and a particularly well documented case history in Italy. Briefly, use the following steps:

a. Obtain the DMT data in the sands, without measuring thrust.

b. Obtain parallel CPT q_c data representative of the soils tested by the DMT. Use the electric tip for the CPT. If using a mechanical tip use the less desirable alternative of converting to cylindrical-tip q_c values . The editor uses the trend line conversion in Fig. 7B.1.

c. Calculate the effective overburden pressure at each DMT and divide the matching electric q_c by this pressure to obtain the q_c/σ_v' ratio.

d. Solve for K_o using the following empirical equation obtained by Marchetti from paper [8] in the 7A. preprint.

$$K_o = 0.376 + 0.095\,K_D - (1/300)(q_c/\sigma_v')$$

e. Enter Fig. 7B.2, prepared by Marchetti, with the above q_c/σ_v' and K_o values to obtain the matching peak, axi-symmetric sand friction angle. Marchetti used the Durgunuglu & Mitchell theory to prepare Fig. 7B.2. It does not include normalizing to a particular stress level.

BACK

f. OCR is still calculated with the same formula used previously in DIGEST item 1B.

$$OCR = [K_o/(1-\sin\phi_{ax})]^{1/0.8 \sin\phi_{ax}}$$

The above method produces a lower, and sometimes much lower K_o and OCR and higher ϕ than the currently used method described in DIGEST item 1B. You may wish to try it as an alternate method now undergoing evaluation. Marchetti reports (personal communication) adopting it as his routine method for uncemented sands.

7C. Blade Dimensions

DMT blades currently in production by GPE and Marchetti have a small increase in their thickness (15 mm vs. 13.7 mm) and width (96 mm vs. 94 mm) for better stiffness. Marchetti's early research with various style blades indicated that these changes have a negligible effect on the raw data. The computer programs for data reduction now include input to incorporate the thickness change. Its effect is generally $\leq$ 0.1 degrees on the ϕ'_{ps}. GPE blades numbered GB-25 and higher have the larger dimensions.

7D. Computer Program Update

7D.1 Concerning the HP 41 data reduction program: we have recently discovered a minor error that rarely comes up. However, we suggest correcting it by making the changes noted in Appendix B.

7D.2 The FORTRAN data reduction program "DILLY4" has undergone a series of evolutionary changes since it was first published. These changes are documented at the beginning of the program shown in Fig. 7D.1. The user may consult the listing to decide if he wishes to make these updates. If he desires, GPE can forward a copy of the current program either as a listing or on diskette (see 7D.3). One important change should be made by all users. Shown in Fig. 7D.2, it involves an error in the modulus subroutine. The other changes in the listing are optional program enhancements.

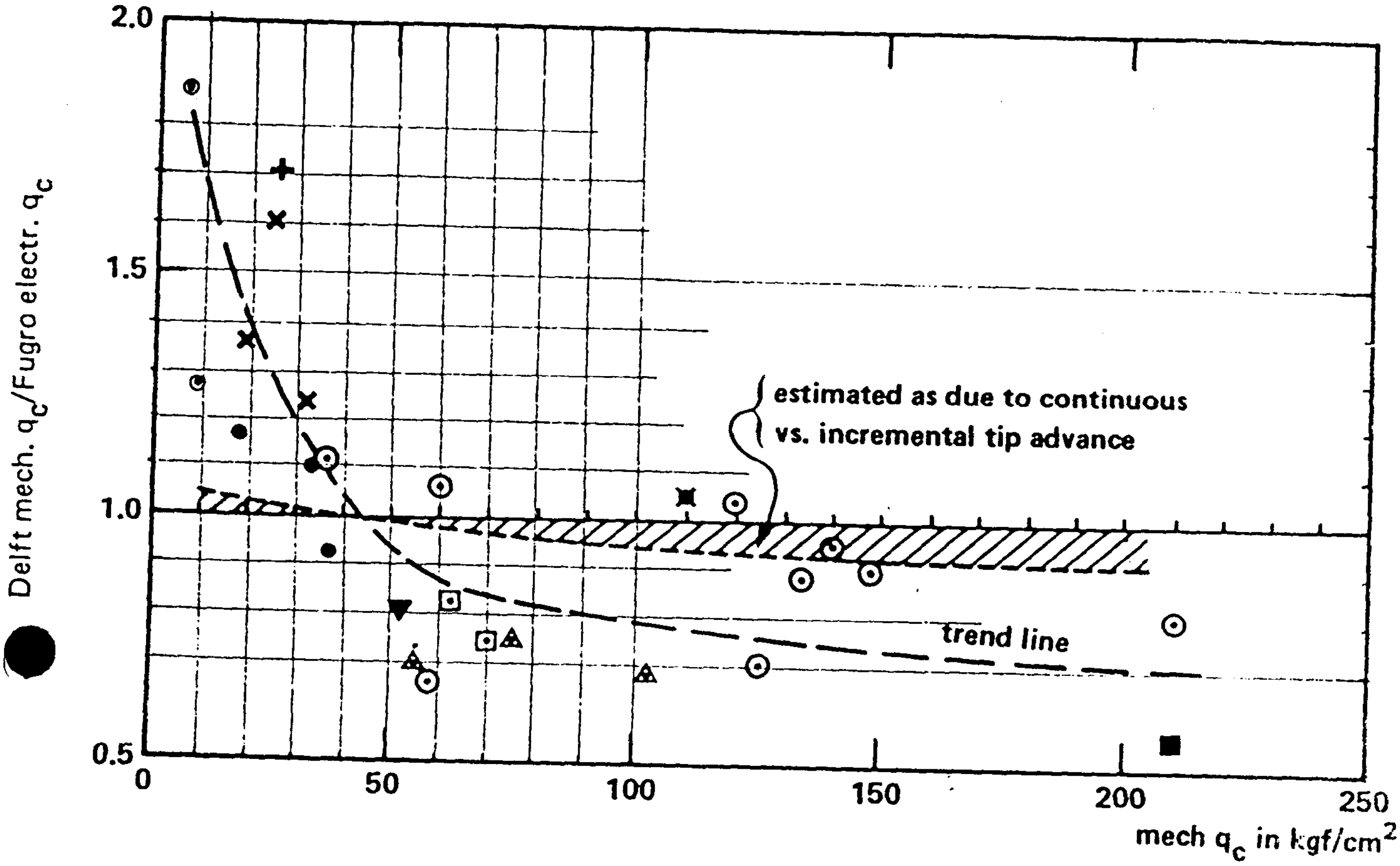
7D.3 We also now have available an IBM-compatible FORTRAN program on an MS-DOS diskette. Please see the attached GPE memorandum, Fig. 7D.3. Contact Paul Bullock of GPE, Inc. for more information.

John H. Schmertmann
Editor

BACK

(FHWA 1978)

7B.1



Legend: ⊙ Fugro tests, below WT (Joustra, 1974)
⊡ Delft tests, below WT (Heijnen, 1973)
▲ Kok (1974), below WT
■ U.F., field below WT
✚ U.F., field, below WT, sandy clay
● U.F., field, above WT
▼ U.F., chamber, dry uniform med. sand
◉ Ft. Pierce, Fla., silty sand below WT
✖ Raleigh, NC, above WT, residual silt
⌘ Raleigh, NC, below WT, residual silt

All points represent averages of a layer at least 1.0 m thickness

FIGURE I-4 – COMPARISONS BETWEEN q_c OBTAINED WITH DELFT MECHANICAL AND FUGRO ELECTRIC STATIC CONE TIPS

BACK

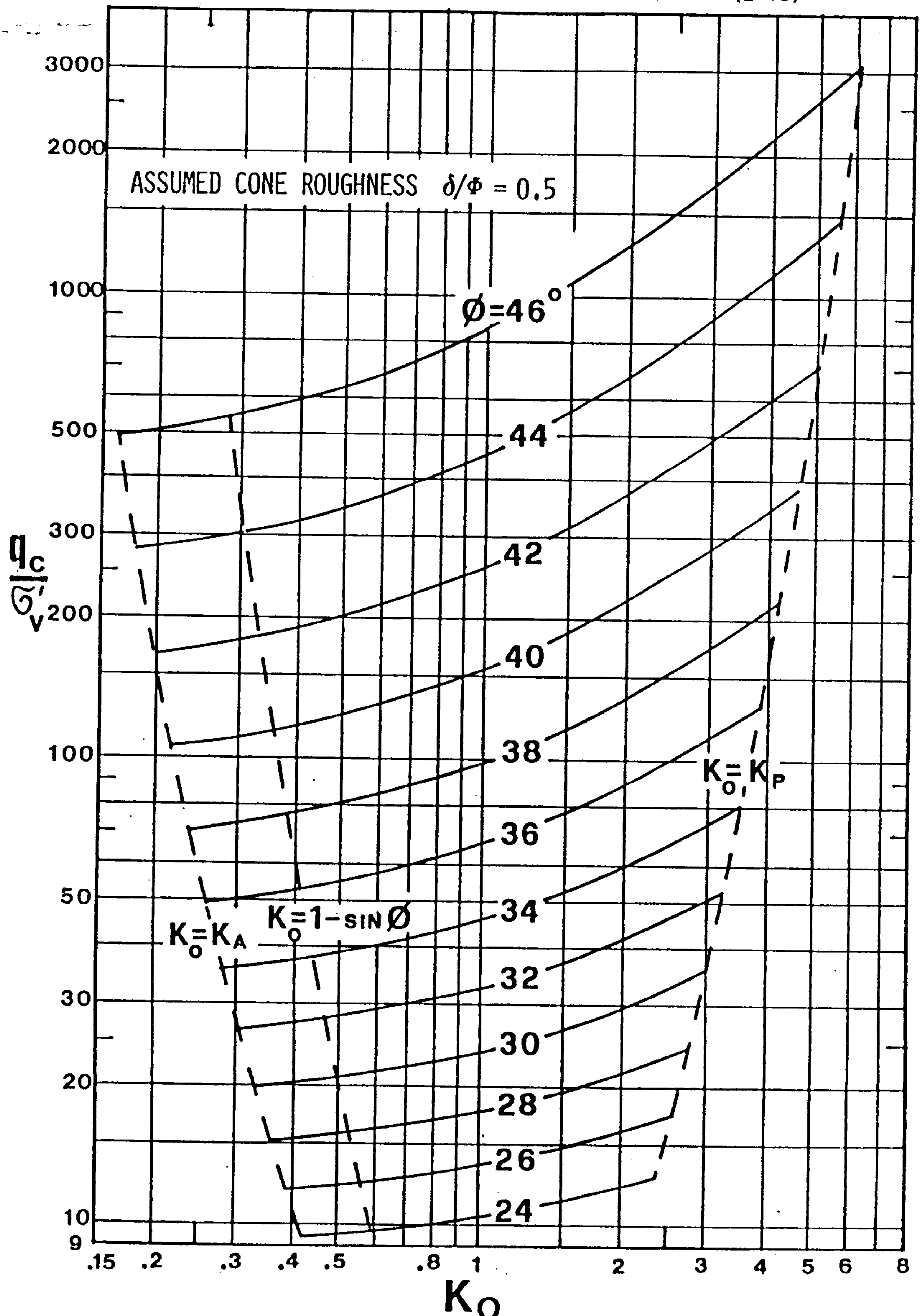
DILLY4.FOR

```
C     ***************************************************************
C     *                                                             *
C     *                       D I L L Y 4                           *
C     *                                                             *
C     *                  VECTOR3 CP/M VERSION                       *
C     *                                                             *
C     ***************************************************************
C
C     DILATOMETER DATA REDUCTION PROGRAM
C     DEVELOPED BY: SCHMERTMANN AND CRAPPS, INC.
C     WRITTEN BY  : PAUL J. BULLOCK
C
C     USES DATA REDUCTION CALCULATIONS BASED ON MARCHETTI'S
C     FLAT DILATOMETER MANUAL AND SCHMERTMANN'S PENETRATION PAPER.
C     OUTPUT IS IN BOTH TABULATED AND PLOTTED FORMAT.
C
C     REVISED  1/83: CONVERT FROM MAINFRAME VERSION (CIRCA 12/82) TO
C                    VECTOR FORMAT - PJB & B. DEHOFF
C     REVISED  4/83: INCLUDED SCHMERTMANN METHOD FOR KO/PHI IN SANDS-PJB
C     REVISED  5/83: ELIMINATED ITERATIVE SOLUTION. FOR GAMMA ANGLE IF
C                    DELTA:PHI=0.5; ALLOW INPUT OF DELPHI, U0, PLOT
C                    DEPTH INTERVALS AND H20 UNIT WT.; REWRITE SOILD
C                    AND SRGAMM SUBROUTINES FOR BETTER EFFICIENCY.  -PJB
C     REVISED  6/83: REMOVED SOIL DESCRIPTION, ADDED NORMALIZATION OF
C                    PHI TO 2.75 BARS (BALIGH), REMOVED SIGFF FROM
C                    OUTPUT AND REPLACED WITH PC, CHANGED OCR PLOT TO PC
C                    & SV AND MOVED PHI-C PLOT TO LEFT MARGIN, CHANGED
C                    ALL VARIABLES TO 4 BYTE STORAGE (EXCEPT PLOTTING
C                    VARIABLES), GENERAL REVISION OF OUTPUT FORMAT AND
C                    ADDED PHI-KO ERROR CONDITIONS.                 -PJB
C     REVISED  7/83: CHANGED KO/PHI ALGORITHM - MORE EFFICIENT.     -PJB
C     REVISED  3/84: ADDED I/O FOR COMPANY NAME AND ADDED STATEMENT
C                    ABOUT PHI ANGLE NORMALIZATION.
C                    ALSO ADDED INPUT FOR GAMMA AND SV AND ADDITIONAL
C                    PLOT AXES AND EXTRA SPACE AT TOP OF OUTPUT.  THEN
C                    CORRECTED ERROR IN OUTPUT FORMATTING WHERE CHECK
C                    WAS MADE FOR BOTTOM OF PAGE BEFORE END OF DATA.-PJB
C     REVISED 11/84: MORE EFFECTIVE PLOT ROUTINE.                   -PJB
C     REVISED  2/85: CHANGED U1 CALC. - INPUT U1 NOW PRESSURE/BARS. -PJB
C     REVISED  2/85: CHANGED LINE COUNTING LOGIC & NUMBERS.         -PJB
C     REVISED 11/85: PROVIDE FORMLENGTH AND BLADE THICKNESS I/O.    -PJB
C     REVISED  1/86: CORRECT ERROR IN BLADE THICKNESS CHANGE.       -PJB
C
C     LOGICAL UNIT NUMBERS (LUN) USED:
C        6 - INPUT FROM DISK (SET UP WITH FILE NAME USING RDINIT)
C        2 - OUTPUT TO PRINTER
C        1 - CONSOLE I/O (USED IN RDINIT SUBROUTINE ONLY)
C
C     ***************************************************************
C
C     THIS VERSION OF DILLY4 WILL RUN ONLY IN THE CP/M FORMAT.  IF IT
C     IS DESIRED TO RUN DILLY4 ON A MAINFRAME COMPUTER IT WILL BE
C     NECESSARY TO MAKE THE FOLLOWING CHANGES:
C        - REMOVE THE SUBROUTINE "RDINIT" AND ITS CALLING STATEMENT
C        - CHANGE THE LUN ON ALL " READ" STATEMENTS FROM 6 TO 5
C        - CHANGE THE LUN ON ALL "WRITE" STATEMENTS FROM 2 TO 6
C        - CHANGE FORMAT STATEMENT 5005 AS FOLLOWS:
C           OLD:  (20A4/1X,20A4/1X,5A4/1X,5A4/1X,20A4/1X,20A4/1X,20A4)
C           NEW:  (20A4/20A4/5A4/5A4/20A4/20A4/20A4)
C        - ADD THE NECESSARY JCL FOR YOUR SYSTEM
C
C     ***************************************************************
C
      DIMENSION Z(200),SIG(200),PC(200),CU(200),
     1 ISIG(21),ICU(21),IM(42),CHECK(200),CID(200),CPHI(200)
      DIMENSION THRUST(200),TOPAX(27),BOTAX(27)
      REAL ID,KD,KO,M(200),IP,CONAM(20),JOBNAM(20),JOBNUM(5)
      REAL ITYPE(3),ITEST(5),ILOCAL(20),IDATE(20),ITECHS(20)
      INTEGER ZCHK,PHIOPT,PLTSIG,PLTCU,PLTPHI,PLTM,PHIMIN,OCROPT
```

CHRONOLOGY OF PROGRAM ALTERATIONS

BACK

from MARCHETTI (1985)



BACK

A

PREPRINT

Prepared for publication in the Proc.
of INNOVATIONS IN GEOTECHNICAL ENGINEERING,
A conference to be held 17-18 Apr 86 in
Harrisburg, PA, sponsored by PennDOT
and the Central PA Section A.S.C.E.

BACK

"SOME 1985-6 DEVELOPMENTS IN DILATOMETER TESTING AND ANALYSIS"

by: John H. Schmertmann [1], F. ASCE

In the 1985 Annual PennDOT Geotechnical Conference the writer presented a paper titled "Introduction to the Marchetti Dilatometer Test (DMT)". During the past year developments have continued with respect to DMT techniques, test interpretation, and the use of the test results for design. Those engineers interested in the DMT should find this update of interest.

1. C-READING MEASUREMENTS FOR INSITU WATER PRESSURE, WATER TABLE, AND EXCESS HYDROSTATIC RESPONSE

The DMT research performed at the University of British Columbia resulted in an important discovery by Campanella et. al. (see [4] in Table 1). As shown in Figure 1, they found that the DMT membrane closing pressure matched closely with the insitu water pressure in sands and with the insitu water pressure plus excess hydrostatic (resulting from the DMT blade insertion and membrane expansion) in clays. Thus, by the simple addition of a closure pressure, or C-reading, after the standard A- and B-reading sequence, the engineer can determine important information about insitu water pressure conditions and pore pressure generation behavior. Using the C-reading avoids the complication of adding a pore pressure transducer and the associated electric readout equipment.

As shown by the relevant comparisons in subsequent Table 4 herein, performing C-readings in a sand deposit, and/or in sand layers or zones within a silt and clay deposit, allows the accurate determination of insitu water pressures and profiles. This in turn permits the more accurate calculation of vertical effective stress profiles for use in the other DMT data reduction procedures and in many other geotechnical calculations. Such insitu water pressure profiles may be simple hydrostatic, show one or more perched water tables, show artesian pressure layers, or show various combinations. The usual assumption of simple hydrostatic conditions may be correct, as shown by the C-readings

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[1] Schmertmann & Crapps, Inc., Consulting Geotechnical Engrs., 4509 NW 23rd Ave, Suite 19, Gainesville, FL 32606

BACK

in Figure 2a. Conditions may also differ considerably from hydrostatic, as shown in Figure 2b. The C-reading data are available immediately for the interpretation of insitu water conditions and, as explained subsequently, may be superior to borehole-determined data.

The water or drilling fluid level measured in boreholes can provide ambiguous or incomplete information. A boring usually does not make a good piezometer. Given sufficient time to reach equilibrium, the water level indicates the highest piezometric elevation over the uncased length (assuming no casing joint leaks) of the borehole, but occurring at an unknown elevation within that uncased length. The engineer does not have sufficient time for water level stabilization in many cases and thus has further ambiguity. Boreholes can also collapse and prevent sounding for the water table.

Sometimes C-readings can locate the water table even in fine grained soils that may generate significant excess hydrostatic pore pressure during the DMT. If this excess hydrostatic maintains a constant ratio to hydrostatic, then the upward extrapolation of the C-readings will still show the correct elevation for the water table. Figure 2c shows an example in residual clayey silt.

Professor P. K. Robertson of the University of British Columbia reports (personal communication) obtaining C-readings similar to those obtained from the piezocone, but with less stratigraphic detail. Penetrating and testing soft clays produces high excess hydrostatic C-readings. Soils with a dilative structure, such as overconsolidated clays, show much less excess hydrostatic pressure. Silts produce still less, and sands essentially zero. The data accumulated by the writer in Figure 3 show approximate hydrostatic C-readings when $I_D \geq 2$ and that excess hydrostatic pressures generally increase with lower I_D in the silt and clay range. Thus, the C-readings may also prove useful to help interpret the I_D data for stratigraphy and to help define the relative positive or negative dilative behavior of silts and clays.

Although in the realm of speculation, it also seems likely (see subsequent paper [11]) that a sequence of followup A-readings with time, A_2, A_3,... after the deflation C-reading, may provide information about pore pressure dissipation with time. The extrapolation to infinite time should then allow obtaining the insitu water pressure in silts and clays also. Such measurements could lead to using the DMT to estimate rate-of-consolidation and permeability properties, much in the same way as has been attempted with piezocone data. However, such use would come at the expense of dissipation-time delays in the progress of a DMT sounding.

BACK

2. NEW DMT-RELATED LITERATURE

Research and practical work using the DMT has continued to expand during the past 12 months between PennDOT Conferences. As part of our Tasks for PennDOT Research Project 84-24 we have compiled a list of DMT references from the technical literature. As of February, 1986 this list totaled 63 papers. Twenty-three of these 63 have become available since April 1985, or have been prepared and will shortly become available. Table 1 presents a listing of these papers for the reader´s convenience and for the subsequent discussion. The writer has organized them into the following groups: contributions to XI ICSMFE in San Francisco, to IN SITU ´86 at VPI, from consulting projects, and from other general sources.

2.1 XI ICSMFE

Jamiolkowski´s et. al. theme lecture, paper [1], presents a very extensive, state-of-the-art overview of laboratory and insitu testing. The insitu testing part of this paper includes the DMT as one of the principle tests investigated and discussed, with generally favorable comparisons and comments. Papers [2] and [3] are discussions intended for publication in the Conference discussion volume. Leonards in [2] recommends that field experience focus on the DMT. Marchetti in [3] presents an improved method for using the DMT to predict K_o and friction angle in sands if parallel CPT data are available.

Paper [4] discusses several insitu tests, including the DMT. This paper also presented important new research data (Fig. 1) showing pore pressure effects during the DMT. This pointed the way for DMT pore pressure measurement using the C-reading, as discussed in Section 1. Paper [5] suggests the DMT has potential for identifying collapsible loess layers via low K_D values. Paper [6] presents the results from using several insitu tests in deltaic silts, and indicates poor results from the DMT. However, this paper contains serious errors in the DMT data reduction which, when corrected, might lead the authors to modify their conclusions relating to the DMT.

2.2 ASCE IN SITU ´86

The writer knows of 6 papers that discuss the DMT and have been prepared for publication in the Proceedings of the ASCE Specialty

BACK

Conference titled "IN SITU ´86", to be held at the VPI, Blacksburg, VA, in June 1986. The first, paper [7] makes only minor mention of the DMT. The other five emphasize the DMT. Paper [8] by Baldi et. al. discusses the extensive large calibration chamber testing done with the DMT in Italy. These results should eventually provide the basis for a method to further improve the DMT predictions of K_o, OCR and friction angle in sands. Papers [9] and [10] provide case histories for using the DMT for the insitu quality control testing related to the ground improvement of loose sands and silts. Paper [11] presents the results of research and demonstrates the potential use of the DMT to predict the design friction capacity of piles. The suggested method involves successive A-readings after penetration to monitor pore pressure dissipation and extrapolate to the fully drained lateral stress against the pile. Soil/pile friction coefficients, believed to exist in a relatively narrow band, are then estimated and used to multiply by the above drained lateral stress to obtain pile side friction.

Paper [12] describes in detail the simple settlement calculation procedure used with DMT data -- based on the 1-dimensional modulus concept developed by Janbu. This paper presents an example calculation and also compiles 16 comparisons between DMT-predicted and measured settlements (all those available to the author at the time). Paper [12] includes a table summarizing this experience and the writer has reproduced it herein as Table 2. The average ratio of (DMT/measured settlement) = 1.18, with extremes of 2.2 and 0.7, and a standard deviation of 0.38.

2.3 Consulting Projects

In paper [13] Fabius describes the use of the DMT in 8 routine consulting projects and concludes "In general the dilatometer has been both economical and useful in improving the quality of data on which final design recommendations are based." Papers [14] and [15] deal with the use of a variety of insitu tests, including the DMT, to help with the geotechnical exploration and design for a very large bridge over Tampa Bay, Florida. Over 750 DMTs helped significantly in the design of the drilled shaft and pile foundations for this bridge founded in hard clays. Another 250 DMTs provided data for sheet pile wall and embankment designs. The authors of paper [16] describe incidental DMT testing and results for a high-rise bank structure over a lightly cemented, very sensitive clayey silt in Fredricton, Canada. The DMT testing at this site, made for research purposes, showed clearly the too-low-modulus results obtained when driving the DMT blade into such sensitive silt vs. advancing by quasi-static push (as with the Dutch

BACK

CPT). Unfortunately, in paper [16] the authors did not separate the few push tests from the many driven nor did they use other push test results at an adjacent site. When the writer considered only the push tests, he obtained the comparison given in case 5c in Table 2.

2.4 Other

Professor Borden at North Carolina State University has continued his active research with the DMT with NCDOT-related problems. He presented paper [17] at the 1985 TRB meeting, dealing with estimating the CBR using DMT data. At the 1986 TRB meeting he presented paper [18] dealing with the DMT evaluation of the compressibility of compacted embankments. The FLDOT and PennDOT also have active DMT-related research underway but have not yet published results.

As part of ESOPT II in Amsterdam, the Delft Soil Mechanics Laboratory oversaw the performance of a variety of insitu tests at a research site. These included the DMT. The recently published paper [19] gives a detailed comparison of the various insitu test results. Paper [20] presents a suggestion by Robertson and Campanella that the DMT K_D values may prove useful as an indicator of liquefaction potential in sands. This idea of relating structure-collapse to K_D seems similar in concept to that suggested for loess in the aforementioned paper [5].

Papers [21] and [22] differ significantly from the aforementioned, perhaps more ordinary types of papers. Paper [21] presents a mini-state-of-the-art paper on the importance of insitu lateral stress to a great variety of geotechnical design problems. Table 3 herein presents the SUMMARY & CONCLUSIONS page from [21]. Paper [21], as well as [10] which presents the same data in more detail, suggests that high initial insitu K values may limit the effectiveness of sand improvement methods such as dynamic compaction. Paper [22] is scheduled for publication in June. It will present ASTM committee D18.02.10's proposed SUGGESTED METHOD for the performance and data reduction from the DMT for exposure and comment. Table 4 herein comes from paper [22], but was initially supplied by the writer and based on his compiled comparison experiences with DMT data obtained by himself and (mostly) others.

3. NEW DMT EQUIPMENT

There have been new developments and improvements in DMT equipment during the past 12 months. Figure 4 shows photographs of the new items

BACK

discussed herein.

3.1 C-reading unit:

Figure 3a shows an annotated photo of the optional add-on equipment the writer now uses routinely with the standard control box so as to permit efficent C-readings for pore pressure. The unit quick-connects to the dilatometer port (1) on the box. The cable from the dilatometer then quick-connects into this unit at (2). The unit includes a low range Bourdon gauge (3), protected by a regulator and check valve to prevent overloading. The operator uses this gauge for a more accurate measurement of the C-reading and also as a sensitive low range gauge in weaker soils. This gauge also has a negative range and thus, in conjunction with a quick-connect port (4) for the membrane calibration syringe, can be conveniently used for the both $\triangle A$ and $\triangle B$ membrane calibrations. Note that using the same gauge for calibration as for readings eliminates the need for a gauge zero correction when using the low range gauge.

To obtain the C-reading the operator performs the following steps: After the audio signal returns to signal the B-reading (at 1.1 mm membrane expansion) the operator depresses the vent control on the control box to rapidly deflate the membrane until reaching about 1/2 the B-reading pressure. This pressure release stops the audio signal. He or she then uses the special flow control valve (5) on the new unit to slowly control the final deflation. When the membrane again rests in its initial, A-reading position, the audio signal returns and the operator then takes the C-reading.

The controlled deflation serves two purposes: 1) Allows a more accurate reading of the gauge during deflation, and 2) Helps to prevent the excessive hydraulic gradients that might develop in the cavity forming behind the deflating membrane by its too-rapid deflation. The writer recommends deflation times of 15-30 sec. -- the same time intervals recommended for each of the A- and B-readings.

In summation, the new C-unit serves the multiple functions of furnishing a more sensitive gauge for low-range readings, substituting for the previous special calibration gauge, and also providing the flow control needed for the pore pressure measurement.

3.2 Research control box:

BACK

Figure 3b shows a photo of a new control box, presently undergoing research use. It incorporates internally all the features described above for the C-reading unit. The photo has the previous numbering to indicate the deflation control valve (5), the low range gauge (3) and the membrane calibration port (4). Both gauges have expanded scales, with a -1 to +10 bar low range and a 0 to 60 bar high range gauge. The new control box also has a special port (6) to allow plugging in a remote audio signal source for use in headphones or other devices that can be held closer to the ear in noisy environments. This new control box has proven very convenient to use.

3.3 High strength steel:

After considerable experimentation, Marchetti has developed another stainless steel membrane of the same thickness as used previously, but now made with a much higher yield strength steel. GPE, Inc. has also developed a high strength steel blade with about six times the yield strength and about three times the hardness of the standard blade. Figure 3c shows a photograph of the new membrane and blade. They have the same dimensions and look just like the regular stainless steel equipment. The new membranes have already proven much more durable and they involve only a modest extra cost. They require a longer pre-conditioning effort, but they also have more stable $\triangle A$ and $\triangle B$ values and can greatly reduce replacement problems. We recommend the new "H" membranes for standard use and the older "S" membranes for soft soils.

The new steel should reduce sand-abrasion wear of the blade, and greatly reduce blade wrinkling and bending problems. However, the blade improvements may not help significantly with the push rod bending and breaking problems that some users have experienced with high magnitude of penetration thrust (over 5 tons) in difficult soils. We expect to be able to recommend the new blade for use in strong soils, for when the blade must be driven to obtain insertion, and for soils where the blade may encounter obstructions such as rock lenses, cemented inclusions, gravel or larger particles, etc.

3.4 Hogentogler equipment:

Hogentogler & Company, working with GPE, Inc., has developed a data acquisition and reduction option for the standard and the experimental DMT control boxes. They inserted a transducer in the pressure line to the dilatometer and take off transducer readings at the appropriate

BACK

electrical-audio signals, digitize the results, and use them in the appropriate software to print out the DMT data and the interpreted soil properties. This equipment is presently an option to the H&CO automatic data acquisition system used with their electric CPT equipment. The user of the new DMT system must already have or purchase the CPT data acquisition system.

H&CO also plans the development of an adaptor to be placed between the push rods and the DMT blade. They intend to instrument it with a load cell and inclinometer. The load cell will allow the measurement of penetration thrust of the unit itself and eliminate the complication of uncertain push rod friction when measuring thrust at the surface. The inclinometer will warn of any excessive out-of-plumb drifting of the blade and hopefully warn users with high thrust-capability equipment of impending blade damage or rod breakage.

4. ADDITIONAL NEW ANALYSIS METHODS AND USES

The previous sections of this paper have already mentioned various new uses for DMT data in geotechnical analyses. Still other uses have evolved, both in research and practice, that the reader might find of interest but should consider in the preliminary stages of development.

4.1 p-y Curves for Pile Lateral Loading

Marchetti originally started the DMT by attempting to develop an insitu test for evaluating the lateral pile loading problem. However, he realized and subsequently concentrated on the more general applicability of the DMT. Paper [23] presents the results from a laboratory DMT p-y study in which the authors obtained optimistic, but preliminary results. In a separate study Professor Peter Robertson of the University of British Columbia reports (personal communication) initial success in an effort to use the DMT to predict the non-linear p-y curves in the soil layers surrounding a laterally loaded pile. The concept involves using the DMT to determine two positions on the curve, taken from the A- and B-readings, and then to fit the general shape of such curves through these points. He reports that a student successfully did this with a large test pile. He plans to check the method by predicting the performance of smaller test piles.

4.2 Surcharge Loading On Pipes

BACK

Judging by a recent consulting experience, the writer believes the DMT may prove especially useful in evaluating the bedding and surcharge conditions around and above buried pipes and culverts. According to the widely used Marston theory (see Soil Engineering by Spangler & Handy, 4th Ed., Ch. 26, or the American Concrete Pile Association's Concrete Pipe Design Manual) the loading on a pipe depends on the type of trench constructed, the bedding under the pipe, the relative flexibility or modulus of the pipe compared to the surrounding backfill soil, and the friction-arching capability of the trench backfill over the pipe. This latter capability depends on the lateral stresses developed and the friction coefficient of the soil, both of which the DMT determines routinely. Thus, when a problem comes up concerning loadings on an existing pipe, DMT soundings positioned between the outside of the pipe and the inside of its trench can provide very useful information relating to the bedding achieved, the modulus of the backfill soil surrounding the pipe, and the lateral stress coefficient K and the friction coefficient values needed to calculate the part of the trench backfill load that acts on the pipe.

5. CONCLUSIONS

5.1 A simple, non-electronic, C-reading addition to the DMT testing sequence gives valuable and accurate data about insitu water pressure profiles, ground water tables, and perhaps also dilatent/contractent soil behavior.

5.2 The past year has seen much publishing activity, from both research and consulting, to investigate and expand the usefulness of the DMT in geotechnical practice. Table 1 includes a listing of twenty-three newly published or about-to-be-published papers relating to the DMT.

5.3 New equipment has been developed to conveniently obtain the new C-reading and to provide a parallel, more sensitive, gauge for all pressure readings in weaker soils. High strength membranes and blades are now available to reduce equipment damage in difficult soils. Significant progress has been made toward automatic data acquisition and reduction.

5.4 Various new uses for the DMT have evolved or are beginning to evolve, including: obtaining pore pressure data, evaluating the collapse potential of loess, evaluating liquefaction potential in sands, a better understanding of lateral stress effects, evaluating CBR and subgrade properties for pavements,

BACK

determining pile friction for design, evaluating p-y curves for lateral loadings of piles, evaluating the loading conditions around buried pipes, and providing quality control and design data for ground improvement methods such as dynamic compaction.

5.5 The latest update of DMT soil property prediction accuracy continues to show excellent capabilities in predicting insitu stresses, strengths and moduli.

5.6 A new compilation of settlement prediction experience shows a 16-case average ratio of (DMT-prediction/measured) settlement = 1.18.

BACK

TABLE 1 - RECENT DMT-RELATED PAPERS

SF 85

[1] Jamiolkowski, B.M., C.C. Ladd, J.T. Germaine and R. Lancellotta (1985) "New Developments in Field and Laboratory Testing of Soils", Theme Lecture, Session 2, XI ISCMFE; San Francisco, 1985.

[2] Leonards, G. A. (1985) Discussion of Theme Lecture No. 2, "New Developments in Field and Laboratory Testing of Soils", by Jamiolkowski, et. al., 1 p. Submitted for publication in the Discussion Volume, Proc. XI ICSMFE, San Francisco.

[3] Marchetti, S. (1985) "On the Field Determination of K_o in Sand", submitted for publication in the discussion volume, Proc. XI ICSMFE, San Francisco.

[4] Campanella, R.G., P.K. Robertson, D.G. Gillespie and J. Greig (1985) "Recent developments in In-Situ Testing of Soils", Proceedings XI ICSMFE, San Francisco, Vol. 2, pp. 849-854. (also in UBC SM Series #84, Sept 84)

[5] Hamamdsiev, K. B., and Lutenegger, A. J. (1985) "Study of OCR of Loess by Flat Dilatometer," Proc. XI ICSMFE, Vol. 4, pp. 2409-2414.

[6] Konrad, J. M., and Law, K. T. (1985) "Study of In-Situ Test Methods in Deltaic Silts," Proc. 11th ICSMFE, Vol. 2, pp. 879-886.

IN SITU ´86

[7] Aas, G., S. LaCasse, T. Lunne and C. Madshus (1984) "In Situ Testing: New Developments," Norwegian Geotechnical Institute Publication NR.153, pp. 1-7.

[8] Baldi, G., Bellotti, R., Ghionna, V., Jamiolkowski, M., Marchetti, S. and E. Pasqualini (1986) "Validation of DMT in Sand", submitted to In Situ ´86, ASCE Specialty Conference, Blacksburg, Virginia Tech, June 1986.

[9] Lacasse, S. and T. Lunne (1986) "Dilatometer Tests in Sand", submitted to In Situ ´86, ASCE Specialty Conference, Blacksburg, Virginia Tech, June 1986.

[10] Schmertmann, J., Baker, W., Gupta, R. and K. Kessler (1986) "CPT/DMT QC of Ground Modification at a Power Plant", submitted to In Situ ´86, ASCE Specialty Conference, Blacksburg, Virginia Tech, June 1986.

BACK

TABLE 1 (continued

[11] Marchetti, S., Totani, G., Campanella, R. G., Robertson, P. K. and Taddei, B. (1986)
"The DMT-σ'_{hc} Method For Piles Driven In Clay", submitted to In Situ ´86, ASCE Specialty Conference, Blacksburg, Virginia Tech, June 1986.

[12] Schmertmann, J. (1986)
"Dilatometer to Compute Foundation Settlement", submitted to In Situ ´86, ASCE Specialty Conference, Blacksburg, Virginia Tech, June 1986.

<u>Consulting Projects</u>

[13] Fabius, M. (1985)
"Experience With The Dilatometer In Routine Geotechnical Design", <u>Proceedings</u>, 38th Canadian Geotechnical Conference, Edmonton, Sept., 7 pp.

[14] Handy, R.L., J.H. Schmertmann, and A.J. Lutenegger (1985)
"Borehole Shear Tests in a Shallow Marine Environment", Strength Testing of Marine Sediments: Laboratory & Insitu Measurements, ASTM STP 883, pp. 140-153.

[15] Sonnenfeld, S.L., J.H. Schmertmann and R.C. Williams (1985)
"A Bridge Site Investigation Using SPTs, MPMTs and DMTs from Barges", Strength Testing of Marine Sediments: Laboratory & Insitu Measurements, <u>ASTM STP 883</u>, pp. 515-535.

[16] Valsangkar, A. O., Landva, A.O., and J. C. Adkins (1985)
"Performance of a raft foundation supporting a multi-storey building", <u>Proc.</u> 38th Canadian Geotechnical Conference.

<u>Other</u>

[17] Borden, R. H., Aziz C. N., Lowder W. M. and Khosla N. P. (1985)
"Evaluation of Pavement Subgrade Support Characteristics by Dilatometer Test", <u>Proc. 64th Annual Meeting of the Transportation Res. Board</u>, Washington, D.C., Jan 1985.

[18] Borden, R. H., Saliba, R. E. and Lowder, W. M. (1986)
"Compressibility of Compacted Fills Evaluated By The Dilatometer", Center for Transportation Engineering Studies, N.C. State Univ., Raleigh, NC, prepared for Session #136, 65th Annual Meeting of The Transportation Research Board, Washington, D.C., Jan, 30 pp.

[19] Heijnen, W. J. and E. Janse (1985)
"Case studies of the second european symposium on penetration testing - esopt II -", Delft Soil Mechanics Laboratory, No. 91, Aug.

[20] Robertson, P.K. and R.G. Campanella (1986)
"Estimating Liquefaction Potential of Sands Using the Flat Plate Dilatometer", ASTM, Geotechnical Testing Journal, March.

BACK

TABLE 1 - (continued)

[21] Schmertmann, J.H. (1985)
"Measure and Use the Insitu Lateral Stress"
reprinted from THE PRACTICE OF FOUNDATION ENGINEERING - a Volume honoring Jorj O. Osterberg, published by The Department of Civil Engineering, Northwestern University, pp. 189-213.

[22] ASTM Subcommittee D 18.0210, J. H. Schmertmann, Chairman (1986)
"Suggested Method for Performing the Flat Dilatometer Test", ASTM Geotechnical Testing Journal, scheduled for publication in June.

[23] Motan, E.S. and A.G. Muhammed (1984)
"A Flat-Dilatometer Study of Lateral Soil Response"
Proceedings of ASCE Symposium on Analysis and Design of Pile Foundations, San Francisco, October, pp. 232-248.

BACK

COMPARISONS BETWEEN DMT-CALCULATED AND MEASURED SETTLEMENTS

No. 5.2.	Location	Structure	Compress. soil	Settlement (mm) DMT	**	Meas.	ratio DMT / Meas.
1	Tampa	bridge pier	HOC Clay	* 25	b,d	15	1.67
2	Jacksonvll.	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	Fredricton	surcharge	sand	* 11	a	15	0.73
b	"	3´ plate	sand	* 22	a	28	0.79
c	"	building	quick cl. silt	* 78	a	35	2.23
6a	Ontario	road embankment	peat	*300	a,o	275	1.09
b	"	building	peat	*262	a,o	270	0.97
7	Miami	4´ plate	peat	93	b	71	1.31
8a	Peter-borough	Apt. bldg	sd.& si.	* 58	a,o	48	1.21
b	"	Factory	"	* 20	a,o	17	1.18
9	"	water tank	si. clay	* 30	b,o	31	0.97
10a	Linkoping	2x3 m plate	si. sand	* 9	a,o	6.7	1.34
b	"	1.1x1.3m plate	si. sand	* 4	a,o	3	1.33
11	Sunne	house	silt & sand	* 10	b,o	8	1.25

* Denotes Ordinary M method used

** b denotes settlements calculated before the event
a denotes settlements calculated after the event
o denotes settlement calculations by other than the writer
d denotes dilatometer advanced by driving with SPT hammer.

TABLE 2 FROM PAPER (12)

BACK

SUMMARY & CONCLUSIONS

1. The K conditions at a site can dominate soil engineering behavior and design analyses, and significantly affect safety. Table 5 summarizes the effects of K in most of the geotechnical analyses discussed in this paper:

TABLE 5 - QUALITATIVE EFFECTS OF CHANGING K ON ENGINEERING BEHAVIOR
(arrows show direction of usual less conservative behavior)

Engineering Behavior	Insitu Low K → High K
Bearing capacity	← safety decreases
Slope stability	safety decreases →
Fracture of dams	← safety decreases
Pressure on walls	increases →
Pile friction	← decreases
Settlement/deformation	← increases
Liquefaction	← safety decreases
Ground treatment improvement	more difficult →

2. Insitu soil K conditions vary over a range greater than 0.2 to 6 -- a ratio of over 30. The variation may be considerable, not only between sites but also within a site or along a single profile. Anisotropic K conditions may also exist. Many natural and man-made factors affect K in a particular soil layer. Thus, without measurements the engineer may have a difficult task to make a reasonable estimate of K conditions at a site.

3. The K conditions at a site can control the design and/or interpretation of laboratory and field test results.

4. Vertical profiling of K may add significantly to understanding the geotechnical history and conditions at a site.

5. A variety of laboratory, and particularly field methods now exist for evaluating insitu K conditions. A suitable and practical method exists for most geotechnical problems in soils finer than gravel.

The writer suspects Mother Nature has a bag full of surprises for us when it comes to insitu K conditions. Some of these will be pleasant and others unpleasant in their consequences. Reduce the unpleasant possibilities, and at the same time have the enjoyment of understanding our sites better, by measuring and then using K on a routine basis.

TABLE 3 FROM PAPER (21)

BACK

TABLE 4 - SUMMARY OF ACCURACY EXPERIENCE WITH RESULTS FROM DMT SOUNDINGS
(as compiled 9 Jan 86)

Based on data from 24 field sites and lab studies, using averages from individual distinct layers or groups of tests where the alternate test results were probably superior (i.e. test embankments) or might be judged as superior to DMT results (i.e. field vane).

SOIL PROPERTY	$\left(\frac{\text{DMT-meas.}}{\text{meas.}}\right)$ "error" comparisons in % No.	mean	std. dev.	range		usual superior data	Range of ave. DMT values [7]
STRESS							
OCR[1] (sand & silt)	5	+17	21	+50	-50	NC geology, chamber tests	0.9-1.5
OCR (clay & org)	17	+4	30	+44	-60	Oed. tests	1.0-9
K_o (sand & silt)	6	+10	23	+53	-14	NC geology, chamber tests	0.3-0.9
K_o (clay & org)	10	+7	28	+32	-40	triax, PMTs	0.4-3.4
u_o in sands [2]	12	+1	12	+30	-20	calc. from known GWT	0.00-1.2
DEFORMATION, SETTLEMENT [3]							
M (sand & silt)	7	+1	20	+20	-29	Oed. tests or meas. settlements	10-2000
M (clay & org)	22	-11	40	+55	-79		1.5-440
STRENGTH							
ϕ_{tr} (sands)	4	+0.1	7	+10	-8	triaxial tests	33-41 [8]
s_u (clay & org) [4]	38	-0.2	22	+80	-38	field vane	.007-4.7
DEPTH TO GROUND WATER TABLE [5]	12 (8 sites)[6]	(DMT - meas) meters -0.08	0.23	+0.3	-0.6	free water surface, borehole	abv. surface to 5 m

1. or preconsol. stress = p_c'
2. I_D > 2.0.
3. Similar errors expected for E = Young's modulus.
4. I_D ≤ 0.6.
5. From upward projections of linear fits through C readings to depth where C = 0.
6. 6 sand, 2 silt & clay.
7. All stresses in bars = 100 kPa (≃ 1 tsf)
8. ϕ_{ps} from DMT converted to $\phi_{tr} = \phi_{ps} - (\phi_{ps}-32)/3$

BACK

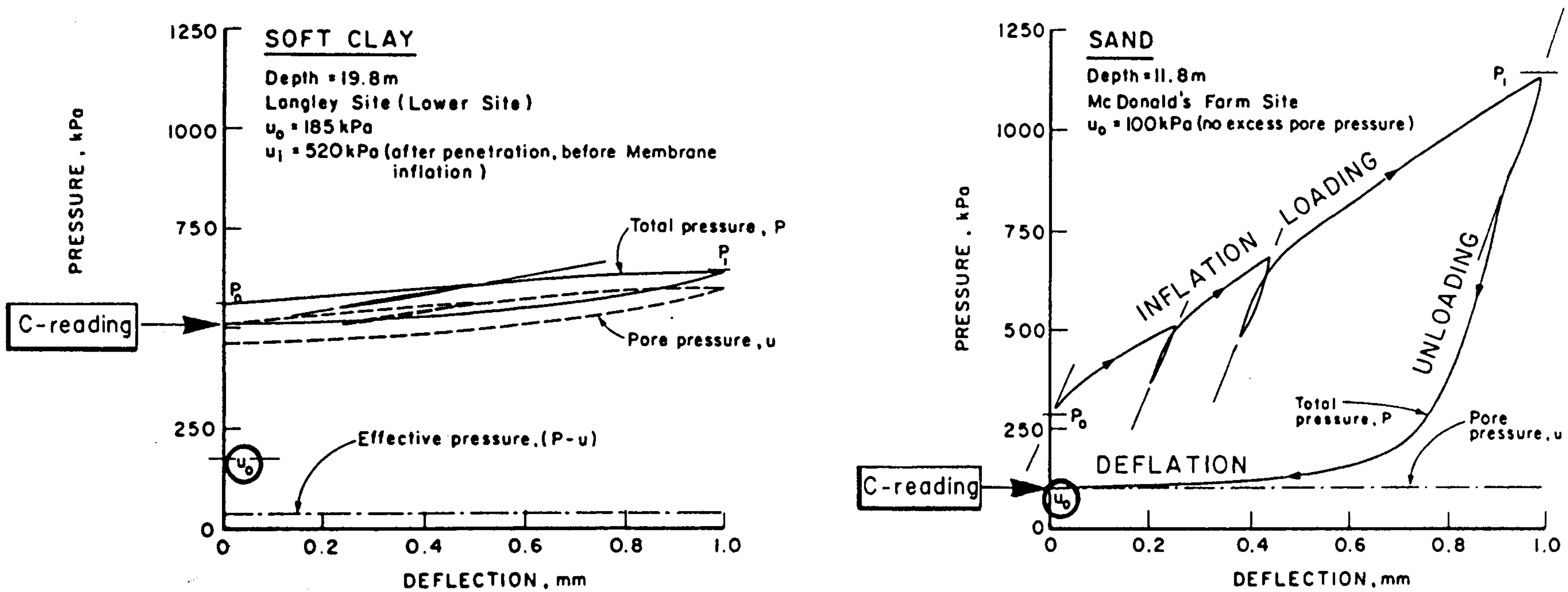


FIGURE 1 - RESULTS FROM A UBC RESEARCH DILATOMETER SHOWING TOTAL AND PORE PRESSURES ACTING ON THE MEMBRANE DURING ITS 1mm INFLATION AND DEFLACTION, IN SOFT CLAY AND SAND (annotated from paper [4])

BACK

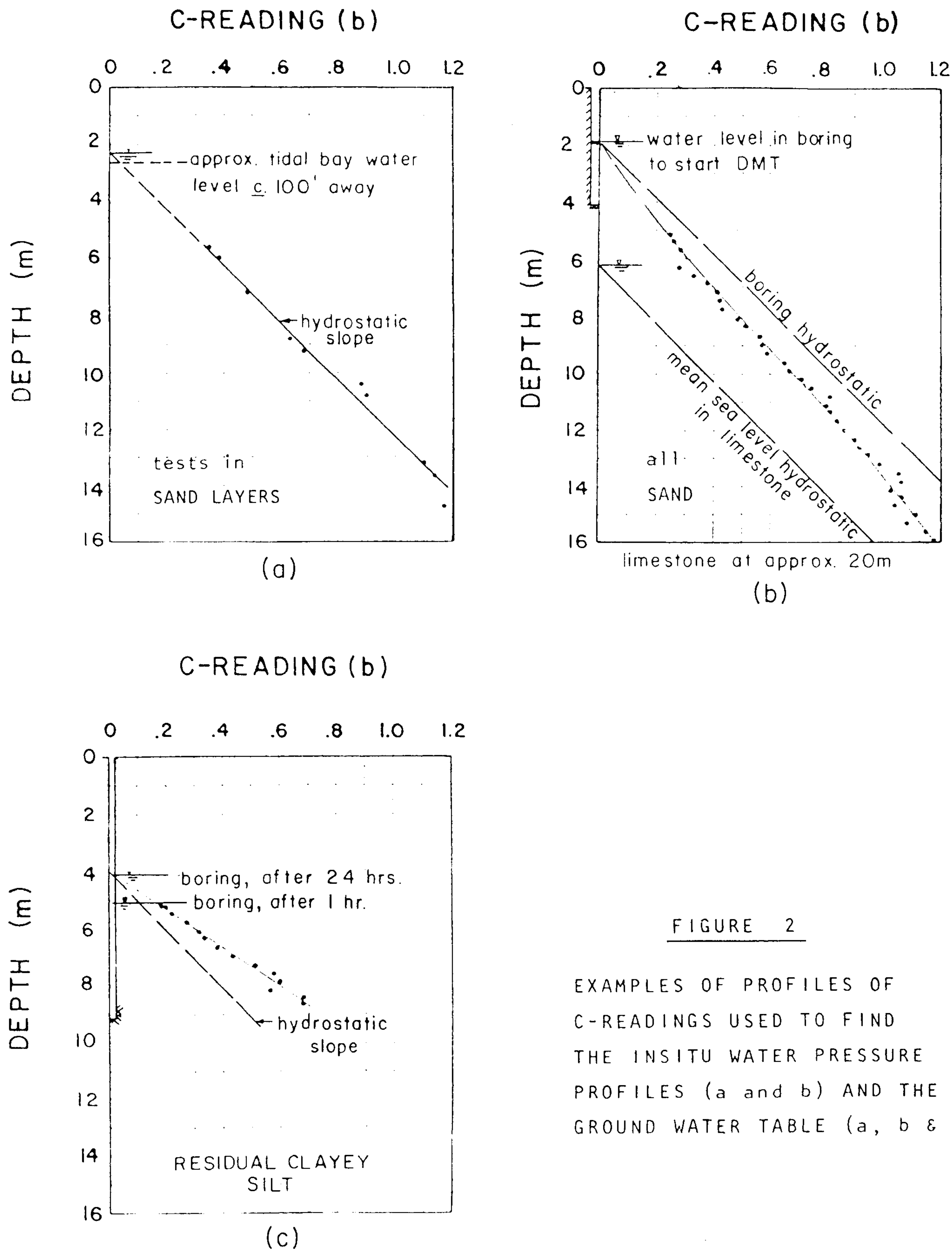
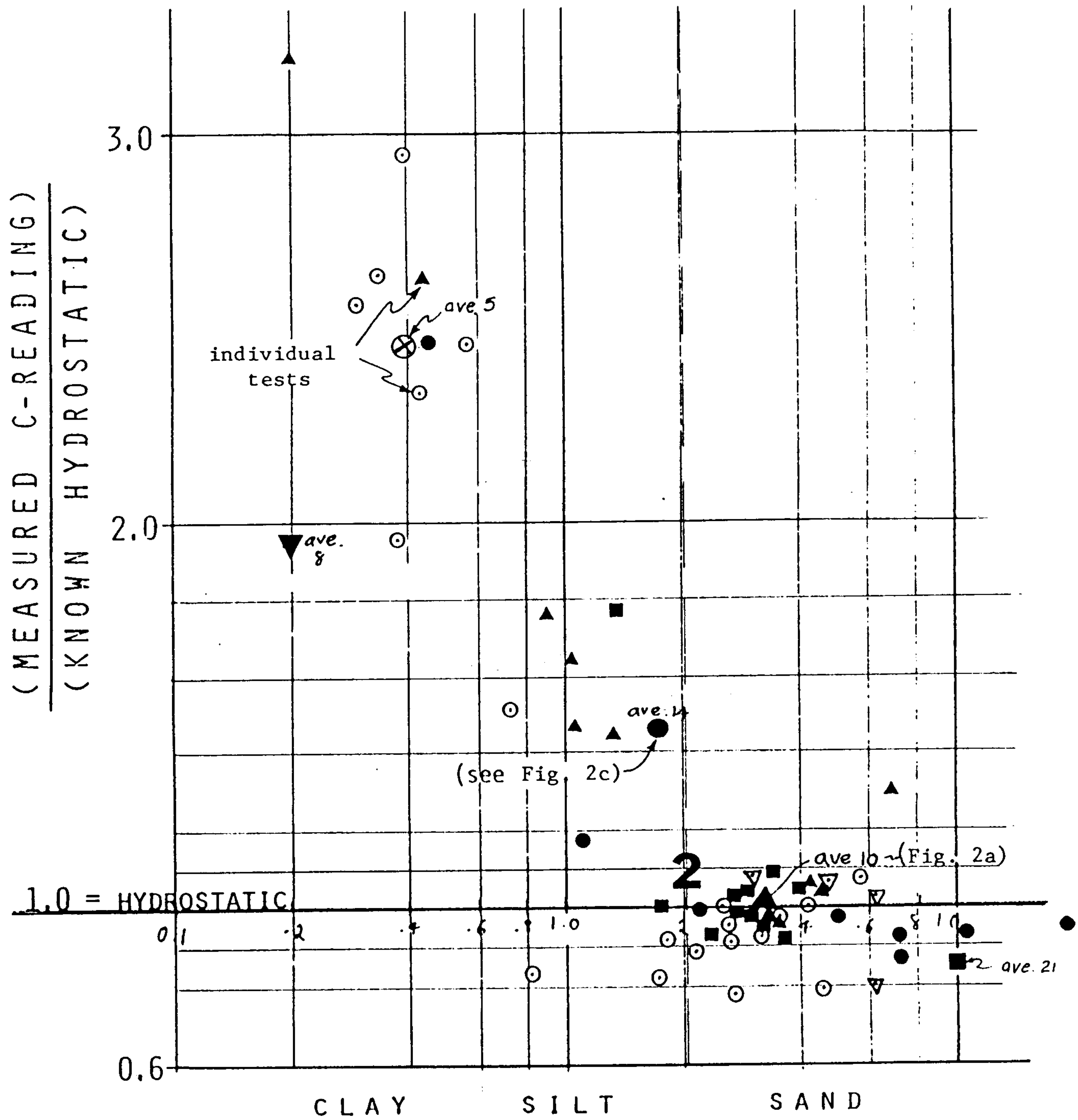


FIGURE 2

EXAMPLES OF PROFILES OF C-READINGS USED TO FIND THE INSITU WATER PRESSURE PROFILES (a and b) AND THE GROUND WATER TABLE (a, b & c)

BACK

FIGURE 3 - COMPARATIVE C-READING AND HYDROSTATIC WATER PRESSURES, SHOWING THE APPROX. I_D = 2 MINIMUM FOR AVOIDING EXCESS HYDRO[illegible]TATIC IN THE C-READING



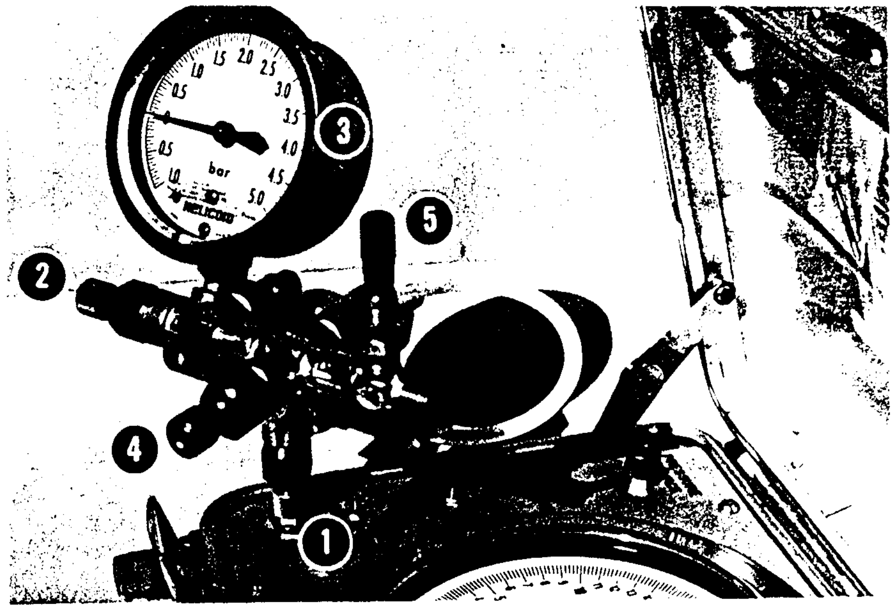
I_D = MATERIAL INDEX FROM THE DMT

BACK

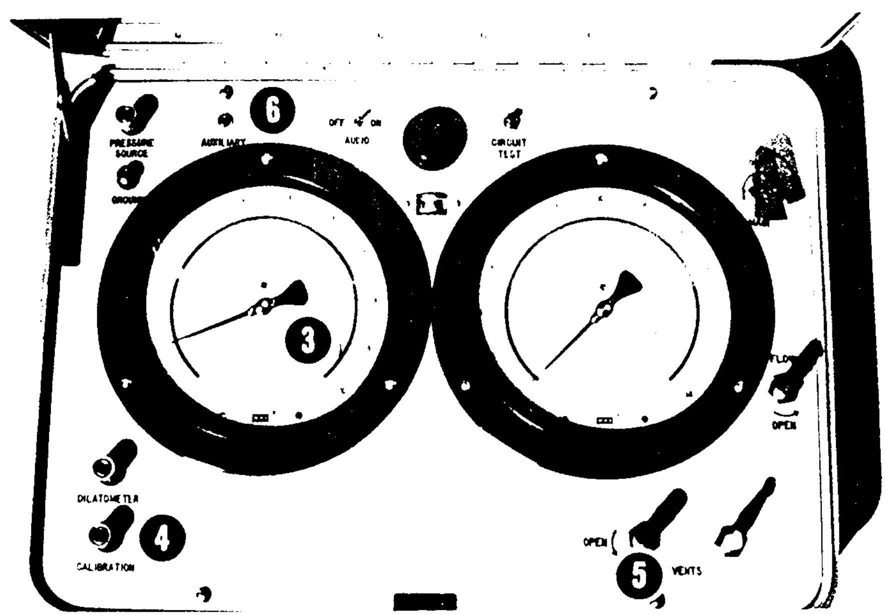
(c) High strength steel membrane & blade

FIGURE 4

SOME NEW DMT EQUIPMENT



(a) C-reading unit for water pressures



(b) Research control box

BACK

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Geotechnical Equipment

B

INDEX TO NOTES COVERING HP-41CV PROGRAM #30, "DMT"
(revised Jan 1986)

For data reduction from the Marchetti dilatometer test:

Note re: pore pressures - Program automatically calculates fresh water hydrostatic pressure at each depth using depths in Instruction steps 7 and 12. Now the User can insert own values for pore pressure using Instruction steps 13,a,b. For the automatic calculation of hydrostatic pore pressure in salt water substitute value of 0.100 for 0.0981 in program step 066.

January 1986 Revision: Changes were made in the program to correct a minor error in the calculation of ϕ'_{ps}. Input for the blade thickness was also added, registers cleared at the beginning of the program and a zero value initialized for the user input gamma question. These changes were made by P.Bullock and checked by hand and against the FORTRAN program for accuracy. The lines altered/added are highlighted by an '*' in the listing for convenience to the user updating his program. Please note also that the program now requires SIZE 055.

4509 N.W. 23RD AVENUE, SUITE 19 GAINESVILLE, FLORIDA 32601 PHONE (904) 378-2792

#30 revised (Jan 86)

User Instructions

SCHMERTMANN & CRAPPS
HP 41CV program

REDUCTION OF DATA FROM THE MARCHETTI DILATOMETER TEST

1 2

p. 1

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Press 'ON' with 'CLX' held down				
*2	XEQ 'SIZE' 055				[redacted]
3	Insert 8 memory cards, Program #30 (15 sides)				common
4	XEQ 'DMT' O-GAGE =	m	R/S		for
5	DELTA-A =	b	R/S		all A &
6	DELTA-B =	b	R/S		B readings
7	DPTH-W =	m	R/S		starting
8	first A & B readings @ "1st DPTH ="	D_1 = m	R/S		at D_1
9	total vert. stress at 1st depth = SIGVT =	b	R/S		
10	diam friction reducer on rods = d-REDUC =	cm	R/S		
11A	effective wt. rods = "EWT-ROD" =	kg/m	R/S		
*11B	LBL A → 11B blade Thickness = "BLADE-T" =	mm	R/S		[redacted]
12	(for each successive DMT reading depth) DEPTH =	m	R/S		
13	YOUR U, Y=1	for hydrostatic addition of Δu	R/S		
13a	To input U :	1	R/S		
13b	U =	b	R/S		
14	A =	b	R/S		
15	B =	b	R/S		I_D =
16			R/S		K_D =
17	if $I_D < 1.2$ (assumes cohesionless)		R/S		K_0 =
18	if $I_D \leq 0.9$ (" cohesive)		R/S		"NO PHI"
19	if $I_D > 0.9$			Cu = (b)	"No Cu"
20	if $I_D \geq 1.2$ TNET-P =	not zero kg	R/S		
20a	the closer your estimates for φ, the less time for calc.				
20b	(ϕ_{ps}) EST PHI-PS =	°	R/S		
20c	LBL B allow 1 to 2 min for iteration for φ				K_0 =
20d	'beep' = start next ϕ_{trial} cycle, musical tone = ($\phi_{calc} = \phi_{trial}$),		R/S		$\phi_{o\,ps}$ = °
20e		PHI-O-PS =			(for $\sigma_{ff}' = 2.72$ b)
20f			R/S		P_c = (b)
21	if you want to skip calcs. for φ, K_0, pc in sand → TNET-P =	enter 0 kg	R/S		NO PHI
22			R/S		NO Pc
23	when $I_D < 1.2$		R/S		P_c = (b)
24			R/S		M = (b)
25			R/S		σ_v' = (b)
26	OWN GAM? Y(es) = 1	if only press →	R/S		Computes Marchetti: γ
26a		if enter "1" and →	R/S		GAMMA = g/cc
	enter own γt for next ΔZ	= g/cc	R/S		

if input error, can return by GTO 'A' before step #26

auto return after #27

BACK