GPE, INC.
Geotechnical Equipment

DILATOMETER DIGEST No. 6
July, 1985

This DIGEST has a different format compared to previous DIGESTs. It contains only two items, each with an enclosure that GPE thinks you might find useful. We also hope that you will have the opportunity to review these items and send us your suggestions for improvement.

6A. Proposed ASTM Standard Practice

ASTM Subcommitte D18.02 has a committee looking into the preparation of a suggested Standard Practice for the performance of the Marchetti flat plate dilatometer test. The various drafts have now matured to the one enclosed, which while not in its final form might nevertheless be useful to the reader.

Dr. Ralph Brown of Law Engineering Testing Company, Chairman of D18.02, has made initial arrangements for having a draft of this suggested Standard Practice published in the ASTM Geotechnical Testing Journal to promote discussion and provide a step toward eventual approval as a published Standard Method. We would like to get the best document we can that reflects the experience and opinions of the current users of the DMT. Please send GPE any suggestions for improvements.

6B. DMT Bibliography

The DMT has now reached the state of maturity where a considerable body of literature exists about the test and its use in research and practice. For your possible use we have enclosed as complete a bibliography as we have at present concerning published papers, research reports, student theses, etc. that make significant use or mention of the DMT.

Please help us by sending the information we need to add any other references you know of to our present listing.

John H. Schmertmann
Editor

P.S. GPE will have a DMT display booth, No. 77, at the XI ICSMFE in San Francisco. Please visit if you come to SF and share your DMT experiences, problems, suggestions, etc. with us.

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(Proposed)
STANDARD PRACTICE FOR PERFORMING THE FLAT PLATE DILATOMETER TEST
17 July 85

1. Scope

1.1 This practice describes an insitu penetration plus dilation test. The operator performs the test by first forcing the steel dilatometer blade, with its sharp cutting edge, into a soil or soft rock. Each test consists of this increment of vertical penetration followed by the expansion of a circular, metallic membrane into the surrounding soil. The test provides information about the soil's insitu stratigraphy, stress, strength, compressibility and pore water pressure for use in the design of earth works and foundations.

1.2 This practice includes specific requirements for the reduction of dilatometer test data to assess soil properties for engineering design. It does not specify how the engineer shall use the determined property values.

1.3 This practice applies best to those sands, silts, clays and organic soils that the engineer can penetrate with the dilatometer blade using either static push or the dynamic impact from a hammer (see 6.2).

1.4 This practice is not applicable to soils that cannot be penetrated by the dilatometer blade without causing significant damage to the blade or its membrane.

2. Summary of Practice

2.1 - Performing a dilatometer test consists of forcing the dilatometer blade vertically into the soil to a desired test depth, measuring the thrust to accomplish this penetration (see Notes 1 and 5), and then using gas pressure to expand a circular steel membrane located on one side of the blade. The operator measures and records the pressure required to produce expansion of the membrane into the soil at two preset deflections. The operator then deflates the membrane and advances the blade the desired increment of depth and repeats the test. Each test sequence typically requires about 2 minutes. A dilatometer sounding consists of the results from all the tests at one location presented in a fashion indicating variation with depth.

Note 1 - The quasi-static thrust to advance the blade is an important part of the data interpretation in sands and silty sands. Engineers have also found it useful to help evaluate stratigraphy in all soils. Engineers have found the magnitude of thrust

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insensitive to rate of penetration in all but the loosest sands and silty sands (which may liquefy at high rate). Also see 5.2.1.

2.2 - The operator may advance the blade using either a static push or dynamic impact from a hammer.

Note 2 - In soils sensitive to impact and vibrations, such as very loose sand or very sensitive clays, dynamic insertion methods can significantly change the test results compared to those obtained using a quasi-static push. In general, structurally sensitive soils will appear conservatively more compressible when tested using dynamic insertion methods. In such cases the engineer may need to check such dynamic effects and, if important, calibrate and adjust test interpretations accordingly.

2.3 - The vertical depth increment typically used in a DMT sounding varies from 0.15 to 0.30 m (0.5 to 1.0 ft). Testing below impenetrable layers will require preboring and supporting (if required) a borehole with a diameter of at least 100 mm (4 in.).

2.4 - The operator performs a membrane calibration before and after each DMT sounding. The calibration requires about 5 minutes.

2.5 - The engineer then interprets the field data to obtain vertical profiles of those engineering soil properties of interest over the depth range of the DMT sounding.

3. Definitions

3.1 A-pressure = the gas pressure against the inside of the membrane when the center of the membrane has lifted above its support and moved horizontally 0.05 (+0.02, -0.00) mm into the soil surrounding the vertical blade.

3.2 B-pressure = the gas pressure against the inside of the membrane when the center of the membrane has lifted above its support and moved horizontally 1.10 $\pm$ 0.03 mm into the soil surrounding the vertical blade.

3.3 DMT = abbreviation for the flat plate dilatometer test as described herein.

3.4 DMT sounding = the entire sequence of dilatometer data and results along a single, vertical, line of testing in the soil

3.5 ΔA = the gage gas pressure inside the membrane required to overcome the stiffness of the membrane and move it inward to a center-expansion of 0.05 mm (a negative gage or suction pressure, but recorded as positive).

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3.6 ΔB = the gage gas pressure inside the membrane required to overcome the stiffness of the membrane and move it outward to a center-expansion of 1.10 mm.

3.7 E_{25} = Young's modulus, secant value at triaxial compression test stress of 25% of the failure stress.

3.8 E_D = the dilatometer modulus, based on linear elastic theory, and the primary index used in the correlation for the constrained and Young's moduli, $E_D = 34.7\ (p_1 - p_o)$ (see 3.18 and 3.19).

3.9 ϕ'_{ops} = the secant plane strain friction angle in non-cohesive soils, determined at a reference stress level (because of Mohr envelope curvature).

3.10 I_D = the dimensionless dilatometer index, used to identify soil type and delineate stratigraphy, $I_D = (p_1 - p_o)/(p_o - u_o)$. (see 3.23).

3.11 K_D = the dimensionless dilatometer horizontal stress index, the primary index used in the correlation for insitu horizontal stress and undrained shear strength in cohesive soils, $K_D = (p_o - u_o)/\sigma_v'$. (see 3.21).

3.12 K_o = the ratio of the insitu horizontal effective stress at the depth of the center of the blade membrane to the computed vertical effective stress at the same point, all for the undisturbed condition prior to insertion of the blade.

3.13 M = the constrained modulus of soil compressibility. Tangent value from vertical, drained loading, applicable at the insitu effective stress. Also = $1/m_v$, where m_v = the coefficient of volume change in one dimensional compression.

3.14 membrane = a flexible 60 mm diameter piece of sheet metal (usually stainless steel) that mounts on one side of the dilatometer blade, and which, as a result of an applied gas pressure, expands into the soil in an approximate spherical shape along an axis perpendicular to the plane of the blade.

3.15 OCR = overconsolidation ratio.

3.16 P = the total push, or thrust force required to advance only the dilatometer blade to its test depth, exclusive of soil friction along the pushrods. Used to calculate q_D (see 3.20, 10.3 and Note 5).

3.17 p_c' = the vertical effective stress in one-dimensional compression at which the soil structure changes relatively abruptly and becomes significantly more compressible than at lower

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pressures. For the case of a young soil subjected to one or more cycles of loading and unloading, p_c' = the maximum previous effective stress to which the soil has been subjected. For the case of an older soil, p_c' includes the quasi-preconsolidation effect due to secondary aging, and also any cementation effects.

3.18 p_o = the A-pressure reading, corrected for both the ΔA membrane stiffness at 0.05 mm expansion and the 0.05 mm expansion itself, to give the net soil pressure against the membrane immediately prior to its expansion into the soil (0.00 mm expansion). [$p_o = 1.05(A-Z_M+\Delta A)-0.05(B-Z_M-\Delta B)$]

3.19 p_1 = the B-pressure reading corrected for the ΔB membrane stiffness at 1.10 mm expansion to give the net soil pressure at 1.10 mm membrane expansion. [$p_1 = (B-Z_M-\Delta B)$]

3.20 q_D = the quasi-static bearing capacity of the soil along the bottom edge of the dilatometer blade at the instant it penetrates to the new test depth.

Note 3 - Both theory and experience show that q_D approximately equals the cone bearing capacity, q_c, from the electric quasi-static cone penetration test (CPT, see ASTM D3941). In sands $q_D \simeq 1.0\ q_c$.

3.21 σ_v' = vertical effective stress at the depth of the center of the membrane prior to the insertion of the DMT blade.

3.22 s_u (also c_u) = the undrained shear strength of cohesive soils, based on correlations vs. unconfined compression and field vane tests.

3.23 u_o = the pore water pressure acting at the depth of the center of the membrane prior to the insertion of the DMT blade (often assumed as hydrostatic below the water table surface).

3.24 Z_M = the gage pressure deviation from zero when vented to atmospheric pressure.

4. Apparatus

4.1 The annotated Figure 1 illustrates the major components of the DMT equipment, exclusive of that required to insert the blade. The dimensions, tolerances, deflections, etc. have been set by the inventor, and holder of the dilatometer patent, S. Marchetti. See 10.2 for details.

- Blade (1) and membrane (2)

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- Control unit with a pressure readout system (3) which can vary in type, range and sensitivity as required. The unit shown has a single, manually read Bourdon gage. The control unit also includes a pressure source quick connect (5), a quick connect for the pneumatic-electrical cable (shown with calibration unit in place), an electrical ground cable connection and valves to control gas flow and vent the system (6).

- Calibration unit (4) with a pressure gage and vacuum and pressure source for determining the ΔA and ΔB membrane calibrations.

- Pneumatic-electrical cable (7) to transmit gas pressure and electrical continuity from the control unit to the blade.

- Ground cable (8) to provide electrical continuity between the push rod system and the calibration unit.

4.2 Appropriate equipment to insert the dilatometer blade vertically into the soil. This may be accomplished by means of quasi-static thrust from cone penetration test equipment (CPT) (see ASTM D3441), blows from a hammer such as that used in the Standard Penetration Test (SPT) (see ASTM D1586 and Note 2), or other equipment suitable for forcing the dilatometer blade into the soil. Drill rig support may be required to bore through impenetrable soil or rock layers above the layer(s) to be tested.

4.3 Push rods to transfer the thrust from the surface insertion equipment and to carry the pneumatic-electrical cable from the surface control unit to the dilatometer blade. The rods are typically those used with the CPT (D-3441) or SPT (D-1586) equipment. Suitable adaptors are required to attach the blade to the bottom of the rod string and to allow the cable to exit below the tops of the rods so as not to interfere with the action of the quasi-static or dynamic insertion equipment. When testing from the bottom of a borehole the operator will usually use another adaptor to allow the cable to exit from the rod string some suitable distance above the blade. The cable is then taped to the outside of the rods at approximate 3 m intervals to the surface. This facilitates the addition and removal of rods from the rod string when entering or exiting the borehole. The exposed length of cable should not penetrate the soil.

4.4 A gas pressure tank with suitable regulator and tubing to connect it to the control unit. The operator may use any non-flammable, non-corrosive gas as a pressure source.

<u>Note 4</u> - Dry nitrogen has proven to be generally available, inexpensive and maintenance free.

4.5 A suitable load cell to measure the thrust, P, required to produce the blade penetration (see Notes 1 and 5, and reference 10.3).

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Note 5 - The primary purpose of measuring P is to permit calculating q_D, which is needed to obtain K_o, $\emptyset$ and p_c' in sandy soils (see Table 1). While it is desireable to measure the thrust by a suitable load cell immediately above the blade, this is presently impractical and not done except for research purposes. As an alternative, the engineer can measure P at the ground surface and subtract the parasitic soil-rod friction (and bearing against the friction reducer, if any) above the blade. Another alternative involves measuring the thrust needed for downward penetration and the pull required for upward withdrawal. The difference gives a measure of the end bearing capacity of the blade. A third alternative uses q_c values from adjacent CPT data by using a previously determined or estimated ratio of q_D/q_c (see 3.20). A fourth alternative is to convert a dynamic blowcount to an equivalent static thrust by the use of published correlations, on-site experiment or previous experience.

5. Procedures

5.1 Preparation for testing

5.1.1 Select for testing only blades that are known to be in conformance with the manufacturer's internal tolerance adjustments and that are in good visual external condition. The blade should have no discernible bend, defined as a clearance of 0.5 mm or more under a 150 mm straight edge placed along the blade parallel to its axis. Its penetrating edge should not deviate more than 2 mm from the axis of the rods to which the blade attaches. Other requirements include a straight and sharp penetration edge, and a membrane free of any deep scratches, wrinkles or dimples. When in doubt, check the membrane using the calibration procedure described in 5.1.4. The membrane should expand smoothly upon pressurization without popping or snapping sounds.

5.1.2 Attach the pressure source and pneumatic-electrical cable to the control box. Check for gas leakage in the control unit and cable by plugging the blade end of the cable with an appropriate fitting and applying pressure to the cable through the control unit. Then close the flow control valve and observe the gage for any pressure drop that would indicate a leak in the system. Leakage in excess of 100 kPa/min is unacceptable and requires repair. Smaller leaks, though undesireable and indicative of a potential problem, will not affect the test results significantly. In a field situation the operator should note and monitor a small leak but may wait until return to the office to make repairs.

5.1.3 Attach the pneumatic-electrical cable to the dilatometer and connect the two ends of the electrical ground cable to the control unit and blade respectively. Press the center of the membrane down until it makes contact with its support pedestal. At this contact the electrical and/or audio signal must go on. If not, make the appropriate repair.

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5.1.4 Use the calibration equipment to determine the ΔA and ΔB membrane stiffness calibration pressures. These calibrations should fall within the tolerances given by the manufacturer for the type of membrane used and are recorded as positive values. See Note 6. During this calibration the electrical/audio signal should stop unambiguously at the 0.05 mm expansion and return unambiguously at the 1.10 mm expansion. Replace any membrane that fails these checks.

Note 6 - New membranes typically require about 20 cycles of preconditioning expansion/deflation to reach an approximately stable ΔB value. Use the maximum expansion pressure recommended by the membrane manufacturer to avoid permanent membrane distortion.

5.1.5 Thread the pneumatic-electrical cable through as many of the push rods as needed and connect it to the blade. Include the lower blade adaptor and the upper adaptor to exit the cable from the rods. Disconnect the cable and reconnect it to the blade or the control box as required. Caution: Always cap the ends of all cables immediately after releasing from any connection. This helps prevent contamination of the cables and corrosion of the terminals.

5.2 Testing

5.2.1 Advance the dilatometer blade to the first depth. Measure the maximum thrust required during the last 10 mm of penetration or count the number of blows for each 150 mm of penetration. Record this value. If using blow count, average the counts for the 15 mm above and below the test depth to estimate the static force. Borehole predrilling with casing or drilling mud is acceptable as required. The rate of quasi-static penetration has minor importance in sands and can vary between 10 and 100 mm/s. In silts and clays use 10 to 30 mm/s.

5.2.2 Within 15 sec. after reaching test depth unload any static force on the rods and use the gas flow valve on the control unit to pressurize the membrane. The gage pressure at the instant the electrical/audio signal stops is the A-pressure reading. Observe and record it by any appropriate method. Obtain this reading within 15 to 30 seconds after beginning the gas flow. Then, within the next 15 to 30 seconds continue increasing the gas pressure until the signal returns. At this instant the gage indicates the B-pressure reading. After mentally noting this value, immediately vent the system to depressurize the cable to the dilatometer and then close the gas control valve. This procedure prevents further expansion of the membrane which may permanently deform it and change the calibrations. Record the B reading pressure by any appropriate method.

Note 7 - Experiments have determined that testing within the above time limits results in essentially drained conditions in sands and undrained conditions in clays. They also indicate

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that the results are not sensitive to time-for-reading changes by a factor of 2 from those given above. However, in saturated silty soils and sand/clay mixtures with intermediate permeabilities, partially drained conditions probably exist and the results and correlations depend more importantly on the proper time intervals. Unsaturated soils are not as well understood, but probably behave in a drained fashion.

Note 8 - For the most accurate pressure readings the operator should use the gas control valve to allow the pressure to increase rapidly to some value just below the lowest expected A-pressure and then decrease the pressurization rate to better read the value at the instant the signal goes off. He then repeats the increase-decrease technique for the B-pressure reading. The above technique involves the risk of getting a poor A- or B-pressure reading if it occurs at an unexpectedly low pressure.

Note 9 - The operator may check the adequacy of the flow rate he has chosen by closing the gas flow control valve during the test procedure and then observing the gage for a drop in pressure before stabilizing. If the pressure drops in excess of 2%, the rate is too fast and requires reduction. Longer cables will require a slower flow rate for accurate readings.

5.2.3 The electrical/audio signal usually returns after the depressurization following the B-pressure reading, but not always. The blade is then advanced to the next test depth. At this point the audio/electrical signal must have returned. If not, and the problem cannot be identified, remove the blade and repair as required.

Note 10 - Recent research and testing indicate that the pressure against the membrane when it deflates and returns to its initial A liftoff position provides a measure of the initial insitu water pressure u_o in sand soils or in sand layers in clay soils when I_D is equal or greater than approximately 2. The signal returns at this point. Dilatometer equipment may include another gas flow regulator to allow a controlled depressurization from the B-pressure to a subsequent "U-pressure" reading at the return of the signal. Allow 15-30 sec for depressurization to the signal return. In sands, after the A membrane stiffness correction, the U-pressure may give the value of "u_o" (see 3.23) needed by direct field measurement rather than by estimation (see 7.7 and Table 1). A profile of insitu u_o may also prove of value for the geotechnical evaluation of a site.

Note 11 - At shallow depths in very weak soils, especially when above the water table, p_o may not suffice to overcome the ΔA membrane stiffness and thus not produce the required initial

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signal. For sensitive testing of this type the operator needs to choose a blade whose membrane has low and consistent calibration values. An alternative is to apply an initial suction behind the membrane and then close the flow control valve before advancing to the test depth. This can be accomplished using the calibration unit which then remains in place during the test. The operator reads the A-pressure (vacuum), records its as a negative value and then continues the pressurization to obtain the B-pressure. If the B-pressure is out of the range of the calibration unit gage, this method should not be used. Also, the operator can bypass shallow testing until reaching a depth that produces the initial signal.

5.2.4 Repeat the test sequence for a new set of A- and B-pressures, etc. at each depth interval down to the maximum depth of the sounding.

5.3 After Completion of Testing

5.3.1 After completion of the final DMT, withdraw the blade to the surface, inspect it and note any significant cutting edge damage, blade bending, or membrane damage. Repeat the calibration procedure as described in 5.1.4 to check the magnitude of the ΔA and ΔB readings and the proper operation of electrical/audio signals. Record these ΔA and ΔB values. If the blade or the membrane has sustained major damage, if the A- and B-pressure electrical signals do not occur satisfactorily in proper sequence, or if the membrane calibration values differ from the initial values by an amount significant to the interpretation of the data (see Note 12), then repair or replace the blade and/or membrane and repeat the sounding. If the damage is attributable to a specific depth in the sounding, then only tests below this depth need to be repeated.

<u>Note 12</u> - Significance will vary with the strength of the soil and the intended use of the DMT results by the engineer. Trial calculations using both the initial and final membrane calibration values will show their importance to the results.

5.3.2 Reduce the field data using the formulas in section 7 and present the complete results in a tabular format. Also plot those of special interest in a graphical sounding format. Data reduction is most easily accomplished by using a computer program designed for the purpose.

6. <u>Special Precautions</u>

6.1 Damage to the membrane typically occurs when brushing against or pushing aside gravel, shell, unweathered rock, etc. particles. When in soils containing such particles be alert for membrane malfunction (see 6.9) and be prepared to replace membranes when required. Continued usage in highly abrasive soils, such as dense quartz sands, gradually wears down membranes and

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makes them more susceptible to wrinkling and tearing. Replace them when wear or wrinkling appears excessive.

6.2 Bending of the blade or wrinkling of its cutting edge typically occurs with a high thrust P required to advance the blade, as when penetrating hard clays or dense sands, combined with coarse-particle inclusions in the soil such as gravel, large shells, unweathered rock, cemented inclusions, etc. Experience has shown that the probability of bending becomes signficant when the thrust P reaches approximately 50 kN (5 tons) and becomes high when P exceeds approximately 100 kN (10 tons). Blade bending can also occur due to buckling of the overhead connector rods when penetrating a strong soil after just passing through one meter (3.3 ft) or more thickness of very weak soil that provides little lateral support against buckling.

> Note 13 - Bent, wrinkled or scratched cutting edges are often repairable in the field using hammer and file methods. Bent blades are often repairable by a machinist. Recheck blade alignment and the membrane support and movement mechanism and tolerances after each repair (see 3.1, 3.2, 5.1.1, 5.1.4).

6.3 The blade and its connections are not designed for high torsion forces. Make all rod connections using no more torsion than produced by hand wrench tightening. Do not allow the making of connections with the aid of engine power.

6.4 The dilatometer blade is subject to drifting out of plumb when inserted with initial horizontal forces acting, or when encountering obstructions which the blade must bypass. The deeper the sounding the more likely that appreciable deflection may occur. The presence of stones, gravel layers, large shells, irregular cementation, etc. also increases the likelihood of appreciable deflection. Experience has shown that with usual care this problem is not significant in ordinary sands and clays for sounding depths of less than 15 meters. However, the user needs to be alert for indications such as the pushrods becoming non-plumb at the surface, suspicious data or encountering marker soil layers at greater apparent sounding depth than expected from nearby borings or other data.

6.5 Ensure that the pneumatic-electrical cable does not pass through or over any objects with sharp edges that might cut the cable when accidentally pulled or stepped on. Avoid having the cable exposed at locations where such accidents might happen.

6.6 The operator can periodically and easily check for any leaks in the lines or connections by momentarily closing the control valve during the pressure increase interval between the A- and B-pressures and noting the behavior of the pressure gage. If the pressure remains constant then the system has no leaks, as required. Any leak severe enough to interfere with the required accuracy of the A- and B-pressures (refer to section 5.1.2.) means that the sounding must be stopped and the leak repaired before continuing. In the event that leakage forces the termination of the sounding, it is wise to maintain a pressure of 100-200 kPa above u_o in the system while

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withdrawing the blade. If done quickly enough, this may prevent entry of dirt and liquid into the blade.

6.7 Experience has shown that during field testing it is prudent to have spares of some of the more critical items. These include extra membranes, an extra blade and additional cables.

6.8 In very noisy testing environments it can become difficult to hear the audio signal which prompts the A- and B-pressure readings. The user must then rely on the visual cue given by the galvanometer or use an earphone or headset to insure timely detection of the audio signal.

6.9 If the signal does not cease at a reasonable A-pressure then it is possible that the membrane has ruptured or water has entered the mechanism behind the membrane, causing an electrical short. Remove the blade, inspect it and repair as necessary.

7. Methods for Data Reduction

7.1 The blade produces a deep bearing capacity failure in cohesionless soils and a lateral limit pressure failure in cohesive soils, thus forming the basis for evaluating friction angle and undrained shear strength properties, respectively.

7.2 The A-pressure reading forms the basis for predicting insitu horizontal effective stress, and therefore also the related predictions for OCR and p_c'.

7.3 The difference between the B- and A-pressures, obtained over a precise and relatively small increment of membrane displacement, forms the basis for evaluating the insitu, drained modulus and compressibility behavior.

7.4 The stress and modulus measurements occur after the disturbance of the blade penetration. Therefore, research and experience are used to establish reliable correlations between the desired insitu properties before the insertion of the blade and those measured after its insertion.

Note 14 - The shape of the dilatometer blade represents a compromise between minimizing insertion disturbance and providing adequate structural strength for practical use.

7.5 The ratio of modulus to horizontal stress depends on the soil's pore pressure generation and permeability properties, and thus provides an indicator of soil type.

7.6 Table 1 presents a summary of the steps from the collection of the field data, through the calculation of two normalized dilatometer indices for material type and lateral stress and a theoretical modulus index, to the determination of generic engineering properties for design. The engineer has as many as three measurements to work with and must estimate the pore water

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pressure and vertical effective stress at the test depth. Table 1 shows which parameters are needed for correlation with each engineering property and indicates the reference publication. It also notes the empirical, semi-empirical (combined theoretical-empirical), or theoretical nature of each correlation.

Note 15 - In the interest of a common understanding of the way in which users of this practice communicate their findings, all should report their results using the correlations referenced in Table 1. However, local experience may demonstrate the need to somehow modify or apply correction factors to the results obtained to make them more accurate for the local conditions. In that event they should also report the corrections they used. New correlations with other soil properties should likewise be reported.

7.7 The calculations of 7.6 include those for the vertical effective stress at the test depth. This requires knowledge of soil unit weights and equilibrium pore water pressures. Marchetti (ref 10. 2) recommends the unit weight matrix chart shown in Figure 2. Most of the current computer programs incorporate this matrix for the automatic summation of total overburden pressure. Pore water pressure is normally taken as the hydrostatic value from a given water table condition, with values of zero assumed above the water table. If pore pressure conditions differ significantly from hydrostatic, and/or a better estimate of soil unit weight is available, then these data should be used in place of the above assumptions. Note that the effective stress and pore water pressures referred to here are those existing prior to the insertion of the DMT blade.

7.8 The engineering properties determined by the DMT are listed in Table 1 and also in the example outputs of Figures 3 and 4. These are basic or generic soil properties that an engineer can use in any design method requiring such values. They are not linked to any analysis or design methods developed especially for DMT data.

8. Precision and Accuracy

8.1 Table 2 presents the currently (Jun 84) compiled information concerning the average accuracy and variability with which the DMT predicts engineering soil properties. This compilation does not include any refinement with respect to soil classification, geologic soil type, stress history, etc.

8.2 Recent research shows that the DMT tests sand in approximately fully drained conditions and clays in approximately fully undrained conditions. The best results are obtained at these extremes. Silts, clayey sands, fissured clays, and other soils may have only partial drainage during the DMT, to an unknown and possibly variable degree. This may lead to more variable and possibly less accurate predictions of their soil engineering properties.

8.3 Use the average of at least three DMTs for the interpretation of the properties of any single soil layer. For a variety of reasons the results from any one DMT can deviate significantly from the average accuracy noted in Table 2. If the results from a single deviant test may have special importance, then repeat the test using parallel soundings as a check on accuracy.

8.4 Experience has shown the DMT to be exceptionally reproducible and operator independent. Engineers with experience estimate results are reproducible with a coefficient of variation of approximately 10%.

9. Report

9.1 Figures 3 and 4 show example reports of the findings from two DMT soundings, as produced by computerized data reduction in the office. In addition to these tabulated results, the engineer will usually produce graphical depth logs of one or more of the DMT-interpreted soil properties.

9.2 Although computerized output is desireable, and common, the engineer can also obtain and present results by hand calculator and graphs. This may be convenient for data reduction and presentation in the field.

9.3 It is anticipated that some users will have the DMT equipment connected to transducers and computers for automatic data acquisition, processing, and presentation directly in the field.

10. References

The subsequent Tables 1 and 2 refer to these references for the details of data reduction to obtain engineering properties.

10.1 Jamiolkowski, B. M., C. C. Ladd, J. T. Jermaine and R. Lancelotta, "New Developments in Field and Laboratory Testing of Soils", Theme Lecture, Session II, XI ISCMFE, San Francisco, 1985 (see p. 51).

10.2 Marchetti, S., "Insitu Tests by Flat Dilatometer", ASCE, Journal of the G.E. Div., Vol. 106, GT3, March, 1980, pp. 229-321. Discussion and closure in Vol. 107, GT6, pp. 831-837.

10.3 Schmertmann, J., "A Method for Determining the Friction Angle in Sands from the Marchetti Dilatometer Test", Proc., European Symposium on Penetration Testing II, Amsterdam, May 1981, Vol. 2, pp. 853-861.

10.4 Schmertmann, J., "The New In-Situ Marchetti Dilatometer Test", Geotechnical News, Vol. 2, No. 3, Sep-Nov 1984, p. 34.

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TABLE 1 - MEASUREMENTS USED TO CONVERT DILATOMETER DATA TO SOIL PROPERTIES FOR ENGINEERING DESIGN

FIELD DATA:

a.	test readings A and B corrected using equipment calibrations	: $p_o = f(A)$, $p_1 = f(B)$
b.	est'd. insitu pore water pressure	: u_o (also see Note 10)
c.	est'd. insitu effective vertical stress	: $\sigma'_v = (\sigma_v - u_o)$
d.	est'd. DMT bearing capacity, q_D. Obtained from thrust = P data	: q_D

DMT INDICES:

Material Index (a normalized modulus)

$I_D = f(A,B,u_o) = (p_1 - p_o)/(p_o - u_o)$

Horizontal Stress Index (a normalized lateral stress)

$K_D = f(A,u_o,\sigma'_v) = (p_o - u_o)/\sigma'_v$

Dilatometer Modulus (theoretical elastic modulus)

$E_D = f(A,B) = 34.7(p_1 - p_o)$

INTERPRETED SOIL ENGINEERING PROPERTIES:

				reference
Soil Type				
I_D	$= f(p_o,p_1,u_o)$	$= f(A,B,u_o)$	empirical	10.2
Lateral Stress (drained)				
K_o (sand)	$= f(K_D,\phi')$	$= f(A,\sigma'_v,u_o,q_D)$	semi-empirical	10.1
K_o (clay)	$= f(K_D)$	$= f(A,\sigma'_v,u_o)$	empirical	10.2
Strength				
ϕ' (sand)	$= f(K_o,\sigma'_v,P)$	$= f(A,\sigma'_v,u_o,q_D)$	theoretical	10.1,10.4
s_u (OC clay)	$= f(K_D,\sigma'_v)$	$= f(A,\sigma'_v,u_o)$	empirical	10.2
s_u (NC clay)	$= f(p_o)$	$= f(A,u_o)$	empirical	10.2
Compressibility (drained)				
$M = (1/m_v)$	$= f(E_D,I_D)$	$= f(A,B,u_o)$	semi-empirical	10.2
p'_c (sand)	$= f(K_D,\phi')$	$= f(A,\sigma'_v,u_o,q_D)$	semi-empirical	10.1
p'_c (clay)	$= f(K_D)$	$= f(A,\sigma'_v,u_o)$	empirical	10.2
Modulus (drained, ν = poisson's ratio))				
E_{25} (sand)	$= f(E_D)$	$= f(A,B)$	semi-empirical	10.1
E (clay)	$= f(M,\nu)$	$= f(A,B,u_o,\nu)$	semi-empirical	10.2

BACK

TABLE 2 - SUMMARY OF ACCURACY EXPERIENCE WITH THE RESULTS FROM DMT SOUNDINGS (as compiled in ref. 10.4)

Based on averages of data from various sites or individual distinct layers 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).

	Ko	OCR	ϕ' o $I_D \geq 1.2$	s_u $I_D \leq 0.9$	M_D
% ERROR: *					
Average	+ 7	+ 1	+ 1	+ 2	- 18
Std. Dev.	22	30	-	27	33
Maximum	+ 30	+ 50	+ 1	+ 80 c	+ 20
Minimum	- 40	- 60	0	- 47	- 79
No. Comparisons	11[a]	17	2[b]	22 c	22[d]
Range in Ave. DMT Values	0.3 to 1.6	1 to 15	33 to 37°	0.007 to 0.80 bars	2 to 500 bars

* % Error = [(DMT-Meas.)/(Meas.)] x 100%

Notes: a. 9 of these from research by the Norwegian Geotechnical Insitute.

b. Very limited superior data found for ϕ'. Impression that DMT results in the range ϕ'_{ps} = 25 to 45° are reasonable if a moderately accurate estimate of net thrust is available (say ± 25%). The standard deviation in ϕ' is probably about 2°.

c. One comparison of +180% (Univ. British Columbia, Langley research site) was omitted because it falls outside the Chauvenet criteria for validity. Most of the comparitive values are field vane results.

d. Five of the 22 cases compare M_{DMT}-calculated settlement with measured performance. Three of these 5 cases involved peat and organic silt/sand as the compressible soil.

BACK

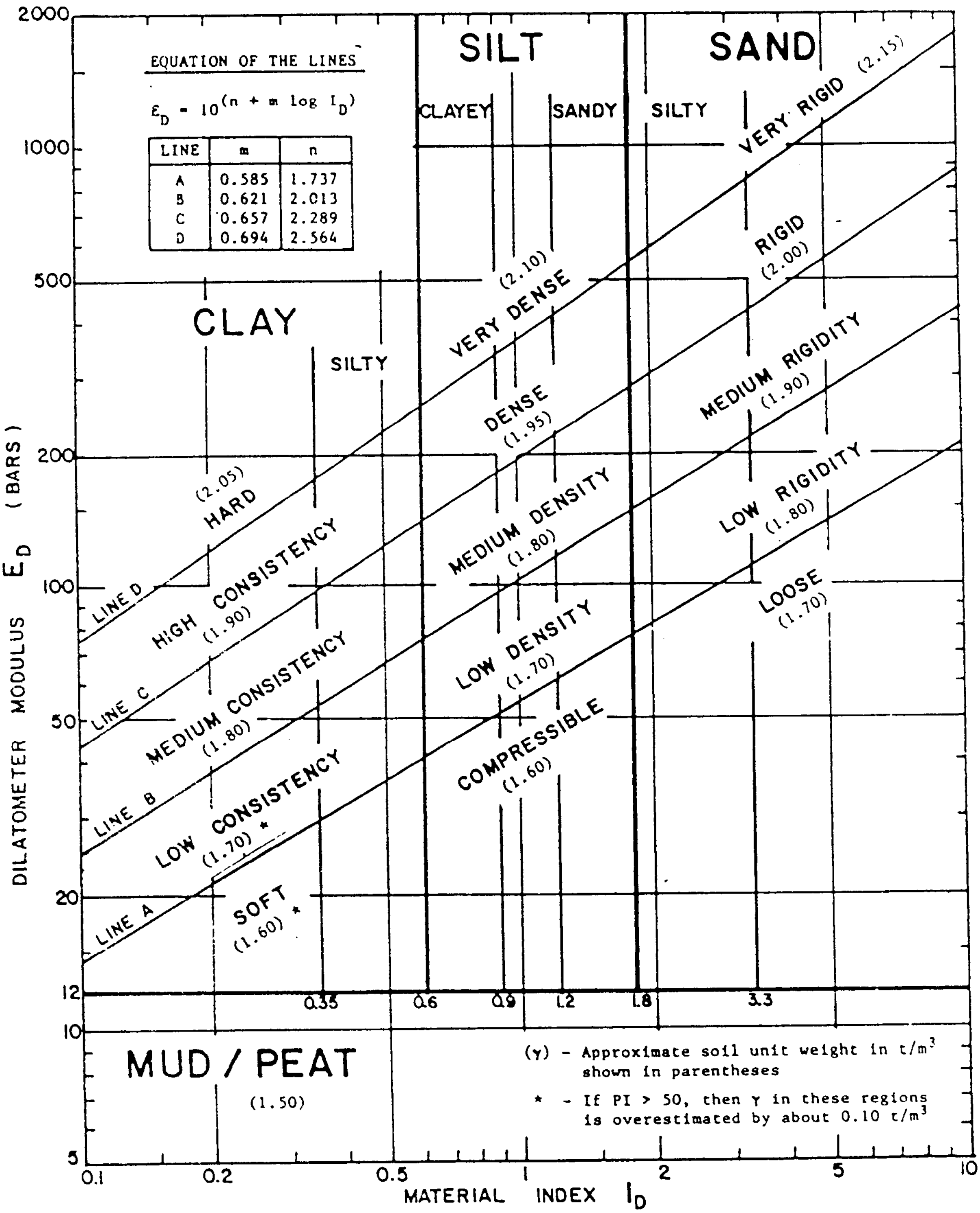

Figure 2 Chart for determination of soil description and unit weight.

BACK

ACME ENGINEERING INC. TEST NO. DMT-1
FILE NAME: EXAMPLE SOUNDING
FILE NUMBER: 85-500

RECORD OF DILATOMETER TEST NO. DMT-1
USING DATA REDUCTION PROCEDURES IN MARCHETTI (ASCE,J-GED,MARCH 80)
KO IN SANDS DETERMINED USING SCHMERTMANN METHOD (1983)
PHI ANGLE CALCULATION BASED ON DURGUNOGLU AND MITCHELL (ASCE,RALEIGH CONF,JUNE 75)
PHI ANGLE NORMALIZED TO 2.72 BARS USING BALIGH'S EXPRESSION (ASCE,J-GED,NOV 76)
MODIFIED MAYNE AND KULHAWY FORMULA USED FOR OCR IN SANDS (ASCE,J-GED,JUNE 82)

LOCATION: 6 FT. NORTH OF CPT-1 (CPT SOUNDING)
PERFORMED - DATE: 1 APRIL 1985
BY: J.SMITH & W.JONES --- HYDRAULIC PUSH WITH CPT TRUCK

CALIBRATION INFORMATION:
DA= .15 BARS DB= .68 BARS ZM= .10 BARS ZW= .70 METERS
ROD DIA.= 3.60 CM FRICTION RED. DIA.= 4.70 CM ROD WEIGHT= 6.50 KG/M DELTA/PHI= .50

1 BAR = 1.019 KG/CM2 = 1.044 TSF = 14.51 PSI ANALYSIS USES H20 UNIT WEIGHT = 1.000 T/M3

Z (M)	THRUST (KG)	A (BAR)	B (BAR)	ED (BAR)	ID	KD	UO (BAR)	GAMMA (T/M3)	SV (BAR)	PC (BAR)	OCR	KO	CU (BAR)	PHI (DEG)	M (BAR)	SOIL TYPE
*****	******	*****	*****	*****	*****	*****	******	******	******	*****	*****	*****	*****	*****	******	************
1.00	781.	1.17	5.32	121.	3.40	5.99	.029	1.800	.171	.68	3.96	.74		39.4	248.6	SAND
1.20	1033.	1.69	6.95	161.	3.17	7.87	.049	1.800	.187	1.23	6.57	.95		39.9	369.9	SILTY SAND
1.40	1535.	3.38	15.55	413.	4.26	13.67	.069	1.900	.204	4.04	19.75	1.66		39.7	1145.2	SAND
1.60	1451.	3.52	13.75	342.	3.28	13.56	.088	1.900	.222	4.52	20.36	1.69		38.7	946.9	SILTY SAND
1.80	1409.	3.85	15.05	378.	3.33	13.66	.108	1.900	.240	5.12	21.37	1.74		37.9	1046.9	SAND
2.00	907.	2.84	10.72	257.	3.07	9.36	.128	1.900	.257	2.94	11.41	1.29		35.6	627.5	SILTY SAND
2.20	279.	.81	2.31	24.	1.04	2.52	.147	1.600	.269	.39	1.44	.68			27.5	SILT
2.40	258.	.84	4.76	113.	5.71	2.01	.167	1.700	.283	.42	1.48	.54		29.6	124.6	SAND
2.60	405.	1.21	7.55	201.	7.25	2.67	.186	1.800	.299	.54	1.81	.57		32.4	271.8	SAND
2.80	488.	1.64	3.03	20.	.40	4.69	.206	1.600	.310	1.17	3.78	1.11	.198		35.2	SILTY CLAY
3.00	405.	1.79	3.02	15.	.26	4.95	.226	1.600	.322	1.32	4.11	1.15	.220		25.9	CLAY
3.20	237.	.95	2.37	21.	.85	2.17	.245	1.600	.334	.38	1.14	.59	.081		20.6	CLAYEY SILT
3.40	237.	.90	2.57	31.	1.37	1.86	.265	1.600	.346	.53	1.53	.58		27.6	26.3	SANDY SILT
3.60	279.	.91	3.54	66.	3.23	1.63	.285	1.700	.359	.45	1.25	.52		29.1	60.6	SILTY SAND
3.80	321.	1.07	3.51	59.	2.30	1.97	.304	1.700	.373	.55	1.48	.55		29.6	59.5	SILTY SAND
4.00	300.	1.16	3.56	57.	2.04	2.09	.324	1.700	.387	.64	1.65	.59		28.6	59.6	SILTY SAND
4.20	237.	1.43	3.37	40.	1.08	2.71	.343	1.600	.399	.64	1.61	.72			48.7	SILT
4.40	258.	1.63	2.78	12.	.26	3.18	.363	1.500	.408	.84	2.07	.82	.161		15.5	MUD
4.60	279.	1.28	2.69	21.	.66	2.18	.383	1.600	.420	.48	1.15	.59	.103		20.0	CLAYEY SILT
4.80	279.	1.28	2.66	20.	.64	2.08	.402	1.600	.432	.46	1.07	.57	.100		18.0	CLAYEY SILT
5.00	405.	1.56	4.69	84.	2.25	2.41	.422	1.700	.446	.82	1.84	.60		29.9	100.0	SILTY SAND
5.20	551.	1.89	7.60	178.	4.08	2.72	.442	1.800	.461	.90	1.95	.60		32.0	243.3	SAND
5.40	572.	1.72	6.61	148.	3.86	2.32	.461	1.800	.477	.75	1.58	.54		32.6	181.9	SAND
5.60	530.	2.33	9.10	216.	3.89	3.25	.481	1.800	.493	1.28	2.60	.70		30.5	329.8	SAND
5.80	593.	1.69	6.40	141.	3.90	2.06	.500	1.800	.509	.70	1.37	.51		32.7	159.2	SAND
6.00	719.	2.41	7.74	164.	2.76	3.27	.520	1.800	.524	1.26	2.41	.65		32.9	247.8	SILTY SAND
6.20	1284.	3.73	13.18	314.	3.22	5.18	.540	1.900	.542	2.28	4.20	.81		36.0	605.9	SILTY SAND
6.40	907.	3.17	10.07	221.	2.70	4.21	.559	1.900	.560	1.89	3.37	.75		33.5	383.1	SILTY SAND
6.60	593.	2.18	8.55	202.	4.23	2.39	.579	1.800	.575	1.00	1.74	.58		31.5	253.6	SAND
6.80	405.	1.67	6.21	135.	4.16	1.58	.599	1.800	.591	.77	1.30	.54		29.0	121.6	SAND
7.00	342.	1.82	5.95	120.	3.19	1.79	.618	1.800	.607	.97	1.61	.62		26.9	121.0	SILTY SAND
7.20	447.	1.66	4.97	90.	2.75	1.53	.638	1.700	.620	.76	1.22	.52		29.6	76.8	SILTY SAND
7.40	321.	1.83	3.35	25.	.61	1.88	.658	1.600	.632	.57	.91	.51	.129		21.4	CLAYEY SILT
7.60	279.	2.01	3.78	34.	.74	2.07	.677	1.600	.644	.68	1.06	.56	.148		30.9	CLAYEY SILT
7.80	237.	2.23	4.07	37.	.69	2.34	.697	1.600	.656	.84	1.28	.63	.175		37.5	CLAYEY SILT
8.00	279.	1.62	3.28	30.	.96	1.37	.716	1.600	.668	.37	.55	.36			25.7	SILT
8.20	258.	1.22	2.17	4.	.24	.78	.736	1.500	.677	.16	.23	.14	.046		3.7	MUD
8.40	154.	1.17	1.95	-2.	-.11		.756	P01 =	1.22	P0 =	1.22	P1 =	1.17			QUESTIONABLE
8.60	175.	.93	1.90	5.	.74	.28	.775	1.500	.697	.03	.05	-.14	.013		4.3	MUD
8.80	175.	.98	2.24	16.	2.11	.30	.795	1.700	.711	.56	.79	.52		23.6	13.3	SILTY SAND
9.00	195.	1.13	2.77	30.	2.62	.45	.815	1.700	.724	.62	.86	.53		23.9	25.1	SILTY SAND
9.20	216.	1.37	3.42	44.	2.44	.71	.834	1.700	.738	.75	1.01	.56		24.0	37.8	SILTY SAND
9.40	258.	1.05	2.04	6.	.71	.32	.854	1.500	.748	.04	.06	-.12	.017		5.0	MUD
9.60	342.	2.03	7.55	171.	5.07	1.27	.873	1.800	.764	.98	1.28	.58		26.3	145.2	SAND

END OF SOUNDING

FIGURE 3: EXAMPLE COMPUTER OUTPUT FROM A FORTRAN PROGRAM

BACK

ANALYSIS OF DILATOMETER TEST NO. 32-4943
REFERENCE: MARCHETTI(ASCE,J-GED,MARCH 1980);
SCHEMERTMANN (ESOPT II, MAY 1982);BULLOCK(DILLY 4,1982,S & C,INC.)
PROGRAMMED BY: RAMESH C. GUPTA, PROJECT ENGINEER, HBC
LOCATION: DMT# 32-4943
PERFORMED BY- DATE: 17 MAY 1983
BY: J. Russel and L. Bennett SURFACE EL. 14
CALIBRATION INFORMATION:
DA= .1 DB= .53 ZM= .05 ZW= 3.05 M
1 BAR = 1.019 KG/CM2 = 1.044 TSF = 14.51 PSI H2O UNIT WT. = 1.0 TONNE/M3

Z (M)	A (BAR)	B (BAR)	THRUST (KG)	ED (BAR)	UO (BAR)	ID	GAMA (T/M3)	SV (BAR)	KD	OCR	KO	CU (BAR)	PHI (DEG)	SIGFF (BAR)	M (BAR)	SOIL TYPE
2.00	5.90	17.70	3085.	401.	0.00	2.14	2.00	0.353	15.38	24.60	1.86		43.0	0.59	1163.	SILTY SAND,RIGID
2.20	4.80	17.40	3212.	431.	0.00	2.90	2.00	0.392	10.93	11.77	1.27		44.1	0.67	1110.	SILTY SAND,RIGID
2.40	4.90	18.00	3085.	449.	0.00	2.97	2.00	0.432	10.11	10.49	1.20		43.5	0.73	1126.	SILTY SAND,RIGID
2.60	5.20	19.40	3339.	489.	0.00	3.07	2.00	0.471	9.79	9.80	1.16		43.5	0.79	1212.	SILTY SAND,RIGID
2.80	5.50	23.20	3593.	616.	0.00	3.76	2.00	0.510	9.28	8.71	1.09		43.7	0.86	1499.	RIGID SAND
3.00	5.59	21.20	3657.	543.	0.00	3.25	2.00	0.549	8.80	7.95	1.04		43.5	0.93	1297.	SILTY SAND,RIGID
3.20	6.10	21.70	3593.	540.	0.01	2.88	2.00	0.574	9.45	9.60	1.16		42.8	0.96	1322.	SILTY SAND,RIGID
3.40	6.50	23.00	3721.	572.	0.03	2.87	2.00	0.593	9.70	10.18	1.19		42.6	1.00	1415.	SILTY SAND,RIGID
3.60	7.10	24.60	3657.	609.	0.05	2.80	2.00	0.613	10.26	11.71	1.28		42.1	1.02	1535.	SILTY SAND,RIGID
3.80	6.30	23.00	3721.	579.	0.07	3.04	2.00	0.633	8.71	8.26	1.07		42.6	1.06	1379.	SILTY SAND,RIGID
4.00	6.70	26.10	4102.	678.	0.09	3.40	2.00	0.652	8.82	8.25	1.07		43.0	1.10	1620.	RIGID SAND
4.20	8.20	28.50	4166.	710.	0.11	2.86	2.00	0.672	10.70	12.66	1.33		42.1	1.12	1818.	SILTY SAND,RIGID
4.40	7.60	27.30	3911.	688.	0.13	3.01	2.00	0.692	9.54	10.25	1.20		42.0	1.15	1693.	SILTY SAND,RIGID
4.60	6.50	28.40	4484.	768.	0.15	4.14	2.00	0.711	7.55	5.78	0.88		43.6	1.20	1733.	RIGID SAND
4.80	9.10	29.90	5120.	728.	0.17	2.63	2.15	0.734	10.91	12.65	1.33		42.8	1.23	1878.	SILTY SAND,V.RIGID
5.00	6.90	24.90	3975.	627.	0.19	3.06	2.00	0.753	7.87	6.97	0.99		42.2	1.26	1436.	SILTY SAND,RIGID
5.20	6.70	19.90	3466.	452.	0.21	2.20	2.00	0.773	7.69	7.13	1.01		41.1	1.28	1022.	SILTY SAND,RIGID
5.40	7.20	19.70	3085.	427.	0.23	1.91	2.00	0.793	8.15	8.46	1.11		39.8	1.30	985.	SILTY SAND,RIGID
5.60	5.80	19.20	3212.	460.	0.25	2.66	2.00	0.812	6.15	4.76	0.83		41.0	1.35	950.	SILTY SAND,RIGID
5.80	5.90	18.60	3085.	434.	0.27	2.45	2.00	0.832	6.15	4.89	0.84		40.6	1.37	894.	SILTY SAND,RIGID
6.00	6.00	17.30	2957.	383.	0.29	2.10	2.00	0.852	6.18	5.09	0.87		40.1	1.40	787.	SILTY SAND,RIGID
6.20	5.70	18.20	3085.	427.	0.31	2.53	2.00	0.871	5.61	4.16	0.78		40.5	1.44	845.	SILTY SAND,RIGID
6.40	5.80	17.70	3085.	405.	0.33	2.34	2.00	0.891	5.61	4.21	0.79		40.4	1.47	799.	SILTY SAND,RIGID
6.60	6.10	20.10	3212.	481.	0.35	2.69	2.00	0.910	5.68	4.27	0.79		40.5	1.50	961.	SILTY SAND,RIGID
6.80	5.70	17.10	3212.	387.	0.37	2.29	2.00	0.930	5.25	3.69	0.74		40.6	1.53	739.	SILTY SAND,RIGID
7.00	5.00	17.40	3212.	423.	0.39	2.98	2.00	0.950	4.33	2.55	0.61		41.0	1.57	750.	SILTY SAND,RIGID
7.20	6.40	20.50	3339.	485.	0.41	2.59	2.00	0.969	5.58	4.17	0.78		40.3	1.60	959.	SILTY SAND,RIGID
7.40	5.00	19.20	3085.	489.	0.43	3.55	2.00	0.989	4.03	2.33	0.59		40.6	1.63	835.	RIGID SAND
7.60	6.90	25.80	4229.	659.	0.45	3.39	2.00	1.009	5.58	3.77	0.73		41.8	1.68	1314.	RIGID SAND
7.80	6.70	23.70	3975.	590.	0.47	3.10	2.00	1.028	5.35	3.62	0.72		41.3	1.71	1155.	SILTY SAND,RIGID
8.00	6.90	25.80	3848.	659.	0.49	3.41	2.00	1.048	5.33	3.70	0.73		41.0	1.73	1288.	RIGID SAND
8.20	6.50	23.00	3848.	572.	0.51	3.13	2.00	1.067	4.95	3.22	0.68		41.1	1.77	1081.	SILTY SAND,RIGID
8.40	7.30	24.40	3848.	594.	0.53	2.84	2.00	1.087	5.55	4.09	0.77		40.6	1.79	1178.	SILTY SAND,RIGID
8.60	6.60	21.70	3466.	521.	0.54	2.78	2.00	1.107	4.90	3.39	0.71		40.1	1.82	975.	SILTY SAND,RIGID
8.80	7.50	25.60	4229.	630.	0.56	2.96	2.00	1.126	5.46	3.83	0.74		41.1	1.87	1243.	SILTY SAND,RIGID
9.00	9.60	31.40	5374.	765.	0.58	2.75	2.15	1.149	7.00	5.76	0.90		41.8	1.91	1671.	SILTY SAND,V.RIGID
9.20	10.00	34.10	5374.	848.	0.60	2.95	2.15	1.171	7.09	5.97	0.92		41.6	1.95	1867.	SILTY SAND,V.RIGID
9.40	9.30	30.80	4738.	754.	0.62	2.82	2.00	1.191	6.48	5.28	0.87		40.9	1.97	1597.	SILTY SAND,RIGID
9.60	10.70	37.70	6137.	954.	0.64	3.12	2.15	1.214	7.27	6.02	0.92		42.2	2.03	2120.	SILTY SAND,V.RIGID

FIGURE 4: EXAMPLE COMPUTER OUTPUT FROM A BASIC PROGRAM

BACK

DMT BIBLIOGRAPHY
(compiled 17 July 1985)

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

[2] Bellotti, R., G. Bizzi, V. Ghionna, M. Jamiolkowski, S. Marchetti and E. Pasqualini, (1979).
"Preliminary Calibration Tests of Electrical Cone and Flat Dilatometer in Sand", Proceedings, 7th European Conference on Soil Mechanics and Foundation Engineering, Vol. 2, Sept., 1979, Brighton, England, pp. 195-200.

[3] Boghrat, A. (1982)
"The design and construction of a Piezoblade and an evaluation of the Marchetti Dilatometer in some Florida Soils", University of Florida Ph.D. Dissertation.

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

[5] Brown, S.G. (1983)
"In-Situ Testing Techniques Applied to Embankments Over Soft Organic Soils", Master's Thesis, Department of Civil Engineering, The University of British Columbia, Vancouver, Canada, October, 229 pp.

[6] Bullock, P.J. (1983)
"The Dilatometer: Current Test Procedures and Data Interpretation" Master's Thesis, Department of Civil Engineering, University of Florida, Gainesville, Florida, Fall 1983.

[7] Burgess, N.C., J.M.O. Hughes, R. Innes, J. Gladowe (1983)
"Site investigation and in-situ testing techniques in arctic seabed sediments". Offshore Technology Conference, No. 4583, Houston, May, p. 27.

[8] Campanella, R.G. and P.K. Robertson (1982)
"State of the art in In-Situ Testing of soils; Developments since 1978", Conf. on "Updating Subsurface Sampling of Soils and Rocks and their in-situ testing", Engineering Foundation, held in Santa Barbara, California, Jan., pp. 245-267.

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

[10] Davidson, J. and A. Boghrat (1983)
"Flat Dilatometer testing in Florida, USA", International Symposium on In Situ Testing, Paris, Vol. II, pp. 251-255.

BACK

[11] Davidson, J.L. and A. Boghrat (1983)
"Displacements and Strains Around Probes in Sand", ASCE Speciality Conference on geotechnical practice in offshore engineering, Austin Texas, April, 1983, pp. 181-203.

[12] D'Antonio (1981)
"Soil Investigations and Stability Analysis of Gravity Quaywalls" (in Italian), Civile, Consiglio Superiore del Lavori Pubblici, Giornale del Genio, Rome, No. 1, 1981.

[13] First International conference on the Flat Dilatometer, Edmonton, Alberta, Canada, Feb. 4th, 1983.
- Schmertmann, J.H.
"Past, Present and Future of the Flat Dilatometer"
- Hayes, J.A.,
"Case Histories involving the flat dilatometer"
- Mekechuk, J.
"Flat Dilatometer use on C N Rail Lines"
- Burgess, N.,
"Use of the Flat Dilatometer in the Beaufort Sea"
- Campanella, R.G.,
"Current Research and Development of the Flat Dilatometer"
(also in UBC SM Series #68)

[14] Handy, R.L., J.H. Schmertmann, and A.J. Lutenegger (1984)
"Borehole Shear Tests in a Shallow Marine Environment", ASTM Symposium on Marine Testing, San Diego, Jan. 1984.

[15] 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.

[16] Lacasse, S. and T. Lunne (1982)
"Penetration tests in two Norwegian clays", Proc. 2nd European symp. on Penetration testing, Amsterdam II., pp. 661-669.

[17] Lacasse, S. and T. Lunne (1982)
"Dilatometer Tests in Two Soft Marine Clays", N.G.I. Publication No. 146, Oslo, pp. 1-8. Also in Conf. on "Updating Subsurface Samplings of Soils and Rocks And Their In-Situ Testing", Engineering Foundation, held in Santa Barbara, CA, Jan, pp. 369-379.

[18] Lacasse, S., and T.S. Olsen (1983)
"Dilatometer Tests in Haga City", Internal Report Norwegian Geotechnical Institute No. 40019-2, Oslo, Dec. 1983.

[19] Lacasse, S., T. Lunne and C. Madshus (1984)
"In Situ Testing: New Developments" Nordisk Geoteknikermote, Linkjoping, June, 1984, Vol. II, pp. 7050-716.

[20] Lunne, T. and H. P. Christoffersen (1983)
"Interprettion of Cone Penetrometer Data for Offshore Sands", Proceedings of the 15 Annual Offshore Technology Conf., May 2-5, Houston, Texas, Vol. 1, pp. 181-192. (reprinted in N.G.I. Publication No. 156, Oslo, 1985)

BACK

[21] Lunn T., and Lacasse S.
"Design Parameters for Offshore Sands; Use of In Situ Tests", <u>Proc. Conf. "Offshore Site Investigation ´85"</u>, Soc. for Underwater Technology, London, March.

[22] Lutenegger, A.J. and P. Donchev (1983)
"Flat Dilatometer testing in some metastable loess soils", International Syposium on In Situ Testing, Paris, Vol. II, pp. 337-340.

[23] Marchetti, S. (1975)
"A New In Situ Test for the Measurement of Horizontal Soil deformability", <u>Proceedings</u> Conference on In situ Measurement of Soil Properties", ASCE speciality Conference, Raleigh, N.C., Vol. 2, June 1975, pp. 255-259.

[24] Marchetti, S. (1977)
"Devices for in situ determination of Soil Modulus E_S", Speciality Session N. 10, IX International Conf. on Soil Mech. and Found. Engineering, Tokyo, July, 1977.

[25] Marchetti, S. (1979)
"The in Situ Determination of an "Extended" Overconsolidation ratio", <u>Proceedings</u>, 7th European Conference on Soil Mechanics and Foundation Engineering, Vol. 2, Sept., 1979, Brighton, England, pp. 239-244.

[26] Marchetti, S. (1979)
"Determination of Design Parameters of Sands by means of Quasi-Statically Pushed Probes", <u>Proceedings</u>, 7th European Conference on Soil Mechanics and Foundation Engineering, Panel Presentation, Main session C, Sept., 1979, Brighton, England.

[27] Marchetti, S. (1979)
"Stress History of Clay Deposits", <u>Proceedings</u>, 7th European Conference on Soil Mechanics and Foundation Engineering, Discussion Session 4: Design Parameters for Stiff Clays, Discussion Vol., Sept., 1979, Brighton, England, pp. 143-145.

[28] Marchetti, S. (1979)
"On the Determination of In Situ K_o in Sand", <u>Proceedings</u>, 7th European Conference on Soil Mechanics and Foundation Engineering, Discussion Session 7: Design Parameters for Sands, Discussion Vol., Sept., 1979, Brighton, England.

[29] Marchetti, S. (1980)
"In Situ Tests by Flat Dilatometer", Journal of the Geotechnical Engineering Division, ASCE, Vol. 106, No. GT3, Proc Paper 15290, Mar. 1980, pp. 299-321.

[30] Marchetti, S. (1981)
"Closure to Marchetti (1980), Journal of the Geotechnical Engineering Division, ASCE, Vol. 107, No. GT6, June, pp. 832-837.

[31] Marchetti, S. and C. Panone (1981)
"Distorsion induced in Sands by Probes of different shapes", (in Italian~~a~~) Rivista Italiana di Geotecnica, Vol. 15, No. 1, 1981.

BACK

[32] Marchetti, S. (1982)
"Detection of liquefiable sand layers by means of quasi static penetration tests", Proceedings, 2nd European symposium on Penetration testing, Amsterdam, pp. 689, vol. 2, May, 1982.

[33] Marchetti, S. (1983)
"Il dialometro Piatto", XI Series of Conferences on Soil Mechanics, Polytechnic University of Turin, Nov. 1983, (in Italian).

[34] 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.

[35] DMT Digests (Editor J.H. Schmertmann) (Available from G.P.E. Inc., 4509 N.W. 23rd Ave., Suite 19, Gainesville, FL 32606)
No. 1, April 1983
No. 2, July 1983
No. 3, Feb 1984
No. 4, June 1984
No. 5, Feb 1985

[36] Robertson, P.K. and R.G. Campanella (1984)
"The Flat Plate Dilatometer Test for Liquefaction Assessment".
Univ. Br. Columbia SM Series #79.

[37] Schmertmann, J. (1981)
Discussion of Marchetti (1980), Journal of the Geotechnical Engineering Division, ASCE, Vol. 107, No. GT6, June, pp. 831-832.

[38] Schmertmann, J.H. (1982)
"A method for determining the friction angle in sands from the Marchetti dilatometer test (DMT)", Proceedings, 2nd European Symposium on Penetration Testing, Amsterdam, p. 853, Vol. 2, May 1982.

[39] Schmertmann, J.H. (1984)
"The New In-situ Marchetti Dilatometer Test", Geotechnical News, Vol. 2, No. 3, Sep-Nov 1984, pp. 34-35.

[40] Schmertmann, J.H. and D.K. Crapps (1983)
"Use of Insitu Penetration Tests to Aid Pile Design & Installation", Proceedings of the GEOPILE ´83 Conference, Hollywood, Florida, April, 1983 (published by Associated Pile & Fitting Corp., P.O. Box 1043, Clifton, NJ 07014)

[41] Schmertmann, J.H. (1985)
"Measure and Use the Insitu Lateral Stress", Osterberg Volume, Northwestern University, Dept. of Civil Engineering, in print.

BACK

[42] Schmertmann, J.H. (1985)
"Introduction to the Marchetti Dilatometer Test (DMT)", Proceediings, Conference on Innovations in Geotechnical Engineering, Sponsored by Central PA Section ASCE and PennDOT, Harrisburg, Apr 18-19, 11 pp.

[43] Sonnenfeld, S.L., J.H. Schmertmann and R.C. Williams (1984)
"A Bridge Site Investigation Using SPTs, MPMTs and DMTs from Barges", ASTM Symposium on Marine Testing, San Diego, Jan. 1984.

[44] Szabo, G. (1979)
"In situ Talajvizsgalatok Lapdilatometerrel" Melyepitestudomanyi Szemle, Kulonlenyomat 1979 Evfolyam 5 Szamabol, Budapest. (In Hugarian).

[45] Williams, R.C. and S.L. Sonnenfeld (1982)
"Comparison of In Situ Testing Techniques", Proceedings 1982 Annual Meeting, Florida Section, ASCE, Orlando, Sep 2-5, 19 pp. (Available from Williams & Associates, Inc., 12290 US Highway 19 South, Clearwater, Florida, 33516)

BACK