Designation: D 6635 – 01

Standard Test Method for Performing the Flat Plate Dilatometer[1]

This standard is issued under the fixed designation D 6635; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes an in-situ penetration plus expansion test. The test is initiated by forcing the steel, flat plate, dilatometer blade[2], with its sharp cutting edge, into a soil. Each test consists of an increment of penetration, generally vertical, followed by the expansion of a flat, circular, metallic membrane into the surrounding soil. The test provides information about the soil's in-situ stratigraphy, stress, strength, compressibility, and pore-water pressure for use in the design of earthworks and foundations.

1.2 This method includes specific requirements for the preliminary reduction of dilatometer test data. It does not specify how to assess or use soil properties for engineering design.

1.3 This method applies best to those sands, silts, clays, and organic soils that can be readily penetrated with the dilatometer blade, preferably using static push (see 4.2). Test results for soils containing primarily gravel-sized particles and larger may not be useful without additional research.

1.4 This method is not applicable to soils that cannot be penetrated by the dilatometer[2] blade without causing significant damage to the blade or its membrane.

1.5 The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock and Contained Fluids[3]

D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils[3]

D 2435 Test Method for One-Dimensional Consolidation Properties of Soil[3]

D 3441 Test Method for Mechanical Cone Penetration Tests of Soil[3]

D 3740 Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction[3]

D 5778 Test Method for Performing Electronic Friction Cone and Piezocone Penetration of Soils[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *A-pressure*—the gage gas pressure against the inside of the membrane when the center of the membrane has lifted above its support and moved laterally 0.05-mm (tolerance +0.02, -0.00 mm) into the soil surrounding the blade.

3.1.2 *B-pressure*—the gage gas pressure against the inside of the membrane when the center of the membrane has lifted above its support and moved laterally 1.10-mm (± 0.03 mm) into the soil surrounding the blade.

3.1.3 *C-pressure*—The gage gas pressure against the inside of the membrane when the center of the membrane returns to the *A*-pressure position during a controlled, gradual deflation following the *B*-pressure.

3.1.4 *DMT*—abbreviation for the flat plate dilatometer test as described herein.

3.1.5 *DMT sounding*—the entire sequence of dilatometer tests and results along a vertical line of penetration in the soil.

3.1.6 *DMT test*—the complete procedure of penetration, membrane inflation and then deflation for a single test depth using the fiat plate dilatometer.

3.1.7 Δ*A*—the gage gas pressure inside the membrane (corrected for Z_m) 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

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Evaluations.

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[2] The dilatometer is covered by a patent held by Dr. Silvano Marchetti, Via Bracciano 38, 00189, Roma, Italy. Interested parties are invited to submit information regarding the identification of acceptable alternatives to this patented item to the Committee on Standards, ASTM Headquarters, 100 Barr Harbor Drive, West Conshohocken, PA 19428–2959. Your comments will receive careful consideration at the meeting of the responsible technical committee, which you may attend.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] *Annual Book of ASTM Standards*, Vol 04.09.

positive) with only ambient atmospheric pressure acting externally.

3.1.8 ΔB—the gage gas pressure inside the membrane (corrected for Z_m) required to overcome the stiffness of the membrane and move it outward to a center-expansion of 1.10 mm against only the ambient atmospheric pressure.

3.1.9 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 (see Section 9).

3.1.10 G_m—bulk specific gravity = moist soil unit weight divided by the unit weight of water.

3.1.11 I_D—the dimensionless dilatometer material index, used to identify soil type and delineate stratigraphy (see Section 9).

3.1.12 K_D—the dimensionless dilatometer horizontal stress index, the primary index used in the correlation for in-situ horizontal stress, overconsolidation ratio, and undrained shear strength in cohesive soils. K_D is similar to the at-rest coefficient of earth pressure except that it includes blade penetration effects.

3.1.13 *membrane*—a thin, flexible, 60-mm diameter circular piece of sheet metal (usually stainless steel), fixed around its edges, that mounts on one side of the dilatometer blade and which, as a result of an applied internal gas pressure, expands into the soil in an approximate spherical shape along an axis perpendicular to the plane of the blade.

3.1.14 *P*—the total push, or thrust force required to advance only the dilatometer blade to its test depth, measured at its test depth and exclusive of soil or other friction along the pushrods.

3.1.15 p_0—the *A*-pressure reading, corrected for Z_m, the ΔA membrane stiffness at 0.05-mm expansion, and the 0.05-mm expansion itself, to estimate the total soil stress acting normal to the membrane immediately before its expansion into the soil (0.00-mm expansion, see Section 9).

3.1.16 p_1—the *B*-pressure reading corrected for Z_m and the ΔB membrane stiffness at 1.10-mm expansion to give the total soil stress acting normal to the membrane at 1.10-mm membrane expansion (see Section 9).

3.1.17 p_2—The *C*-pressure reading corrected for Z_m and the ΔA membrane stiffness at 0.05-mm expansion and used to estimate pore-water pressure (see 9.3).

3.1.18 σ'_v—vertical effective stress at the center of the membrane before the insertion of the DMT blade.

3.1.19 σ_v—total vertical stress at the center of the membrane before the insertion of the DMT blade, generally calculated from unit weights estimated using the DMT results.

3.1.20 u_0—the pore-water pressure acting at the center of the membrane before the insertion of the DMT blade (often assumed as hydrostatic below the water table surface).

3.1.21 Z_m—the gage pressure deviation from zero when vented to atmospheric pressure (an offset used to correct pressure readings to the true gage pressure).

4. Summary of Test Method

4.1 A dilatometer test (DMT) consists of forcing the dilatometer blade into the soil, with the membrane facing the horizontal direction, to a desired test penetration, measuring the thrust to accomplish this penetration 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, possibly recording an optional third measurement, advances the blade the desired penetration increment 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.

4.2 The operator may advance the blade using either a quasi-static push force or dynamic impact from a hammer, with quasi-static push preferred. A record of the penetration resistance (thrust force or blows per penetration increment) is desirable both for control of the penetration and later analyses.

NOTE 1—In soils sensitive to impact and vibrations, such as medium to loose sands or 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 more compressible when tested using dynamic insertion methods. In such cases check for dynamic effects and, if important, calibrate and adjust test interpretations accordingly.

4.3 The penetration increment typically used in a dilatometer test (DMT) sounding varies from 0.15 to 0.30 m (0.5 to 1.0 ft). Most soundings are performed vertically and this Test Method requires that the membrane face the horizontal direction. Testing below impenetrable layers will require preboring and supporting (if required) a borehole with a diameter of at least 100 mm (4 in.).

4.4 The operator performs a membrane calibration before and after each DMT sounding.

4.5 The field data is then interpreted to obtain profiles of those engineering soil properties of interest over the depth range of the DMT sounding.

5. Significance and Use

5.1 Soundings performed using this test method provide a detailed record of dilatometer results which are useful for evaluation of site stratigraphy, homogeneity, depth to firm layers, voids or cavities, and other discontinuities. The penetration resistance and subsequent membrane expansion are used for soil classification and correlation with engineering properties of soils. When properly performed at suitable sites, the test provides a rapid means of characterizing subsurface conditions.

5.2 The DMT test provides measurements of penetration resistance, lateral stress, deformation modulus and pore-water pressure (in sands). However, the in-situ soil properties are affected by the penetration of the blade. Therefore, published correlations are used to estimate soil properties for the design and construction of earthworks and foundations for structures, and to predict the behavior of soils subjected to static or dynamic loads.

5.3 This test method tests the soil in-situ and soil samples are not obtained. However, the interpretation of the results from this test method does provide an estimate of the types of soil penetrated. Soil samples from parallel borings may be obtained for correlation purposes, but prior information or experience may preclude the need for borings.

6. Apparatus

6.1 The annotated Fig. 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.

6.1.1 *Blade*, (1), 96 mm wide (95 to 97 mm) and 15 mm thick (13.8 to 15 mm).

6.1.2 *Membrane*, (2), 60 mm diameter.

6.1.3 *Control Unit*, with a pressure readout system (3) that can vary in type, range, and sensitivity as required. Gages with an accuracy better than ¼ percent of span are recommended. The unit shown has both low-range and high-range Bourdon gages that are read manually. Older units have a single Bourdon gage, typically medium-range. The gages should be annually calibrated against a traceable standard, more often if heavily used. The control unit also includes connections (5) for a pressure source, a pneumatic-electrical cable, and an electrical ground cable, and has valves to control gas flow and vent the system (6).

6.1.4 *Calibration Syringe*, (4) for determining the ΔA and ΔB membrane calibrations using the low-range Bourdon gage. Some control units have a separate low-range pressure gage which attaches to the control unit for determining the ΔA and ΔB membrane calibrations

6.1.5 *Pneumatic-Electrical Cable*, (7) to transmit gas pressure and electrical continuity from the control unit to the blade.

6.1.6 *Ground Cable*, (8) to provide electrical continuity between the push rod system and the calibration unit.

6.2 Insertion equipment is required to advance the blade to the test depth. The blade may be pushed using the quasi-static thrust of a drill rig or cone penetrometer rig (CPT, see Test Method D 3441/D 5778), driven using a hammer such as in the standard penetration test (SPT, see Test Method D 1586 and Note 1), or inserted using other suitable equipment. Drill rig support may be required to born through impenetrable soil or rock layers above the desired test depth.

6.3 Push rods are required 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 (Test Method D 3441/D 5778) or SPT (Test Method D 1586) equipment. Suitable adapters are required to attach the blade to the bottom of the rod string and allow the cable to exit near the top of the rods. When testing from the bottom of a borehole, the cable may exit from the rod string some suitable distance above the blade and then be taped to the outside of the rods at appropriate intervals. The exposed cable should not be pinched or allowed to penetrate the soil.

6.4 A gas pressure tank with a suitable regulator and tubing to connect it to the control unit is required. The operator may use any nonflammable, noncorrosive, nontoxic gas as a pressure source. Dry nitrogen is recommended.

6.5 A suitable load cell, just above the blade or at the top of the rods, is required to measure the thrust P applied during the blade penetration. Hydraulic ram pressure may also be used to measure thrust with proper correlation. Parasitic soil-rod friction is generally insignificant in sands, but may be measured during upward withdrawal.

7. Procedure

7.1 *Preparation for Testing and Calibration*:

7.1.1 Select for testing only blades that conform to 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 be straight and sharp, and it should not deviate more than 2 mm transverse to the axis of the rods.

7.1.2 Attach the pressure source and pneumatic-electrical cable to the control unit. Plug the blade end of the cable with an appropriate fitting and apply 4000-6000 kPa pressure to the cable through the control unit. Close the flow control valve and

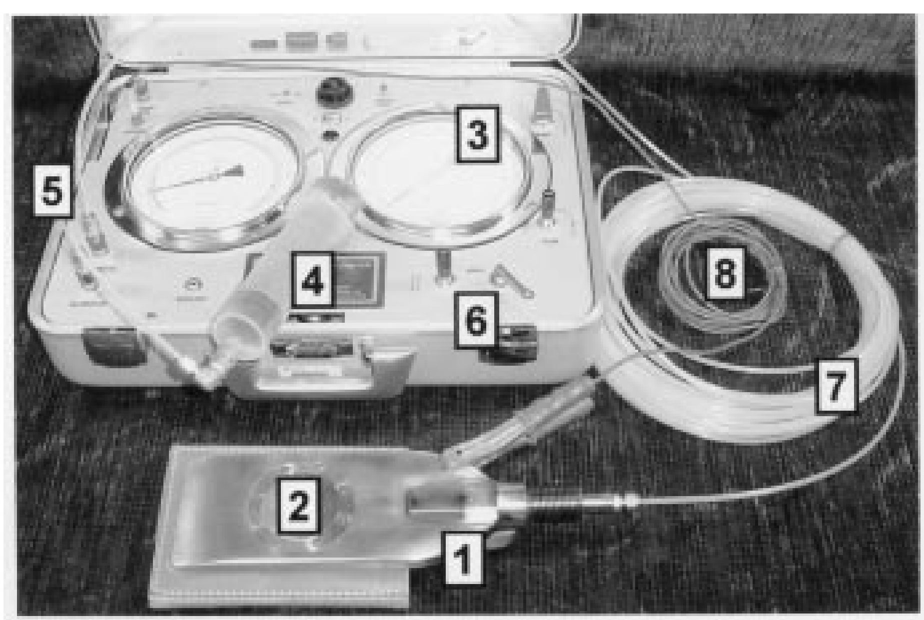

FIG. 1 DMT Equipment

observe the gage for any pressure drop that would indicate a leak in the system. Locate and repair any leaks in the cable. Small leaks (less than 100 kPa/min) in the control unit, though undesirable and indicative of a potential problem, should not significantly affect the test results.

7.1.3 Thread the pneumatic-electrical cable through the lower blade-rod adapter, as many of the push rods as needed and any other adapters, stabilizers or push frames as required. Always cap the cable ends to prevent contamination of the cables and corrosion of the terminals. Connect and tighten the cable to the blade. Insure that the blade and any lower adapters shoulder squarely and tightly to the bottom rod.

7.1.4 Attach the pneumatic-electrical cable to the control unit and connect the ends of the electrical ground cable to the control unit and blade, respectively. To check the circuitry, press the center of the membrane down to activate the electrical/audio signal on the control unit.

7.1.5 With the membrane unrestrained, use the calibration equipment to determine and record the ΔA and ΔB membrane stiffness pressures. Correct the ΔA and ΔB for the gage offset, Z_m. The calibrations should fall within the manufacturer tolerances and are recorded as positive values. The electrical/audio signal should stop and start unambiguously at the 0.05-mm and 1.10-mm expansions. The membrane should be free of wrinkles and deep scratches and should expand smoothly during pressurization without popping or snapping sounds. Repeat the calibration procedure several times to verify consistency. Replace any membrane that fails these checks.

7.1.6 The calibration procedure provides a final check of the equipment prior to testing. If the equipment is disassembled for any reason, the operator should verify the calibrations before proceeding.

7.2 *DMT Tests*:

7.2.1 With the vent valve open and the push rods vertical, advance the dilatometer blade to the first depth. Advance the blade by means of quasi-static push at a rate of 10-30 mm/sec. If possible, measure and record the thrust just before reaching the test depth. An example field data sheet is shown in Fig. X1.2. Alternatively advance the blade using a drop hammer and record the number of blows required for each 100-150 mm of penetration. If estimating the equivalent static thrust from blow counts, use an average of above and below the test depth. Borehole predrilling with casing or drilling mud is acceptable as required.

7.2.2 The blade penetration must produce an electrical/audio signal to indicate the membrane has been pressed flush against the blade to start the 7.2.3 DMT sequence. See 8.3.

7.2.3 Within 15 seconds after reaching the test depth, unload any static force on the push rods, close the vent valve, and pressurize the membrane. The gage pressure at the instant the electrical/audio signal stops (0.05-mm membrane displacement) is recorded as the *A*-pressure reading. Obtain this reading within 15 to 30 seconds after beginning the gas flow. Without stopping the gas flow at the *A*-pressure, continue pressurization of the membrane until the signal comes on again at a 1.10-mm displacement. This is the *B*-pressure reading and-should be obtained 15 to 30 seconds after beginning the gas flow. Without stopping the gas flow at the *A*-pressure, continue pressurization of the membrane until the signal comes on again at a 1.10-mm displacement. This is the *B*-pressure reading and should be obtained 15 to 30 seconds after the *A*-pressure. These time limits require that the pressurization rate be varied according to the anticipated pressure readings, faster in stiff soils and dramatically slower in soft soils. Read the gages with the best possible accuracy, typically 1 kPa for a low-range gage and 5-10 kPa for a high-range gage. Upon reaching the *B*-pressure, immediately open the vent valve and stop the gas flow. Immediate depressurization prevents over-expansion of the membrane, which may change its calibrations. See 7.2.4 for an alternative, controlled depressurization procedure to obtain the "*C*-pressure" (strongly recommended).

NOTE 2—The difference between the *A*-pressure and *B*-pressure readings should always be greater than the sum of the ΔA and ΔB calibrations.

7.2.4 At least every other DMT test in a sounding (preferably more) should include a smooth, controlled depressurization to measure the *C*-pressure. Newer control units include a flow control vent valve for this purpose. Read the *C*-pressure on the low-range gage when the membrane has deflated to the *A*-pressure position (0.05-mm deflection) and the electric signal comes on again (not when the *B*-pressure signal stops). Obtain the *C*-pressure within 15 to 30 seconds immediately following the *B*-pressure. Readings to the nearest 1 kPa are recommended.

NOTE 3—The pore-water pressure must exceed the ΔA calibration to result in a positive *C*-pressure reading. If the electric signal does not activate during the *C*-pressure deflation then use the calibration syringe to apply a suction and obtain a negative *C*-pressure. The value of p_2 will remain positive provided the magnitude of the negative *C*-pressure does not exceed the ΔA calibration (see Table 1).

NOTE 4—The *C*-pressure is sensitive to operator technique. Abrupt pressure changes during the membrane deflation may collapse the soil in front of the membrane and yield a poor measurement. In free-draining soils, the *C*-pressure will not change significantly with time and the operator may check it by repeating the (A-B-C) sequence. The *A*- and *B*-pressures will change from the initial test but the *C*-pressure should remain constant. The repeated *A*- and *B*-pressures are not generally useful. Soils which are not freely-drained will behave differently (see 7.3).

7.2.5 Repeat the test sequence for a new set of *A*-, *B*-, and possibly *C*-pressures, at each depth interval down to the maximum depth of the sounding. The minimum penetration increment between tests is 100 mm (4 in.). Pressure check the system every third or fourth test during the sounding. See 8.8 for details.

7.3 *A-Pressure Dissipation Tests*:

7.3.1 In poorly drained soils, with $I_D < 2$, the excess pore-water pressure induced by the blade penetration usually dissipates over a period of time longer than required for the DMT tests. The coefficient of consolidation may be estimated by observing the dissipation of the *A*-pressure. To perform a dissipation test, stop the blade penetration at the chosen test depth and make successive *A*-pressure readings over time. Dissipation tests can be time consuming and are performed only as needed. Two similar test procedures, the A_2-method and the A-method, are described in 7.3.2 and 7.3.3 respectively. Either is acceptable.

NOTE 5—Before making a detailed analysis of the time-dissipation

TABLE 1 Calculations for Preliminary Reduction of Dilatometer Test Data[A,B,C]

Parameter	Symbol	Formula	Notes
		Preliminary Calculations	
Corrected *A*-pressure	p_0	$1.05(A–Z_m+\Delta A) – 0.05(B–Z_m–\Delta B)$	
Corrected *B*-pressure	p_1	$(B–Z_m–\Delta A)$	
Corrected *C*-pressure	p_2	$(C–Z_m+\Delta A)$	
		Estimate of Pore-Pressure and Effective Vertical Stress	
In-situ Water Pressure	u_0	Estimate from groundwater table or p_2	use p_2 depth profile, see 9.3
Bulk Specific Gravity	G_M	use best estimate	see Fig. X1.1
Total Vertical Stress	σ_v	Σ(layer unit weight × height) where layer unit weight = G_m × unit weight of water	see 9.4
Effective Vertical Stress	σ_v'	$(\sigma_v – u_0)$	
		DMT Indices (include effect of blade penetration)	
Material Index	I_D	$(p_1–p_0) / (p_0–u_0)$	see Fig. X1.1
Horizontal Stress Index	K_D	$(p_0–u_0) / \sigma_v'$	correlate with K_0
Dilatometer Modulus	E_D	$34.7(p_1–p_0)$	correlate K_D and E_D with M

[A] Schmertmann, John H., "Guidelines for Using the CPT, CPTU and Marchetti DMT for Geotechnical Design," U.S. Dept. of Transportation, Federal Highway Administration, Report No. FHWA-PA-024+84-24, Vol 3.
[B] Marchetti, S., "In-Situ Tests by Flat Dilatometer," *Journal of Geotechnical Engineering Division*, American Society of Civil Engineers, Vol. 106, No. GT3, March, 1980, pp. 299–321.
[C] Briaud, J.L., and Miran, J., "The Flat Dilatometer Test", FHWA-SA-91–044, Federal Highway Administration, Feb., 1992.

curves in 7.3.2 and 7.3.3, the *A*-pressure measurements may be corrected to obtain p_0 values. If a paired *B*-pressure measurement is available, as for the final *A*-pressure, then p_0 may be calculated as shown in Table 1. For dissipation analysis a paired *B*-pressure is generally not available, and the following equation may be used to correct *A*-pressure readings:

$$p_0\,(dissipation) = (A - Z_m + \Delta A)$$

7.3.2 *A_2-method Dissipation*—This procedure attempts to measure the pore-water pressure directly and determine consolidation parameters from analysis of the resulting pore-pressure curve. The A_2-method requires a complete DMT test (A-B-C) before beginning a series of *A*-pressure only measurements. When carried to complete dissipation in free-draining soils, the final value of p_0 (see Note 5) should equal the in-situ pore-water pressure, u_0. Ideally, the initial DMT test opens a 1.10-mm cavity and the subsequent *A*-pressures measure only the pore-water pressure in the open cavity (or greatly disturbed soil zone) immediately adjacent to the membrane. If the time-dissipation curve approaches u_0 asymptotically, then this assumption is justified.

7.3.2.1 After penetration to the test depth, follow the full DMT sequence of readings (A-B-C). Start a stopwatch or record initial time at the instant of the thrust removal. Note the time elapsed in seconds at the instant of the *C*-pressure reading and record the data.

7.3.2.2 Immediately repressurize the system, obtain an *A*-pressure reading, and then vent the pressure without further membrane expansion. Record the reading and elapsed time in seconds at the instant of this *A*-pressure reading. Obtain *A*-pressure readings to the nearest 1 kPa.

7.3.2.3 Continue performing the test sequence in 7.3.2.2 to obtain reasonably spaced data points for the time-dissipation curve (see 7.3.2.4). A factor of 2 increase in time at each *A*-pressure is satisfactory (i.e. *A*-pressures at 1, 2, 4, 8, 15, 30 minutes...). A *B*-pressure should be obtained following the final *A*-pressure.

7.3.2.4 Plot the *A*-pressure readings obtained as soon as convenient and continue the plot for each successive reading. Plot the *A*-pressure (uncorrected) vs. the elapsed time for each reading. A square-root-of-time scale works well for the extrapolations described below. (See Fig. 2 for an idealized example field plot.)

7.3.2.5 Stop the dissipation test only after making enough measurements to determine t_{50}, the time at 50 percent dissipation of the *A*-pressure. Use t_{50} to calculate the coefficient of consolidation.[5] If convenient, continue the test long enough for the dissipation curve to approach its eventual asymptote at 100 percent dissipation, A_{100}. This helps define A_{100} (ideally = u_0 when corrected). A possible method for obtaining t_{50} is outlined below:

(*1*) Extrapolate the beginning of the dissipation curve back to the *A*-pressure intercept at time = 0, A_0, mathematically or graphically. A straight line through the early data points is usually adequate.

(*2*) Extrapolate the end of the dissipation curve forward to estimate the asymptotic *A*-pressure, A_{100}. Alternatively, estimate A_{100} from the expected in-situ pore-water at the test depth:

$$A_{100}\,(estimated) = (u_0 - \Delta A + Z_m)$$

(*3*) Average A_0 and A_{100} to find A_{50} at 50 percent dissipation.

(*4*) The time corresponding to A_{50} on the dissipation curve is t_{50}.

7.3.3 *A-method Dissipation*—This procedure obtains only *A*-pressure readings at the chosen test depth, never expanding the membrane beyond the *A*-pressure position. This method measures the total stress against the blade and determines consolidation parameters from analysis of the resulting total-stress-dissipation curve. When carried to complete dissipation, the final p_0 value (see Note 5) should approximately equal the total lateral stress against the blade. This lateral stress will

[5] Schmertmann, John H., "Guidelines for Using the CPT, CPTU and Marchetti DMT for Geotechnical Design," U.S. Dept. of Transportation, Federal Highway Administration, Report No. FHWA-PA-024+84-24, Vol 3.

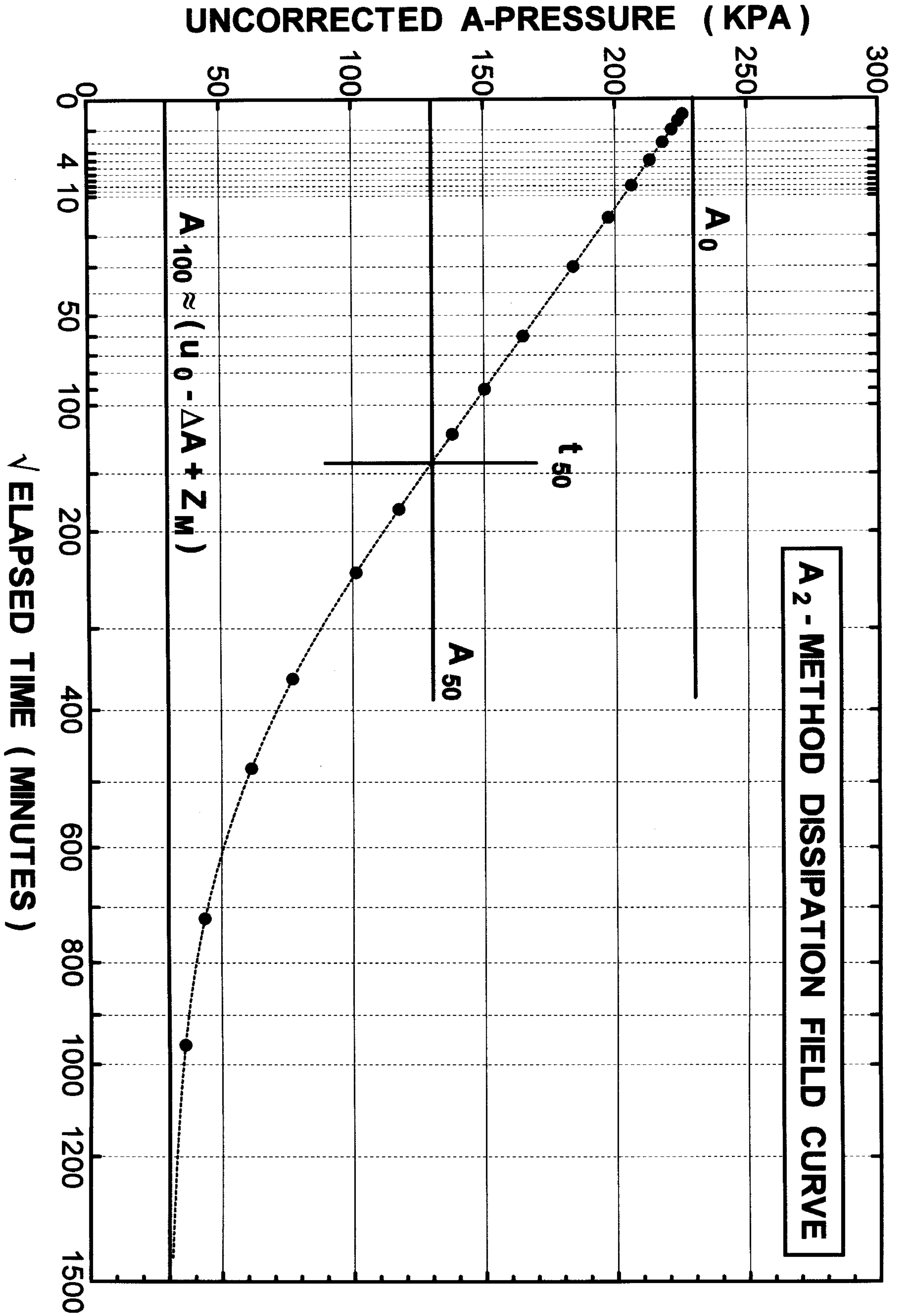

FIG. 2 Idealized Example Field Plot of Uncorrected A_2-Method Dissipation Data

differ from the in-situ lateral stress because of the blade penetration, but it may be useful for the design of deep foundations. The following procedure is recommended:

7.3.3.1 After penetration to the test depth, quickly unload the push rods and start a stopwatch or record time zero at the instant of the thrust removal. Then, without delay, pressurize the membrane to obtain and record the *A*-pressure. After reading the *A*-pressure, immediately vent the system without further membrane expansion so as not to affect the dissipation. Obtain *A*-pressure readings to the nearest 1 kPa. Record elapsed time to the nearest second at the instant of the *A*-pressure.

7.3.3.2 Continue to make additional *A*-pressure readings to obtain reasonably spaced data points for the time-dissipation curve (see 7.3.3.3). A factor of two increase in time at each *A*-pressure is satisfactory (i.e. *A*-pressures at 0.25, 0.5, 1, 2, 4, 8, 15, 30 minutes). A *B*-pressure should be obtained following the final *A*-pressure.

7.3.3.3 Plot the *A*-pressure readings obtained as soon as convenient and continue the plot for each successive reading. Plot the *A*-pressure (uncorrected) vs. the log of the elapsed time for each reading. Shown in an idealized field plot in Fig. 3, this curve will normally assume a sigmoidal shape, with flatter slopes (less change in A per increment in log time) at the early and late times, and a point of inflection between.

7.3.3.4 Stop the dissipation test when it is clear that the slope of the A vs. log time curve has flattened sufficiently to find the point of inflection. The time at the point of inflection is T_{flex}. Use T_{flex} as a qualitative measure from which to estimate the coefficient of consolidation. If convenient, continue the test until the dissipation curve clearly approaches its eventual asymptote at 100 percent dissipation, A_{100}. The Table 1 value of p_0 obtained for the final *A*-pressure / *B*-pressure may represent the final horizontal stress against the blade.

7.4 *After Completion of Testing*:

7.4.1 After completion of the final Dilatometer test, 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 section 7.1.4 and record the 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, then repair or replace the blade or membrane or both 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. The significance of calibration changes varies with the strength of the soil and the intended use of the DMT results. Trial calculations using both the initial and final membrane calibration values will show their importance to the results.

7.4.2 Complete the field log, including as much of the required report data as available. Note any deficiencies. (See Section 10 and Fig. X1.2.)

7.4.3 Reduce the field data and calculate the DMT indices as described in Section 9. Prepare a report as described in Section 10.

8. Special Precautions

8.1 *Timely Readings*—Experiments have determined that testing within the time limits of 7.2.3 results in essentially drained conditions in sands and undrained conditions in clays and that the results are not sensitive to time-for-reading changes by a factor of 2. 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 use of proper time intervals. Unsaturated soils are believed to behave in an approximately drained fashion.

8.2 *Rate of Pressurization*—Since very little membrane movement occurs before the *A*-pressure, the operator may reduce testing time by initially pressurizing at a rapid rate, then slowing to accurately read the *A*-pressure. This technique has minimal effect on the *A*-pressure measurement but does risk a poor reading if it occurs unexpectedly. A steady, readable rate is preferred for the pressure increment from the *A*- to *B*-pressure. Check the chosen flow rate by closing the flow control valve during the test and observing the gage for a drop in pressure before stabilizing. If the pressure drops in excess of 2 percent, the rate is too fast. Longer cables require a slower flow rate for accurate readings.

8.3 *Weak Soils*—Accurate, timely readings are very important when testing soft or weak soils. Also at shallow depths in very weak (or partially saturated soils), the lateral soil pressure may not exceed the ΔA membrane stiffness to produce the required initial signal. For sensitive testing of this type, choose a membrane with low and consistent calibration values. As an alternative, before advancing to the test depth, close the vent valve, use the calibration syringe to collapse the membrane with an initial suction or vacuum, and then remove the syringe leaving the negative pressure locked in. After advancing the blade with the membrane collapsed, read the *A*-pressure as in 7.2.3, recording vacuum as a negative value. The calibration unit can also be used to apply the initial vacuum, but it cannot be removed until reading zero pressure during the test. Alternatively, bypass shallow testing until reaching a depth that produces the initial signal.

8.4 *Membrane Damage*—Damage to the membrane typically occurs when brushing against or pushing through gravel, large shells, unweathered rock, concretions, miscellaneous fill, and buried obstructions. In soils containing such obstacles be alert for membrane malfunction. Continued usage in highly abrasive soils, such as dense quartz sands, gradually wears down blades and membranes and makes them more susceptible to further damage. Replace membranes when wear or wrinkling inhibits the smooth expansion of the membrane or will likely cause rapture during penetration.

8.5 *Blade Damage*—Bending of the blade, excessive wear and wrinkling of the cutting edge typically occur when a high penetration thrust P is required such as in hard clays or dense sands, especially with gravel, large shells, unweathered rock, cementations and similar inclusions. The probability of damage is significant above a thrust of approximately 44 kN (5 tons) and very high above 89 kN (10 tons). Weak soil layers provide poor lateral support to the drill rods and also increase the risk of damage to both rods and blade.

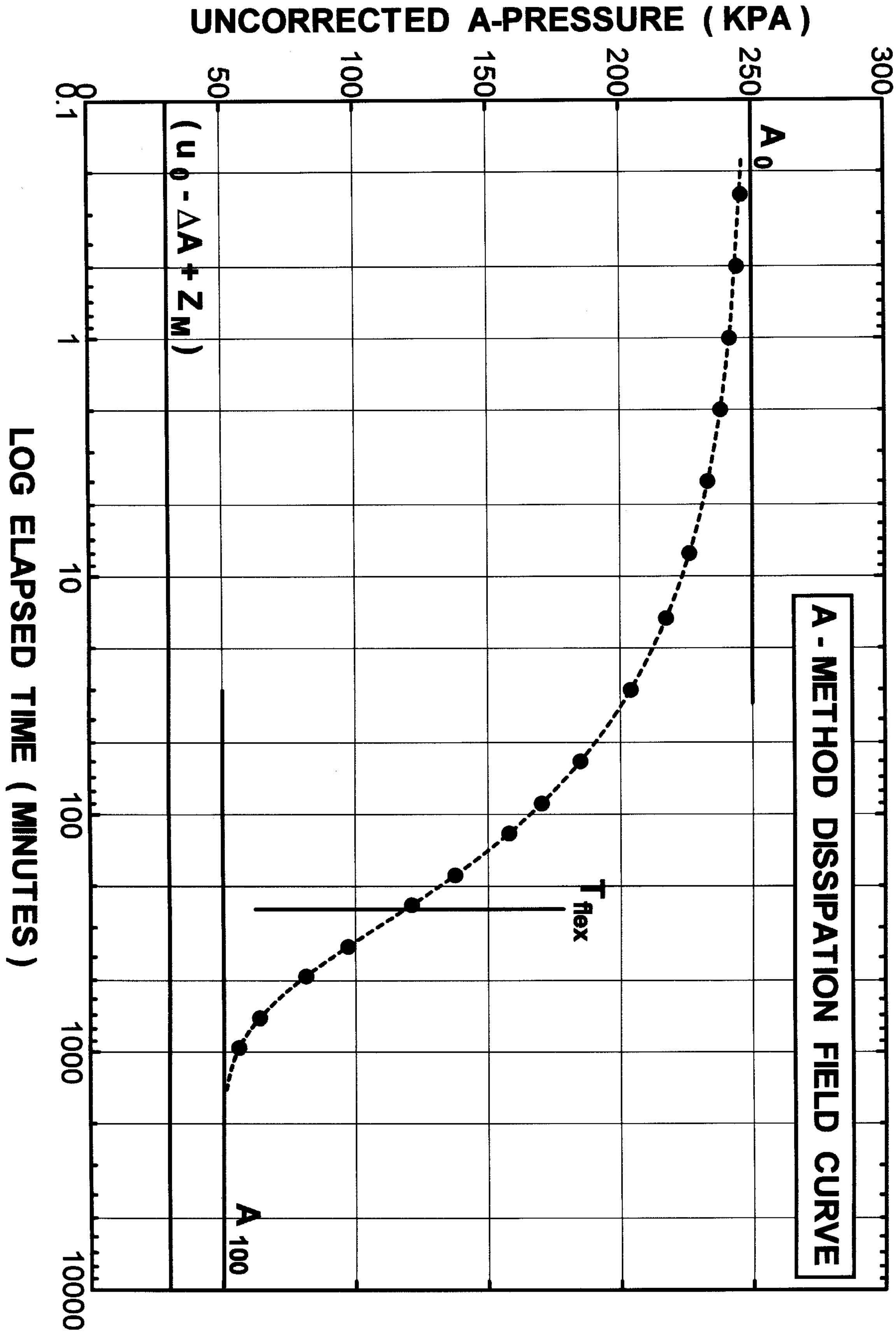

FIG. 3 Idealized Example Field Plot of Uncorrected A -Method Dissipation Data

8.6 *Rotary Drilling Equipment*—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.

8.7 *Verticality*—The dilatometer blade may drift out of plumb when inserted with initial horizontal forces acting, when penetrating soils with inclusions (see 8.5) or when encountering obstructions. The deeper the sounding the more likely that appreciable deflection may occur. With usual care this problem is not significant in ordinary sands and clays for sounding depths of less than 15 m. However, be alert for indications of drift, such as unusual "crunching" sounds, out of plumb rods, suspicious data, or specific soil layers encountered deeper than expected. Research indicates no significant effect on the test results for soundings performed within 15 degrees of the vertical axis.

8.8 *Leak Checks During Sounding*—Periodically check for any leaks in the lines or connections by momentarily closing the control valve during the interval between the *A*- and *B*-pressures. If the pressure remains constant, then the system has no leaks, as required. Identify the source of any leaks before continuing the sounding. Control unit leakage greater than 100 kPa/min and any leaks in the blade or cable must be repaired before continuing. In the event that subsurface leakage forces termination of a sounding, maintain a pressure in the system of 100 to 200 kPa above u_0 while withdrawing the blade to prevent entry of soil and water.

8.9 *Prompt Readings*—Make all gage readings promptly and accurately. In very noisy testing environments or poor electrical grounding conditions it may be difficult to hear the audio signal that prompts and *A*- and *B*-pressure readings. In this case, use either a visual cue on the control unit or an earphone to insure timely detection of the audio signal.

8.10 *Electrical Short*—If the electric audio signal does not cease at a reasonable *A*-pressure (based on previous readings and thrust measurements), then a short circuit is likely. Possible causes include a poorly connected cable (especially at the blade), entry of soil or water into the cable through a torn tubing or loose fitting, or infiltration of soil or water into the blade, especially through a ruptured membrane. Locate and correct the short before continuing the sounding.

8.11 *Electrical Discontinuity*—If the electric audio signal does not initiate when penetrating to the test depth, or does not return at a reasonable *B*-pressure (based on previous readings and thrust measurements), then a discontinuity is possible in the electrical circuit to, from or within the blade. (See section 8.3 also.) Over-expansion of the membrane and unacceptable changes in the membrane calibrations may result if the *B*-pressure is exceeded. Soil inside the blade may interfere with the electrical switching and cause this problem. Locate and correct the discontinuity before continuing the sounding.

8.12 *Nearby Soundings and Borings*—DMT soundings should not be performed within the zone of soil affected by another sounding or boring. Good test practice requires a minimum clear distance of 1.0 m from an existing CPT sounding (Test Method D 3441/D 5778) and 25 boring diameters from an existing, unbackfilled or uncased boring. Increase these/distances if the sounding or boring logs include significant lateral drift, borehole collapse or loss of circulation. If possible, complete the DMT soundings before any borings.

8.13 *Borings Used to Advance DMT Soundings*—When DMT tests are performed below a borehole, disregard any DMT results within the zone of disturbance at the hole bottom, typically three to five borehole diameters. Casing or drilling mud or both should be used to stabilize borings in saturated soils, and drill fluid should be maintained above the ground water surface at all times. Bottom discharge drill bits am not permissible for advancing DMT soundings.

9. Calculation

9.1 Table 1 presents a summary of the steps from the collection of field data, through the calculation of the Dilatometer Indices for material type (I_D), lateral stress (K_D), and a modulus (E_D).

9.2 The *A*-, *B*- and *C*-pressures should be corrected and reported as p_0, p_1, and p_2 respectively (see Table 1). Note that the calculation for p_0 is a linear extrapolation from the B-reading (1.10 mm expansion) through the A-reading (0.05 mm expansion) to a zero membrane expansion. The value of ΔA, typically obtained by suction pressure, is recorded and used in the Table 1 equations as a positive number.

9.3 Porewater pressure, u_0, is normally taken as hydrostatic below a groundwater surface, with a value of zero assumed above. If better information is available, it should be used in place of this assumption. The *C*-pressure directly measures, u_0, in free-draining sand soils (or in sand layers within clay soils) when $I_D \geq 2$ (approximately). In this case the corrected *C*-pressure, p_2, may be used as u_0 in the Table 1 calculations. *C*-pressures are usually significantly higher than u_0 in undrained soils (silts and clays), primarily because of the blade penetration. Because *C*-pressures typically contain some experimental scatter use a depth profile of p_2 values to provide a pore-water pressure trend rather than rely on individual measurements. A depth profile of p_2 also helps identify stratigraphy.

9.4 The calculations of Table 1 include those for the vertical effective stress at the test depth. This requires knowledge of soil unit weights. Schmertmann[5] recommends the approximate bulk specific gravity values shown in Fig. X1.1. To obtain unit weight, enter the chart with E_D and , I_D find the recommended bulk specific gravity, and then multiply by the unit weight of water. Most of the current computer programs incorporate this matrix for the summation of total overburden pressure, however, local correlation is preferred and other interpretations are acceptable. If a better estimate of soil unit weight is available, then it should be used in place of Fig. X1.1. Note that the effective stress and pore-water pressures referred to here are those existing before the insertion of the DMT blade.

9.5 Use the calculated p_0 and p_1 values and the estimates for u_0 and σ_v' to calculate the Dilatometer Indices I_D, K_D and E_D. Note that the calculation of E_D assumes a membrane diameter of 60 mm and a B-reading expansion of 1.10 mm.

9.6 The DMT measures lateral stress (p_0) and modulus (E_D) in the soil after the soil is disturbed by the blade penetration. The size and shape of the blade are intended to minimize this disturbance while preventing damage to the blade. However, because of the insertion disturbance, research and experience are required to establish correlations between the DMT measurements and the undisturbed, in-situ soil parameters. Some of the published correlations for interpretation of the dilatometer data are presented in the Appendix. The methods included in the Appendix are neither exhaustive or exclusive. Other interpretations may be used, as deemed appropriate.

10. Report

10.1 Field logs should include all of the information necessary to produce a concise report of each DMT sounding. The inclusion of field logs in a report is optional. An example field log form is shown in Fig. X1.2. Notes should include any deviations from this Test Method.

10.2 General information to be included in each DMT sounding report:

10.2.1 Name and location of the job,

10.2.2 Names of DMT operator and any helpers,

10.2.3 Date and number of sounding,

10.2.4 Location coordinates of sounding,

10.2.5 Ground surface elevation at sounding,

10.2.6 Depth reference elevation (if different from ground surface),

10.2.7 Water surface elevation or other information used to estimate in-situ water pressure for each DMT test,

10.2.8 Serial number, thickness, width, and condition of DMT blade,

10.2.9 Names of penetration rig operator and any helpers,

10.2.10 Type of penetration rig and method of penetration

10.2.11 Method and calibration of thrust measurement,

10.2.12 Type, diameter and linear weight of penetration rods,

10.2.13 Rod friction reducer diameter,

10.2.14 Casing depth, predrill depth, method of drilling, and type of drilling fluid used,

10.2.15 Pressure gage ranges and deviations from zero when vented,

10.2.16 ΔA and ΔB blade calibrations (corrected for Z_m), before, during (as obtained), and after each sounding,

10.2.17 Method used to estimate total vertical stresses,

10.2.18 Orientation of blade membrane during sounding,

10.2.19 Location and orientation of topographical features which may affect horizontal soil stresses (embankments, cuts, etc.),

10.2.20 Deviations from this Test Method,

10.2.21 Notes on difficulties, abnormalities or equipment damage.

10.3 Test specific information to be included in a DMT sounding report for each DMT test (clearly note any deviations from the calculation methods shown in Table 1):

10.3.1 Depth of test below reference elevation,

10.3.2 Measured thrust (P) (optional),

10.3.3 *A*- and *B*-pressure test readings,

10.3.4 *C*-pressure test reading (optional),

10.3.5 ΔA and ΔB blade calibrations and gage zeroes,

10.3.6 Corrected test readings p_0, p_1, and (optional) p_2,

10.3.7 Estimated bulk specific gravity or unit weight of soil,

10.3.8 Estimated total vertical stress, in-situ water pressure, and effective vertical stress,

10.3.9 Material Index (I_D), Horizontal Stress Index (K_D), and Dilatometer Modulus (E_D).

10.4 Optional interpreted soil properties for each DMT test, such as listed in Table X1.1, may be included in a DMT sounding report along with a description of the analysis methods used.

10.5 Computerized data reduction programs may be used to produce DMT sounding reports. Results may also be calculated by hand methods. The name of the engineer performing the analysis and the date should be included on each sounding. Optional depth profile graphs of the results are useful also. Example computer tabulations and graphs are shown in X1.3 – X1.5.

11. Precision and Bias

11.1 *Precision*—Experience has shown the DMT test results (A,B,C) to be exceptionally reproducible and operator insensitive when performed within the guidelines of this standard. Engineers with experience estimate that test results are reproducible with a coefficient of variation of approximately 10 percent.

11.2 *Bias*—There is no accepted reference for this test method, therefore bias cannot be determined.

11.3 *Correlations*—The average accuracy and variability with which the DMT correlations in Table X1.1 predict engineering soil properties have been investigated by many researchers. Schmertmann[5] found that these correlations generally provided reasonable accuracy except in very sensitive clays, weathered clay crusts, and aged/cemented clays.

12. Keywords

12.1 compressibility; deformation; dilatometer; DMT; earth pressure; exploration; in-situ soil test; modulus; penetration; settlement; stratigraphy; strength; stress

APPENDIX

(Nonmandatory Information)

X1.

X1.1 This appendix contains previously published and widely accepted soil property correlations. These correlations are included by way of example. Other correlations are available and may be more appropriate for a given test site.

X1.2 This appendix contains an example data sheet, tabulated results, and an example depth profile. These figures are for reference only.

X1.3 The thrust force, P, required to advance the blade and the horizontal pressure against the blade (p_0) may be used together to calculate the dilatometer tip bearing q_D. The tip bearing is the axial thrust force at the end of dilatometer blade divided by the projected cross-sectional area of the blade normal to the penetration. The DMT tip bearing is similar to the cone resistance, q_c (see Test Method D 3441) and may be used to evaluate stratigraphy. In cohesionless soils, q_D and K_D may be used to estimate the friction angle, overconsolidation ratio and at rest coefficient of earth pressure.

X1.4 The K_D value is the basis for predicting in-situ horizontal effective stress, and also related predictions for OCR and p'_c.

X1.5 The blade can be considered to produce a lateral passive limit pressure failure in cohesive soils, thus forming the basis for evaluating the undrained shear strength.

X1.6 The Dilatometer Modulus, E_D, is based on the difference between the p_1, and p_0 obtained over a precise and relatively small increment of membrane displacement, and is the basis for evaluating the in-situ, drained modulus and compressibility behavior. Research indicates that the stress-strain behavior of the soil is essentially linear between p_0 and p_1 but not necessarily elastic.

X1.7 The ratio of modulus to horizontal stress, reflected by the Material Index, I_D, depends on the soil's rigidity, pore-pressure generation, and permeability properties, and thus provides an indicator of soil type.

TABLE X1.1 Engineering Soil Properties Calculated form Dilatometer Test Data[A,B,C]

Soil Property	Symbol	Formula	Notes
Soil Type		clay $I_D < 0.6$, sand $I_D > 1.8$	see Fig. X1.1
Coefficient of Earth Pressure, at rest	K_0	$(K_D/1.5)^{0.47} - 0.6$ uses K_D and friction angle	clay, $I_D < 1.2$ sand and silt, $I_D \geq 1.2$
DMT Tip Bearing (see section X1.3)	q_D	Estimate from thrust measurement also $q_D \approx (1.1 \pm 0.1)\, q_c$	$I_D \geq 1.2$
Angle of Internal Friction, Plane Strain, Drained	$\phi_{ps'}$	Summation of forces during penetration, q_D and K_D	sand and silt, $I_D \geq 1.2$
Undrained Shear Strength	s_u	$0.22\sigma_v'\,(0.5K_D)^{1.25}$	clay, $I_D \leq 0.6$
Tangent Constrained Modulus of Soil Deformation (see Test Method D 2435)	M	$M = R_M E_D$(minimum $R_M = 0.85$) $R_M = 0.14 + 2.36\log K_D$ $R_M = R_{M,0} + (2.50 - R_{M,0})\log K_D$ $R_{M,0} = 0.14 + 0.15(I_D - 0.6)$ $R_M = 0.50 + 2.00\log K_D$ $R_M = 0.32 + 2.18\log K_D$	 if $I_D < 0.6$ if $0.6 < I_D < 3.0$ if $I_D \geq 3.0$ if $K_D > 10$
Young's Modulus(secant value at 25 % of failure stress, triaxial compression test)	E_{25}	$\approx E_D$ for uncemented NC sands	
Overconsolidation Ratio	OCR	$(0.5K_D)^{1.56}$ $[K_0/(1-\sin\phi'_{ax})]^{(1/0.8\sin\phi ax')}$ ϕ'_{ax} = axisymmetric friction angle	 clay, $I_D < 1.2$ sand, $I_D \geq 1.2$
Horizontal Coefficient of Consolidation	c_h	analyze dissipation test	
Horizontal Coefficient of Permeability	k_h	$c_h\gamma_w / M_h$, $M_h \approx K_0$ M and γ_w = unit weight of water	

[A] Schmertmann, John H., "Guidelines for Using the CPT, CPTU and Marchetti DMT for Geotechnical Design," U.S. Dept. of Transportation, Federal Highway Administration, Report No. FHWA-PA-024+84-24, Vol 3.

[B] Marchetti, S., "In-Situ Tests by Flat Dilatometer," *Journal of Geotechnical Engineering Division*, American Society of Civil Engineers, Vol. 106, No. GT3, March, 1980, pp. 299–321.

[C] Briaud, J.L., and Miran, J., "The Flat Dilatometer Test", FHWA-SA-91–044, Federal Highway Administration, Feb., 1992.

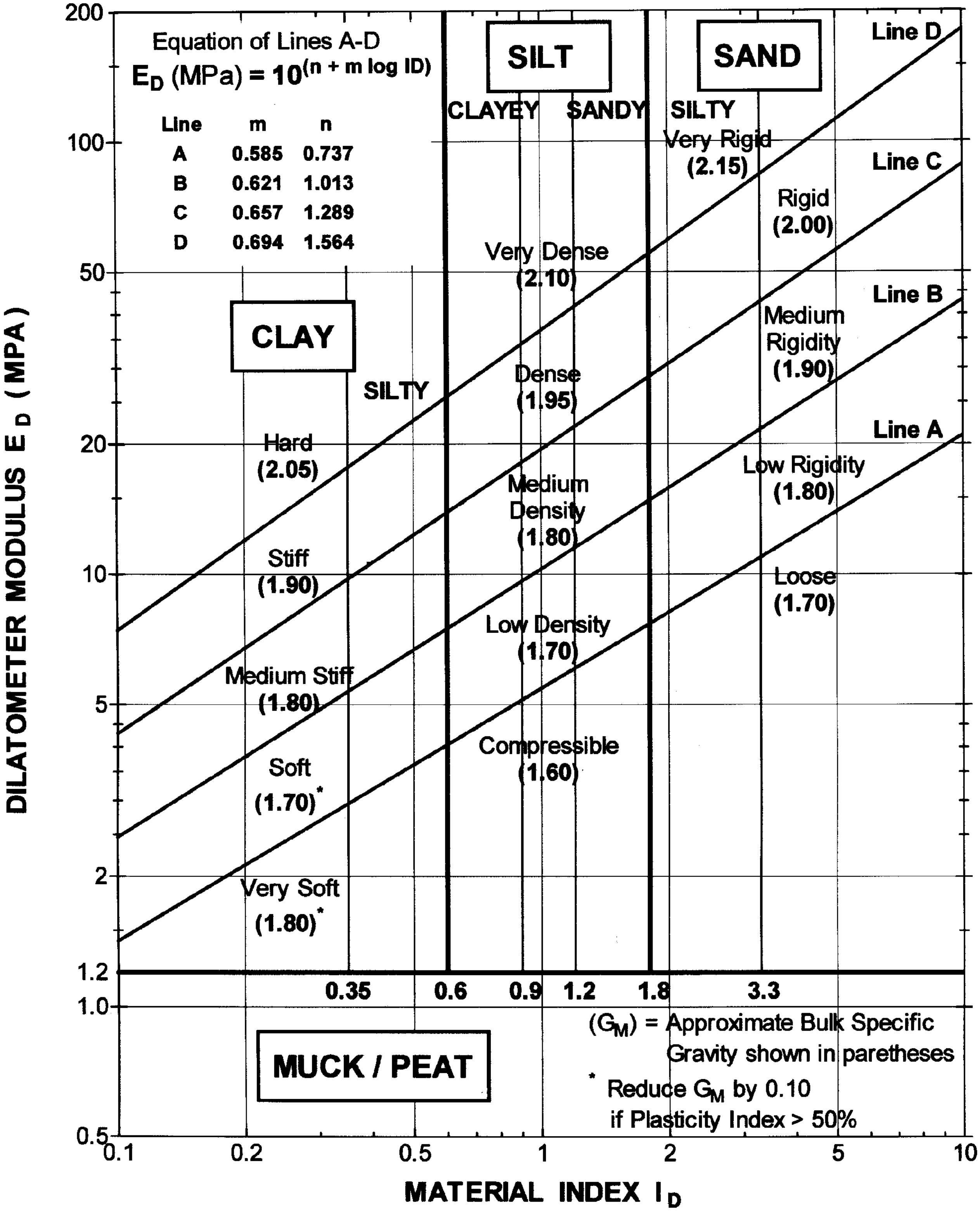

FIG. X1.1 Chart for Estimating Soil Type and Bulk Specific Gravity

Dilatometer Sounding No. ________

Page _____ of _____

Project No. ____________

Date ____________

Project/Client ________________________________

DMT Operator / Co. ________________________

Location ________________________________

Rig Operator / Co. ________________________

Low Range Gage 0	________kPa	Ground Surf. Elev.	________m	Rig Type	____________
High Range Gage 0	________kPa	Ground Water Depth	________m	Blade No.	____________
Rod Type	________	Casing Depth	________m	Blade Width	________mm
Rod Diameter	________mm	Predrill Depth	________m	Blade Thickness	________mm
Rod Weight	________N/m	Initial Depth z_i	________m	Pore Pressure u_{0i}	________kPa
Frict. Red. Diam.	________mm	Tot.Vert.Stress σ_{vi}	________kPa	Eff.Vert.Stress σ'_{vi}	________kPa

Depth ( )	Thrust ( )	A kPa	B kPa	C kPa	Depth ( )	Thrust ( )	A kPa	B kPa	C KPa
		ΔA =	ΔB =						
							ΔA =	ΔB =	

Notes ____

FIG. X1.2 Example Field Data Sheet

DILATOMETER DATA LISTING & INTERPRETATION (BASED ON THE 1988 DILATOMETER MANUAL) SNDG. NO. FRZ006
University of Florida / S&C PAGE 1
JOB FILE: Pile Freeze Research FILE NO. : 866
LOCATION: Vilano West, SE of Pile
SNDG.BY : P.Bullock/B.Grajales SNDG.DATE: 08/14/98
ANAL.BY : P.Bullock/T.Esin ANAL.DATE: 11/16/98

ANALYSIS PARAMETERS: LO RANGE = 9.80 BARS ROD DIAM. = 3.57 CM BL.THICK. = 15.0 MM SU FACTOR = 1.00
SURF.ELEV. = 0.94 M LO GAGE 0 = 0.00 BARS FR.RED.DIA. = 3.57 CM BL.WIDTH = 96.0 MM PHI FACTOR = 1.00
WATER DEPTH = 0.44 M HI GAGE 0 = 0.50 BARS LIN.ROD WT. = 6.50 KGF/M DELTA-A = 0.14 BARS OCR FACTOR = 1.00
SP.GR.WATER = 1.026 CAL GAGE 0 = 0.00 BARS DELTA/PHI = 0.50 DELTA-B = 0.47 BARS M FACTOR = 1.00
MAX SU ID = 0.60 SU OPTION = MARCHETTI MIN PHI ID = 1.20 OCR OPTION= MARCHETTI K0 FACTOR = 1.00
UNIT CONVERSIONS: 1 BAR = 1.019 KGF/CM2 = 100 KPA = 1.044 TSF = 14.51 PSI 1 M = 3.2808 FT

Z (M)	ELEV (M)	THRUST (KGF)	A (BAR)	B (BAR)	C (BAR)	DA (BAR)	DB (BAR)	ZMRNG (BAR)	ZMLO (BAR)	ZMHI (BAR)	ZMCAL (BAR)	P0 (BAR)	P1 (BAR)	P2 (BAR)	U0 (BAR)	GAMMA (T/M3)	SVP (BAR)
*****	******	******	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	******	******	******
0.40	0.54	164.	0.20	1.30		0.14	0.47	9.80	0.00	0.50	0.00	0.31	0.83		0.000	1.60	0.071
0.60	0.34	589.	0.56	3.76		0.14	0.47	9.80	0.00	0.50	0.00	0.57	3.29		0.016	1.72	0.087
0.80	0.14	865.	1.41	5.64		0.14	0.47	9.80	0.00	0.50	0.00	1.36	5.17		0.036	1.81	0.102
1.00	-0.06	373.	0.97	3.54		0.14	0.47	9.80	0.00	0.50	0.00	1.01	3.07		0.056	1.72	0.116
1.20	-0.26	120.	0.70	1.56	0.41	0.14	0.47	9.80	0.00	0.50	0.00	0.83	1.09	0.55	0.077	1.52	0.128
1.40	-0.46	33.	0.72	1.79	0.40	0.14	0.47	9.80	0.00	0.50	0.00	0.84	1.32	0.54	0.097	1.62	0.139
1.60	-0.66	43.	0.64	1.66	0.23	0.14	0.47	9.80	0.00	0.50	0.00	0.76	1.19	0.37	0.117	1.62	0.150
1.80	-0.86	71.	0.47	1.69	0.08	0.14	0.47	9.80	0.00	0.50	0.00	0.58	1.22	0.22	0.137	1.62	0.162
2.00	-1.06	127.	0.63	2.04	0.08	0.14	0.47	9.80	0.00	0.50	0.00	0.73	1.57	0.22	0.157	1.62	0.173
2.20	-1.26	191.	0.66	2.24	0.10	0.14	0.47	9.80	0.00	0.50	0.00	0.75	1.77	0.25	0.177	1.62	0.185
2.40	-1.46	603.	1.33	6.07	0.09	0.14	0.47	9.80	0.00	0.50	0.00	1.26	5.60	0.23	0.197	1.81	0.199
2.60	-1.66	566.	1.69	6.12	0.14	0.14	0.47	9.80	0.00	0.50	0.00	1.64	5.65	0.28	0.217	1.81	0.214
2.80	-1.86	422.	1.84	6.34	0.15	0.14	0.47	9.80	0.00	0.50	0.00	1.79	5.87	0.29	0.238	1.81	0.229
3.00	-2.06	301.	0.87	2.82	0.19	0.14	0.47	9.80	0.00	0.50	0.00	0.94	2.35	0.33	0.258	1.72	0.244

END OF SOUNDING (INTERPRETED SOIL PARAMETERS ON NEXT PAGE)

FIG. X1.3 Example Report Output: Initial Page with Field Data and Preliminary Calculations

DILATOMETER DATA LISTING & INTERPRETATION (BASED ON THE 1988 DILATOMETER MANUAL) SNDG. NO. FRZ006
University of Florida / S&C PAGE 2
JOB FILE: Pile Freeze Research FILE NO. : 866
LOCATION: Vilano West, SE of Pile
SNDG.BY : P.Bullock/B.Grajales SNDG.DATE: 08/14/98
ANAL.BY : P.Bullock/T.Esin ANAL.DATE: 11/16/98

ANALYSIS PARAMETERS: LO RANGE = 9.80 BARS ROD DIAM. = 3.57 CM BL.THICK. = 15.0 MM SU FACTOR = 1.00
SURF.ELEV. = 0.94 M LO GAGE 0 = 0.00 BARS FR.RED.DIA. = 3.57 CM BL.WIDTH = 96.0 MM PHI FACTOR = 1.00
WATER DEPTH = 0.44 M HI GAGE 0 = 0.50 BARS LIN.ROD WT. = 6.50 KGF/M DELTA-A = 0.14 BARS OCR FACTOR = 1.00
SP.GR.WATER = 1.026 CAL GAGE 0 = 0.00 BARS DELTA/PHI = 0.50 DELTA-B = 0.47 BARS M FACTOR = 1.00
MAX SU ID = 0.60 SU OPTION = MARCHETTI MIN PHI ID = 1.20 OCR OPTION= MARCHETTI K0 FACTOR = 1.00
UNIT CONVERSIONS: 1 BAR = 1.019 KGF/CM2 = 100 KPA = 1.044 TSF = 14.51 PSI 1 M = 3.2808 FT

Z (M)	ELEV (M)	KD	ID	UD	ED (BAR)	K0	SU (BAR)	QD (BAR)	PHI (DEG)	SIGFF (BAR)	PHIO (DEG)	PC (BAR)	OCR	M (BAR)	SOIL TYPE
*****	******	*****	*****	*****	******	*****	*****	*****	*****	******	*****	*****	*****	******	************
0.40	0.54	4.40	1.65		18.	0.62		7.1	40.9	0.12	35.9	0.19	2.6	31.	SANDY SILT
0.60	0.34	6.34	4.90		94.	0.32		26.5	48.6	0.15	45.0	0.09	1.0	198.	SAND
0.80	0.14	13.04	2.86		132.	1.42		35.0	45.7	0.17	42.0	1.52	14.9	363.	SILTY SAND
1.00	-0.06	8.21	2.16		72.	1.11		13.7	40.2	0.19	35.9	0.98	8.4	166.	SILTY SAND
1.20	-0.26	5.87	0.35	0.63	9.	1.30	0.11					0.69	5.4	18.	MUD
1.40	-0.46	5.34	0.65	0.60	17.	1.22						0.64	4.6	31.	CLAYEY SILT
1.60	-0.66	4.28	0.67	0.39	15.	1.04						0.49	3.3	25.	CLAYEY SILT
1.80	-0.86	2.73	1.45	0.20	22.	0.77		2.8	27.7	0.24	22.5	0.42	2.6	28.	SANDY SILT
2.00	-1.06	3.30	1.46	0.12	29.	0.74		4.8	31.4	0.26	26.7	0.49	2.8	41.	SANDY SILT
2.20	-1.26	3.11	1.77	0.12	35.	0.64		7.8	34.6	0.29	30.4	0.42	2.3	49.	SANDY SILT
2.40	-1.46	5.35	4.09	0.03	151.	0.72		25.0	41.3	0.33	38.0	0.72	3.6	295.	SAND
2.60	-1.66	6.65	2.82	0.04	139.	0.95		21.1	39.3	0.35	35.9	1.29	6.0	298.	SILTY SAND
2.80	-1.86	6.75	2.63	0.03	142.	1.05		13.8	36.0	0.36	32.4	1.61	7.0	304.	SILTY SAND
3.00	-2.06	2.81	2.05	0.10	49.	0.57		12.8	36.3	0.39	32.8	0.45	1.8	64.	SILTY SAND

END OF SOUNDING

FIG. X1.4 Example Report Output: Final Page with DMT Indices and Interpreted Soil Properties

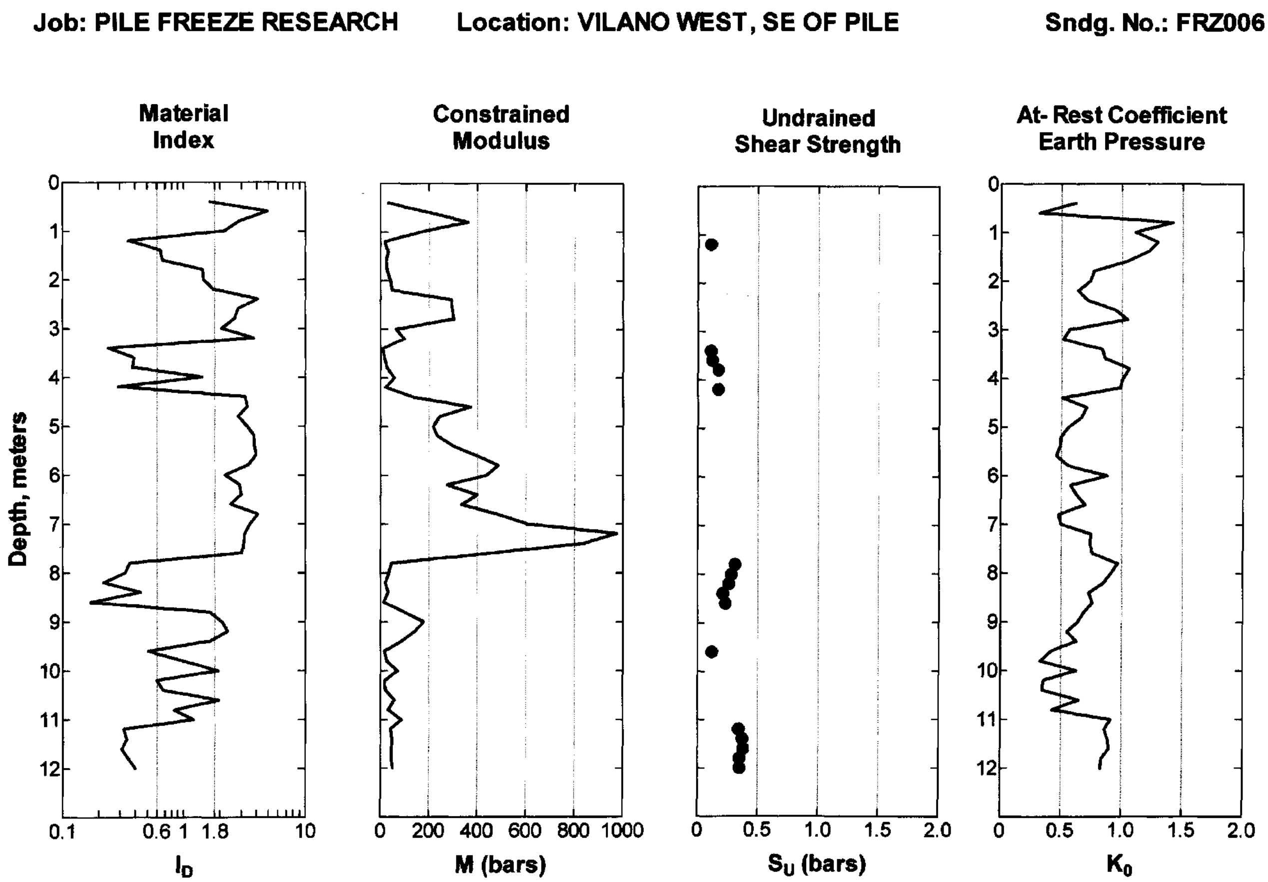

FIG. X1.5 Example Depth Profile of Dilatometer Results

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