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BY JOHN H. SCHMERTMANN

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PALER SA
Piazza Brocchi
6926 Montagnola Ticino
Switzerland
Phone: (091) 543771
Worldwide Distributors

GPE, INC.
4509 NW 23rd Avenue, Suite 19
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DILATOMETERS SETTLE IN

As U.S. use increases, this in situ testing tool imported from Italy is praised as being fast, accurate, and economical.

JOHN H. SCHMERTMANN

Skepticism was my reaction when I heard about the dilatometer test DMT some ten years ago. This geotechnical in situ testing tool was developed and patented by an Italian professor and engineer named Silvano Marchetti. After eight years of research and practical experience with the dilatometer in the U.S., my skepticism has greatly diminished. The DMT delivers a surprising combination of accuracy, reproducibility, ruggedness, economy and versatility. Professor Marchetti has succeeded in combining the simplicity and economy of a penetration test with the sophistication of a test that also measures an insitu stress and modulus. We have found the DMT most useful for the rapid calculation of expected settlements in many types of soil, but it has many other uses.

For those unfamiliar with the DMT (See photo), the technician operator uses a drill rig or other suitable equipment to push or drive the blade into the soil to be tested, stopping at suitably spaced test depth intervals as close as 150 mm. At each depth the operator uses gas pressure to expand and deflate a stainless steel membrane horizontally in the soil and obtains four data readings, typically taking 1 to 2 minutes total. The data are then interpreted to obtain the following information:

- Soil type, in situ lateral stress, one-dimensional compression modulus M, and the effective overconsolidation ratio in all soils
- The excess hydrostatic pore pressure, undrained shear strength, and coefficients of consolidation and permeability in clays
- The friction angle and insitu water pressure in sands
- All for use in any rational design procedures using these soil properties. The special equipment costs vary from $9-15,000 and the commercial cost per test typically ranges from $15-35, including data reduction and drill rig time.

QUICK AND ACCURATE

Same-day calculation of ultimate settlements in a wide variety of soil types are often possible with the DMT because of the rapid accumulation of relevant modulus and stress history data. These rapid calculations are sufficiently accurate for most practical work and I find this capability perhaps the most generally useful advantage of the DMT. I have knowledge of 30 case histories of DMT settlement analysis predictions vs measurements. My experience shows we may expect a blind (no adjustments for local experience) calculated/measured ultimate settlement prediction accuracy within a ratio of 0.67 to 1.50 in all penetrable soils, with a mean of 0.95 and a coefficient of variation of 25%. This compares well with the much slower and more expensive conventional soil sampling and laboratory methods.

I've written in detail about the results in 16 of those case histories; the following three examples illustrate my point with predictions prior to construction.

The Sunshine Skyway Bridge Main Piers. At this recently constructed bridge site, the DMT

DMT tests at the Sunshine Skyway bridge piers were more accurate than lab tests; the results from the latter indicated the need for a more costly foundation design.

DMT equipment showing control and readout box, blade and membrane, the pneumatic-electric cable and a tank source of gas pressure.

proved more accurate than lab consolidation tests. If we had relied on the lab tests alone, we might have asked for a more costly foundation design for the piers.

The bridge, across Tampa Bay in Florida, may have the current world record span for cable stayed, post tensioned, concrete box girder construction. Each main pier (see photo) is carried by forty-four 1.5 m diameter drilled shafts founded within and above a hard, calcium montmorillonite, Miocene clay with many limey, cemented zones.

The geotechnical testing constraints included a fast-tracked schedule and a difficult soil to sample at a difficult location. The settlement of the main piers had to fall within acceptable vertical and tilt tolerances so as to mesh successfully with the very detailed segmental construction procedure. We elected to use in situ testing methods to determine elastic and compression moduli, and included Marchetti DMTs for this purpose, supplemented with a few laboratory consolidation tests performed on samples obtained using 4 in. double tube core barrel methods.

There were approximately 1000 DMTs performed for the entire project. We did 35 of these in the calcareous hard clays supporting the two main piers. All 35 required predrilling and using the SPT hammer to drive the blade because the strength of the soil prohibited quasi-static pushing. The DMT indicated average 1-D compression moduli of M = 200 MPa below the drilled shaft foundations, while the lab tests gave approximately M = 50 MPa. We suspected the lab results fell on the low side of reality because of sample disturbance and laboratory equipment compressibility effects. We also thought the DMTs were low because we had to hammer-drive the blade.

Since we did not know the ground truth, and felt this was a very important settlement prediction, we decided to compromise on the conservative side. We used the value of 100 MPa for our settlement calculations. The bridge has just been completed and the engineers have measured a maximum combined immediate (elastic) plus consolidation (volume change) pier settlement of 18 mm vs. our predicted 43 mm for the loads applied. It appears that the ground truth M = approximately 43/18 x 100 = 240 MPa. In this case the DMT proved much more accurate than the conventional lab methods. Had we relied on the lab results, we would have predicted 86 mm of settlement for the load applied and 150 mm for the design maximum loads.

Jacksonville Power Plant. This case history involved the ground improvement quality control for the soils under a major power plant near Jacksonville, Fla. The designers elected to save the cost of a pile foundation by using a combination of deep compaction grouting and shallower dynamic compaction. The goal was to produce a 50 ft layer of sand and silt strong enough to prevent differential settlements of more than 6 mm between major components of the power block. Hayward Baker Co. (now GKN-Hayward Baker Co.) guaranteed maximum differential settlement results and were most anxious to provide the best quality control possible. They utilized more than 900 Dutch cone (CPT) soundings in conjunction with more than 30 DMT soundings. The results proved acceptable, but not without some difficulty.

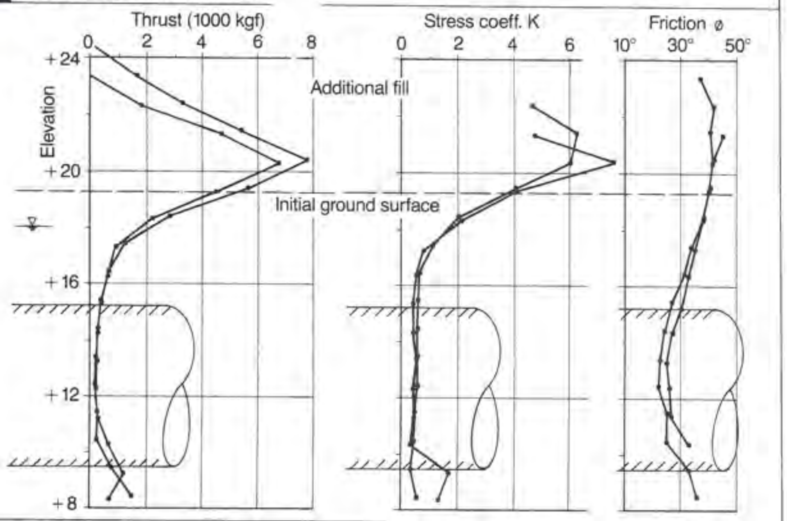
The designers set the quality standards in terms of minimum CPT profiles, which proved difficult to achieve in a trial section of the compaction area. In contrast, the DMT soundings showed M values adequate to meet the 6 mm maximum differential settlement requirement. The engineers, after considerable study, agreed to use the DMTs as a calibration for the CPT soundings. They considered a minimum equivalent M-profile as an alternate acceptance criteria when the CPT soundings did not meet the initially set requirements. The contractor invoked this alternate requirement many times during the ground improvement work and it proved successful.

In my opinion, DMT modulus values are probably more accurate than any values inferred from CPT results. This example is a case in point, but there are at least two reasons for my conviction: The DMT blade causes less soil structure disturbance than the CPT cone, and the DMT actually measures a modulus while the CPT measures only a bearing capacity.

Ontario Orange Juice Tanks. Here, John Hayes, President of Site Investigation Services, Ltd., Peterborough, Ontario, used the DMT M values to predict the settlements under a closely spaced group of four tanks on a common mat foundation (see photo). The initial DMT soundings predicted excessive settlement for the location of first choice. After further DMT sounding exploration, Hayes suggested moving to a location with settlement predictions of acceptable magnitude. He reports that the tanks have now been built, 100% load tested, and are now in service. The measured settlements of the compressible surface sand layer, with some contribution from underlying clay layers, have almost reached the predicted magnitude of 30 mm.

The Ontario experience shows

FIGURE 1
DMT SOUNDINGS



Results of two soundings through compacted trench backfill to an existing rigid pipe.

how effective use of DMT soundings can provide an economical solution to a foundation problem. Hayes reports that as of Sept. 1987, he used the DMT for settlement predictions in approximately 40 projects and has had settlement measurements to check his results in eight cases. All were acceptably accurate.

SPECIAL APPLICATIONS

The Marchetti dilatometer has potential use for other types of problems. The following examples touch on a few possibilities.

Pipe Trench Backfill Pressure—Here the problem involved attempting to compute the soil pressure on a 1.8 m diameter reinforced concrete pressure pipe that had an unexpected compacted fill placed over the pipe. The original design was via the Marston calculation method, which uses the lateral stresses and internal friction of the backfill as the key soil parameters involved in making such a calculation (see Fig 1).

The DMT provides a very practical and suitable tool to investigate such a problem. The blade could be inserted vertically through the trench backfill immediately adjacent to the pipe, going past the pipe and into the underlying natural bedding soil. The blade and its membrane were kept parallel to the axis of the pipe so as to measure the soil pressures in the proper direction perpendicular to the axis of the pipe and trench. Fig. 1 also shows the total thrust to push the blade into the soil, and the lateral stress coefficient K and plane strain friction angle results obtained from the routine DMT data reduction.

In this case use of the Marston equation with these data showed that the computed vertical soil weight carried by the pipe did not exceed the original design calculations and that the surcharge was acceptable without reducing the pressure capacity of the pipe. The DMT data incidentally also showed the absence of any of the specified compaction of the backfill around the pipe.

Pressures Against Existing Walls-The question occasionally arises as to what pressure an existing wall actually carries vs. its design. Perhaps the wall shows signs of distress, or may need to carry an unanticipated surcharge. The DMT can provide a means of measuring existing pressures, including water pressures.

For example, a vertical wall in a buried utility vault showed signs of distress after its height was increased from 18 to 30 ft due to adjacent roadway construction. The question arose as to whether this distress resulted from the unanticipated magnitudes of earth pressure. The engineers involved decided to check the actual earth pressures on the wall with two DMT soundings 5 ft from the wall and 30 ft apart along a portion of the wall showing distress.

A simplified cross section of the wall shows the DMT-determined lateral stresses against the wall, in both the surface backfill layer and the underlying natural residual silty soils. These pressures exceeded the backfigured capacity of the wall and explained its distress.

The speed of performing the DMT soundings was an important advantage at this site. Heavy road traffic had to be blocked to allow the soundings through the pavement and parallel to the wall of the vault. One rig performed both soundings, and blocked only one lane of traffic for about six hours.

Lateral Movement of Piles—The DMT approximately models the problem of the lateral movement of a pile. This is because the blade insertion wedges the soil apart in the horizontal direction and the measured lateral stress and modulus are also in the horizontal direction. Furthermore, the DMT provides detailed data right from the ground surface, where it is the most important for this problem.

New and practical methods for calculating lateral pile movements using the DMT and the p-y curve method are described in several recent paper. Alternatively, one can use the DMT to obtain Young's modulus data and utilize elastic methods that have the advantage of including group effects.

YOUR MOVE

After eight years of experience with the DMT, I believe it represents a big improvement in the practical soil testing tools available to the practicing geotechnical engineer. Almost all the practicing geotechnical engineers I know who have tried the DMT have found it useful. The technical literature now has well over 100 papers that contain many examples in addition to those mentioned here.

A caveat: one should only use the DMT or any other penetrometer test in appropriate soils — for example not in rocky fills and not in very compact and stony glacial tills. Generally, problem soils are finer and weaker where one can easily use the DMT.

John H. Schmertmann is a consulting engineer with his own firm, Schmertmann & Crapps, Inc., and part owner of GPE, Inc., which markets the dilatometer in North America. Both firms are in Gainesville, Fla.