A USEFUL TOOL FOR EARTHWORKS CONTROL - THE DILATOMETER

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ABSTRACT

This paper briefly discusses and promotes the use of the *in situ* Flat Dilatometer test (DMT) for at least some earthworks control. The paper is meant to provoke thought, as follows:

- Geotechnical design is most often based on two parameters, soil strength and modulus. Yet these two parameters are seldom specified or measured as part of earthworks contracts.
- The author holds the view that the main reason for this is "history". Practical methods were not available in the past to directly measure strength and modulus in the field.
- Advances in *in situ* testing technology make such measurements possible today.
- Why not, where relevant, include these design-required parameters within earthworks specifications, and why not measure them and make achievement of them part of the earthworks acceptance process?

One, now available, tool that can defensibly measure both strength and modulus and is robust and simple to use, is discussed within this paper, the Flat Dilatometer.

1 INTRODUCTION

Much geotechnical design is based on two physical soil properties:

(a) *Strength:* Strength dictates batter slopes, bearing capacities, allowable loadings, safety factors, etc.

(b) *Modulus*: Modulus dictates settlements and deflections of structures, embankments, etc. and also dictates design of rigid pavements and on-ground slabs. Modulus of Subgrade Reaction ("k") is directly connected to soil modulus; it is almost never directly measured yet it directly dictates the design of most rigid pavements and slabs.

Thus, strength and modulus, which are critical "necessary outcomes" of a significant majority of earthworks projects are usually neither specified nor measured, nor used as acceptance criteria for earthworks contracts.

To the author, this is a major "disconnect":

- Designers critically rely upon strength and modulus for their designs.
- To determine that these parameters are achieved, specifications rely on laboratory-developed relationships between strength & modulus on one hand and compacted density on the other, assuming (rather hopefully) that the same relationships will apply in the field as in the laboratory.
- Why not specify the strength and modulus parameters that are actually important to the projects and base earthworks control and acceptance around direct measurement of those critical parameters?
- Why take a round-about route when a direct route is available?

2 THE FLAT DILATOMETER TEST (DMT)

The DMT is one direct and defensible route to establishment of strength and modulus, both in the natural state and under earthworks compaction.

The DMT was introduced to geotechnical engineering via a paper by its creator Professor Silvano Marchetti in 1980 (Marchetti, 1980). In 1986, under Dr John Schmertmann's chairmanship, an ASTM subcommittee developed a "Suggested Methodology" and in 1997 and 2001 Eurocode 7 and ASTM published standards for the test procedure.

Thus, it is not a new or untried test method; rather it has been used for almost 30 years, shown to be reliable, and promoted by some of the world's best-known geotechnical professionals as a reliable and useful tool. The two quotations below, both from the well-known Dr John Schmertmann, illustrate.

"In my opinion this test represents the most important recent development in penetration testing... Everyone I know of, including myself, who has had significant experience with the test, has found it exceptionally useful." 1981
"Sixteen examples demonstrate how DMT provides soil compressibility data for the rapid calculation of foundation settlements with an average rate of predicted to actual settlements equal to 1.18. " 1986
- J. H. Schmertmann, Ph.D., USA

The DMT is a type of simplified, low-cost, highly efficient, very robust, push-in pressuremeter, that is well-suited for use in characterisation of soils. It can be pushed into the ground by a CPT rig or alternatively by a drilling rig, by pushing below the base of a borehole. In fact it can be inserted for testing by almost any means (e.g. a backhoe with a simple set of rams attached could be used).

The test principles are shown in the figures below.

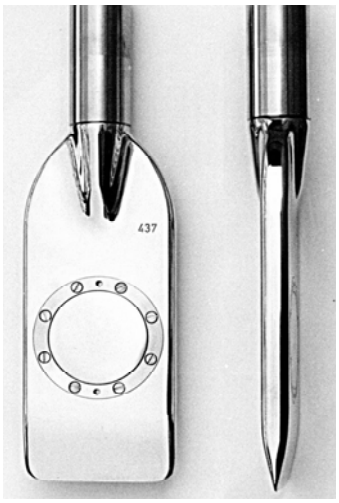


Figure 1a DMT Blade Showing Diaphragm

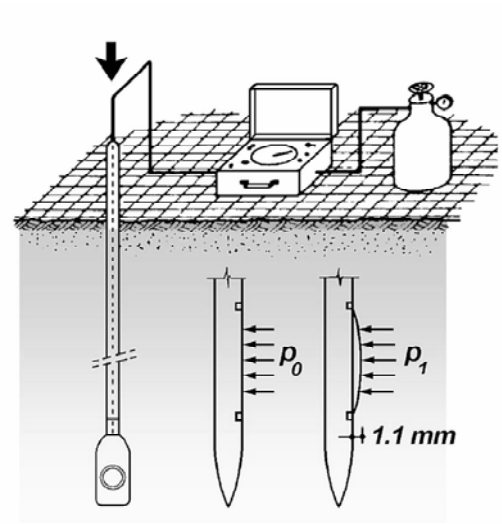


Figure 1b DMT Operating Principle

In Australia, DMT testing is presently available from at least two leading geotechnical consultants and at least four geotechnical testing contractors. It would be far more available if requested by specifications. It is a simple test.

The tool is very rugged. It can be pushed or driven into ground that is not usually thought to be amenable to *in situ* testing. The soil parameters measured are available almost instantly, as distinct from other earthworks control tests that typically take several hours to several days for completion.

3 ONE RECENT LOCAL EXAMPLE

The example that is summarised here is a current project and as such cannot be named within this document. The project is related to design of heavily loaded rigid pavements on top of a compacted sand embankment.

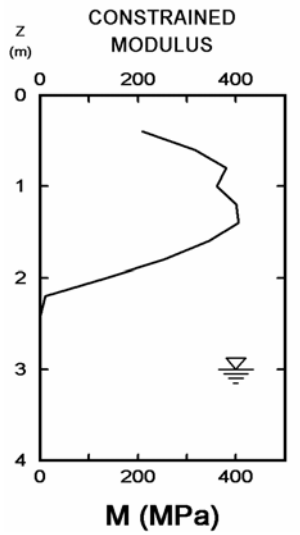
In summary:

- Design of pavements over a heavily compacted (i.e. dense) clean sand subgrade are typically based on a Modulus of Subgrade Reaction ("k") of the order of 60-80 kPa/mm. This is based on conventional laboratory tests from which the parameter "Soaked CBR" is obtained and then "k" is deduced by reference to a "CBR vs k" correlation chart. It is not based on parameter-focused field tests.
- Reference to the literature however suggests that the elastic modulus E of well-compacted dense sand should typically lie in the range 100-250 MPa. By simple calculation this relates to a value of Modulus of Subgrade Reaction ("k") in the range 150-350 kPa/mm, some 200-400% higher than the conventional range 60-80 kPa/mm mentioned above.
- In a comprehensive series of relatively complex and certainly expensive field plate bearing tests on this site about 15 years ago, the table of results below left evolved, demonstrating that much higher "k" values should

be achievable if proven by appropriate testing. Based on this table, a "k" in the range 250-400 kPa/mm might have been more appropriate for the geotechnical component of pavement design for this project than the conventional range of 60-80 kPa/mm mentioned above.

LOAD RANGE kPa	MODULUS OF SUBGRADE REACTION kPa/mm for 762mm dia. plate		
	TEST PLT 1	TEST PLT 2	TEST PLT 3
First Loading			
100 - 200	140	130	150
200 - 300	170	160	180
300 - 400	200	170	210
Reloading			
100 - 200	270/240	260/260	310/320
200 - 300	320/310	310/310	400/440
300 - 400	320/350	290/330	360/400

I acknowledge and thank Golder Associates for permission to use this table



I acknowledge and thank Coffey Geotechnics for permission to use this plot

Figure 2a. Plate Bearing Tests From Early 1990s **Figure 2b. Recent DMT Test**

The trouble is that plate bearing tests are slow and expensive, and logistically complex to implement. In a much more recent project, on the same site, the DMT data above right evolved (a typical test of several undertaken). Based on some elementary calculations, it can be shown that the "k" value that evolved from this much faster and simpler DMT testing was in the same range as that range measured by the earlier much more complex and expensive plate bearing tests. It was again very much higher than the 60-80 kPa based on laboratory CBR testing and correlation charts. It was now also consistent with calculations that can be made based on published E values from the literature.

These two sets of data showed that there is potential for significant design advantage in using parameter-focused tests to measure the properties of this compacted sand fill. Pavement design on this site might reasonably be expected to be much more economical based on the *in situ* test data compared to previous practice. And the DMT data was easy to obtain.

4 DOES THE LITERATURE CONFIRM DMT RELIABILITY?

DMT literature can be tasted by visiting Professor Marchetti's web site www.marchetti-dmt.it. This author advises that the literature confirms that the DMT is a reliable tool for measuring both strength and modulus of soils *in situ*. The small extract below, taken from the literature, illustrates, as do Dr John Schmertmann's comments s quoted in Section 2 of this technical note.

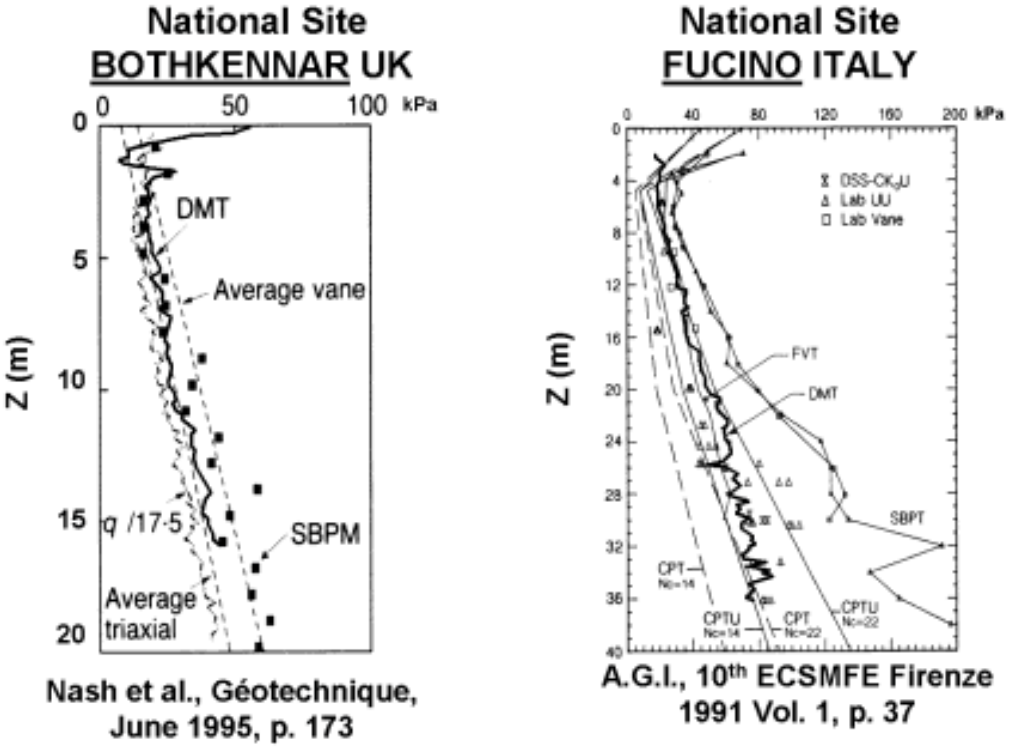


Figure 3: Examples From The Literature – Regarding Shear Strength

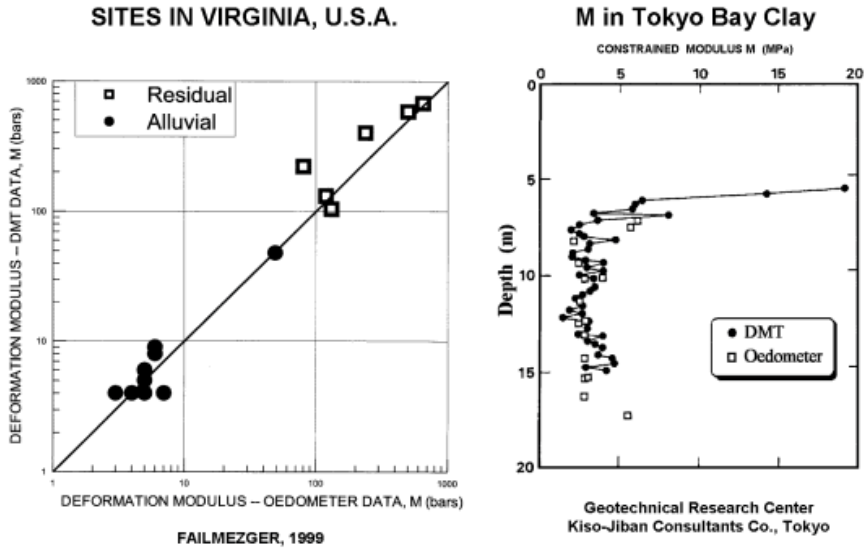


Figure 4. Examples From The Literature – Regarding Modulus

5 DOES THE LITERATURE CONFIRM DMT APPLICABILITY?

Referring again to the same sources, the literature does confirm the applicability of the DMT to measuring the effects of earthworks compaction, as shown below.

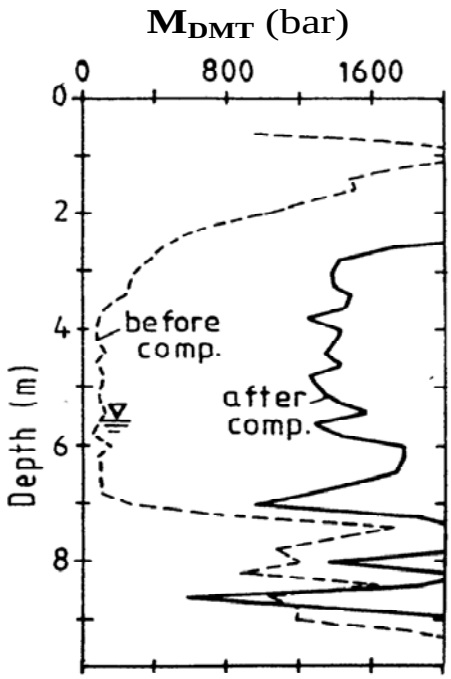
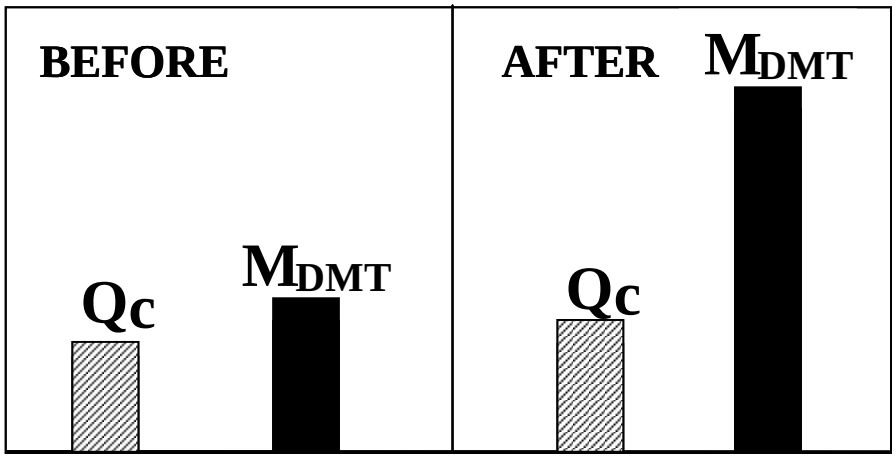


Figure 5. From The Literature – Regarding DMT Showing Compaction

The same source of literature also demonstrates that the DMT is more applicable to measuring the effectiveness of earthworks compaction than the more common in situ test, the Cone Penetrometer Test (CPT).

It is explained in the literature that the flat plate of the DMT is more responsive to changes in a soil's internal stresses, compared to the CPT, as the CPT (while responsive in itself) is influenced by arching of soil around the cylindrical shape of the CPT tool.



<u>Jendeby</u> 92 measured Qc & Mdmt before and after compaction of a loose sandfill

Figure 6. From The Literature – Regarding CPT vs DMT Measuring Compaction

6 CONCLUSION

In conclusion, this author argues that:

- Geotechnical design is most often based on two parameters, soil strength and modulus. Yet these two parameters are seldom specified or measured as part of earthworks contracts.
- The author holds the view that the main reason for this is "history". Practical methods were not available in the past to directly measure strength and modulus in the field.
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7 REFERENCES

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