DMT measurements in saturated loess silts as an example of "niche silts" with partial drainage condition

Krzysztof Nepelski[1,2], *Małgorzata* Tomaszek[2]

[1] Department of Building Materials Engineering and Geoengineering, Lublin University Of Technology, Lublin, Poland
[2] GeoNep Geotechnika Nepelski Chymosz sp.j., Lublin, Poland

1 Introduction

The flat dilatometer test (DMT) is primarily performed to determine the compressibility modulus. The pressure values recorded during the test are also influenced by factors other than soil, such as membrane stiffness, pneumatic cable length, pressure application rate, etc. The time taken to measure the pressure after the blade stops is also important, as its application causes an increase in pore pressure in the soil. Depending on the soil type, this pressure dissipates rapidly (sands) or very slowly (clay). The standard test procedure assumes taking the measurement as soon as possible after the blade reaches the depth. In such cases, undrained conditions occur in clayey soils and drained conditions in sandy soils. Measurements in silty soils, whose behavior is transient, are problematic because they experience partial drainage. In silt soils, A reading (pressure required to move the membrane against the soil) is performed under undrained conditions, and B reading (pressure required to move the center of the membrane 1.1 mm against the soil) after the excess pore pressure has partially dissipated. This paper presents the results of tests conducted on saturated loess silts from the Lublin area in Poland.

2 DMT measurements and transitional soils problem

During the test, a blade is pressed vertically into the ground, and then measurements are taken, usually at 20 cm intervals. The measurement involves applying gas pressure to the membrane using a pneumatic cable. During this process, the membrane expands towards the subsoil and A and B readings (sometimes additionally C) are taken. A-reading is the gas pressure value obtained during the initial phase of the membrane movement (displacement of the membrane center by 0.05 mm), which causes contact with the surrounding soil. B-reading is the pressure value obtained with an additional displacement of the membrane center towards the ground of approximately 1.05 mm, for a total of 1.1 mm. The readings are corrected for ΔA and ΔB, which result from the membrane's inherent stiffness. Pressure application should begin immediately after reaching the test depth (in practice, within a few seconds, e.g., 2-3 seconds). The A-reading should be taken within 10-20 seconds (ideally 15 seconds) of starting to apply pressure. After the A-reading, continue applying pressure until reading B is reached. The B-reading should be taken within 10-20 seconds (ideally 15) of A-reading. The timeline of ideally DMT readings is shown in Figure 1a. The recommended 15 seconds are necessary to allow for pressure equalization along the cable. If A-reading is taken very quickly (less than 10 seconds), the measurement may be subject to error due to pressure imbalance in the long pneumatic cable. However, a time longer than 20 seconds may cause drainage conditions in the tested soil, especially in the case of silts [1, 2].

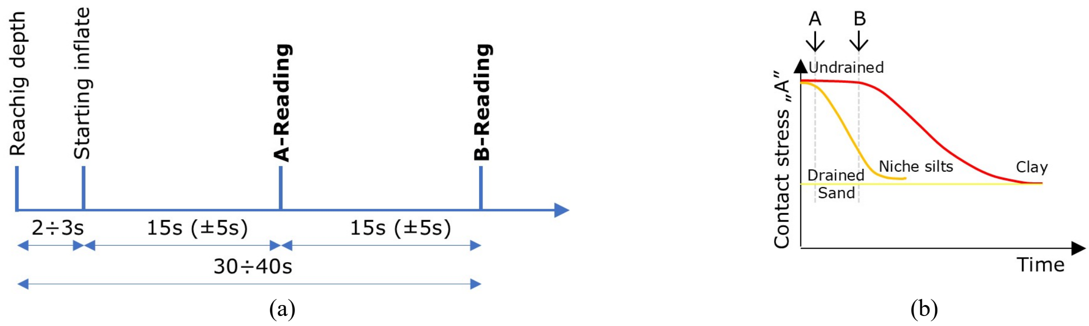


Figure 1. (a) Timeline of DMT test, (b) dissipation curves in various soils.

Silty soils are problematic, as pore water pressure dissipates rapidly, as shown in the diagram in Figure 1b. This is significant because A and B readings, which differ by approximately 15 seconds, are performed under slightly different drainage conditions. Identifying soils with partial drainage conditions, which are therefore sensitive to measurement time, can be accomplished with short dissipation tests, preferably conducted at depths between the actual DMT measurements. These tests allow for determining the level of excess pressure dissipation during the test [2, 3].

* Corresponding author: k.nepelski@pollub.pl

3 Research

The research was carried out in the Lublin region (eastern Poland) in loess soils. The area contains aeolian (loess and loesslike) silts. The loesses are mostly unsaturated, but in the discussed area, in a certain depth zone, saturated silts occur and was the subject of the described analyses. In situ tests are crucial for this type of soil [4]. Figure 2 shows the research location and a subsoil model, with a distinct zone of saturated silts, which are potentially highly sensitive to the applied pressure rate in DMT tests.

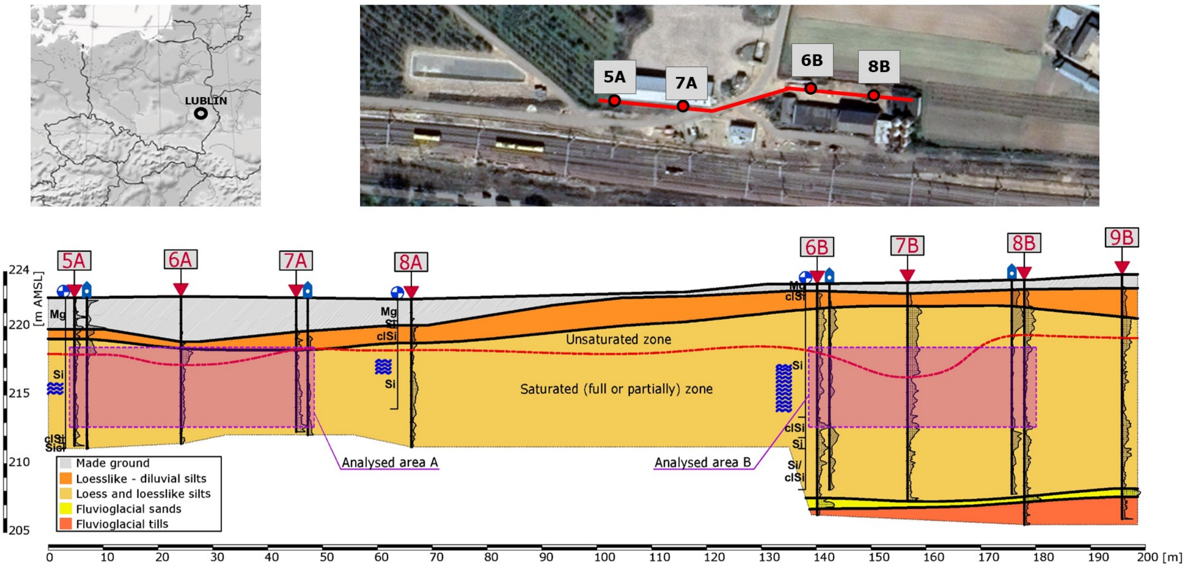


Figure 2. The research location and a subsoil model.

In the first stage, static CPTU soundings were performed, during which dissipation tests were performed at selected depths, where an increase in pressure u_2 was observed. After analyzing the CPTU tests, based on the cone resistance q_c with pore water pressure u_2 values (Figure 3) and data from several CPTU dissipations (Figure 4), the depths of extended DMT tests were planned. In designated zones, during DMT tests at intermediate depths between the actual measurements, additional shortened dissipation tests (lasting approximately 2–5 min) were performed.

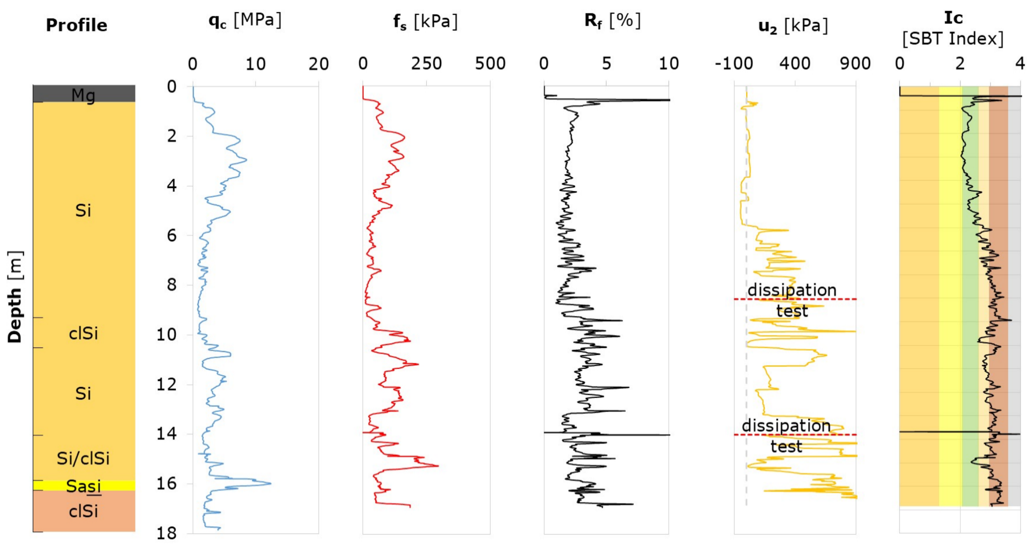
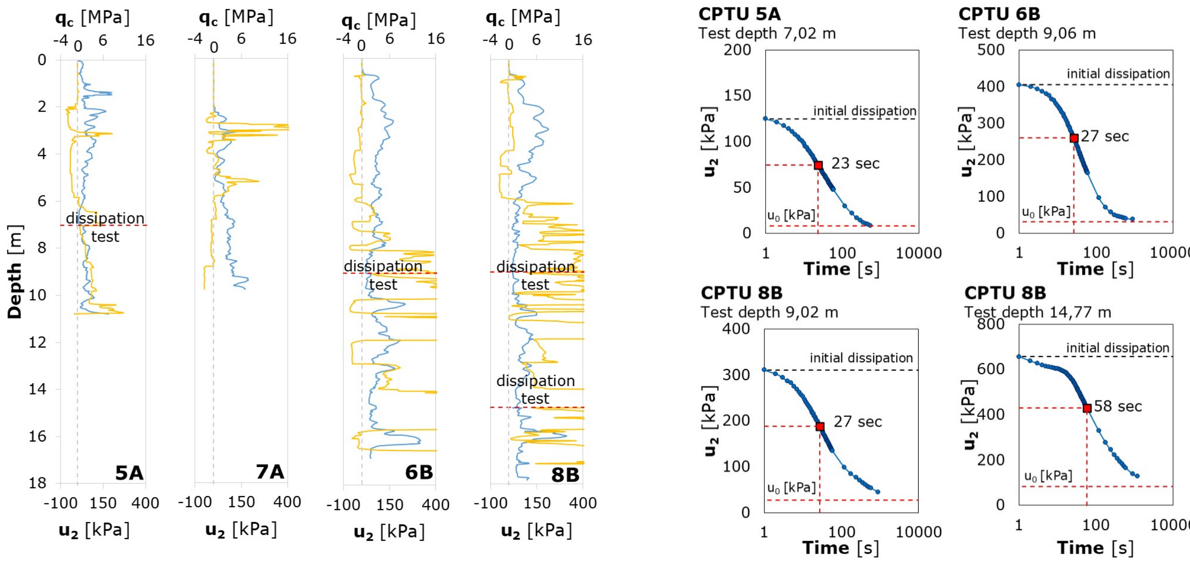


Figure 3. Test parameters for CPTU-8B.

4 Results

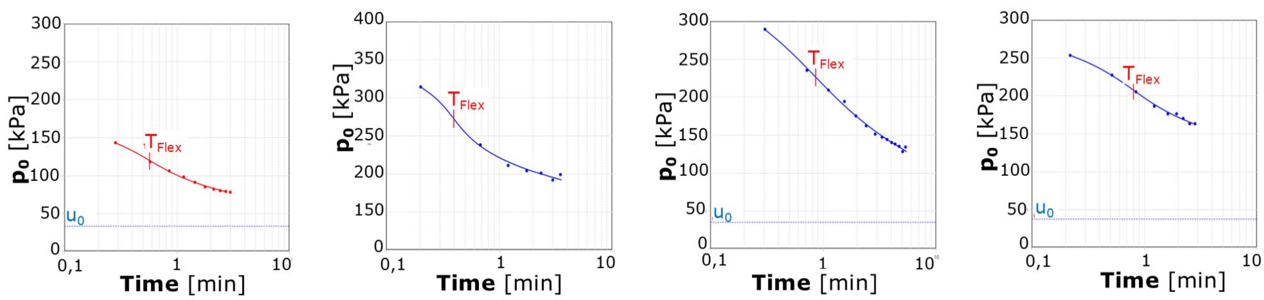
In the analyses performed, the pressure decreases within several dozen of seconds after the blade stops is important. Figure 5 presents selected individual dissipations from DMT tests. The curves are drawn based on several or a dozen of measurements of the A-reading repeated at short intervals. For technical reasons, standard pressure measurement in a dilatometric test does not allow for recording pressure in the first few seconds or over a short time interval, as in, for example, CPTU tests, which makes detailed interpretation somewhat difficult.



(a) (b)

Figure 4. (a) q_c and u_2 profile for CPTU-DMT locations, (b) dissipation curves from CPTU (the first step of research – sensitive zones identification).

With a standard DMT set, it is possible to obtain the first measurements after approximately 10 seconds (this problem is solved in the newest type of Medusa dilatometer, where pressures are automatically recorded at short time intervals) [5]. Therefore, the pressures were reduced to the first reading, which occurred within several seconds of the test initiation. A summary graph of all dissipation tests over 180 seconds (3 min) for data corrected for the pressure difference from the start of the test relative to the first measurement is shown in Figure 6a. In the context of interpretation and repeatability of results, the most important changes are the actual reading times of A and B readings, i.e., in the first 30-40 seconds after the blade stops. Therefore, in Figure 6b, these data are presented in a time range that is significant in the context of standard reading times. For analysis purposes, ideal test times were assumed to be 20 seconds for A-reading and 35 seconds for B-reading.



(a) (b) (c) (d)

Figure 5. Selected dissipation curves from DMT: (a) DMT-5A – 7.9 m, (b) DMT-6B – 8.7 m, (c) DMT-6B – 9.5 m, (d) DMT-6B – 9.7 m.

Tests show that the measurement time affects the pressure value. Therefore, corrections to the results can be taken into account when interpreting them, for example, by increasing the B reading. There are several options:

a) Quantitative correction of the B reading for each reading individually, based on a dissipation test 10 cm higher,
b) Quantitative correction of the B reading based on data averaged from several dissipation tests in a single zone within a given DMT test,
c) Quantitative correction of the B reading based on data averaged from several or a dozen dissipation tests using aggregate data from several DMTs in the analyzed area,
d) Percentage correction of the B reading based on data averaged from several or a dozen dissipation tests using aggregate data from several DMTs in the analyzed area

The first option is the most accurate, but very time-consuming, requiring numerous dissipation tests. It is recommended only for detailed analyses of critical facilities. The last proposed option is the fastest, but least accurate. This approach allows for partial pressure dissipation to be accounted for with the least amount of effort.

(a) (b)

Figure 6. Summary of "relative" dissipation curves: (a) change over 180 seconds, (b) change over the time relevant for the analyses (40 seconds).

An example of the correction and its impact on the DMT 6B test parameter values is shown in Figure 7. After making the corrections, in the 8÷10 m depth range, a shift in the material index I_D diagram classification from clay to silt and an increase in the constrained modulus M_{DMT} value can be observed.

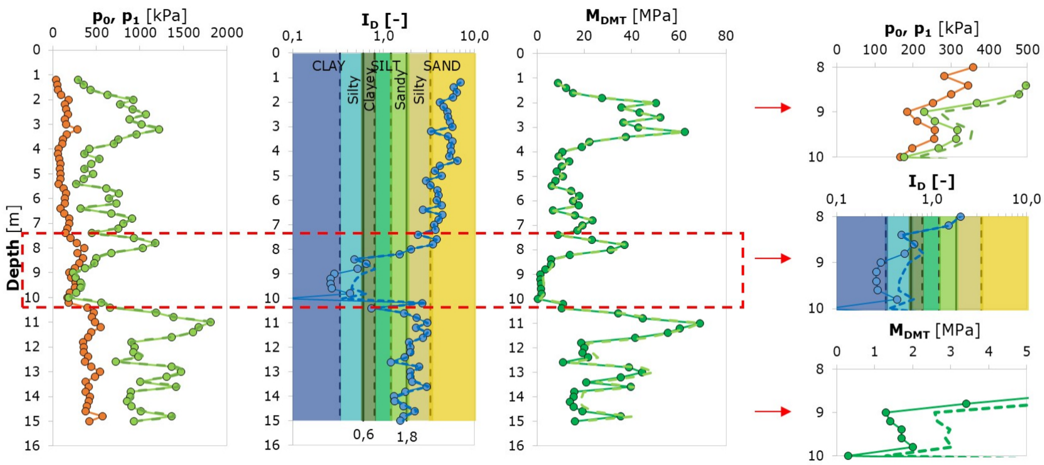


Figure 7. An example of corrected DMT parameters for DMT-6B.

5 Conclusions

Short dissipation tests performed between the actual measurements indicate that during the measurement, i.e., 30÷40 seconds after the blade stops at the measurement level, the excess pressure partially dissipates. Therefore, measurement time is crucial during DMT tests in silts. Performing measurements at times deviating from the standard can result in significant differences in results. Changing the measurement time may be permissible, but this should be done consciously and clearly indicated in the report. Corrective corrections to modulus values can be applied to standard measurement times. Repeated "short dissipation tests" allow for the derivation of corrections that adjust the test parameters, and therefore the interpreted geotechnical parameters.

References

1. S. Marchetti, P. Monaco, G. Totani, M. Calabrese, The flat dilatometer test (DMT) in soil investigations–A report by the ISSMGE committee TC16. In Proc. Int. Conf. on In-Situ Measurement of Soil Properties, Bali, Indonesia 2001 (pp. 95-132).
2. S. Marchetti, Some 2015 updates to the TC16 DMT report 2001. In: The 3rd International Conference on the Flat Dilatometer. 2015. p. 43-65.
3. D. Marchetti, S. Marchetti. Flat Dilatometer (DMT). Some Recent Advances. Procedia Engineering, 2016, **158**: 428-433.
4. K. Nepelski. "Geotechnical Interpretation of the Geological Structure of Loess Covers in Lublin Region." Architecture, Civil Engineering, Environment, vol. 16, no. 3, Silesian University of Technology, 2023, pp. 101-110. https://doi.org/10.2478/acee-2023-0037
5. F. Schnaid, D. Marchetti, E. Odebrecht, M.V.A. Belloli, Medusa DMT in transient silts, in 6th International Conference on Geotechnical and Geophysical Site Characterization (ISC2020) . https://doi.org/10.53243/ISC2020-308