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Comparative tests between Texam and Menard Pressuremeters

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ABSTRACT

Two testing programs were undertaken for comparing results of the Texam and Menard pressuremeters with regards to the deformation modulus (E) and limit pressure (Pl). Two configurations of the Texam pressuremeter were used; one with a probe fitted with metal rings, the other with a probe fitted with polymer (vulcolan) rings. The results of the first program carried out in laboratory and presented in a previous article, have been completed and are presented here. The second testing program have been undertaken in the field. A total of 41 tests were completed in three boreholes in silty and clay materials. The comparative tests produced excellent correlations in the laboratory, with regression coefficients (R^2) of 0.99, and fairly good correlations in the field (R^2 ranging fron 0.64 to 0.73). The main findings are that the Texam produces equivalent or conservative results. More specifically : (1) the Texam with metal-ring probe produces comparable moduli values, (2) the Texam with polymer-ring probe produces lower moduli values, and (3) the two configurations of Texam produce lower limit pressures. The observed differences range between 10 to 20 %. Equivalence factors have been proposed.

Keywords: Pressuremeter; modulus; limit pressure

1. Introduction

The Texam pressuremeter is the most common type of pressuremeter in North America. It is considered to produce results comparable to those obtained with the Menard pressuremeter with respect to the first loading pressuremeter modulus (E) and the limit pressure (Pl) as defined in the ASTM D4719 standard (Hartman 1974) (Briaud 1992). In order to verify this, we have undertaken a test program in a controlled environment, i.e. in polymer tubes of various stiffness and dimensions. The results obtained in these tubes have been previously published (Marcil 2020). Here these results are repeated, completed and compared. The test simulation tubes allow a precise and repeatable comparative analysis by excluding errors due to the heterogeneity of the soil and the placement of the probe. However, they do not represent failure conditions with any degree of similarity, and they do not allow, in any case, to push the test very far in plastic zone without risk of breakage. Therefore, it was not possible to get accurate comparisons of the limit pressures from the tests performed in these tubes. In order to include comparisons of limit pressures and yield pressures (Py), it was decided to undertake geotechnical drilling and PMT testing on real soil deposits.

2. Equipment used

For this study, we used a Model GAM Menard pressuremeter and a Texam pressuremeter. These types of pressuremeters operate hydraulic probes, i.e. probes with no onboard sensors. The Menard probe uses a tricell while the Texam probe uses a monocell membrane. The N-size probes were fitted with rubber membranes protected with metal strips. Test results from the Menard pressuremeter were compared with those from two Texam configurations, one with a probe fitted with metal rings (Tex-MR), the other with a probe fitted with polymer rings (Tex-PR, or Vulcolan rings). The tricell Menard probe was considered not to be affected by the type of rings, and was therefore fitted with polymer rings only.

3. Laboratory Testing - Results and Analysis

The results obtained in 2020 were complemented by other tests in an additional test simulation tube. The results are presented in the table 1.

The tests with the Texam were conducted following the volume increment method (Procedure B of the ASTM D4719-07, or volume-controlled loading), and those with the Menard following the pressure increment method (Procedure A, or pressure-controlled loading). They were repeated several times in each tube, allowing to determine a repeatability error lower than 2% while estimating E.

Figures 1 and 2 show the relationship of the moduli produced with these types of pressuremeters. Linear trend lines were set with a zero intercept. We note that the modulus values are strongly correlated as indicated by very high regression coefficients R^2. Overall the moduli from the Texam with the metal-ring probe compare well with those of the Menard. However, the moduli obtained with the Texam with the polymer-ring probe are clearly lower.

Table 1. Test Results – Modulus vaues (E) – Lab testing

Test Simulation Tube	E – Menard MPa	E – Tex-MR MPa	E – Tex-PR MPa
1	12.3	14.0	10.7
2	17.9	17.9	15.1
3	44.0	45.3	35.7
4	136.9	135.6	109.7

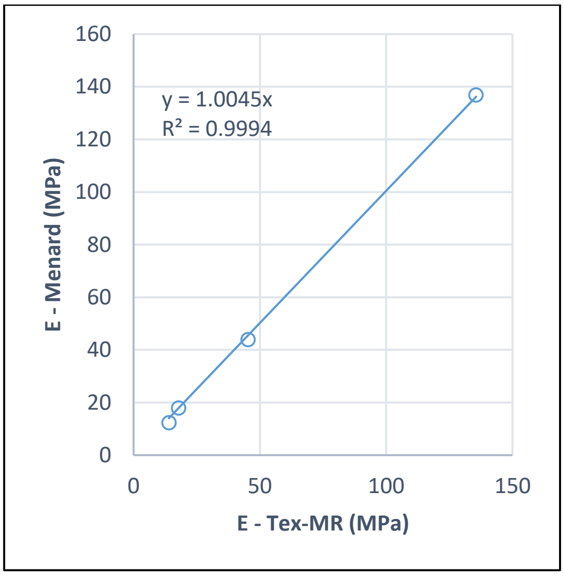

Figure 1. Correlation between E from Texam-MR and Menard – Lab testing

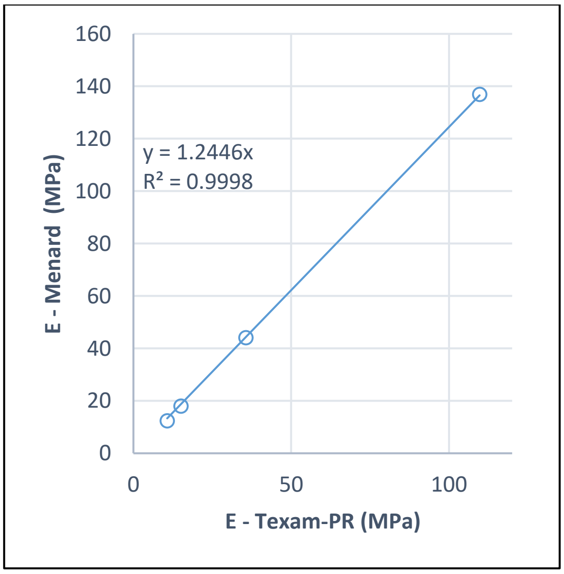

Figure 2. Correlation between E from the Texam-PR and Menard – Lab testing

4. Field Testing

4.1. Tests description and results

A drilling and PMT testing program have been completed during the Summer of 2022, on a site by Lake Erie, near Port Rowan, Norfolk County, Ontario. A total of 41 PMT tests were completed in three boreholes, each down to about 23 m depth. These boreholes were 3 m apart from each other. The local soils, down to the explored depths, consist of silty and clay materials. The boreholes were done by rotary mud drilling, using a dense bentonite-based drilling fluid and with a 2-15/16'' (nominal size) drag bit, suitable for these clay-silt materials.

The tests and data reducing were done according to ASTM-D4719-07. The Menard tests were performed following Procedure A of the standard, and the Texam tests were performed following Procedure B. The results are presented in table 2 and figure 3.

Table 2. Field testing results

Type of Pressuremeter	**Depth m**	**E MPa**	**Pl MPa**	**Py MPa**
Menard	2.0	38.1	1.70	0.47
	4.8	12.5	1.27	0.37
	6.4	12.8	0.81	0.32
	8.0	19.1	0.97	0.43
	9.4	26.9	1.06	0.47
	10.7	27.4	1.22	0.46
	12.3	32.2	1.50	0.53
	14.1	33.6	1.42	0.52
	15.6	22.2	1.19	0.59
	17.1	32.5	1.24	0.56
	18.6	36.6	1.29	0.59
	20.2	35.8	1.31	0.58
	21.7	31.3	1.39	0.64
	23.2	34.4	1.44	0.72
Tex-PR	1.9	30.3	1.40	0.37
	4.9	8.9	0.80	0.24
	6.4	12.5	0.75	0.31
	7.9	15.8	0.78	0.35
	9.6	14.3	0.79	0.40
	11.0	16.7	1.04	0.40
	12.5	32.8	1.21	0.57
	14.1	30.7	1.27	0.53
	15.5	18.7	1.16	0.65
	17.2	33.1	1.10	0.63
	18.7	27.2	1.12	0.64
	20.1	28.2	1.12	0.64
	21.7	29.0	1.15	0.65
	23.2	23.8	1.16	0.69
Tex-MR	2.2	26.1	1.72	0.48
	4.7	16.0	0.89	0.28
	6.3	17.1	0.66	0.27
	7.8	19.6	0.81	0.31
	9.3	26.5	0.99	0.37
	10.9	25.3	1.10	0.46
	12.4	35.7	1.21	0.51
	13.9	34.8	1.16	0.56
	15.3	30.7	1.15	0.56
	16.9	32.8	1.17	0.56
	20.1	34.8	1.13	0.56
	21.6	31.7	1.25	0.66
	23.1	27.7	1.26	0.73

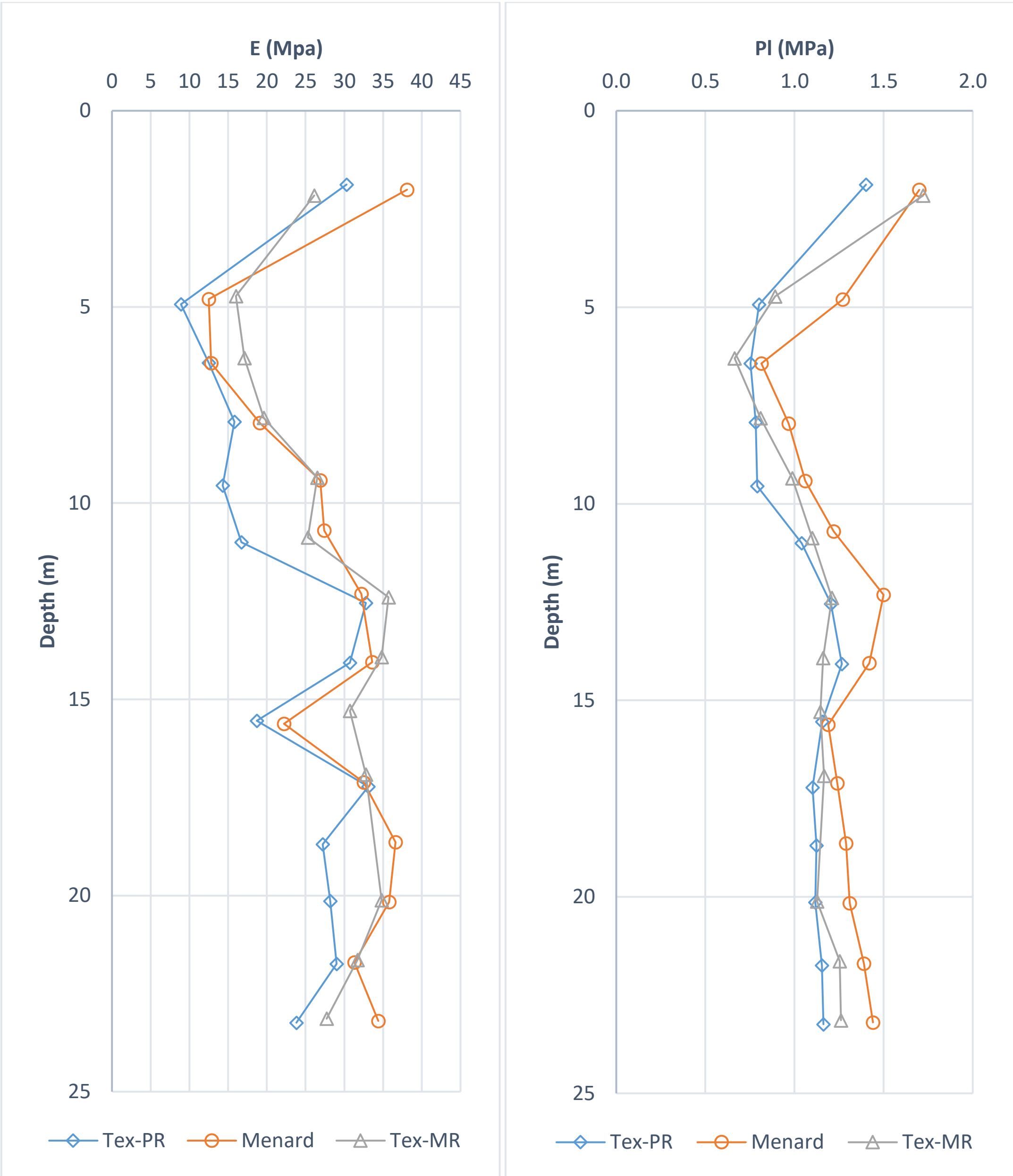

Figure 3. Field testing results

The average values of the parameters obtained with the different pressuremeters are given in table 3.

Table 3. Average values of parameters – Field testing

Type of Pressuremeter	E MPa	Pl MPa	Py MPa	E/Pl
Menard	28.2	1.27	0.52	22.2
Tex-MR	27.6	1.12	0.49	24.6
Tex-PR	23.0	1.06	0.50	21.7

Figure 4 presents the linear relations of E and Pl between the types of pressuremeters.

4.2. Evaluation of Test Results

4.2.1. Modulus (E)

It can be seen that the average deformation modulus obtained with the Tex-MR is similar to that of the Menard as shown by a small difference in mean values (27.6 vs 28.2 MPa), and by a linear regression factor close to 1 (1.0058). On the other hand, we note that the modulus produced by Tex-PR is significantly lower, as illustrated by a lower mean value (23 vs 28.2 MPa), and by a linear regression factor of 1.19.

These two observations confirm the results obtained during laboratory testing.

The potential causes for this difference have been analyzed during the laboratory testing (Marcil 2020). It was then shown that the difference is essentially due to membrane's end-effects of the monocell Texam probe. These end-effects were quantified by measuring the

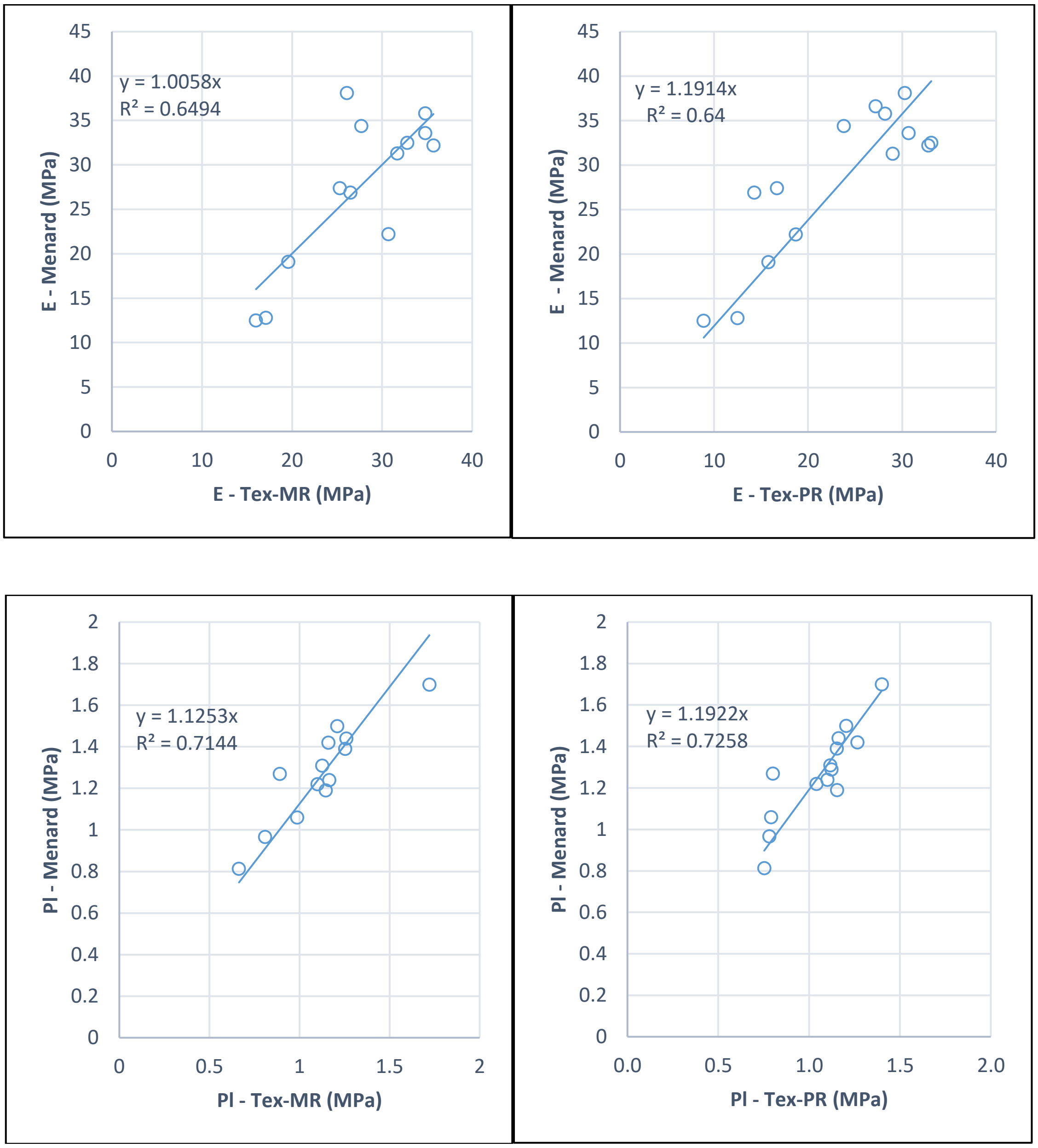

Figure 4. Correlation between E and Pl from the Texam and Menard – Field testing

contact length between the membrane and the test simulation tubes. It was then shown that the discrepancy between the assumed and measured contact length was directly related to the difference of E between the monocell and tricell probes. This difference is more pronounced with the Tex-PR due to a more conservative assumed contact length (or membrane theoretical length).

Another element we have noted is the greater dispersion of E compared to Pl, as illustrated by a lower regression coefficient R^2 (0.645 vs. 0.720 in average). This is possibly due to the greater sensitivity of the first loading modulus E to drilling and probe placement.

4.2.2. Limit Pressure (Pl)

It can be seen in table 3 that the average Pl values obtained with the Tex-PR and Tex-MR are significantly lower than the average value of the Menard (1.06 and 1.12 MPa versus 1.27 MPa).

This is an important finding that could not be observed in the laboratory study.

Two factors are proposed as possible explanations for the discrepancies: the probe length/diameter (L/D) ratio and the loading speed.

Regarding the L/D ratio, we can mention that according to Laier (Laier 1973), Pl evolves in the opposite way to L/D, i.e. Pl decreases when L/D increases. And this is what we observe here. The L/D ratio is 5 for the Menard probe and close to 7 for the Texam. So the greater length of the Texam probe would have the effect of reducing the Pl value measured by it.

Pl also evolves in the opposite way to loading speed (Briaud 1992). In the present case, the duration of the plastic yielding zone (past the pseudo elastic zone) during the test is equivalent for both types of pressuremeters (4-5 minutes in average). However, we believe that this loading speed is a function not only of the total loading duration, but also of the loading procedure. With the volume increment procedure, deformation is rapidly imposed on the soil at the start of each loading increment, followed by a period of pressure stabilization during which no deformation occurs. With the pressure increment procedure, deformations are more gradual and occur over the entire test duration. In other words, imposing rapid deformation at the start of each loading step could accelerate yielding of the soils and reduce Pl value. This hypothesis is based on theoretical grounds related to the loading speed and on a comparative study published earlier (Marcil et al. 2015). This study presents comparative tests carried out with the Texam, but operated successively following the volume increment and pressure increment procedures - this equipment can be operated following any of these procedures. It was then found that limit pressures were systematically lower (by about 15% on average) when the Texam was operated with the volume increment procedure. This study concerned a dozen tests carried out on different sites in Canada in silts, sands and clays, and for Pl ranging from 0.6 to 1.8 MPa.

4.2.3. Yield Pressure (Py)

The average yield pressure value (Py) is slightly lower in the case of the Texam.

4.3. Correction of Results

The differences observed for E and Pl values can be mitigated using the linear regression factors obtained in the field tests, i.e. multiplying E-Tex-PR by 1.19, Pl-Tex-PR by 1.19, and Pl-Tex-MR by 1.125.

Figures 5 and and table 4 show the values obtained after the proposed corrections.

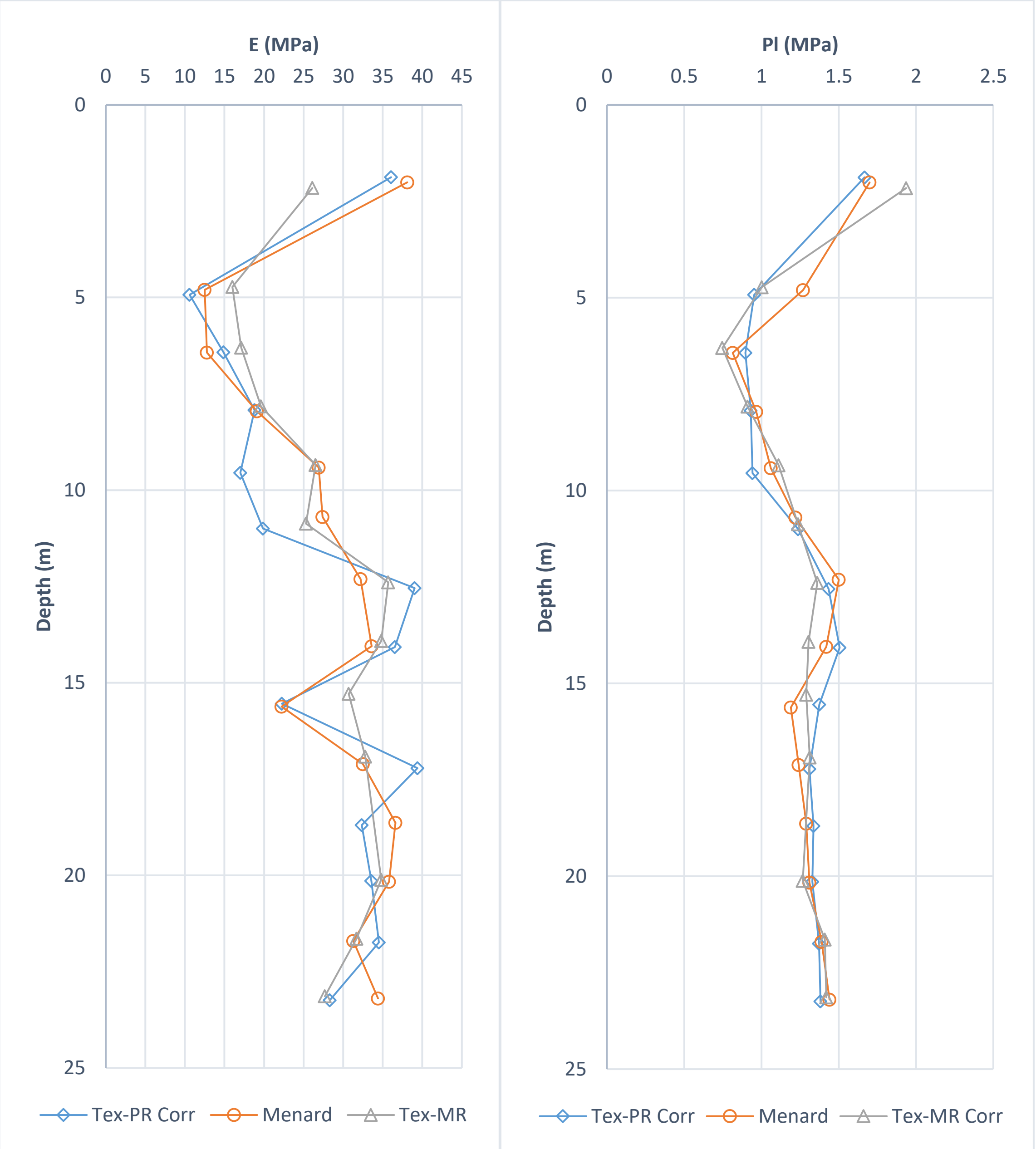

Figure 5. Corrected E and Pl – Field Testing

Table 4. Average corrected values of parameters

Type of Pressure-meter	Corrected E MPa	Corrected Pl MPa	Py MPa	E/Pl
Menard	28.2	1.27	0.52	22.2
Tex-MR	27.6	1.25	0.49	22.1
Tex-PR	27.4	1.26	0.50	21.7

In a conservative approach, the rounded factors in table 5 can be considered:

Table 5. Suggested equivalence factors

Type of Pressuremeter	Equivalence Factor MPa
Tex-MR	1 x E (no adjustment) 1.10 x Pl
Tex-PR	1.15 x E 1.15 x Pl
Tex-MR / Tex-PR	1 x Py (no adjustment)

This recommendation applies to N-size probes with membranes protected with metal fins, for the types of soils and parameters' range considered.

5. Conclusions

This study compares the results of the Texam pressuremeter with those of the Menard. The Texam pressuremeter was tested in two configurations : with a metal-ring probe and with a polymer-ring probe. Testing was performed in a controlled environment (in polymer tubes) and in situ. The main findings of this study are presented below.

Both laboratory and in situ tests have shown that (1) the Texam with metal-ring probe and the Menard produce comparable moduli values, and (2) that the Texam with polymer-ring probe produces lower moduli (about -19%).

In situ tests carried out with the Texam produced lower limit pressures than the Menard (about -12% for the Texam with metal-ring probe, and -17% for the Texam with polymer-ring probe)

Elements likely to explain these deviations have been proposed.

These differences can be mitigated using linear regression factors obtained from the test data. Such adjustment is easy, and seems to give good results, especially in the case of Pl, which shows smaller scatter than E.

This analysis applies to N-size probes with membranes protected with metal fins, for the types of soils and parameters' range considered (E ranging from about 10 to 150 MPa and Pl from 0.5 to 2 MPa). Additional testing in other soil types and stiffnesses are recommended.

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