DEVELOPMENT OF A ROBUST PUSH-IN PRESSUREMETER

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ABSTRACT – A push-in pressuremeter was developed using slotted steel casing with a monocell “Pencil” probe. The larger diameter cone rods were used so that both the pressuremeter and cone penetrometer cables could be threaded through. The pressuremeter was 1 meter above the cone. The CPT data were used to determine the best depths to perform the pressuremeter tests.

1. Introduction

When a pressuremeter is pushed in the soil, the amount of disturbance to the sidewalls of the soil is the same for tests within similar geologic conditions. Often during pushing, however, a conventional pressuremeter membrane is torn and one must restart the sounding. By inserting a conventional pressuremeter inside a section of slotted casing, the pressuremeter is protected during pushing. At the ends of the pressuremeter, steel spacers are screwed on, which keeps the slotted casing from flexing while pushing.

By examining the cone penetrometer test data, the engineer can determine where best to perform the pressuremeter tests. Cone pressuremeter tests are conducted rapidly because hole preparation time is eliminated. A case study is presented comparing results with CPT and DMT data.

2. Development Details

A robust push-in pressuremeter was developed allowing the operator to apply a thrust up to 10,000 kgf without damage (Figure 1). The center of the pressuremeter was located 1.00 meters above the cone penetration tip. The engineer can examine the CPT data and determine the best locations to perform the pressuremeter tests.

The pressuremeter was a monocell Roctest “pencel” probe. This probe was chosen because it has a small diameter and is easy to replace the membrane and saturate the system. The probe was placed inside a slotted steel casing, which protects the membrane. Steel spacers connected to the ends of the probe butted up against the adapter pieces allowing the probe to be pushed without flexing the steel casing. The longitudinal slots in the steel casing were “V” shaped, which helped prevent soil from getting between the steel casing and the pressuremeter membrane. A silicone caulk was also applied to the slots to assist with keeping soil out. The steel casing had an outside diameter of 1.79 inches (45.5 mm) and also served as the friction reducer for the cone.

Larger size CPT rods were used (1.00 inch/25.4 mm ID and 1.75 inch/44.5 mm OD). This size rod allowed the operator to thread both the CPT and PMT cables through the rods. A quick-connect fitting was used for the pressuremeter, which kept the tubing saturated and allowed the operator to conveniently replace a membrane if necessary (Figure 2).

Figure 1: Push-in pressuremeter being pushed into soil

Figure 2: Push-in pressuremeter showing tubing quick-connect and calibration tube

3. Calibration

The pressuremeter probe was calibrated for system compressibility and membrane resistance. For system compressibility the probe was inserted inside a steel pipe that was 52.6 mm ID, 76.2 mm OD and 914 mm long. Volume measurements were made at pressure increments of 5 bars to 60 bars. Generally, the calibration became linear after 25 bars and the calibration line was best fit for those upper pressures. An unload-reload loop was performed from 50 bars to 25 bars and back to 50 bars to determine the reload factor. (Tucker, et. al., 1990).

The probe was calibrated for membrane resistance using a low pressure gauge (-1 to 5 bar). Pressure measurements were made at volume increments of 25 cm^3 to 300 cm^3. Typically, at 300 cm^3 the pressure readings were about 2.5 bars.

4. Case Study

Three seismic cone pressuremeter test soundings were performed on the east embankment side of the Mississippi River for the Route 20 Bridge in East Dubuque, Illinois. The pressuremeter tests were conducted at 1.5 m interval in each of the soundings. Soundings 1 and 2 were advanced to 15 m and Sounding 3 was advanced to 12 m. Twenty-eight (28) pressuremeter tests were conducted in 3 days.

The tests were performed as strain-controlled tests using volume increments of 10 cm^3. Near the end of the elastic portion of the pressuremeter curve, an unload-reload test was done to determine the reload modulus. A creep test was performed at the next volume increment. By holding the pressure at a constant value, we took volume readings at 1, 2, 4, 7, and 10 minutes. By plotting the log (volume-initial volume) versus log (incremental time), we found that the data had linear relationships. A least squares regression method was used to determine the slope of the line, n. Generally, the coefficient of correlation was more than 0.99. The test was continued until the data became asymptotic with a pressure and the plastic limit could be determined or the injected volume was 300 cm^3.

With the pressuremeter test, the modulus is determined in an approximate elapsed time of 1 minute. The design life for a structure is much longer. To account for the time effects, the modulus values can be reduced with the following equation (Briaud, 2002):

$$E_{design}/E_{test} = (t_{design\ time}/t_{=1\ min})^{-n},$$

where n = the slope of the creep line plotted on log scale as indicated above.

The pressuremeter curves from this site had shapes either similar to self-boring pressuremeter tests, where the elastic portion started at zero radial strain or had classical “S” shapes of a prebored pressuremeter test. We were unable to determine why both types of curves occurred. A summary of the pressuremeter test results is presented below (Table 1).
Presented as Figure 5 is a comparison the push-in pressuremeter results with electric cone penetrometer tests and dilatometer tests. The limit pressure was about 20% of the corrected cone bearing, q_T. The shape of both profiles was quite similar. The dilatometer constrained deformation modulus, M, was in between the initial modulus and reload modulus for the upper 7 m, but then matched closely to the initial modulus below 7 m.

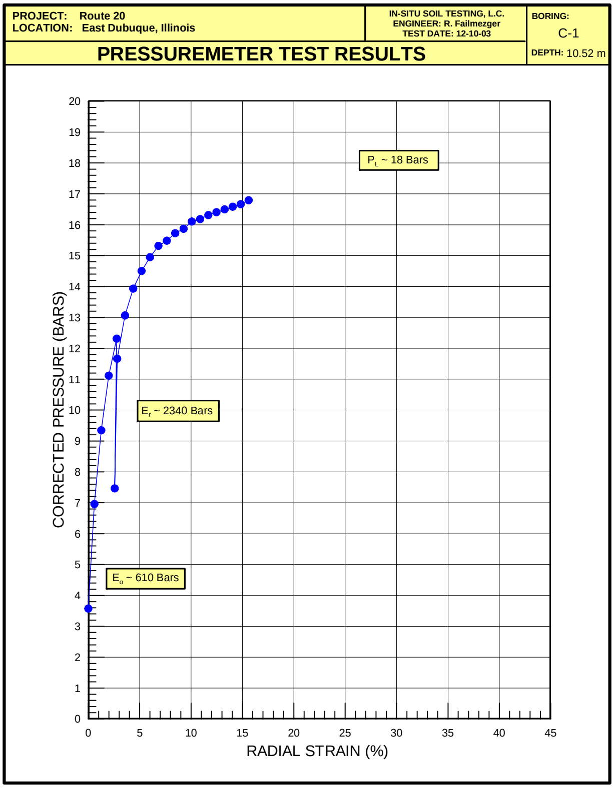

Figure 3. Typical Push-in Pressuremeter Test Results

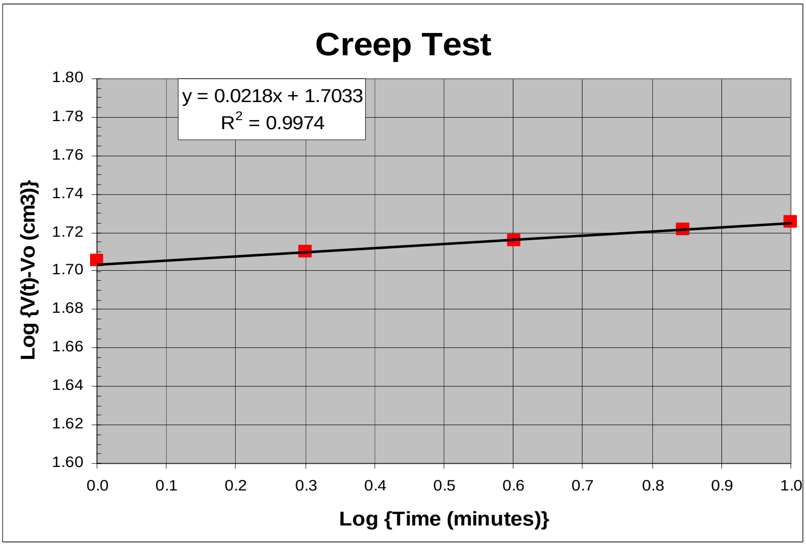

Figure 4. Creep test results from the above pressuremeter test

Table I. Summary of Push-in Pressuremeter Tests

Sounding Number	Depth (meters)	E_o (bars)	E_r (bars)	P_l (bars)	Creep Test Results: Holding Pressure (bars)	Creep Factor, n	Coefficient of correlation r^2
C-1	1.52	170	640	9	4.41	0.0145	0.9948
	2.99	380	1900	14	10.6	0.0196	0.9927
	4.52	540	2190	15	12.2	0.0210	0.9997
	6.02	540	2040	20	13.35	0.0166	0.9984
	7.52	470	1750	17	10.56	0.0204	0.9967
	9.02	440	1680	14	9.47	0.0317	0.9987
	10.52	610	2340	18	13.06	0.0218	0.9974
	12.02	900	3090	22	16.06	0.0269	0.9982
	13.52	1100	7210	24	18.16	0.0263	0.9995
	14.42	1020	3500	26	18.2	0.0241	0.9964
C-2	1.52	230	910	9	5.89	0.0168	0.9952
	3.02	380	1700	13.5	9.13	0.0156	0.9981
	4.52	290	1230	12	7.3	0.0111	0.9782
	6.02	350	1020	15	6.92	0.0135	0.9922
	7.52	320	1280	16	8.17	0.0128	0.9983
	9.02	570	1940	19	11.79	0.0179	0.9883
	10.52	740	2430	23	14.52	0.0167	0.9961
	12.02	630	2120	19	13.17	0.0152	0.9995
	13.52	1560	3620	29	19.51	0.0243	0.9954
	14.52	1610	4680	32	24.16	0.0550	0.9798
C-3	1.52	250	810	7	5.66	0.0288	0.9819
	3.02	320	910	8	6.4	0.0239	0.9930
	4.52	360	1060	9.5	6.95	0.0118	0.9762
	6.02	450	1070	9.5	7.21	0.0280	0.9926
	7.52	350	1170	11	7.6	0.0208	0.9938
	9.02	1110	2750	24	16.7	0.0159	0.9928
	10.52	870	3740	30	18.03	0.0143	0.9972
	12.02	1590	4270	27.5	22.42	0.0507	0.9899

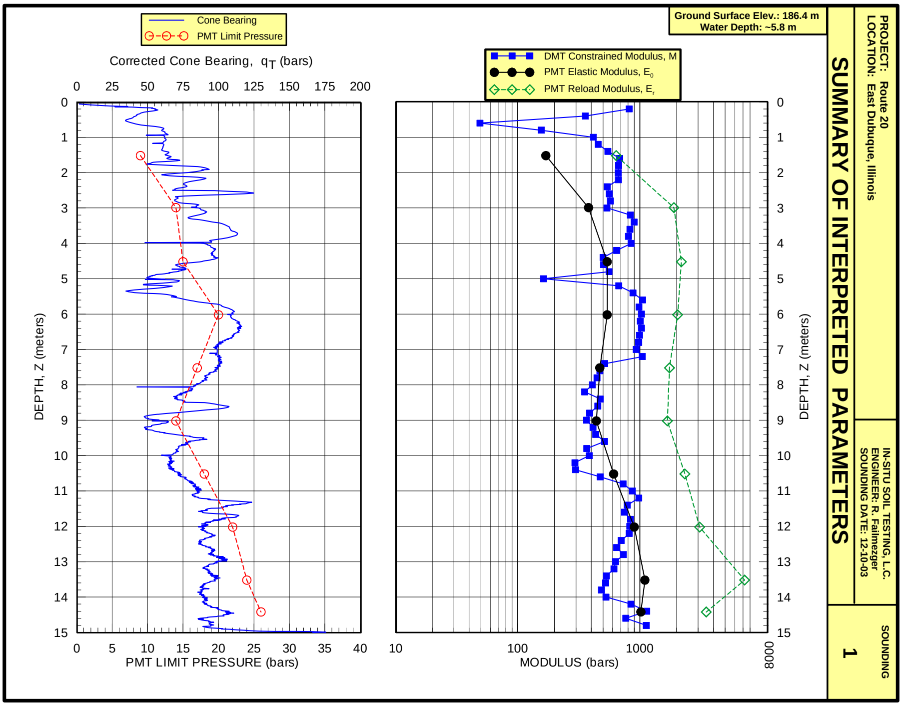

Figure 5. Comparison of push-in pressuremeter tests with CPT and DMT

5. Conclusions

1. The push-in pressuremeter test can be an efficient method of obtaining pressuremeter data.

2. The cone penetration test data that are acquired 1.00 meter below the center of the pressuremeter can be used to determine the best locations for pressuremeter tests.

3. The disturbance to the borehole will be the same for each test within similar geologic conditions, making comparisons between different tests easier to do.

4. The push-in pressuremeter test gives different results than the classic prebored pressuremeter tests. Additional research needs to be conducted to determine appropriate correlation coefficients for design.

6. References

Briaud, Jean-Louis (1992), *The Pressuremeter*, A. A. Balkema, Brookfield, VT, USA

Briaud, Jean-Louis (2002), personal communication

Tucker, L., Briaud, J.L., (1990), *User's Manual for PRESRED*, Texas A & M University