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Geotechnic Parameters Analysis Obtained by Pencel Presuremeter Test on Clayey Soils in Resistencia City

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Abstract
The Resistencia city has characteristic geomorphological environments of river valleys, mainly due to the influence of the Parana River and its tributaries. In many areas there is high heterogeneity of geotechnical profiles, sedimentary clayey, silt and sand soils, and water table near the ground surface. This brings many problems for designing and construction of engineering works, including low soil bearing capacity for the project of foundations and higher construction costs. To analyze the behavior under load of these soils, geotechnical engineering practice in the region commonly used field tests like the standard penetration test (SPT) and the cone penetration test (CPT). In order to improve the quality of the studies being conducted in the area, it is analyzed in this study the use of the pencel pressuremeter test (PPMT), which allows a stress-strain curve of soil in situ. It has been considered to use this test because the equipment and the test procedure are relatively inexpensive to incorporate into engineering practice. As the use of this type of pressuremeter test is relatively recent, this study has the objective to validate their results by comparing them with correlations available in the literature between CPT and traditional pressuremeter tests. The results indicate that the geotechnical parameters obtained through pencel pressuremeter test are consistent with the correlations available in the international literature. Although the universe of data analyzed is small and should be extended, preliminary results are favorable on the potential use of the pencel pressuremeter test for geotechnical studies in the region.

1. Background

Metropolitan area of Great Resistencia has characteristic geomorphologic environment of river valleys, due mainly to the influence of Paraná River and its tributaries (Popolizio, 1986). In many areas there is high heterogeneity profiles, sedimentary clayey, silt and sand soils, and water table near the ground surface. This brings many problems for designing and construction of engineering works, including low soil bearing capacity for the project of foundations and higher construction costs. Upper strata are mainly clayey soils whose consistency varies from soft to very compact according the formation and history of tensions (Bosch et al 2008). Consequently, parameters that describe their stress-strain behaviour acquire primary importance for foundation projects of civil engineering works.

To determine these parameters local geotechnical engineering practice employs field test like Standard Penetration Test (SPT). In the past decade it was also used frequently for field tests the cone penetration test (CPT), which consists of driving a tip with electronic load cells allowing to estimate the resistance that the soil offers to penetration (Lunne et al, 1997). The most common practice consists of correlate directly results of SPT and CPT tests with geotechnical parameters of strength and deformation. There exists countless correlations, many of them international, which allow to estimate parameters of geotechnical behavior from the before mentioned tests (Lunne et al, 1997; Briaud, 1992). Considering that both the SPT and the CPT test performed measurements of soil resistance and no deformation under load, correlations available in the international literature related deformation parameters (Young's modulus for example) are less reliable. As every correlation present certain dispersión of results, it is common in practice to use conservatively lower limits of such correlations. As a result, many times the bearing capacity obtained are lower than that would be obtained if intermediate values were adopted in dispersion of values, a situation that is considered could be possible in many cases if there were geotechnical methods more reliable and economically applicable (Sotelo & Bosch, 2001). Although present situation could not seem a major problem because building seem to be safer, many times this situation forces to adopt deep foundations instead shallow foundations, becoming them significantly more expensive. In real estate projects this results in a higher final price of the property which has even caused the unviability of many projects in the area.

As an alternative to improve this problem, the use of the pencel pressuremeter test is used in this work which consists of introducing a cylindrical probe into the soil which is then is radially expanded by water injection (Roctest Inc., 2005). It has been considered to employ this test because of the equipment and the test procedure are relatively low cost to be incorporated to the routine practice in geotechnical studies in the zone. During the expansion process of the cylinder probe applied pressure and radial deformations were registered, allowing to obtain a stress-strain curve in the field from which rupture and deformation parameters of soil can be obtained using formulations of a cylindrical expansion of a cavity (Mair & Wood, 1987). As the use of this type pressuremeter test is relatively recent, this work has the objective to validate its results comparing them with existing correlations in literature between the CPT and traditional pressuremeter tests.

2. The Pencel Pressuremeter Test

The pencel pressuremeter test (PPMT) was developed by Menard (Menard, 1956), from which arose different equipment up to the present. The pencel pressuremeter test is relatively new. It has a probe diameter of 1,35 inches which is connected to a pressure and volume control unit by means a plastic tube as shown in Figure 1. The probe is pushed into the soil statically or dynamically until it reaches the desired depth. The rotation of a handle by the operator moves a piston placed into the control unit which injects water through the system that produces a volume change in the probe and thus pressure may be measured. Before performing the test it is necessary to make two calibrations, one to measure resistance to the membrane and the other to determine expansion of system under pressure. Besides, a correction for the pressure is applied as a result of the hydraulic pressure generated by the depth in which the test is placed. The standard test is of controlled deformation, where the operator injects 5 cm^3 of water, waits for 30 seconds and registers the pressure that offers the soil to expansion. Then the process is repeated until maximum deformation of the equipment is reached. Alternatively, cycles of load and reload may be made during the process.

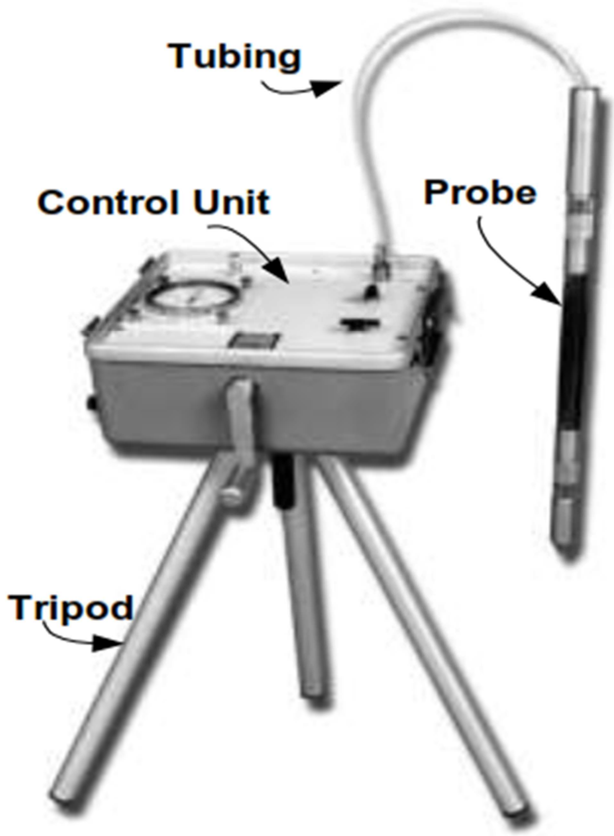

Figure 1. *The pencel pressuremeter test. (Roctest Inc., 2005).*

Once obtained data, corresponding corrections to stiffness of membrane are made, also to expansion of system out of the probe and to the initial hydraulic pressure. Figure 2 shows a typical result where the phases of elastic, plastic a load-reload behavior are observed. From this information the Pressuremeter Modulus (Eo), the Pressuremeter Rebound Modulus (Er) and the Limit Pressure (pl) are determined.

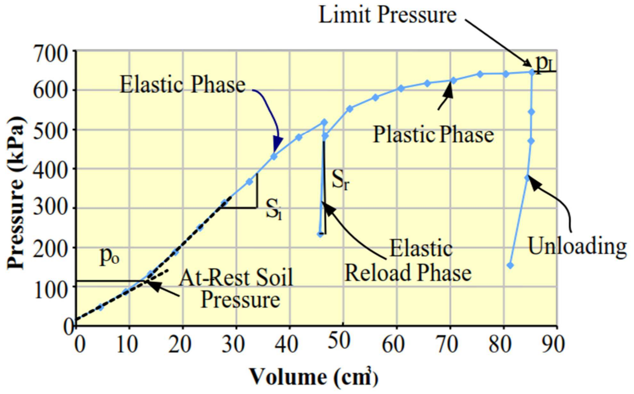

Figure 2. *Geotechnical parameters obtained from corrected curve. (Roctest Inc., 2005).*

For determining Pressuremeter Modules, it will be used:

$$E = 2 * (1 + \nu) * (Vo + Vm) * \frac{\Delta P}{\Delta V}$$

Where
ν: Poisson´s ratio
Vo: Initial Volume
Vm: Average Volume
ΔP: Change in Pressure
ΔV: Change in Volume

3. The Cpt – Correlations with Pressuremeter Test

The cone penetration test CPT consists of driving a tip with electrically instrumented load cells allows the meassurement of the cone tip resistance (qc) and sleeve friction resistance (fs). The equipment used in the zone has a pushing unit with hydraulic pistons which guarantee a static driving to a standardized velocity, a system of reaction that attaches the equipment to the soil with helical anchorages, bars and a cone tip standardized according ASTM D3441-86 and acquisition data system that registers electronically and with great sensitivity the tip resistance and the sleeve friction. Resistance registers are made every 10 cm deep or less, obtaining a great detail of soil stratigraphy. Figure 3 presents a typical result of the CPT test (Meigh, 1987).

One of the great advantages of this field test is its automation that makes it low sensitive to problems related to sample alterations or human errors during its performance. For this reason international correlations with other tests are reliable enough to extrapolate results. Table 1 shows correlations between the CPT and the Pressuremeter Test (PMT) (Briaud, 1992).

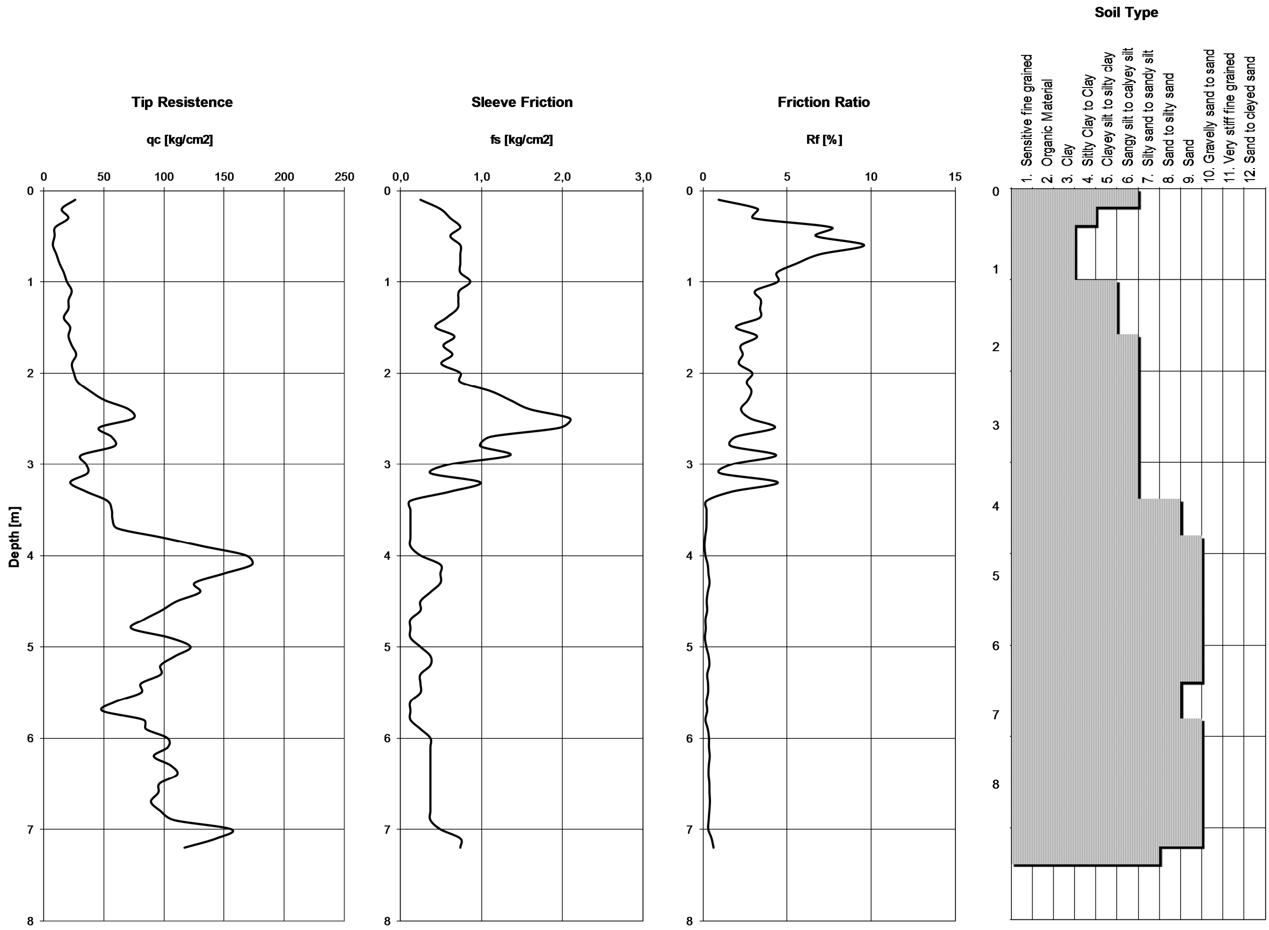

Figure 3. *Typical result of the CPT in study area.*

Table 1. *Correlation between PMT and CPT (Briaud, 1992).*

Soil Type	PMT Parameter	Correlation to CPT
Clay	Pl	0.20 qc
	Eo	2.50 qc
	Er	13.00 qc
Sand	Pl	0.11 qc
	Eo	1.15 qc
	Er	6.25 qc

4. Materials Y Methods

This work has the objective to validate results obtained with the pencel pressuremeter test (PPMT) in clayey soils in the Resistencia City. As a method of validation it has been adopted the criterion of comparing results obtained in this test with existing correlations in literature between traditional pressuremeter and CPT. The study place selected has clayey soils in the upper layer, very common in the city of Resistencia (Bosch et al, 2008). In this site three standard penetration tests (SPT), three cone penetration tests (CPT) and six pencel pressuremeter tests (PPMT) were performed. The PPMT tests were made to 1,00 y 1,50 meter depth, which correlate to shallow foundation levels normally adopted in the engineering practice of the zone.

5. Results Obtained

Results of the SPT and CPT indicate that the study place is characterized for presenting in surface and approximately 2,50 m depth a silty clay stratum that classifies as CL in the Unified Soil Classification System (U.S.C.S.). This soil has an average SPT N value of 10 and approximately 3.000 kPa tip resistance in the CPT. Afterwards, and up to 5,00 meters depth approximately there are silty soils that classify as ML in the U.S.C.S. From there and up to 10 meters depth there are silt sands that classify as SM in the U.S.C.S. Figure 4 shows cone tip resistance in the CPT tests at the interest depth for this analysis.

Results obtained by pencel pressuremeter tests are indicated in Table 2. Also, relation between geotechnical parameters obtained and cone tip resistance in the CPT are presented here. In Figures 5, 6 and 7 are graphed relationship between parameters obtained in the PPMT (pl, Eo y Er) with cone tip resistance in the CPT.

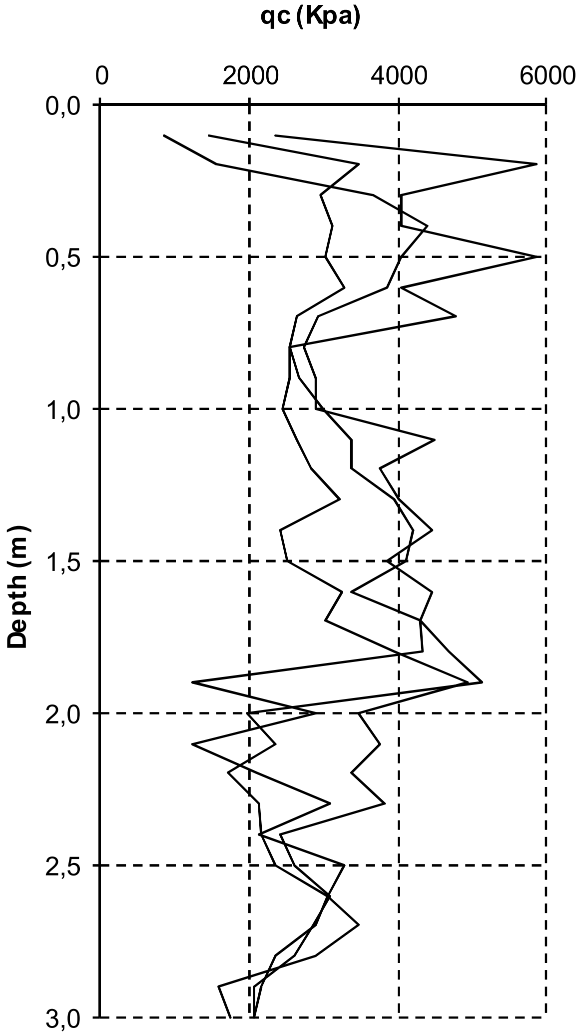

Figure 4. *Cone tip resistance. CPT tests.*

Table 2. *Results of PPMT tests and relationship with CPT.*

PPMT	Depth m	pl kPa	Eo kPa	Er kPa	qc kPa	pl/qc	Eo/qc	Er/qc
1	1.5	420	5801	30301	2717	0.15	2.14	11.2
2	1.0	376	6413	29261	2550	0.15	2.51	11.5
3	1.5	566	5219	50578	3900	0.15	1.34	13.0
4	1.0	568	7757	51820	3006	0.19	2.58	17.2
5	1.5	789	8614	55724	4257	0.19	2.02	13.1
6	1.0	582	6435	34561	3425	0.17	1.88	10.1
				Average values		0.17	2.08	12.67

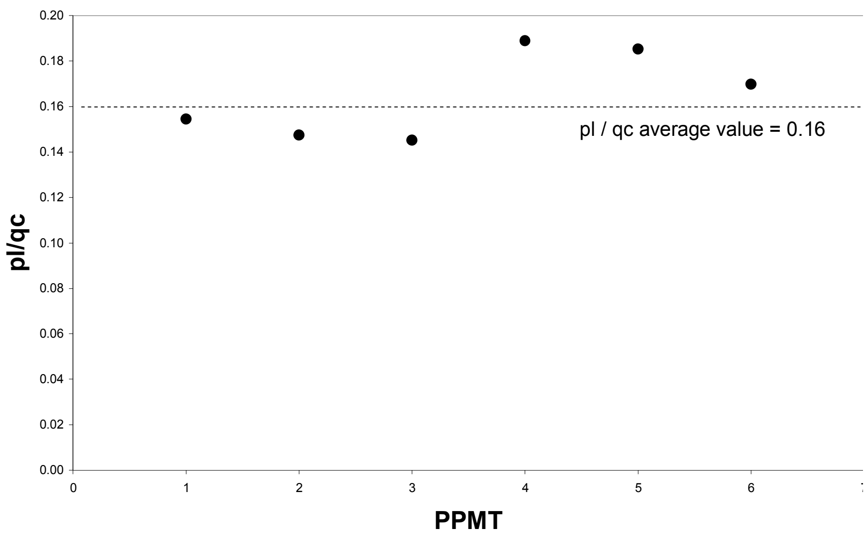

Figure 5. *Relationship between limit pressure (pl) and cone tip resistance (qc).*

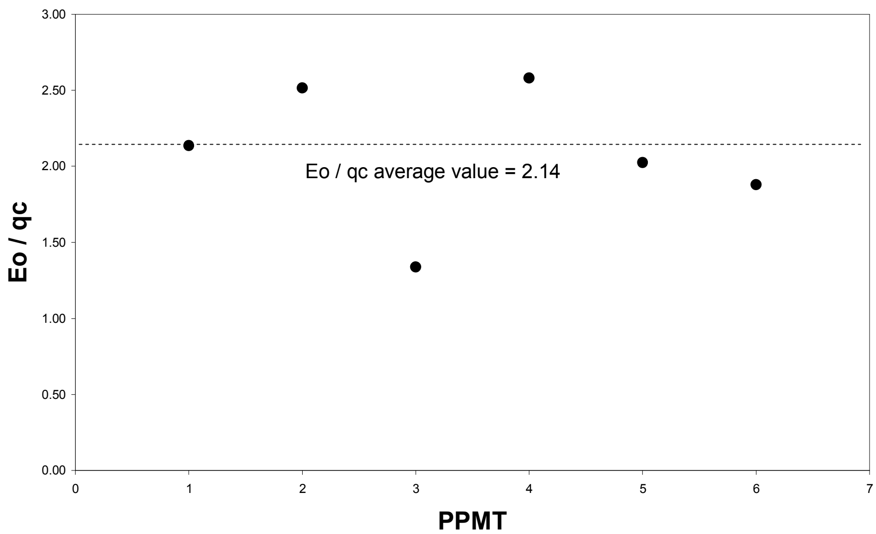

Figure 6. *Relationship between pressuremeter modulus (Eo) and cone tip resistance (qc).*

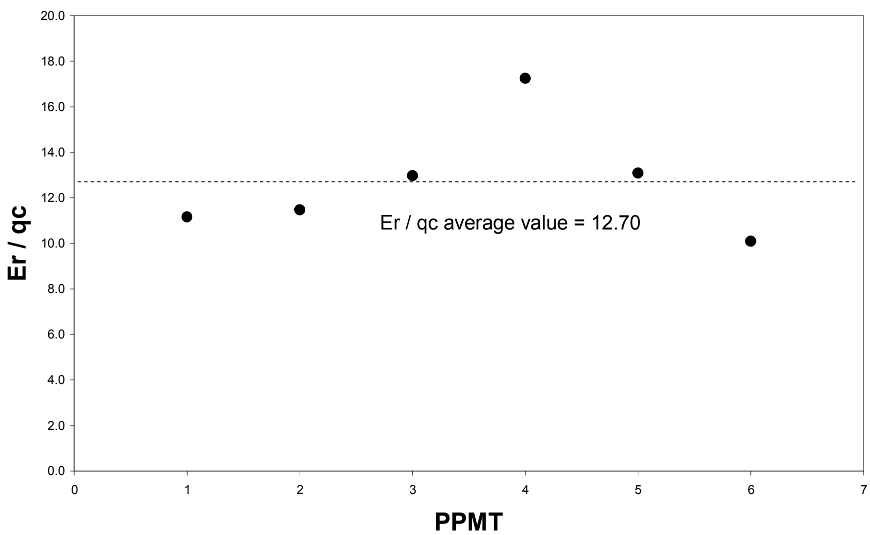

Figure 7. *Relationship between pressuremeter rebound modulus (Er) and cone tip resistance (qc).*

As it may be observed in Table 2 and in Figures 5 to 7, relationship pl/qc varies from 0,15 to 0,19, with an average value of 0,17. For relationship Eo/qc values between 1,34 and 2,58 were obtained with an average of 2,08. Regarding relationship Er/qc value obtained vary between 10,10 y 17,20 and an average 12,67. Although exists certain dispersion in the results, these values agree with proposed correlations by Briaud (1992) for traditional pressuremeter tests according presented in Table 1. Although data universe is small and should be enlarged, preliminary results are favorable regarding the potential use of pencel pressuremeter in routine geotechnical studies in the zone.

6. Conclusions

In this work it has been considered employing the pencel pressuremeter test to improve routine geotechnical studies due to equipment and test procedures are relatively low cost so as to incorporate to the engineering practice in the zone. In cases analyzed a good agreement was found between geotechnical parameters obtained by means the pencel pressure meter tests and available correlations in literature between resistance of toe CPT and geotechnical parameters in traditional pressuremeter tests.

Although universe of data is small and should be enlarged, preliminary results are favorable related to the potential use of the pressuremeter test for routine geotechnical studies in the zone.

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