Comparison between some plate tests results and theoretical calculations

Comparaison entre quelques résultats d'essais de plaque et des calculs théoriques

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ABSTRACT: This paper presents 5 plate test results. The tests were performed using a plate of 0.60 m of diameter and were done on an embankment with a "tout venant" top layer over a compacted soil. Graphics of load-settlement are presented and the modulus of subgrade reaction and residual settlements are obtained from them. The "tout venant" and the soil have been tested in laboratory and the modulus of deformation calculated from them. With these and the two elastic layer theory the combined subgrade reaction has been calculated and compared with the actually measured in the field.

RESUME: Dans cette communication son présenté les résultats de cinq éssais de plaque. Les essais ont été realizés avec une plaque rigide de 0.60 m de diamètre et on les a fait dans un remblai avec un "tout venant" placé sur le sol compacté. Courbes charge-tassement sont présentées et le module de réaction du sol et les tassements résiduels sont obtenus a partir d'elles. Le "tout venant" et le sol ont été essayés au laboratoire où le module de déformation a été obtenu. Avec ces résultats et la téorie des deux couches élastiques, le coefficient de réaction a été calculé et comparé avec le coefficient réellement obtenu au champ.

1 INTRODUCTION

In the Braga region (North of Portugal) it was necessary to install high precision machines in an old industrial pavilion constructed on a soil embankment done without any care of compaction. Therefore, before install the machines, the embankment was compacted with a vibratory roller. Over this soil a "tout venant" layer of 0.35 m of thickness was placed and compacted with the same roller.

To evaluate the deformability of the ground five plate tests were done. Four cycles load-unload were done for each plate test.

2 RESULTS OBTAINED

2.1 *Plate Tests*

The graphics of load-settlement for plate tests number 1 (PL1) and 4 (PL4) are presented in figures 1 and 2.

At each maximum load the settlements were measured until the difference in readings were less than 0.02×10^{-3} m/min.

From those graphics and the other plate tests results the modulus of deformation (tangent and secant) and the coefficient of subgrade reaction were obtained for the first and second cycles. The modulus of deformation were obtained at 2/3 of the maximum load reached in each cycle.

The results are presented in the table 1.

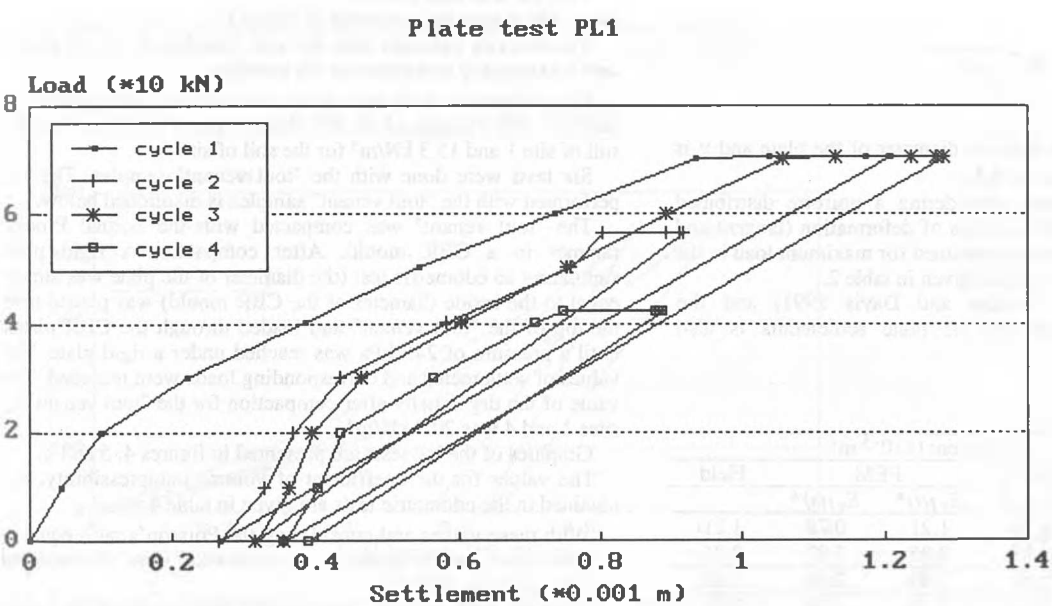

Figure 1. Load-settlement curves for the plate test PL1.

Plate test PL4

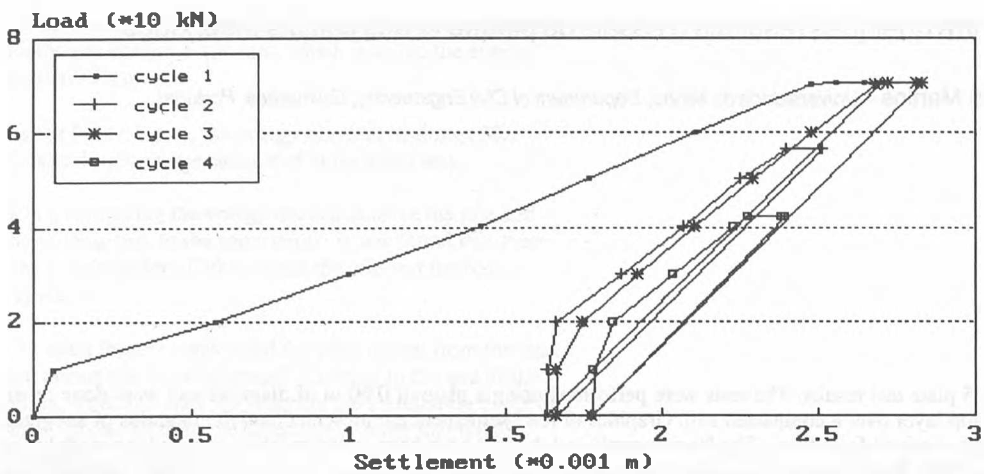

Figure 2. Load-settlement curves for the plate test PL4.

Table 1. Plate load results.

Test	k_{s1}	k_{s2}	$E_{s1}(t)$*	$E_{s1}(s)$*	$E_{s2}(t)$*	$E_{s2}(s)$*
PL	(10^3 kN/m^3)			(10^3 kPa)		
1	259.3	324.0	93.40	144.6	99.60	213.4
2	171.3	174.2	28.74	38.20	63.58	131.6
3	236.7	240.5	37.36	42.56	90.55	159.7
4	227.9	229.2	42.70	42.29	76.62	152.7
5	193.6	197.0	33.21	47.19	69.49	133.2

* obtained at 2/3 of the maximum load

Where k_{s1} and k_{s2} are the modulus of subgrade reaction for the first and second cycles, $E_{s1}(t)$ and $E_{s2}(t)$ are the modulus of deformation tangent for the first and second cycles and $E_{s1}(s)$ and $E_{s2}(s)$ are the modulus of deformation secant for the first and second cycles.

To obtain the modulus of deformation, E, the following formula was used (Craig 1992):

$$s = \frac{Q}{B} \times \frac{(1-\nu^2)}{E} \qquad (1)$$

where s is the settlement, B is the diameter of the plate and ν is the Poisson's ratio assumed as 0.3.

With a FEM programme considering a uniform distributed flexible load and using the modulus of deformation (tangent and secant) values of the settlement obtained for maximum load in the first cycle were computed and are given in table 2.

The elastic solutions (Poulos and Davis 1991) and the measured "in situ" values for the plate settlements is also presented in table 2.

Table 2. Plate settlements

Test	Settlement ($\times 10^{-3}$ m)				
	Poulos and Davis		FEM		Field
PL	$E_{s1}(t)$*	$E_{s1}(s)$*	$E_{s1}(t)$*	$E_{s1}(s)$*	
1	1.12	0.73	1.21	0.78	1.21
2	3.66	2.75	3.95	2.97	3.86
3	2.81	2.47	3.03	2.66	2.92
4	2.46	2.48	2.66	2.68	2.71
5	3.16	2.23	3.41	2.40	2.88

* obtained at 2/3 of the maximum load

Table 3. Residual settlements

Test	s_1	s_2
PL	($\times 10^{-3}$ m)	($\times 10^{-3}$ m)
1	0.265	0.315
2	2.43	2.51
3	1.89	1.91
4	1.63	1.66
5	1.62	1.66

The residual settlements after the first (s_1) and second cycles (s_2) are given in table 3.

2.2 *Laboratory Tests*

For performing laboratory tests, 6 remoulded samples of the "tout venant" layer and 8 undisturbed samples of the soil foundation were obtained in the points where the plate tests 1 (site 1) and 4 (site 4) were done.

Two particle size analysis for each of the two materials were done. The results are presented in figure 3.

The analysis indicates that the soil foundation is non plastic and is essentially composed by silt particles.

Eight edometric tests were done with the base undisturbed soil samples. The average of the dry density was 13.9 kN/m^3 for the soil of site 1 and 15.3 kN/m^3 for the soil of site 4.

Six tests were done with the "tout venant" samples. The test performed with the "tout venant" samples is mentioned below.

The "tout venant" was compacted with the normal Proctor rammer in a CBR mould. After compaction a rigid plate simulating an edometric test (the diameter of the plate was almost equal to the inside diameter of the CBR mould) was placed over the top of the "tout venant" and loaded through the CBR piston until a pressure of 245 kPa was reached under a rigid plate. The values of settlements and corresponding loads were recorded. The value of the dry density after compaction for the "tout venant" of sites 1 and 4 was 20.4 kN/m^3.

Graphics of the lab tests are presented in figures 4, 5 and 6.

The values for the coefficient of volume compressibility, m_v, obtained in the edometric tests are given in table 4.

With these values and considering the Poisson's ratio equal to 0.3 the values for the modulus of deformation were obtained and are also given in table 4.

From the tests with the "tout venant" were obtained the values for the coefficient of volume compressibility, m_v, and modulus of deformation given in table 5.

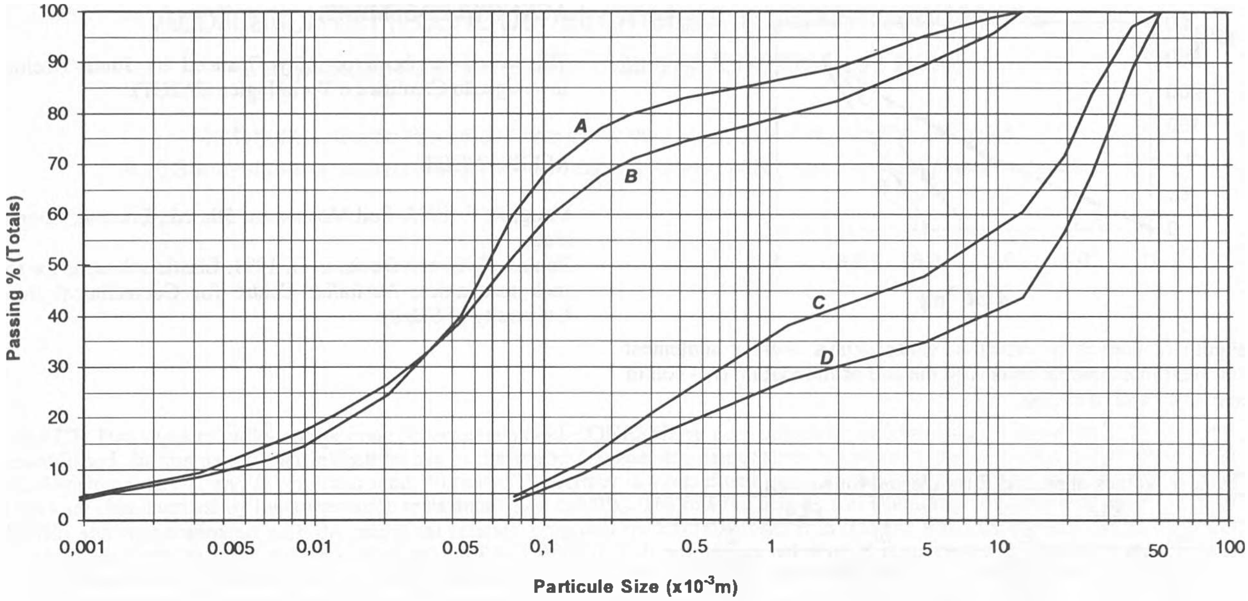

Figure 3. Grain size distribution curve for the soil foundation (A and B) and the “tout venant” (C and D).

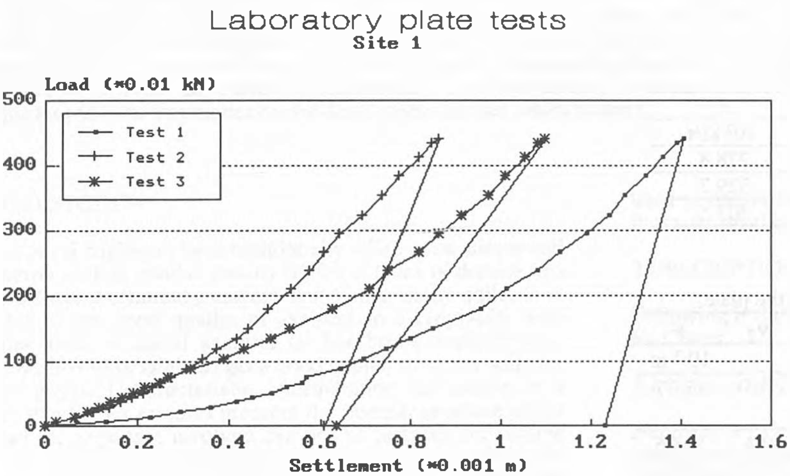

Figure 4. Load-settlement curves obtained in lab with "tout venant" of site1.

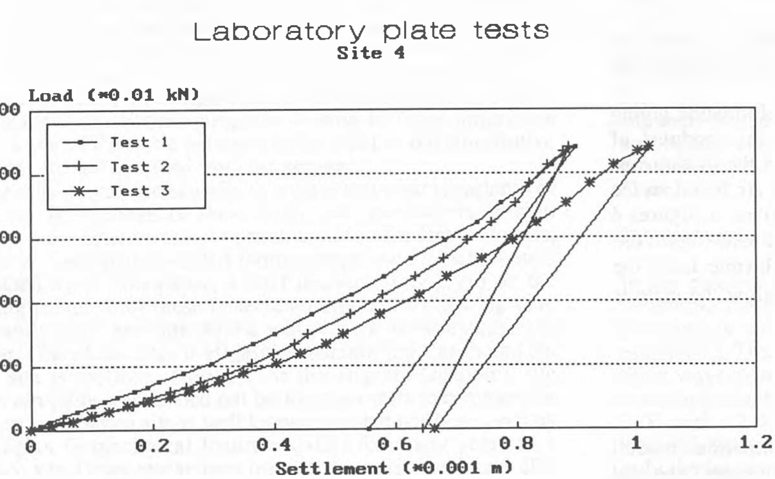

Figure 5. Load-settlement curves obtained in lab with "tout venant" of site 4.

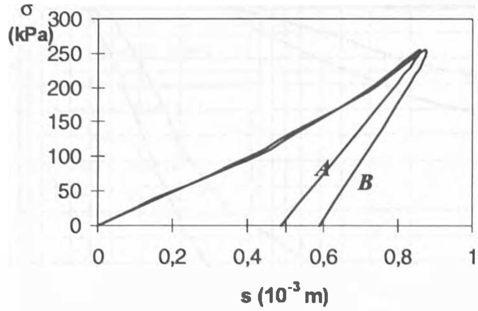

Figure 6. Curves of effective stress versus average settlement obtained in edometric tests with the soil of foundation (A - soil of site 1, B - soil of site 4).

Table 4. Values of m_v and E for the soil foundation.

PL1		PL4	
m_v	E	m_v	E
10^{-4} (kPa)$^{-1}$	10 kPa	10^{-4} (kPa)$^{-1}$	10 kPa
1.091	681.4	1.317	564.0
1.820	408.2	1.320	562.8
1.207	615.5	1.412	526.2
1.684	441.2	2.174	341.7

Table 5. Values of m_v and E for the "tout venant".

PL1		PL4	
m_v	E	m_v	E
10^{-5} (kPa)$^{-1}$	10^2 kPa	10^{-5} (kPa)$^{-1}$	10^2 kPa
2.503	296.8	2.665	278.8
2.244	331.1	2.254	329.7
2.497	297.6	2.448	303.5

Table 6. Theoretical values of the settlements of the plate.

Author	E_e	E_1	E_2	v_1	v_2	s
	10 kPa	10^2 kPa	10 kPa			10^{-3} m
Ueshita and Meyerhof	936.9	---	---	0.5	0.5	11.77
Burmister	---	306.3	517.6	0.2	0.4	14.06
Thenn de Barros	---	306.3	517.6	0.35	0.35	12.76
Burmister	---	306.3	517.6	0.5	0.5	12.78

To obtain the theoretical value of the settlements of the centre of the plate considered flexible four solutions given in Poulos and Davis (1991) were used (table 6).

In table 6 E_e is the value of the modulus of deformation giving the same settlement in the half space, E_1 is the modulus of deformation of the "tout venant" layer and E_2 is the modulus of deformation of the soil foundation. These values are based on the results obtained in the last third of the curves given in figures 4 and 5 and on the results obtained in the edometric tests (figure 6).

Using FEM programme and considering a flexible load, the mean of the values of the settlement obtained below the plate is 11.0×10^{-3} m.

3 CONCLUSIONS

1. The settlement calculated from the deformation moduli obtained from the lab "edometric" tests for "tout venant" and soil are about 10 times greater than those measured in the field. This surely reflects disturbances in sampling and that the appropriate lab compaction test is the heavy, not the normal as we have done.
2. The differences between the settlement calculated by the various methods are not significant.

ACKNOWLEDGEMENT

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REFERENCES

Craig, R. F. 1992. Soil Mechanics, 5th. ed., London, Chapman & Hall.

Poulos, H. G. and Davis, E. H. 1991. Elastic solutions for soil and rock mechanics, Australia: Centre for Geotechnical Research, University of Sidney