Load tests and load transfer on short bored piles

Essais de chargement et transfert de charge en pieux forés

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SYNOPSIS This paper deals with the behaviour of short reinforced concrete bored piles, in holes drilled with bentonite slurry, through the interbedded shales and limestones corresponding to the Taquari member of the Riachuelo formation, a Cretaceous shallow-marine deposit, which makes up the sub-surface material at the Potassio Sergipe Project of Petrobrás Mineração S.A.-PETROMISA.

To obtain the actual load transfer profile from piles inserted in the aforementioned ground, two vertical compression tests on piles instrumented with strain-gages and tell-tales were performed.

The measured Friction and Point resistances are presented and correlated, at each test pile, to the sub-surface geological column as indicated by two previous percussion and rotary borings, performed at the same locations.

The test results showed the prevalence of the Friction (F) over the Point (P) resistance even for short piles, although the F/P ratio increased significantly with pile length.

INTRODUCTION

A pile foundation was mandatory for the industrial structures that compound the Potassio Sergipe Project. In order to optimize pile length and to evaluate pile behaviour, a few non-destructive vertical compression pile load tests, with settlement readings confined to pile head, were initially performed. The data obtained, however, were unsatisfactory for a true knowledge of the load transfer characteristics along the pile. It was decided, then, to instrument two pilot piles by means of strain-gages and tell-tales, and load test them up to rupture, or up to 11000 kN, whichever came first. Both were 0.80m diameter piles; the shorter was 8.05m long and the other 14.00m long (see figures 1a and 1b). The load was applied by two 7000kN-capacity hydraulic jacks pushing against a steel reaction frame fastened deeply into the ground, by eigtheen 900kN-capacity tiebacks.

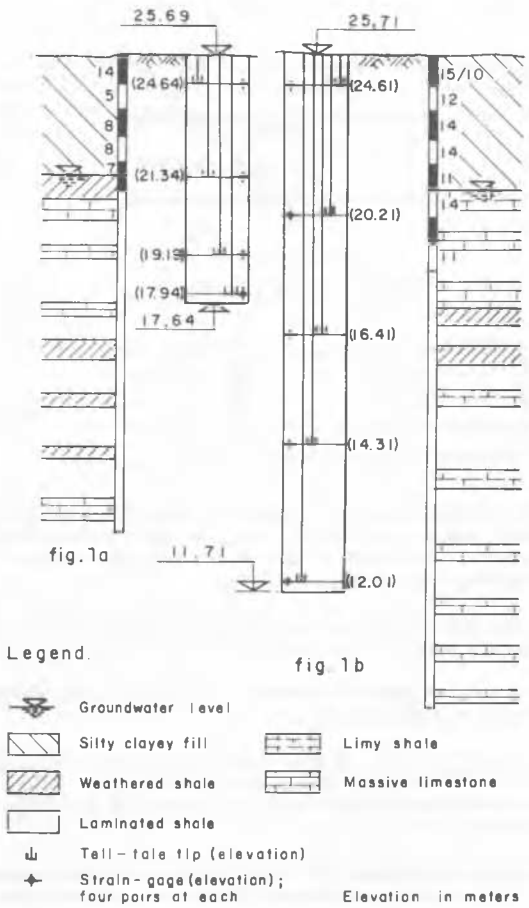
GEOTECHNICAL AND ELASTIC CHARACTERISTICS

The sub-surface materials fall into three classes geotechnically:

1st) The topmost fine-grained fill (whose SPT index varies between 5 and 8 at the 8.05m pile location, and between 11 and 14 at the 14.00m pile location) and the weathered portions of limy and shaly beds (whose SPT varies between 11 and 14).

2nd) The shale beds, varying from laminated to massive, with an average Young's Modulus of 25×10^5 kPa and a Poisson's ratio of 0,25.

3rd) The limestone beds, varying from



brecciated to massive, with an average Young's Modulus of 85×10^5kPa and a Poisson's ratio of 0,20.

The fill and the weathered materials invariably occupied the top of the geologic column at each pile; the limestone and shale beds occur erratically at bottom. Thicknesswise, the laminated shale prevails, as can be seen from figures 1a and 1b.

LOAD TEST PROCEDURES

Figure 2a indicates the load frame assembly which was used for both tests and figure 2b indicates the reference beams set-up for dial-gages readings.

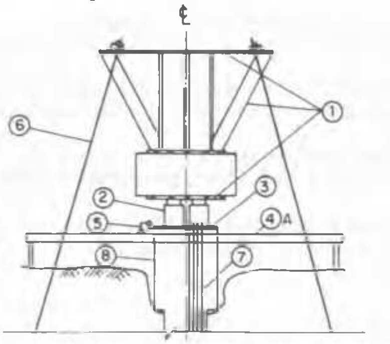


fig. 2a Load frame assembly cross-section

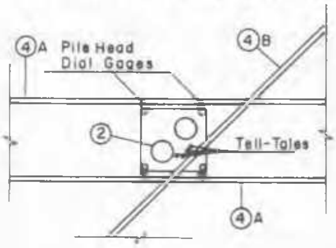


fig. 2b Reference beams set-up

Legend.

1. Steel Reaction Frame
2. Hydraulic Jacks
3. Steel Plates
4. A Reference Beams
4. B Master Reference Beam
5. Dial Gages
6. Tiebacks
7. Tell-Tales
8. Pile Cap

The two jacks were activated simultaneously by an electric pump; the whole system was calibrated previously at a Technical Institution and a certificate was issued.

The pile head displacements were monitored by 4 dial-gages with an accuracy of 10^{-2} mm.

A thermometer was attached to the pile head for temperature monitoring.

Final load for the 8.05m long pile was 10125kN; for the 14.00m long pile was 11000kN. The pile's settlements were of 6.44mm and 10.34mm respectively.

Tell-tale rods were 1" in diameter rebars placed in 2 1/2" galvanized steel casings with a lid at the bottom, previously fastenned to the pile's reinforcement.

Strain-gages were Kyowa's KFC-10-C1-11, installed by pairs so as to have one "active" and one "dummy" for temperature compensation. Strain readings were done in a Peekel B-105 Strainmeter, whose sensitivity is 10^{-6}.

TEST RESULTS AND INTERPRETATION

The pile's reinforced concrete had an Young's Modulus of 3.43×10^7kPa; once confined into the ground, its Elastic Modulus would depend upon the compressive stress level, since the pile becomes mobilized by a three-axial stress condition.

To determine the proper Elastic Moduli for stress computation at each strain-gage level, the following continuity equation was used at the boundary level between the free pile and the confined pile:

$$E_o \cdot \varepsilon_o = E_c \cdot \varepsilon_c$$

where: E_o = 3.43×10^7kPa
ε_o = strain pile's head (applied stress/E_o)
E_c = confined Elastic Modulus
ε_c = strain obtained from the pile's strain-gage profile by projecting it orthogonally to the boundary level (see figures 3a and 3b).

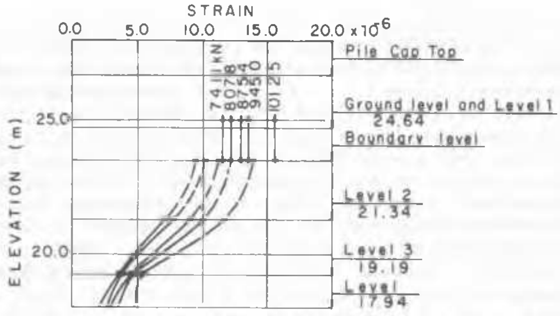


fig. 3a Measured Strain x Depth (8.05m long pile)

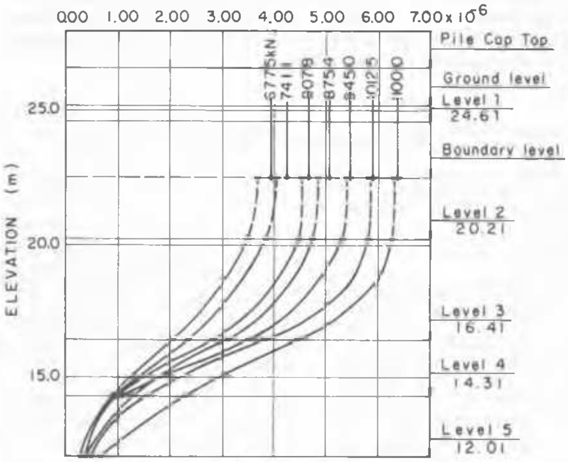


fig. 3b Measured Strain x Depth (14.00m long pile)

The ratio $\varepsilon_o/\varepsilon_c$ was then computed at each load stage and also the E_c values, as shown by the following table of results:

TABLE I

Confined Elastic Moduli E_c

LOAD (kN)	14.00m long Pile		8.05 m long Pile	
	ε_o / ε_c	E_c	ε_o / ε_c	E_c
6 775	1.06	3.64	—	—
7 411	1.06	3.64	1.21	4.15
8 078	1.03	3.53	1.20	4.12
8 754	1.05	3.60	1.15	3.84
9 450	1.01	3.46	1.11	3.81
10125	1.01	3.46	1.12	3.84
11 000	1.01	3.46	—	—

E_c values in 10^7 kPa

Then the compressive stresses (σ_z) were computed at each level using the relationship

$$\sigma_z = E_c \times \varepsilon_z$$

where: ε_z is the measured strain, yielding the following results:

TABLE II

Compressive Stress σ_z

LOAD (kN)	8.05m long Pile				14.00m long Pile				
	Elevation (m)				Elevation (m)				
	24.64	21.34	19.19	17.94	24.61	20.21	16.41	14.31	12.01
6775	—	—	—	—	134.9	128.1	76.8	33.1	10.6
7411	147.5	110.7	58.1	33.4	147.5	140.9	86.6	34.9	11.3
8 078	160.8	123.9	60.4	44.5	160.8	158.1	102.0	35.3	13.4
8 754	174.2	142.3	68.6	46.0	174.2	169.9	113.0	49.3	16.2
9.450	188.0	157.8	72.9	53.2	188.0	184.4	122.8	39.4	—
10125	201.5	171.8	78.0	63.7	201.5	201.4	133.9	55.7	13.1
11000	—	—	—	—	218.9	216.3	156.0	80.3	23.5

σ_z values in 10^2 kPa

Once known the σ_z values, the average friction stress ($\bar{\tau}$) for each interval between instrumented levels were computed. These values were the following:

TABLE III

Average Friction Stress τ

LOAD (kN)	8.05m long Pile			14.00m long Pile			
	24.64 / 21.34	21.34 / 19.19	19.19 / 17.94	24.61 / 20.21	20.21 / 16.14	16.41 / 14.31	14.31 / 12.01
6 775	—	—	—	0.58	2.70	4.16	1.96
7 411	3.41	4.89	3.95	0.58	2.86	4.92	2.05
8 078	3.42	5.91	2.54	0.24	2.95	6.35	1.90
8 754	2.95	6.36	3.62	0.38	2.99	6.07	2.88
9 450	2.30	7.90	3.15	0.31	3.24	7.94	—
10125	2.75	8.73	1.49	0.10	3.58	7.45	3.70
11 000	—	—	—	0.23	3.17	7.21	4.94

$\bar{\tau}$ values in 10^2 kPa

From the aforementioned results it becomes possible to compute the amount of applied load that turned partially into Friction load and partially into Point load:

TABLE IV

Friction and Point Loads

APPLIED LOAD	8.05m long Pile			14.00m long Pile		
	FRICTION	POINT	F/P	FRICTION	POINT	F/P
6 775	—	—	—	6 245	530	11.78
7 411	5 733	1 676	3.42	6 841	570	12.00
8 078	5 842	2 236	2.61	7 408	670	11.06
6 754	6 443	2 311	2.79	7 944	810	9.81
9 450	6 777	2 673	2.54	—	—	—
10 125	6 674	3 451	1.93	9 475	650	14,58
11 000	—	—	—	9 820	1 180	8,32

Loads in kN

The 8.05m pile displacement results from the tell-tales measurements are presented in figure 4a.

The 14.00m pile displacement results from the tell-tales measurements are presented in figure 4b.

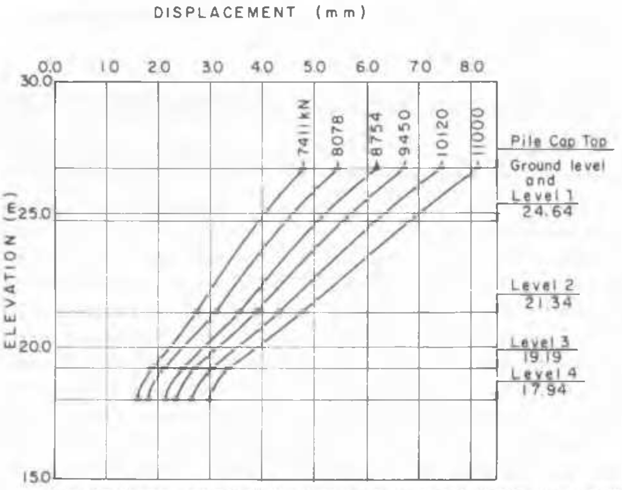


fig. 4a Measured total displacement x Depth (8.05m long pile)

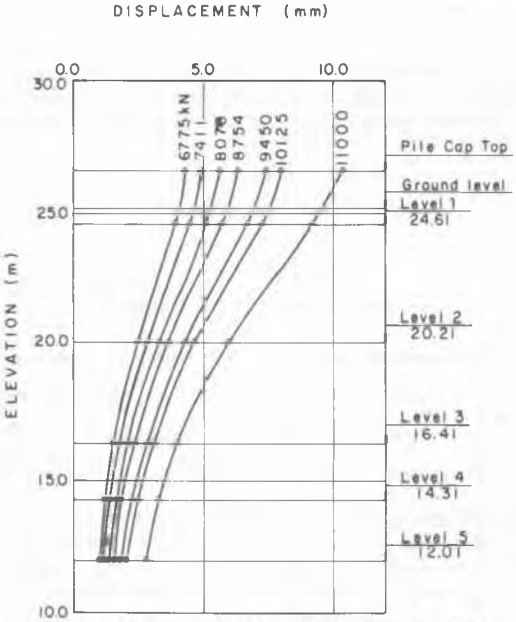


fig. 4b Measured total displacement x Depth (14.00m long pile)

CONCLUSIONS

The tell-tale monitoring allowed for a check on the strain-gage data; it also provided a knowledge of the true piles displacements at their tips.

The Friction load (F)predominated over the Point load (P) for both piles; their ratio (F/P)however was substantially higher for the 14.00 m pile in comparison with the shorter one.

The load transfer characteristics for the shorter pile (8.05m) and for the longer pile (14.00m) were about equal in their stress levels - as can be verified by the σ and τ values-since both are restricted by the same sub-surface materials.

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