BEHAVIOR OF DRIVEN PRECAST-CONCRETE PILES SUBMITTED TO UPLIFT LOADS IN A COLLAPSIBLE SANDY SOIL

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Resumo

Este artigo apresenta uma análise de provas de carga à tração em três estacas pré-moldadas de concreto, cravadas em solo arenoso colapsível. Essas estacas possuíam 12 metros de comprimento e seção quadrada (0,17 x 0,17 m), sendo instrumentadas com *strain gauges*, objetivando conhecer a transferência de carga em profundidade. Provas de carga axiais estáticas (“lentas”) foram efetuadas em três estacas-teste com o solo em sua umidade natural e uma quarta prova, em uma das estacas, com o solo encharcado em torno da cabeça da estaca. No mesmo solo também foram realizadas outras três provas de carga com estacas escavadas, de 12 metros de comprimento e 0,20 m de diâmetro, visando comparar esses resultados com as estacas pré-moldadas. Os ensaios foram realizados no campo experimental de fundações da Universidade de São Paulo (USP). Os resultados obtidos foram avaliados por meio de métodos analíticos e empíricos.

Palavras-chave: *estacas, provas de carga, solos porosos.*

Abstract

This paper presents the analysis of uplift load tests in three precast-concrete piles carried out in a collapsible sandy soil. The piles had 12 m in length and 0.17 x 0.17 m cross section and used strain gauges, in order to know the load transfer in depth. Three tests were performed in a Slow Maintained Load way and conducted in natural soil moisture. A fourth test was carried out after soaking the soil around the pile head. In the same soil it also was carried out other three load tests with bored piles (12 m long and 0.20 m in diameter), aiming at to compare the results with the precast-concrete piles. The tests were performed in the experimental research site at the State University of São Paulo (USP). The results obtained were evaluated by analytical and empirical methods.

Keywords: *piles, load test, porous soils.*

1. Introduction

Colluvial collapsible sand porous soils occur in the west center region of Brazil, representing about 5% of the total country area. The origin of the geologic formation is the Bauru sandstone, a sedimentary rock of Mesozoic age that covers all the region (city of Ilha Solteira, located at the north-west of São Paulo State), in the basalt of Serra Geral Formation. In many places these porous colluvial soils reach the thickness of 15 meters (MENEZES, 1997).

The soil of the site presented high porosity and collapsible characteristics up to 8 m in depth. It is quite often the occurrence of sandy soils in the center-south of Brazil. IN our study the site soil was characterized through field tests (Standard Penetration Test – SPT and Cone Penetration Test - CPT) and laboratory tests.

Precast-concrete piles were built specially to this investigation. They have special elements (tie-rod and iron hose) placed inside along the entire length. In every pile, instrumentation was installed at several depth levels to obtain results of load transfer along the shafts. The piles were driven in sandy soil, with high porosity and collapsible characteristics, in the city of Ilha Solteira. Vertical Slow Maintained Load Tests (VSMLT) were conducted in three piles subject to uplift forces.

Due to the very low bearing capacity in driven piles obtained in the load tests, three bored piles were built and submitted to load tests at the same place for comparison. Results showed an uplift bearing capacity four times higher for the bored piles, indicating a characteristic of skin friction loss for driven piles in the soil, probably during the driven process.

2. Field penetration tests

In the area of load tests, five Standard Penetration Tests (SPT) and five Cone Penetration Tests (CPT) were performed. In these tests the resistance provided by the soil due to the vertical penetration of a Dutch Cone was also registered. The external and internal diameters of the cone were 35.7 and 16.0 mm, respectively. The base area was 10 cm^2. Table 1 shows the results of the penetration tests.

Table 1: Results of the penetration tests.

Depth (m)	SPT	SPT-T (N.m)	q_C (MPa)	f_S (KPa)
1.0	6	32	4.7	60.7
2.0	2	22	1.7	40.1
3.0	2	13	1.9	40.6
5.0	4	31	3.4	66.3
7.0	6	31	4.5	99.6
9.0	7	45	4.8	114.0
11.0	9	78	6.8	228.4
13.0	10	82	6.7	314.5
15.0	10	54	6.9	269.1

3. Laboratory tests

The laboratory tests were performed on soil sub-samples extracted meter by meter from the pit shaft. The consolidation tests, unconfined compression and consolidated undrained triaxial tests were performed on undisturbed samples. Results are shown in Table 2.

Table 2: General characteristics of the soil.

Depth (m)	e	ρ (KN/m^3)	c (KPa)	ϕ (degrees)
1.0	0.85	16.0	0	32.2
2.0	0.93	14.8	3.0	31.8
3.0	1.00	14.9	2.0	32.5
5.0	0.90	14.8	2.0	33.3
7.0	0.81	15.9	3.0	33.0
9.0	0.74	18.4	16.0	30.3
11.0	0.70	17.7	20.0	28.8
13.0	0.70	18.8	20.0	28.8
15.0	0.77	17.0	17.0	30.1

4. Static instrumentation

The static instrumentation consisted of strain gauges along the pile shaft, in five levels. One level of strain gauges was used and placed out of the soil influence at the head of the piles, in order to allow the determination of the value of Young's Module.

5. Load tests

Slow Maintained Load Tests were performed according to the Brazilian Standard NBR-12131/97. The loads were applied with increments of 5 KN. Three tests were performed in a natural condition of moisture content soil. Figures 1, 2 and 3 show the load-settlement curves obtained. A fourth test was carried out after soaking the soil around the pile head (Figure 4).

6. Load transfer

Due to the low skin friction up to eight meters deep, the analysis for the load transfer data, took into account only two parts of the piles shaft. The first was related to the head of the pile, and the other was relative to the intermediate portion of the pile. The load distribution in the piles is shown in Figures 5 to 8.

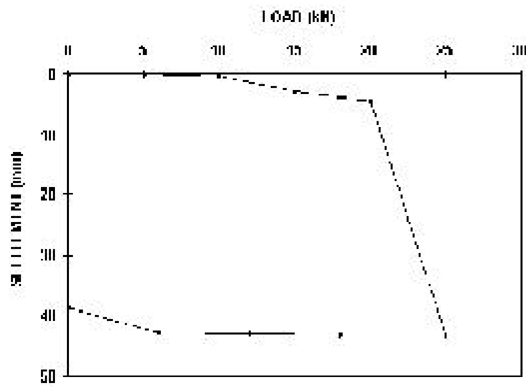

Figure 1: Load-settlement curve (Pile 1).

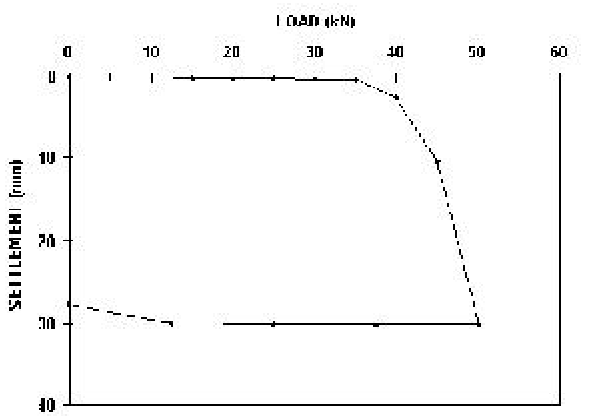

Figure 2: Load-settlement curve (Pile 2).

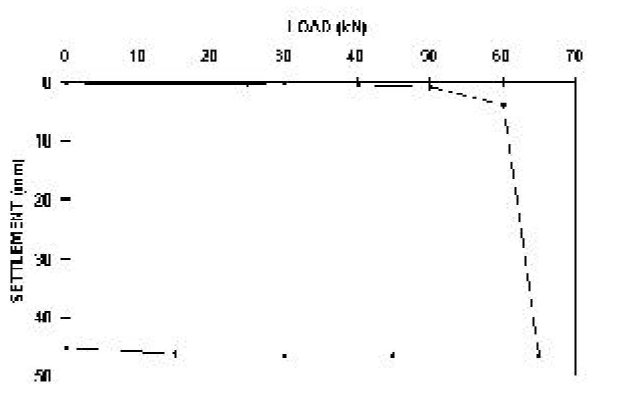

Figure 3: Load-settlement curve (Pile 3).

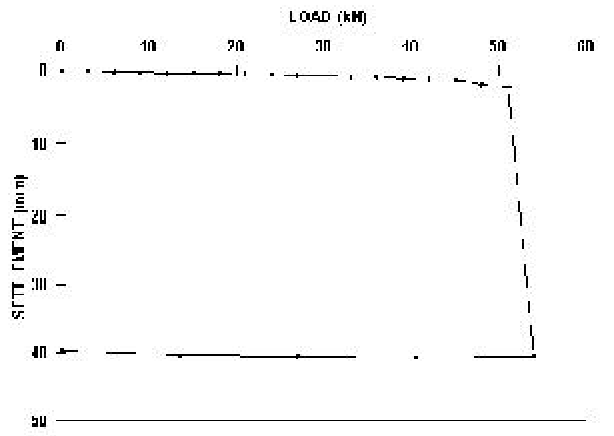

Figure 4: Load-settlement curve (Pile 4).

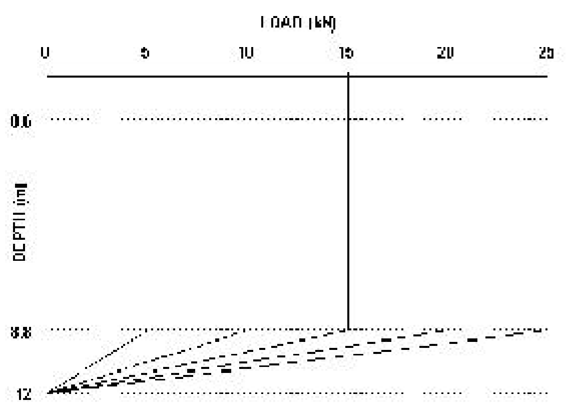

Figure 5: Load transfer results (Pile 1).

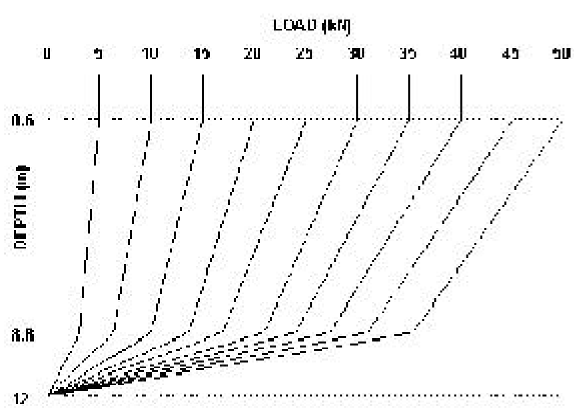

Figure 6: Load transfer results (Pile 2).

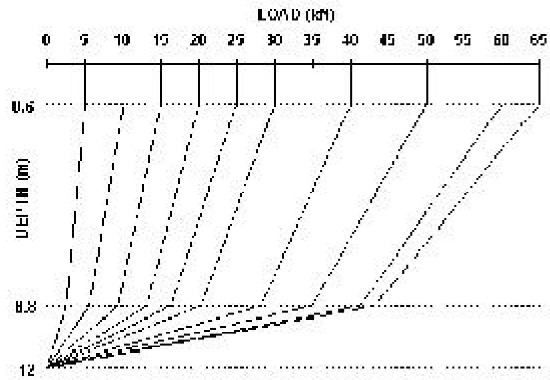

Figure 7: Load transfer results (Pile 3).

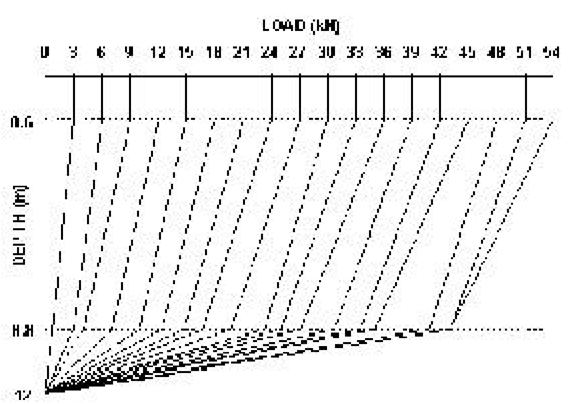

Figure 8: Load transfer results (Pile 4).

7. Discussion of results

Final load values were extremely low in all piles (Table 3). Pile skin friction values were much lower than the expected from those reached by the cast in place piles. The values calculated through analytic and empirical models are presented in Tables 4 and 5, respectively. As the analysis results showed skin friction loss, it became clear that these formulas did not show a good fit for estimating bearing capacity as suggested by LEUNG et al. (1991). Figure 9 shows the load-displacement curves obtained.

Vertical static load tests were applied to three bored piles (12 m long and 0.20 m in diameter) so that uplift load values could be found in another type of foundation (precast-concrete piles). Figures 10, 11 and 12 show the load-settlement curves. The laboratory tests conducted with inundation in some pressures have shown that the soil is collapsible up to 7 m in depth. The collapse index is higher in the first meters as shown in Figure 13.

The aim of these tests was to confront the values obtained with those values reached by the precast-concrete piles. As demonstrated, when submitted to uplift load, the precast-concrete piles showed low bearing capacity.

Table 3: Results of static tests.

Pile test	Soil type	Capacity (KN)
1	Non-soaked	25
2	Non-soaked	50
3	Non-soaked	65
4	Soaked	54

Table 4: Results of analytical methods.

Author[a]	Lateral (KN)	Total (KN)
DAS	224	246
Grenoble	366	378
Meyerhoff	775	787

Table 5: Results of empirical methods.

Method[b]	Lateral (KN)	Total (KN)
Décourt-Quaresma	163	175
P. P. Velloso	613	625

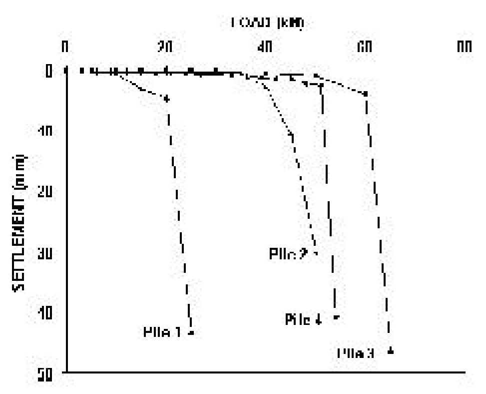

Figure 9: Load-settlement (Piles 1, 2, 3 and 4).

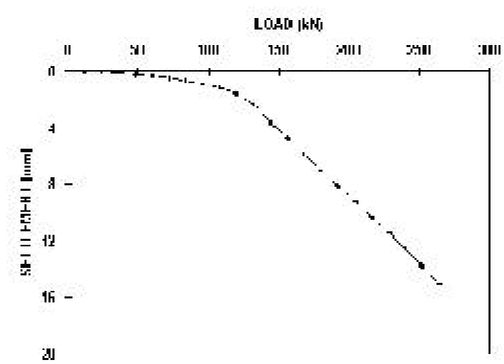

Figure 10: Load-settlement (bored Pile 5).

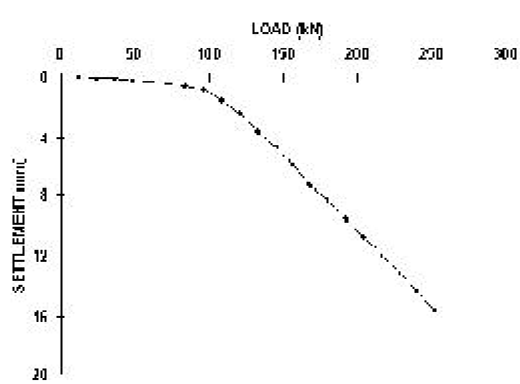

Figure 11: Load-settlement (bored Pile 6).

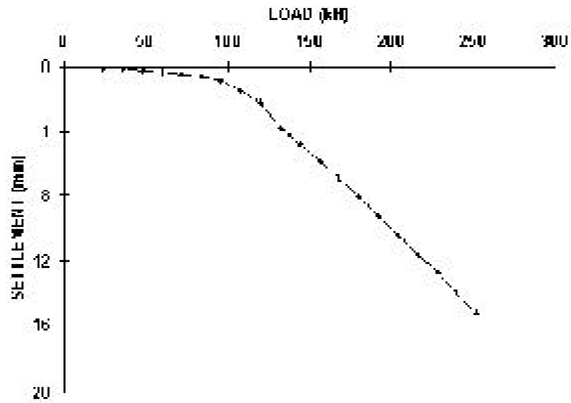

Figure 12: Load-settlement (bored Pile 7).

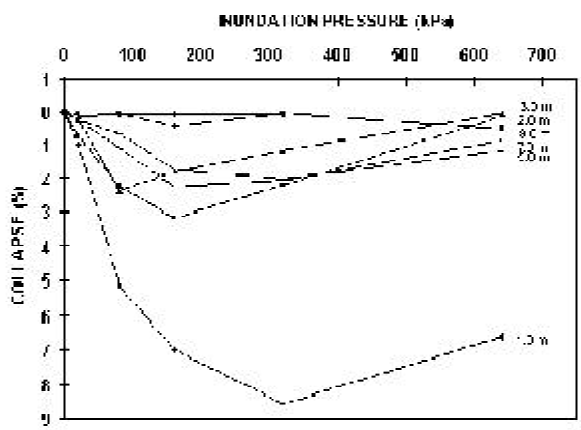

Figure 13: Collapse curves (Piles 1, 2, 3 and 4).

8. Conclusions

The laboratory tests conducted with inundation in some pressures have shown that the soil is collapsible up to 7 m in depth. The collapse index is higher in the first meters. Lower values of bearing capacity for the three precast piles in comparison to the cast in place piles indicate that the precast-concrete piles used are not adequate for soil friction requirement in the site. The field analysis and observations suggest that vibrations due to the driving process cause irrecoverable lateral pile displacement from the soil at a depth of few meters. The soaking of the surface soil around the pile head during 48 hours causes a 50% skin friction loss up to 8 meters in depth.

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