Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical Engineering

doi:10.3233/978-1-61499-656-9-2149

Installation of jacked piles in sandy soils

Installation des pieux enfoncés par vérin dans le sol sablonneux

Jurgis Medzvieckas & Danutė Sližytė
Geotechnical department of Vilnius Gediminas Technical University
jurgism@st.vtu.lt, danute@st.vtu.lt

ABSTRACT

When renovating historic buildings it is often necessary to reinforce the foundations. An effective and often used in Lithuania method is the underpinning with jacked piles. The piles are pressed into the soil without any noise or vibration by using static force. The process of pressing is similar to the static penetration test therefore it would be rationale to compare the pressing force, which has been measured, with the force calculated according to CPT data. The limit compressive resistance of the pile would be very convenient to estimate from the pressing force of the pile.

RÉSUMÉ

Pour la rénovation des bâtiments inscrits au patrimoine historique on est souvent obligé de renforcer les fondations. Un mode efficace et souvent utilisé en Lituanie consiste en renforcement des fondations par des pieux enfoncés dans le sol. A cette fin on applique une force de pression statique, sans bruit et sans vibration. Le processus d'enfoncement est très similaire à l'essai statique de pénétration, donc il est logique de comparer les efforts mesurés au cours de l'enfoncement à ceux calculés suivant les données obtenues à l'aide d'un pénétromètre à cône (CPT). La valeur de la force d'enfoncement appliquée permet d'évaluer le pouvoir porteur des pieux.

1 INTRODUCTION

At every historical stage, human activity is bearing a very large influence on the environment and is changing ground conditions, which determine the installation of foundations and their behaviour when exploiting. Additional foundation settlements may be caused by the influence of transport. As a consequence of the ground changes and the changes of foundation working conditions the cracks in the walls of the structures unclose (J. Medzvieckas and S. Gadeikis, 2002). The preservation of historical buildings must warrant the stability of ground and foundations using most suitable and effective methods. The underpinning with jacked piles is an effective method. Jacked piles may be installed under or beside foundations.

2 THE UNDERPINNING WITH JACKED PILES

Jacked piles are pressed into the soil by jacks without any noise or vibration. According to Perley E.M. and Gdalin S.V., (1990) the installation of jacked piles requires 1,5÷3,0 times less power than the installation of other types of piles. The pressing force and depth are being checked during installation. The pressing is finished after reaching the proper depth and pressing force. The process is similar to static penetration test therefore it would be rationale to compare results.

The researchers of Geotechnical Research Laboratory of Vilnius Gediminas Technical University (VGTU) have made many projects of underpinning with jacked piles and have participated in their realization from 1990 till now. Some of the piles have been tested by the static load tests.

3 THE TESTS WITH JACKED PILES

In 2000-2003 in the sand box of Geotechnical Science Laboratory of VGTU the tests with piles have been carried out, including 3 tests with jacked piles. The piles have been pressed into sands of different densities, prepared for each test in the box.

The diameter (D) of the pile model (Fig. 1) was 0,22m, length 3,2m. Before pressing the pile, the static penetration test in the point of pressing has been carried out. When pressing the piles, the pressing force and the force acting the base of the pile were being measured. After the installation the piles have been tested by static load tests. It was possible not only to estimate the limit resistance of piles, but also to measure the resistance of pile base as also to estimate the shaft resistance from static load tests. The results of pressing and the static load tests are given in columns 3 and 4 of Tab. 1. The results calculated from the data of CPT tests are given in the other columns of Tab. 1. The shaft resistance computed according to the data of local friction f_{si} and the force acting the pile base, computed from the cone resistance q_c at pile tip level, are given in column 5. The limit resistance of the pile was found after having summed the results. The shaft resistance in other columns was computed according to q_c, using the conversion coefficient. Such values of the coefficient were selected that at least in one case they would correspond to the measured values (bold frame in Tab. 1). The forces acting the pile base, given in these columns have been calculated from the cone resistance q_c where:

- the values have been computed in the interval used in Lithuania - 1D (where D is the diameter of the pile) above the pile tip and 4D below the pile tip;
- the values have been computed in the interval suggested by Fleming and Torburn (1983) - 8D above the pile tip and 2D below the pile tip;
- the values have been computed in the interval suggested by Norblund (1963) - 3D above the pile tip and 2D below the pile tip.

The limit pile resistance has been calculated by summing the results given above with the shaft resistance, computed from local friction values from CPT. The curves of the measured force acting the pile base and the force calculated from CPT test are given in Fig. 2.

139 piles have been pressed when underpinning the Rigas Castle in Latvia. The curves of the measured pressing force of 3 piles and the calculated forces from CPT test are given in Fig. 3.

Table 1: The results of tested piles

Mark	Pile lenght (m)	Shaft friction (kN) according to					
		pressing	st.l.test	$f_{s,CPT}$	$q_{c,CPT,0.005}$	$q_{c,CPT,0.017}$	$q_{c,CPT,0.007}$
1	2	3	4	5	6	7	8
FDP-0 / CPT-2	2,85	29	38	20	28	96	40
FDP-1 / CPT-67	3,05	139	120	55	40	137	57
FDP-3 / CPT-35	2,95	130	160	121	98	332	137
		Pile base resistance (kN) according					
		pressing	st.l.test	$q_{c,CPT,0D/0D}$	$q_{c,CPT,1D/4D}$	$q_{c,CPT,8D/2D}$	$q_{c,CPT,3D/2D}$
FDP-0 / CPT-2	2,85	143	102	162	151	124	153
FDP-1 / CPT-67	3,05	128	78	199	173	129	197
FDP-3 / CPT-35	2,95	303	200	313	218	260	343
		Total pile resistance (kN) according					
		pressing	st.l.test	$q_{c,CPT,0D/0D}$	$q_{c,CPT,1D/4D}$	$q_{c,CPT,8D/2D}$	$q_{c,CPT,3D/2D}$
FDP-0 / CPT-2	2,85	172	140	182	171	144	173
FDP-1 / CPT-67	3,05	267	198	254	228	184	252
FDP-3 / CPT-35	2,95	433	360	433	339	381	464
Pile No.62	12,55	500	350	587	516	424	529
Pile No.129	16,00	500	470	565	639	550	668
Pile No.131	14,10	500	450	664	651	602	672

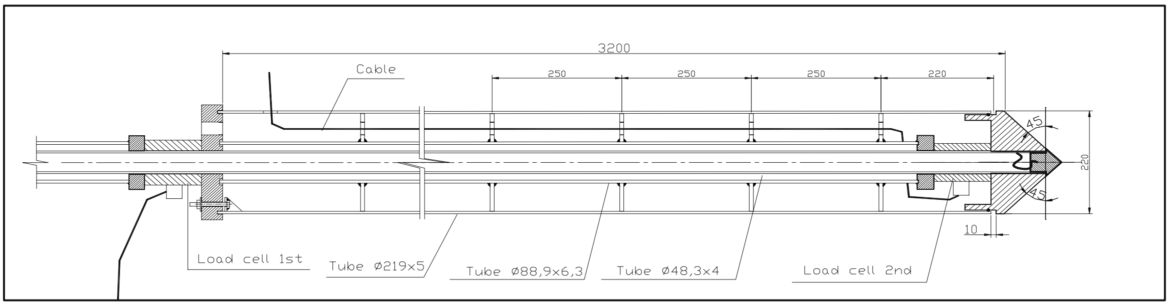

Figure 1. The model of the jacked pile.

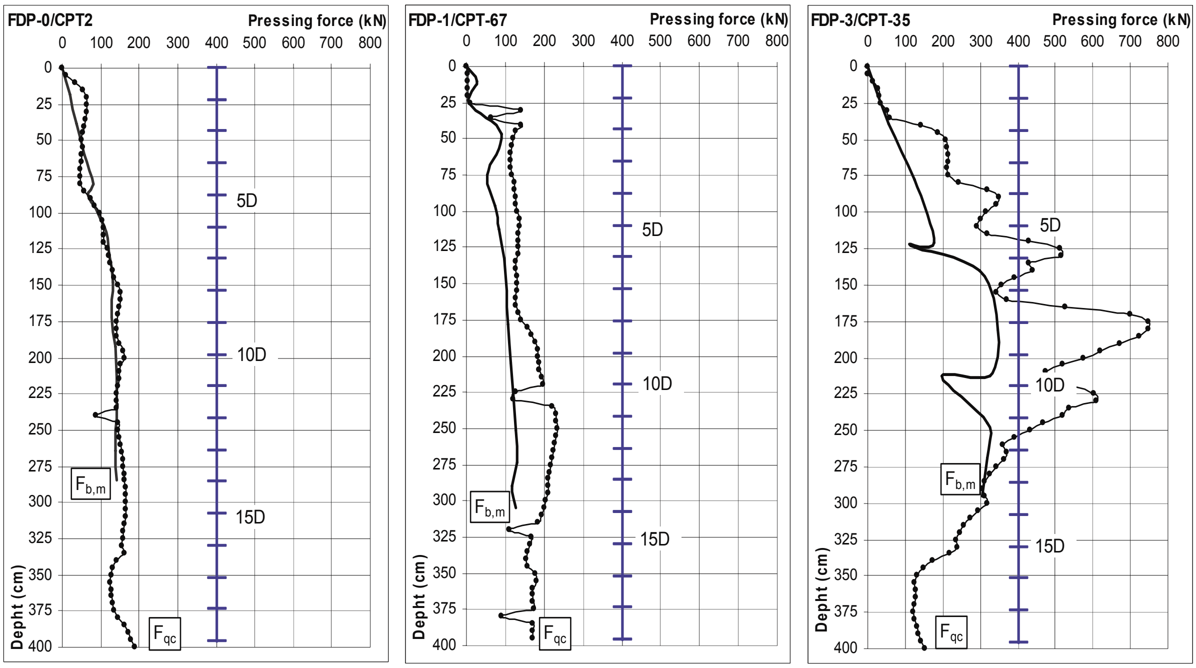

Figure 2. The curves of the measured forces ($F_{b,m}$), acting at the pile tip during installation and curves of the calculated forces according to CPT test ($F_{qc}=Aq_c$)

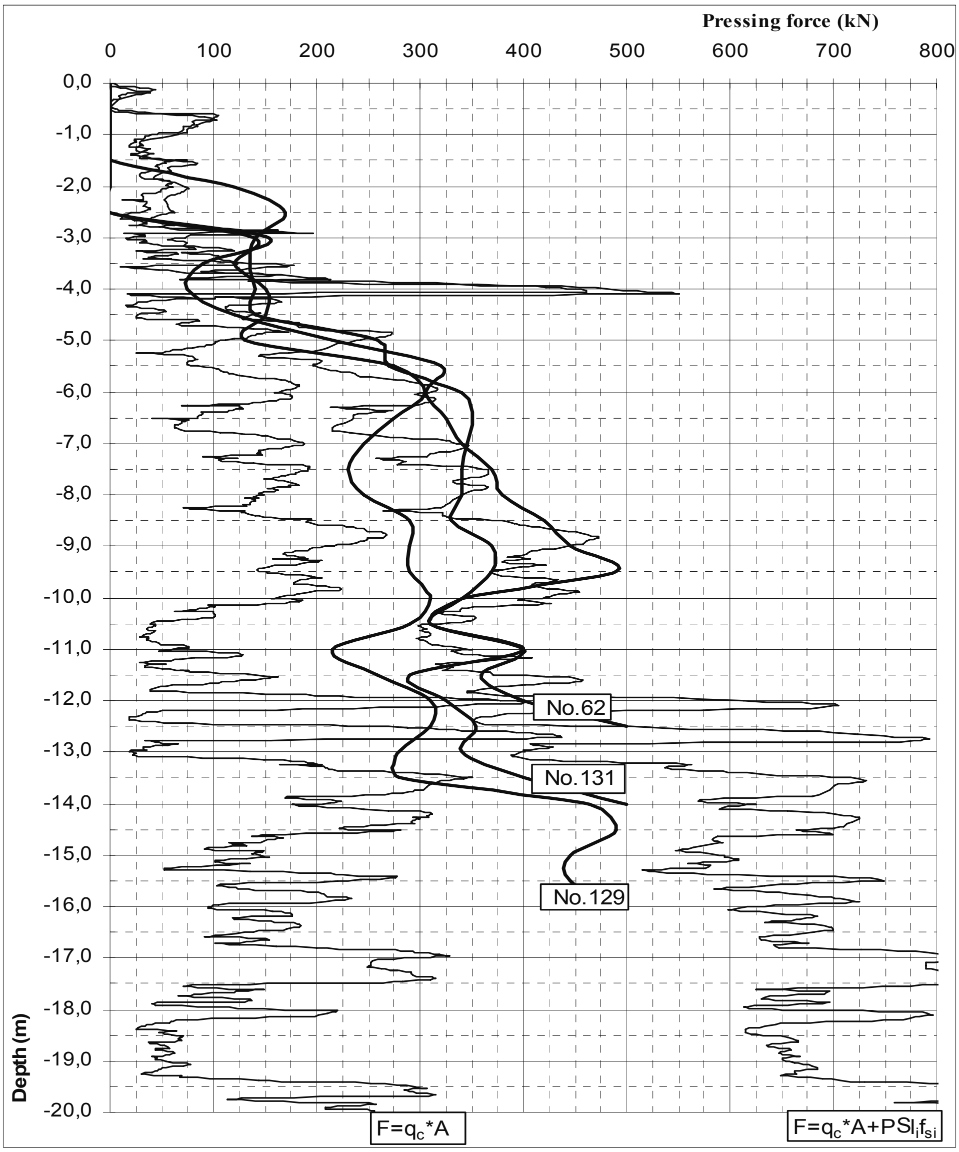

Figure 2. The curves of the measured forces, acting at the pile tip during installation and curves of the calculated forces according to CPT test.

Table 2: The results of tested jacked piles from several sites.

Pile No	Site - soil	Length of pile (m)	Pressing force Fo (kN)	Limit resistance Rc of pile (kN)	Fo/Rc
54	Vilnius, Odminiu str. - saturated fine sand	3,20	475	300	1,58
58	Vilnius, Odminiu str. - saturated fine sand	3,20	475	280	1,70
62	Riga, Pils Laukumas str.- sand	12,55	500	350	1,43
129	Riga, Pils Laukumas str.- sand	16,00	500	470	1,06
131	Riga, Pils Laukumas str.- sand	14,10	500	450	1,11
20	Vilnius,Totoriu str. - saturated sand	2,90	460	340	1,35
19	Vilnius,Totoriu str. - saturated sand	2,60	500	430	1,16
51	Vilnius,Laisves av. - sand	3,60	500	380	1,32
52	Vilnius,Laisves av. - sand	3,60	500	380	1,32
FDP-0	VGTU - sand	2,85	172	140	1,23
FDP-1	VGTU - sand	3,05	267	198	1,35
FDP-3	VGTU - sand	2,95	433	360	1,20

These 3 piles were selected from series of piles, which had been tested by the static load tests, because the CPT test had been carried out near to them. The forces measured and calculated for these piles are given in Tab. 1.

The ratio between pressing force and limit resistance of the piles from the static load tests is given in Tab. 2. Only a few results from large amount of piles, pressed in sandy soils and tested by the static load tests, are given in Tab. 2.

4 THE ANALYSIS OF THE DATA

The ratio between measured and calculated forces is not very large and depends on shaft resistance evaluation and interval, when computing the ground resistance around the pile tip from CPT data. However, there is a clear-cut distinction between measured and calculated forces when evaluating the pile base resistance and shaft resistance separately. In one case, the measured and calculated values in the test are close, while in the other cases there are distinct differences. Minimal differences between measured and calculated values have been found when computing the resistance of the pile base in the interval of 1D above and 4D below the pile tip. Close measured and calculated curves of pressing force during installation for jacked piles have been found when using this interval.

The limit and design resistance would be very convenient to calculate from the pressing force. The ratio between pressing force and limit pile resistance, estimated from the static load test, for piles installed in sands are ranging from 1,06 to 1,7. Having evaluated all the piles tested, the ratio mostly is ranging between 1,25÷1,35.

Bacholdin B.V.,(1988) suggested to calculate the long-termed bearing resistance of a pile, estimating the relaxation in the ground:

$$F = \frac{F_t - F_o \cdot e^{-t/T}}{1 - e^{-t/T}} \tag{1}$$

where F_t – the load under which the pile reached limit resistance after time t, F_o – the maximum pile load, which corresponds to the pressing force, T – period of relaxation. The author presents such results, while the maximum load (pressing force) F_o = 2520 kN, the load that the pile held for 8 min F_t = 2380 kN and the calculated long-termed load F = 2200 kN.

Perley E.M., Gdalin S.V.(1990) suggested to compute the limit resistance using:

$$F = F_o \cdot K_v \cdot K_t \tag{2}$$

where K_v – empirical coefficient that estimates the speed of pressing; K_t – empirical coefficient, that estimates the alteration of bearing resistance because of the relaxation in the ground. The values of these coefficients for sandy soils depend on the soil permeability.

Shagin A. L. et al. (1991) suggested a more simple formula to define the limit resistance:

$$F = F_o \cdot \chi \tag{3}$$

where χ – coefficient of correlation (for sands – 0.85).

If we referred to the recommendations of EC7 such equation is acceptable and convenient to calculate the resistance of jacked piles. The characteristic value of limit resistance of the pile then will be equal:

$$R_{c,k} = \alpha \cdot F_o \tag{4}$$

where : α – coefficient of transition. Its size would depend from soils of the ground. The value of transition coefficient for a sandy soil should be 0,7.

5 CONCLUSIONS

There is a clear-cut distinction between measured and computed forces, which act the base and shaft of the pile.

The difference between measured and computed limit resistance of the pile is not so distinct, as for base and shaft of the pile separately.

The interval 1D/4D, used in Lithuania, is suitable to compute the limit resistance of jacked piles.

The most simple and applicable way to estimate jacked pile limit resistance would be calculation from the pressing force.

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