Panel discussion: Bored pile foundation execution and its relation to overall pile load settlement

Débat de spécialistes: Relation entre l'exécution des pieux forés et le tassement total du pieu chargé

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ABSTRACT: Bored piles are still of a wide use in engineering practice. Large diameter piles can bear significant vertical and horizontal loads which are in various range transmitted by shaft and base of piles to the ground. The fundamental role in estimation of work of a pile plays load - settlement relationship (settlement curve). The strengthening of base of large diameter piles in terms of prestressing essentially improves settlement curves, especially within the range of working loads. Presently, new non-vibration technologies of piles' execution are more commonly used. It mostly regards CFA, Atlas, Omega and jet-grouting piles. These piles are very effective by revealing significantly greater rigidity then classical bored piles. In this short report some exemplary solutions are presented.

RESUME: L'utilisation de pieux forés est tonjours bien répandue en pratique. Des pieux des larges diamèters peuvent transmettre de larges forces verticales et horizontales, avec des charges reparties différement entre la base et le fût du pieux. La rélation charge-tassement (courbe de tassement) a une grande importance dans l'evaluation du comportement d'un pieu dans le sol.
Le renfocement de la base d'un pieu à large diamètre va améliorer sensiblement la courbe de tassement, specialement dans le domaine des charges courrantes. Les téchnologies nouvelles de l'execution des pieux sans choc telles que pieux CFA, Atlas, Omega, Jet-grouting sont utilisées de plus en plus souvent. Ces pieux sont très effectifs et présentent la résistance considérablement pus élevée que des pieux forés classiques. Quelques examples des solutions des pieux sont donnés dessous.

APPLICATION OF NEW TECHNOLOGIES TO BORED PILES

Prof. W. F. Van Impe (1997) in his Theme Lecture has mentioned deep foundations as one of three main topics being analysed during Session 2.

Among the papers accepted for Session 2 almost 54% dealt with piles what means that there is a significant interest to this type of foundations. In recent years one can observe a great development of new technologies of piles' performance. Traditional methods have been essentially improved in order to correct the load - settlement characteristics.

Increasing vertical and horizontal loadings together with new possibilities of construction of strong devices continuously contribute to the application of large diameter bored piles.

On the other hand in the same period of time several new technologies have been introduced in the group of displacement piles, for example CFA, Atlas, Omega and Jet-grouting.

For the work of pile a fundamental role plays load-settlement relationship. As an example the generalised load-settlement curves for bored piles have been shown in Fig. 1.

Present activities in engineering practice aim at the increase of stiffness, particularly in the primary and working loading phase. General characteristic of load-settlement curve may be significantly improved when taking into account secondary loading of pile, where we deal with prior base displacement, see Fig. 2.
In the world are used preloading cells (with stones) for compressing the soil beneath base of bored piles by grouting (Bolognesi and Moretto, 1973).

The injection of cement grout beneath the pile base was used in order to decrease the deformation of disturbed subsoil (Yeats, O'Riordan, 1989 and Gawor et al., 1994). In this case, the injection tubes were brought under the base of piles and injection holes in the tubes were sleeved with rubber (manchette).

In the Geotechnical Department of Gdańsk Technical University the special cell performed from semi-permeable geotextilie is being used for injection under the pile base. Next figures regard an example of the pile structure in Gdynia (Poland). The investigations of a subsoil for this construction were performed using CPT test (see Fig. 3). The pile executed in medium dense sands with prestressing under the base reveals good load-settlement characteristic up to 10 MN of load (see Fig. 4).

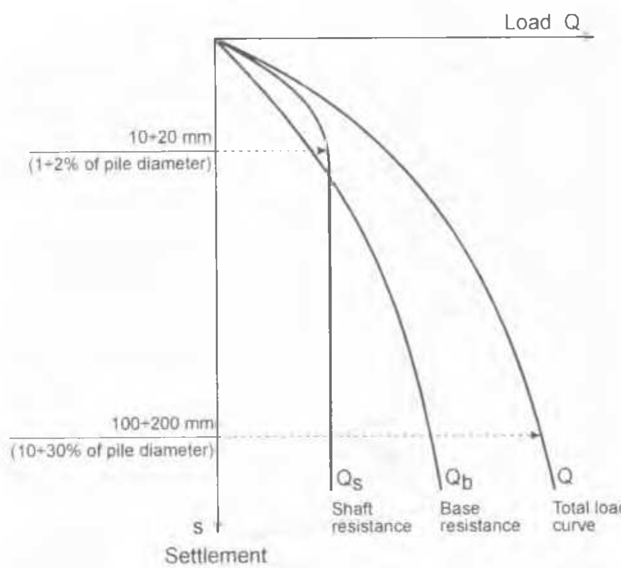

Figure 1. Generalized load-settlement curves for bored piles.

In next part of the report transfer functions method together with numerical code PALOS will be used in order to carry out the comparative analysis of settlement curve (see, Gwizdała, 1997, Gwizdała and Tejchman, 1997).

New technologies of execution of piles improve the character of load - settlement curve. It can be observed in the exemplary figure 5, where the results for bored Wolfsholz pile (concreted under pressure) and for CFA pile are shown (Kartuzy, Poland).

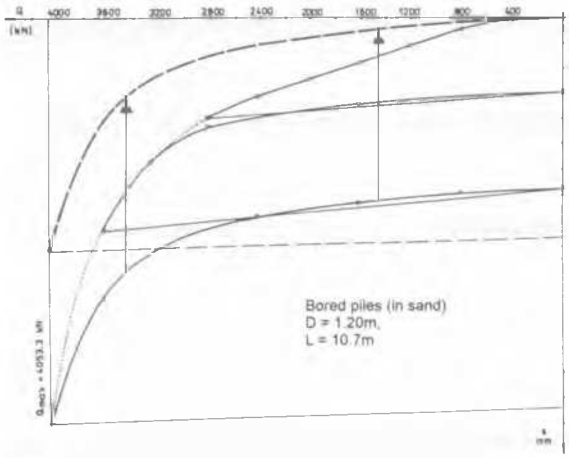

Figure 2. Load-settlement curve for large diameter bored pile in sand

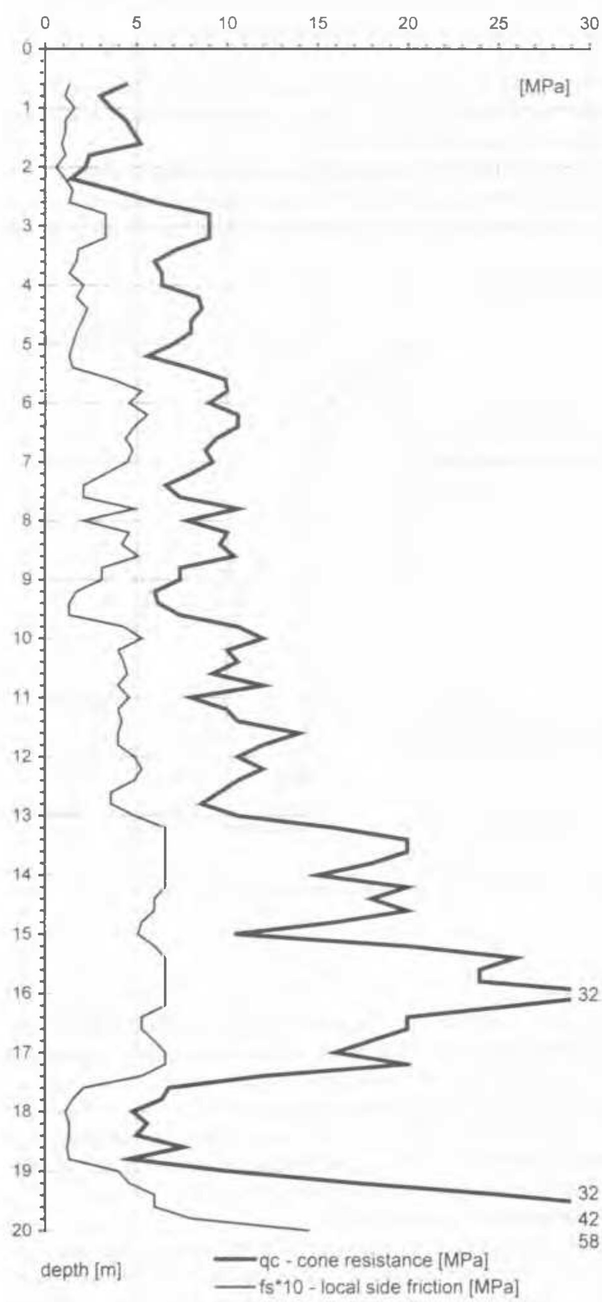

Figure 3. Test results from a CPT(U) test (Gdynia).

For another CFA pile ϕ 800 mm executed in layered subsoil characterised by a differentiated bearing capacity, the comparison between theoretical load-settlement curve according to PALOS calculations with the results of field test accompanied by the 30% increase of the resistance has been performed (see Fig. 6).

Another effective technology is Jet-grouting. In Table 1 the proposals of shaft resistance for cohesive soils for this type of piles and the values for bored piles are collected. The proposed values of shaft resistance are around 1.5 to 2.0 times greater then for bored piles (see C group in Table 1). The comparative calculations of overall load - settlement curve in terms of PALOS numerical code demonstrate good consistence with in situ measurements taken from model tests. Detailed calculation results taking into account load - settlement relationship (Q-s), base resistance (Q_b-s), shaft resistance (Q_s-s) and shortening of pile ΔL for subsequent levels of load are presented in Table 2. Application of proposed values of shaft resistance from Table 1 yields good consistency with the results of filed tests (see Fig. 7).

Table 1 Shaft resistance t in kPa for jet grouting piles

	Soil type	Liquidity Index, I_L					
		< 0	0	0.25	0.5	0.65	0.75
		JET GROUTING PILES					
	[Zmudziński, Motak, 1996]:						
A	- sandy clay	135	110	80	50	30	18
	- clay	125	100	70	40	25	14
	- silt, sandy silt	110	85	75	35	20	9
		BORED PILES					
	[Polish Code, PN-83/B-02482]:						
B	- sandy clay	95	50	41	31	14	13
	- clay	95	50	28	25	17	11
	- silt, sandy silt	65	30	23	16	11	7
		ratio A/B					
	- sandy clay	1.42	2.20	1.95	1.61	2.14	1.38
C	- clay	1.32	2.00	1.84	1.60	1.47	1.27
	- silt, sandy silt	1.69	2.83	3.26	2.19	1.82	1.29

Table 2 PALOS calculation for pile No 3, diameter D = 0.8 m, L = 12.0 m

Load Q	kN	365	901	1347	2373	2599
Base resistance Q_b	kN	41	129	205	593	819
Shaft resistance Q_s	kN	324	772	1142	1780	1780
Q_b/Q	%	11.2	14.3	15.2	25.0	31.5
Head settlement s	mm	0.71	2.65	5.03	25.05	46.85
s/D	%	0.09	0.33	0.63	3.26	5.86
Base settlement s_b	mm	0.10	1.00	2.50	21.00	41.00
s_b/D	%	0.01	0.13	0.31	2.63	5.13
Pile shortening: $\Delta l = s - s_b$	mm	0.61	1.65	2.53	5.05	5.85

CONCLUSIONS

Bored piles are still of wide use in the engineering practice. They transmit its load by shaft and base. The redistribution of loads between shaft and base changes with type and state of the soil and depends on the phase of loading. The strengthening of the base of large diameter pile in terms of prestressing, for example by injection process significantly improves the characteristic of load-settlement curve, particularly in the range of working loads.

New, non-vibrated technologies of execution of piles are very effective. It regards for example CFA, Atlas, Omega, Jet-grouting piles.

Settlement curves reveal essentially greater stiffness, especially for working loads. One can also observe greater bearing capacity of such piles then for bored piles executed by standard methods.

In this report some exemplary results are presented. The results have been confirmed by significant number of observations. It is planned to elaborate these results from the statistical point of view (see, Gwizdała, 1997).

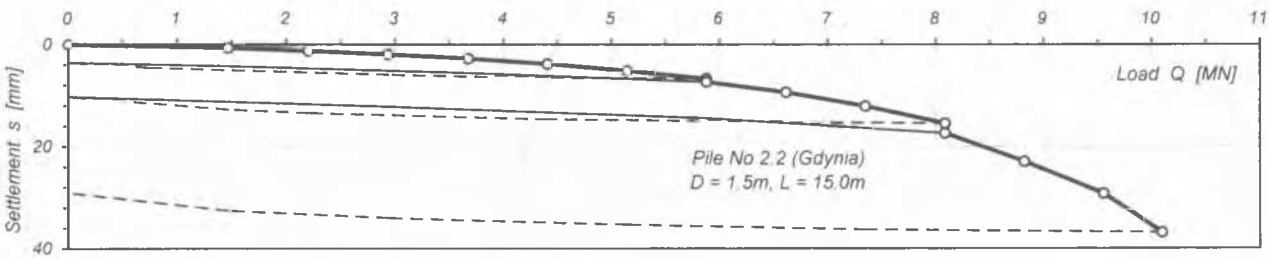

Figure 4. Load-settlement curve for large diamenter bored pile (Gdynia).

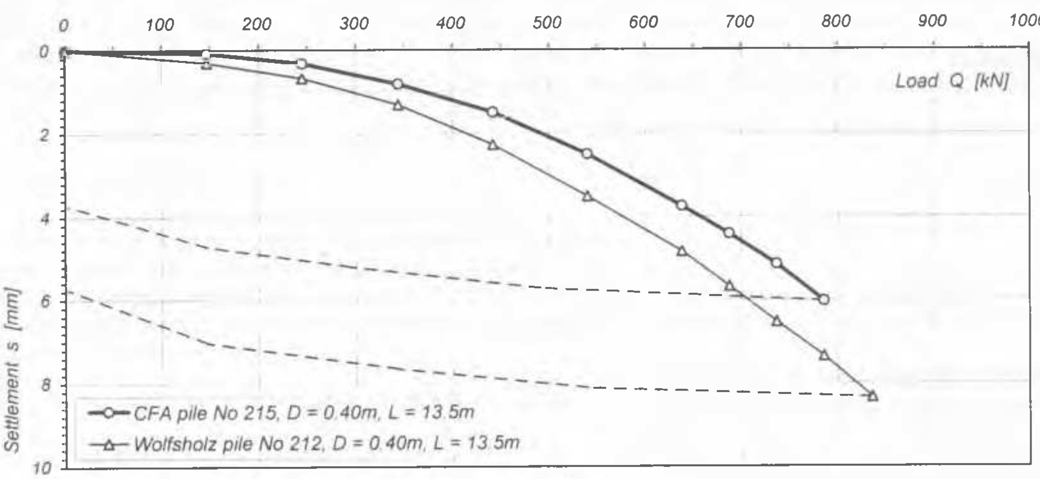

Figure 5. Load-settlement curves for CFA and Wolfsholz piles (Kartuzy).

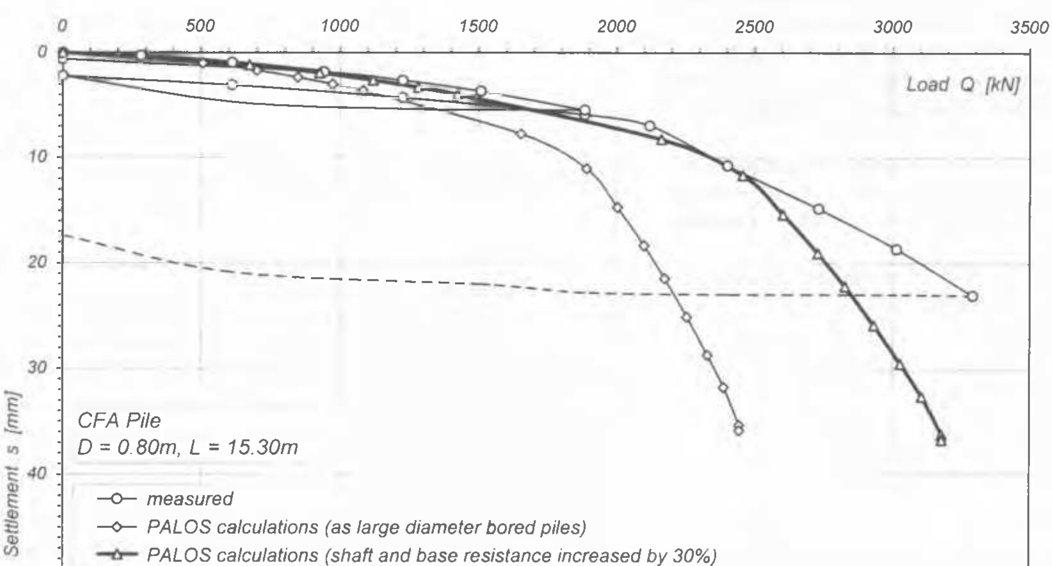

Figure 6. Load-settlement curves for CFA pile, measured and calculated (Poland).

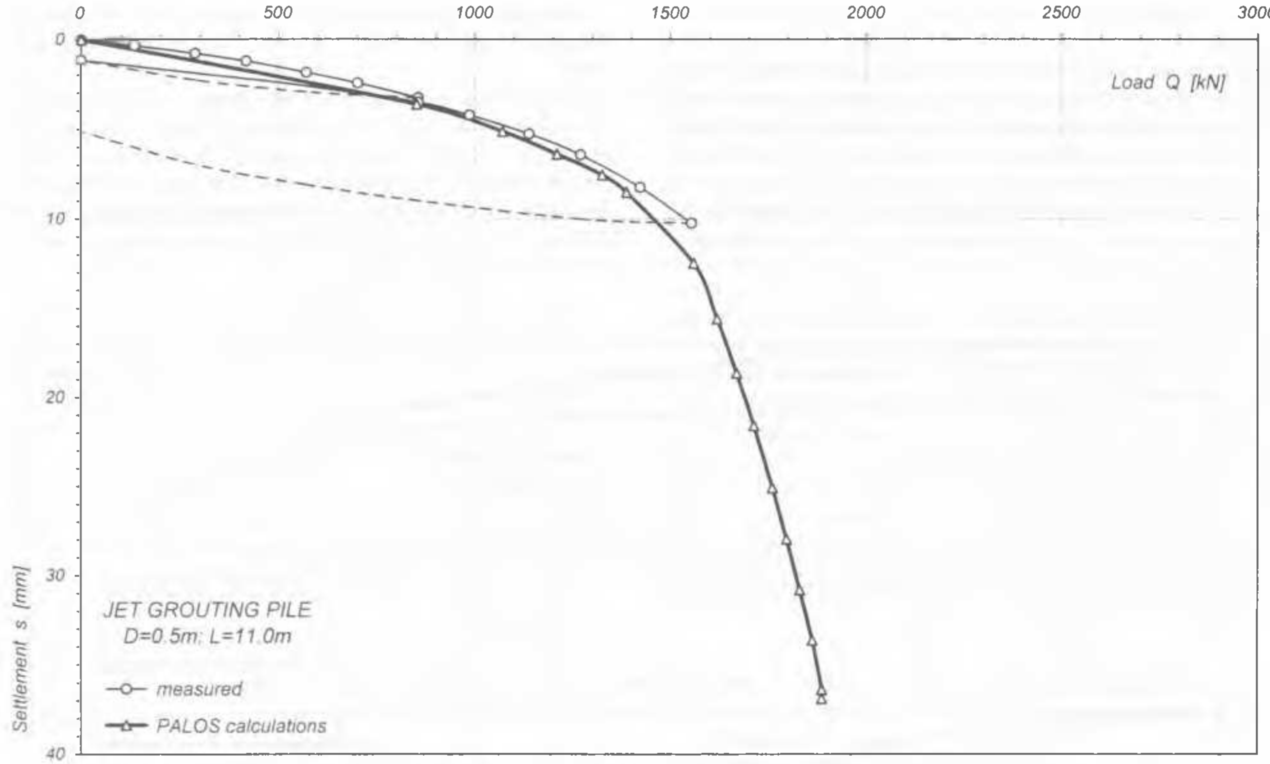

Figure 7. Load-settlement curves for Jet-grouting pile, measured and calculated.

REFERENCES

Bolognesi, A.J.L. Moretto, O. 1973. Stage grouting preloading of large piles in sand. *Proc. of the 8th Int. Conf. ISSMFE*. Moscow, Vol. 2.1, 19-25.

Gawor, B. et al., 1994. Bearing capacity increase of pile base in terms of injections. National experience. (In Polish). *Inżynieria i Budownictwo*, No. 9/1994, 355-358.

Gwizdała, K. 1997. Polish design methods for single axially loaded piles. *Proc. of ERTC3 Seminar*. Brussels. 291-306.

Gwizdała, K. Tejchman, A. 1997. Numerical modelling of pile-subsoil interaction. *Proc. XIVth ICSMFE*. 673-676. Hamburg, September 1997.

Van Impe, W.F. 1997. Recent developments in foundation techniques. *Proc. XIVth ICSMFE*. Hamburg, September 1997.

Yeats, J.A. O'Riordan, N.J. 1989. The design and construction of large diameter base-grouted piles in Thanet Sand. *Proc. of Int. Conf. on Piling and Deep Foundations*. London. Vol. 1. Balkema, Rotterdam.

Żmudziński, Ż. Motak, E. 1995. *Estimation of calculation of bearing capacity of piles executed in terms of high pressure stream injection method.* (In Polish). Kraków Technical University, No 194.

Polish Code PN-83/B-02482. 1983. *Foundations Bearing capacity of piles and pile foundations.*