Influence of the time after construction on static load testing of pre-cast driven-in piles

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Abstract:

After the foundation piles have been installed in the ground, the increase of their load capacity may be observed, due to the dissipation of ground water pore pressures (reconsolidation of the soil) and the reestablishment of internal bindings around the pile. Hence, the norms and regulations recommend that the pile load capacity tests should be carried out from several to dozens days after the piles have been constructed. The article presents the test results for capacity tests performed before the norm-conditioned time limit, with reference to the soil types. The subject has been exemplified on the basis of foundation works in course of the construction of several road projects in Poland since 2004.

Key-words:

pile, static load test, bearing capacity

1 Introduction

Preserving a long time span between the pile installation and their testing (as well as the continuation of the whole pile construction work) may cause, for one thing, many problems from the point of view of organisation; secondly, delay and additional costs.

The installation of pre-cast driven-in piles enables one to estimate their load capacity on the basis of dynamic formulae, systematically, as the installation work progresses. The examining of the load capacity increase in time permits to determine that increase in terms of its quantity. On the basis of those data it is possible to accelerate the pile load capacity testing, and thus reduce the time of the entire foundation construction works.

2 Current conditions

The current possibility of obtaining financial resources from the European Union funds results in the increase of road investments in Poland. Development of motorway and land road network, connected with simultaneous construction of ring roads for many towns, brings about the necessity of erecting a large amount of engineering objects – bridges and viaducts.

The majority of those objects are founded on foundation piles, for the following reasons:

- severe restrictions for construction support settlement and horizontal movement
- the necessity to transfer large loads, in which horizontal forces may play a significant role,
- unfavourable geotechnical conditions under the structure (especially in the case of bridges),
- the necessity to protect the bridge abutments and pillars, located near to the river main stream, from the possible jetting.

The construction of piles underneath the erected objects is preceded by the obligatory testing determined by the code of practice, and thus leads to the prolonging of the works execution. As it is in the whole EU, static testing constitutes the basic bearing capacity testing due to local regulations (Polish code of practice) and, as follows, contract specifications (see fig 1.). High-strain dynamic testing (CASE, CAPWAP, DLT, PDA) and integrity testing (PIT, SIT) are typically carried out as the additional control procedures, which provides the quality, and not quantity, assessment. Kinetic bearing capacity testing (STATNAMIC, DYNATEST) are not frequently used (unfortunately) (see Brzozowski et al. (2004), Holeyman (2006)).

Neither is the pile bearing capacity assessment admitted on the basis of the following practices carried out "in-situ":

- counting and the analysis of blows in course of pre-cast concrete pile driving-in process,
- the measurement of energy (power) necessary for driving-in the continuous flight auger (CFA), or driving-in the full displacement piles (ATLAS).

FIG. 1 – Static load testing stand

FIG. 2 – Hydraulic jacks and measure equipment

Such analyses are of course carried out and are especially helpful for the contractor and the supervisor on the building site. Those methods provide fast and reliable information about the conformity of actual geotechnical conditions with the previously assumed data. It must be mentioned here, that the binding Polish codes of practice, regulating the pile and pile foundation designing and the execution of works, date back to the early '80s of the previous century. The works leading to updating the codes and the implementation of EU standards (Eurocode 7 and execution guidelines) to local conditions are still being carried out. Time pressure in the execution of pile foundations, combined with high reliability requirements, causes the situation in which some piling technologies are favoured over the others. Nowadays, we deal with the renaissance of the pre-cast concrete piles, which did not appear until the mid-eighties of the 20th century.

Pre-cast concrete piles become more and more present in civil engineering. Pile drivers have relatively small dimensions and weight, and, as such, enable piling on hardly accessible sites. The application of pre-cast concrete piles allows for eliminating the use heavy piling rigs, the transport of which may be expensive and technically complicated. In the case of prefabricated piles, only a small amount of equipment is necessary on site. Basically, only the pile driver is indispensable, after the piles have been unloaded with the help of travelling crane.

The common use of pre-cast concrete piles in bridge engineering is also conditioned by:

- the possibility to load prefabricated piles in a very short time (immediately after driving in), which allows to gain time needed for the hardening of the concrete,
- very high pile durability resulting from the use of high homogeneity and quality of concrete, as well as its resistance against aggressive factors.

It is not insignificant that the piling process may be carried out very fast. Depending on the soil conditions it is possible to drive in 200-350 running metres of piles per day, using a single pile driver. It is commonly objected that the pile driving process may have a severe dynamic influence on the surrounding area and structures. The dynamic influence may be generally neglected in the case of the investments outside built-up areas. Even in the urban areas, the measurements carried out during pile driving prove that the noise and vibration levels caused by that process have no vital influence on the neighbouring objects.

The pile driver mast may be inclined in the wide range of angles. However, for the sake of the machine stability, if the pile length exceeds 12 meters, the possible inclination of the mast is limited to 30 deg. The designing of inclined piles allows to reduce the dimensions of pile capping beam, as well as to transfer significant part of horizontal forces (fig.3). Static load test of an inclined pile seem to be a difficult work but it can be performed (see fig.4).

FIG. 3 – Driving in of an inclined pile.

FIG. 4 – Static test of an inclined pile

In course of the pile driving it is possible to verify constantly the pile bearing capacity assumed in the original design. The basis for the bearing capacity control is the counting of the blows required for each 20-centimeter penetration of the pile. Such measurement makes it possible to test (evaluate) pile bearing capacity right away on the building site. However, when geotechnical conditions vary from the expected, Pile driving analysis may lead to false results. This happens, when a weak layer appears below the pile toe. Such a fact may be neglected by the pile driving analysis, but may seriously affect a long time behaviour of the pile.

FIG. 5 – STATNAMIC load capacity testing equipment.

The piles may, therefore, undergo dynamic or STATNAMIC testing shortly after they have been driven in. Fig. 5 provides a relevant example of the necessary equipment. Static load test remains in this case a reference test anyway. Proper interpretation and validation of dynamic testing require some information from static testing on the building site. Especially, the ultimate load capacity can be helpful information for model calibration. In the case of STATNAMIC testing, the engineer has to undertake an analysis which provides information corresponding to static testing.

3 The subject of the study

Because of the above mentioned advantages, the use of prefabricated piles leads to the shortening of pile work time. The time span, which should be preserved between the driving in of a pile and its static bearing capacity testing, is also noteworthy. Those time intervals are presented in Chart 14 in the code PN-83/B-02482 (see Table 1 below). Therefore, it is troublesome to postpone the decision about the continuation of pile work until the static load test results.

TABLE 1 – Time span between the driving in of a pile and its testing.

Piling technology	Ground conditions		
	non-cohesive		cohesive
driven-in	7 days	20 days	30 days
bored	30 days	30 days	30 days

Another organisational difficulty arises from the necessity to adjust the building site only in order to install the piles in the testing site (the transport of pile driver). That disadvantage is crucial especially when the number of piles is small and the cost of re-adjustment of the building site or the standstill in the works caused by the testing methodology are irrelevantly expensive in comparison with the contract value. The conditions presented above form the basis for the undertaken attempt at the analysis of the influence of the time - elapsing between the pile installation and the static load test – on the test results. Such an influence reported by Skov (1988) and Svinkin (2005) should be significant, especially in the case of stiff cohesive soils where so called soil “setup effect” accompanied by dissipation of pore pressure at the soil pile interface zone may last in terms of years. The detailed analysis of setup in sands is a subject of recent studies by Jardine et Al. (2006) and König and Grabe (2006). Even a 20% increase of bearing capacity in sand is noteworthy in terms of money.

4 Test results

The analysis considered prefabricated pile bearing capacity tests, carried out by the Institute of Geotechnics and Hydrotechnics at Wroclaw University of Technology. Numerous (over 100) static load test results have been gathered for the last two years. The analysis comprised a wide range of pile lengths (from 6 m up to 26 m), different pile sections, and different soil conditions. The research has been done for the chosen 33 foundation piles constructed as the elements of bridge foundation where the settlement restrictions are severe. The Table 2 juxtaposes: the dates of pile driving, the dates of static load tests, geotechnical conditions (cohesive or non-cohesive subsoil) and load testing results compared with the pile bearing capacity computations. In most of the cases, the time which elapsed between pile installation and its testing was shorter than the requirement stated in the PN-83/B-02482 (Polish Code of Practice).

TABLE 2 – Data for the analysis and test results compared with the pile bearing capacity.

piling project	pile	pile installation	test	pile length	ground	time (days)	result*
Highway A2 WD-184 40×40cm	1/18	------	2005-01-19	16,0	clay	------	51%
	2/21	------	2005-01-20	14,0		------	51%
	3/17	2005-01-21	2005-01-27	6,7		6	58%
Highway A2 MA-194 40×40cm	1L/17	2004-11-23	2005-01-07	11,0	sand	14	-3%
	2L/31	2004-11-22	2005-01-11	8,0		19	15%
	3L/17	2004-11-24	2004-12-15	8,0		21	27%
	4L/73	2004-11-24	2004-12-12	8,0		18	56%
Highway A2 WD-196 40×40cm	31/1	2005-01-30	2005-02-06	16,0	sand & clay	7	16%
	16/2	2005-01-29	2005-02-05	16,0		7	38%
	11/3	2005-01-28	2005-02-04	16,0		7	20%
Highway A2 WD-201 40×40cm	23/1	2005-01-26	2005-02-10	12,0	sand & clay	14	66%
	12/2	2005-01-25	2005-02-01	13,8		6	11%
	11/3	2005-01-24	2005-01-31	11,0		6	65%
Highway A2 WD-202 40×40cm	25/1	2005-01-27	2005-02-03	11,6	sand	7	65%
	11/2	2005-01-26	2005-02-11	11,3		15	54%
	11/3	2005-01-27	2005-02-14	8,3		17	61%
Highway A2 WDp-206 40×40cm	1/08	2005-01-29	2005-02-16	20,0	clay	18	47%
	2/05‘	2005-01-31	2005-02-19	17,4		19	53%
	3/23	2005-01-31	2005-02-17	20,0		17	56%
Kwidzyn ring 30×30cm	P1.13	2005-05-01	2005-05-09	15,0	sand	8	55%
	P2.16	2005-04-28	2005-05-10	15,0		12	51%
Elblag ring 40×40cm	nr12/P3	2005-04-07	2005-04-11	12,0	sand	4	21%
	nr12/P4	2005-03-31	2005-04-12	11,0		12	32%
Szubin ring 40×40cm	T1/48	2005-04-04	2005-04-16	11,0	sand	12	40%
	T2/111	2005-04-04	2005-04-12	11,0		8	58%
Szubin ring 40×40cm	T1/98p	2005-03-19	2005-04-15	14,0	clay	26	76%
	T2/45p	2005-03-10	2005-04-13	14,0		33	-30%
Szubin ring 40×40cm	T1/93p	2005-03-08	2005-04-11	14,0	clay	33	75%
	T2/59p	2005-03-04	2005-04-05	14,0		31	20%
	T3/32p	2005-03-06	2005-04-13	14,0		37	30%
Szubin ring 40×40cm	T1/005	2005-04-06	2005-04-27	14,0	clay	21	60%
	T2/010	2005-04-28	2005-05-11	14,0		14	60%
	T3/118p	2005-04-06	2005-05-09	14,0		33	45%

* Additional bearing capacity (above the required safety margin)

5. Discussion of the results

After the analysis of the static load tests it seems that the time which elapses between the pile installation and its testing is of secondary importance from the point of view of the test running and its result. It is inadvisable to underestimate the influence of the pore pressure dissipation in the pile surroundings after the pile has been driven in. It has been stated that the decisive factors for the pile bearing capacity obtained in the test are:

- the conformity of geotechnical conditions with those assumed in the pile design,
- the adequacy of computation model (design quality).

It is necessary to remark that in some of the analysed cases the test results were negative and pointed to an insufficient pile bearing capacity. As a rule, that resulted from the lack of conformity between the actual geotechnical conditions and the data assumed for the need of pile bearing capacity computations. At the same time, for the same reason in many cases the pile bearing capacity obtained from the test confirmed the pile suitability, despite the fact that they haven't been driven in to the penetration depth required in the project.

Bearing in mind that the bearing capacity of a pile driven into cohesive subsoil increases significantly in time (setup effect), it is the contractor who takes the risk of the acceleration of the testing procedure. If the static load test result is negative, the testing procedure may be repeated after the time required by the codes of practice. The obtaining of a positive result makes the further examination unnecessary. Possible further increase of pile bearing capacity forms additional safety margin for the design.

In the case of sandy subsoil, reported values of capacity increase ranging app. 20% does not affect much the evaluation of pile bearing capacity and the design procedure.

It is important to state that Skov (1988) mentioned that some authors have observed an opposite effect called relaxation, which can appear in silty soil. The author, however, have never noticed this effect. On the contrary, the numerous static testing of foundation piles designed for Auchan Commercial Centre in Raciborz (Poland) have proved an significant time-based increase of bearing capacity of piles in silt.

6. Conclusions

In the presented juxtaposition of many static load tests there was no single case in which the acceleration of the testing procedure affected the appraisal of its suitability in the object foundation. According to the authors intention, the carried out tests, after they are supplemented with the results of the subsequent bearing capacity tests, are supposed to form the basis for contract specifications.

Such specifications should determine general conditions for static load testing and help to split responsibility between the contractor, the client and engineering design office.

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The results of dynamic pile bearing capacity tests carried out by AASLEFF Sp. z o.o. (Private communication)