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# 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. It occurs due to the dissipation of groundwater pore pressures (reconsolidation of the soil) and the reestablishment of internal bindings around the pile. Hence, the standards and regulations recommend that the pile load capacity tests should be carried out from several days to several dozen days after the piles have been constructed. The article presents the results of capacity tests performed before the standard-conditioned time limit, with reference to the soil types. The subject has been exemplified on the basis of foundation work during making several roads in Poland since 2004.

## 1. INTRODUCTION

A long time between the piles' installation and their testing (as well as the continuation of the whole pile construction work) may cause on the one hand many orgnizational problems, and on the other one the delay of works and some additional costs.

The installation of pre-cast driven-in piles enables one to estimate their load capacity based on dynamic formulae, systematically, as the installation work progresses. The examining of the load capacity increase with time permits one 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 to 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. The 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 on 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 close to the river main stream, from a possible jetting.

Fig. 1. Static load testing stand

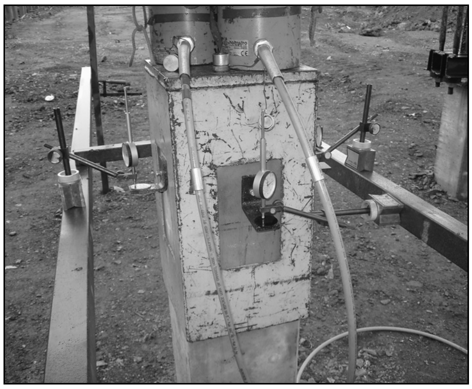

Fig. 2. Hydraulic jacks and measuring equipment

The construction of piles underneath the erected objects is preceded by the obligatory testing determined by the code of practice, and thus it leads to the prolonging of the works. As is common 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 figure 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, but not the quantity, assessment. Kinetic bearing capacity testing (STATNAMIC, DYNATEST) is not frequently used (unfortunately) (see BRZOZOWSKI et al. [1], HOLEYMAN [2]). Neither is the pile bearing capacity assessment admitted on the basis of the following practices carried out in-situ:

• the counting and analysis of blows in the 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).

Such analyses are, of course, carried out, being 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 those previously assumed. 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) into local conditions are still being carried out. The pressure of time in the execution of pile foundations, combined with high reliability requirements, leads to the situation in which some piling technologies are preferred to 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 frequently used 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 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 of loading prefabricated piles in a very short time (immediately after driving in), which allows one to gain the time needed for the hardening of concrete,
- very high pile durability due to the use of concrete of high homogeneity, quality and resistance to aggressive factors.

It is not without significance 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 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.

Fig. 3. Driving-in of an inclined pile

Fig. 4. Static test of an inclined pile

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 one to reduce the dimensions of pile capping beam and to transfer a significant part of horizontal forces (figure 3). Static load tests of an inclined pile seem to be a difficult work, but it can be done (see figure 4).

In the course of the pile driving, it is possible to verify continuously 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 a measurement makes it possible to test (evaluate) the pile bearing capacity right away on the building site. However, when geotechnical conditions differ from the expected ones, 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 in 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. Figure 5 provides a relevant example of the necessary equipment. Static load test remains in this case a reference test anyway. A proper interpretation and validation of dynamic testing require some information about static testing on the building site. The ultimate load capacity can be especially helpful information necessary for model calibration. In the case of STATNAMIC testing, the engineer has to perform 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. A span of time, which should pass 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). Therefore, it is troublesome to postpone the decision about the continuation of pile work until the static load test results are obtained.

Table 1

A span of time 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 prepare the building site only in order to install the piles in the testing site (the transport of pile driver). This disadvantage is crucial, especially when the number of piles is small and the cost of re-preparation 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 analysis of the influence of the time that elapses between the pile installation and the static load test on the test results. Such an influence reported by SKOV [5] and SVINKIN [6] should be significant, especially in the case of stiff cohesive soils, where the so-called soil "setup effect" accompanied by the dissipation of pore pressure at the soil–pile interface zone may last for years. A detailed analysis of setup in sands is recently studied by JARDINE et al. [3] and KÖNIG and GRABE [4]. Even a 20% increase of bearing capacity in sand is noteworthy in terms of money.

## 4. TEST RESULTS

The results of prefabricated pile bearing capacity tests, carried out at the Institute of Geotechnics and Hydrotengineering, Wrocław University of Technology, were analysed. Numerous (over 100) results of static load test 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. 33 foundation piles constructed as the elements of bridge foundation, where the settlement restrictions are

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 40×40 cm | 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 40×40 cm | 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 40×40 cm | 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 40×40 cm | 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 40×40 cm | 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 40×40 cm | 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 30×30 cm | 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 40×40 cm | nr 12/P3 | 2005-04-07 | 2005-04-11 | 12.0 | sand | 4 | 21% |
| | nr 12/P4 | 2005-03-31 | 2005-04-12 | 11.0 | | 12 | 32% |
| Szubin ring 40×40 cm | 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 40×40 cm | 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 40×40 cm | 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 40×40 cm | 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).

severe, were chosen for the research. Table 2 presents: 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 cases, the time between pile installation and its testing was shorter than that recommended in the PN-83/B-02482 (Polish Code of Practice).

## 5. DISCUSSION OF THE RESULTS

Based on the analysis of the static load tests it can be concluded that the time between the pile installation and its testing is of the secondary importance if the test course and its result are taken into account. 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 as follows:

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

It should be stressed that in some of the cases analysed the test results were negative and testified to an insufficient pile bearing capacity. As a rule, this resulted from the lack of conformity between the actual geotechnical conditions and the data assumed for the pile bearing capacity computations. At the same time and for the same reason, in many cases the pile bearing capacity obtained from the test confirmed the pile suitability, despite the fact that they have not been driven into the penetration depth required in the design.

Bearing in mind that the bearing capacity of a pile driven into cohesive subsoil increases significantly with 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. A positive result makes a further examination unnecessary. Possible further increase of pile bearing capacity widens the safety margin for the design.

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

It is important to state that SKOV and DENVER [5] mention that some authors have observed a reverse effect, called relaxation, which can appear in silty soil. The author of this paper, however, has never noticed this effect. On the contrary, the numerous static testings of foundation piles designed for Auchan Commercial Centre in Racibórz (Poland) have proved a significant time-based increase of bearing capacity of piles in silt.

## 6. CONCLUSIONS

In any of the static load tests presented, there was no single case, where the acceleration of the testing procedure affected the assessment of its suitability for the object foundation. According to the author's intention, the tests carried out, after being 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 place responsibility on contractor, client and design office.

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