

Pile integrity testing as a problem of on site quality control

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ABSTRACT : When low strain integrity testing is carried out on cast in situ piles there exists a remarkable danger of a certain percentage of piles to be rejected. This might easily lead to very awkward situations for the site management. Because there is usually not a standstill on the building site between installation of the piles and agreement upon the results of the integrity tests the necessary actions in case of a rejected pile have to be discussed when the piling equipment has been (hopefully) passed on to another site and the piles may even not be accessible for any kind of heavy equipment. Therefore pile integrity testing has to be carefully embedded into the construction schedule and work programme of a building site in cooperation of client, consultant and contractor. The problem is discussed with respect to two different sites.

1 INTRODUCTION

Low strain integrity testing is a tool of quality control of cast in situ concrete piles. In some countries (e.g. Austria) this has been acknowledged and testing has been codified accordingly. With such a codification a certain benefit can be given with respect to safety factors.

Other countries (e.g. Germany) did by now not introduce low strain integrity testing as a means of quality control. Therefore only recommendations exist with respect to the execution of the tests but no benefit can be gained when tests are carried out. Therefore when the tests are carried out this happens mostly in a hostile environment, where consultant, contractors and authorities argue about the real quality of the pile.

Consultants and authorities might have their reason to mistrust the work of the contractor because of concrete quality in pile top parts that have been excavated or because

the concrete consumption deviates from the planned volume of the pile. Then an independent statement on the true quality of the pile is demanded and a low strain integrity test is wanted.

The tests have to be carried out under quite adverse circumstances. Because of the number of meetings that have taken place the construction works on site have reached a state where most of the good piles are incorporated into the upgoing structure, i.e. base slabs, foundation gridworks and such. The piling contractor finally gives in and orders the test of the questionable piles. The tests are to be carried out in the instance after the telephone call and the result has to be presented immediately afterwards.

The tester who is employed for the job faces a very awkward situation :

1. The tests have to be carried out under the sceptical surveillance of the consultant and

authority engineers as well as under the eyes of the piling contractor who himself might not be too sure about the quality of his piles. Curious and interested colleagues of either side will also be present.

2. There has mostly been not much time to prepare the surface of the pile and to bend away the reinforcement so that the application of the acceleration pickup and the hammer blow becomes sweatdriving tasks.

3. The most questionable pile is indicated as the one to be tested first, and after the first hammer blow all the people around want to know all about it.

4. When the pile shows severe defects and must be rejected the possible actions are :

- a) excavating and installing a new pile
- b) installing a new pile next to the other.

In the second solution a recalculation of the foundation construction is needed for the load transfer to the new pile position.

Usually at the time of the integrity testing the piling equipment has been moved to another site or at least to a remote part of the site wher piling is still going on. As the pile concrete should be at least seven days old for the execution of low strain integrity tests it can be assumed, that at the area of the tested piles the construction works have been going on and reached another state. Thus with the installation of an additional pile there will be another interruption of the construction works, and the site has to be prepared to put the heavy piling machinery in place. All this at the cost of the piling contractor or his insurance and all this because of the result of low strain integrity testing.

Most times the total cost of the piling will be less than the cost of this additional pile.

As low strain integrity testing is comparably cheap it is ordered without a thought towards the consequences.

For the tester this means that he has to be very careful during the negotiations and should observe the following :

1. Not to be forced to render statements by the test of a single pile but always try to have a number of piles for comparison so that an average good pile for a site can be defined.

2. Not to promise results that cannot be supported by the testing method (i.e. deviations within the range of 10% or less).

3. Not to promise results that cannot be supported by the one dimensional wave theory (e.g. one sided bulges or necksings).

4. To definitely state that the application of the method is confined to concrete piles of constant cross section with pile depths of up to 15 m.

If he is able by his experience or the specific properties of the piles at the site to give one sided or less than 10% deviations or results for longer piles or for piles inserted in upgoing construction the tester can produce this as additional results, but on the other hand if the situation is not like this he faces severe difficulties when explaining the reasons for not being able to produce these results.

2 INTEGRITY TESTING AND QUALITY ASSURANCE OF PILES

Compared to the situation described in the introduction an adequate use of the method can be made when low strain integrity testing is fully acknowledged and incorporated into the quality control of piles.

In that case first a benefit can be gained with respect to piling foundation safety and second the execution of the method can be considered within the time schedule of the total construction.

In this environment all involved parties can first agree to an acceptance procedure that guarantees a joint understanding of the test reults and binds them to a final decision within the reasonable time window for consequences as e.g. installing additional piles. Such an acceptance procedure can read as follows :

Acceptance Procedure

- Rules for the execution of tests
- Classification of test results
 - description of signal
 - description of pile
- Assessment
 - accepted = 1
 - rejected = 0

Rules for the execution are to be established in order to gain uniform test signals :

Rules for the execution of tests

1. Pile top must be accessible for the application of a hammer blow, pile top must be clean and the surface for hammer blow must be smoothed sound pile concrete.
2. Hammer blows must be reproducible, a number of comparable blows are to be recorded.
3. For the evaluation appropriate signals have to be chosen for an averaging procedure.
4. Magnification and smoothing has to be the same for all evaluated signals.

Such an agreement on the execution of the tests will be the basis of a joint acceptance of the correctness of the gained signals and thus of the evaluation of the time histories. With respect to the interpretation of the signals it must be clearly distinguished between features of the signal at a specific site and the conclusions that can be drawn with respect to the shape of the pile.

Classification of test results

- description of signal
 - normal time history
 - good tip reflex
 - weak tip reflex
 - no tip reflex
 - positive deviation from base line
 - negative deviation from base line
- description of pile
 - as planned cross-section
 - decrease in cross-section
 - step to smaller diameter
 - step to larger diameter
 - increase in cross-section
 - longer than according to plan
 - low wave velocity (< 3.5 m/ms)/
 - poor concrete quality
 - shorter than according to plan
 - high wave velocity (< 4.5 m/ms)/
 - good concrete quality
 - (aged concrete)

Additionally it can be agreed upon to evaluate the frequency transforms as well as computer simulations such as PITWAP or TNOWave.

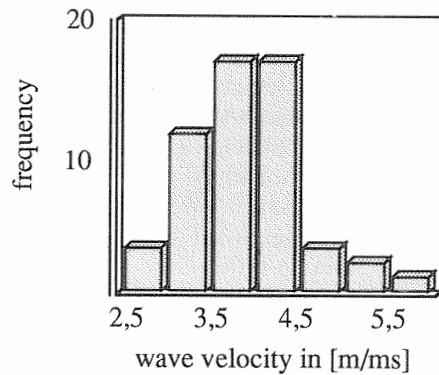
3 TWO EXAMPLES

In Fig.1 the statistical evaluation of a site is given where the testing of the piles has been executed to verify/testify questionable piles. Piles have been installed from a level two meters above base slab, Therefore excavations started after piling has been finished revealing some piles with necking in the top two meters. Low strain integrity testing has been ordered with respect to the question whether the lower portions of the piles show also neckings of any kind.

Fortunately it was possible to test all the piles at the site so that an average good site pile could be defined and also fortunately no neckings below the construction level have been found.

On the other hand the wave velocity statistics show quite a large scatter. Either it could be argued that the low velocity piles are of bad concrete and the high velocity piles are too short or that the low velocity piles are longer than planned and the high velocity piles are of extremely good concrete of older age.

As a result this site could be judged to be an average piling job with ordinary quality control.



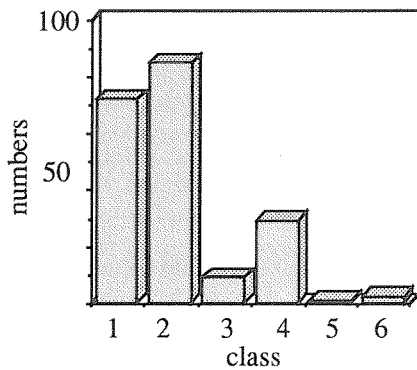
$$c = \frac{2 \cdot L_{\text{plan}}}{T_{\text{measured}}}$$

Fig.1 : Integrity testing
- wave velocity statistics

Fig. 2 shows the frequency graph of classified piles of a site where integrity testing has been a part of the total quality assurance of piles. The integrity testing has been incorporated in the piling schedule and acceptance procedure as well as rules for the execution have been agreed to.

Less than one percent of the piles have been rejected and as the schedule has been drawn with respect to integrity testing additional piles have been installed at marginal costs.

At this site the piling job can be judged excellent with a very good quality control and a high reliability of the pile foundation.



- class 1 : ideal signal -
pile according to plan
- class 2 : small deviations -
layer boundary shown at 8,5 m
- class 3 : weak/uncléar tip reflex
- class 4 : layer boundary at 8,5 m
very clear - weak tip reflex
- class 5 : cross sectional reduction
- no tip reflex
- class 6 : strong cross sectional
reduction - no tip reflex

- class 1 - 4 : accepted
- class 5 : drop weight test
recommended
- class 6 : rejected

Fig.2 : Integrity testing - class statistics