Design methods based on dynamic pile load tests

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ABSTRACT

Even as it is over 20 years that dynamic pile load tests have been introduced by EC7.7.5.3 as an alternative load tests for the verification of pile capacity the tests were carried out in most countries without any regulation. In the last 5 years EC7 has come into force in many European countries and also National attachments have been installed. However the practice is still varying. There are countries were dynamic pile load tests are used as a routine practice (like Sweden) to countries were dynamic tests are not known (Like Macedonia). An overview over European practice on the basis of National reports is given and recommendations for the evolution of EC7 is given. The development of a Standard 22477-4 for dynamic load tests is described.

1. INTRODUCTION

Dynamic pile load tests are considered as a tool for pile design in EC7 7.5.3 and 7.6.2.4 to 7.6.2.7. EC7 defines impact tests evaluated by driving formula and especially refers to dynamic pile load tests with measurements of force and velocity at pile head. The latter methods of dynamic pile load tests are available since 1970 and could be accepted as a state of the art when EC7 was first drafted in the 80ies. EC7 was finally published in 1994 as ENV 1997-1 however it took until 2004 to turn it into a European standard and it took more years that this standard was accepted in the different countries. Also fairly recently the countries where EC7 came into force edited national annexes. Some countries where Dynamic Pile Load Tests are accepted for verification of safety concepts addressed Dynamic Pile Tests in their national annexes and some even provided their own national rules including national correlation factors.
For 17 countries a report on pile design according to EC7 is available and has been evaluated with respect to dynamic pile load tests.
A short review of the ongoing process of formulating an executional standard for dynamic pile load tests is also given.

2. OVERVIEW

For the following countries information on the practice of dynamic pile load tests is available (see the national reports of this :

2.1. Austria

Dynamic pile load tests are not mentioned in a National attachment. Not used in regular practice but in special cases. Especially in the Western provinces.

2.2. Belgium

Dynamic pile load tests are named as means to verify the ULS provided the equivalence to static tests have been demonstrated.

2.3. Denmark

Dynamic pile load tests are used as the standard to verify the ULS for driven piles. Also wave equation based methods and a Danish driving formula are in use. Cast-in-place piles are rare and dynamic pile tests on these piles the exception.
National regulations and safety factors are used.
In addition a calculation of setup is proposed with suitable parameters. This latter feature is unique in comparison to all other countries reviewed.

2.4. Estonia

Special driving formulas are in use as dynamic pile load tests. Primarily Gersevanov's theoretical considerations are followed.

2.5. Finland

Dynamic pile load tests according to EC7 regulations are widely in use. In some cases it is even possible to base design on dynamic load tests without accompanying static tests. As an extension to the correlation factors in table A11 the correlation factors are not only dependent on number of piles tested but also on the percentage of piles tested in a foundation. The lowest correlation factor also applies to a situation where 100% of the piles are tested.

Also national model factors are defined.

2.6. France

Dynamic pile load tests are not addressed in national regulations on pile design.
Description of integrity testing of piles also covers dynamic pile load tests.

2.7. Germany

Dynamic pile load tests are applied for driven piles mostly in the coastal areas and for cast-in-place piles more in the middle and south. Germany national annex clarifies the implicit hierarchy of dynamic piles tests as can be extracted from EC7 (see Klingmüller/Schallert 2012).
As a special regulatory feature a set of corrections for the correlation factors is proposed depending on the demonstrated equivalence of dynamic to static pile load tests.
A correction to correlation factors with respect to the percentage of piles tested is proposed in an addendum to the German recommendations for piles (see Moormann/Kempfert 2014).

2.8. Hungary

Dynamic pile load tests are regularly applied. No national annex to EC7 exists for Dynamic Pile Load tests. Simple driving formulas are not used since at least 30 years.

2.9. Ireland

Dynamic pile load tests are regularly applied and understood to be related to quality control. No national annex to EC7 exists for Dynamic Pile Load tests.

2.10. Italy

NTC 2008 encourages the design based on static or dynamic load test, with a clear preference for the former since the validity of the results of dynamic load tests has to be demonstrated by comparing the results against static load tests in comparable situations.
Correlation factors are taken from EC7.

2.11. Macedonia

No pile design by load tests. No comment on dynamic pile tests.

2.12. The Netherlands

Pile design based on load tests is seldom performed in the Netherlands because of the good relation between CPT results and bearing capacity and the relative dense grid of CPT locations (25 m x 25 m).
It is expected that in the future, with the development of new cast in situ piles, the amount of pile load tests will increase.
No special considerations in a National annex to EC7.
Dynamic pile tests including rapid load tests are seen in the context of quality control.

2.13. Poland

Dynamic pile load tests are used. Static load tests on the same site are required for demonstration of equivalence.

2.14. Russia

Dynamic pile load tests are used in the form of refined driving formula derived by Gersevanov using a set of adequate safety factors.

2.15. Spain

There is not a unique national annex to EC7 for application to all piles. There are different codes for buildings and bridges.
Load test of piles is not common in Spain. Perhaps the reason is that many piles are bearing on rock. Just some static load tests of piles in compression in projects with high loads. Dynamic load test in driven piles are routinely done by drivers, only a few by specialized independent consultants. Dynamic load test is not standard in bored piles.
Non-destructive or integrity testing of piles is common in Spain. Geotechnical codes recommend them in many cases. Big piles are routinely tested with cross-hole sonic logging or sonic transparency inside embedded tubes (CSL). Piles in building foundations are tested sometimes by sonic or echo test method with a handheld hammer. There are few specialized consultants and many general testing laboratories doing integrity testing of piles.

2.16. Sweden

Dynamic load testing is the main design method in Sweden since an overwhelming majority of piles are either driven end-bearing piles or drilled end-bearing piles.
As dynamic load tests have a 40 years tradition also the EC7-National annex is advanced compared to other countries. There is an extension to teh table of correlation factors as well as a refined set of model factors.

2.17. United Kingdom

The National Annex provides a safety concept for piles including dynamic pile load tests. The correlation factors of table A.NA.11 define a more conservative apporach than in the original EC7 A.11 proposal. However also the loading factors are evaluated by a dffienerent approach (see NA to BS EN 1997-1:2004)..

3. REVIEW OF CURRENT SITUATION

As can be learned by the reports of 16 countries the application of dynamic pile load tests is varying in a wide range within the area where the EC7 is effective. On the one side a country like Sweden where dynamic pile tests are regularly applied as a tool for pile design and on the other side a lot of countries where dynamic pile load tests are not known. Between these two extremes there are all variations of regular application sometimes according to EC7 regulations and sometimes without a special regulation. However in most cases it is found necessary to proof equivalence of dynamic to static tests in a reliable way.

4. INTEGRITY BY DYNAMIC TESTING

Some national regulations consider dynamic pile tests in context with quality control and with low strain tests and other non destructrive tests. This may be due to the fact that also in EC7 quality control of piles by non destrctive testing is not described in a consistent manner.

5. PERSPECTIVES

As was shown in Klingmueller/Schallert 2012 the EC7 regulations are not consistent. Several items need clarification:

- In addition to dynamic pile load tests by measurements of force and velocities at pile top and evaluation by wave equation models (CASE) and signal matching (CAPWAP) the use of driving formulas with and without elastic deformation and also wave equation solutions are accepted. However the latter are not described in a way that assures comparable and reliable results.
- Calibration. The verification of dynamic and static equivalence is defined with different wording. Therefore there are no unique approaches. In some cases it is possible to relate ultimate capacities however in many cases a static pile test is only carried out for 150% of the working load and a relation to ultimate resistance from dynamic tests can not be calculated
- For larger pile foundations a combination of load tests is used: dynamic, static pile tests, wave equation solutions and driving formula. A consistent safety concept should provide benefits for any additional tests (see Klingmüller/Schaalert 2012).

A better and consistent application of dynamic pile tests can be achieved by the new standard prEN 22477-4 Dynamic Pile Load Tests which is in the course of elaboration.

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