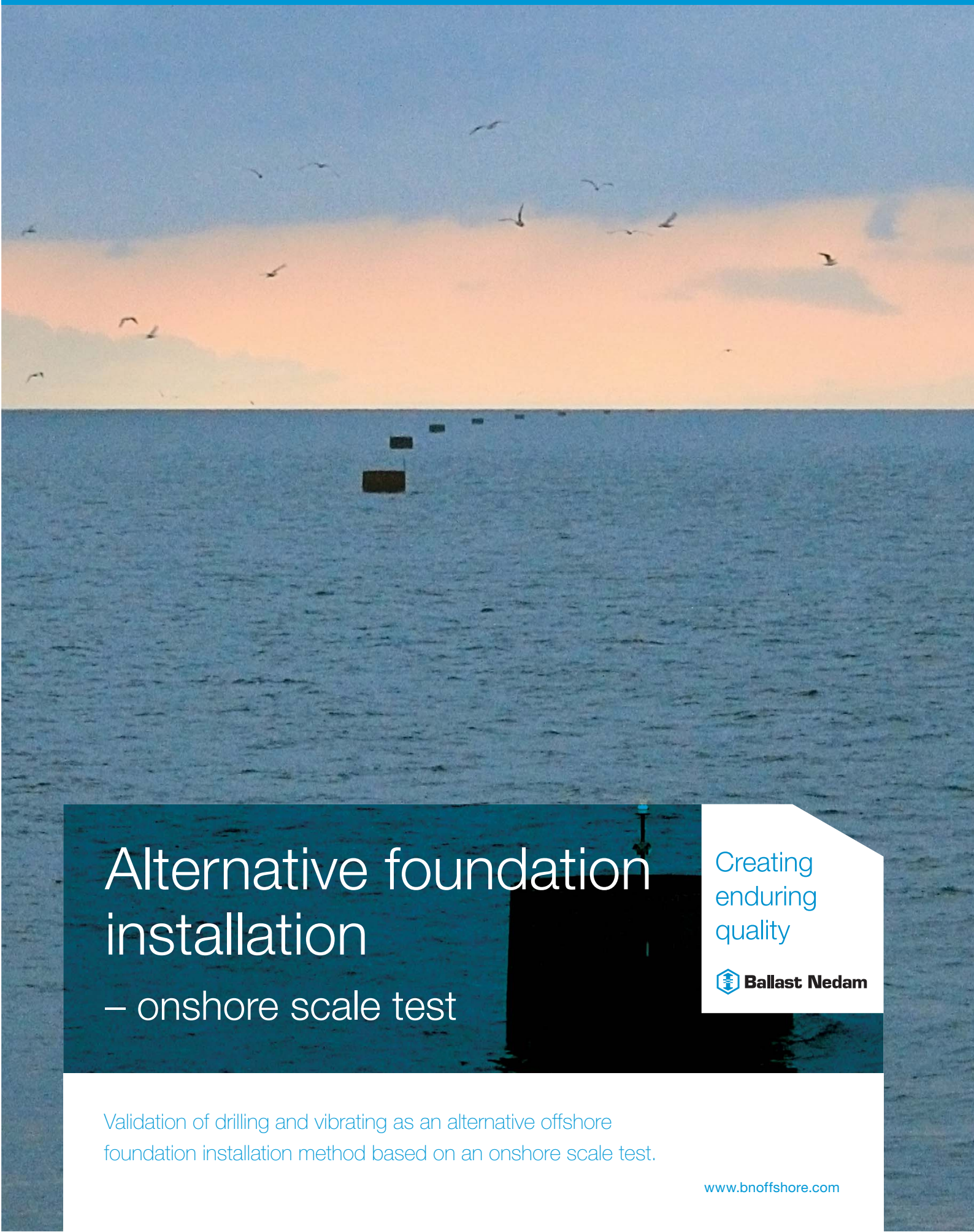
# Supporting offshore wind



# Alternative foundation installation

## – onshore scale test

Creating enduring quality

Ballast Nedam

Validation of drilling and vibrating as an alternative offshore foundation installation method based on an onshore scale test.

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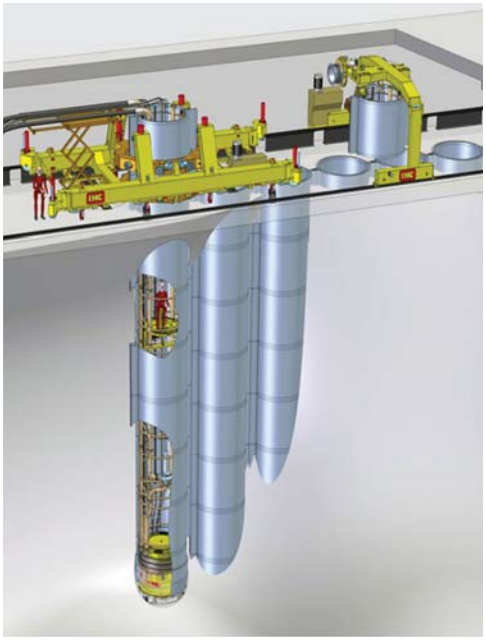
# Alternative foundation installation – onshore scale test

## Validation of drilling and vibrating as an alternative offshore foundation installation method based on an onshore scale test.

Alternative installation methods are necessary for a number of reasons. Challenging soil conditions require alternate approaches, for example, drilling through rock. Next to this Underwater acoustics and environmental effects are imposing limitations on the installation of monopiles for offshore wind farms in Europe. In Germany, for example, the Bundesamt für Seeschifffahrt und Hydrographie (BSH) insists on a maximum sound pressure of 160 dB at 750 metres from the installation. Anti-noise legislation in the Netherlands prohibits pile driving from January to July.



Bubble curtains and solid noise mitigation screens that reduce the noise add both time and costs to the installation of offshore wind foundations. And since the offshore wind market needs to reduce costs if it is to achieve sustainable growth, there is a clear need for alternative installation methods.

Less noisy alternative installation methods are already available, but they cannot be used in offshore wind foundations as long as they remain untested, uncertified, and have yet to be implemented in the guidelines.

### Drilling

Drilling techniques or drilled piles based on excavation of the soil are commonly chosen for axial loads and onshore applications, mainly because of the high bearing capacity provided by the large pile tip. Vertical tunnelling has been applied on projects in the Netherlands, with bentonite being used to prevent collapse of the overcut and as lubricant. The bentonite is replaced with grout after installation, so that the additional shaft friction contributes to the total bearing capacity of the pile. There is much experience with horizontal tunnelling methods in installing large and long tubes in soil. Vertical drilling for offshore wind foundations seems to be a promising technique though as mentioned before the techniques has to be certified.

## Vibrating

Another less sound-intensive alternative to driving is vibrating. Installing, potentially large, tubular piles with a vibrating hammer is a common technique for axially loaded onshore foundations. Vibrating hammers are used offshore as well, but pile driving is usually resorted to when close to the final installation depth (For example BARD offshore wind farm - 80 Tripiles/400 MW, Alpha Ventus wind farm - 12 foundations u.w. tripods/60 MW or Irene Vorrink nearshore wind farm - 28 Monopiles/16.8 MW).

The Irene Vorrink project presented no known restrictions to the vibrational installation method. The measurements that were carried out were only to investigate the influence of the foundation on the nearby dike. Installation therefore proceeded using a PVE 110M1 vibrating hammer, with a driving hammer being substituted only if the chosen vibrating hammer could not reach the desired depth. One of the monopiles was actually installed using a vibrating hammer alone. The simple fact that the wind farm has been in use for over 15 years so far testifies to the feasibility of this alternative installation method.

Nonetheless, vibration remains an uncertified installation technique for (primarily) laterally loaded piles, and therefore it cannot be used on a large scale in offshore wind farms. Ballast Nedam aims to change this situation, too.

## Onshore test

The installation method has implications for the lateral design of the foundations. Current design standards prescribe p-y curves in the lateral design of piles in the soil – and this method implies pile driving. To enable the application of alternative installation methods an onshore test is needed.

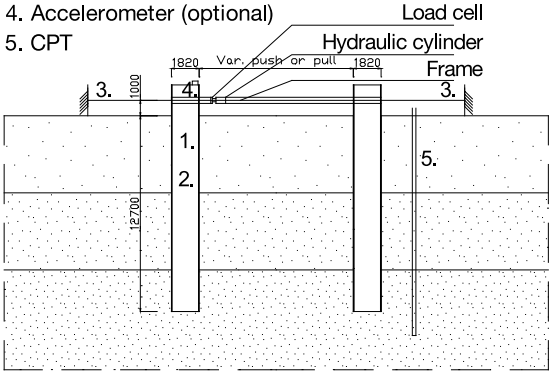
Calculations have been performed on a representative offshore pile, scaling the results to a test pile to take account of diameter and wall thickness as well as loading. The displacement behaviour of the offshore pile was simulated by adjusting the penetration depth to make the lateral deflections (dimensionless) equal to those of the offshore piles.

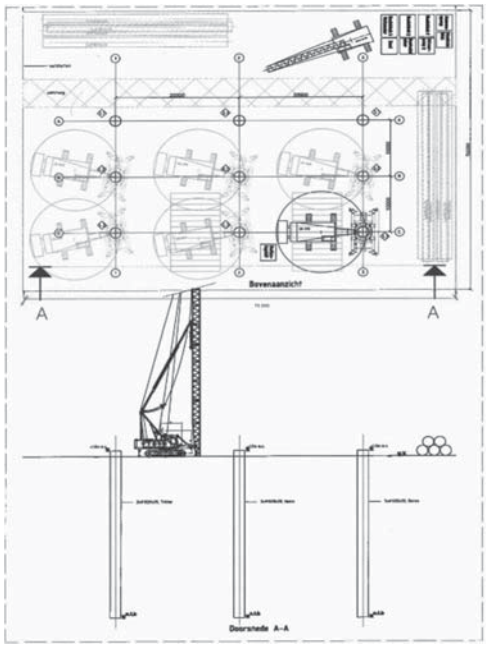
The lateral load test will be performed in sand. The lateral load test will be based on two interconnected piles. The direction of loading can be either outward or inward, as the distance is chosen so as to limit the influence zone of the soil on the other pile. Loading is performed statically, and as an option also dynamically. There will be no cyclic testing since there is believed to be no cyclic degradation from the current codes and standards through the drilling or vibrating process.

The measurements on the pile and soil will determine the p-y parameters: the stresses and deformations over the pile height. The p-y curves will be determined using the results of the static test only.

The measurement sensors will consist of strain gauges, extensometers, inclinometers and, for optional dynamic testing, accelerometers. The loads will be applied with hydraulic jacks that are equipped with load cells to provide the necessary precision. Pre-test and post-test CPT's will reveal any difference in soil behaviour attributable to the installation techniques in relation to the lateral design.


1. Extensometer
2. Inclino meter
3. Deflection gage
4. Accelerometer (optional)
5. CPT






## Validation

The tests are intended to confirm and validate the design assumptions for the pile-soil interaction of piles installed by both drilling and vibrating. These design assumptions and test set up are described in the Ballast Nedam Engineering report 'Background for p-y determination in onshore scale tests', which was reviewed by DNV earlier this year. The resulting Letter of Approval states 'According to this review, the methodology is found to be acceptable to prove that the governing standards for pile-soil interaction are also applicable for the alternative installation methods'. A successful outcome of the tests can lead the way to certified designs of offshore foundations installed by drilling and vibrating.

## Test site

A test site is being sought that has properties that are representative of an offshore location. The possible test sites are being evaluated based on currently available information. This evaluation focuses on the site-specific handling needed for proper test execution, the soil profile based on available CPT tests, and owner information (information of the owner, use of land, etc.). Several sites have been investigated, CPT's have been executed and the final choice will follow in the coming months.

## FLOW R&D Programme and financial support

The Far and Large Offshore Wind (FLOW) programme is instrumental in achieving the Dutch government's renewable targets, in accelerating the development of economically viable offshore wind energy technology. The onshore scale tests are a part of the Alternative Installation Project of the FLOW R&D Theme 2, 'Support Structures'.

The total costs of the tests will be approximately 2 million euros, of which 50% will be funded by the FLOW R & D programme. Ballast Nedam Offshore is willing to back up the substantial investments it has made already with investment in the onshore scale test. Nevertheless, the final step towards validation of the alternative installation methods will require support from interested development partners.

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