Advances in Jacket Foundation Design for Offshore Wind Farms in Chalk

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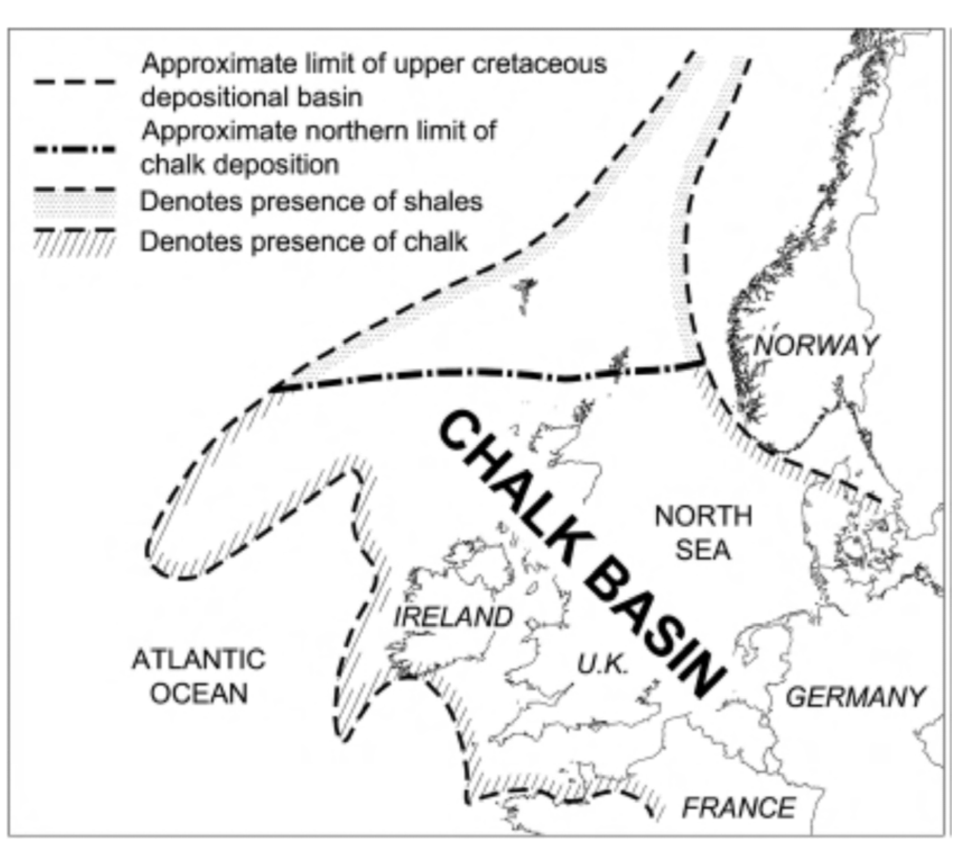
Abstract/Abstrakt

In the UK over 10GW of wind power is expected to be harnessed by offshore wind farms by 2020. Jacket structures are widely used to support offshore substations and are also used to support offshore wind turbines particularly in deeper waters. The majority of foundations for these jacket structures comprise conventional driven tubular steel piles for which design methods in sands and clays are well established. However, design methods for driven piles in chalk are limited and potentially conservative due to a paucity of well documented testing. Furthermore these methods do not explicitly consider potential for strength degradation under the cyclic loading experienced by offshore jacket piles. Chalk is widely present in the southern North Sea and English Channel and these limitations have created challenges for designers and developers. This paper presents testing and design methods developed to overcome these challenges on a number of UK wind farms. These methods include the specification, interpretation and use in design of advanced static and cyclic soil testing on higher quality samples and back analysis of installed piles in order to verify design parameters.

Introduction/Einführung

As the industry seeks to meet carbon reduction targets, offshore wind has been accepted as a viable alternative source of energy. The construction of offshore wind farms has brought new challenges to the civil engineering industry. Novel approaches for the foundation systems of offshore wind turbines and substations are required in difficult soils, such as chalk.



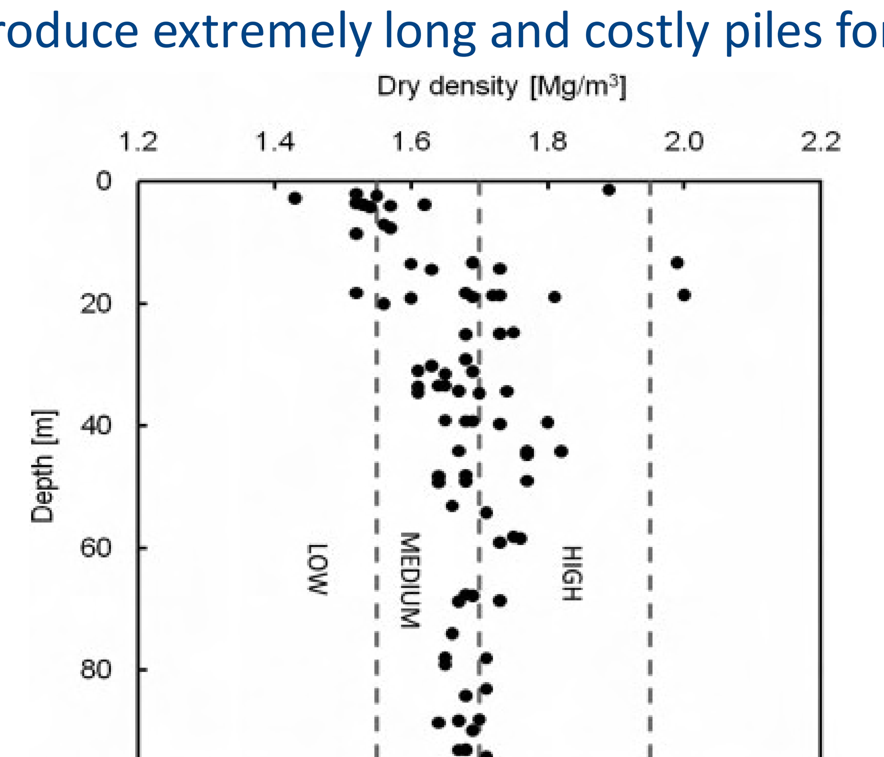
Extent of chalk deposition over the North West European continental shelf (Anderton, 1979)

The extent of chalk deposits encompasses the North Sea, and includes the continental shelf of the UK, Ireland, France, Denmark and Germany. Constructing offshore wind farms in any of these waters may require engineering solutions in the chalk deposits.

The main issue in designing these foundations is the variability of the material and the lack of testing or experience that model the chalk behaviour. Furthermore, the limited knowledge of onshore behaviour does not capture the complexities of offshore loading.

Available Guidance/Verfügbar Führung

The design of foundations in chalk in the UK, have primarily been done to the recommendations of CIRIA C574. This document gives guidance on the design of open-ended driven piles based on very limited onshore experience. The grading of chalk, which is one of the main classification criteria, is based on its dry density and the full range of low to high density can be found across the North Sea. CIRIA C574 states that if it can be proven that the chalk is high density Grade A chalk, the ultimate shaft friction of 120kPa can be adopted, otherwise this is to be limited to 20kPa. This latter limit would inherently produce extremely long and costly piles for offshore wind installations.

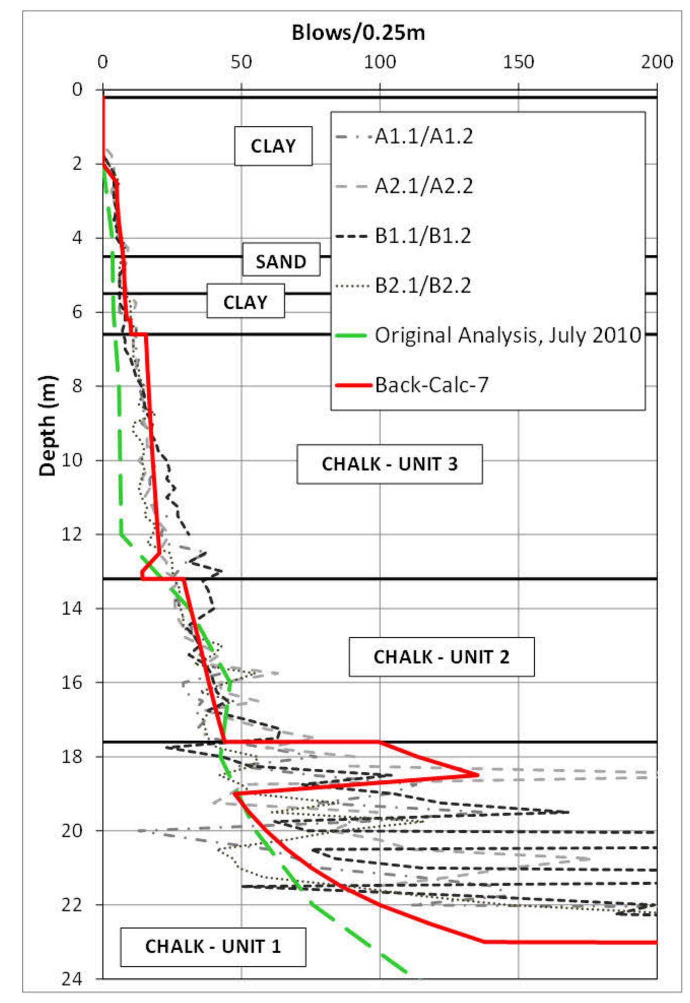


Dry density range for Southern North Sea (Carrington et al., 2011)

High density Grade A chalk

Low density Grade D chalk

Advances in Pile Design/Fortschritte in Pfahlsysteme

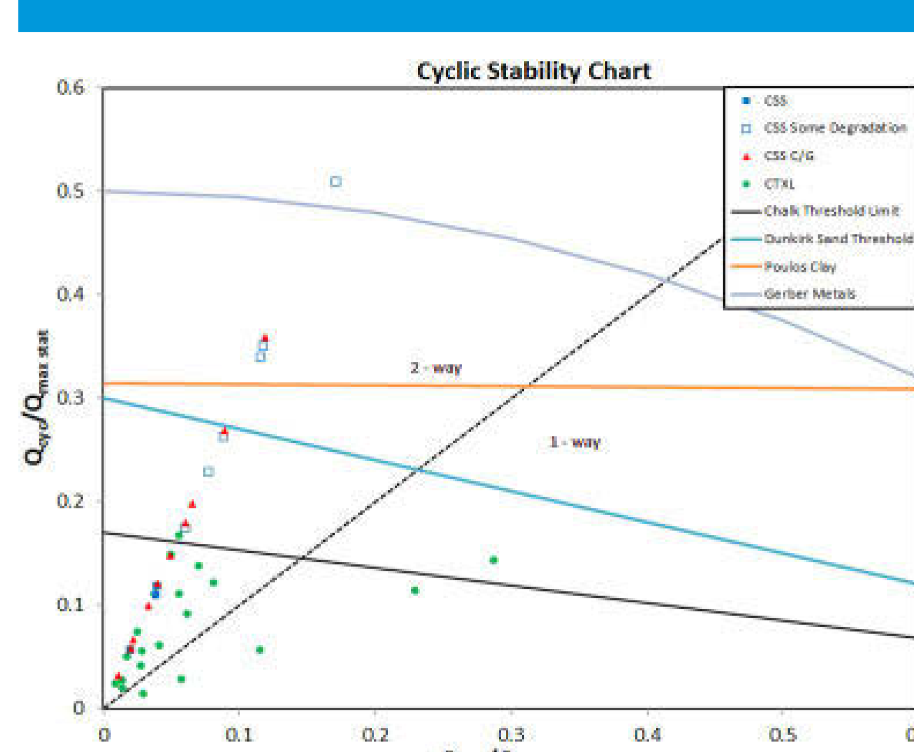


Research into the properties of chalks, Carrington et al. (2011) have found that the lower limit set out by CIRIA can be increased up to 50kPa for the ultimate shaft friction, thereby significantly reducing the design length of piles. This adjustment was derived from tests intended to simulate the gain in friction after pile installation, possibly due to re-cementation.

Further experience has shown that chalk classification from high quality care samples is of extreme importance and should only be performed by experienced engineering geologists. This classification gives the designer a better idea of the most probable solution. If the piles are found to be mainly in high quality Grade A chalk with high to very high density, driven piles may be economic. However there is a risk of premature refusal and this must be suitably mitigated using pile instrumentation and dynamic testing to validate installed capacity.

If the chalk is found to be low to medium density then alternative pile solutions may be required, such as drill and grouted piles. In this case, a primary pile is driven through the surficial deposits, the soil column is then drilled out under-reaming below the pile toe to the target depth, the base of the pile is grouted using a tremie method, and an insert pile is installed into the drilled socket and filled with grout. The design here is similar to a bored pile however advanced tests are to be performed on the chalk-grout-steel interfaces and care taken during installation to remove any slurry between the grout and the chalk. The pile length can reduced considerably as a result of using this process.

Cyclic Loading/Zyklischer Belastung



Offshore foundations are required to withstand high levels of cyclic loading. For the drill and grouted solution, the cyclic shaft resistance can be characterised using high quality core samples prepared with a grout face bond in cyclic simple shear tests. Results from these tests can be used to produce cyclic stability diagrams to inform pile design under cyclic axial loads.

Conclusions/Schlussfolgerungen

- A thorough understanding of the geology is of utmost importance as this will dictate the design solution adopted.
- A carefully planned suite of tests are required to characterise chalk behavior under cyclic loading and can be used to increase the ultimate skin friction recommended by CIRIA C574.
- The design engineer must interpret the potential degradation of shaft capacity under cyclic loads and apply this reduction appropriately to the pile design.

References/Referenzen

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2. Lord, J.A., Clayton, C.R.I., Mortimore, R.N. "Engineering in chalk" *CIRIA C574*, 2002