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Towards an updated analysis method concerning the resistance of pile foundations subjected to vertical and lateral loads.

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INTRODUCTION

The growth of the renewable energy market and especially the offshore wind energy sector leads to an increasing number of offshore wind turbines installed on soils with varying mechanical properties.

Pile foundation and support structure design is strongly dependent on soil behaviour. In this context, predicting soil reactions for axially or laterally loaded piles is a major concern for optimizing pile foundations and support structure.

Empirical formulas for the (t-z), (Q-z) and (p-y) curves recommended by API and DNV-GL were generated from tests with piles foundation having a size limited to a diameter of 610mm and a length of 21m. Since the realization of these tests, offshore structures have evolved in size. Nowadays, most of piles installed in European wind farms have wider diameter and could have longer penetration.

In the framework of R&D project called CHARGEOL, **numerical studies & laboratory soil tests using new piles dimensions have been performed and new (t-z), (Q-z) and (p-y) curves have been generated in order to better estimate the resistance of pile foundations.**

Research studies have been carried out by STX France, IFSTTAR, INNOSEA, and ECN with support of *Région Pays de la Loire*.

NUMERICAL TOOL DEVELOPMENT

Pile design is an optimum between soil parameters estimation, in place analysis, installation impact & Offshore rules.

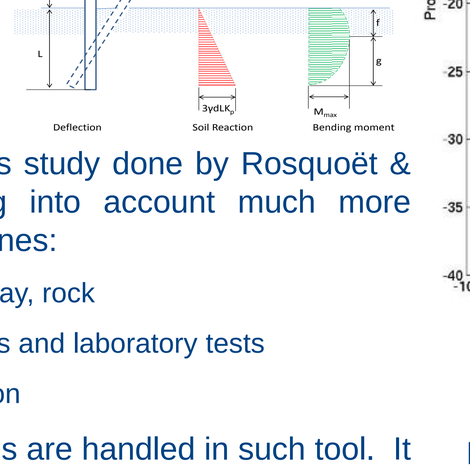

Figure 1

Several numerical tools have been developed but none of them take all parameters into account, avoiding potential optimisation.

In this project, dedicated tool for optimisation of piles has been developed. Part of it is dedicated to numerical evaluation of P-Y curves. This module is realised in parallel of laboratory campaign and integrate them.

The main global aim of this tool is to determinate displacements and stresses on all along short and long piles subject to bending and shear stresses.

Figure 2

Validated thanks to previous study done by Rosquoët & Al. [1], this tool is taking into account much more parameters than the other ones:

- Soil multi-layers with sand, clay, rock
- P-Y,Q-Z,T-Z curves from rules and laboratory tests
- Pile multi thickness distribution

In addition, rock mechanisms are handled in such tool. It has to be noted that very few lateral load tests on drilled shafts have been realised for such soil . However, a single study by Reese [2] has been published and has established criteria for selection of P-Y curves in rock. Such methods have been implemented in the numerical tool, giving the opportunity to integrate rocks in soil layers and pile design.

EXPERIMENTAL CAMPAIGN

Large experimental campaign has been carried out using IFSTTAR centrifuge test means in 2014 in order to evaluate new P-Y, T-Z & Q-Z curves.

Numerous samples have been realised with large diameter piles: 1800mm and long embedment: 40,0m. The studied soil was the well-known cohesionless Fontainebleau sand, which is one of the two most used type of soil for academic research purposes. Its density is 1630kg/m^3.

Campaign was focusing on monotone but also cyclic loads. Group effect has also been subject of studies, using scaled jacket type model.

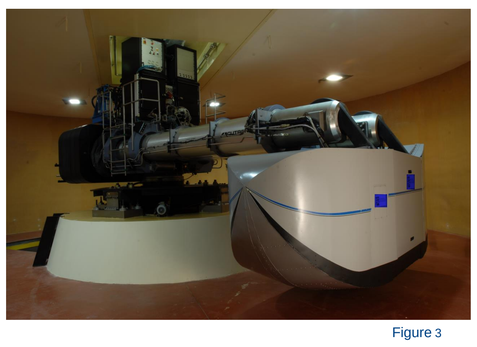
Figure 3

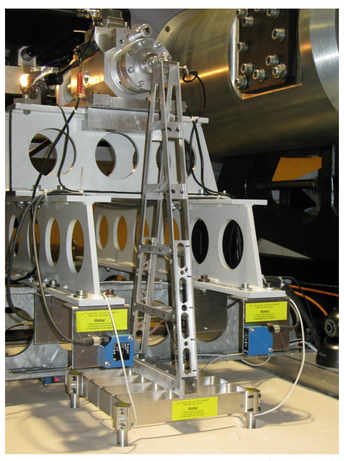
Figure 4

Following figures gives an overview of obtained results in term of pressure and bending moment all along the scaled piles.

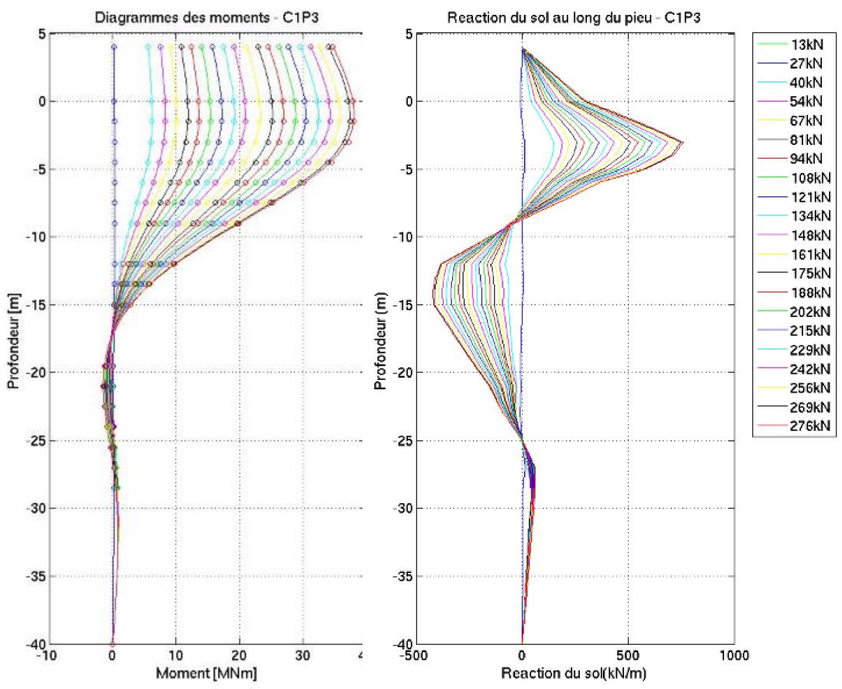

Figure 5

From samples, full scale P-Y curves are blended for a large range of shear forces applied on pile head: from 13kN to 276 KN, as shown on figure 5.

Global behaviour of the reconstituted P-Y curves correspond to the attended ones. Indeed, active and passive earth pressures zones occurs as expected.

ANALYSIS OF RESULTS

For shallow soil depth, comparison of experimental results (figure 5) with API / DNV-GL formulas (figure 6) demonstrates that soil reactions are underestimated by API / DNV-GL where piles will be subject to large displacements.

This statement is of main importance considering that such area constitute a crucial zone for lateral resistance of piles.

For local deeper zones where soil reaction is very low, empirical formulas does not give accurate results in term of lateral resistance (cf. z = 8m and z = 25m, figure 5).

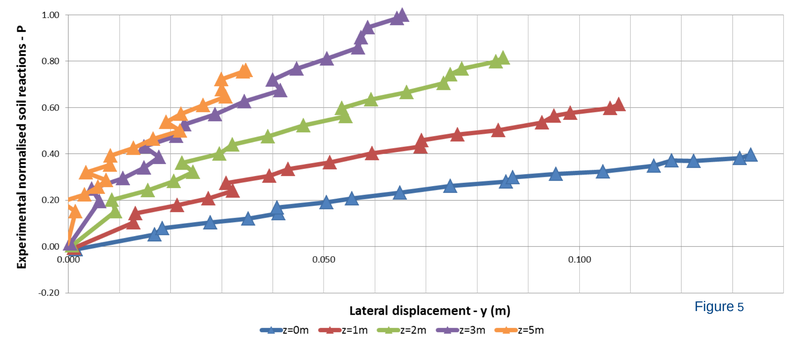

Figure 5

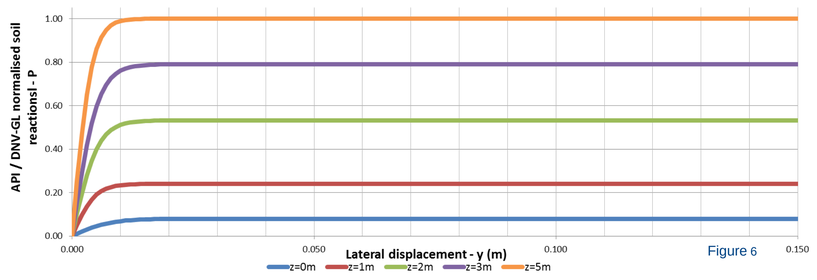

Figure 6

Coming back to global pile behaviour, this overestimation of rules has impact on displacement of the overall structure. For example, pile head displacement is overestimated about 15% (fig. c).

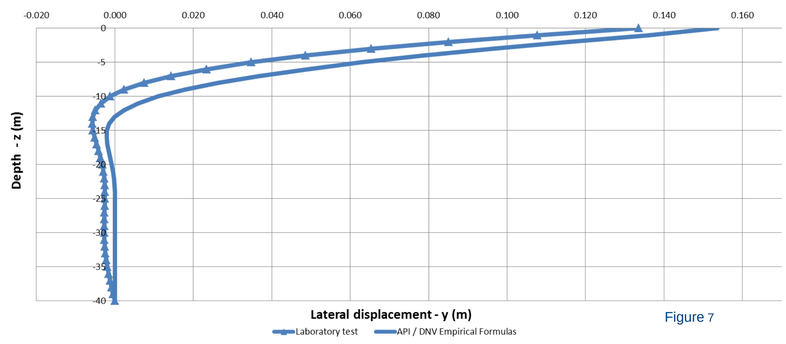

Figure 7

For axial purpose, this overestimation also appears and conclusions are the same (cf. figure 8 below).

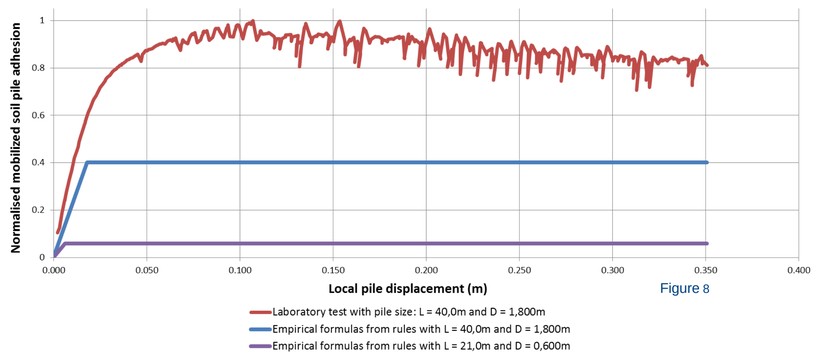

Figure 8

CONCLUSIONS

CHARGEOL R&D project gives the opportunity to reconsider P-Y curve estimation for offshore wind sector.

Based on O&G industry, new tests have shown the importance of reconsidering them with new challenges encountered in Wind Energy and the overestimation shown during the project.

Integration of experimental results come in addition of an innovative tool where all main drivers of pile conception are taken into account and real optimization can be handled.

References

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