

SCOUR DEVELOPMENT AROUND JACKET FOUNDATIONS ON A SANDY SEABED - AN ANALYSIS OF THE TEMPORAL EVOLUTION

PIET HAERENS ⁽¹⁾⁽²⁾, ANNELIES BOLLE ⁽¹⁾⁽³⁾ & FRANCISCO ARACIL ⁽¹⁾⁽⁴⁾

⁽¹⁾ International Marine and Dredging Consultants,
Coveliersstraat 15, B-2600 Antwerp, Belgium, tel +32 (0)3 270 92 95.

⁽²⁾Senior engineer; pih@imdc.be; ⁽³⁾Engineer advisor; abo@imdc.be; ⁽⁴⁾Project engineer; far@imdc.be

1. Introduction

Recently the offshore wind farm projects have been more and more shifted from small to medium offshore wind turbine generators (2–3 MW) to larger wind turbines (5–6 MW). Design and research activities for larger offshore wind turbines (8–10 MW) have started and test sites are already planned for execution in the upcoming years. In view of this, the interest of the offshore industry in jacket foundations is recently increased and seabed and scour development related questions will need to be answered more frequently. In view of this the analysis of the scour behaviour around already installed jacket foundations can bring new insights and guidance.

C-Power started in 2011 to install jacket foundations to complete their offshore wind farm situated at about 37 km off the Belgian coastline on top of the Thornton Bank. In this second phase in total 30 turbines of 6.15 MW each will be installed on jacket foundations between 2011 and 2012, together with a second high voltage cable and an Offshore Transformer station (OTS).

Within this paper the key findings from a detailed seabed monitoring program related to the temporal evolution of the scour development around the jacket foundations will be presented and compared with the values reported in literature and within guidelines. Although further research will be needed in the upcoming years, this first dataset can provide a valuable contribution to the set-up of guidelines and empirical formulas for the prediction of the time scale of scour development around jacket foundations.

2. Methods

Whereas around the GBFs a rock armour scour protection has been installed, the jackets have been designed to be able to cope with the expected scour holes around the piles. In the design phase IMDC was requested to define the design seabed level for the geotechnical design of the foundations taking into account the future developments of the seabed, including local and global scour development due to the jacket foundations. Beside the estimate of the scour pit dimensions (extent and depth) an estimate of the temporal evolution of the scour depth was provided. Scour protection around monopiles has already been intensively studied and reported (Sumer and Fredsøe, 2001; 2002; Den Boon et al., 2004; Harris J.M. and Whitehouse et al., 2011) and some manuals (Whitehouse, 1998) and guidelines (DNV, 2011; GL 2005) are available. For scour around jacket foundations only a few studies are available. The research work published by Sumer and Fredsøe (2002) includes a number of results of physical model tests around pile groups and foundations with complex configurations. These results have shown that horizontal or inclined bracers can have large influence on the scour development around more complex structures. In lack of any guideline or standard, IMDC applied a methodology which included the definition of alarm, intervention and danger lines to define design seabed levels and to cope with uncertainties related to the prediction of scour around jacket foundations.

From the seabed around the jacket foundations high resolution multi-beam measurements are available since the start of the marine works. In February 2012 already 12 datasets were available for each location. An example of the surveys is shown on the contour plots for jacket foundation E2 in Figure 1. In combination with the hydrodynamic conditions this results form a valuable dataset for the assessment of the scour formation around the jacket foundations. Only two storms occurred during this period: December 2011 (H_s up to 4 m) and January 2012 (H_s from 3.5 to 4.5 m).

The main focus of the analysis is the scour pit development around the jacket foundations in time. The general evolution of the sea bottom (due to general erosion of the seabed or due to the movement of sand waves) is taken into account in the reference seabed level (RSBL) which corresponds to the lowest expected seabed level, without the presence of structures, during the considered lifetime of the project. This RSBL is also to be followed up, but is not the subject of the analysis presented in this paper. The theoretical temporal scale of the scour pit developments described by DNV (2010) and Sumer and Fredsøe (2002) is been verified with the results of the in-situ multi-beam measurements around the jacket foundations. Since for the estimates of the temporal evolution

of the scour holes, empirical formulas have been used which are independent from these parameters, no further hydrodynamic analysis has been made up till now, but it should be further investigated if these conditions influenced the temporal evolution of the scour hole.

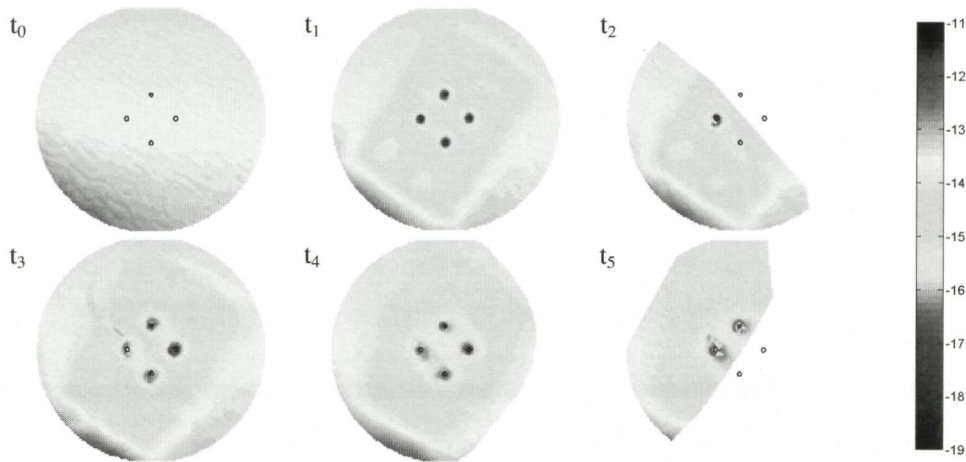


Figure 1 – Temporal scour development around jacket foundation at wind turbine E2.

3. Results and discussion

After pre-piling distinct circular scour holes developed around the piles. The average erosion depth is $0.65D$, compared to the expected value of about $1.3D$ for indefinitely high piles. The maximum observed scour depth is $1.2D$, lower than the expected value. The time between the survey and the pile installation is on average 2.5 months, which should be enough to have fully developed scour, according to the DNV formula (DNV, 2011) which is similar to the relationship suggested by Sumer and Fredsoe (2002) for the depth of the scour hole as a function of time. For typical conditions of $U = 0.6$ m/s, $H_s = 0.5$ m, $T_p = 4$ s and water depth of 25 m, the expected scour depth should be reached after nearly one month. The reasoning why the scour development in time is not stopped yet, meaning that no scour equilibrium is met, is still under investigation.

4. Conclusions

This research targets the study of the development in time of the seabed scour around jackets. The observations from measurements are compared with available guidance for less complex structures, like pile groups. The influence of complex structure on the scour pattern and development is investigated. The analysis of these types of measurements in combination with site conditions can contribute to adapted formula for the prediction of the temporal evolution of the scour development around jacket foundations.

Acknowledgments

We would like to thank C-Power for making the datasets available and for sharing these findings.

References

- Den Boon J.H., Sutherland J., Whitehouse R.J.S., et al., 2004. 'Scour behaviour and scour protection for monopile foundations of offshore windfarms'. In *Proceedings of the European Wind Energy Conference & Exhibition*, London, UK, 22–25 November. EWEA, Brussels, Belgium. Available: www.2004ewec.info
- DNV (Det Norske Veritas), 2011. 'Design of Offshore Wind Turbine Structures'. Det Norske Veritas, Bærum, Norway, Offshore Standard Report DNV-OS-J101.
- GL (Germanischer Lloyd), 2005. 'Guidelines for the Certification of Offshore Wind Turbines'. Germanischer Lloyd, Hamburg, Germany.
- Harris J.M., Whitehouse R.J.S. and Benson T., 2010. 'The time evolution of scour around offshore structures'. *Proceedings of the Institution of Civil Engineers – Maritime Engineering*, 163(1), 3–17.
- Sumer B.M. and Fredsøe J., 2001. Wave scour around a large vertical circular cylinder. *Journal of Waterway, Port, Coastal and Ocean Engineering*, volume 127, issue 3, pages 125–134.
- Sumer B.M. and Fredsøe J., 2002. 'The mechanics of scour in the marine environment. Advanced series on Ocean Engineering', Volume 17, World Scientific, Singapore. ISBN 981-02-4930-6
- Whitehouse R.J.S., 1998. 'Scour at Marine Structures', ThomasTelford, London, UK. ISBN 0 7277 2655 2
- Whitehouse R.J.S., Harris JM, Sutherland J et al., 2011, *Marine Pollution Bulletin*, volume 62, issue 1, pages 73–88.