Paper Abstract No. 327 – 32nd International Conference on Coastal Engineering (ICCE), 2010, Shanghai, China

WAVE LOADS AND STABILITY OF NEW FOUNDATION STRUCTURE FOR OFFSHORE WIND TURBINES MADE OF OCEAN BRICK SYSTEM (OBS)

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1 INTRODUCTION

In the context of climate changes and ocean utilisation, innovative concepts and structures are not only urgently needed for coastal defences (Oumeraci, 2009), but equally also for offshore structures, especially for structures related to the use of renewable energy from and in the ocean.

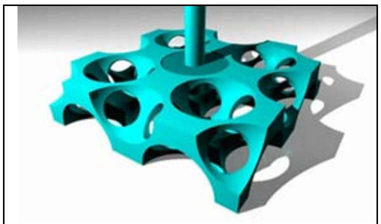


Fig. 1 OBS-Foundation for Offshore Wind Turbines

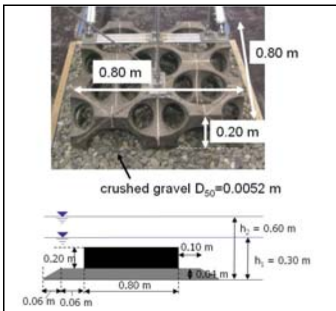
With this background, a modular system called the OBS (**O**cean **B**rick **S**ystem), which consists of hollow concrete precast blocs (10m x 10m x 10m) piled up like cubes and interconnected to create a stiff, light and strong structure. The latter can be used for artificial islands, artificial reefs, evaluation of vulnerable low lands, deep water ports, breakwaters and foundation of offshore wind turbines. The entire structure or components can be built in a dry dock and then floated and towed to the planned construction site. OBS Ltd. has commissioned the Leichtweiss-Institute (LWI) to conduct systematic hydraulic model studies on the wave loading and hydraulic performance of different types of structures made of ocean bricks such as foundation of offshore wind turbines, harbour breakwaters and quay walls.

The primary objective of these studies is to understand and predict the hydraulic functioning (e.g. wave transmission, reflection, dissipation, overtopping), the total wave loads and stability of the OBS used for a wide range of coastal, harbour and offshore structures, including artificial islands. A further objective is to identify the limitations of the OBS with respect to both hydraulic performance and stability against wave loads, but also to test possible solutions for reducing these limitations, (e.g. increase of stability, decrease of wave transmission).

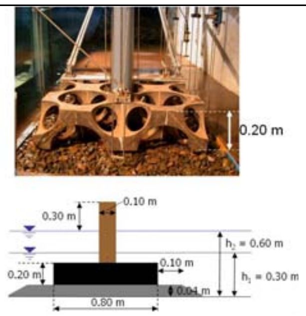
Some of the first experimental results of the study on wave loads and stability of an OBS used for the foundation of an offshore wind turbine have recently been presented by focusing on the measuring techniques employed and preliminary design diagrams, but without providing any design formulae for the prediction of the wave load and the stability of the OBS structure and its rubble foundation (Oumeraci, et al, 2009).

This paper will first summarize the previous findings and will then focus on the development of design formulae.

2 EXPERIMENTAL SET-UP AND TESTING PROGRAM



a) Mini-Offshore model without monopile (Model set-up 1)



b) Mini-Offshore model with monopile (Model set-up 2)

Fig. 2 OBS-Model (1:50) in the LWI-wave flume performed for the stability of the rubble foundation

The prototype OBS-structure (40m x 40m x 40m) was scaled 1:50 and tested in the LWI wave flume (90m x 1.25m x 2m) with and without a monopile (Fig. 2) to determine the total wave loads on the OBS-structure. Additional tests where irregular waves (JONSWAP-spectrum) were used (at least 600 waves/test) with a significant wave height H_s=0.05-0.23m (Prototype H_s=2.5-12.5m) and peak period T_p=1.0-2.8s (Prototype T_p=7-19s). Moreover, solitary waves were used to get a better insight into the underlying processes, and thus to check the reliability of the irregular wave tests. In this paper, however, only the results of the irregular wave tests will be addressed. Further details are given in the final report by Oumeraci et al (2008). Two water depths were tested: h=0.30m and h=0.60m (Prototype h=15m and 30m). Each test was repeated at least twice. A total of more than 200 tests were conducted.

3 WAVE LOAD PREDICTION

The main objective is to determine design formulae for the prediction of the total horizontal and vertical wave forces as well as the overturning moment inducted by irregular waves on the OBS-structure. Since the OBS-structure is large as compared to the wave length, diffraction effects are important. Using wave theory and dimensional analysis, the most dominant influencing parameters for the range of wave conditions tested were found to be (i) relative water depth h/L (dispersion parameter), (ii) wave steepness H/L (nonlinearity parameter), (iii) diffraction parameter 2πa/L (where a is a characteristic linear dimension of the OBS-structure) and (iv) relative water depth (h/a). The effect of each of these parameters on the total wave loads on the OBS-structure is first analysed separately and in combination to better assess their relative importance. In Fig. 3 the effect of the diffraction parameter 2πa/L on the dimensionless horizontal wave force is exemplarily shown for the relative depth h/a=6 and h/a =12 to illustrate the relative importance of both parameters on the wave load. The effect of the other parameters and the obtained prediction formulae will be presented at the conference and in the paper.

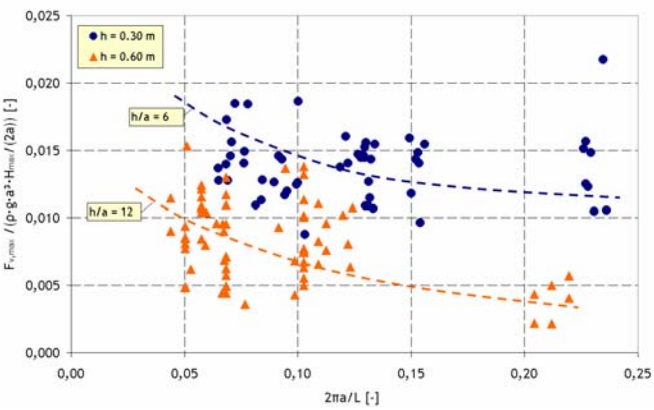


Fig. 3. Effect of diffraction parameter 2πa/L and relative water depth h/a on the dimensionless horizontal wave force

4 STABILITY ANALYSIS OF OBS-STRUCTURE

Based on the results of sliding tests to determine the static friction f_R factor between the OBS-structure and the rubble foundation, showing that f_R=0.6, as well as on the prediction formulae for wave loads, the stability analysis of the OBS-structure (with and without monopole) against sliding and overturning is performed. The results show that (i) the OBS-structure proved is stable enough against wave loads for both investigated water h=15m and h=30m and the associated design wave conditions (H_s=9m, T_p=11.3s and H_s=14m and T_p=17s). Although the contribution of the wind loads on the monopile to the total overturning moment varies from 40% to 90% depending on the water depths tested, the OBS-structure proved to be safe enough. However, the complex wind loads on the nacelle and on the rotor wings should also be considered. (ii) Even without considering the additional effect of wind loads, the OBS-structure may slide for the tested water depths and wave conditions. Countermeasures to enhance the safety against sliding will be proposed at the conference (e.g. filling the voids of OBS with appropriate rubble material).

The detailed results of the stability analysis, including the stability of the rubble foundation will also be presented at the conference and in the paper.

ACKNOWLEGEMENTS

The authors would like to thank Mr. Richard Scheiner, Consultant Engineer OB System, for the preparation of the T.O.R. for the tests, and OBS Ltd. for providing the Oceanbricks (patented) models and for the financial support.

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