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SIMULATION OF EXTREME EVENTS OF OBLIQUE WAVE INTERACTION WITH POROUS BREAKWATER STRUCTURES

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INTRODUCTION

This paper introduces a numerical approach for the analysis of extreme events of oblique wave interactions with breakwater structures. The use of numerical models for analysis of wave-structure interaction is seen more often. However, the major challenge for three-dimensional simulations is the computational cost. For many applications a two-dimensional approximation is valid, however, for investigating oblique wave interaction with coastal structures, a three-dimensional simulation is required.

For extreme event analysis it is necessary to determine the characteristics of the extreme events which will occur during an irregular sea state of a given duration. A three-dimensional simulation of a full irregular sea state with duration of e.g. 3 hr. will be a large computational burden.

The present work proposes a methodology where the analysis is performed in two steps. 1) A two-dimensional simulation of a full 3 hr. irregular sea state is performed including the breakwater structure. The extreme events are observed in terms of loads on the super-structure. 2) The extreme events are reproduced in a three-dimensional model as oblique waves by short realizations.

If the individual extreme events can be reproduced by short sequences without the need for simulating the full irregular sea state, a considerable gain in efficiency can be achieved. The main challenge in this respect is determining the necessary length of the irregular sea state to be included in the short reproduction sequence, in order to accurately capture the same event as seen in the full 3 hr. sea state.

NUMERICAL MODEL AND SETUP

The numerical model is based on the Volume averaged Reynolds Averaged Navier-Stokes equations where the resistance from the porous material is included by the extended Darcy-Forchheimer equation. The numerical method is based on a finite volume discretization on a collocated grid arrangement and is implemented in the OpenFOAM® CFD library.

The numerical model domain for the two-dimensional screening process is set up with approximately two wave lengths in front of the breakwater and one wave length behind the breakwater. For the three-dimensional simulations the domain is extended in the transversal direction in order to include oblique waves. Relaxation zones are utilized for both wave generation and absorption.

The two-dimensional screening process was performed with an irregular sea state based on a JONSWAP spectrum. The simulation time was 3 hr. corresponding to 700-1000 waves depending on the wave peak period. All simulations were performed in prototype scale.

RESULTS

The proposed methodology is applied for analyzing extreme event interaction with a breakwater with several core, filter, and armour layers. Results are obtained for the two-dimensional screening process and for the three-dimensional extreme event reproductions.
For the two-dimensional simulations the statistical properties for the irregular sea state are analyzed in order to evaluate the statistical distribution of overtopping events, impact events etc. Also the wave statistics in front of the structure is evaluated. Based on the two-dimensional screening a number of extreme events are selected for reproduction in a three-dimensional setup. In the three-dimensional simulations the waves are applied as oblique waves relative to the structure. Effect of the angle of attack on overtopping, reflection, and forces are analyzed.