VOFBREAK^2

DEVELOPMENT OF TWO-DIMENSIONAL NUMERICAL WAVE FLUME FOR SIMULATION OF WAVE INTERACTION WITH RUBBLE MOUND BREAKWATERS

Introduction

Contributing to the ongoing research on wave interaction with coastal structures, a numerical model for the simulation of free surface breaking waves at permeable coastal structures is developed at the Department. This numerical wave flume aims at a better description of the wave-induced flows and pressures, resulting in a better design (tool) of coastal structures.

The numerical model VOFbreak^2, VOF-algorithm for breaking waves on breakwaters, is based on the original SOLA-VOF code capable to compute free surface flow when the fluid domain becomes multiply connected. Incompressible Newtonian fluid with uniform density is assumed in the vertical plane (two dimensional), governed by the Navier-Stokes equations and the continuity equation. Finite difference solutions are obtained on an Eulerian rectangular mesh in Cartesian geometries.

Key Innovations

The key innovations required for simulation of wave interaction with permeable rubble mound structures are :

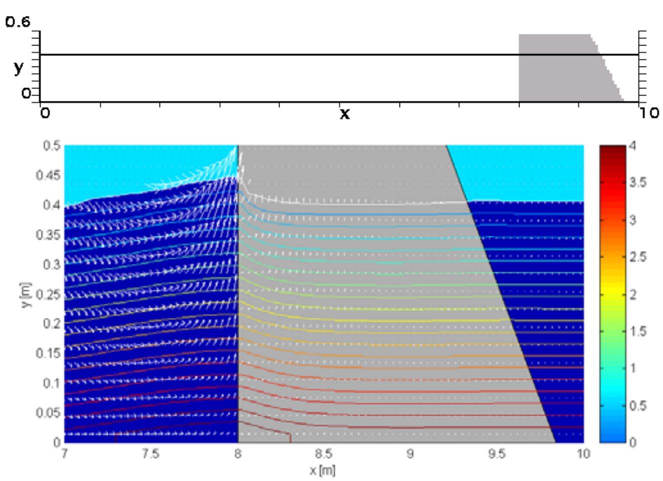

Fig. 1. *Validation of wave interaction with a breakwater with vertical front face: general overview of model set-up (top) and detailed view of flow field near breakwater (bottom).*

Porous Flow Model

The governing Navier-Stokes equations are extended, to include the simulation of porous flow inside the permeable coastal structure (Fig. 2), using Forchheimer flow resistance terms.

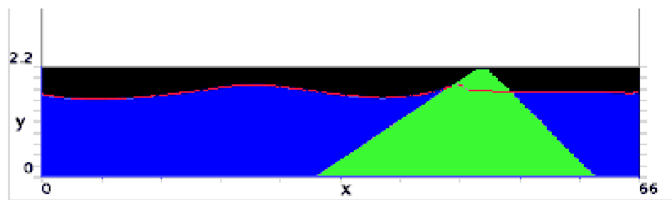

Fig. 2. *Wave interaction with a permeable rubble mound breakwater with homogeneous core.*

Wave Boundary Conditions

A number of wave boundary conditions are implemented. Incident waves are generated using boundary wave generation. Any wave theory can be applied at the boundary of the computational domain to provide the surface elevation and the velocity components at the boundary.

For absorption of reflected waves at the boundary, an active wave absorbing technique is used. This numerical boundary condition is based on an active wave absorption system that is well known already for physical wave flume application using a wave paddle. The method applies to regular and irregular waves. Velocities are measured at one location inside the computational domain. The reflected wave train is separated from the wave field in front of the structure by means of digital filtering and subsequent superposition of the measured velocity signals. An additional incident wave train is determined in order to absorb the reflected wave train.

Code Portability

The code is implemented using ANSI C, providing general computer compatibility, and providing a flexible code structure for adaptations with little effort. A series of post-processing tools has been developed, using

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Tcl/Tk for the visualisation, processing and interpretation of the computed results. Numerical instrumentation for the acquisition of relevant phenomena (wave height, run-up level, pore pressure, surface elevation, ...) is included for easy access to calculated data.

Validation

The numerical model is verified with both physical model data acquired at Aalborg University (Denmark, Fig. 1) and at Leichtweiss Institut für Wasserbau (Germany), and prototype data (Fig. 3 and Fig. 4). This latter validation is unique world-wide by using the Zeebrugge breakwater (Belgium) prototype wave and pressure data. Validation results will help to improve further developments of the numerical wave flume.

Contact

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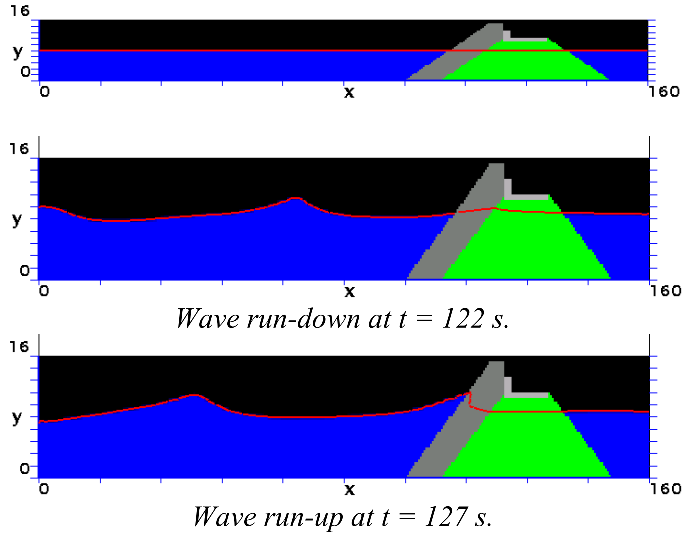

Fig. 3. *Validation of wave interaction with the Zeebrugge breakwater with armour layer and core: general overview of model set-up (top) and detailed view of flow field near breakwater (bottom) during wave run-down and run-up resp.*

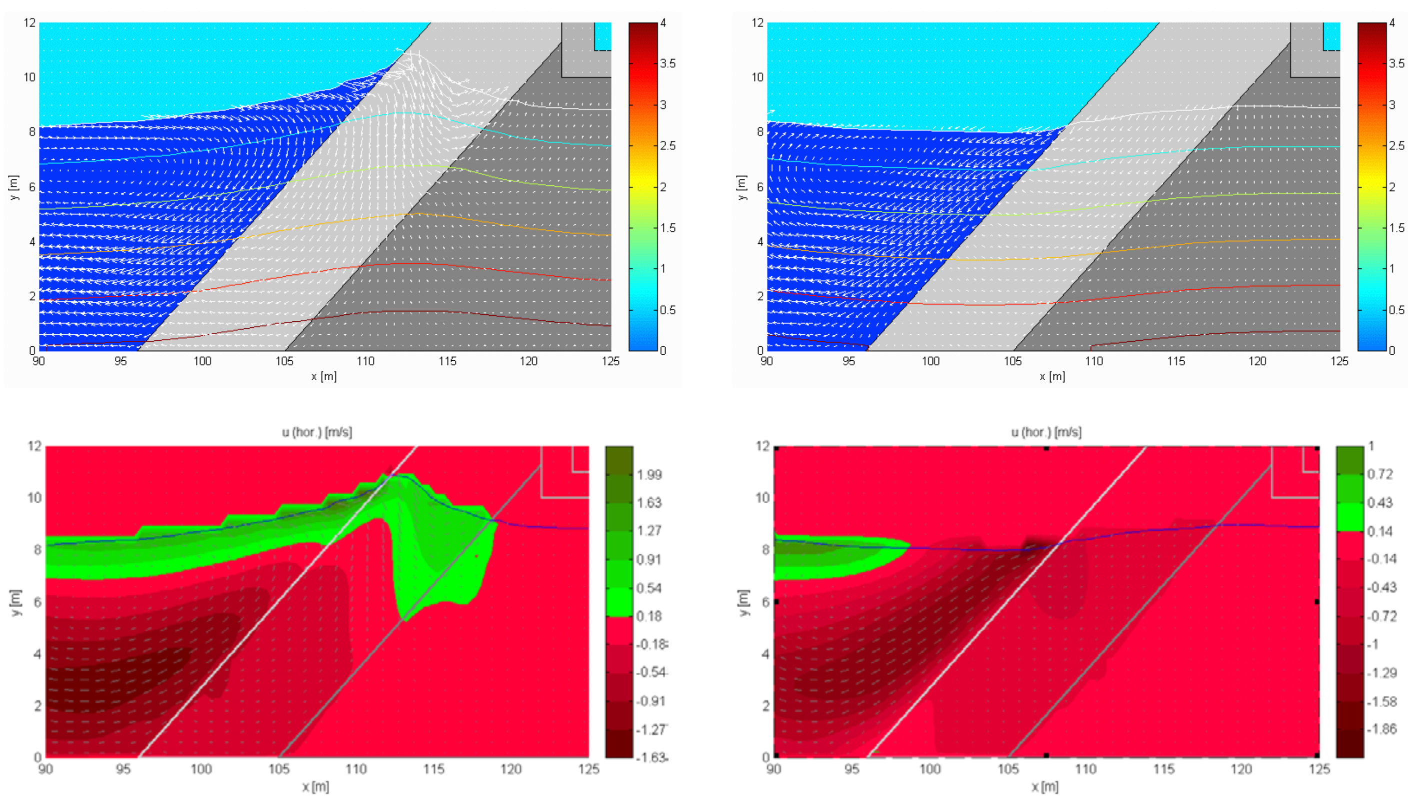

Fig. 4. *Detailed view of flow field near breakwater with pressure field and velocity field (top), and magnitude of horizontal velocity component (bottom, red: to the left, green: to the right).*