Performance of Numerical Boundary Condition based on Active Wave Absorption

Troch, Peter; De Rouck, Julien; Frigaard, Peter

Published in:
Proceedings of the 27th International Conference on Coastal Engineering : ICCE '00, Sydney, Australia

Publication date:
2001

Document Version
Early version, also known as pre-print

Performance of Numerical Boundary Condition based on Active Wave Absorption System

Peter TROCH *, Julien DE ROUCK *, Peter FRIGAARD °
* Dept. of Civil Engineering, Ghent University, Technologiepark 9, B-9052 Ghent, Belgium, PeterB.Troch@rug.ac.be
° Hydraulics & Coastal Engineering Laboratory, Aalborg University, Aalborg, Denmark

1 Introduction

The performance of a new active wave generating-absorbing boundary condition for a numerical model based on the Volume Of Fluid (VOF) method for tracking free surfaces is presented. The numerical boundary condition has been implemented in the numerical model VOFbreak² (e.g. Troch (1997), Troch and De Rouck (1998)).

The numerical boundary condition is based on an active wave absorption system (AWASYS) that was first developed in the context of physical wave flume experiments, using a wave paddle (Frigaard and Christensen, 1994). Fig. 1 shows a conventional numerical wave flume set-up. Waves are generated at the left boundary of the computational domain and propagate towards a rubble mound breakwater positioned near the other boundary. The incident waves interact with the porous breakwater causing reflected waves to propagate towards the wave generating boundary. At the boundary an absorbing boundary condition is required allowing the reflected waves to leave the computational domain without disturbing the interaction of the incident waves with the breakwater.

2 Principle of AWASYS boundary condition

The AWASYS system originally is based on the simultaneous on-line measurement of the surface elevation at two different points. The system for VOFbreak² is based on orbital velocities. The principle requires two steps. First an on-line detection of the reflected wave field is performed using the set of spatially co-located velocities (u, v). Secondly the wave generator has to generate the incident wave η_i and an additional wave η^* that cancels out the reflected wave (Fig. 1).The correction signal η^* is determined from superposition of the two filtered velocity signals. The digital FIR-filters are operated using a time-domain discrete convolution of the velocities (u, v) and the impulse response h^i, where i = u or v.

The theoretical derivation and the practical design of the filters for use in the numerical model is explained in Troch and De Rouck (1999).

3 Optimisation of AWASYS for VOF type numerical models

The active absorption system for VOFbreak² includes significant modifications required for optimal performance in the numerical model. The most important are summarised here.

The boundary condition uses a velocity meter based system because velocities are readily (or computationally cheap) available from the computations. Hald and Frigaard (1996) show that the performance (or absorption characteristics) of both elevations and velocities systems is similar.

The digital filters that are based on velocities are easier to realise than filters based on surface elevations: generally less filter coefficients are necessary due to less singularities in the frequency response of the filters.

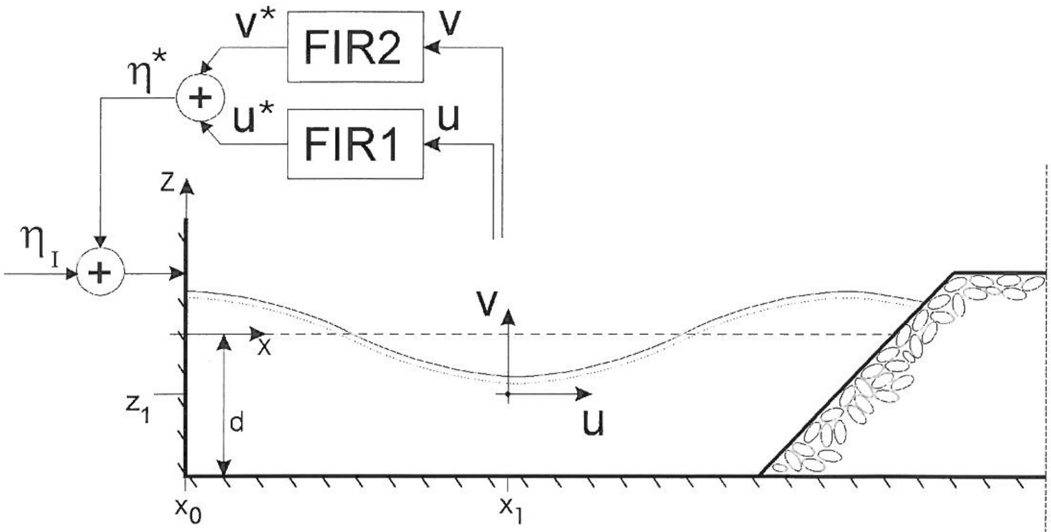

Fig. 1. Definition sketch of numerical wave flume set-up

Execution of the filter convolution is required only at regular time steps Δt_f. Usually the time step Δt_{VOF} of the numerical simulation is smaller than the time step of the convolution Δt_f, requiring η^* values without filtering. For these tests simply the previous corrected elevation η^* is used until a new value becomes available. More practical guidelines for optimal use in a numerical model will be described in the paper.

4 Numerical simulations

A number of numerical simulations have been carried out using VOFbreak² to illustrate the effectiveness of the active wave absorbing boundary condition. Both the cases of pure absorption and simultaneous generation and absorption of waves will be presented in the paper. Here only one example will be provided.

For the case of pure absorption, consider a computational domain with a wave generating boundary at the right boundary x_R = 5.42 m. The left wave generating-absorbing boundary x_0 will operate in absorption mode only and the absorbing wave component η_{-R} at x_0 is calculated from the filtered velocity signals at x_1 = 2.99 m, z_1 = -0.05 m. Optimal performance is achieved when the incident waves are absorbed completely at x_0, i.e. when elevation η and velocities (u, v) at x_0 are equal to elevation (with opposite phase) and velocities (in phase) at x_R. From Fig. 2 it is seen that the absorption of the waves starts after exactly two wave periods, when the incident wave has reached the other boundary. As soon as the wave generation has stopped at t = 60 s, the wave absorbing boundary absorbs the last two waves propagating inside the flume, and very soon afterwards the water inside the flume returns quiescent.

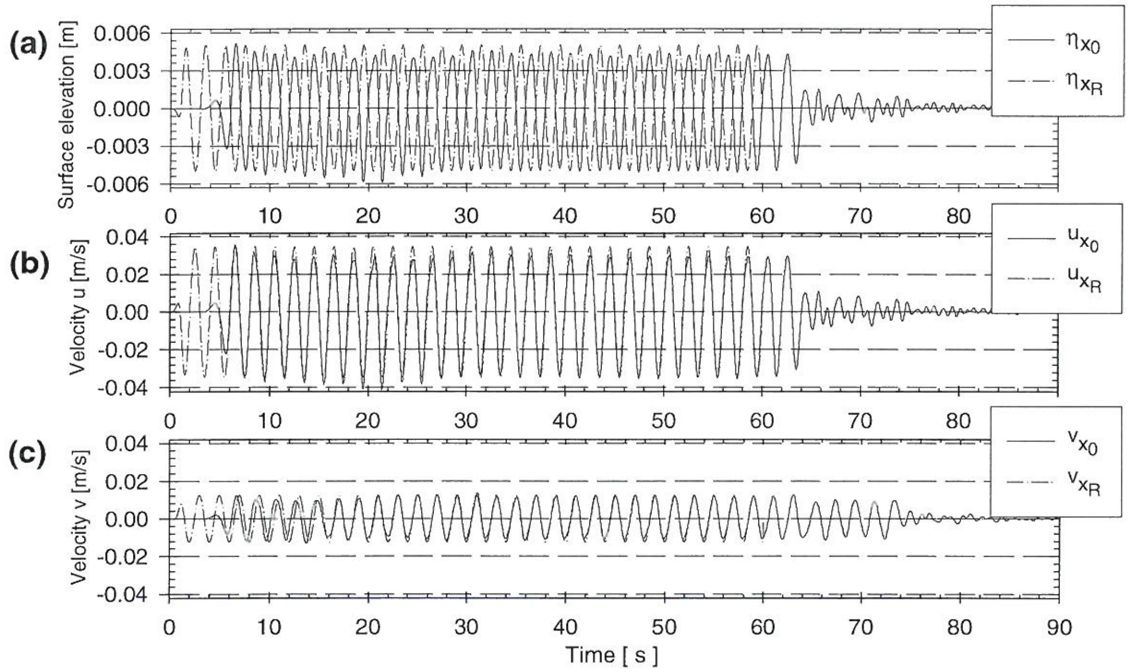

Fig. 2. Time series at x_0 = 0.0 m and at x_R = 5.42 m for: (a) surface elevation η, (b) horizontal velocity component u, (c) vertical velocity component v. Incident wave characteristics H_i = 0.01 m, T = 2.0 s, d = 0.20 m. Velocity components at level z_l = -0.05 m.

REFERENCES

Frigaard P. and Christensen M., 1994. An absorbing wave-maker based on digital filters. In: Proceedings, 24th ICCE, Kobe, Japan, Vol.1, pp. 168-180.

Hald T. and Frigaard P., 1996. Performance of active wave absorption systems – comparison of wave gauge and velocity meter based systems. In: Proceedings 2nd ICOPMAS, Tehran, Iran.

Troch P., 1997. VOFbreak², a numerical model for simulation of wave interaction with rubble mound breakwaters. In: Proceedings 27th IAHR Congress, San Francisco, USA, pp. 1366-1371.

Troch P. and De Rouck J., 1998. Development of 2D numerical wave flume for simulation of wave interaction with rubble mound breakwaters. In: Proceedings 26th ICCE, Copenhagen, Denmark.

Troch P. and De Rouck J., 1999. An Active Wave Generating-Absorbing Boundary Condition for VOF type numerical model. Coastal Engineering, Vol. 38(4), pp. 223-247, Elsevier, The Netherlands.