NUMERICAL MODELLING OF LARGE-SCALE COASTAL WAVE IMPACTS IN SHALLOW FORESHORE CONDITIONS

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INTRODUCTION

Low-lying countries typically have mildly-sloping beaches as part of their coastal defence system. For countries in north-western Europe high-rise buildings are a common sight close to the coastline. They are usually fronted by a low-crested sea dike with a relatively short promenade, where the long (nourished) beach in front of it acts as a very/extremely shallow foreshore as defined by Hofland et al. (2017). Along the cross-section of this hybrid beach-dike coastal defence system, storm waves are forced to undergo many transformation processes before they finally hit the buildings on top of the dike. These hydrodynamic processes include: shoaling, sea and swell wave energy transfer to sub- and superharmonics via nonlinear wave-wave interactions, wave dissipation by breaking and bottom friction, reflection against the dike, wave run-up and overtopping on the dike, bore impact on a wall or building, and finally reflection back towards the sea interacting with incoming bores on the promenade.

For the design of storm walls or buildings on such coastal dikes, the wave impact force expected for certain design conditions needs to be estimated. Due to the complexity of the processes involved, usually physical modelling is applied, but numerical modelling of these combined processes has become feasible during the last decade. This paper investigates which type of numerical model is practically applicable for this case. Three open-source CFD models are selected, each representing one of the most popular in its category: (1) a RANS model (OpenFOAM®, OF), (2) a weakly compressible SPH model (DualSPHysics, DSPH), and (3) a non-hydrostatic NLSW equations model (SWASH). They are validated and compared to large-scale experiments of overtopped wave impacts on coastal dikes with a very shallow foreshore and their model performance is evaluated.

LARGE-SCALE PHYSICAL MODELLING

The large-scale hydraulic experiments (Streicher et al., 2017) were performed in the Deltares Delta Flume (L x W x H: 291.0 m x 5.0 m x 9.5 m) and the model geometry was built at scale 1/4.3. The moveable sandy foreshore had a transition slope of 1:10 and a slope of 1:35 up to the toe of the dike. The smooth impermeable concrete dike had a slope of 1:2 and a promenade width of 2.35 m. The promenade had an approximate inclination of 1:100 in order to help drain the water after an overtopping event. At the end of the promenade a 1.6 m high wall was built which covered the entire flume width. Measurements included: free surface elevations, flow layer thickness and horizontal velocity U_x on the promenade, pressures p and horizontal force F_x on the vertical wall. Both bichromatic and irregular waves were included in the test matrix.

NUMERICAL MODELLING COMPARISON

Bichromatic wave tests are selected from the experiments for the numerical model validation and comparison, because of their short duration (limits computational cost and a fixed bottom foreshore assumption becomes acceptable). Model accuracy for all measurements is quantified and evaluated by model performance (Willmott's refined index of agreement) and pattern statistics (bias, standard deviation and correlation) to describe the nature of the error. Model snapshots of key time instants are compared during an impact on the vertical wall (Fig. 1): OF shows the best agreement with the experiment. More detailed results of the model comparison and recommendations on the application of each numerical model will be presented at the conference.

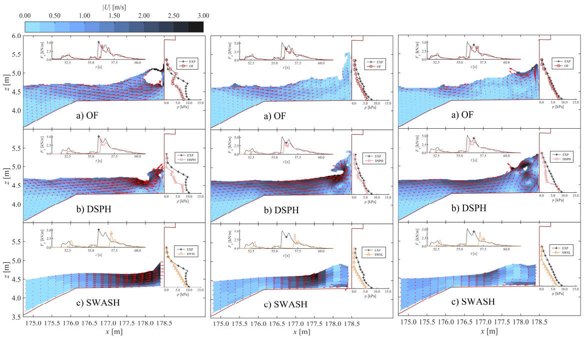

Figure 1 - Snapshots of numerical model results on the dike for three key time instants (red arrows are U vectors)

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