Towards an improved numerical modelling methodology for wave overtopping on a dike with a very shallow foreshore

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Climate resilient flood protection is essential for low-lying countries, such as Belgium. To increase coastal safety, the Belgian coastal defence system is currently being adapted by a combination of a beach nourishment and dike crest level increase by a storm wall [1]. In other words, the Belgian coastal defence system comprises of a dike fronted by a nourished beach, acting as a very shallow foreshore. As a result, waves undergo many transformations before they reach the dike, due to the limited water depth.

In the functional design of these storm walls, their height is calculated by determining wave overtopping, which is limited to a specific safety criterion. The wave impact forces need to be resolved for the design of their structural stability. Current state-of-the-art methodologies to design this type of defence system still contain simplifications that are too conservative for this kind of situation. For example, these do not take into account important physical processes resulting from the complex geometry of the typical Belgian coastal profile, which often leads to conservative assumptions.

The aim of this research is to develop less conservative and more accurate modelling tools for calculating wave overtopping and forces on the dike and buildings on top, while maintaining the required computational time at a reasonable level. This is being achieved by applying an advanced numerical model (OpenFOAM [2]), resolving the hydrodynamic flow in full 3D (or 2DV). This allows for a much more accurate prediction of individual wave overtopping volumes and impacts on buildings or storm walls. However, this type of numerical model requires a high computational effort. To reduce this as much as possible, the model should only be applied where the most complex flows occur, i.e. on the dike. The wave transformation up to the dike is then modelled using a simplified numerical model (SWASH [3]), thereby reducing the computational time significantly: from weeks to merely hours. A coupling strategy between these models is being developed within the present research.

However, to establish sufficient confidence in the numerical modelling results, their verification is necessary. This is achieved by comparing to hydrodynamic experiments conducted in a 2D wave flume. OpenFOAM has been validated using wave impact tests at scale 1:4.3 in the Delta Flume of Deltares (Hydralab+ WaLoWa project [4]) and SWASH has been validated using the CREST tests at scale 1:35 performed in the large wave flume of the Coastal Engineering Research Group of Ghent University.

Contrary to laboratory experiments, field tests do not suffer from scale effects nor from model effects. That is why field tests are also a crucial part of the numerical validation process. Field observations of wave overtopping and impact will be achieved by constructing an “Artificial Dike” close to the high water line, effectively lowering the crest of the sea dike and thereby allowing such measurements on the short term. The wave transformation from offshore until the Artificial Dike will be measured by an offshore wave buoy and sensors on the intertidal beach. These observations are currently foreseen for a period of at least five years, starting from winter 2019-2020. The field test setup will be located on the beach in Raversijde (Ostend).

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