Numerical modelling of changing beach morphodynamics and wave-interactions with a dike for very shallow foreshores

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Low-lying countries such as Belgium and the Netherlands have a very typical coastal defence system along most of the coastal urban areas: a mildly sloped and (very) shallow beach in front of a dike with a promenade and high rise buildings close to the dike crest. The current threat of sea level rise and the expected increase in storminess due to climate change, may lead to a higher risk of overtopping during storm surges. To guarantee enough safety for the entire Flemish coast until the year 2050, the coastal defence systems are therefore being reinforced with beach nourishments and storm walls on top of the promenade. The presence of a shallow and morphologically dynamic foreshore in front of the dike has a significant influence on overtopping and wave loading forces as waves transform considerably before reaching the dike. Besides, substantial morphological processes take place such as erosion due to the intense hydrodynamic dissipation process. The effect of the latter on overtopping and wave loading forces and the wave-interactions with the dike are not yet fully understood and pose a challenge in current design methodologies.

The main objective of the current research, carried out within the CREST project (www.crestproject.be/en), is to develop a more accurate tool to predict wave-induced overtopping and wave loads on coastal structures including the effect of the changing beach morphodynamics for shallow foreshore conditions and to obtain a thorough understanding of the nearshore coastal processes. Numerical modelling is a suitable tool to investigate these processes and deliver reliable results. In this research, the Computational Fluid Dynamics (CFD) open-source software OpenFOAM (Weller and Tabor, 1998) is applied with olaFOAM boundary conditions for wave generation (Higuera et al., 2013a) to resolve the flow over the complete water depth and allow modelling of the complex overtopped flow on the dike and promenade. This is necessary to be able to model wave-interactions with dikes of very complex geometries (e.g. with storm walls, parapets, etc...). OpenFOAM has already shown to be able to provide accurate results for simulating coastal engineering processes (Higuera et al., 2013b). Additionally, the code can be easily adapted to account for user-specific applications, which makes it a suitable research tool for this work.

For example, the dynamic beach profile is modelled at the same time as the overtopping process to assess the effect on the overtopping flow and possible effects of the energy consumption by sediment transport on the wave transformation over the beach. Therefore, a sediment transport and morphology (i.e. bed changes) module is implemented within the OpenFOAM source code.

The new code is currently being validated with wave flume experiments including sediment transport, documented in literature. Further validation will be done by experimental data (including bed profile measurements) from the European Hydralab+ project WaLoWa (Kortenhaus et al., 2017). These experiments have been performed at very large scale (1/4.3) and include a shallow foreshore and a movable sand bed. The large scale ensures that scale effects will be limited.

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