Probabilistic Assessment of Overtopping of Sea Dikes with Foreshores including Infragravity Waves and Morphological Changes: Westkapelle Case Study

Authors:
Patrick Oosterlo[1,*ID] , Robert Timothy McCall[2], Vincent Vuik[1,3], Bas Hofland[1,2], Jentsje Wouter van der Meer[4,5] and Sebastiaan Nicolaas Jonkman[1]

[1] Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands
[2] Deltares, Delft, The Netherlands
[3] HKV Consultants, Lelystad, The Netherlands
[4] Van der Meer Consulting BV, Akkrum, The Netherlands
[5] IHE Delft, Delft, The Netherlands
[*] Correspondence: P.Oosterlo@tudelft.nl

Abstract

Shallow foreshores in front of coastal dikes can reduce the probability of dike failure due to wave overtopping. A probabilistic model framework is presented, which is capable of including complex hydrodynamics like infragravity waves, and morphological changes of a sandy foreshore during severe storms in the calculations of the probability of dike failure due to wave overtopping.

The method is applied to a test case based on the Westkapelle sea defence in The Netherlands, a hybrid defence consisting of a dike with a sandy foreshore. The model framework consists of the process-based hydrological and morphological model XBeach, probabilistic overtopping equations (EurOtop) and the level III fully probabilistic method ADIS.

By using the fully probabilistic level III method ADIS, the number of simulations necessary is greatly reduced, which allows for the use of more advanced and detailed hydro- and morphodynamic models. The framework is able to compute the probability of failure with up to 15 stochastic variables and is able to describe feasible physical processes. Furthermore, the framework is completely modular, which means that any model or equation can be plugged into the framework, whenever updated models with improved representation of the physics or increases in computational power become available. The model framework as described in this paper, includes more physical processes and stochastic variables in the determination of the probability of dike failure due to wave overtopping, compared to the currently used methods in The Netherlands. For the here considered case, the complex hydrodynamics like infragravity waves and wave set-up need to be included in the calculations, because they appeared to have a large influence on the probability of failure. Morphological changes of the foreshore

during a severe storm appeared to have less influence on the probability of failure for this case. It is recommended to apply the framework to other cases as well, to determine if the effects of complex hydrodynamics as infragravity waves and morphological changes on the probability of sea dike failure due to wave overtopping as found in this paper hold for other cases as well. Furthermore, it is recommended to investigate broader use of the method, e.g., for safety assessment, reliability analysis and design.

Keywords:

Probabilistic modelling; foreshore; infragravity waves; wave overtopping; morphological changes; safety assessment.