Comparison between the turbulence parameter in the COM and the turbulence predictions of an OpenFOAM model for wave overtopping flow over a simple dike profile

In the Netherlands, dikes are often used as flood defences along rivers and coasts to protect the hinterland from flooding. Wave overtopping is one of the main reasons that dikes are damaged or breach and occurs when high waves approach a flood defence, run up onto the waterside slope and pass across the crest onto the landward slope of the dike. An important, yet less understood mechanism known to contribute to wave overtopping failure is turbulence, as it impacts the onset of erosion, the erosion location and the amount of erosion. Therefore, wave overtopping turbulence has a critical effect on the failure process of a dike. Currently, the relative depth-averaged turbulence intensity (r_0) is used within empirical equation of the critical flow velocity (U_c), used to predict dike erosion under wave overtopping using the Cumulative Overload Method (COM), and account for the processes related to wave overtopping turbulence. However, due to the knowledge gap on the topic of wave overtopping turbulence, the turbulence intensity can take a range of possible values, without the ability to determine the correctness of the applied values. Therefore, the turbulence intensity is often adjusted as a way to correct the critical flow velocity (U_c) based on observed damage, rather than being calculated using the available equations.

An OpenFOAM model was used to simulate different wave overtopping volume (V) and roughness height (k_s) scenarios for wave overtopping over a simple dike profile with a single slope and uniform roughness. The resulting depth-averaged turbulent kinetic energy or TKE (k_0) is analysed to quantify the sensitivity of the modelled turbulence for changes in wave overtopping volumes and roughness heights. In addition, the sensitivity of the relative depth-averaged turbulence intensity (r_0) was analysed by computing the turbulence intensity with two different equations.

This study revealed that the trends of the modelled TKE (k_0) and the empirically calculated relative turbulence intensities (r_0) are similar for an increasing roughness height, but present opposing trends for an increasing wave overtopping volume (Table 1). Furthermore, both calculation methods for the turbulence intensity present similar trends, but differ in magnitude and sensitivity. One method presenting larger intensities (0.25 - 0.6) than the other method (0.05 - 0.4). This research points out that the turbulence intensity might be used incorrectly, as often reverse engineering is used to obtain r_0. Separating the turbulence intensity from the critical flow velocity equation could provide more realistic representations.

Table 1. Results for the TKE maxima and turbulence intensity for increasing volumes and roughnesses.

	Parameter	Result
TKE maxima (k_0)	Volume increase	TKE maxima (k_0) increase Location shifts towards the toe of the dike
	Roughness increase	TKE maxima (k_0) increase Location shifts towards the crest of the dike
Turbulence intensity (r_0)	Volume increase	Turbulence intensities (r_0) decrease
	Roughness increase	Turbulence intensities (r_0) increase

Figure 1: Wave overtopping simulated with the wave run-up simulator

Figure 2: Erosion damage due to wave overtopping

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