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IMPACT LOADS ON A VERTICAL WALL DUE TO OVERTOPPING BORE - LARGE SCALE PHYSICAL MODEL EXPERIMENTS -

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1. Introduction

Wide crested dikes are often built along coastal towns (eg. Belgian coast) both as coastal protection and recreational promenade. A lot of apartments and recreational facilities are built on these dikes close to the sea. Thereby these constructions are under risk during storm surges. Building vertical storm walls on the dike crest can be a solution to reduce the flooding risk of such coastal cities (Figure 1. left). Schematic illustration of the overtopping bore impact on storm walls is shown in Figure 1 (right). Here, the overtopping bore flows along the dike crest and hits the vertical wall, and overtops again. The remaining water flows back to the sea. If the dike crest is longer than a few meters, the overtopping will be significantly reduced as the kinetic energy can be dissipated over the crest.

Designing of such storm walls requires determination of hydrodynamic loading due to the overtopping bore. However, this is not straightforward as no empirical formulas are given in the literature for this type of configuration. Therefore, large scale physical model experiments were carried out as a joined research project between Ghent University (Belgium) and Forschungszentrum Küste (Germany), in order to quantify the impact loading on storm walls due to overtopping bore.

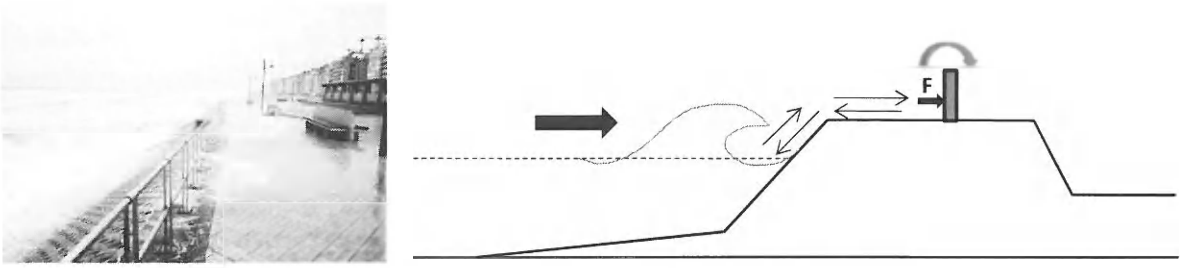

Figure 1. Typical Belgian coastline (left), schematized overtopping bore impact on a wall (right)

2. Experimental setup

The Large Wave Flume in Hannover has a length of about 300 m, a width of 5 m and a depth of 7 m. All the tests were carried out at 1:1 scale on a dike with a slope of 1:3 and crest height of 6.5 m followed by a horizontal section of about 10 m (Figure 2. left). Two storm walls (vertical and horizontal plates) are installed at the end of the dike crest (Figure 2, right). Two different hydraulic conditions are considered during the experiment:

- Fully closed wall (gaps between the walls are closed)
- Partially closed wall (gaps between the walls are open to let the water evacuate between the walls).

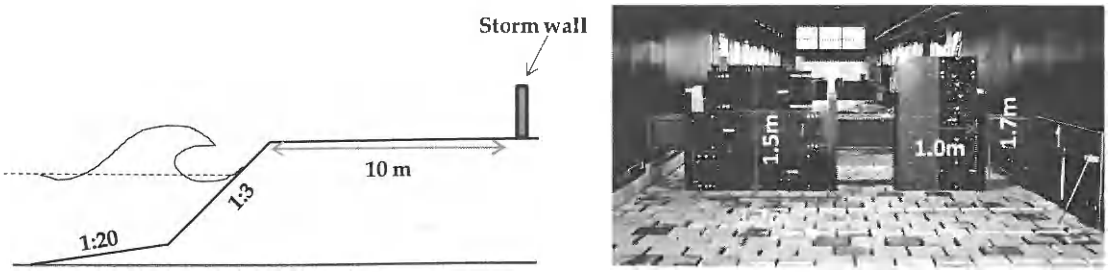

Figure 2. Cross section of the dike and storm wall at the end of the crest (left), storm walls (right)

Series of tests were performed with regular waves and JONSWAP spectra, with wave heights ranging from 1 m to 1.6 m, periods of 6 s to 12 s, and free board heights of 1.5 m and 2 m. Simultaneous measurements of pressures and forces at the walls, wave conditions in the flume and the parameters including the layer thicknesses and velocities of the overtopping bore at the dike crest also measured. Further details of the experimental setup including the measurement equipment on the storm walls can be found in Van Doorslaer et.al (2012) and Ramachandran et.al (2012).Comparison of the measured forces and integrated pressures and the distribution of the impact loads over the height of the wall are fully treated in Ramachandran et.al (2012).

Experiments with regular waves are treated in this paper as they can be used to have a better understanding of the hydraulic behavior (flow depth and flow velocity) in reflective conditions. Irregular waves have a highly complex behavior on the crest which requires more sophisticated approach, and are treated separately in De Rouck et.al (2012).

3. Main processes

Incoming waves break at the dike surface and overtopping occurs due to wave run-up. At the transition line from the seaward slope to the dike crest, the run-up separates into two flow fields (Schüttrumpf and Oumeraci., 2005). The portion of the water passing this line flows over the crest and results in overtopping. The rest flows back to the sea as waves run-down. The overtopping tongue arrives at the dike crest as a turbulent bore and hits the wall (Figure 3.a, b). The reflected bore flows towards the wave flume. In the second overtopping phase, the reflected bore interacts with the incoming bore before it flows back to the flume (Figure 3.c). The energy of the incoming wave is reduced due to this interaction.

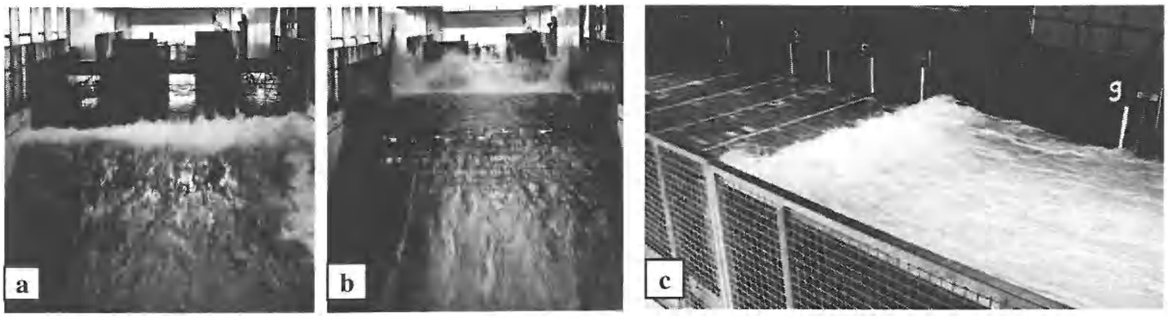

Figure 3. Overtopping bore a) arrives at the dike crest b) hits the walls c) reflected bore interacts with the incoming bore.

4. Analysis and discussion

The impact pressure on the wall highly depends on the kinematics of the incoming bore. The kinematics of the bore can be studied from the flow depths and velocities on the dike crest. However, the velocity propellers fail to measure the actual velocity of the incoming water layer due to debris, highly turbulent water and residual water layer on the crest. Therefore, the layer thicknesses measured at different positions on the dike crest and the distances between them were used together with video analysis for the determination of the flow velocity.

A residual water layer of 5-10 cm remains at the crest throughout the experiments with regular waves except during first couple of waves. The reflection can be avoided by only considering the first wave. However, it was observed that the first wave does not always give the highest impact loads on the wall. Therefore, the reflection must be treated carefully during the analysis.

The full paper deals with both fully and partially closed wall cases under regular waves and describes the influence of the residual water layer thicknesses on the impact loads. Further, parameters such as flow depth, flow velocity and overtopping rate are linked to the impact loads at the wall.

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