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Overtopped wave loads on walls (WALOWA)

Internal report

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Internal report

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Abstract

In this WALOWA (WAve LOads on Walls; a part of the EU program HYDRALAB+) project, a large scale physical model test was carried out in the new Delta Flume (The Netherlands) to study overtopping wave impacts on storm walls and buildings situated on top of a dike and for mild foreshore conditions.

A number of important data and outputs are produced within the research activities in the project (reports, conference papers and peer-reviewed journal papers). This document summarizes these data and output.

Contents

1 Introduction

Coastal profiles of low-lying countries, such as in Belgium, are often comprised of a shallow foreshore, a wide-crested dike and a storm wall or building on top of it. In such configuration, waves are running up the dike and overtopping the crest, and cause severe impacts on the storm wall or buildings situated at the end of the promenade. The loads due to the impact of these bores need to be predicted to enable a reliable design and protection from failure. However none of studies provides a fully comprehensive understanding of the complex phenomenon of overtopped wave loads on such structures.

In this WALOWA (WAve LOads on Walls; a part of the EU program HYDRALAB+) project, a large scale physical model test was carried out in the new Delta Flume (The Netherlands) to study overtopping wave impacts on storm walls and buildings situated on top of a dike and for mild foreshore conditions. Note that the project was a collaboration between Ghent University (Belgium), TU Delft (The Netherlands), RWTH Aachen (Germany), Polytechnic University of Bari, University of L'Aquila, University of Calabria, University of Florence (Italy) and Flanders Hydraulics Research (Belgium).

A number of important data and outputs are produced within the research activities in the project (reports, conference papers and peer-reviewed journal papers). This document summarizes these data and output. Next Chapter shows the data location, and a list of publication including the summary of each publication. Note that the publications listed below are limited to ones which included researchers from FHR as co-author.

2 Output

2.1 Data

WALOWA Data-set The WALOWA data-set is open access and available following the download link: http://doi.org/10.5281/zenodo.2843140.

2.2 Key publications

2.2.1 Streicher *et al.* (2019b)

Streicher, M.; Kortenhaus, A.; Gruwez, V.; Suzuki, T.; Altomare, C.; Saponieri, A.; Pasquali, D.; Valentini, N.; Tripepi, G.; Celli, D.; Risio, M. Di; Aristodemo, F.; Damiani, L.; Cappietti, L.; Breteler, M.K.; Kaste, D. (2019b). Proceedings of the HYDRALAB + Joint User Meeting , Bucharest , May 2019 OVERTOPPED WAVE LOADS ON WALLS (WALOWA) – NUMERICAL AND PHYSICAL MODELLING OF LARGE-SCALE EXPERIMENTS IN THE DELTA FLUME EXPERIMENTAL SET-UP Proceedings of the HYDRALAB + Joint User Meeting , Bucharest , May 2019 (May): 1–10

This paper is an overview paper, summarizing the objectives, model settings, morphological sand bed evolution (with the entire test program of WALOWA experiments), wave propagation, wave overtopping. Here below is the abstract of the paper:

Large-scale experiments on overtopping wave impact loads on dike mounted walls were conducted in the Deltares Delta Flume for mildly sloping foreshore and shallow water conditions. The experiments were accompanied by a set of numerical model tools in order to help design the experimental set-up, extend the measured data by the high resolution output of the numerical models and to numerically remodel a change in geometry. The methods used for the hybrid modelling approach and first results are herein discussed.

2.2.2 Streicher *et al.* (2019a)

Streicher, M.; Kortenhaus, A.; Altomare, C.; Hughes, S.; Marinov, K.; Hofland, B.; Chen, X.; Suzuki, T.; Cappietti, L. (2019a). STUDY OF UNCERTAINTIES IN LABORATORY WAVE IMPACT MEASUREMENTS ON DIKE, *in*: (2019a). *OMAE2019*. pp.1–10

This paper compares the wave impact in the small scale experiment and the large scale experiment. Here below is the abstract of the paper:

Overtopping wave impact forces on a dike mounted vertical wall were measured in similar Large-Scale (Froude scale factor 1-to-4.3) and Small-Scale (Froude scale factor 1-to-25) models. The uncertainties due to scale effects were studied, by comparing the up-scaled force measurements from both models in prototype. It was noted that if a minimum layer thickness, velocity of the overtopping flow and water depth at the dike toe were maintained in the Small-Scale model, the resulting uncertainties in impact force due to scale effects are within the range of uncertainties due to non-repeatability and model effects. The uncertainty in impact force due to scale effects was measured as 4%, 9%, 8%, 13%, 16% for Fmax, F1/250, F10, F20, F30 respectively. The average uncertainty related to non-repeatability of impact forces was already in the order of 10%-20% for the maximum impact force Fmax.

2.2.3 Gruwez *et al.* (2020b)

Gruwez, V.; Altomare, C.; Suzuki, T.; Streicher, M.; Cappietti, L.; Kortenhaus, A.; Troch, P. (2020). Validation of RANS Modelling for Wave Interactions with Sea Dikes on Shallow Foreshores Using a Large-Scale Experimental Dataset. *J. Mar. Sci. Eng. 8*(*650*). doi:10.3390/jmse8090650

This paper is a detailed modelling of OpenFOAM comparing with the large scale physical model test. Here below is the abstract of the paper:

In this paper, a Reynolds-averaged Navier–Stokes (RANS) equations solver, interFoam of OpenFOAM®, is validated for wave interactions with a dike, including a promenade and vertical wall, on a shallow foreshore. Such a coastal defence system is comprised of both an impermeable dike and a beach in front of it, forming the shallow foreshore depth at the dike toe. This case necessitates the simulation of several processes simultaneously: wave propagation, wave breaking over the beach slope, and wave interactions with the sea dike, consisting of wave overtopping, bore interactions on the promenade, and bore impacts on the dike-mounted vertical wall at the end of the promenade (storm wall or building). The validation is done using rare large-scale experimental data. Model performance and pattern statistics are employed to quantify the ability of the numerical model to reproduce the experimental data. In the evaluation method, a repeated test is used to estimate the experimental uncertainty. The solver interFoam is shown to generally have a very good model performance rating. A detailed analysis of the complex processes preceding the impacts on the vertical wall proves that a correct reproduction of the horizontal impact force and pressures is highly dependent on the accuracy of reproducing the bore interactions.

2.2.4 Gruwez et al., (2020a)

Gruwez, V.; Altomare, C.; Suzuki, T.; Streicher, M.; Cappietti, L.; Kortenhaus, A.; Troch, P. (2020a). An Inter - Model Comparison for Wave Interactions with Sea Dikes on Shallow Foreshores: 1–38. doi:10.3390/jmse8120985

This paper shows a detailed inter model comparison between OpenFOAM, DualSPHyscis and SWASH models. Here below is the abstract of the paper:

Three open source wave models are applied in 2DV to reproduce a large-scale wave flume experiment of bichromatic wave transformations over a steep-sloped dike with a mildly-sloped and very shallow foreshore: (i) the Reynolds-averaged Navier–Stokes equations solver interFoam of OpenFOAM® (OF), (ii) the weakly compressible smoothed particle hydrodynamics model DualSPHysics (DSPH) and (iii) the non-hydrostatic nonlinear shallow water equations model SWASH. An inter-model comparison is performed to determine the (standalone) applicability of the three models for this specific case, which requires the simulation of many processes simultaneously, including wave transformations over the foreshore and wave-structure interactions with the dike, promenade and vertical wall. A qualitative comparison is done based on the time series of the measured quantities along the wave flume, and snapshots of bore interactions on the promenade and impacts on the vertical wall. In addition, model performance and pattern statistics are employed to quantify the model differences. The results show that overall, OF provides the highest model skill, but has the highest computational cost. DSPH is shown to have a reduced model performance, but still comparable to OF and for a lower computational cost. Even though SWASH is a much more simplified model than both OF and DSPH, it is shown to provide very similar results: SWASH exhibits an equal capability to estimate the maximum quasi-static horizontal impact force with the highest computational efficiency, but does have an important model performance decrease compared to OF and DSPH for the force impulse.

References

Gruwez, V.; Altomare, C.; Suzuki, T.; Streicher, M.; Cappietti, L.; Kortenhaus, A.; Troch, P. (2020a). An Inter - Model Comparison for Wave Interactions with Sea Dikes on Shallow Foreshores: 1–38. doi:10.3390/jmse8120985

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Streicher, M.; Kortenhaus, A.; Altomare, C.; Hughes, S.; Marinov, K.; Hofland, B.; Chen, X.; Suzuki, T.; Cappietti, L. (2019a). STUDY OF UNCERTAINTIES IN LABORATORY WAVE IMPACT MEASUREMENTS ON DIKE, ***in***: (2019a). *OMAE2019*. pp.1–10

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