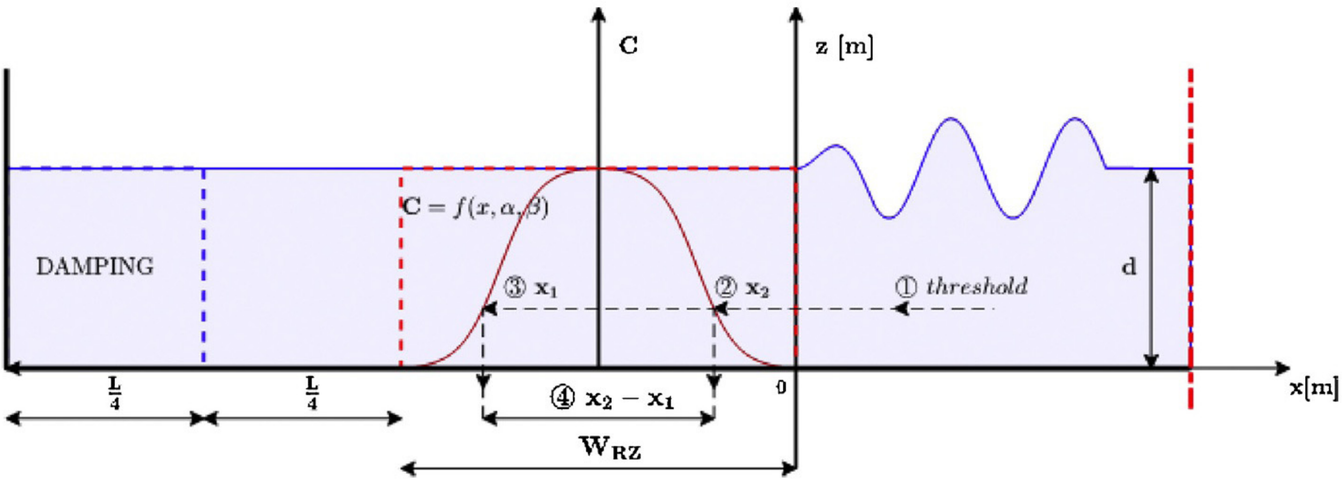


Flanders
State of
the Art

15_009_3
WL rapporten

Coupling between DualSPHysics and SWASH

Relaxation Zone and Graphical User Interface

DEPARTMENT
MOBILITY & PUBLIC WORKS

www.flandershydraulicsresearch.be

Coupling between DualSPHysics and SWASH

Relaxation Zone and Graphical User Interface

Altomare, C.; Suzuki, T.; Vanneste, D.; Mostaert, F.

Flanders Hydraulics Research
Flanders State of the Art

Legal notice

Copyright and citation

This publication should be cited as follows:

Altomare, C.; Suzuki, T.; Vanneste, D.; Mostaert, F. (2019). Coupling between DualSPHysics and SWASH: Relaxation Zone and Graphical User Interface. Version 2.0. FHR Reports, WL2019R15_009_3. Flanders Hydraulics Research: Antwerp.

Document identification

Customer:	Flanders Hydraulics Research	Ref.:	WL2019R15_009_3
Keywords (3-5):	DualSPHysics; SWASH; Coupling; GUI		
Text (p.):	6	Appendices (p.):	2
Confidentiality:	☒ No	☒ Available online	

Author(s):	Altomare, C.; Suzuki, T.

Control

	Name	Signature
Reviser(s):	Vanneste, D.	Getekend door: Dieter Vanneste (Signature) Getekend op: 2019-04-25 15:34:45 +01:00 Reden: Ik keur dit document goed Dieter Vanneste
Project leader:	Suzuki, T.	Getekend door: Tomohiro Suzuki (Signature Getekend op: 2019-04-26 13:57:28 +01:00 Reden: Ik keur dit document goed Tomohiro Suzuki

Approval

Head of Division:	Mostaert, F.	Getekend door: Frank Mostaert (Signature) Getekend op: 2019-04-28 15:07:32 +01:00 Reden: Ik keur dit document goed Frank Mostaert

Abstract

The present document represents the final report, after the third year of the 15_009 project on “Optimized hybrid model for coastal safety assessment”. This document integrates the previous two progress reports and shows that the main goal of the project has been achieved. The SPH-based DualSPHysics model is now capable of generating and absorbing sea waves, mimicking an experimental wave flume and this is achieved in two different ways: using moving boundaries and in a Relaxation Zone framework. The latter allows coupling with wave propagation models, such as SWASH. In this way, the computational cost is reduced whilst maintaining the accuracy of the solution. Finally a Graphical Users Interface has been developed for creating and running cases with DualSPHysics, also employing the Relaxation Zone technique.

Contents

List of figures

1 Introduction

The present document represents the final report, after the third year of the 15_009 project on "Optimized hybrid model for coastal safety assessment". This document integrates the previous two progress reports (Altomare et al., 2017; Suzuki et al., 2017).

1.1 Summary of 1st year

Several different tasks have been defined for the present project, see Altomare et al. (2017). During the first year, three tasks were completed.

1. Literature review of the existing Active Wave Absorption Systems that are used both in physical and numerical wave models.
2. Identification of the AWAS technique/s to be implemented in DualSPHysics as stand-alone model.
3. Implementation and validation of the AWAS technique/s with selected benchmark cases.

Those tasks resulted in a conference paper in SPHERIC 2015, Altomare et al (2015).

The fourth task, identification of the best strategy, has also been conducted (i.e. discussed with UVigo, Prof. Gomez-Gesteira, Dr. Crespo and Dr. Dominguez). As a conclusion, it was recommended to test Relaxation Zone method (also defined Source Generation method in previous documentation).

4. Identification of the best strategy to absorb the re-reflected waves in the hybridized SWASH-DualSPHysics model.

1.2 Summary 2nd year

During the second year, the following task was completed (Suzuki et al., 2017):

5. Implementation of the "wave absorption for hybridization" (AWAS-hy) and validation of the numerical model: this technique needs to be coupled with SWASH (SWASH output will be used to "steer" the movement of the wave maker in DualSPHysics to cancel out the reflected waves)

1.3 Target of 3rd year

The main tasks for the third and final year are summarised as follows:

6. Optimization of the pre-processing tools required for the hybridization strategy with the intention to make it as much user-friendly as possible (e.g. the generation of the geometrical layout in SWASH and SPH has to be standardized and homogenized).
7. Redaction of the user manual that can guide step by step in the application of the hybridization strategy for 2D and 3D cases.
8. Add the transfer to Version Management as final step for integration of the model to be able to access the version.

The third year also comprised a further optimization and validation of the aforementioned SG method, hereafter defined as Relaxation Zone method.

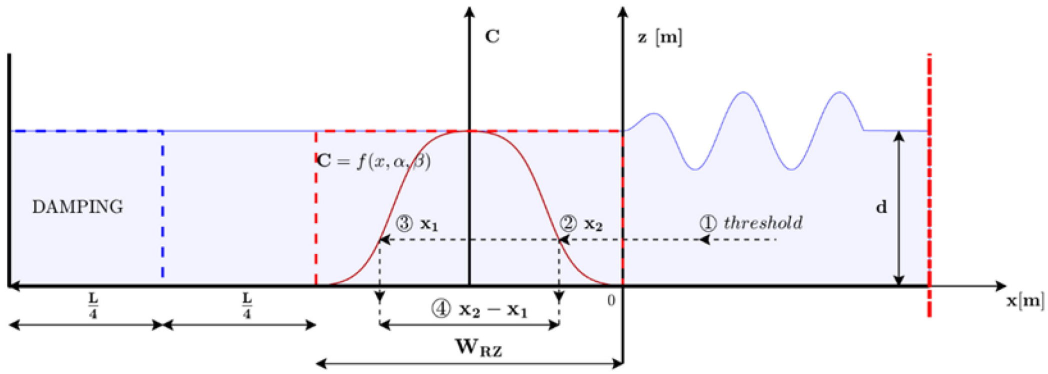
2 Third-year results

The main results achieved during the third and last year of the project are here summarized.

2.1 Coupling optimization and validation

The Relaxation Zone (RZ) technique (former SG) has been optimized and validated for cases of wave-structure interaction in shallow water conditions. The general scheme of the RZ is depicted in Figure 1. A peer-reviewed journal paper has been published (Altomare et al., 2018) where a complete review of RZ embedded in DualSPHysics is reported, including a validation case for overtopping wave impact on sea dikes with shallow foreshores. The paper also describes the procedure to follow for a pre-design of the RZ. The paper is reported in Appendix A. A conference paper, indexed in Scopus, has been also produced (Altomare et al., 2018b) describing further the application of the RZ to coastal engineering (see Appendix B).

Figure 1: Scheme of RZ (red dashed line) and indication of the effective width in case of wave generation (Altomare et al., 2018)



Relaxation Zone technique consists in a framework that allows both wave generation/absorption in DualSPHysics as stand-alone model, and 1-way offline coupling with wave propagation models, e.g. SWASH.

The technique has been validated with analytical solutions for wave generation only and for highly reflective cases. Besides, the technique has been applied to simulate test cases from different experimental campaigns, such as Hydralab+ WaLoWa and Hydralab+ ICODEP.

The aim of the present project is to extend RZ to very shallow water conditions. Therefore, a test case of wave impact on multi-functional sea dikes in presence of shallow foreshore has been selected for further validation. The test case belongs to the experimental campaign carried out at Flanders Hydraulics Research as part of the PhD project of Dr. Xuexue Chen (Chen et al., 2015). See Appendix A for further details.

2.2 Graphical User Interface

A Graphical User Interface (GUI), called *DesignSPHysics* has been realized in collaboration with University of Vigo. DesignSPHysics is open-source and can be downloaded at: http://design.sphysics.org/

DesignSPHysics is embedded as Python macro inside FreeCAD software (https://www.freecadweb.org/) to allow users with CAD knowledge to use DualSPHysics within a familiar framework. Thanks to FreeCAD ease of use, it is straightforward and quick to design new cases.

Although its primary function is to design cases for DualSPHysics, DesignSPHysics integrates all the functions needed create, simulate and post-process cases, so you can use FreeCAD as your common driver, without further coding.

Figure 2: Print-screen of the DesignSPHysics webpage

A complete written guide of RZ is not yet available but will be included in the DualSPHysics Wiki (https://github.com/DualSPHysics/DualSPHysics/wiki) by spring 2019. Nonetheless, part of the work related to the present project (such as long-crested wave generation and absorption with moving boundaries) is already included in the Wiki.

Furthermore, tutorials to use DesignSPHysics have been created and uploaded in youtube (https://www.youtube.com/user/DualSPHysics/playlists).

2.3 Scientific outcomes of the project

The main project outcomes have been reflected in several publications in peer-reviewed international scientific journals and international conference proceedings. Four journal papers resulting from the collaboration with University of Ghent (Belgium), University of Salerno (Italy), University of Vigo and Technical University of Barcelona (Spain) have been published. The published papers are listed as follows:

1) 2018. Altomare C, Tagliafierro B, Dominguez JM, Suzuki T, Viccione G. *Improved relaxation zone method in SPH-based model for coastal engineering applications*, Applied Ocean Research, Volume 81, 2018, Pages 15-33, ISSN 0141-1187, https://doi.org/10.1016/j.apor.2018.09.013.
2) 2018. Verbrugghe T, Dominguez JM, Crespo AJC, Altomare C, Stratigaki V, Troch P, Kortenhaus A. *Coupling methodology for smoothed particle hydrodynamics modelling of non-linear wave-structure interactions*. COASTAL ENGINEERING, vol. 138, p. 184-198, ISSN: 0378-3839, doi: 10.1016/j.coastaleng.2018.04.021. IF:2.674
3) 2017. Altomare C., Domínguez J.M., Crespo A.J.C., González-Cao J., Suzuki T., Gómez-Gesteira M., Troch P., *Long-crested wave generation and absorption for SPH-based DualSPHysics model. Coastal Engineering*, Volume 127, September 2017, Pages 37-54, ISSN 0378-3839, doi: 10.1016/j.coastaleng.2017.06.004. IF:3.221

4) 2015. Altomare, C., Dominguez, J.M., Crespo, A.J.C., Suzuki, T., Caceres, I. & Gomez-Gesteira, M. *Hybridization of the Wave Propagation Model SWASH and the Meshfree Particle Method SPH for Real Coastal Applications*. Coastal Engineering Journal, Vol. 57, No. 4, 1550024 (34 pages). doi: 10.1142/S0578563415500242. IF:0.703

One book chapter has been also published, namely:

1) 2018. Altomare C., Viccione G., Tagliafierro B., Bovolin V., Domínguez J.M. and Crespo A.J.C. *Free-Surface Flow Simulations with Smoothed Particle Hydrodynamics Method using High-Performance Computing*, Computational Fluid Dynamics - Basic Instruments and Applications in Science, Dr. Adela Ionescu (Ed.), InTech, DOI: 10.5772/intechopen.71362.

The main results of the projects have been presented in international conferences and workshops, as listed as follows

a) 2018. Altomare C., Tagliafierro B., Suzuki T., Dominguez J.M., Crespo A.J.C., Briganti R. *Relaxation Zone Method in SPH-based Model Applied to Wave-structure Interaction*. 28th International Ocean and Polar Engineering Conference (ISOPE), Sapporo, Japan, 10-15 June 2015.
b) 2017. Altomare C., *Coupling between DualSPHysics and SWASH models and latest applications to coastal engineering problems*. 3rd DualSPHysics Users Workshop, 13-15 November, 2017. Parma, Italy
c) 2017. Altomare C., Tagliafierro B., Viccione, G. *Applicability of source generation (SG) and absorption technology in a highly reflective condition*. 3rd DualSPHysics Users Workshop, 13-15 November, 2017. Parma, Italy
d) 2017. Usui A., Domínguez J.M., Suzuki T., Altomare C., Tagliafierro B., *Applicability of source generation (SG) and absorption technique in a highly reflective condition*. 12th SPHERIC Workshop, 13-15 June 2017, Ourense, Spain.

2.4 Archiving, git-hub and DualSPHysics beta version

The 4th DualSPHysics Users Workshop was held in Lisbon in October 2018. The beta version 4.3 of DualSPHysics code and the latest version of DesignSPHysics were provided to all the attendees.

The contents of the DualSPHysics v4.3 version, including the latest developments in terms of coupling with wave propagation models (e.g., Relaxation Zone) will be part of the next official code release, foreseen for spring 2019.

Both **DualSPHysics v4.3** and **DesignSPHysics v0.5.1812-03** with coupling functionalities are included as outcomes of the present project and archived accordingly.

3 Conclusions and recommendation

Relaxation Zone technique has been implemented in DualSPHysics as stand-alone wave generation/absorption method and as coupling framework with wave propagation models. The technique has been validated by coupling DualSPHysics and SWASH models applied to test cases of wave-structure interaction in shallow water conditions.

Besides, a Graphical User Interface, called DesignSPHsyics, has been developed and includes also the modules to set-up, run and post-process a case that employs RZ. A complete written guide of RZ is not yet available but will be included in the DualSPHysics Wiki by spring 2019. Video tutorials are available in youtube to set-up and run cases with DualSPHysics and DesignSPHysics.

The latest versions of DualSPHysics (v4.3 beta) and DesignSPHysics (v0.5.1812-03) have been archived in P: drive (eventually moves to R: drive after the project closed).

Overall, the main goal of the present project has been achieved: wave generation and wave absorption techniques have been implemented in DualSPHysics both as stand-alone model and as coupling scheme with less expensive wave propagation models. DualSPHysics has been made user-friendly by developing a GUI that is embedded in an open-source CAD software and that allows not only creating a case but also running it and post-processing the results.

References

Altomare C., Gómez-Gesteira, M., Vanneste, D., Suzuki, T., Peeters, P., Mostaert, F., 2017. Optimized hybrid model for coastal safety assessment: wave generation and absorption in DualSPHysics model, 1st-year progress report. Version 5.0. FHR reports, 15_009_1. Flanders Hydraulics Research: Antwerp. V, 6 + 9 p.appendices pp.

Altomare, C., Dominguez, J.M., Crespo, A.J.C., Caceres, I., Goomez-Gesteira, M., 2016. Hybridisation of the wave propagation model SWASH and the meshfree particle method SPH for real coastal applications. Coastal Engineering Journal 57, 1-34. doi:10.1142/ S0578563415500242.

Altomare, C., Tagliafierro, B., Dominguez, J.M., Suzuki, T., Viccione, G., 2018. Improved relaxation zone method in SPH-based model for coastal engineering applications, Applied Ocean Research, Volume 81, Pages 15-33, ISSN 0141-1187, https://doi.org/10.1016/j.apor.2018.09.013.

Altomare, C., Tagliafierro, B., Suzuki, T., Dominguez, J.M., Crespo, A.J.C. , Briganti, R., 2018b. Relaxation zone method in SPH-based model applied to wave-structure interaction, Int. Ocean Polar Eng. Conf., Sapporo, pp. 627–634.

Chen, X., Hofland, B., Altomare, C., Suzuki, T., Uijttewaal, W., 2015. Forces on a vertical wall on a dike crest due to overtopping flow, Coast. Eng. 95, 94–104. doi:10.1016/j.coastaleng.2014.10.002

Suzuki, T., Altomare, C., Peeters, P., Mostaert, F., 2017. Optimized hybrid model for coastal safety assessment: source generation in DualSPHysics model, 2nd-year progress report. Version 2.0. FHR reports, 15_009_2. Flanders Hydraulics Research: Antwerp. VI, 5 + 42 p. appendices pp.

Annexe A: Improved relaxation zone method in SPH-based model for coastal engineering applications

Full document is archived in P:\15_009-OptHybMod\3_Uitvoering\09_Publications\

Applied Ocean Research 81 (2018) 15–33

Contents lists available at ScienceDirect

Applied Ocean Research

journal homepage: www.elsevier.com/locate/apor

Improved relaxation zone method in SPH-based model for coastal engineering applications

C. Altomare[a,b,*], B. Tagliafierro[c], J.M. Dominguez[d], T. Suzuki[a,e], G. Viccione[c]

[a] Flanders Hydraulics Research, Berchemlei 115, 2140 Antwerp, Belgium
[b] Ghent University, Department of Civil Engineering, Technologiepark 904, 9000 Ghent, Belgium
[c] University of Salerno, Dept. of Civil Engineering, Via Giovanni Paolo II, 132, 84084 Fisciano SA, Italy
[d] EPHYSLAB, Vigo University, AS Lagoas, 32004 Ourense, Spain
[e] Faculty of Civil Engineering and Geosciences, Delft University of Technology, Stevinweg 1, 2628 CN Delft, the Netherlands

ARTICLE INFO

Keywords:
Smoothed Particle Hydrodynamics
Relaxation Zone
Coupling algorithm
Wave generation and absorption
SWASH
Wave-Structure interaction

ABSTRACT

An improved Relaxation Zone (RZ) method has been implemented in the meshless SPH-based DualSPHysics model. Final purpose of this work is to have a general wave generation scheme that allows coupling SPH-based models to other models, e.g. Eulerian based wave models, besides employing the RZ as alternative wave generation in SPH as a stand-alone scheme. Using RZ in SPH, the movement of the fluid particles is controlled by correcting their orbital velocity by means of a weighting function in a specified generation area. In the present work, the new technique is used to couple DualSPHysics to the non-hydrostatic wave-flow model SWASH. The results of RZ employed both as stand-alone wave generation technique and as coupling framework with SWASH model are validated for wave generation and wave reflection for monochromatic waves. Then, the method is tested successfully for generation and absorption of irregular waves. Finally, the coupling between DualSPHysics and SWASH using RZ is validated against experimental data concerning the wave flow impacts on vertical walls. A procedure for a proper design of the RZ (i.e. shape of the weighting function, size of the RZ) is described in the present work. Overall, the results indicate that the proposed improved RZ technique is among the most effective alternatives for wave generation in SPH-based models for coastal engineering application.

1. Introduction

Meshless methods are getting popular in coastal engineering as result of the developments of numerical techniques and computation technologies in the last decades and are more and more often employed to study free-surface flows and wave-structure interaction phenomena [1]. Models based on the so-called Smoothed Particle Hydrodynamics (SPH) [2,3] method are becoming very popular among researchers for their capacity to simulate highly nonlinear free-surface flows (e.g [4]). However the computational cost of the SPH models is still huge, even compared with one of the most expensive wave models, e.g. RANS-VOF models [5]. In particular, one of the SPH models, namely DualSPHysics [6], significantly improved the computational time by using GPU (Graphics Processing Unit) and multi-GPU techniques [7,8], although the computational cost is still high and thus it is not always easy to apply it to realistic coastal engineering projects.

In order to overcome this limitation, a coupling to computationally less demanding wave models was introduced and proved to be useful for coastal engineering applications, as for example in [9]. On the one hand, less demanding computational models (e.g. Boussinesq models, Non-Linear Shallow Water equation models) are accurate enough for wave transformation at a reasonable computational cost but not very accurate for wave-structure interaction due to their assumptions (e.g. depth integrated feature). On the other hand, SPH models are capable of generating accurate results for both wave transformation and wave-structure interaction [10,11] while these are computationally too expensive to cover a large domain at affordable time duration.

Coupling to other models is actually identified as one of the SPHERIC Grand Challenges from the Ercoftac Special Interest Group for SPH (SPHERIC, http://spheric-sph.org/). More and more attempts to enhance the SPH capability of modelling real engineering problems by means of coupling techniques have been presented during the last years (e.g. [12,13]). Previous attempts to couple DualSPHysics with wave propagation models can be found in [14,15]. In [14] SWASH model is hybridized with DualSPHysics. SWASH is a model based on layer-averaged Non-Linear Shallow Water equations with non-hydrostatic

* Corresponding author at: Flanders Hydraulics Research, Berchemlei 115, 2140 Antwerp, Belgium.
E-mail address: corrado.altomare@mow.vlaanderen.be (C. Altomare).

https://doi.org/10.1016/j.apor.2018.09.013
Received 29 May 2018; Received in revised form 10 September 2018; Accepted 18 September 2018

Appendix B: Relaxation zone method in SPH-based model applied to wave-structure interaction

Full document is archived in P:\15_009-OptHybMod\3_Uitvoering\09_Publications\

Relaxation zone method in SPH-based model applied to wave-structure interaction

Corrado Altomare
Flanders Hydraulics Research, Ghent University
Antwerp, Belgium

Bonaventura Tagliafierro
Department of Civil Engineering, University of Salerno
Salerno, Italy

Tomohiro Suzuki
Flanders Hydraulics Research
Antwerp, Belgium

Jose M. Dominguez, Alejandro J.C. Crespo
EPhysLab, Vigo University
Ourense, Spain

Riccardo Briganti
Coastal Dynamics and Engineering Group, University of Nottingham
Nottingham, United Kingdom

ABSTRACT

A coupling technique based on the Relaxation Zone method (RZ) has been implemented between the SPH-based DualSPHysics code and the SWASH model to simulate multi-scale and long-duration phenomena in coastal engineering, which represents a challenge for researcher and practitioners. In fact, despite the fact that SPH-based models are getting more and more popular in coastal and civil engineering, they still present a huge computational cost. In the present work, RZ is validated for phenomena of overtopping flow impacts on vertical walls. The results proved that the RZ is efficient and reliable alternative for wave generation in SPH-based models for coastal engineering applications.

KEY WORDS: DualSPHysics; Relaxation Zone; Coupling; SWASH; Overtopping; Wave impacts.

INTRODUCTION

Smoothed Particle Hydrodynamics method (SPH) is a promising meshless technique for modelling fluid flows as it is capable to deal with large deformations, complex geometries and highly nonlinear phenomena (Violeau, 2012). In the last years, due to the use of modern High Performance Computing techniques, SPH models have been employed more and more as alternative wave-flow models in coastal engineering. Very complex three-dimensional free-surface flow problems can be tackled nowadays with resolutions unthinkable just a decade ago. However the computational cost of most of the SPH-based models is still huge, characterized by very small calculation time steps and big number of neighbor particles (≈ nodal points) in which the continuum is discretized, especially in 3D simulations. The expensive computational cost of SPH in comparison with other methods for CFD problems can be partially alleviated by general-purpose graphics processing unit (GPGPU) where a Graphics Processing Unit (GPU card) is used to perform computations traditionally managed by big cluster machines with thousands of CPU cores. Nevertheless, to simulate multi-scale and multi-phase problems still require resources that cannot be attained by only one numerical model. In particular, the challenge in coastal engineering is to model to whole process of wave propagation, transformation, wave breaking and wave-structure interaction, which is typical and multi-scale and long-duration process. A coupling with computationally less demanding wave models (e.g. Boussinesq models, Non-Linear Shallow Water equation models) represents a possible alternative. Typically these models are accurate for studying wave propagation and wave transformation at a reasonable computational cost, but they are not completely suitable to study wave-structure interaction phenomena characterized by heavy wave breaking or complex geometrical layouts, mainly due to the assumptions behind these codes (e.g. depth integrated feature). Instead, SPH models have been proved to model accurately wave-structure interaction phenomena (e.g. St-germain et al., 2014). Nevertheless, the computational cost is

DEPARTMENT **MOBILITY & PUBLIC WORKS**
Flanders hydraulics Research

Berchemlei 115, 2140 Antwerp
T +32 (0)3 224 60 35
F +32 (0)3 224 60 36
waterbouwkundiglabo@vlaanderen.be
www.flandershydraulicsresearch.be