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The State of the Art and Science of Coastal Engineering

NUMERICAL STUDY OF WAVE INTERACTION WITH A SUBMERGED POROUS BREAKWATER IN COMBINATION WITH A FLOATING BREAKWATER

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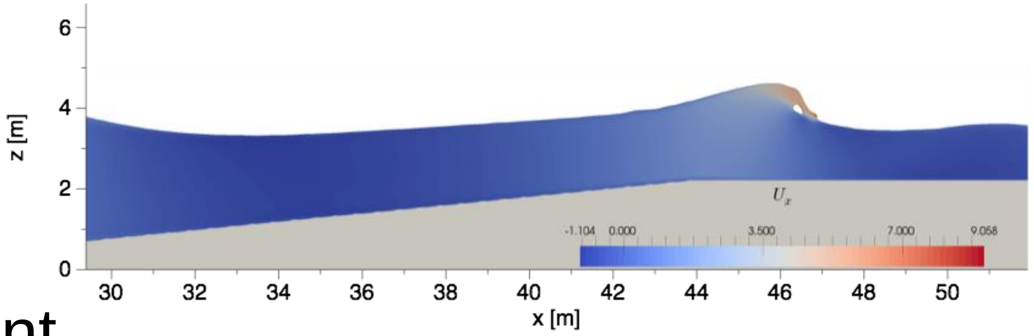
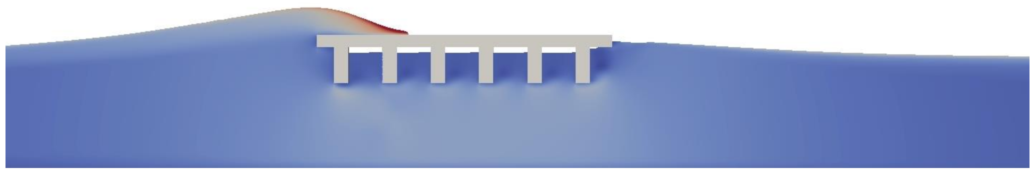
Introduction

- Commonly built coastal protection structures: Rubble mound breakwaters
- High-value developments along the coasts:
  - Safety
  - Visual impact
  - Innovative solutions to coastal protection
- Combination of rubble mound breakwater with a floating breakwater
- CFD modelling to resolve complex wave-structure interaction
- Volume-averaged RANS (VRANS) equations for porous media flow

Numerical Model: REEF3D

- Open-source CFD model REEF3D (www.reef3d.com)
- High-order discretisation schemes
- Fifth-order WENO scheme for convection
- Third-order Runge-Kutta for time advancement
- Level set method to obtain a sharp free surface
- Fully multi-grid preconditioned BiCGStab solver from Hypre
- Cartesian grid (rectilinear grid refinement added recently)
- Ghost cell immersed boundary method





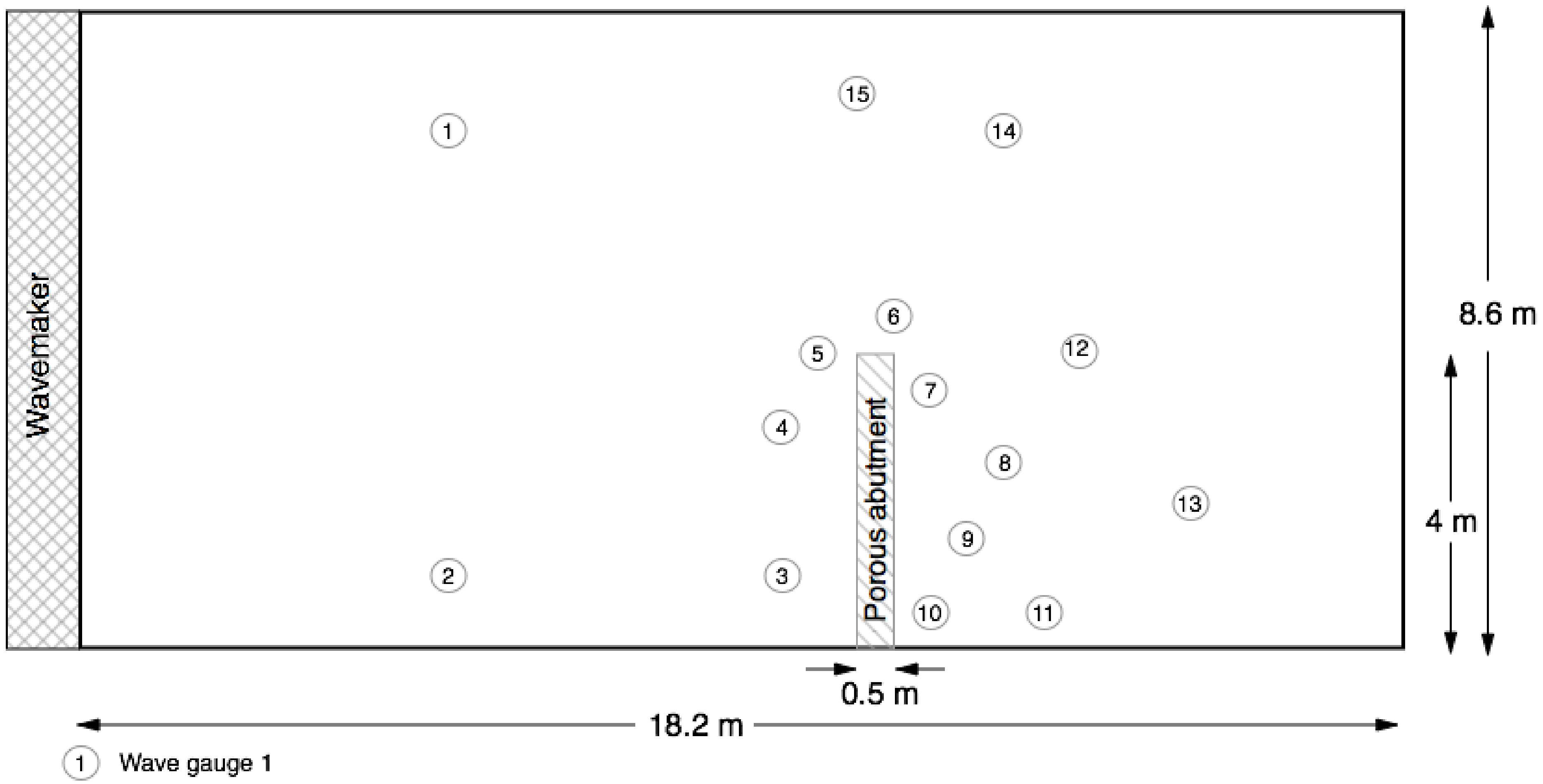
Numerical Model: VRANS

$$(1 + C_m)\frac{\partial}{\partial t}\frac{\langle \overline{u_i} \rangle}{n} + \frac{1}{n}\frac{\partial}{\partial x_j}\frac{\langle \overline{u_i} \rangle \langle \overline{u_j} \rangle}{n} = -\frac{1}{\rho}\frac{\partial \langle \overline{p} \rangle^f}{\partial x_j} + \frac{1}{n}\frac{\partial}{\partial x_j}\nu\left(\frac{\partial \langle \overline{u_i} \rangle}{\partial x_j} + \frac{\partial \langle \overline{u_j} \rangle}{\partial x_i}\right) + g_j + F_i$$

Jensen et al. (2014)

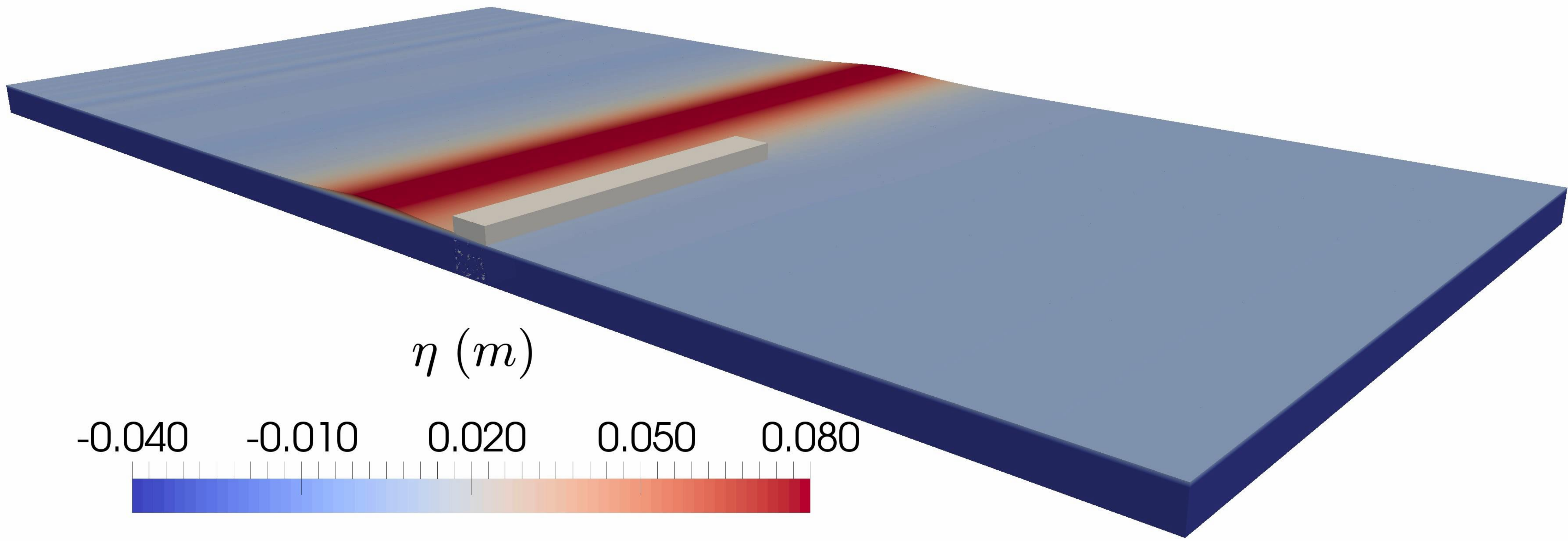
- C_m is the added mass coefficient which takes into account the grain-water interaction
- F_i represents the effect of turbulence in terms of additional resistance, using the extended Darcy-Forchheimer equation

Results: Solitary wave interaction with a porous abutment

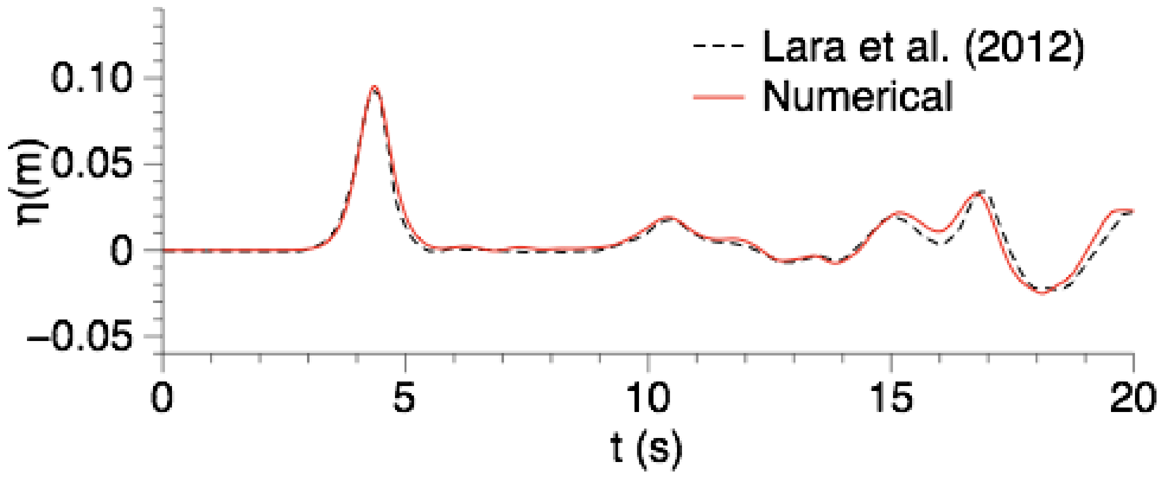


nominal stone diameter, Dn50=0.015 m
porosity, n=0.51
resistance coefficient α=650
resistance coefficient β=2.2

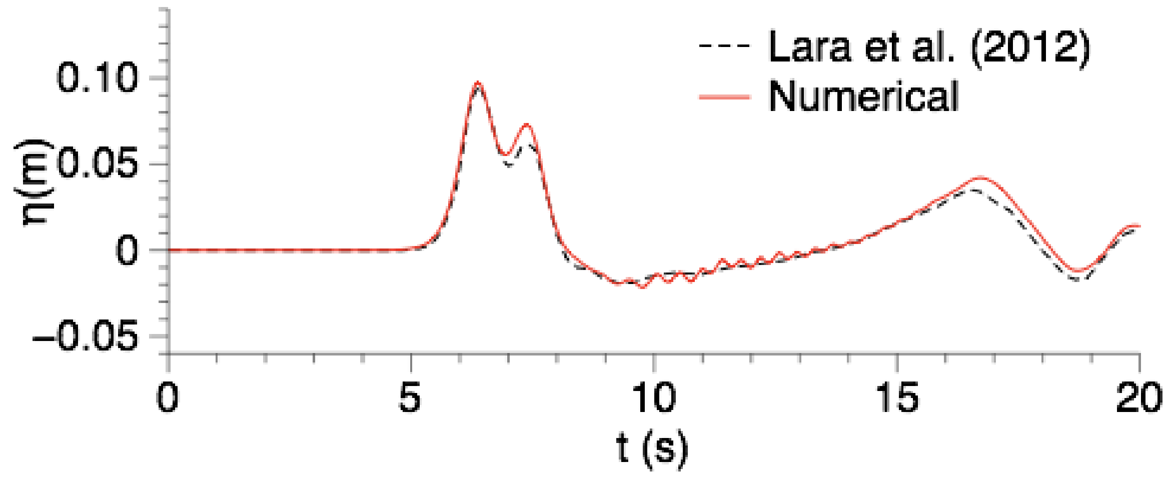
Results: Solitary wave interaction with a porous abutment



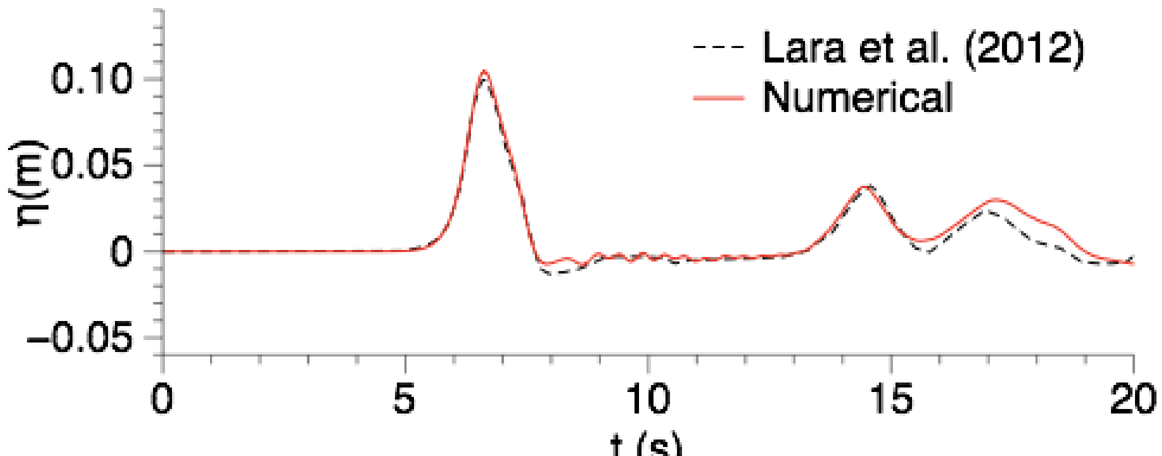
Results: Solitary wave interaction with a porous abutment



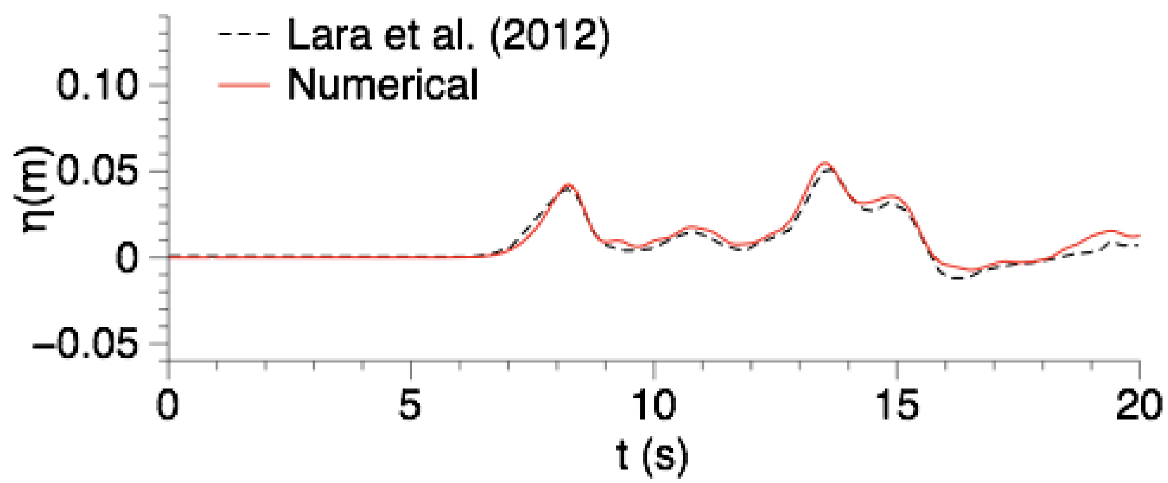
WG 1: in front of the WM, away from the abutment



WG 3: in front of the abutment

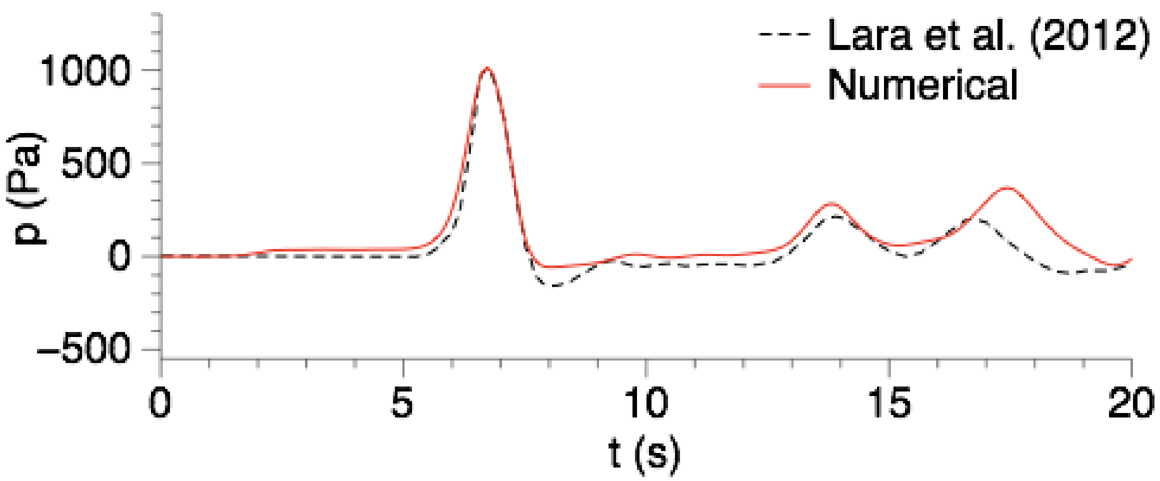


WG 4: in front of the abutment, seawards

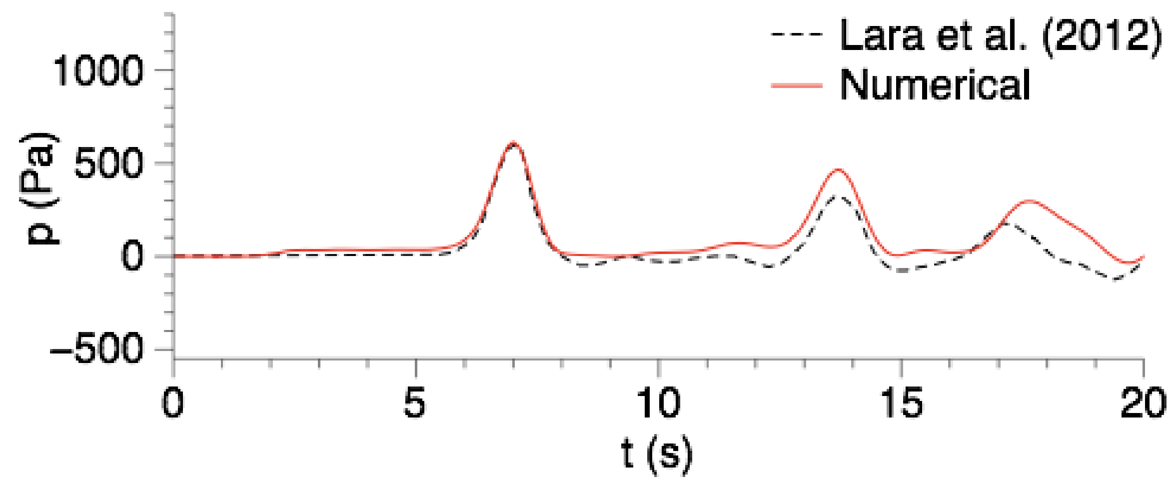


WG 8: behind the abutment

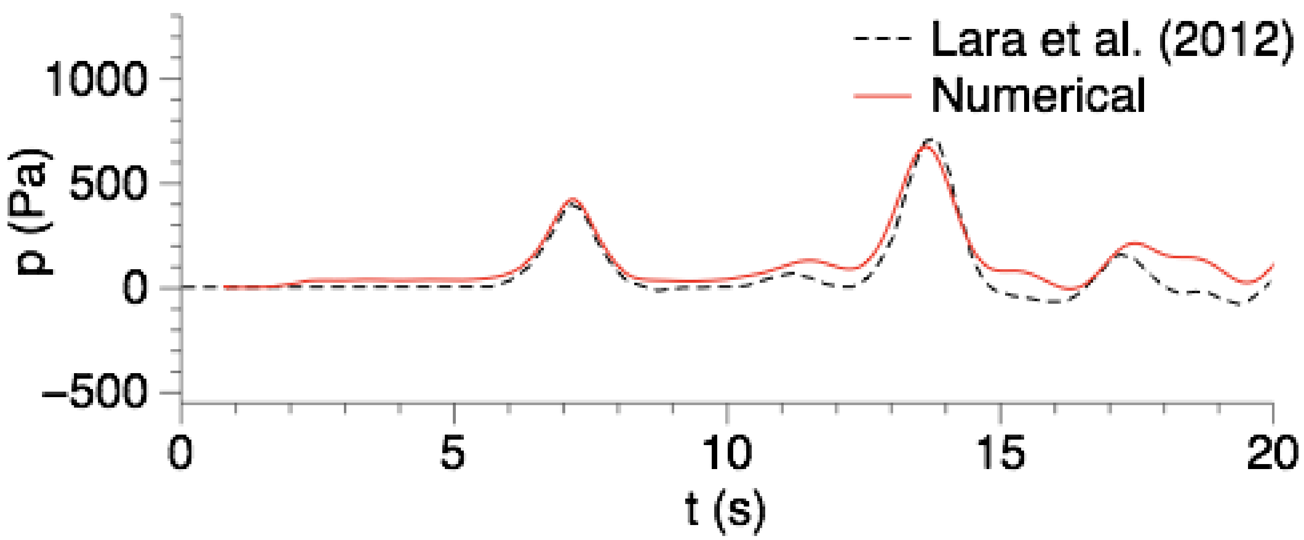
Results: Solitary wave interaction with a porous abutment



PG 1: (10.5, 3.89, 0.11), near head of the abutment, WM side

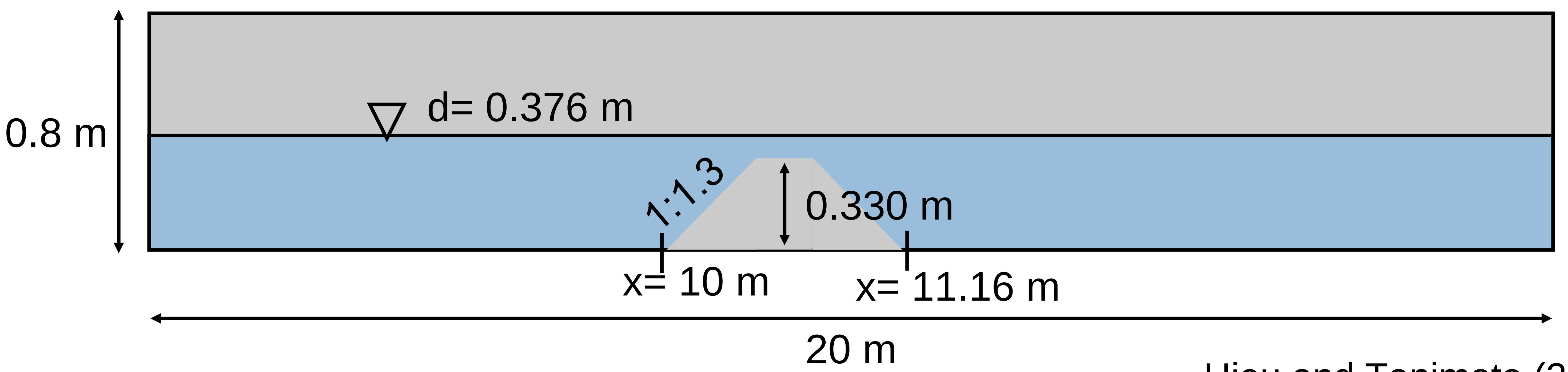


PG 3: (10.89, 4.0, 0.11), at the head



PG 5: (11, 3.7, 0.11) ,weatherside

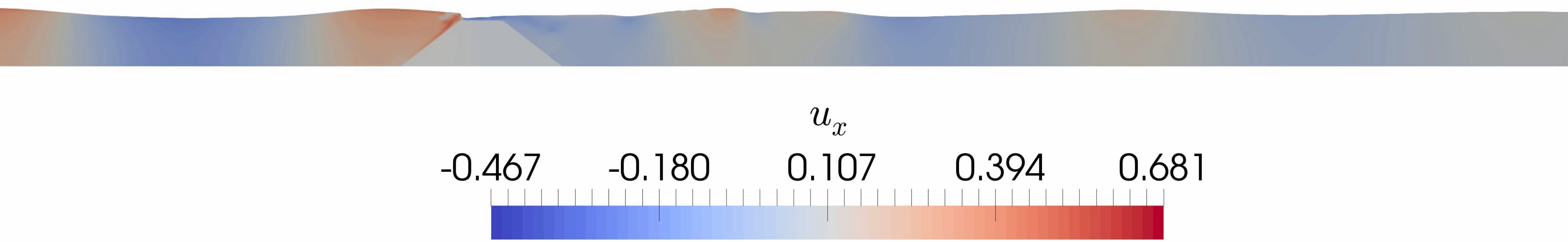
Results: Wave interaction with a submerged porous breakwater



Hieu and Tanimoto (2006)

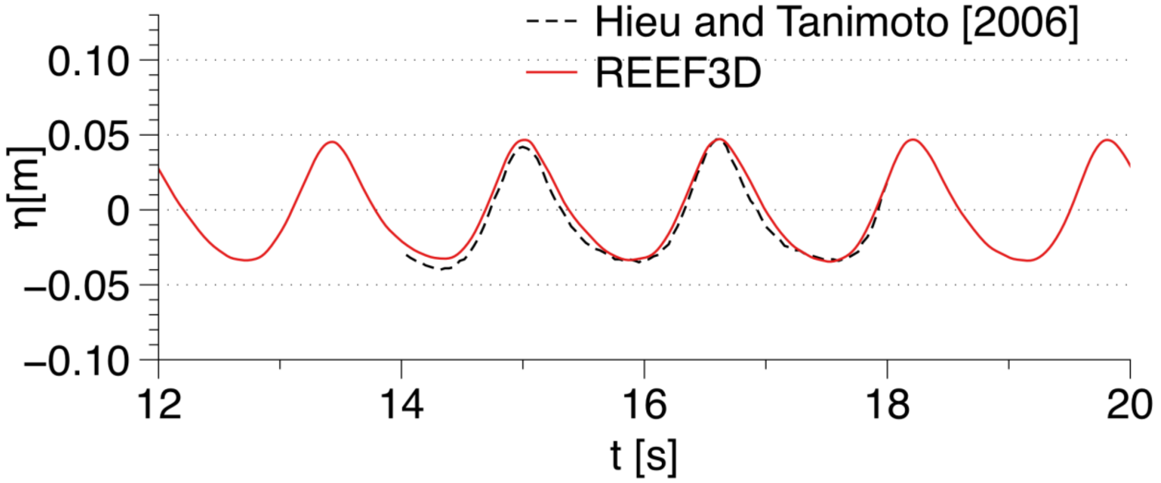
nominal stone diameter, Dn50=0.025 m
porosity, n=0.45
resistance coefficient α=650
resistance coefficient β=2.2

Results: Wave interaction with a submerged porous breakwater

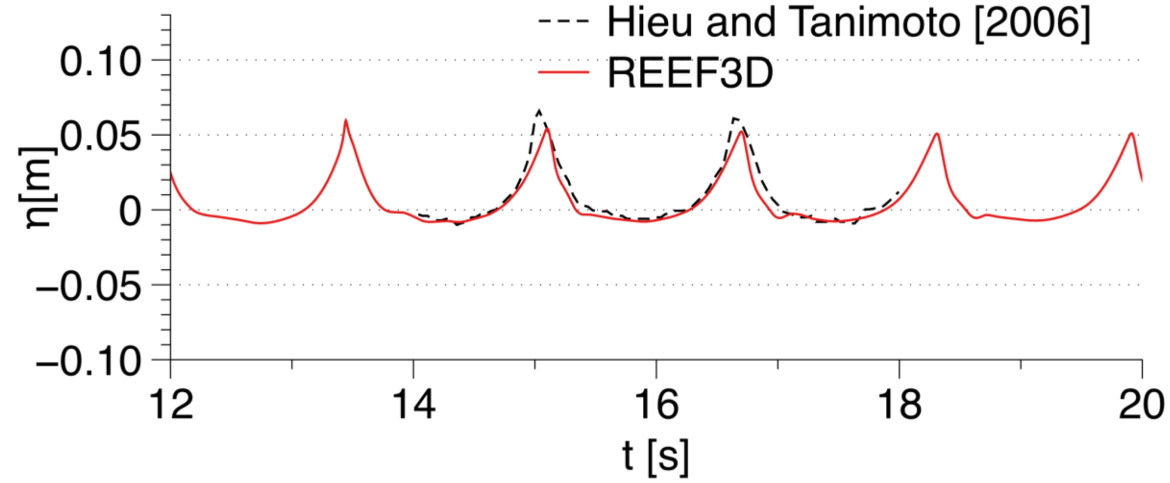


H= 0.092 m, T= 1.60 s
L= 2.83 m, d= 0.376 m
freeboard 0.046 m

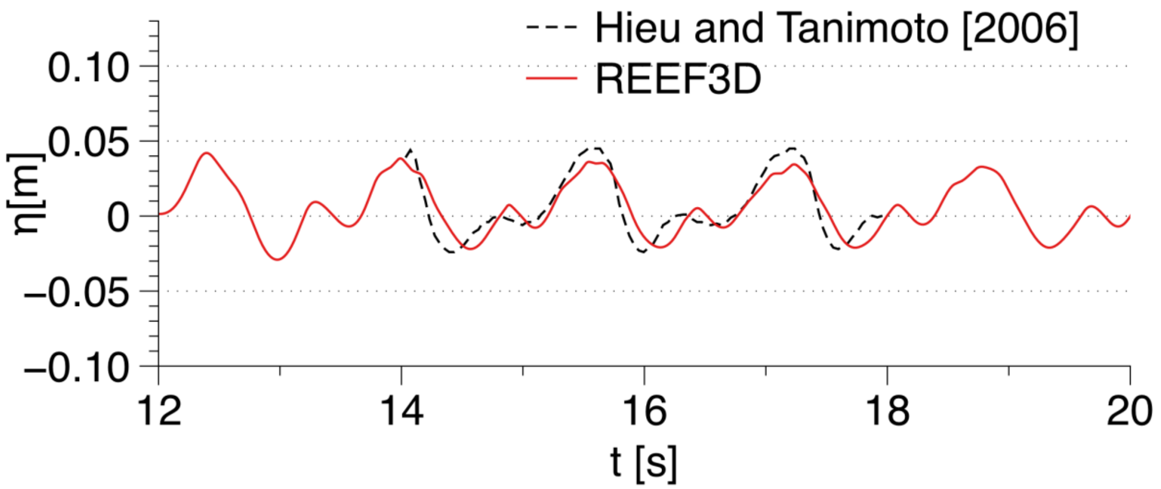
Results: Wave interaction with a submerged porous breakwater



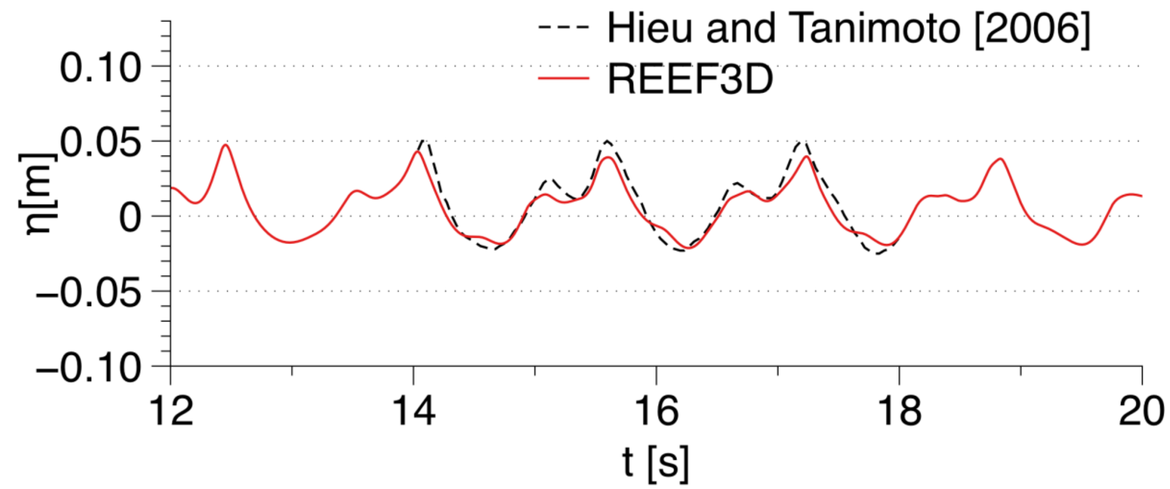
WG 1: incident wave at 8.63 m



WG 4: transformed wave at the leeside 11.28 m (over the leeward toe)

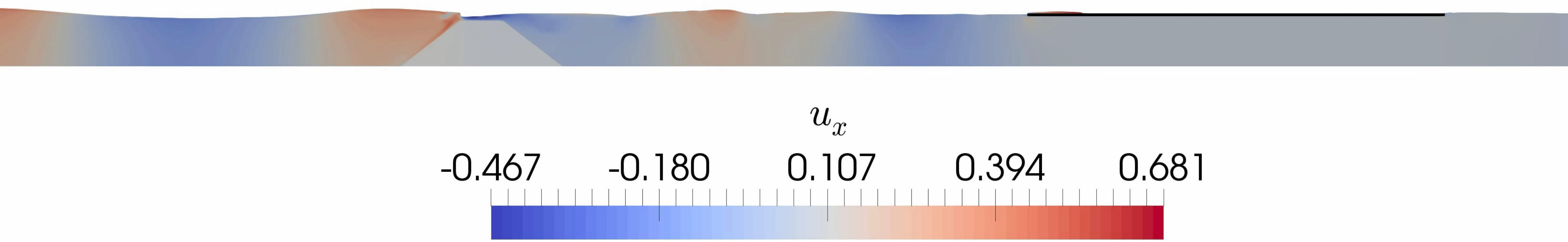


WG 5: decomposed wave at 11.97 m (0.3 L) behind



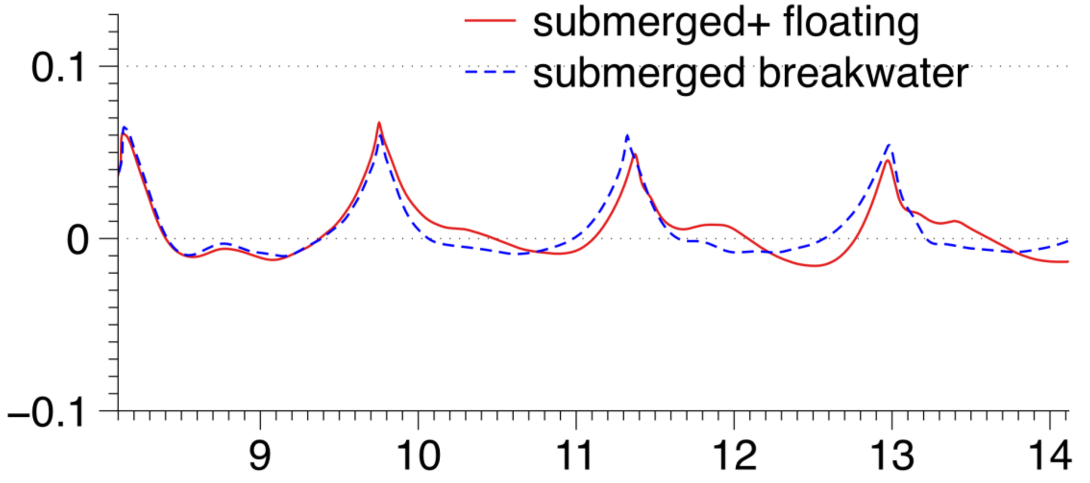
WG 6: decomposed wave at 12.57 m (0.5 L) behind

Results: Wave interaction with a submerged porous breakwater and a floating breakwater

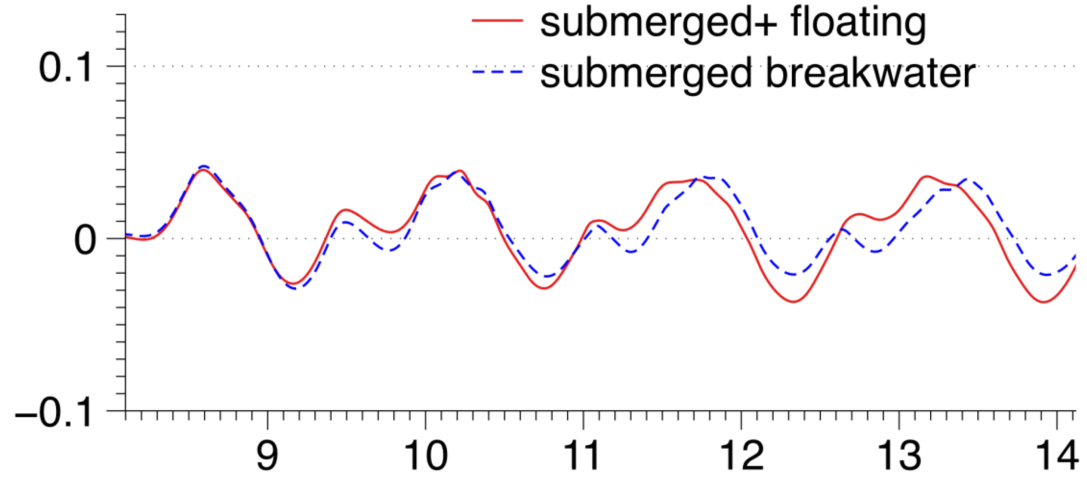


H= 0.092 m, T= 1.60 s
L= 2.83 m, d= 0.376 m
3.0 m long floating breakwater placed at 14.5 m at SWL

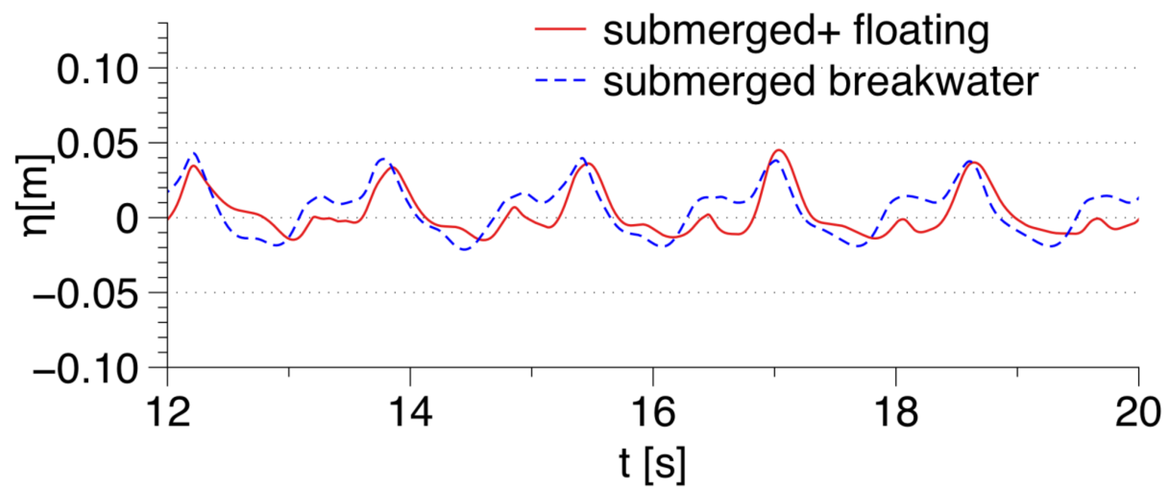
Results: Wave interaction with a submerged porous breakwater and a floating breakwater



WG 4: transformed wave at the leeside 11.28 m (over leeward toe)

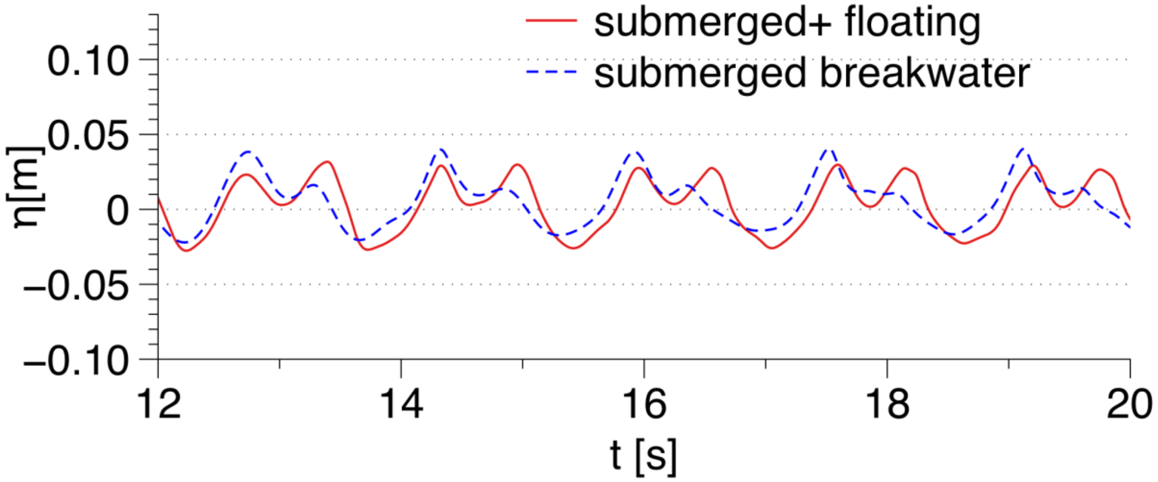


WG 5: decomposed wave at 11.97 m (0.3 L) behind

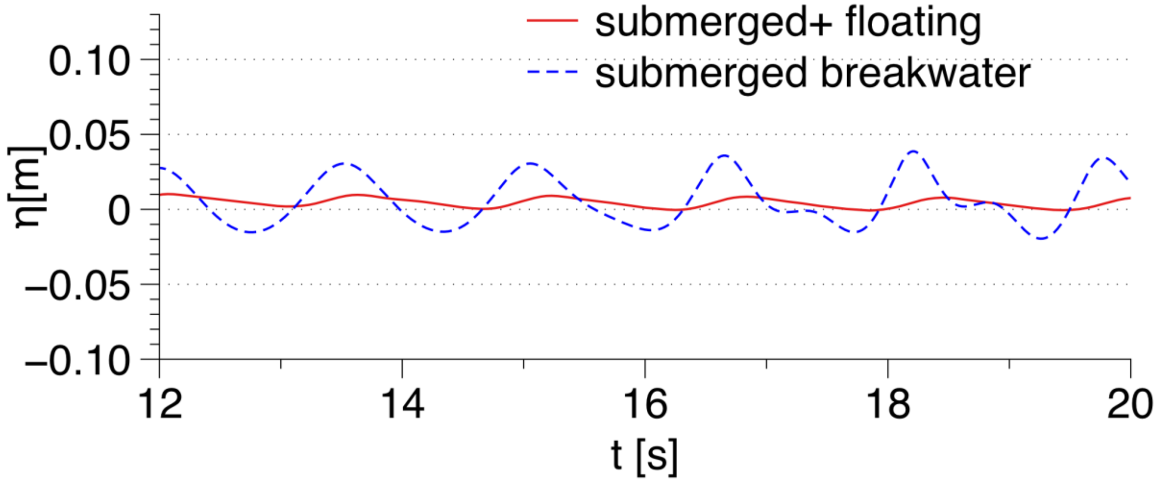


WG 6: decomposed wave at 12.57 m (0.5 L) behind

Results: Wave interaction with a submerged porous breakwater and a floating breakwater



WG 13: incident wave on floating breakwater at 14 m



WG 16: transmitted wave behind the floating breakwater at 18 m

Conclusions

- Open-source CFD model REEF3D used to simulate wave interaction with porous coastal structures
- Good representation of the free surface and pore pressure for solitary wave interaction with a porous abutment from Lara et al. (2012)
- Wave interaction with a submerged porous breakwater simulated
- Numerical results show good agreement with experimental data from Hieu and Tanimoto (2006)
- Wave interaction with a combination of submerged porous structure and a floating breakwater on the leeside simulated
- The wave transmission over the combination is calculated to be 13%
- Future studies: influence of crest height of submerged structure, optimised configuration of the combination

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Special Issue

Special Issue "Computational Fluid Dynamics for Ocean Surface Waves"

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Deadline for manuscript submissions:
20 May 2019

Message from the Guest Editors

Dear Colleagues,

Advances in computational methods and computing infrastructure have made it possible to develop high-resolution models to represent ocean surface waves. Several new modelling approaches have been developed that have greatly advanced the understanding of the different large- and local-scale phenomena in the field of ocean surface waves. Computational Fluid Dynamics can resolve the different processes in wind-wave generation, momentum transfer, coupled interaction, wave breaking and extreme wave interaction. This covers many aspects in mathematics, physical science and engineering to obtain a better understanding of wave generation and extreme events in the ocean, improving the modelling of these events at different scales to obtain new insights into the important physical processes in the ocean environment. This Special Issue aims to publish the most relevant advanced methods and models for ocean wave modelling including the different topics in met-ocean research, free surface wave modelling and wave hydrodynamics.
High quality papers are encouraged, directly related to various aspects, as mentioned below. Novel approaches, methods and techniques are encouraged.

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