Technische Universität Braunschweig

Leichtweiß-Institute for Hydraulic Engineering and Water Resources
Department of Hydromechanics and Coastal Engineering

Physical and numerical modeling of porous bonded revetments

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- Motivation & Objectives
- Large-scale tests: GWK tests overview
- Numerical simulations with COBRAS-UC
- Small-scale tests: BoPoRe project
- Numerical simulations within OpenFOAM®
- Summary and Remarks

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Motivation & Objectives

Rising sea water levels make the development of new coastal protection systems necessary. An **innovative approach** to these **new requirements** is the use of porous bonded revetments.

Improve **understanding of the processes and variables** involved in the interaction between waves and **porous revetments** and how to model it for the analysis of its **hydraulic performance**

Large-scale Tests
(GWK)

Small-scale Tests
(LWI)

Numerical modeling
(COBRAS-UC)
(OpenFOAM® model framework)

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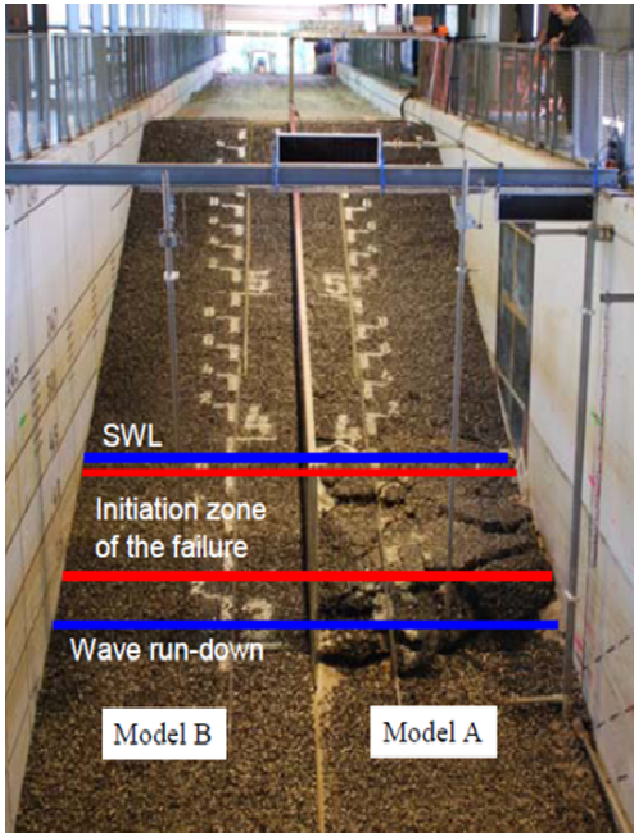
Large-scale tests: GWK-tests overview

- **Objective**
  - Improve understanding of wave-structure interaction & PBA hydraulic performance.

- **Test program**
  - Surf similarity parameter : ξ_m = 1.3 - 8.1
  - Deep water wave height: H_m = 0.17 – 1.4 m
  - Wave period: T_m = 3.0 – 8.1 s
  - Initial water depth: h_0 = 3.4 - 4.2 m
  - Revetment thickness: d_{rev} = 0.15; 0.25 & 0.35 m
  - Slope steepness: cot α = 3

- **Analysis in *Oumeraci et al. (2010)***
  - Reflection analysis
  - Wave run-up and run-down
  - Pressures on and just beneath the revetment
  - Pore pressures in sand foundation

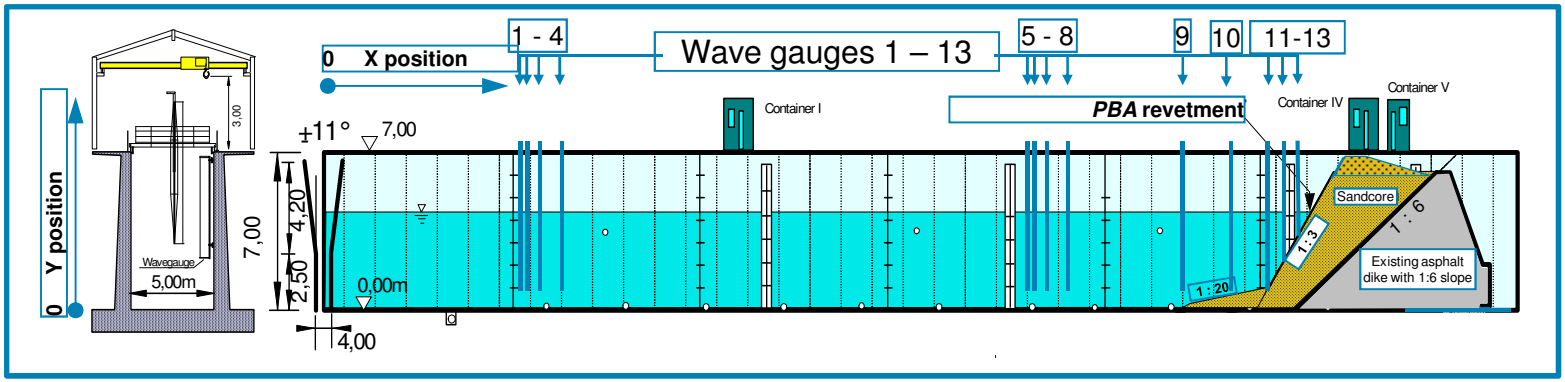


Large-scale model tests in the Grosser Wellenkanal (GWK)

Large-scale tests: GWK-tests overview

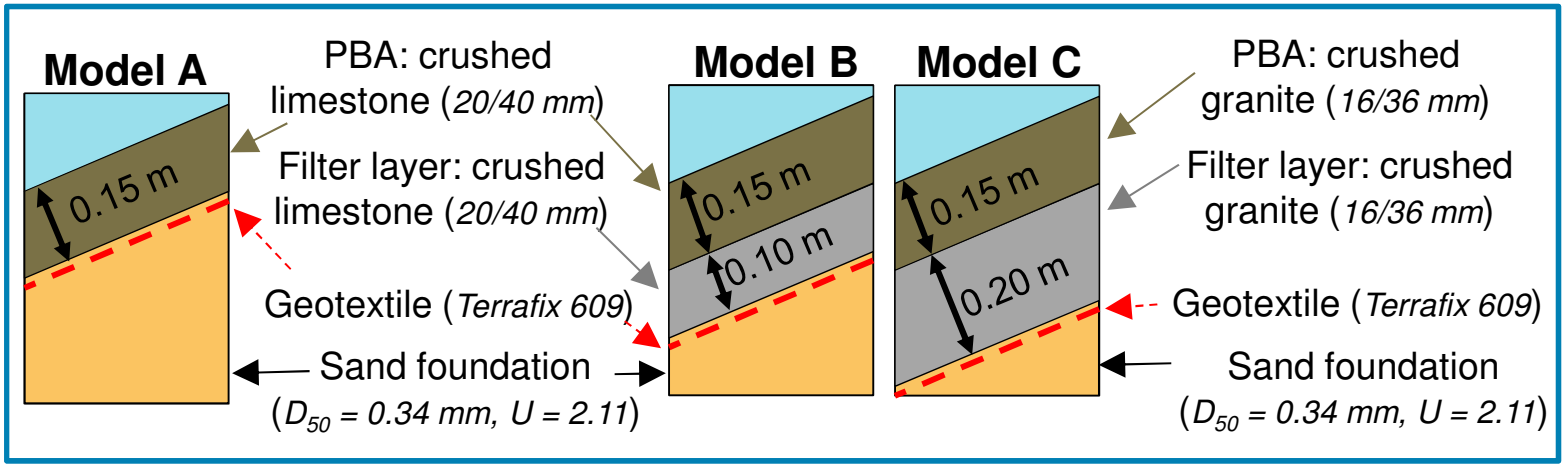
Polyurethane Bonded Aggregate (PBA) revetment in GWK and location of wave gauges

Experimental set-up



Tested PBA revetment models in GWK

PBA revetment models



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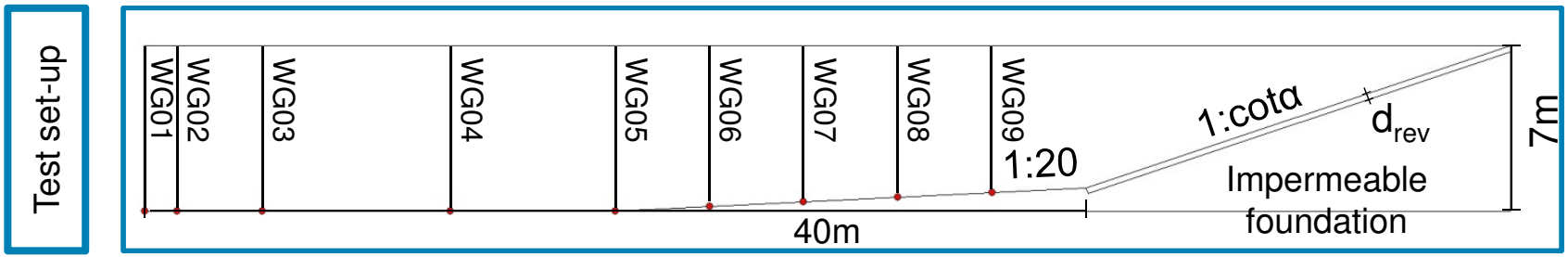
Numerical simulations with COBRAS-UC

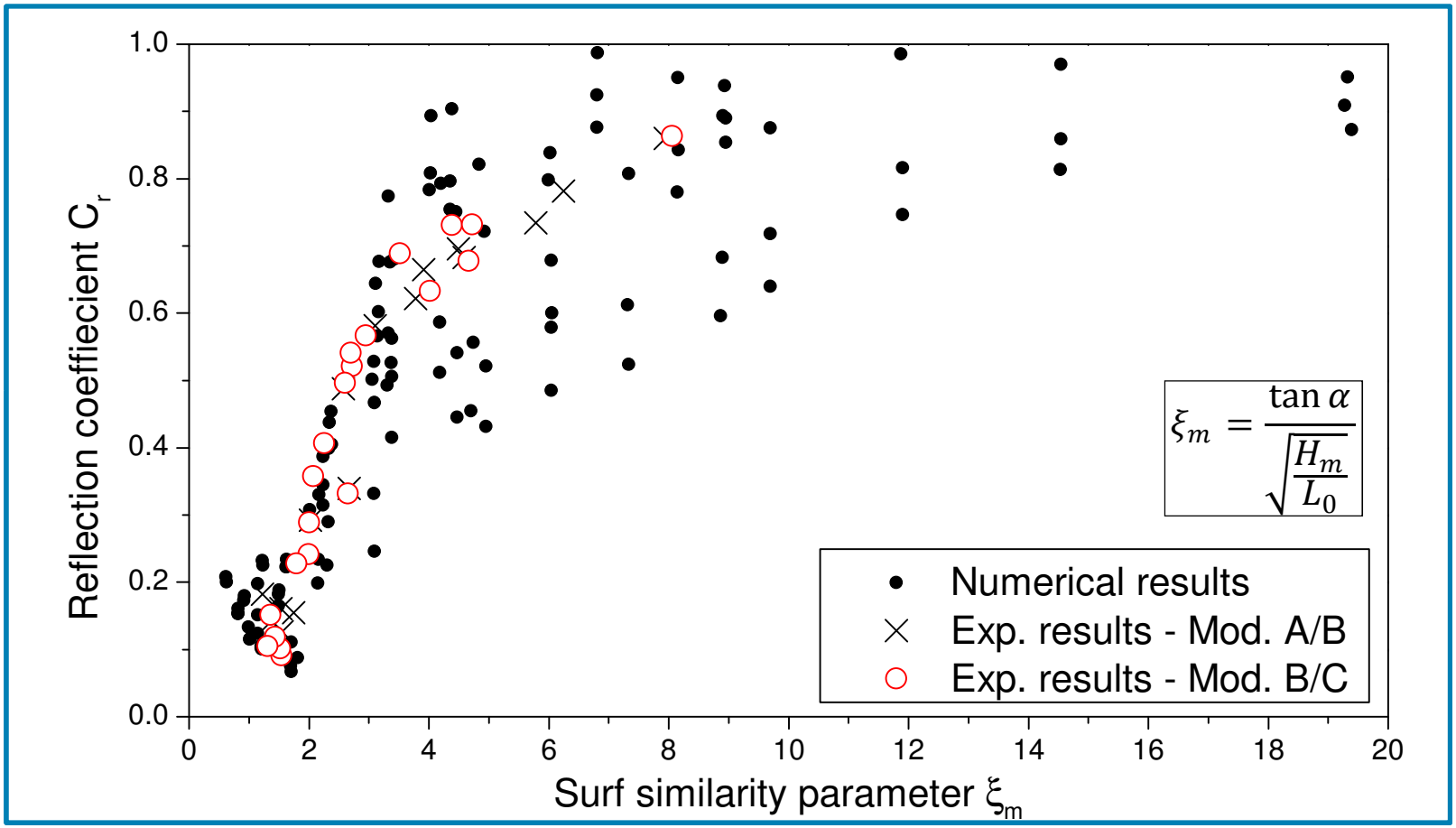
- **Objective**
  - Extend the range of the tested conditions in the GWK



- **Test conditions**
  - Deep water mean wave height H_m = 0.15 – 1.03 m
  - Mean wave period T_m = 2.99 – 9.00 s
  - Surf similarity parameter ξ_m = = 0.62 – 19.40
  - Initial water depth h_0 = 4.0 m
  - Revetment thickness d_{rev} = 0.00; 0.25 & 0.50 m
  - Slope steepness cotα = 1.5; 2; 3; 4 & 6
  - Cell sizes Δx = 2 – 4 cm; Δy = 2 – 7 cm
  - Porosity of revetment & Forchheimer coefficients: n= 0.4; α_f = 200; β_f = 0.8, C_m = 0.34

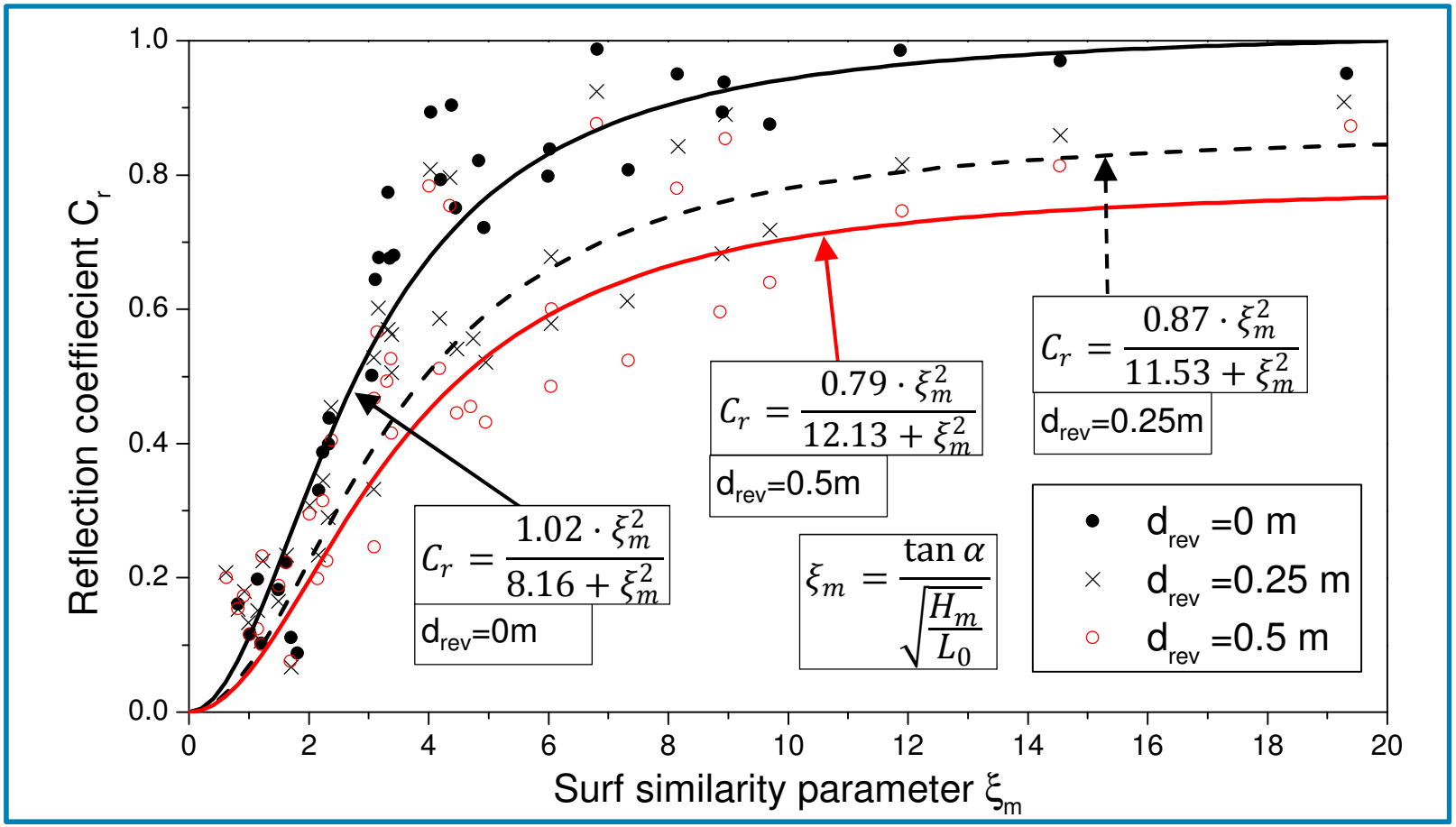
Numerical simulations with COBRAS-UC

Comparison between GWK Results and COBRAS-UC Simulations



Numerical simulations with COBRAS-UC

Effect of revetment thickness on reflection (COBRAS-UC)



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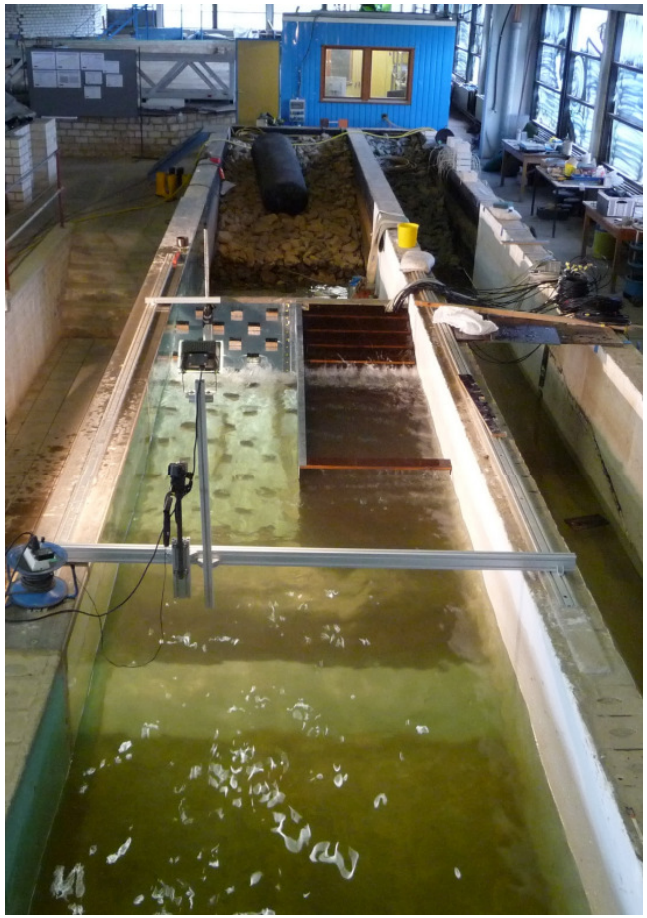
Small-scale tests: BoPoRe project

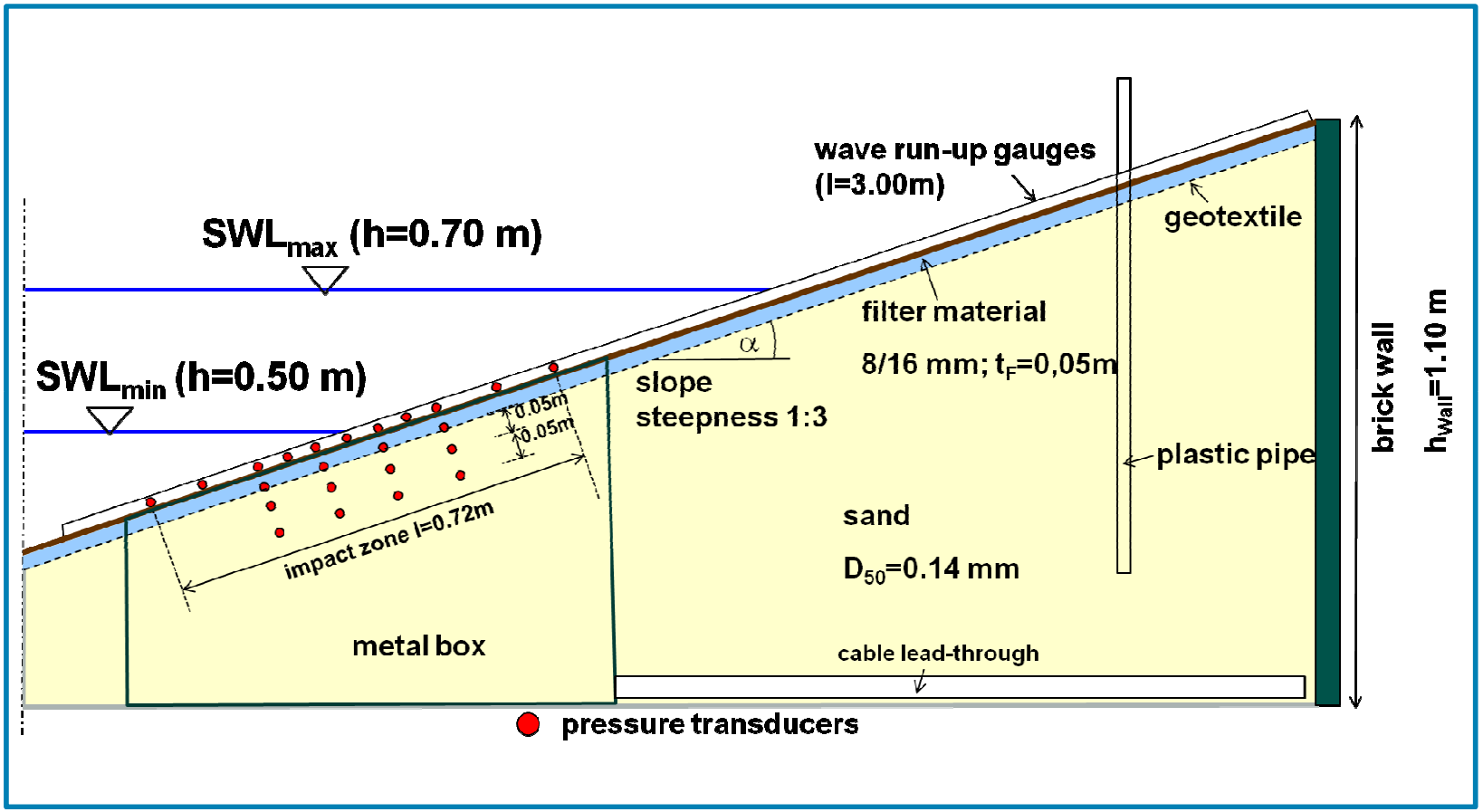
- **Objective**
  - Describe the **effect of the porosity and roughness of revetments** on wave run-up and run-down, wave-induced loads and wave-induced pore-pressure.
  - Develop generic and process-based formulae for the **design** of PBA revetments **with an explicit consideration of porosity**

- **BoPoRe Project description**
  - BoPoRe = Bonded Porous Revetments.
  - Facilities of the Leichtweiß-Institute (LWI) in Braunschweig.
  - Funded by the German Research Council (DFG).



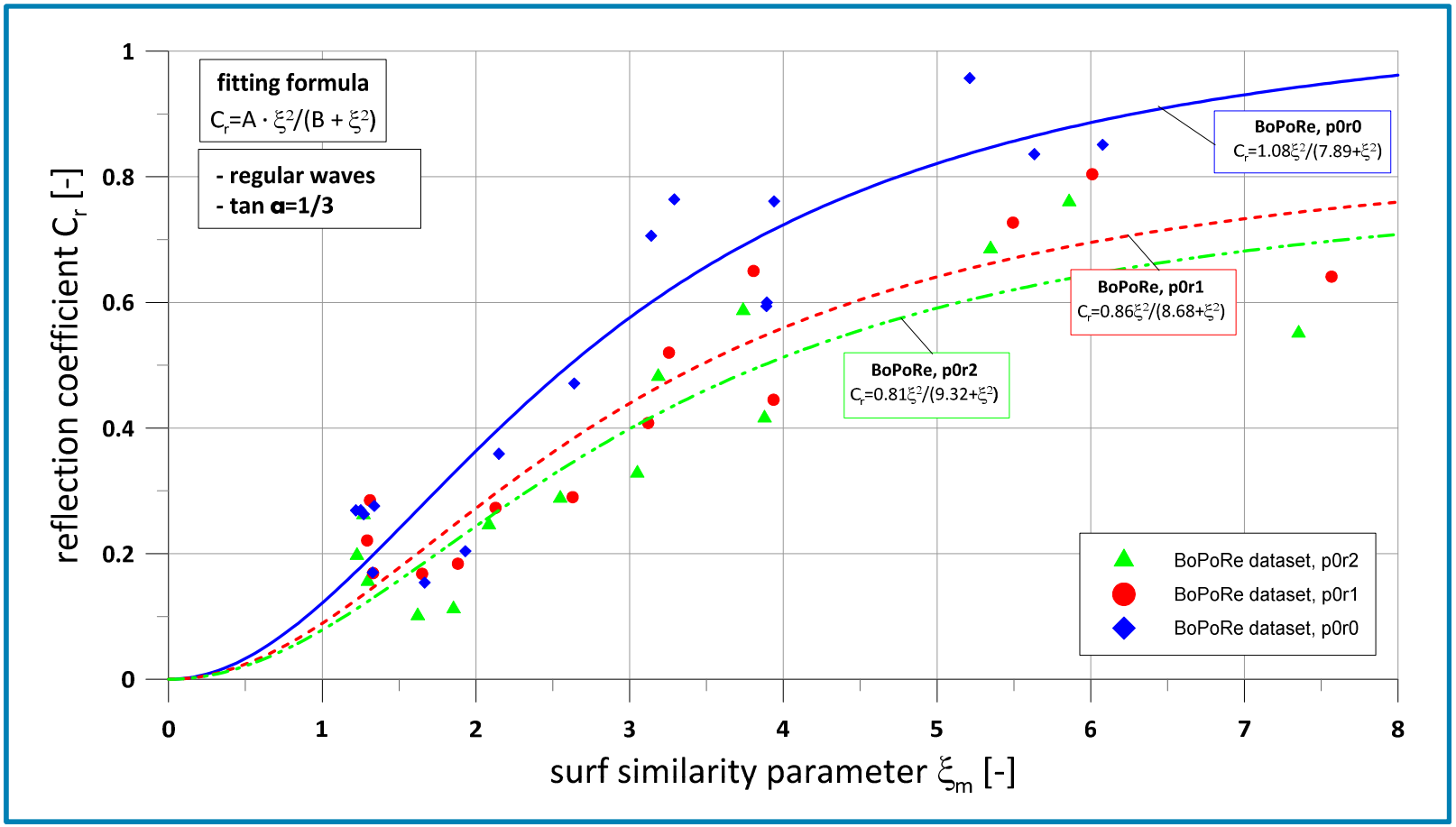
Small-scale tests: BoPoRe project

Set-up



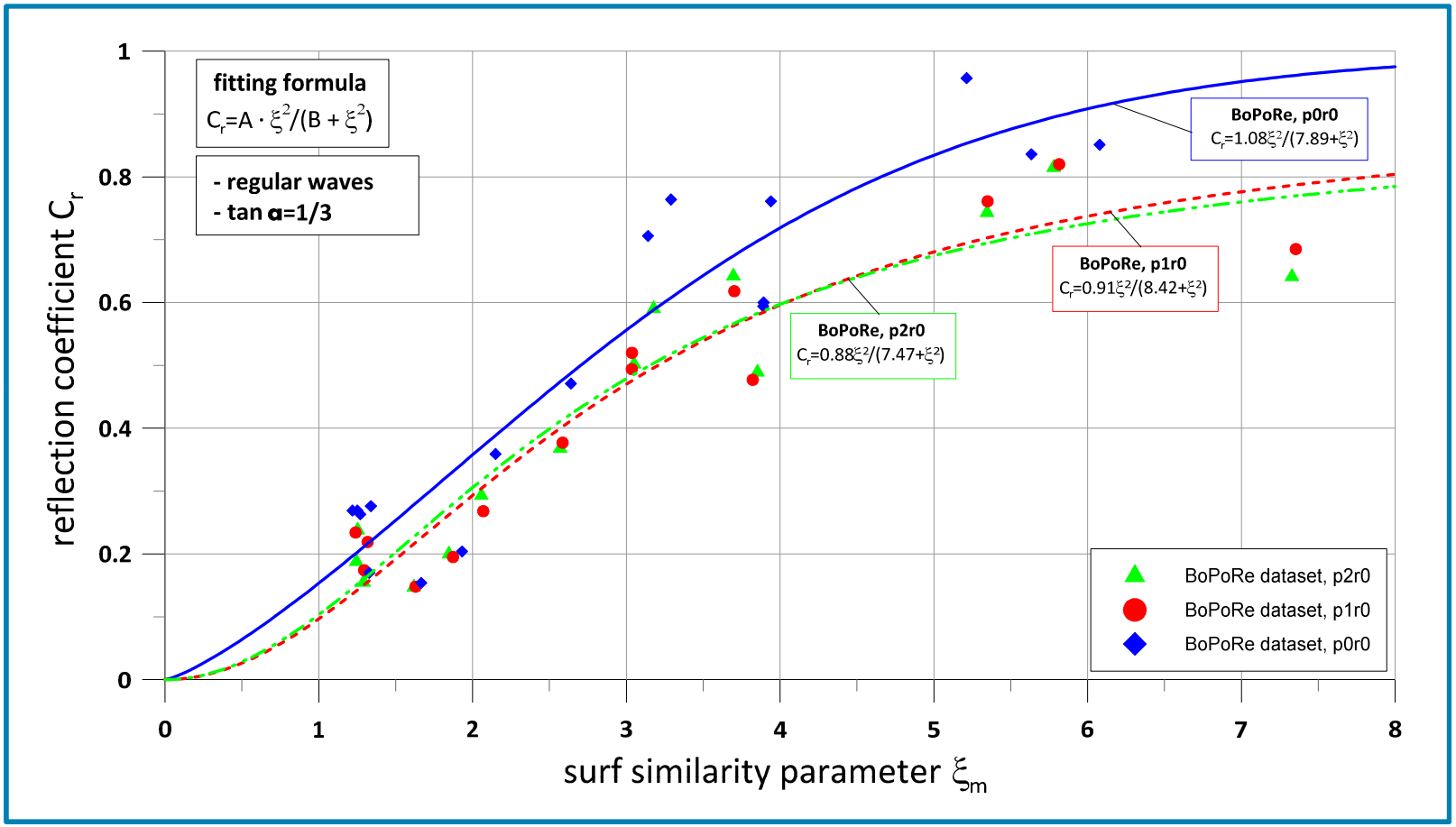
Small-scale tests: BoPoRe project

Reflection behavior for different roughnesses of impermeable revetments



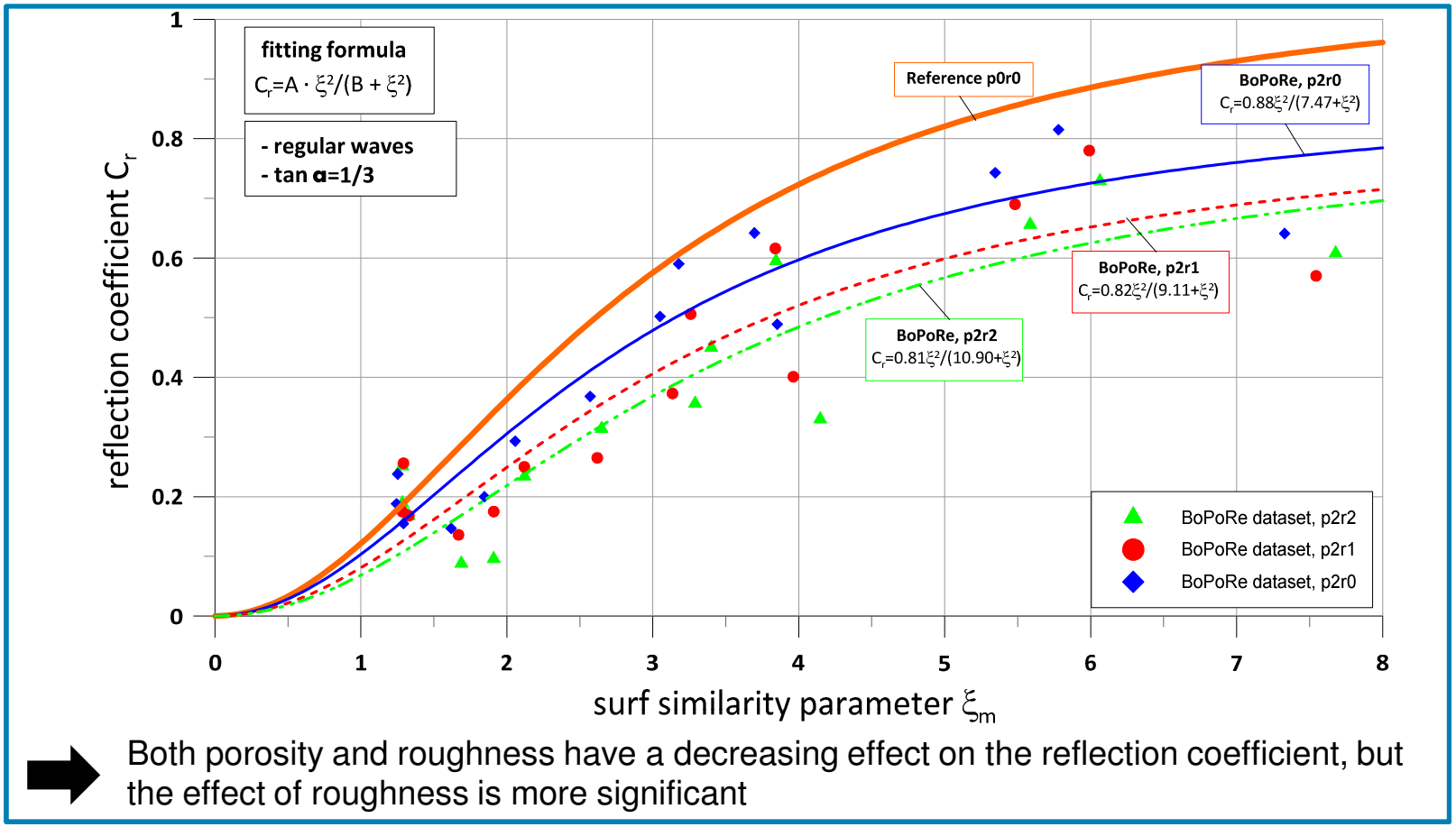
Small-scale tests: BoPoRe project

Reflection behavior for different porosities of smooth revetments



Small-scale tests: BoPoRe project

Reflection behavior for highly porous revetments with different roughnesses



Both porosity and roughness have a decreasing effect on the reflection coefficient, but the effect of roughness is more significant

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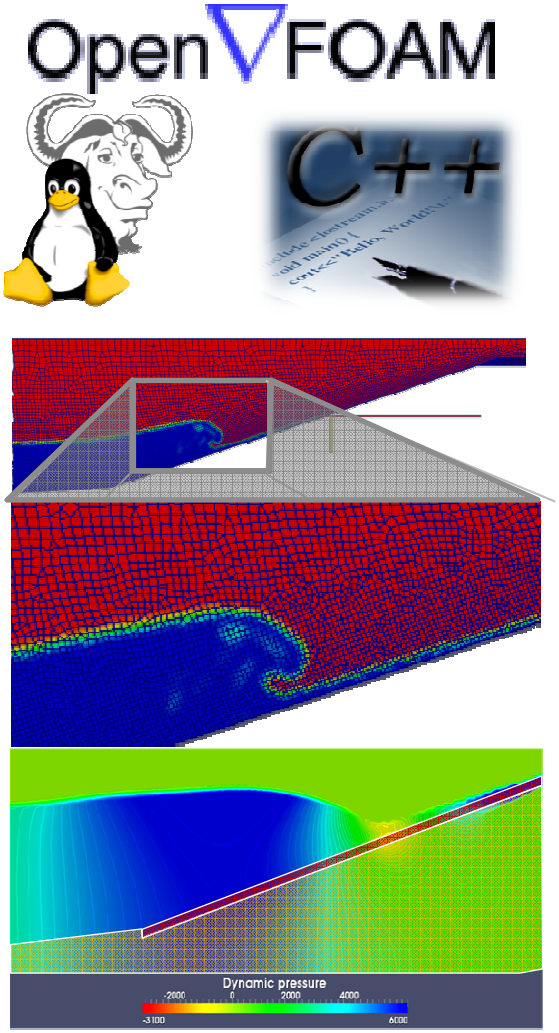
Numerical simulations within OpenFOAM®

- **Objective**
  - Extend GWK tests conditions with…
  - Improve shortcomings observed in other models.
  - **Reproduce hydrodynamic processes** on/beneath the revetment.
  - Develop generic and process-based formulae for the **design** of PBA revetments.

- **Numerical model features**
  - OpenFOAM® : Open source CFD toolbox
  - Volume-Averaged RANS-VOF model
  - **New solver** developed within the OpenFOAM framework:

wavePorousFoam { *waveFoam* (Jacobsen et al., 2012)
porousInterFoam

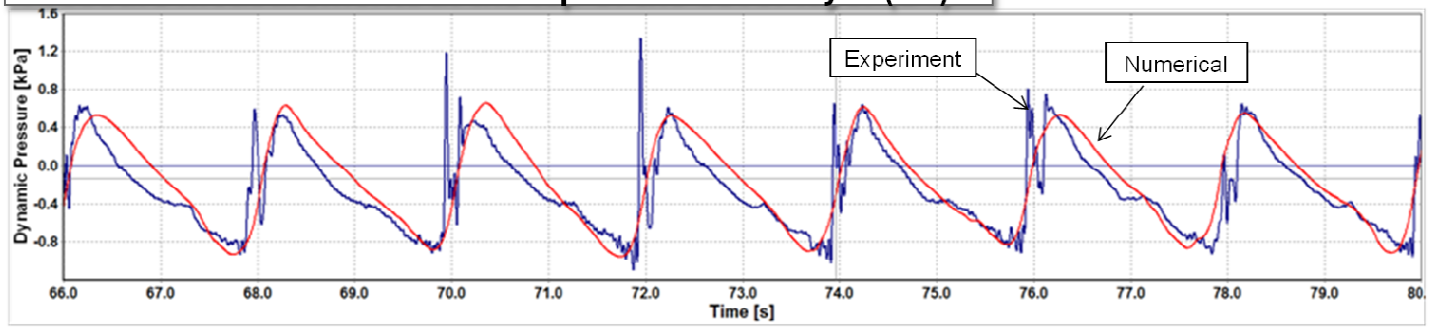


Numerical simulations within OpenFOAM®

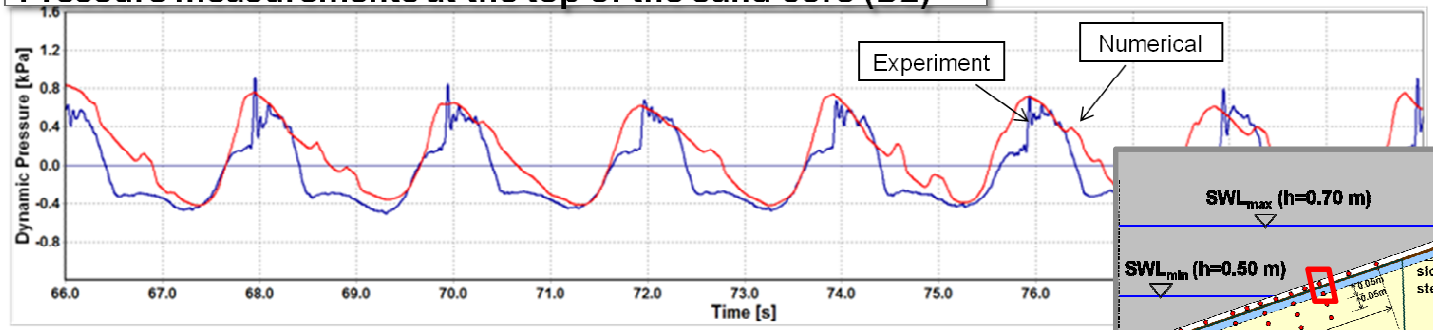
Comparison between GWK Results and *wavePorousFoam* simulations

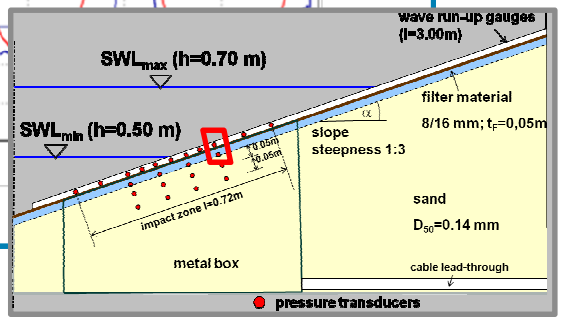
Wave conditions: Regular waves with H=0.16m, T=2.0s, h=0.678m

Pressure measurements at the top of the cover layer (D1)



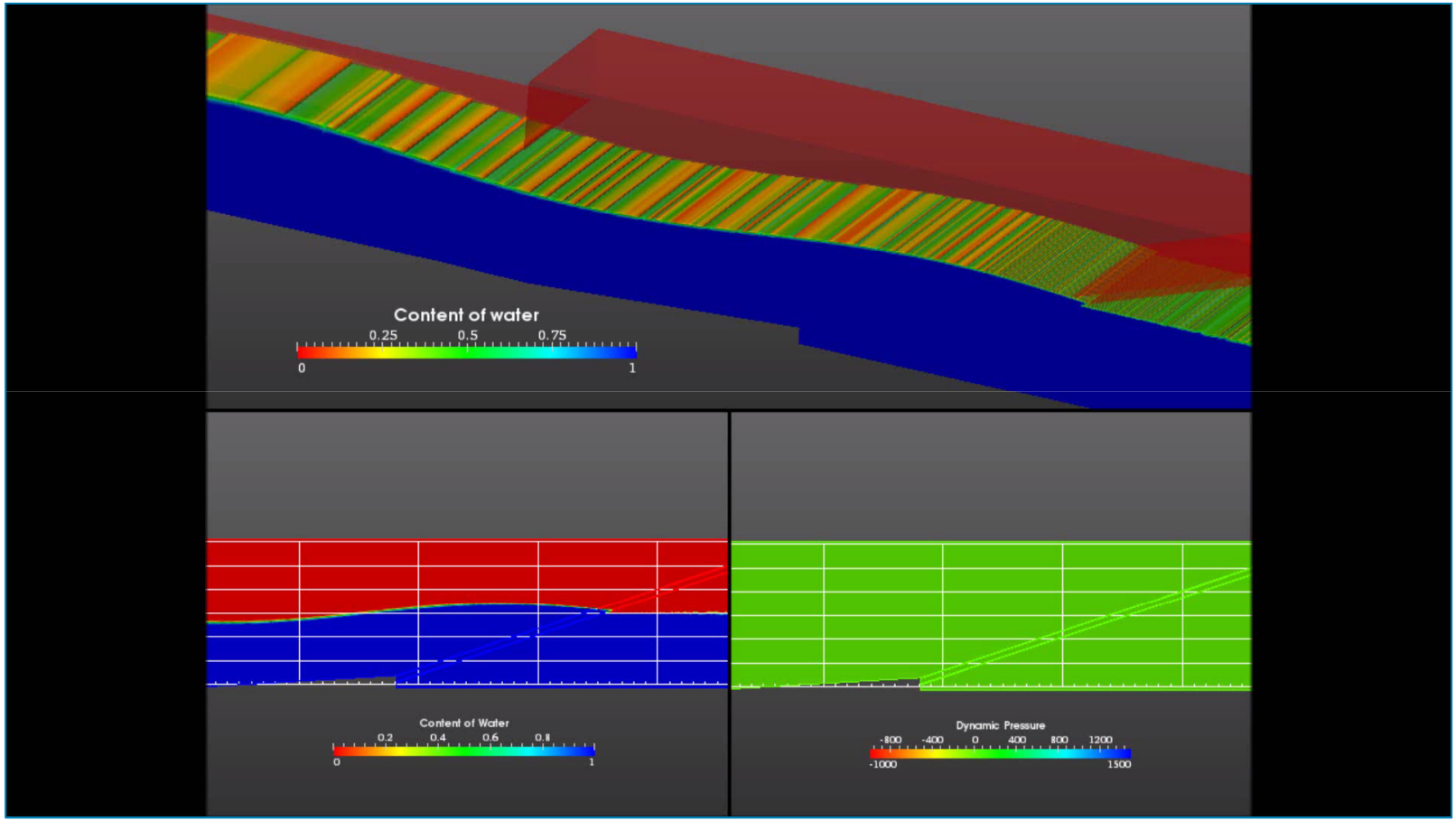
Pressure measurements at the top of the sand core (D2)





Numerical simulations within OpenFOAM

Simulations performed with *wavePorousFoam*



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Summary and concluding remarks

- The large scale tests in the GWK mostly serve as a kind of bench mark tests for all following investigations.

- Using different modelling approaches, (large scale tests, small scale tests and numerical simulations) it is possible to improve the knowledge on the interaction between waves and porous revetments of different roughnesses and porosities on sand foundations.

- The effects of roughness and porosity were analyzed using the reflection coefficient as a comparative parameter between the test series. It was found that the surface roughness affects the reflection more than the porosity.

- Some shortcomings of the numerical model COBRAS-UC were identified. Therefore, a new solver was developed in the OpenFOAM® framework and validated by experimental data.

- The new model, although still under development, show a better performance than COBRAS-UC in terms of the prediction of the porous flow in the revetment

Thank you for your attention!

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