ICCE 2018

36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018

Baltimore, Maryland | July 30 – August 3, 2018

The State of the Art and Science of Coastal Engineering

On the effectivness of Oscillating Water Column Devices in reducing the agitation in front of vertical wall harbour structures

UNIVERSITÀ DEGLI STUDI FIRENZE

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Outlines

Introduction and Motivations

The OWC as antireflection device

The Numerical Wave Tank

Reflected and radiated wave estimation

Results

Conclusion and outlooks

Introduction and Motivations

Need to reduce wave reflection at vertical harbor structures (**reduce harbor agitation**)…

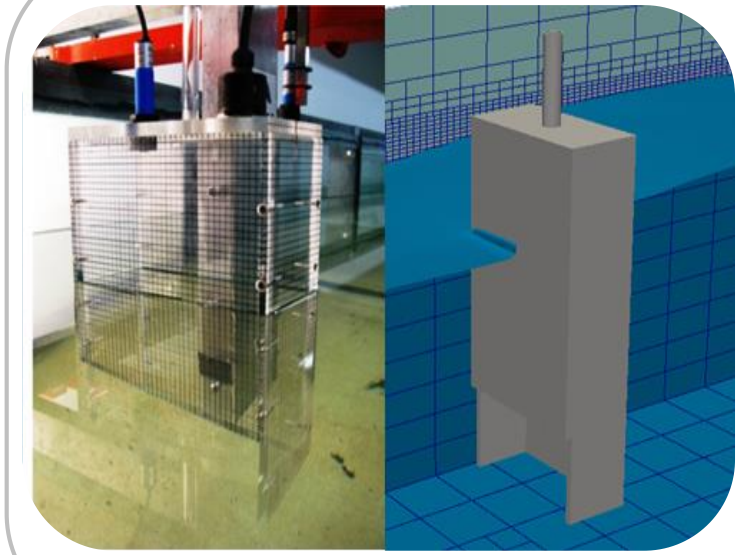
Need to reduce cost of Wave Energy Converters (**WECs**)…

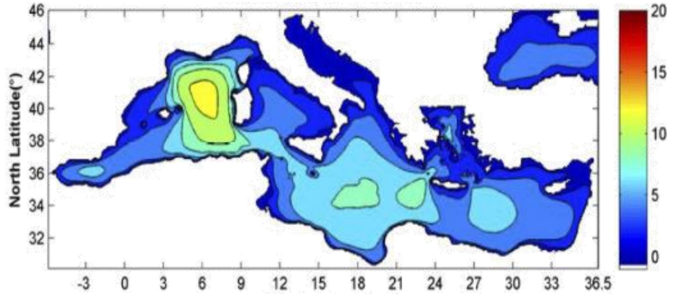
INTEGRATION OF WECs IN COASTAL STRUCTURES!

Introduction and Motivations

…. Our previous works on the OWC WEC device

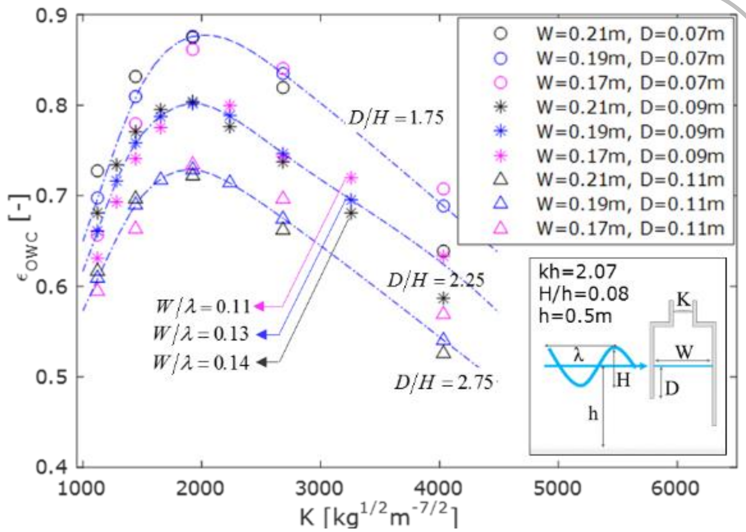
Experimental and numerical modelling ➔ site-specific efficiency maximization of the **OWC chamber** and **PTO damping**





H=2-3m, T=7-8s

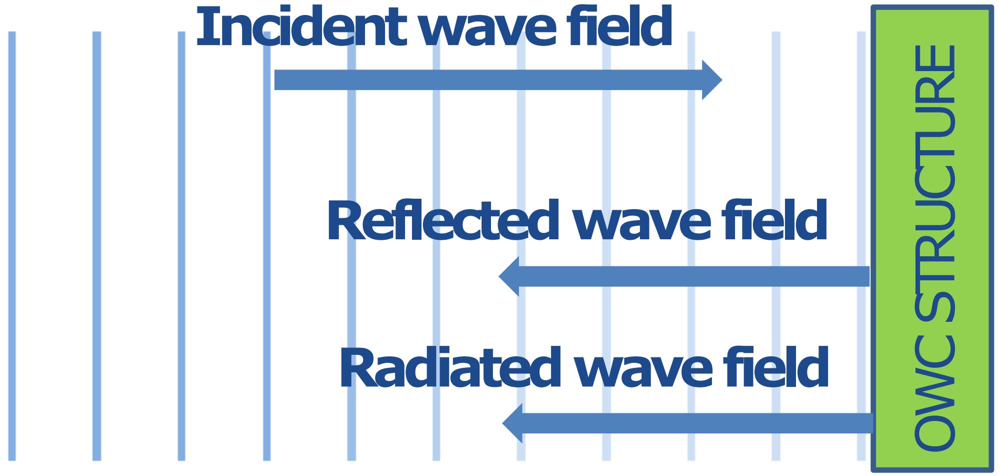
optimal geometry: max capture width ratio (CWR) **≈87%**

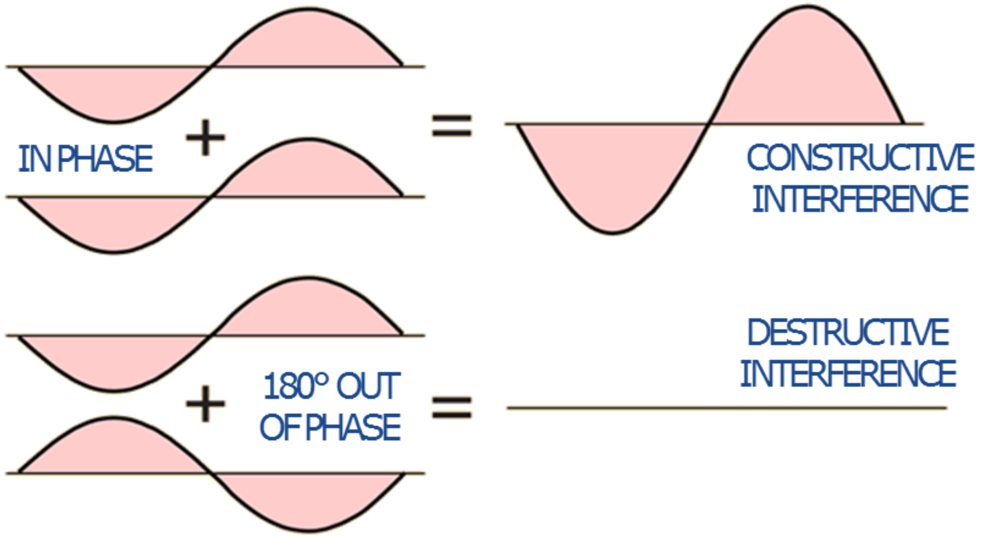


(Simonetti et al., 2017 & 2018)

The OWC as antireflection device

The agitation in front of an OWC integrated into a vertical wall harbor structure is given by the interaction of





Interference may be **constructive** or **destructive** ➡ *f* (OWC geometry, applied damping, incident wave… ….W/L, V/W, L, etc.)

The OWC as antireflection device

…. The specific aim of this work is:

- to evaluate the effectiveness of OWCs for **reducing wave reflection**
- to separate **reflected** and **radiated** wave fields

We consider K_{rr} (reflection + radiation coefficient) as an index!

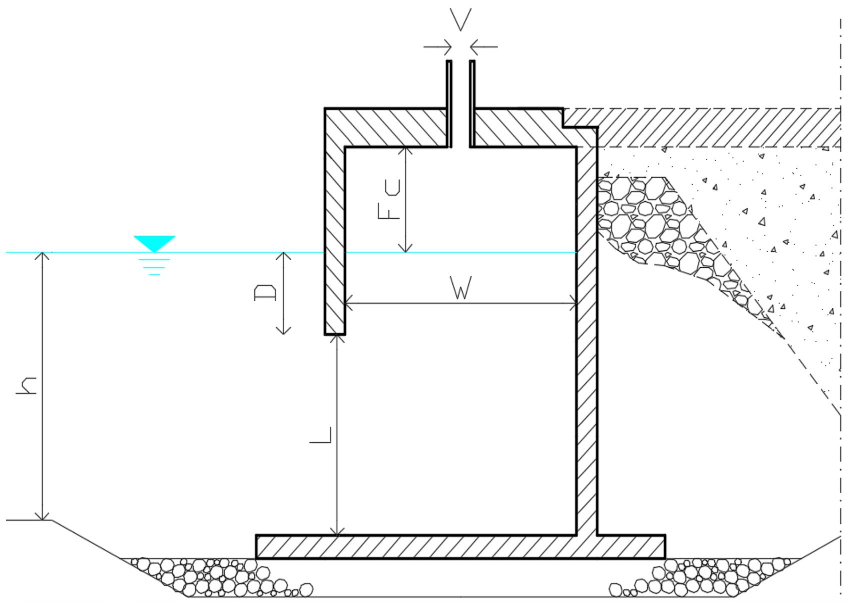
OWC GEOMETRIES & WAVE CONDITIONS

water depth **h**: 5-9m

wave periods **T**: 2-5s

wave height **H**: 0.1-0.7m

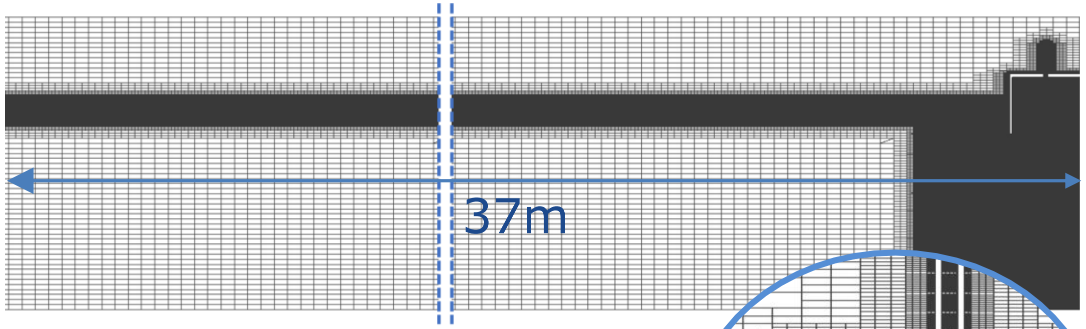
OWC width **W**: 2-3m, draught **D**=1-2m



The Numerical Wave Tank

OpenFOAM

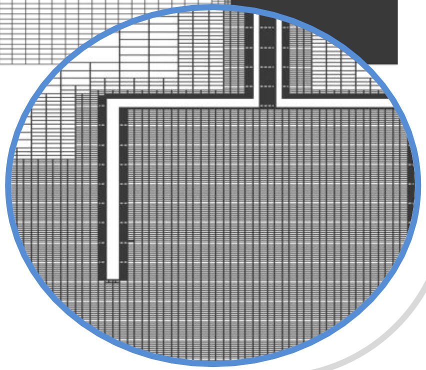
- Volume of Fluid (**VOF**) surface tracking
- **Two-phases**, **incompressible** flow (interFoam)
- Wave generation with **waves2Foam**
- RANS + k-ε turbulence model
- 2D MODEL
- NWT with LABIMA WCF length



FREE SURFACE REFINEMENT:

H/cells ~ 20

λ/cells ~300

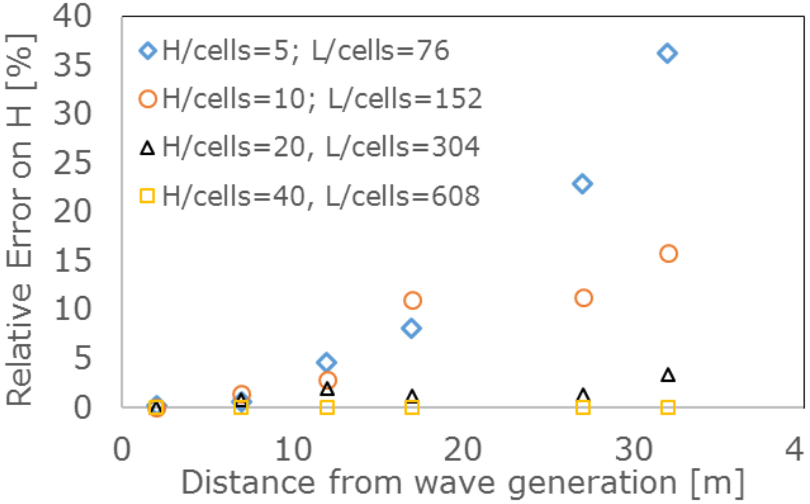


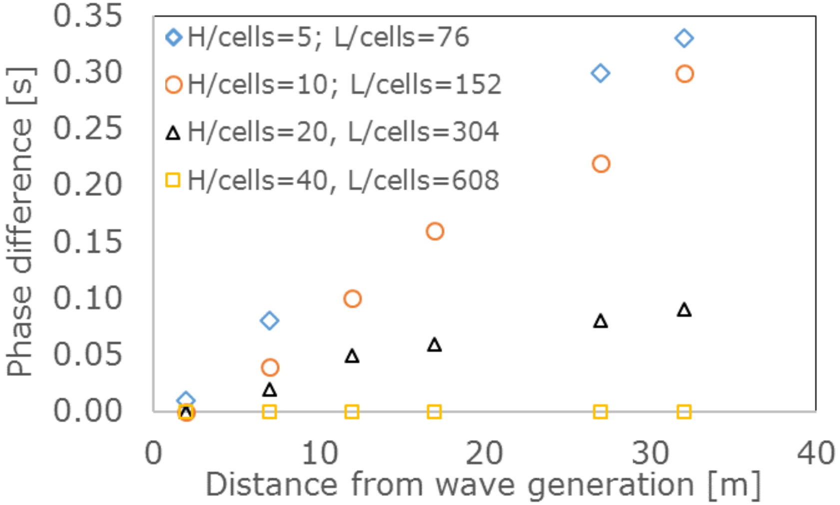
The Numerical Wave Tank – SENSITIVITY TESTS

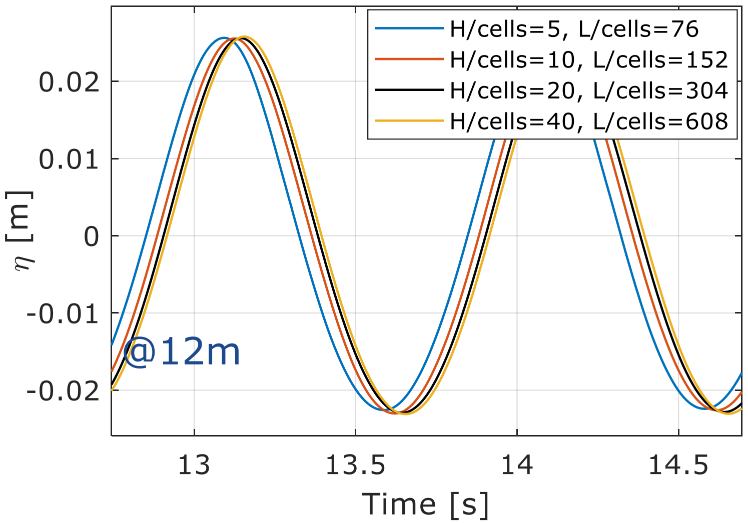
- Sensitivity to the Mesh resolution in the free surface region

Relative error and phase difference with respect to H/cells=40 & L/cells=608 at different distances from wave

REFERENCE WAVE: H=5cm, T=1s







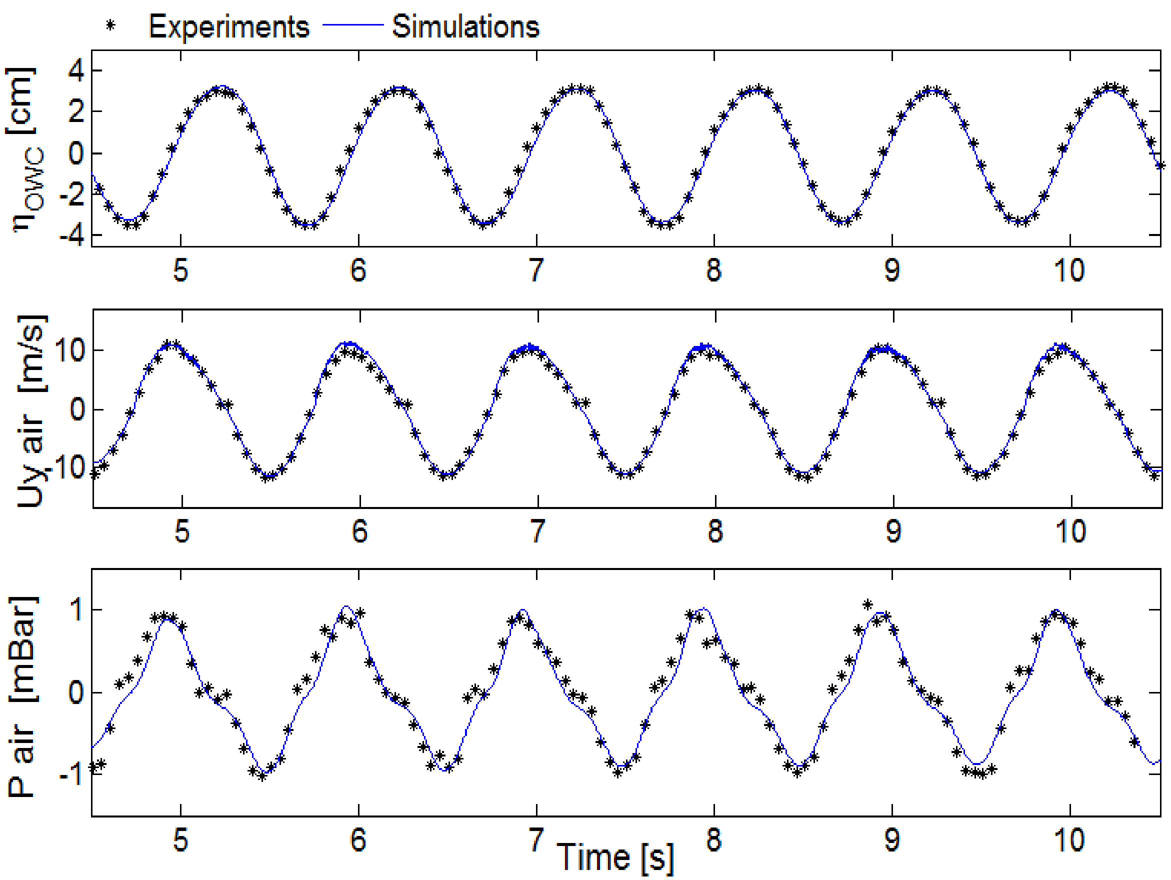
- For H/cells=20 and L/cells=304, error on H<5% and phase difference <0.1s

The Numerical Wave Tank – VALIDATION

Relative error < 15% on all the selected parameters

Good agreement between numerical and experimental data

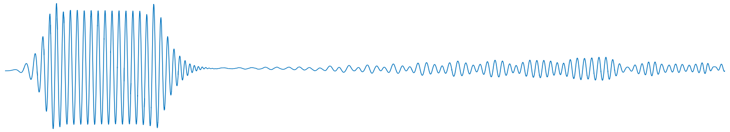
		η_{OWC}	P_{air}	U_y
NRMSE	Aver.	8,1%	9,1%	8,2%
	Max	16%	15%	16%
R^2	Aver.	0,98	0,98	0,97
	Min	0,94	0,94	0,93



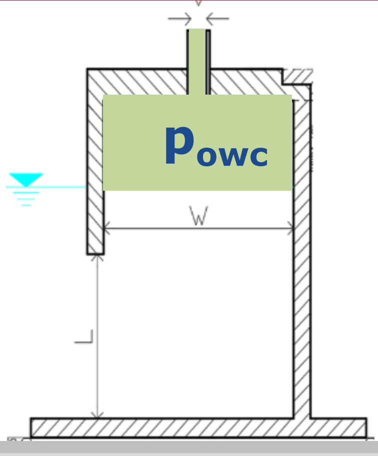
Reflected and radiated wave estimation

NWT – 1st step

WAVE GENERATION:
20 wave periods



TOTAL SIMULATION TIME:
110 wave periods



MEASUREMENTS:

Reflected + Radiated waves

Pressure in the chamber p_{owc}

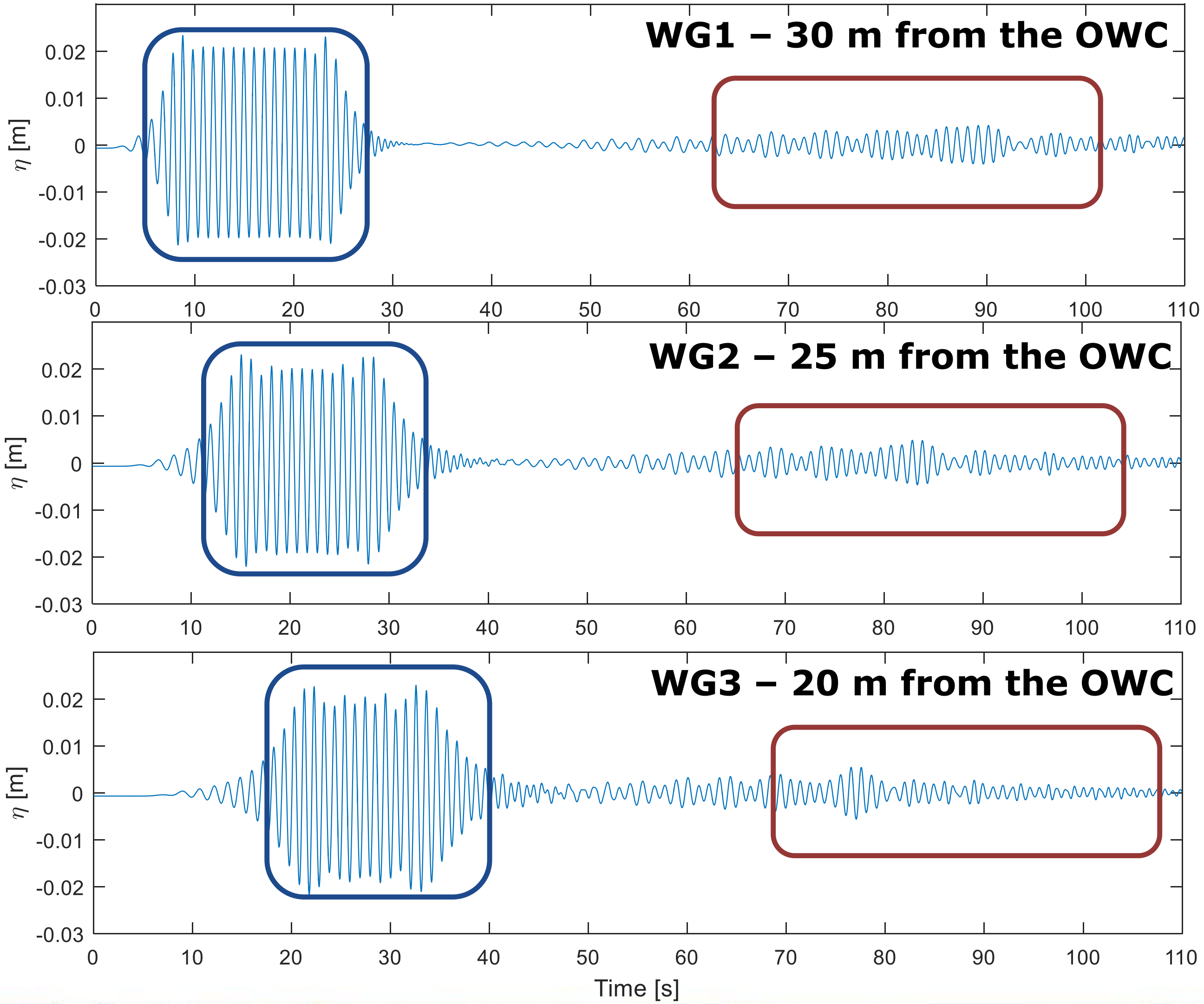
Water levels in the chamber η_{owc}

NWT – 2nd step

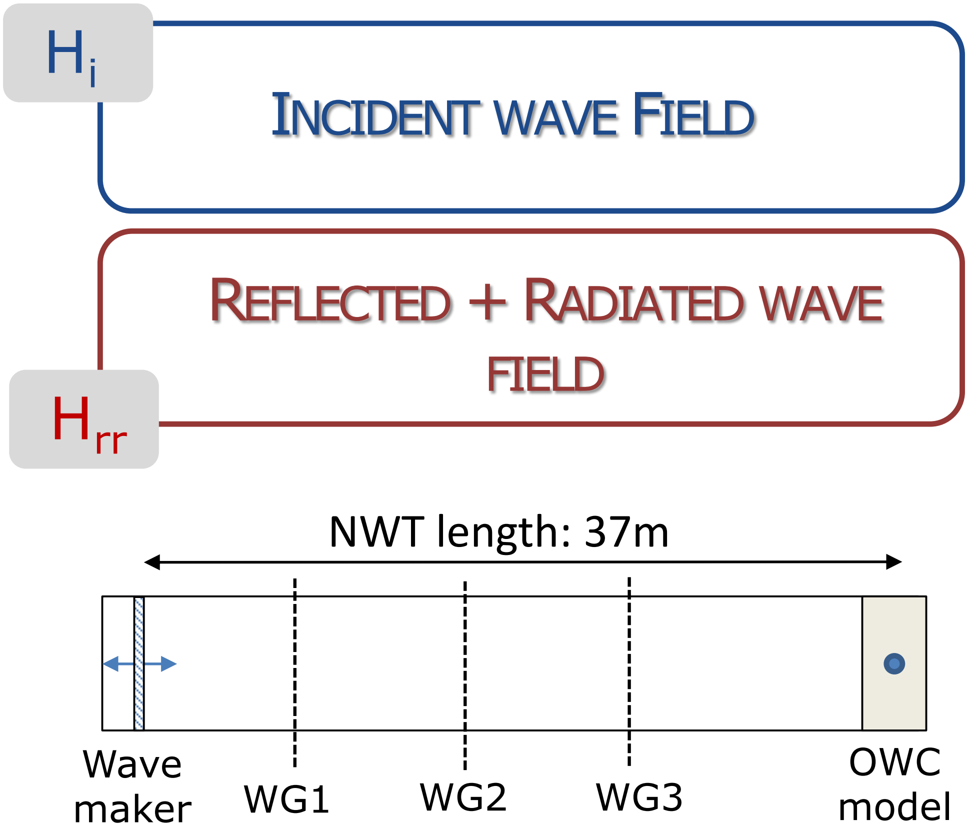
PRESSURE IN THE OWC CHAMBER p_{owc} IMPOSED AS BOUNDARY CONDITION.

Radiated wave field extimation

Results



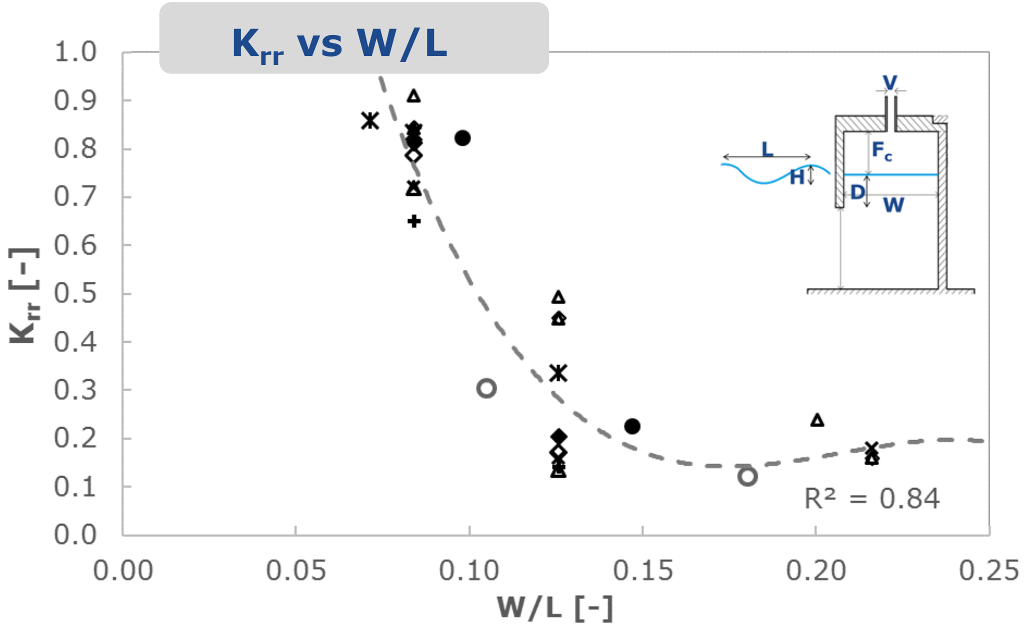
- Zero-Up Crossing (**ZUC**) analysis for determining H

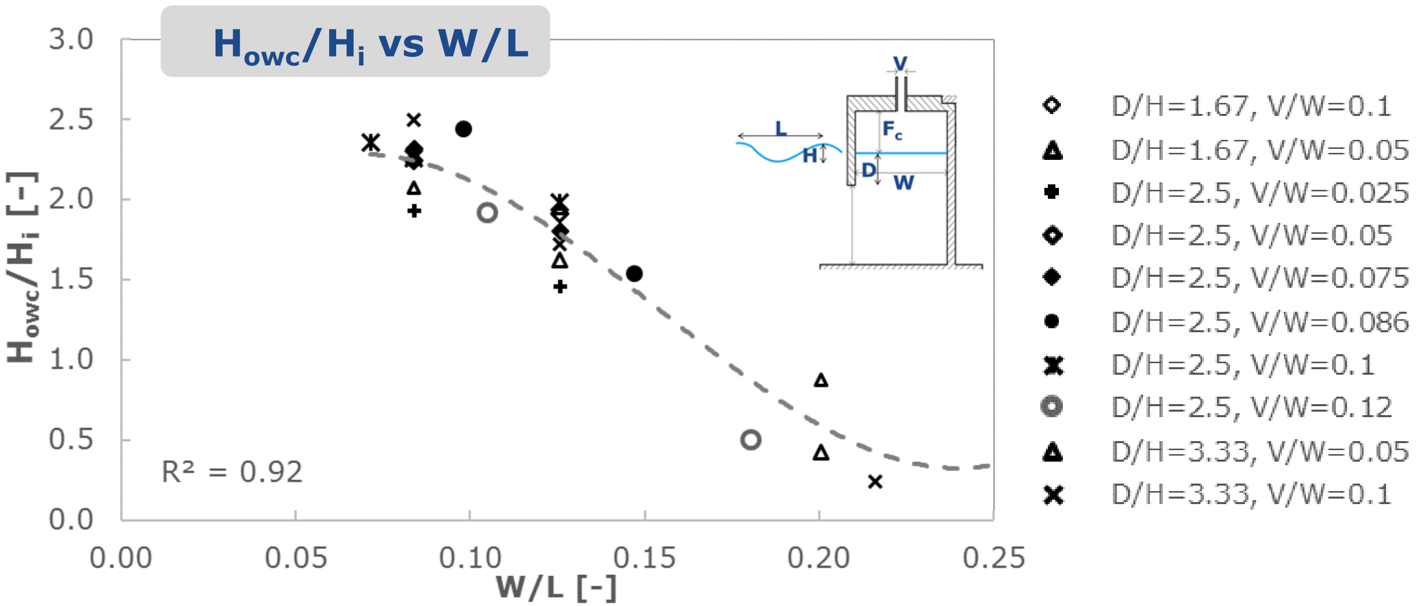


Results – Reflection Coefficients

$K_{rr}=H_{rr}/H_i$

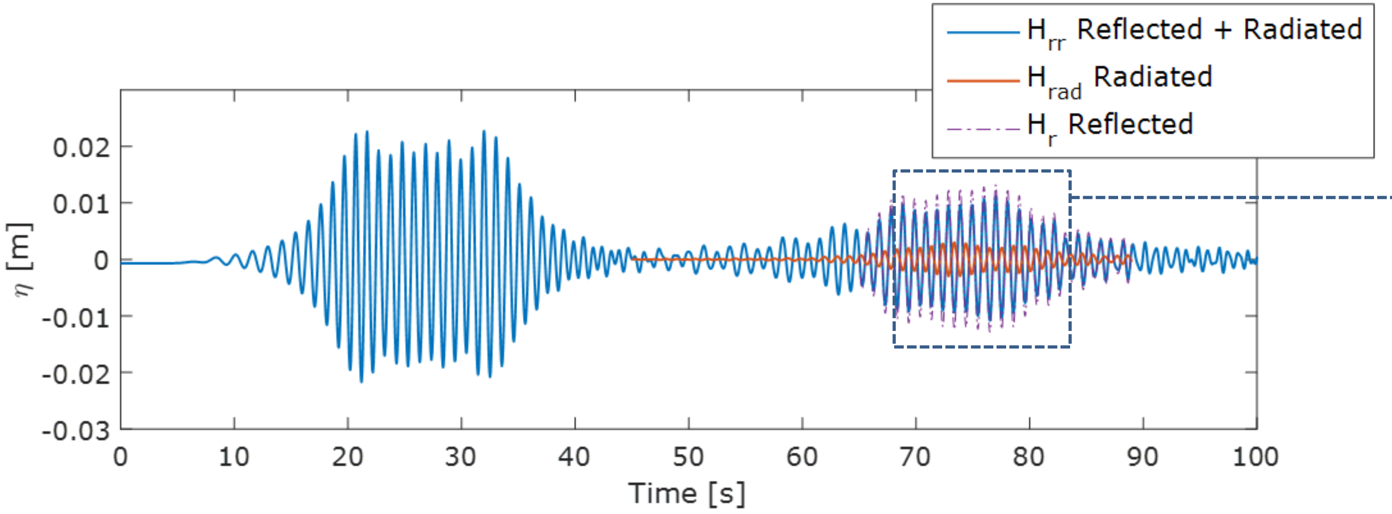
- It also includes the radiated component!

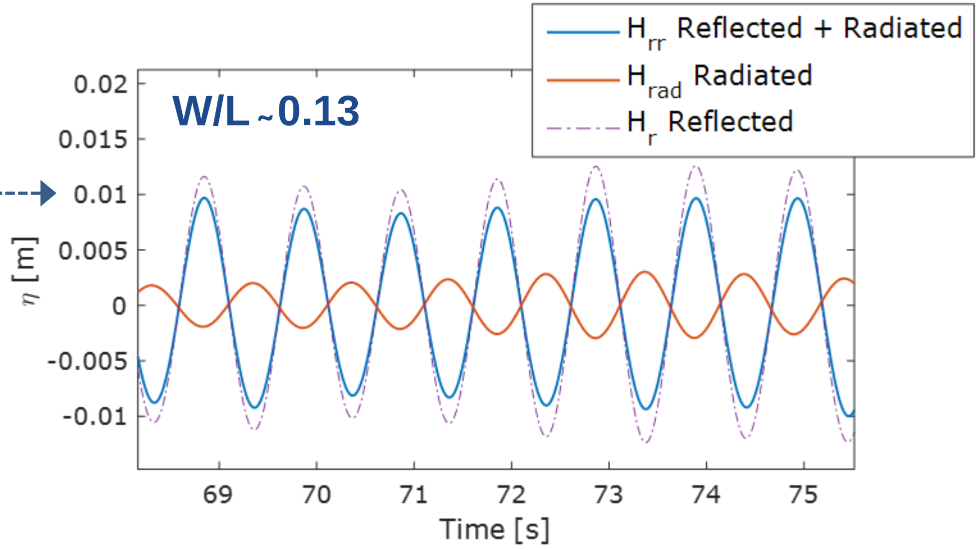


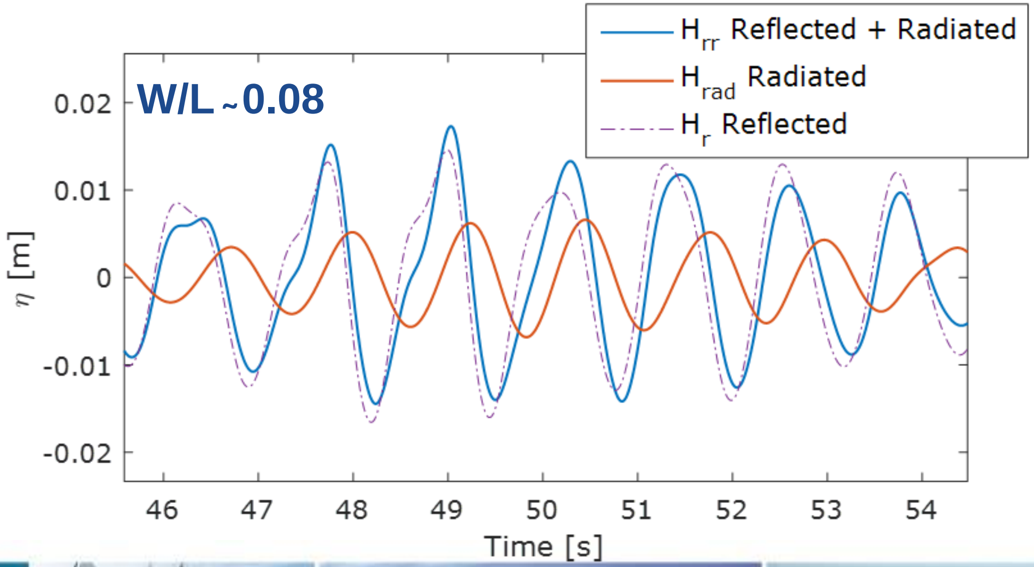


- Min. values of K_{rr} **<0.2** for **W/L = 0.15-0.2**
- Max. values of K_r ~**0.9** for **W/L ~0.08**
- Max. H_{owc}/H_i ~2.5

Results – Radiated Wave Field





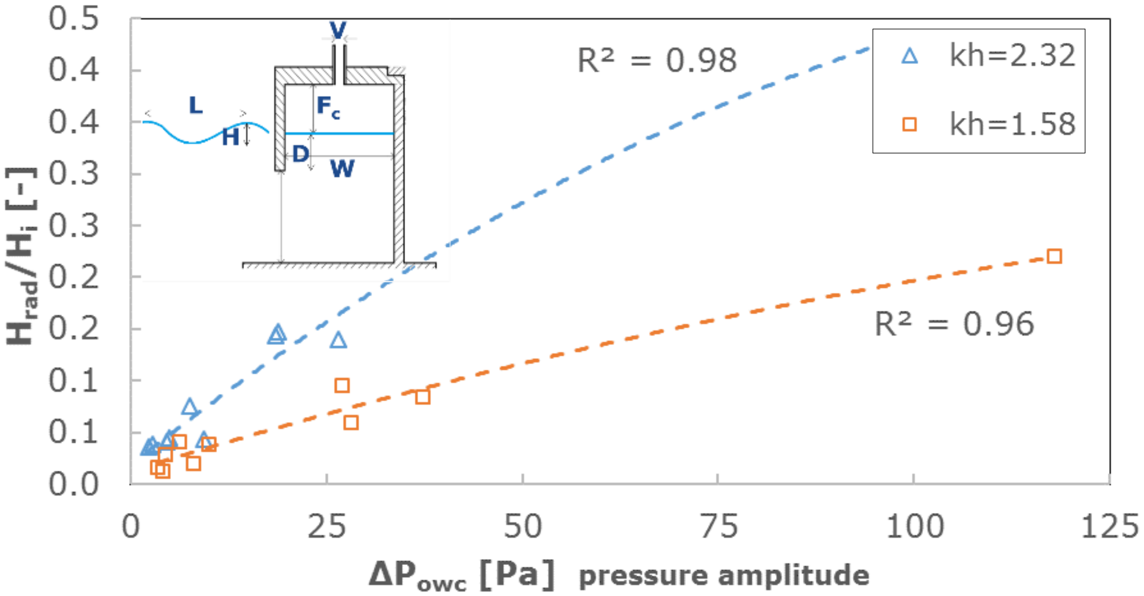


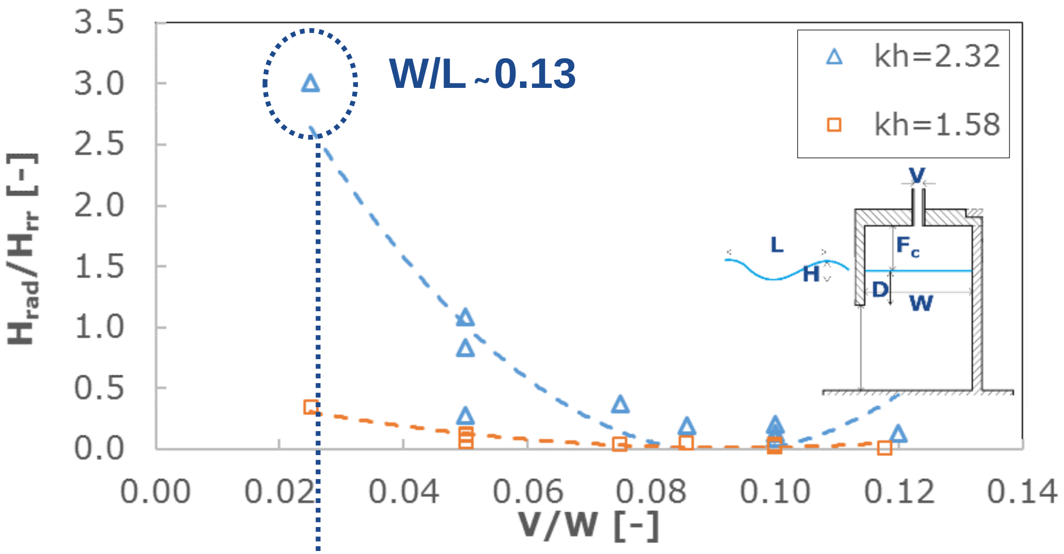
- H_{rr}: Reflected + Radiated → simulated in 1st step
- Radiated = H_{rad} → simulated in 2nd step
- Reflected → hp: linear superposition

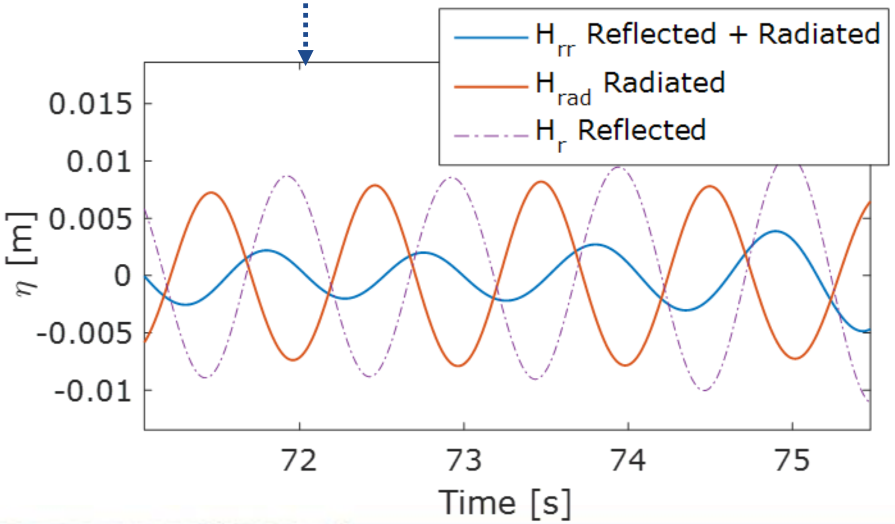
destructive or **constructive** interference between radiated & reflected waves, function of **W/L**

Results – Radiated Wave Field

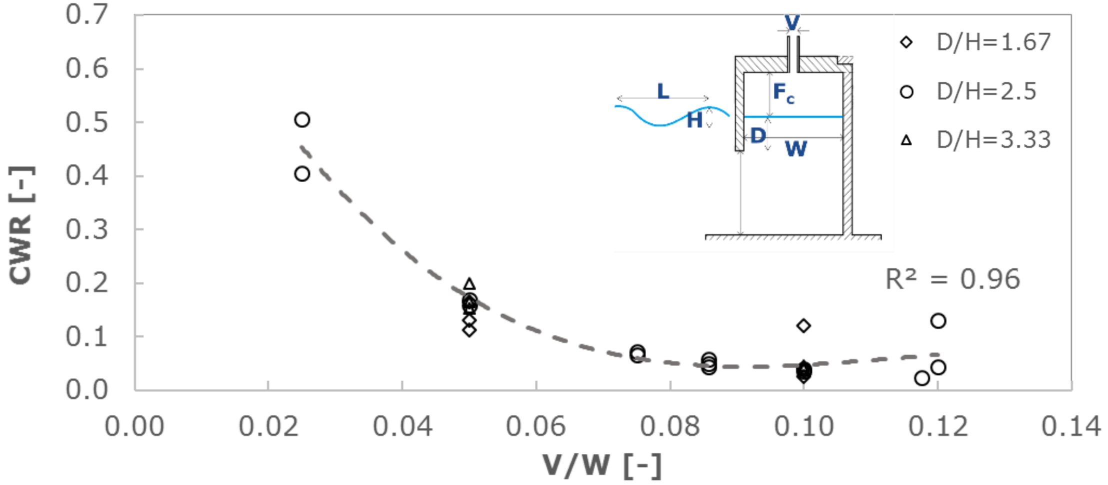
- $H_{rad} > H_{rr}$ → **destructive interference**
- H_{rad}/H_i ~0.4 for **W/L~0.13** & **V/W=0.025**
- H_{rad} strongly related to **V/W (damping)**

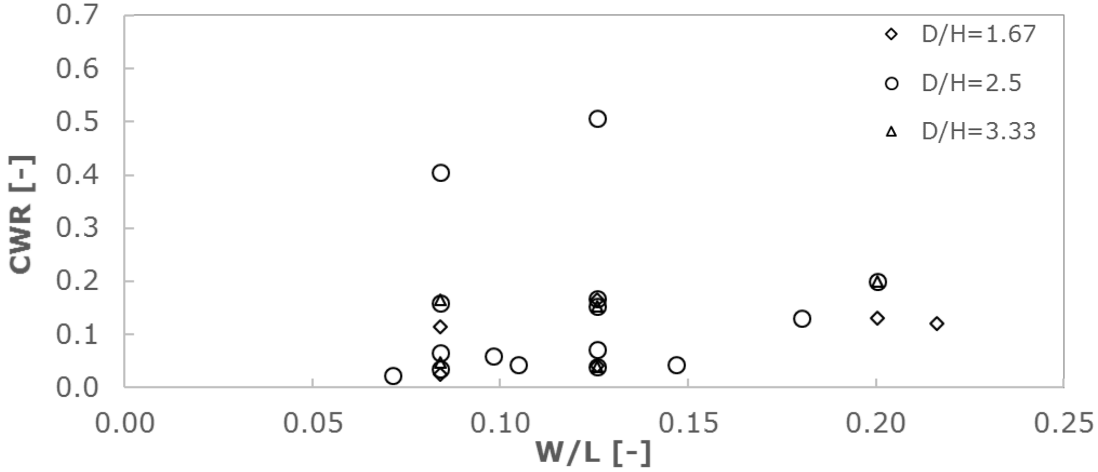






Results – OWC Capture Width Ratio - CWR





$$CWR = \frac{P_{owc}}{P_{wave}}$$

P_{owc} → Period averaged OWC power

P_{wave} → Period averaged incident wave power

$$P_{owc} = \frac{1}{T_{test}} \int_0^{T_{test}} p_{owc}(t) \frac{d\eta_{owc}}{dt} \cdot W \; dt \; \textbf{[W/m]}$$

- ❑ CWR increases for increasing damping
- ❑ max **CWR~0.55**

  for **W/L**=0.13 **D/H**=2.50 **V/W**=0.025

  → **Kr~0.14**

Conclusions & Outlooks

OWC as antireflection device

- Preliminary results: OWC could be effectively used to reduce reflection at vertical structures (**min K_{rr} ~ 0.15**)
- Important role radiated wave field (**also destructive interference!**)
- Max **CWR ~ 0.55** with relatively **low K_{rr}**

Outlooks

- Consider global agitation in front of the structure and not just **reflection/radiation coefficient K_{rr}**
- Increase the tested geometries and wave conditions

Thanks for your attention

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