ICCE 2018
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The State of the Art and Science of Coastal Engineering

Wave loading for recurved parapet walls in non-breaking wave conditions: analysis of the induced impulsive forces.

Myrta Castellino *"Sapienza" University of Rome*

Javier L. Lara *University of Cantabria*

Alessandro Romano *"Sapienza" University of Rome*

Iñigo Losada *University of Cantabria*

Paolo De Girolamo *"Sapienza" University of Rome*

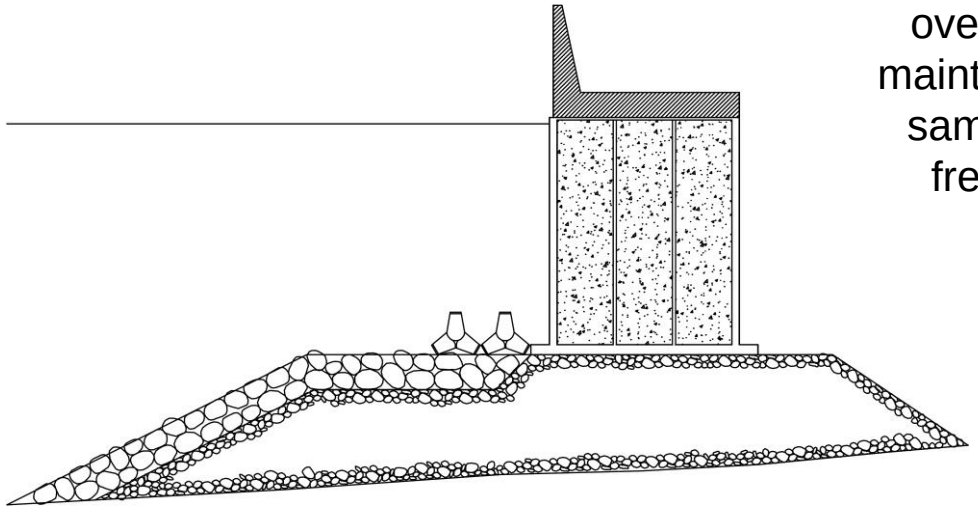



Content

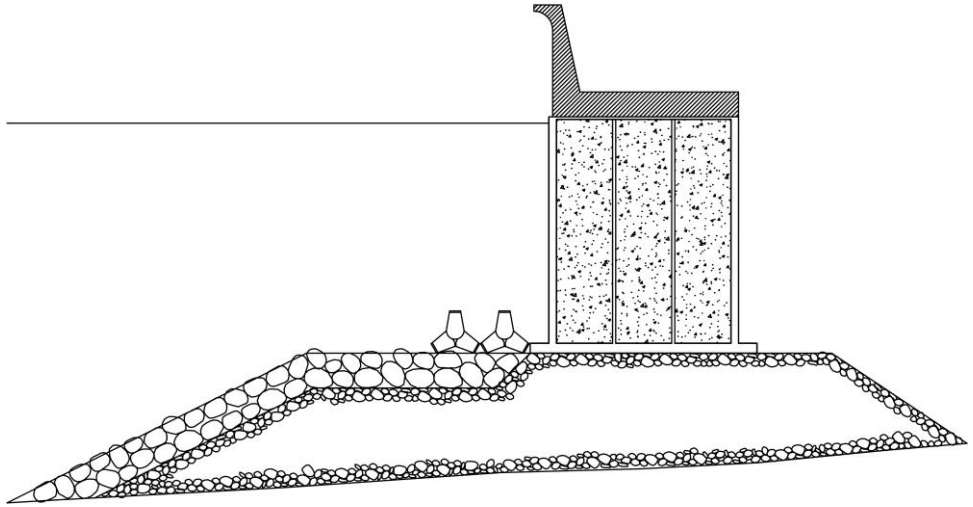
1. **Introduction**
2. **Numerical modelling**
3. **Analysis and Results**
4. **Conclusions**
5. **Ongoing Work**

Introduction – Deepwater vertical breakwater

- **Vertical structure** **vs** **Recurved structure**



To reduce wave overtopping maintaining the same crown freeboard



Large number of design formulae for breaking and non breaking wave conditions

1. Goda (1974)
2. Takahashi (1996) → for impulsive wave condition

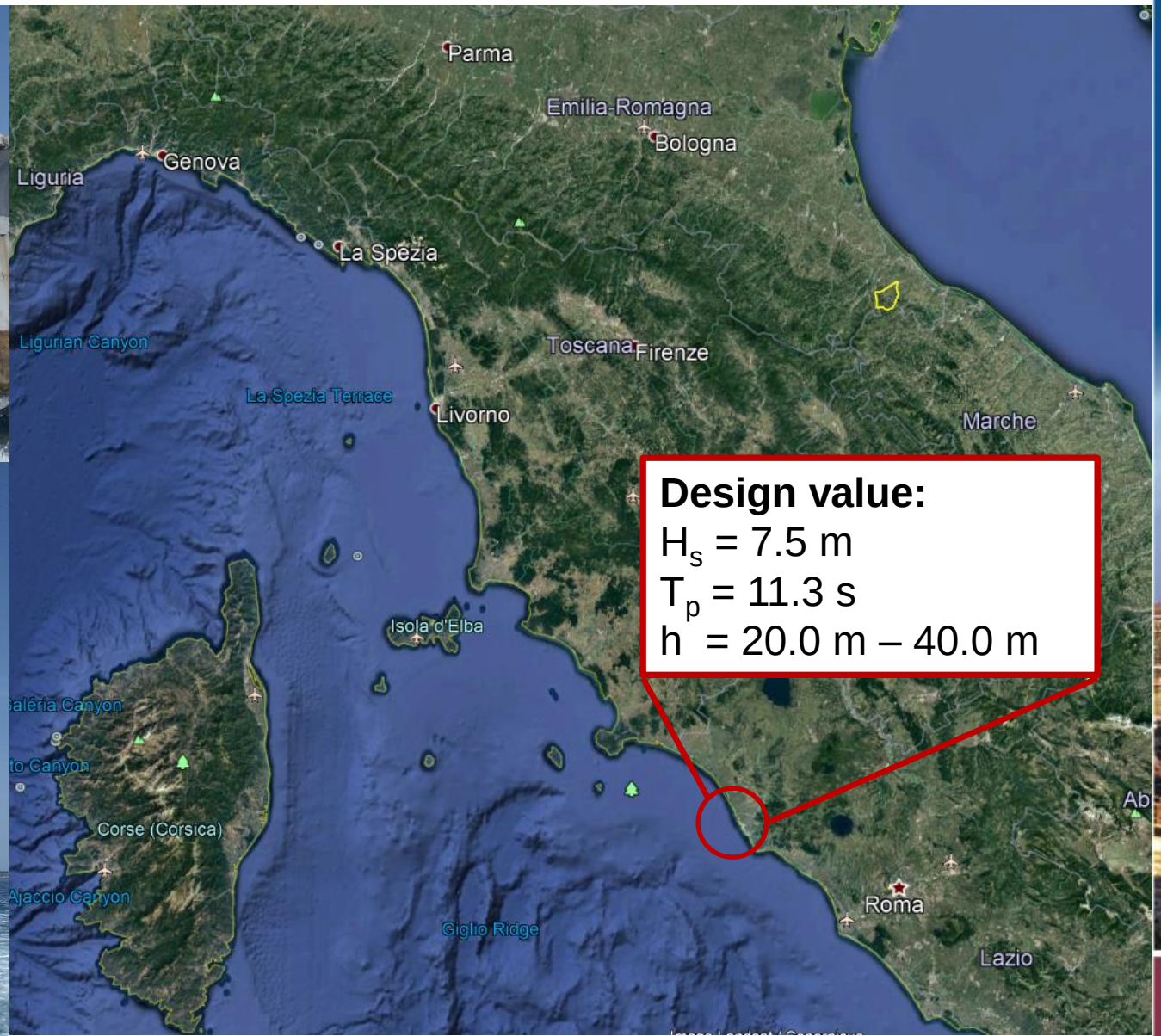
…

Large number of scientific study for breaking wave condition.

Non-breaking wave conditions:

→ ?

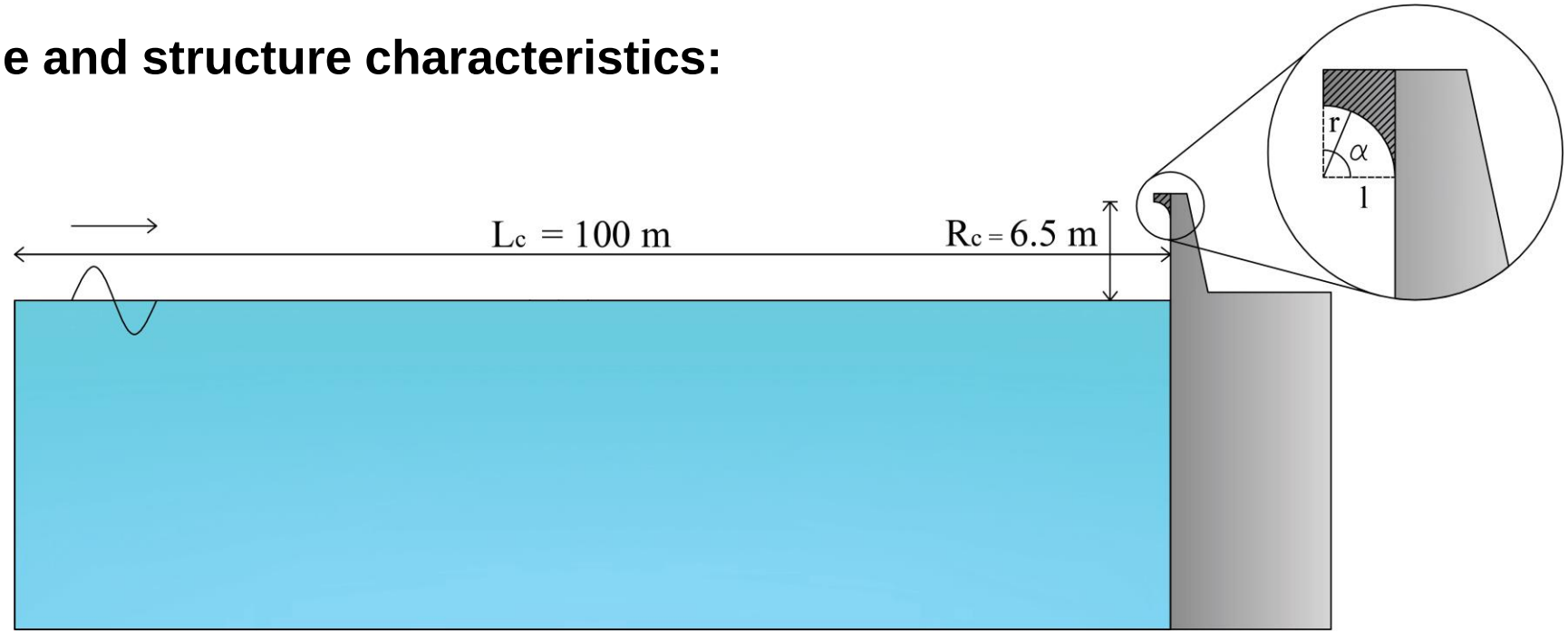
Introduction – Existing damaged recurved parapet (Tyrrhenian sea)



Design value:
H_s = 7.5 m
T_p = 11.3 s
h = 20.0 m – 40.0 m

Numerical model – Numerical setup

- **Wave flume and structure characteristics:**



Channel characteristics:

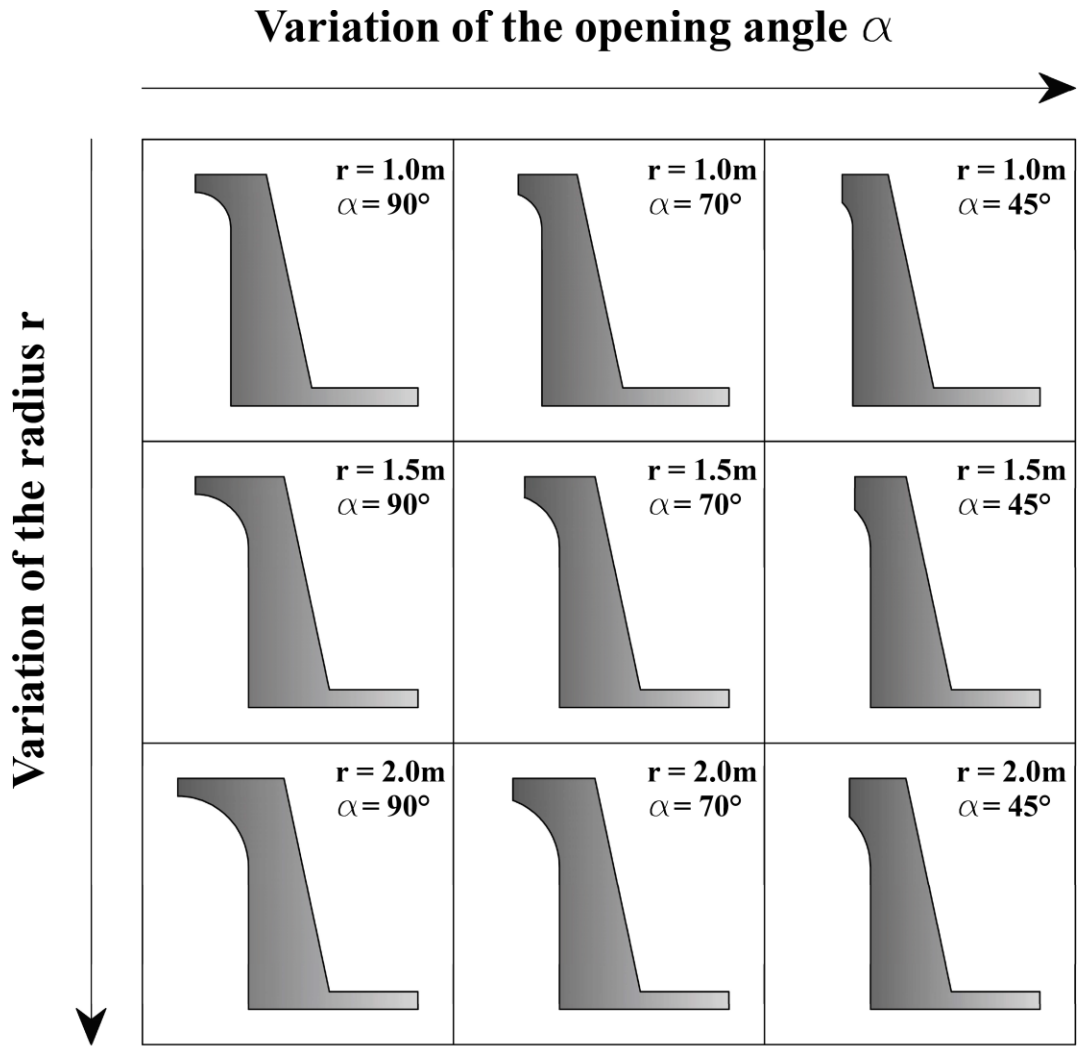
- Channel length = 100.0 m
- Channel height = 40.0 m

Structure characteristics:

- Freeboard = 6.5 m (constant)
- Structure height = 20.0 m (constant)

Numerical model – Numerical setup

- **Wave flume and structure characteristics:**



Geometrical setup:

- α = opening angle
- r = recurved radius

Structure as impermeable object:

- No porous media were considered
- Flat bottom for the wave flume

Numerical model – Numerical setup

- **Test conditions**

Regular and irregular test have been performed

- Regular wave conditions:
  - WR -

	H	T
	(m)	(s)
WR1	1.00	8.00
WR2	2.00	8.00
WR3	3.00	8.00
WR4	4.00	8.00
WR433	4.33	8.00
WR465	4.65	8.00
WR5	5.00	8.00
WR6	6.00	8.00
WR7	7.00	11.00
WR8	8.00	13.00

High wave steepness

- Irregular wave conditions:
  - WI -

	H_s	T_p
	(m)	(s)
WI5	2.77	8.00
WI6	3.33	8.00
WI7	3.88	11.00
WI8	4.44	13.00

$$H_{max} = 1.8H_s$$

Hypothesis of equivalence → same effect (i.e. pressure and force) comparing the results of regular (H and T) and irregular (H_{max} and T_p) test conditions

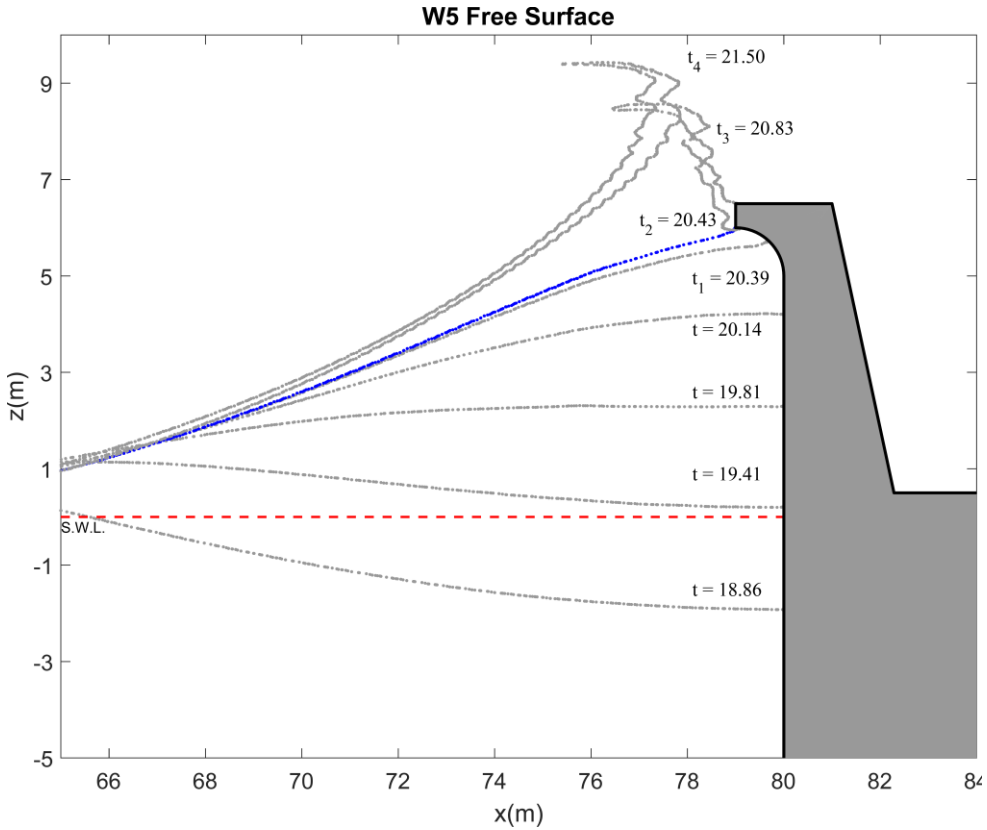
Numerical model – OpenFOAM and IHFoam

- Computational Fluid Dynamics (CFD)
- Open source C++ library
- Suitable for wide range of problems
- IHFoam for wave generation and absorption

- Validation of OpenFOAM for wave - structure interactions
- Impulsive loading condition in non-breaking conditions

It is possible to model the phenomenon under the hypothesis of incompressible fluid

Free surface, evolution along the wall

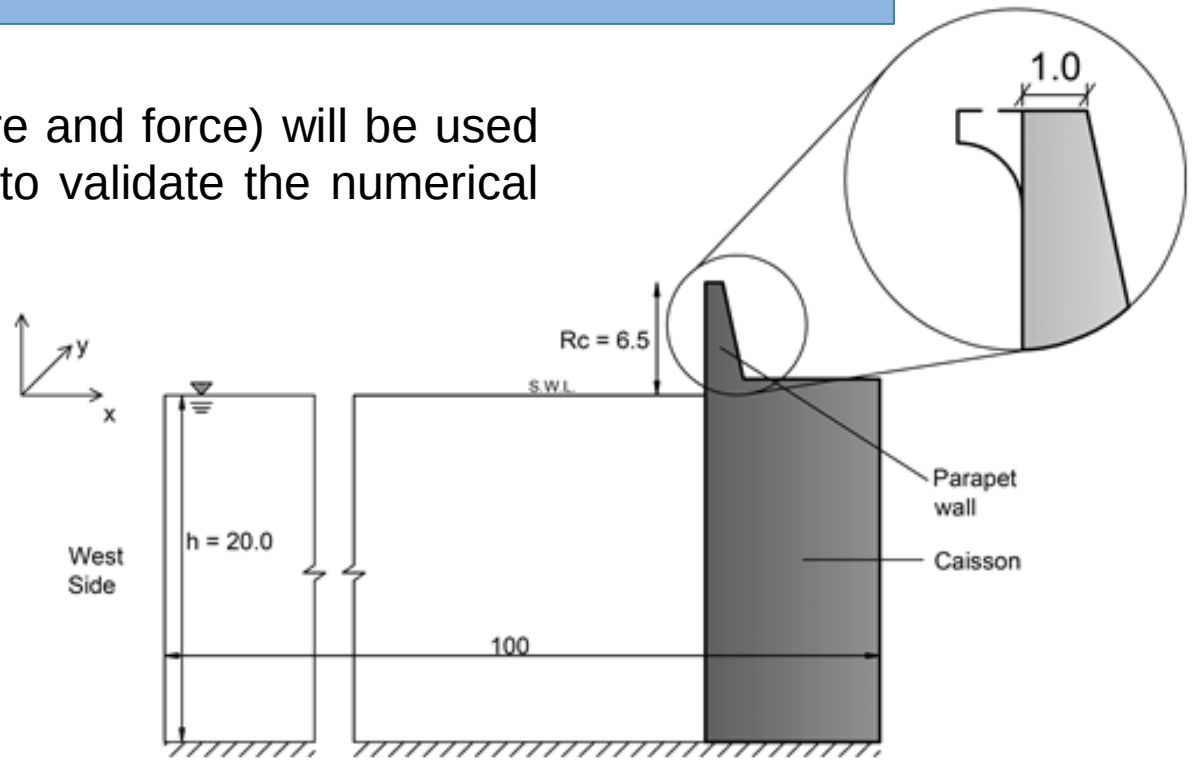


Hypothesis of incompressibility.
Air: no trained or entrained air during the process.
Water: maximum of velocity along the wall [15; 35] m/s minor than the velocity of propagation of the sound in the water.

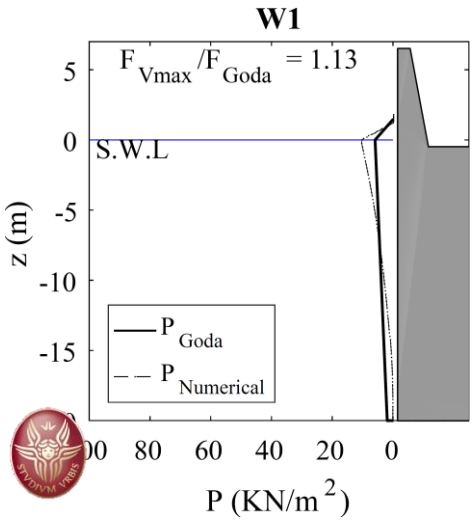
IHFOAM

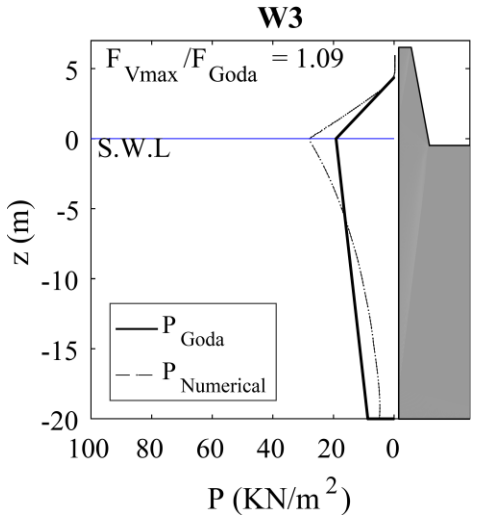
Numerical model – Validation of OpenFOAM simulations

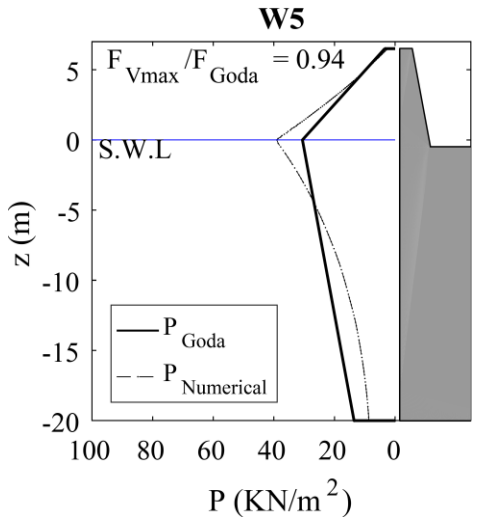
The results on the vertical parapet (velocity, pressure and force) will be used as a comparison parameter. Thus, the first goal is to validate the numerical results with the literature formulae (i.e. Goda, 2010)

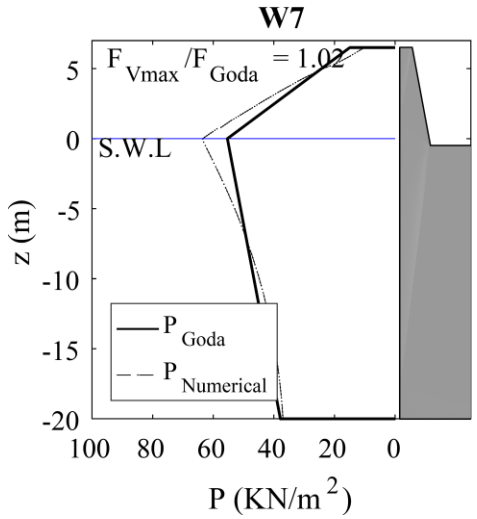


Validation, comparison with Goda's formulae



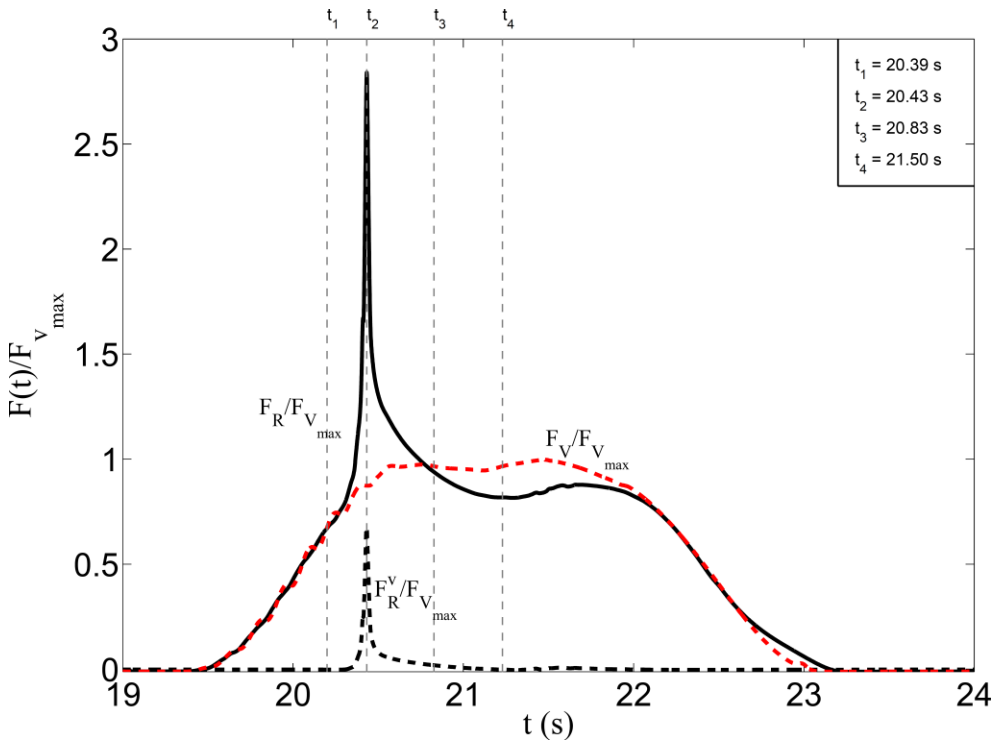




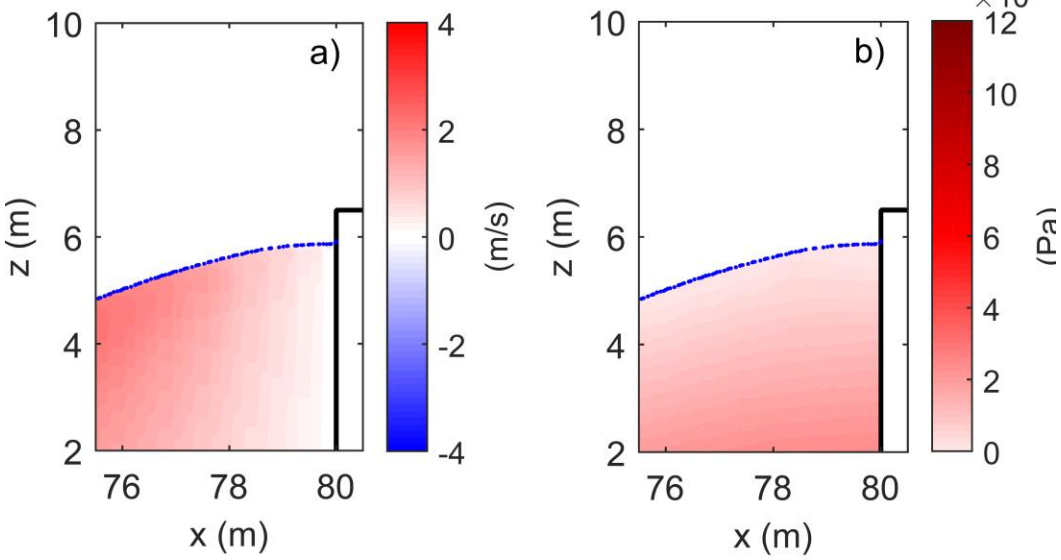


Analysis and Results

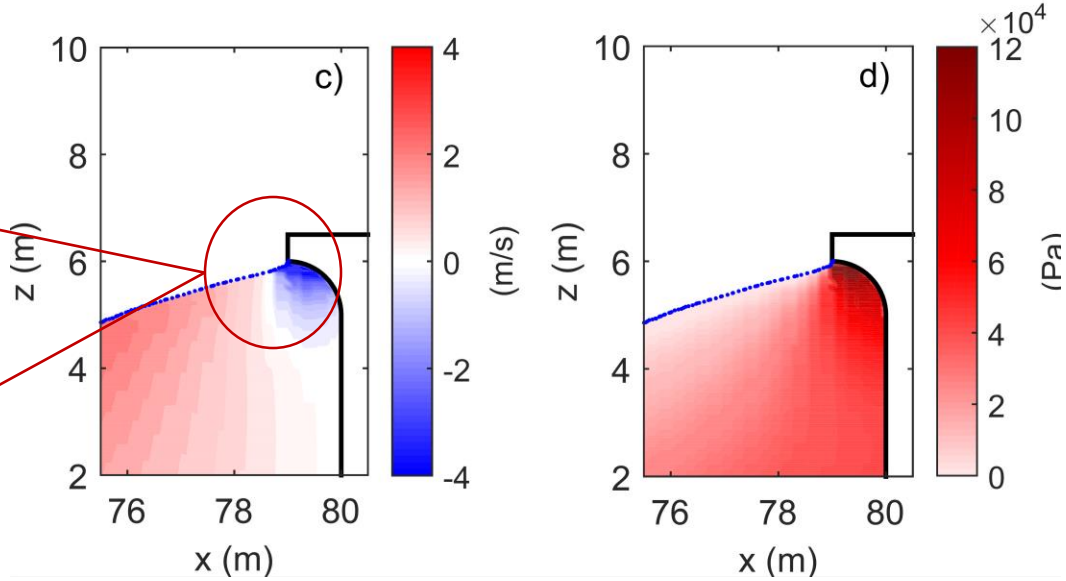
Impulsive load time-history



Pressure field



Velocity field

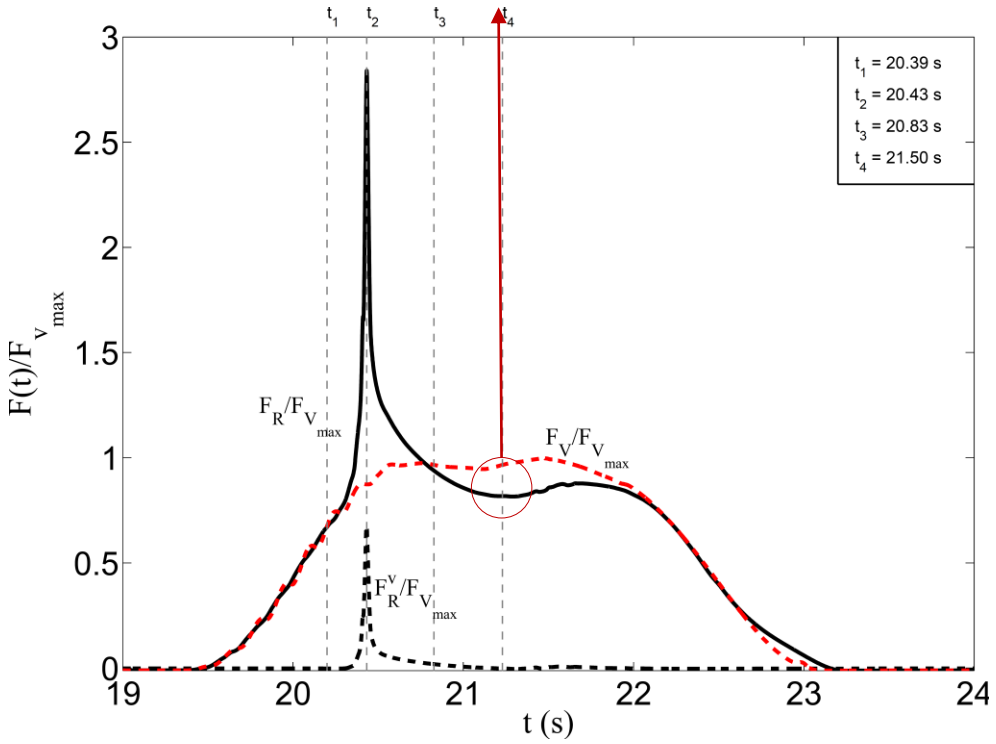


When the surging wave blocks its own running jet, creating a sudden stop of horizontal momentum of a significant water mass, a high impulsive pressures and forces are obtained.

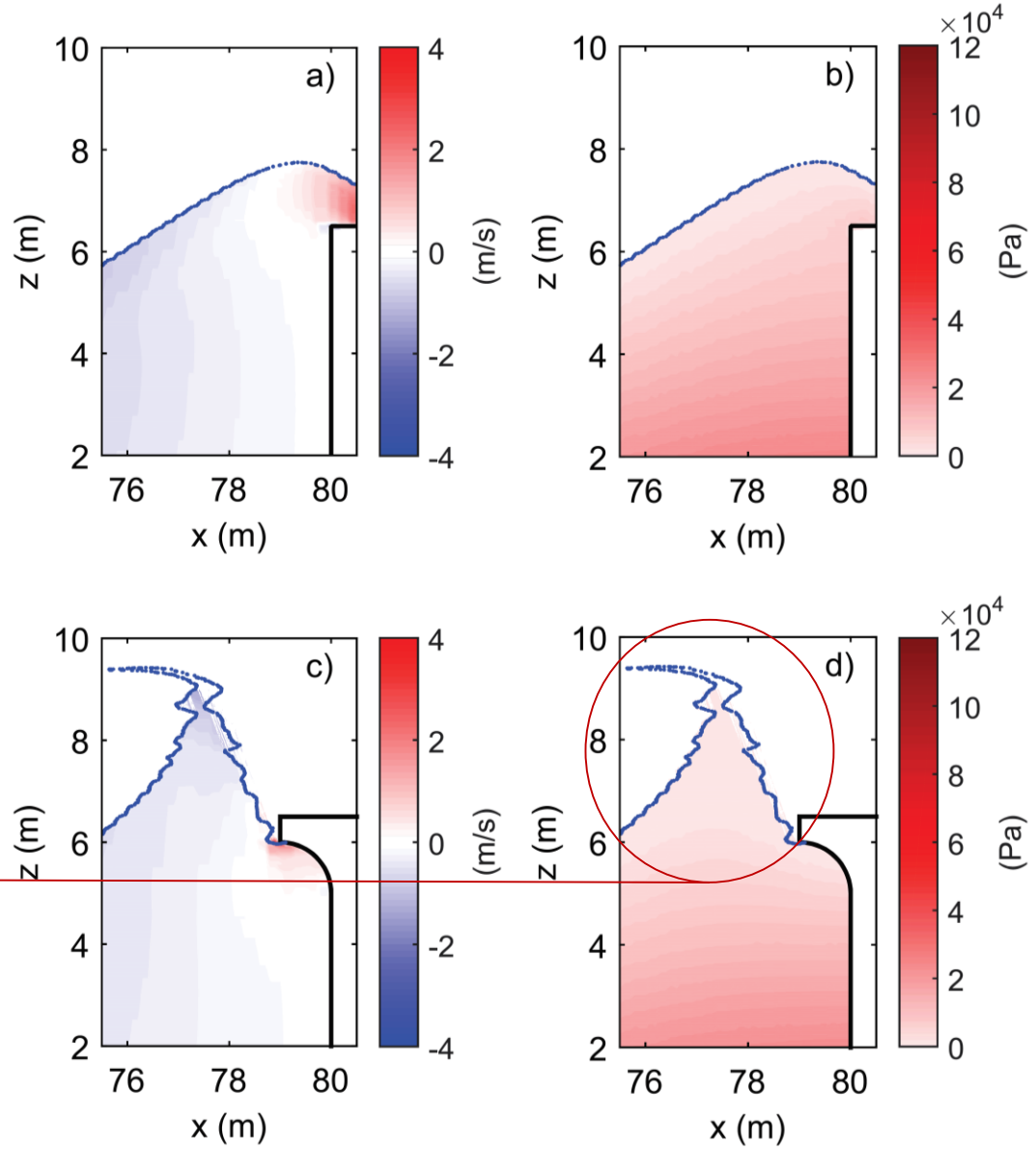
Blockage effect with a new zero velocity area near and above the surface.

Analysis and Results

Maximum water jet high, pressure and velocity fields does not show particular hydrodynamic process



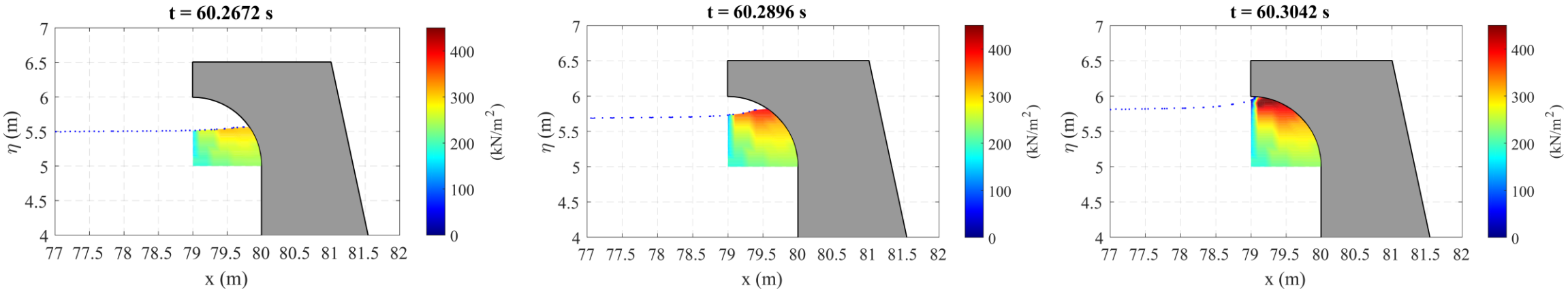
Pressure field **Velocity field**



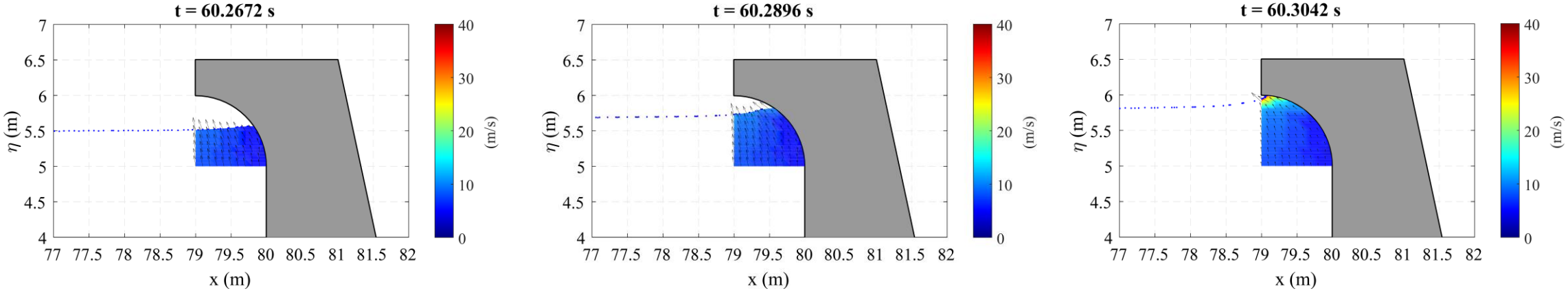
The jet is up in the air and the pressure field back to normal condition.

Analysis and Results

Pressure field evolution



Velocity field evolution



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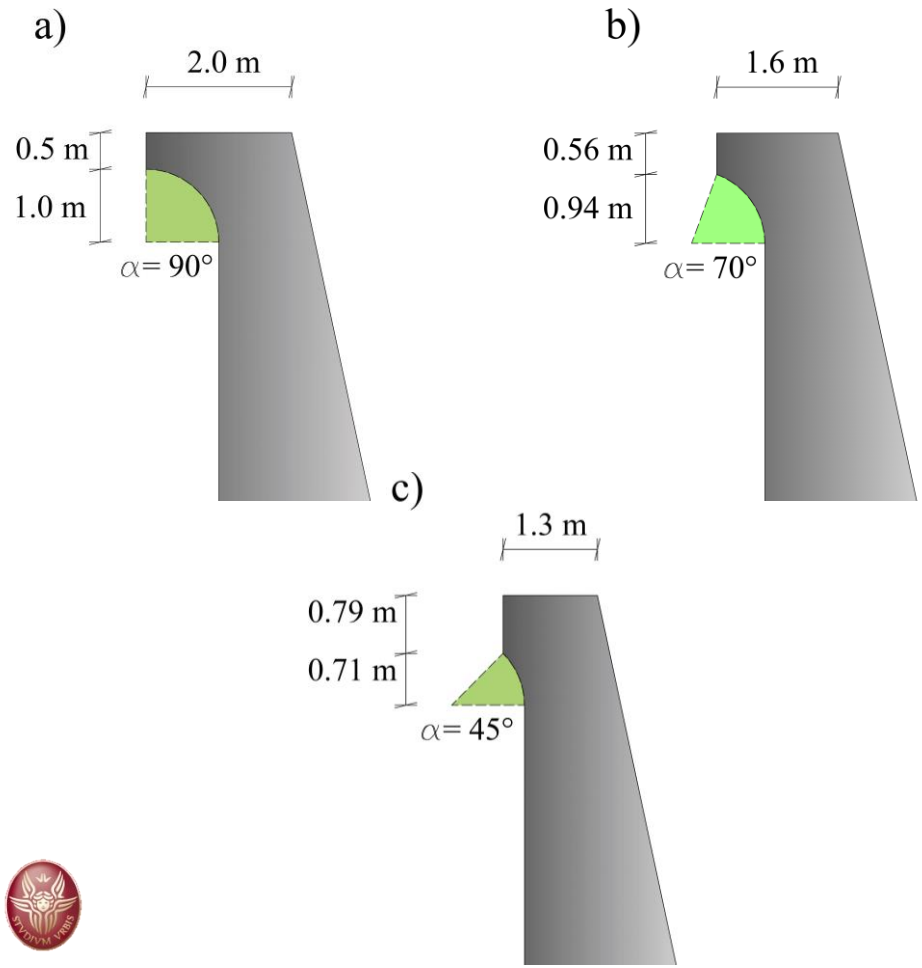
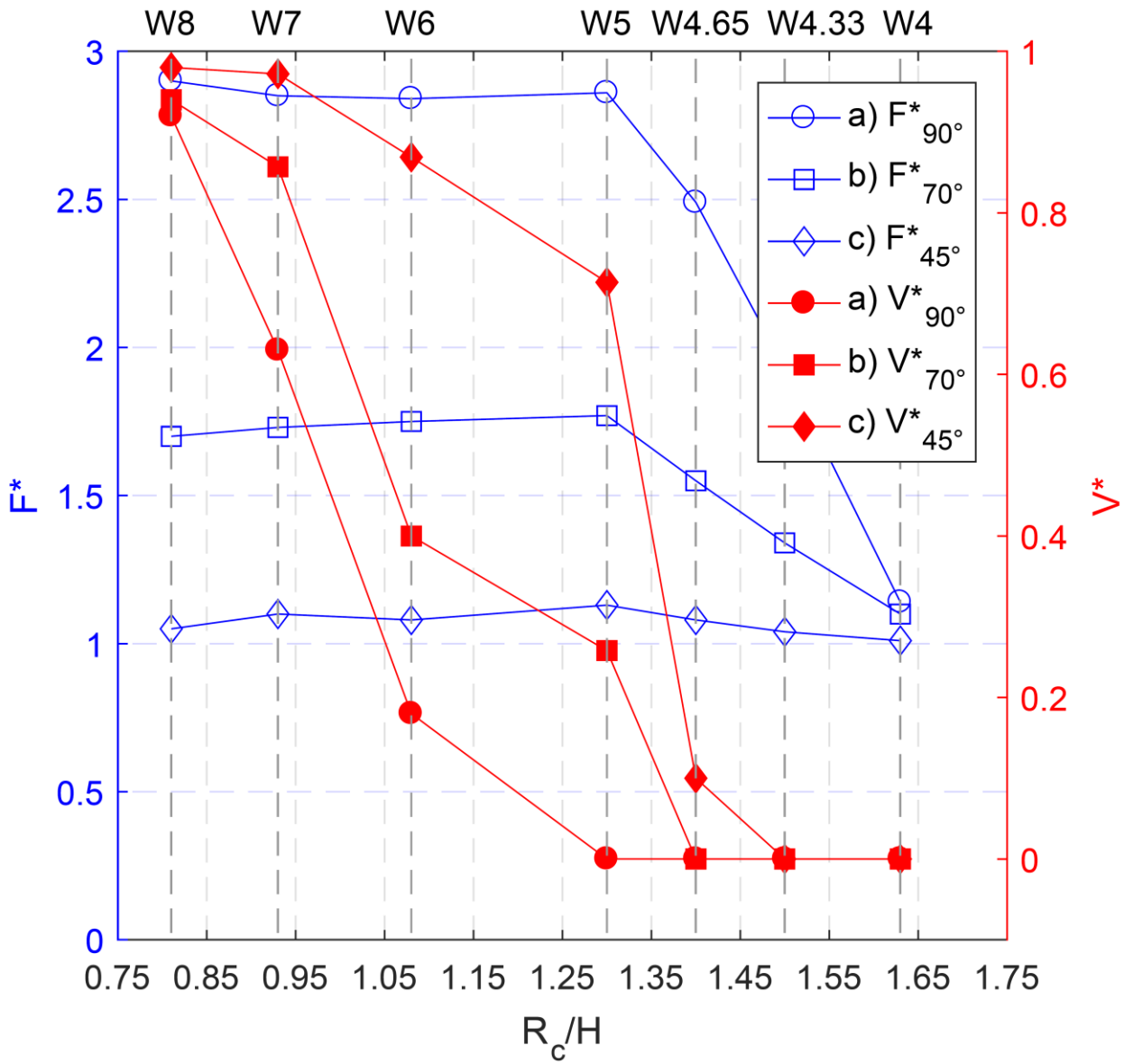
Analysis and Results

Trade off between overtopping and impulsive forces

Fixing the radius, varying the angle

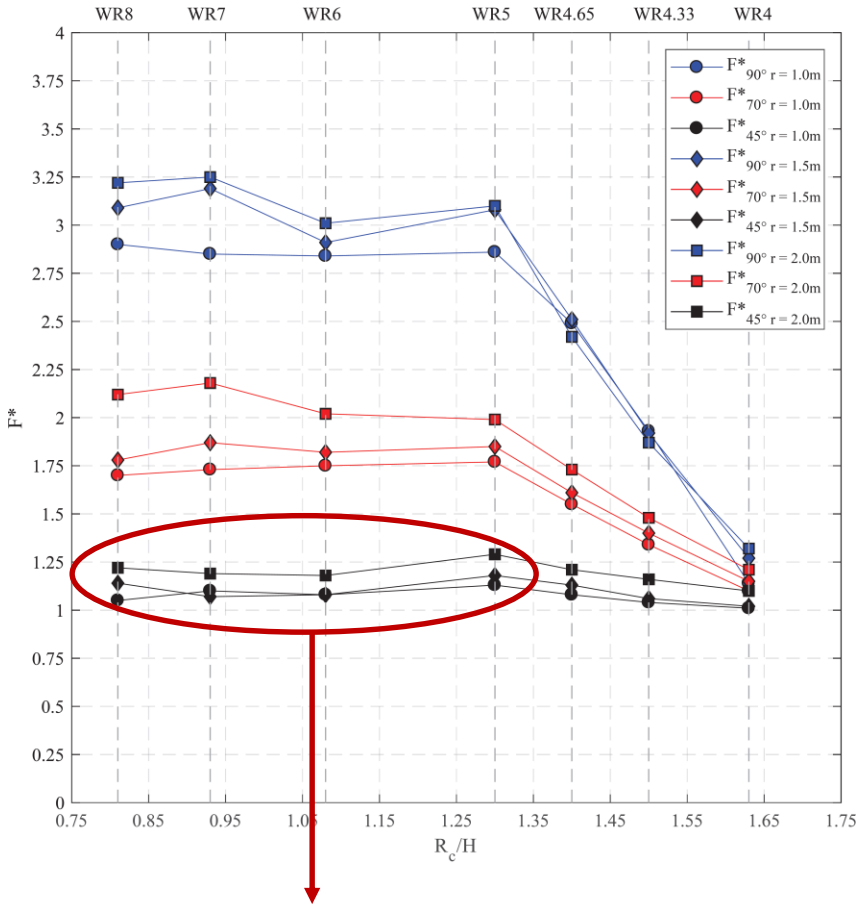




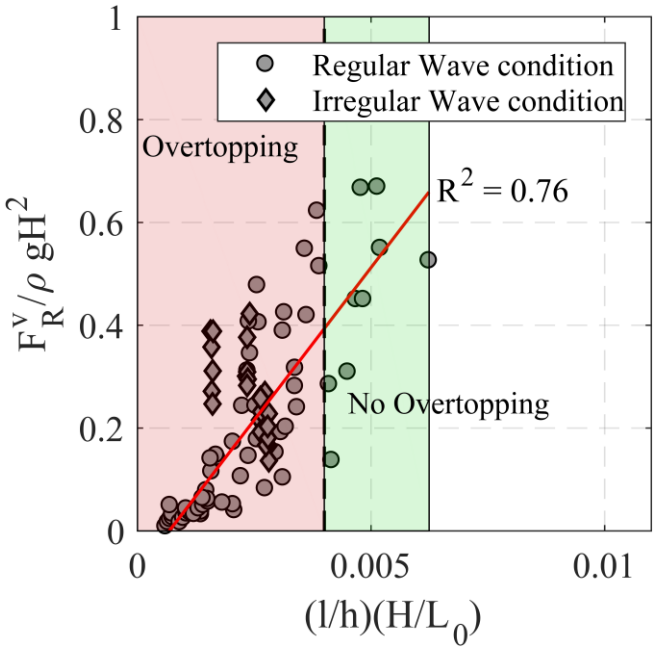
Analysis and Results

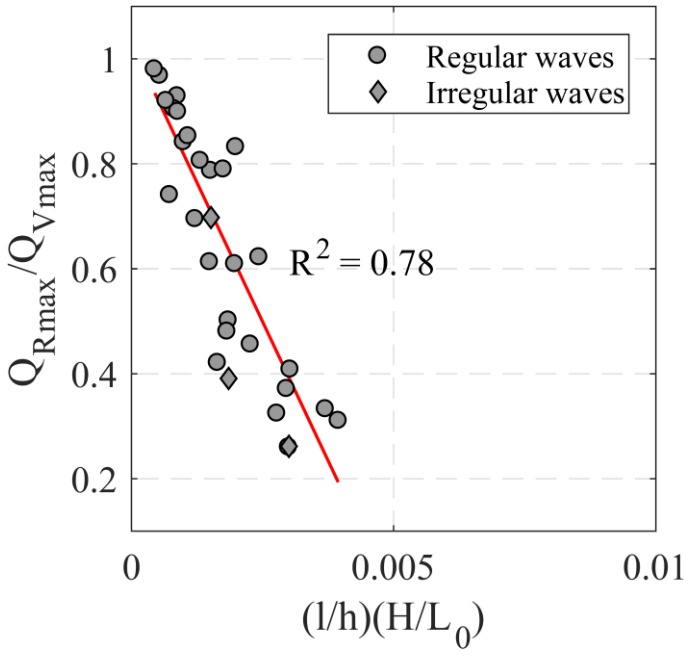
Trade-off between overtopping and impulsive forces

High variability due to the opening angle variation



Low variability due to the radius variation





Conclusions and Ongoing Work

Conclusions:

- The interaction between regular and irregular non-breaking waves hitting a recurved parapet wall have been investigated
- Presence of a recurve leads to a large impulsive force and to a strong wave overtopping reduction
- The impulsive pressure realize when the recurve is completely confined
- The opening angle variation has more influence on the force increase than the radius variation

Ongoing Work:

- Only 2-D simulations have been carried out, a set of 3-D simulations will be analyzed to study the influence of the incident wave angle, both on the force increase and wave overtopping
- Water depth and freeboard variation will be taken into account

Thank you for your attention

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