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

NUMERICAL AND HYDRAULIC EXPERIMENTS ON BORE PRESSURE DUE TO TSUNAMI

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Table of contents

Introduction

The 2011 Tohoku earthquake tsunami struck wide area of the eastern coast of Japan.

- Many coastal structures and buildings were damaged by the tsunami.
- Most of the buildings were damaged by the tsunami wave pressure.

The characteristics of tsunami wave pressures on structures in tsunami inundation areas

- There are three regimes characterizing the vertical pressure profiles.
  - 1st: The impulsive pressure
    - Strong hydrodynamic pressures were generated by the fluid-solid impact process.
  - 2nd: The bore pressure
    - Both the hydrodynamic and hydrostatic pressures contribute the pressure profile.
  - 3rd: The clapotis (standing wave) pressure
    - Quasi-steady hydrostatic pressure

Introduction

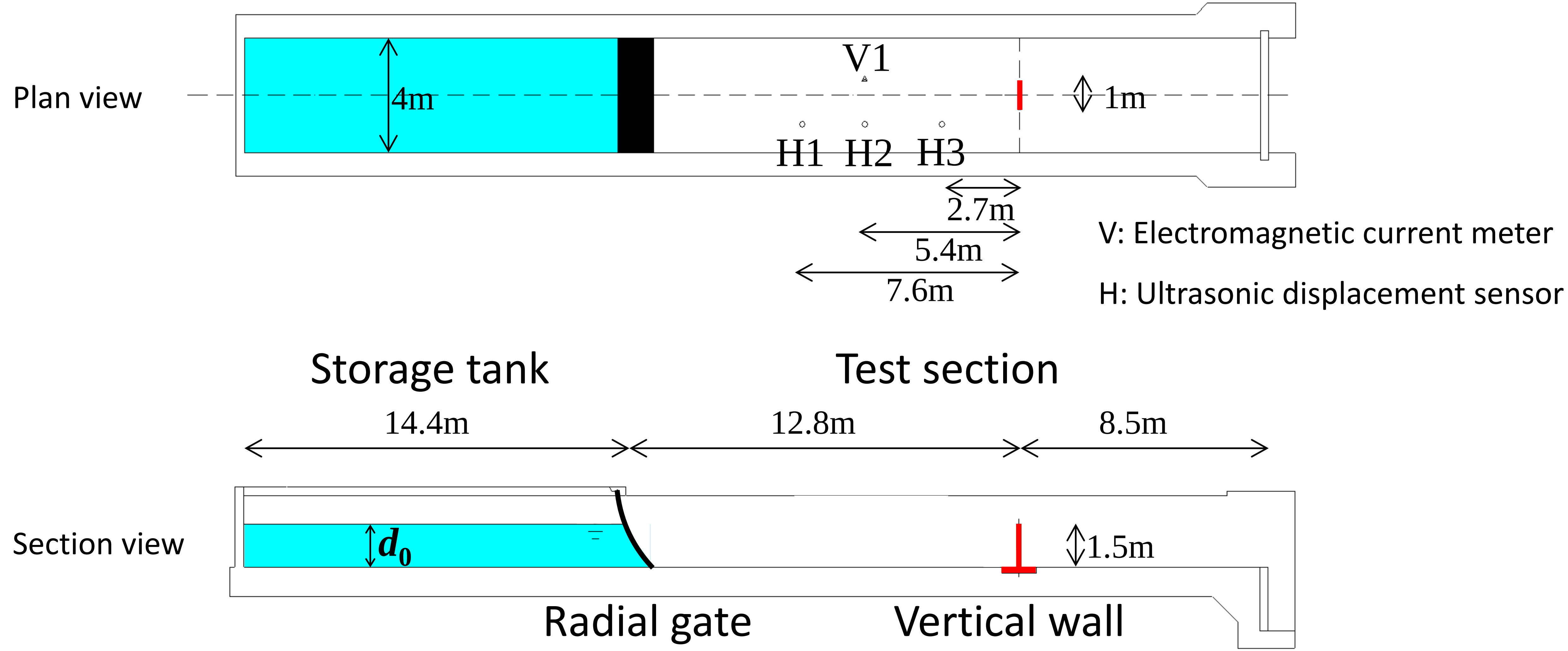
Most of the evaluation equations of tsunami wave pressure proposed can be used against the 1st and 3rd regime.

On the other hand, the characteristics and quantitative evaluations of the bore pressure remains immature.

In this study, in order to clarify the characteristics of the bore pressure, we carried out experiments and 3D numerical simulations on the bore pressure.

Experiments

Experimental apparatus

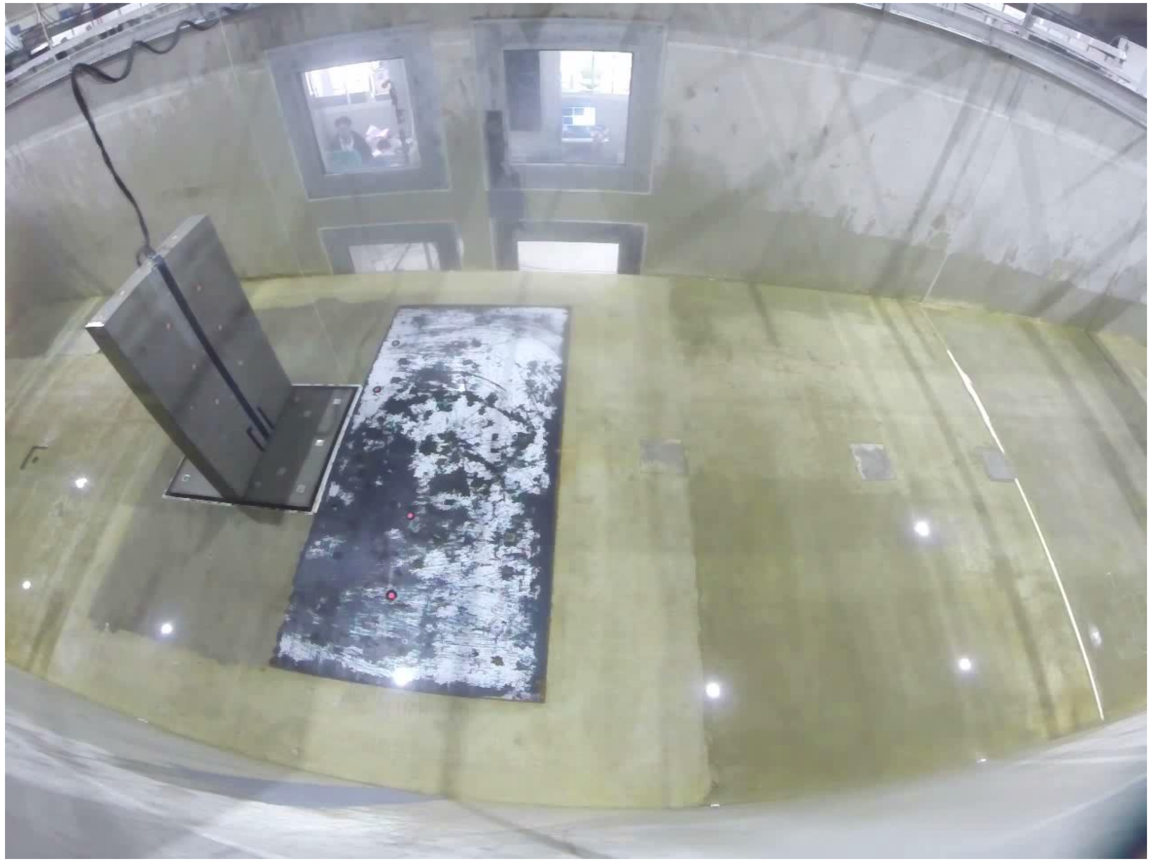


Vertical wall

Height: 1.5 m
Width: 1.0 m
Thickness: 0.15 m

Pressure transducers in upstream face
- 23 points:
  - 1, 5, 10, 15, 20, 25, 30, 31, 35, 40, 45, 50, 55, 60, 70, 80, 90, 100, 110, 120, 130, 140, 149 cm height
- Rated pressure: 49 kPa
- Natural frequency: 6.8 kHz
- Sampling: 10kHz

Experimental cases



Case 3 (d_0 = 2.0m)

Case	d_0 [m]
Case 1	1.3
Case 2	1.7
Case 3	2.0
Case 4	2.3
Case 5	2.45

d_0: initial water depth in the storage tank

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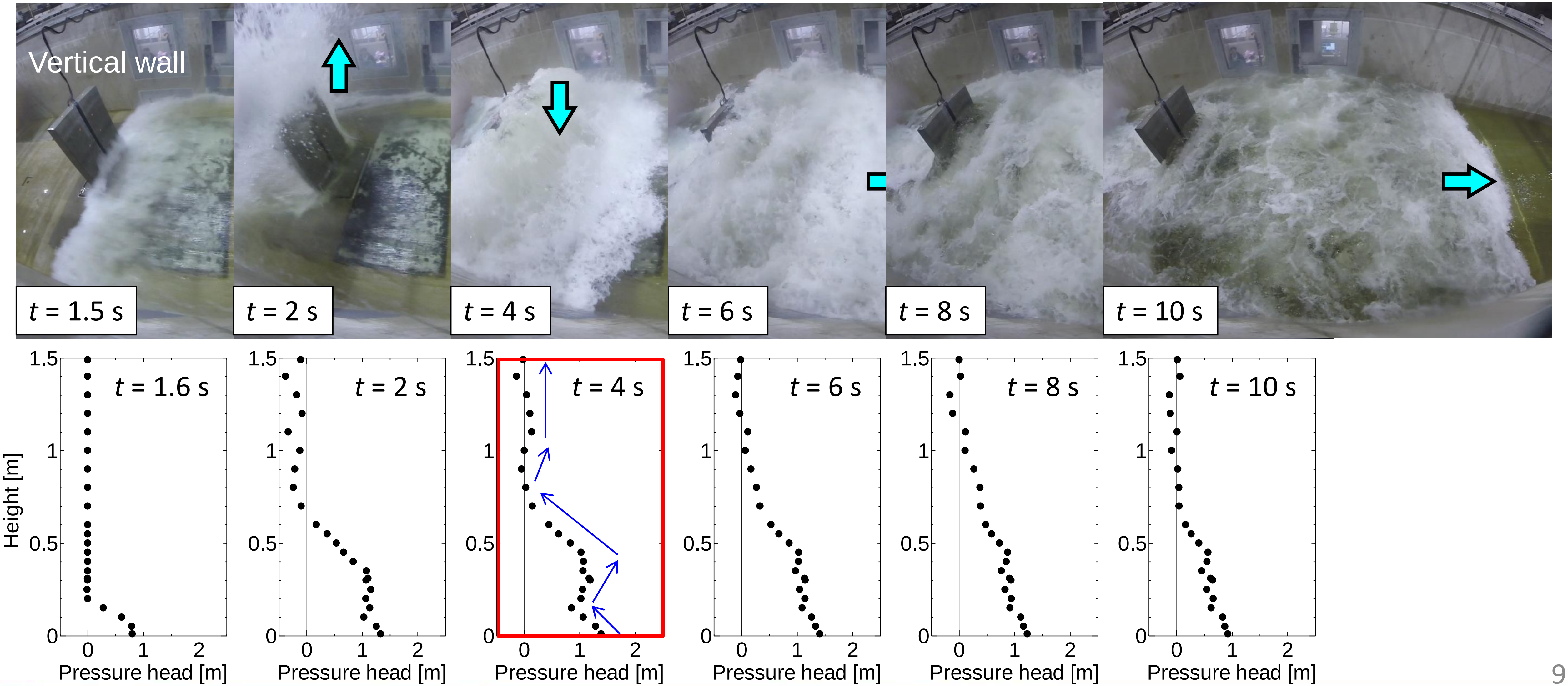
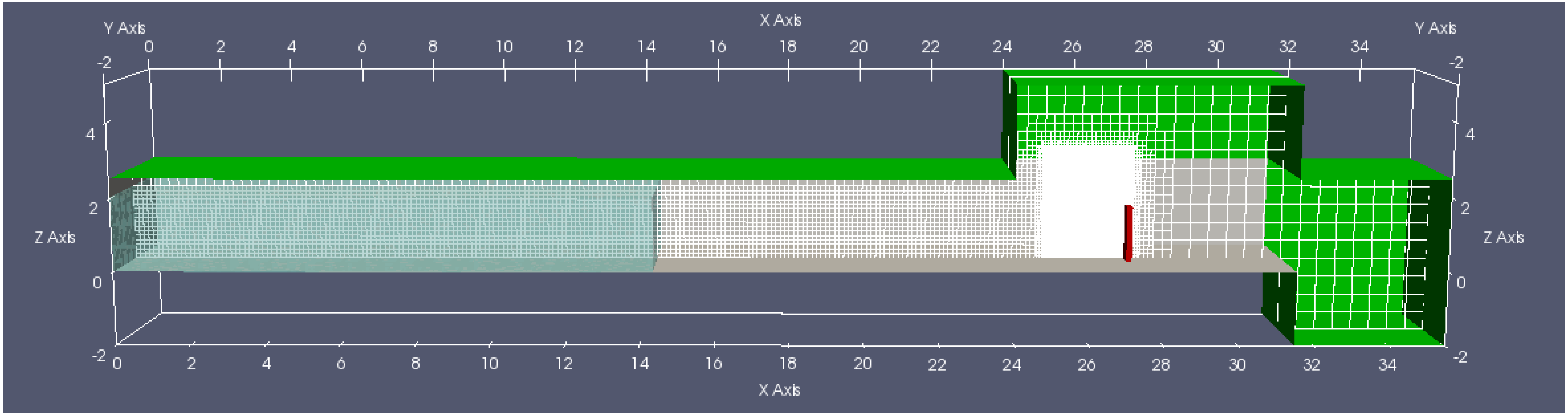
Experimental results (case 3)



Numerical simulations (dam-break)

Numerical simulation model (dam-break simulation)



OpenFOAM (Open source Field Operation And Manipulation)

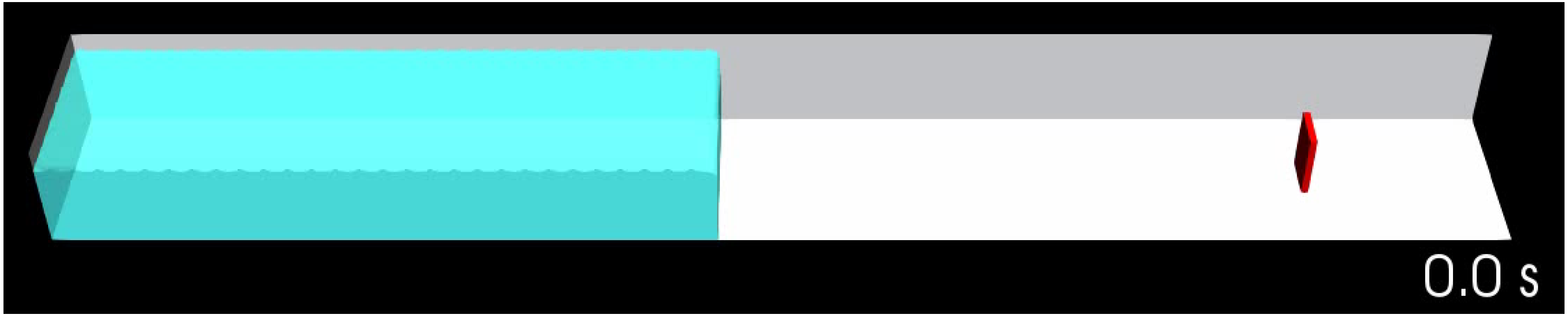
Solver: InterFoam based on the volume of fluid (VOF) method

Mesh size: Δx=12.5cm (upstream), 1.56 cm (near the vertical wall)

Turbulence model: LES Smagorinsky

Boundary conditions: No-slip (floor, side wall, the vertical wall)

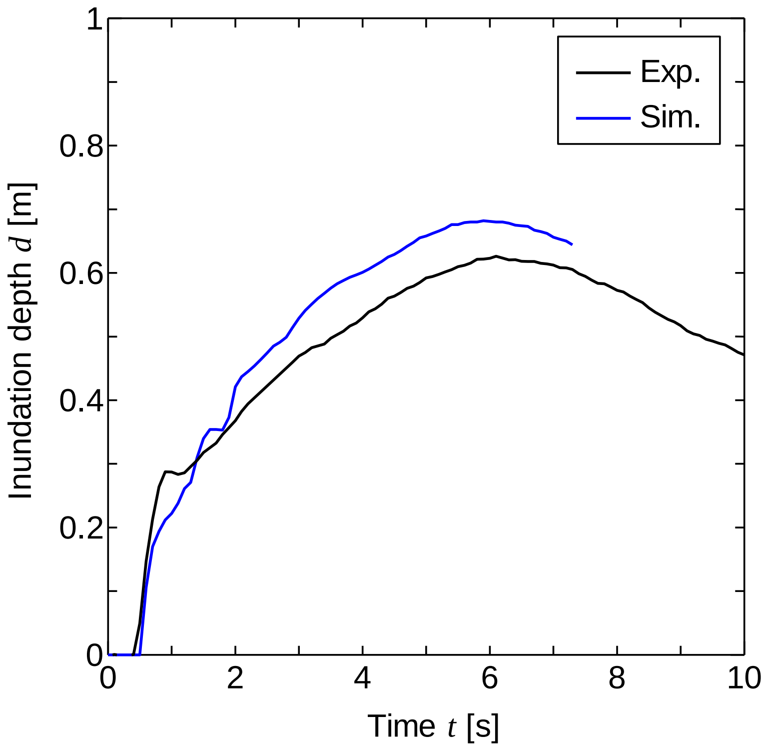
Animation (dam-break simulation, case 3)



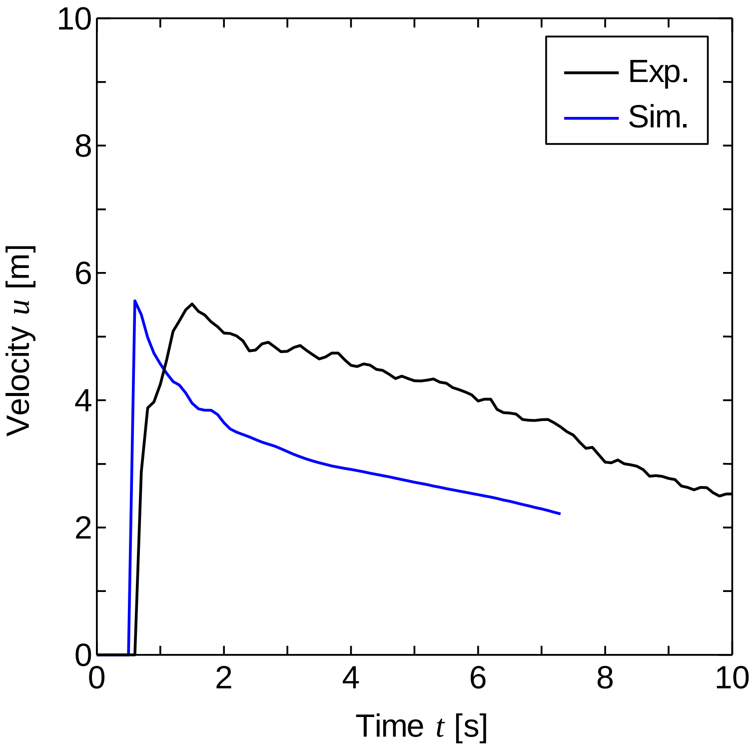
Colored where the phase fraction $\alpha_{\text{water}} \geq 0.5$

Simulation result (dam-break simulation, case 3)

Inundation depth at H2



Velocity in streamwise at V1



Large discrepancy in velocity profile

Experiment
about 2 seconds
for the radial gate to open.

Simulation
No gate

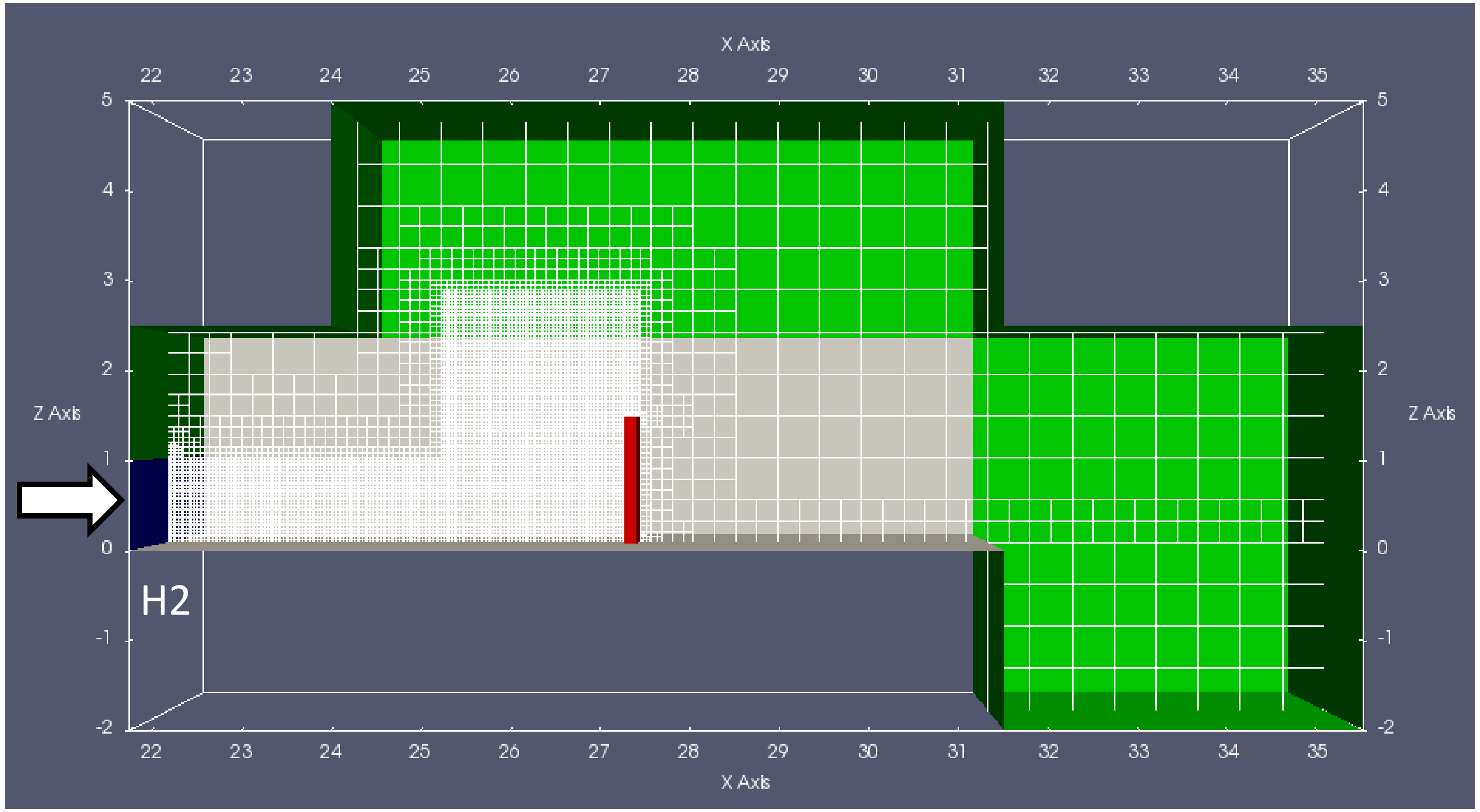
Numerical simulations (inlet model)

Numerical simulation model (inlet model)

Only the downstream side from H2

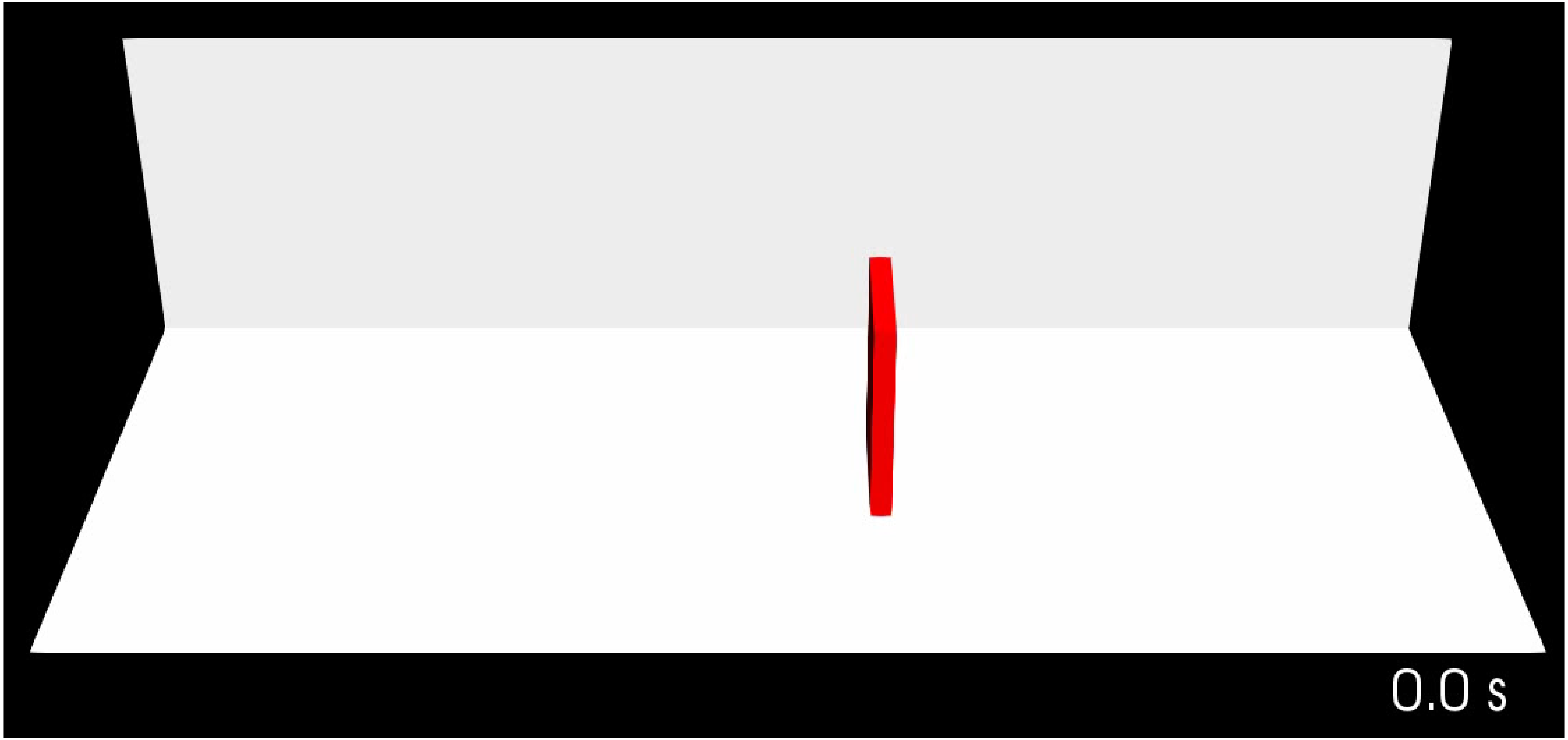
Input the phase fraction α_{water} and velocity u

$$\alpha_{\text{water}} = 1.0\ (z \leq d)$$
$$\alpha_{\text{water}} = 0.0\ (z > d)$$

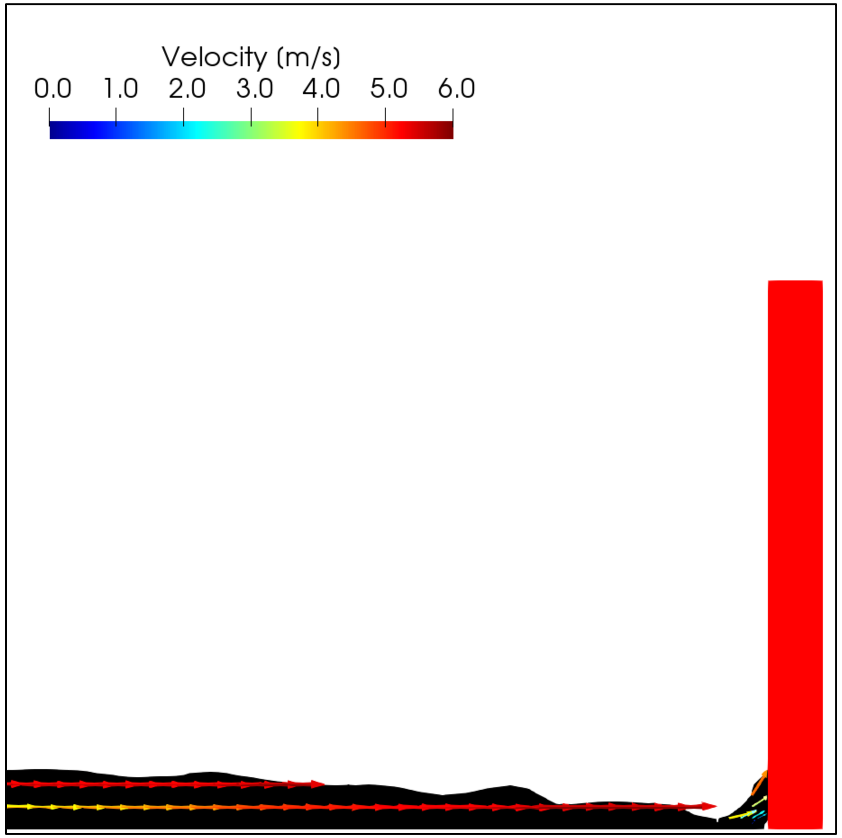


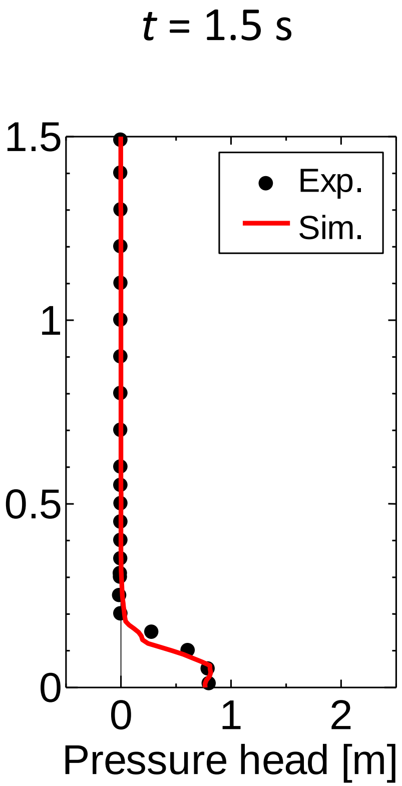
Mesh size: Δx=3.125cm (upstream, near the vertical wall)

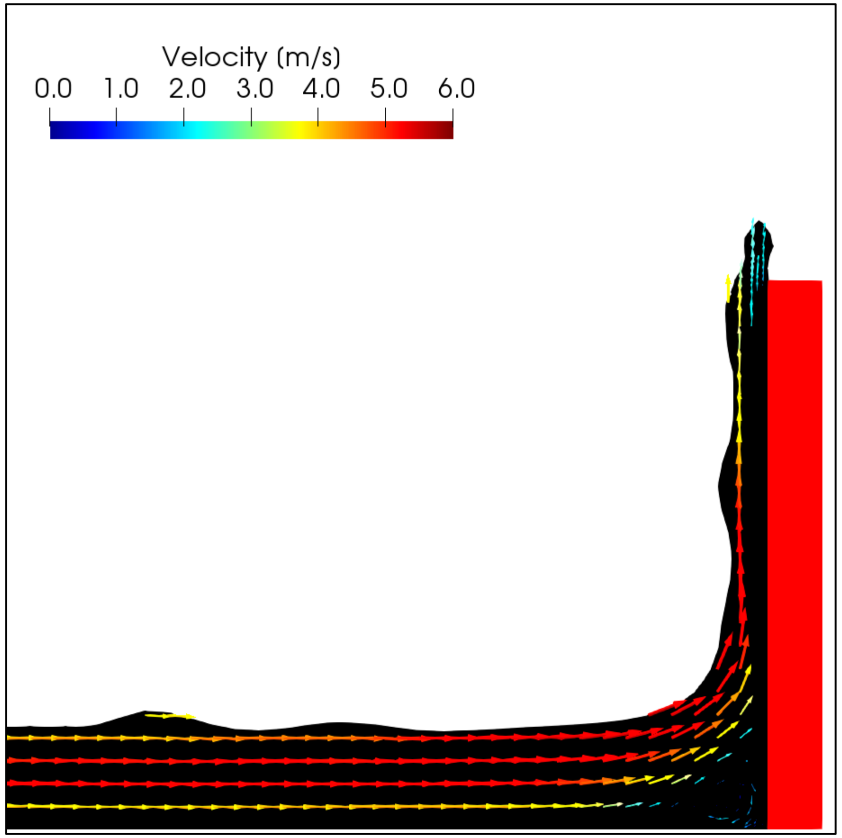
Animation (inlet model)

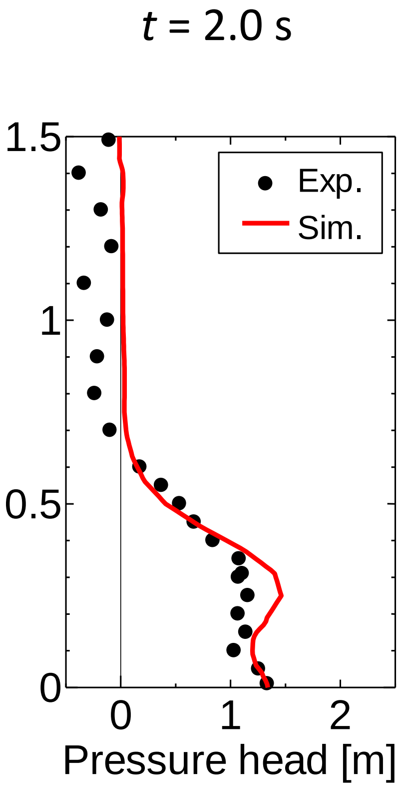


Velocity and pressure distribution (inlet model)

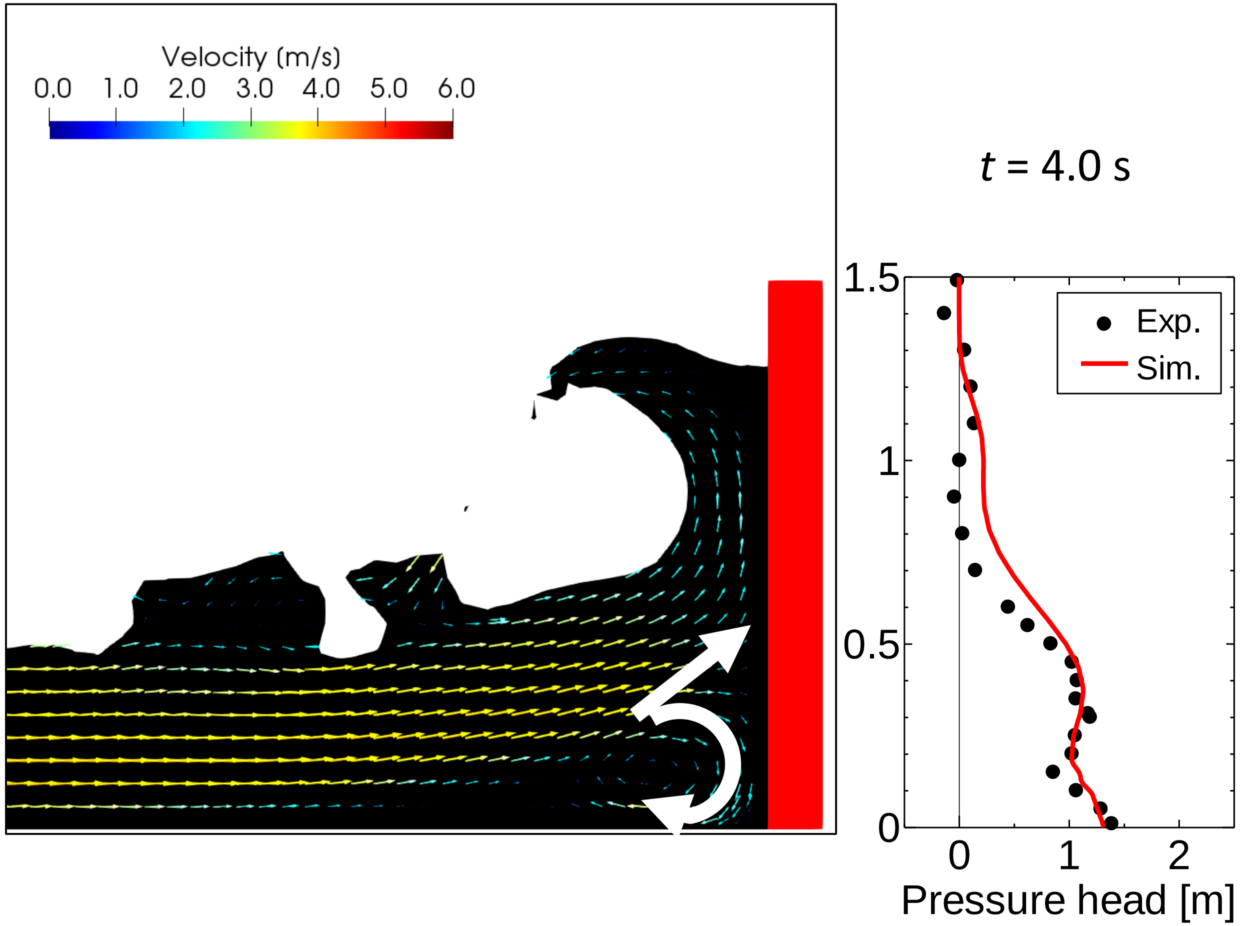


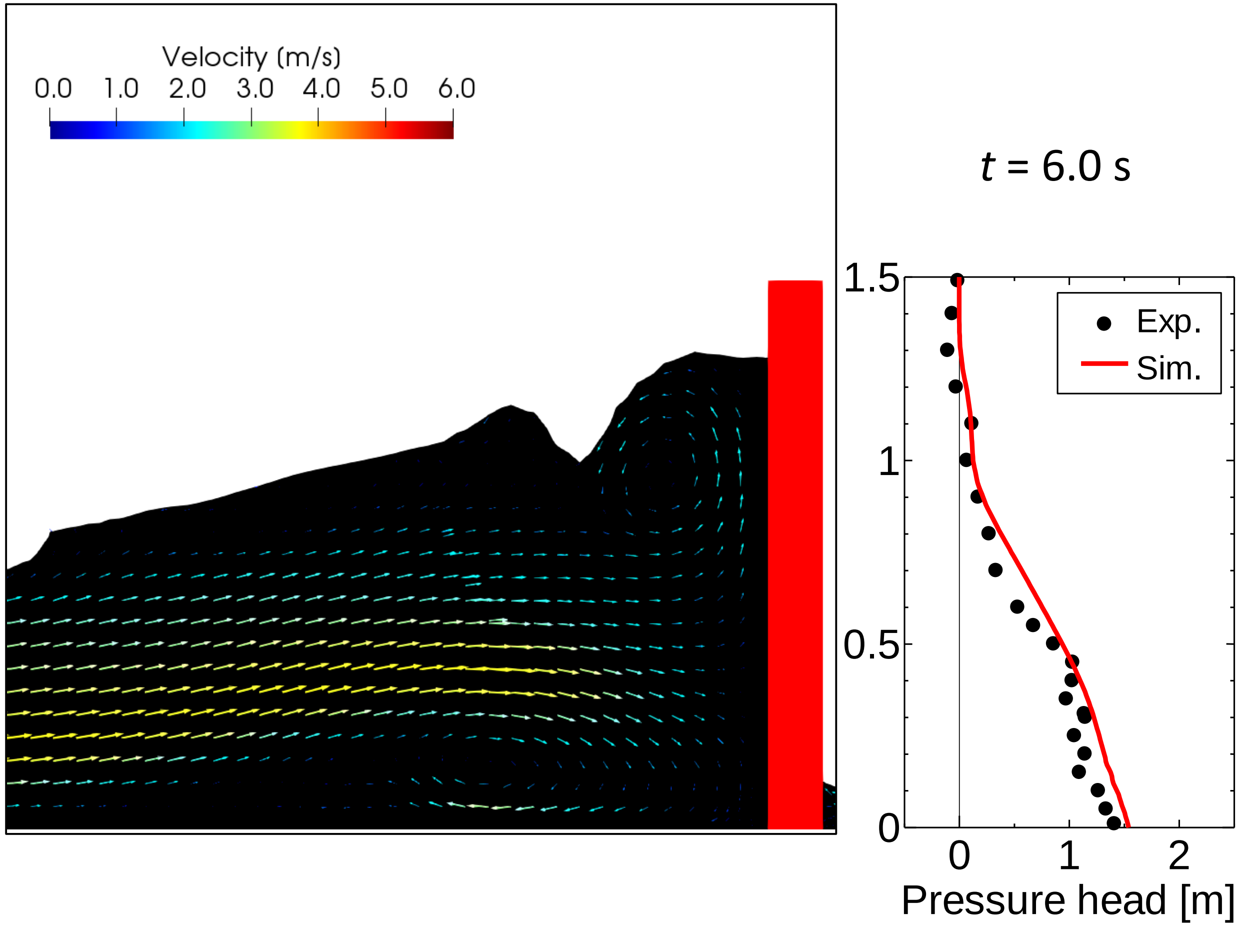






Velocity and pressure distribution (inlet model)





Summary

- Experiments and 3D numerical simulations on the bore pressure due to tsunami

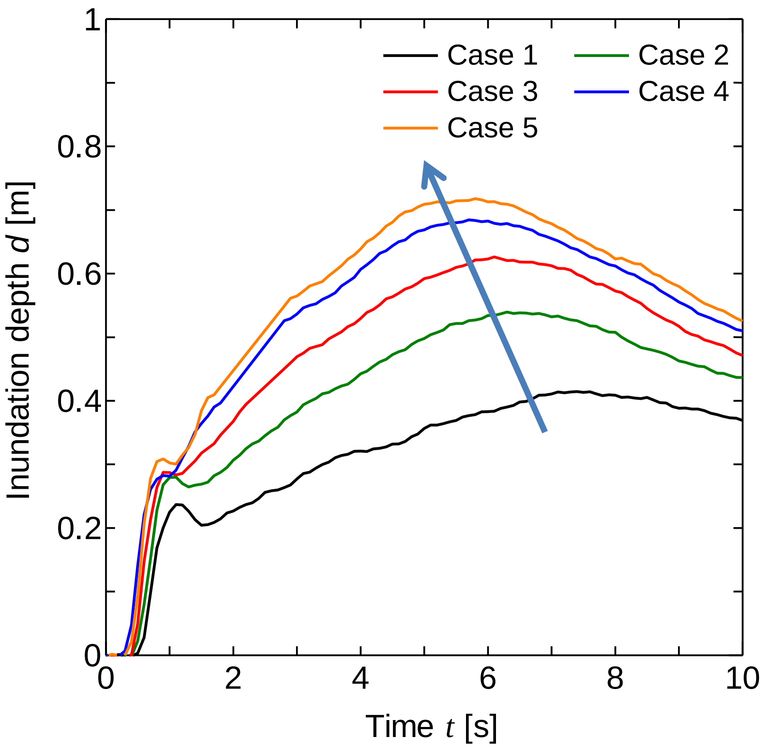
- In the experiments, the pressure profile of the bore pressure is complicated form
  decrease -> increase -> decrease to a negative value -> approach zero

- In the numerical simulations, the pressure profile near the bed (decrease -> increase) can be reproduced. It is caused by the generation of vortex.
  The negative pressure could not be reproduced.

Thank you for your attentions.

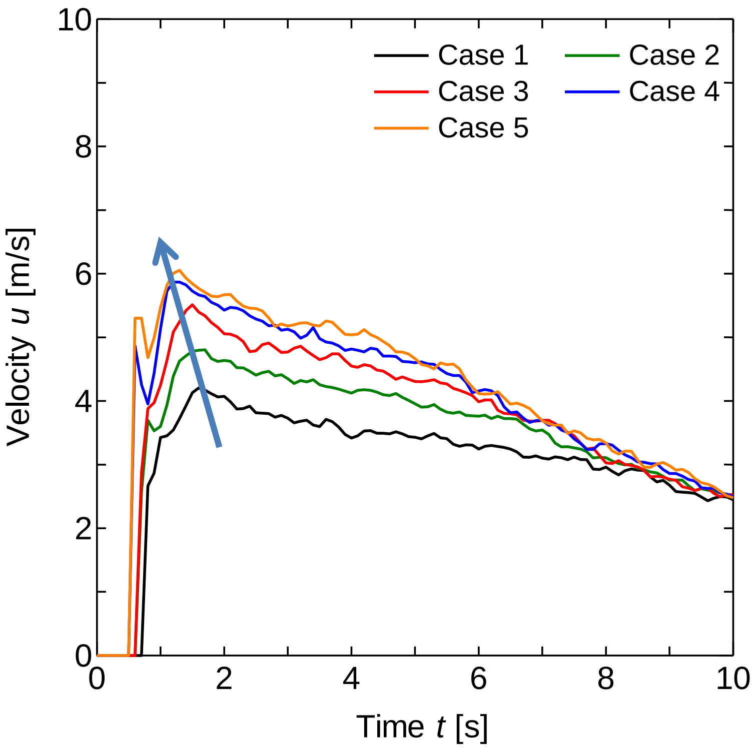
Experimental results (without the vertical wall)

Inundation depth at H2



t=0 when water reached H1

Velocity in streamwise at V1



Foude number