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Relationships Between Fluid Motion and Pressure Variation by Dam-break Flows Colliding with a Vertical Wall

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The Experience of the March 11, 2011 Tsunami

dai Plain on March 11, 2011

8 meters high evacuation hill "Sennen Kibo no Oka"

Various Evacuation Towers in Japan

Iwate Pref.

Iwate Pref.

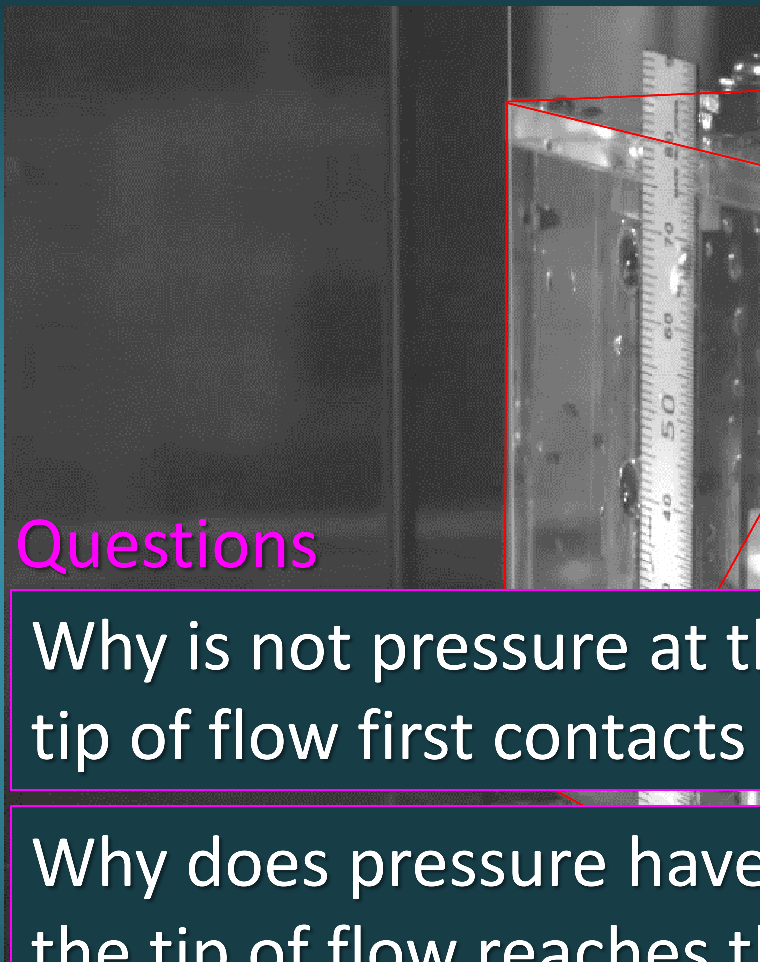
Wakayama Pref.

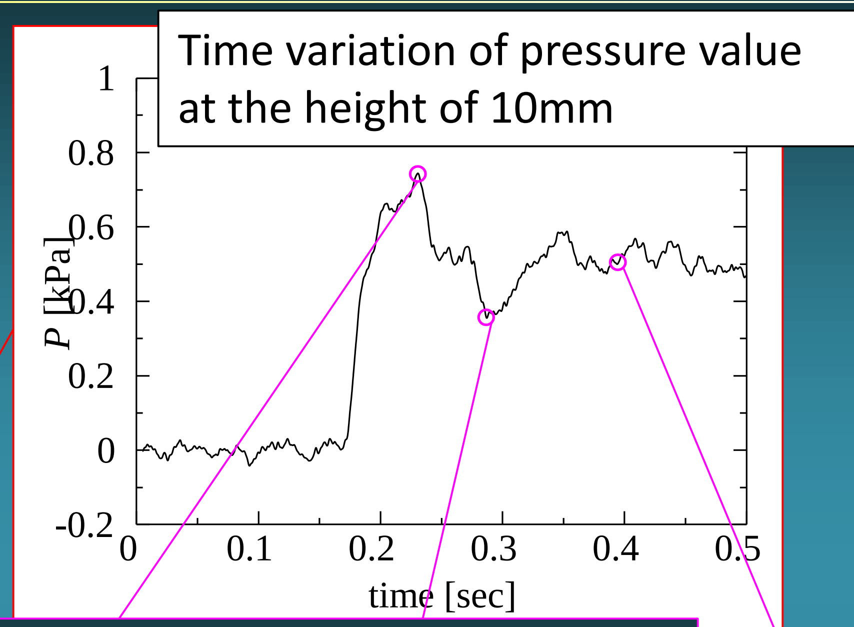
Mie Pref.

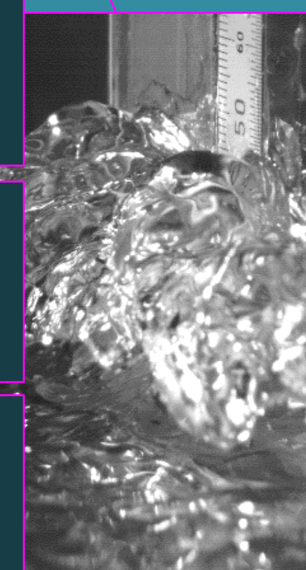
Kochi Pref.

Shizuoka Pref.

Motivation for the Study (Trial Experiment)







Questions

Why is not pressure at the maximum when the tip of flow first contacts the pressure transducer?

Why does pressure have the local minimum when the tip of flow reaches the maximum height?

Why is pressure stable although fluid motion is dynamically changing?

Purpose of this Study

The purpose of this study is to clarify the relationships between fluid motion and pressure variation in order to understand the generation mechanism of collision pressure.

We conducted a series of experiments.

--- Flow impact pressure was measured by pressure transducers.

--- Internal velocity was measured using PIV technique.

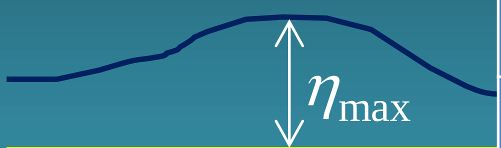
--- Fluid motion was captured by a high speed video.

--- Water surface elevation in front of a structure was measured by a wave gauge.

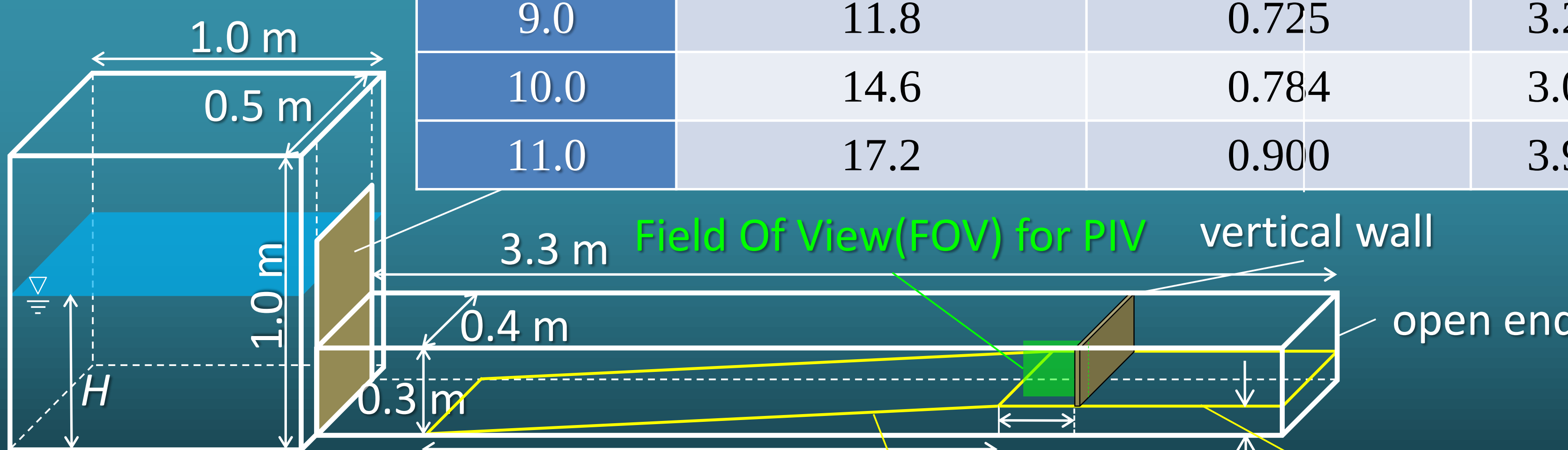
Experimental Setup for a Vertical Wall

Experimental conditions of progressive flow without a structure

Reservoir water level H [cm]	Maximum inundation depth η_{max} [mm]	Maximum velocity V_{max} [m/s]	Fr_{max}
6.0	5.5	0.354	2.07
7.0	7.9	0.540	2.75
8.0	9.8	0.643	3.24
9.0	11.8	0.725	3.29
10.0	14.6	0.784	3.05
11.0	17.2	0.900	3.99

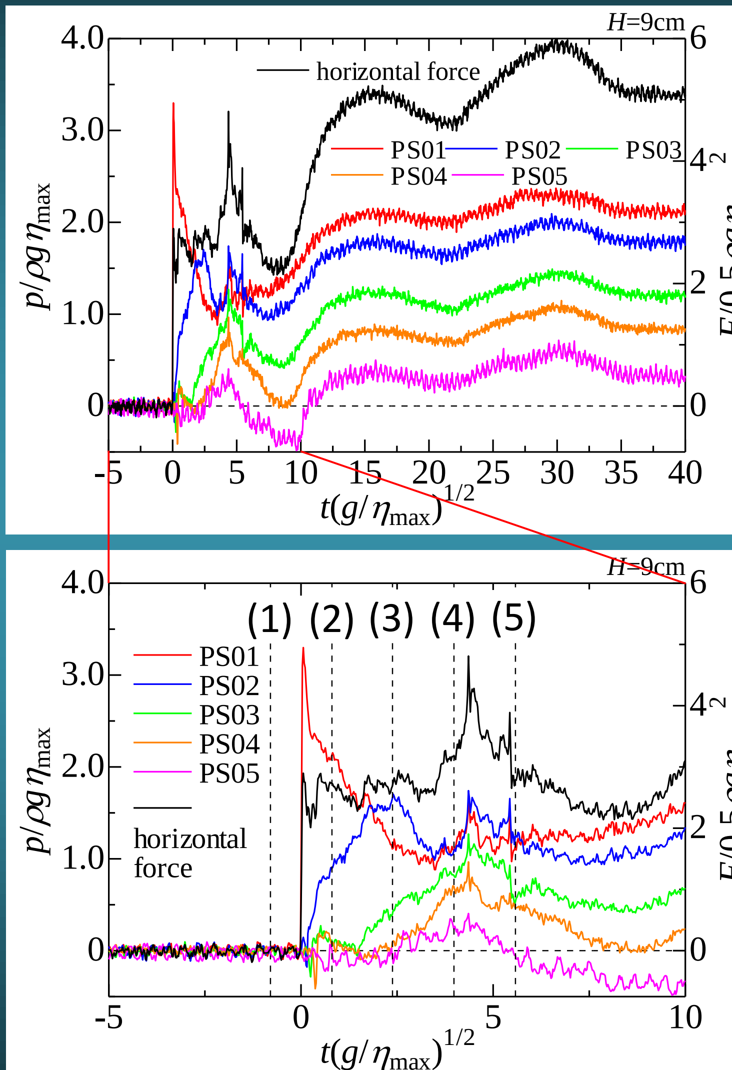


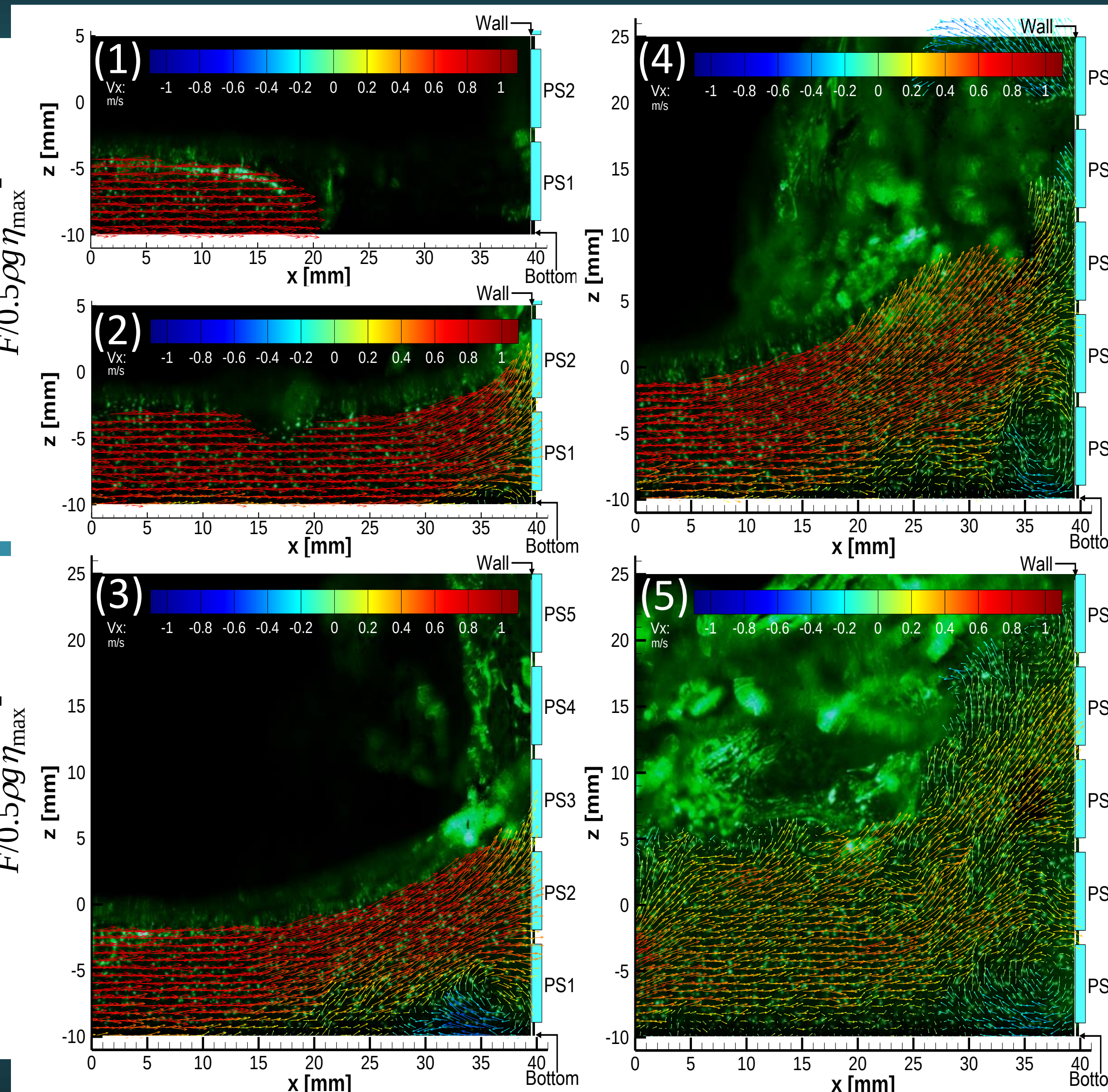
Sampling frequency is 1(
pressure transducers an(



The laser sensor is used as a trigger.

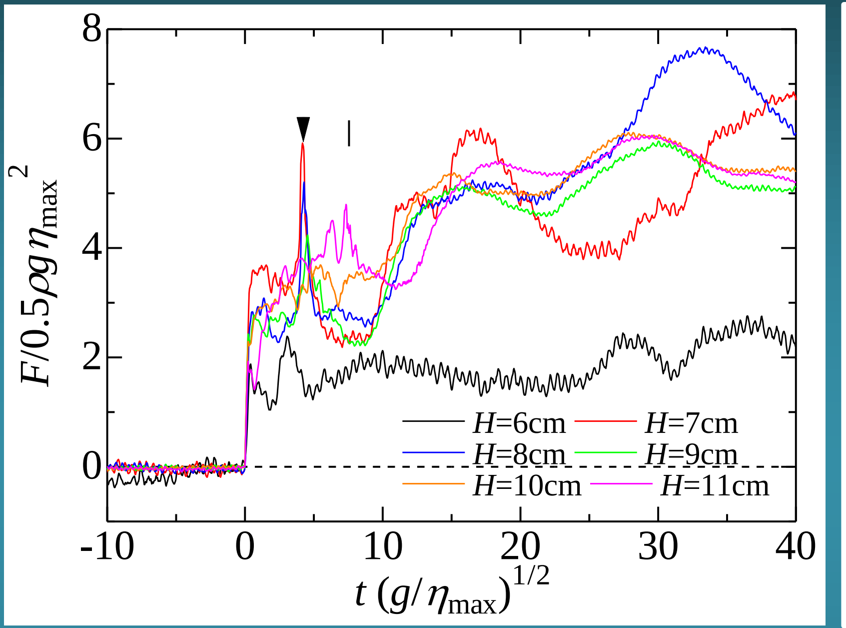
PIV Results in the Case of the Vertical Wall (*H*=9cm)



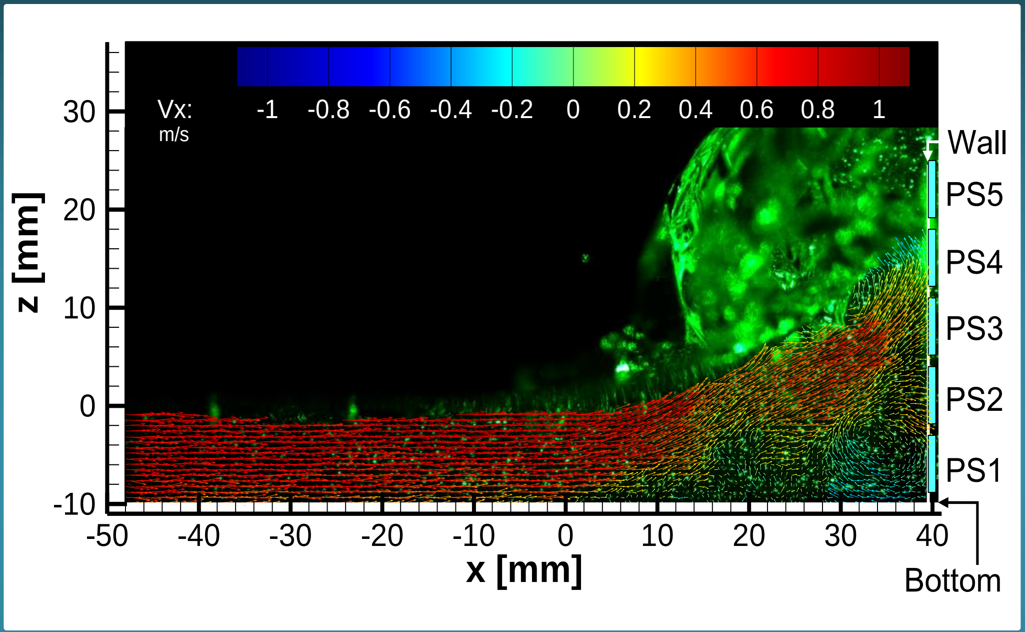


Pressure variations and internal velocity fields acting on the vertical wall (*H*=9cm)

The Local Maximum Horizontal Force



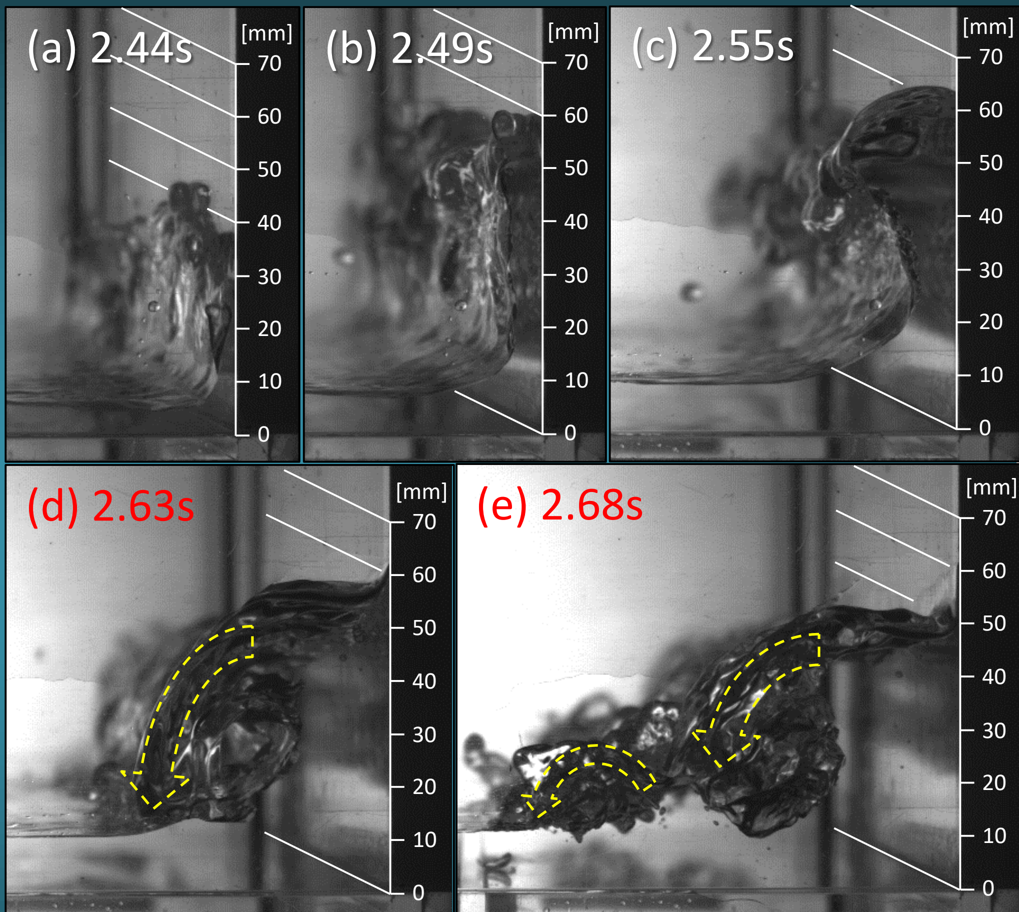
Time variation of the horizontal force in all the case

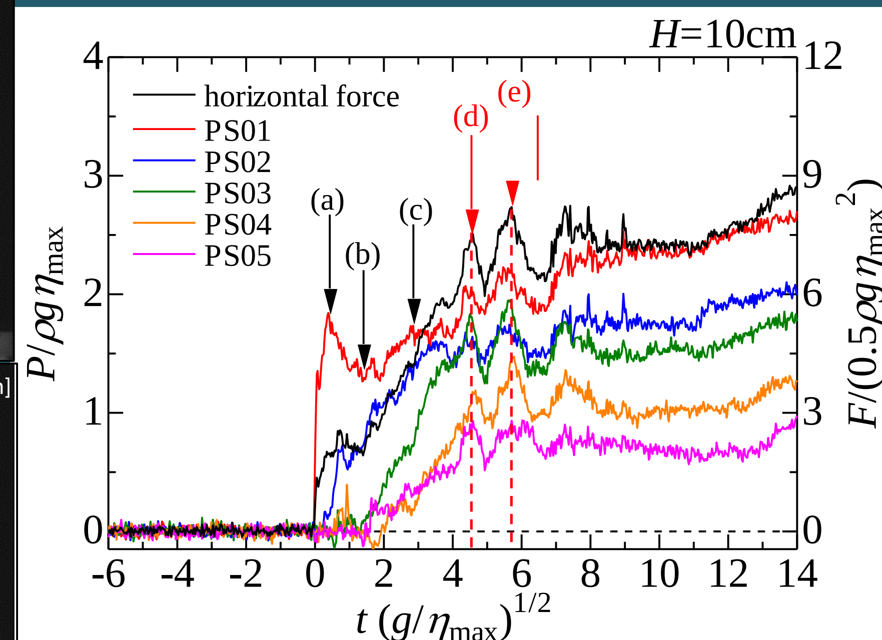


Internal velocity field when the local maximum horizontal force occurred in the case of other *H*=9cm.

The local maximum value of horizontal force occurs a shortly after the first collision. Its features can not be found in the internal velocity field on the right side figure.

Impact Pressure Due to Falling Water Column

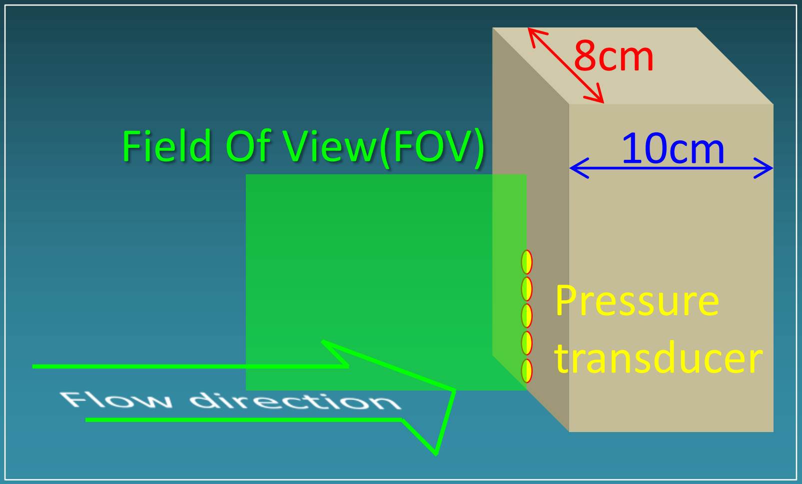


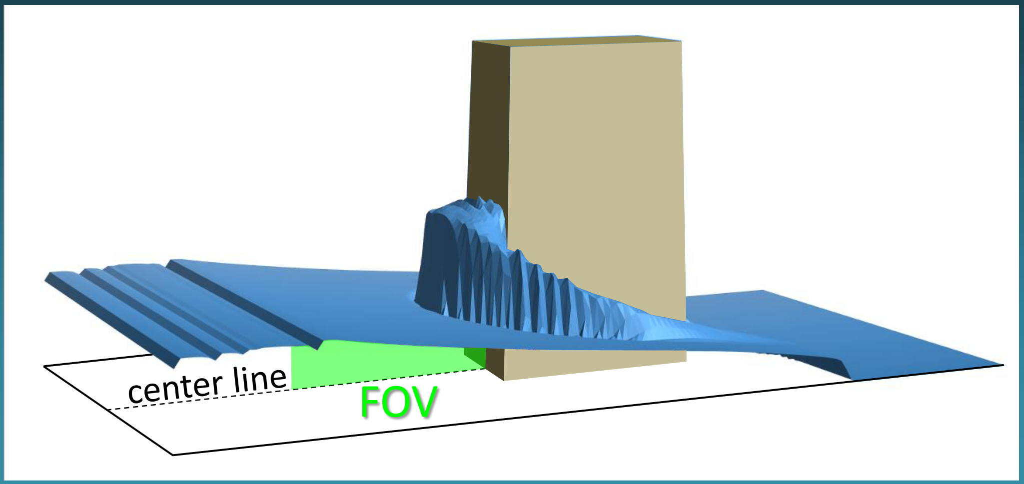


Time variation of the pressure and horizontal force in the case of H=10cm

Images of fluid motion at the side glass wall corresponding to the arrow indicators in the right side figure.

Experiments of Flow Acting on a Building Model





Schematic view of the experiment using the building model

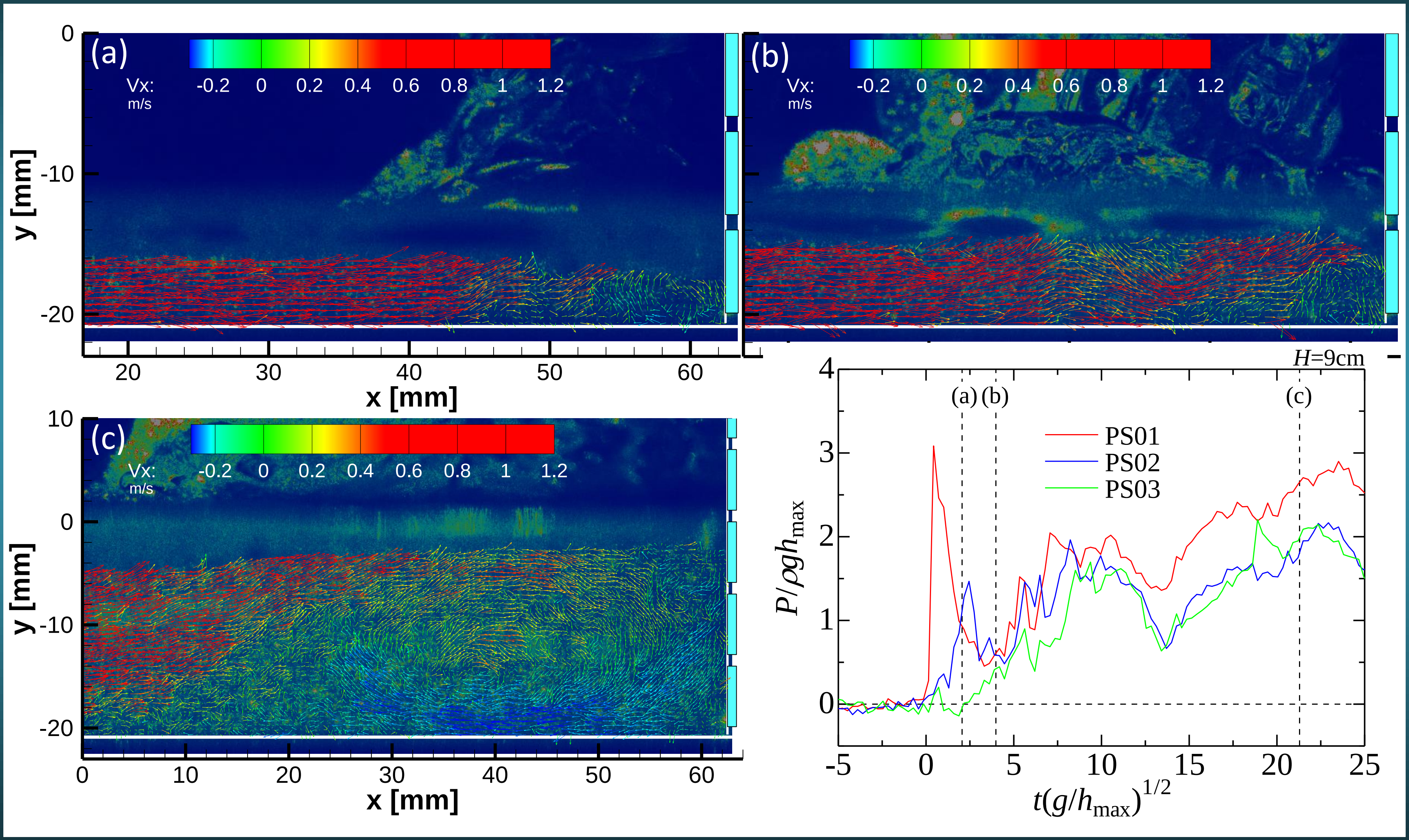
Snapshot of a numerical simulation result by the Shallow Water Equations

In order to comparison, a series of experiments using a building model with the same condition was conducted.

The FOV in the run-up water column at the center of the model can not be seen from the glass side wall.

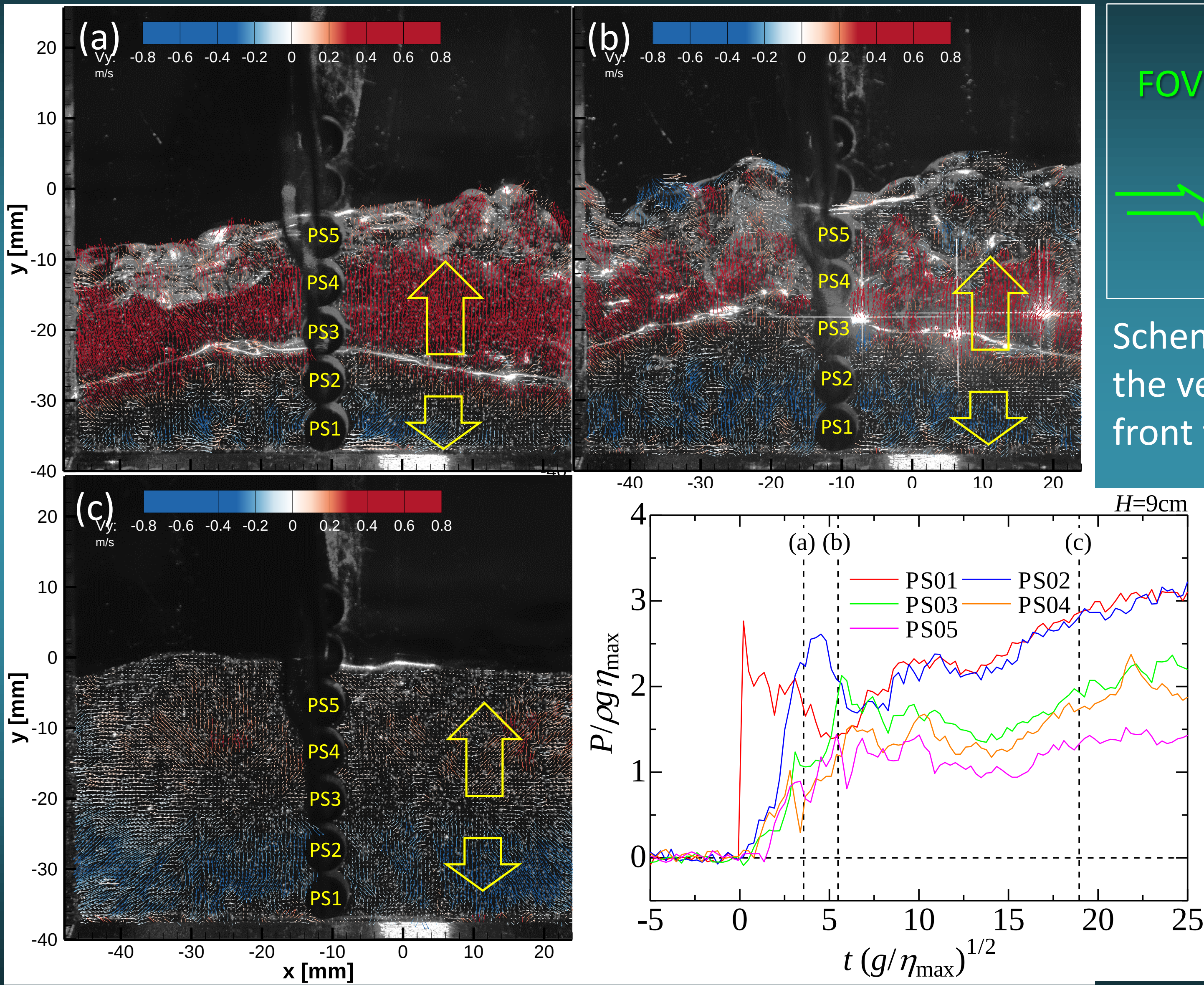
Only under the water surface of the following flow was able to be seen from the side wall for PIV.

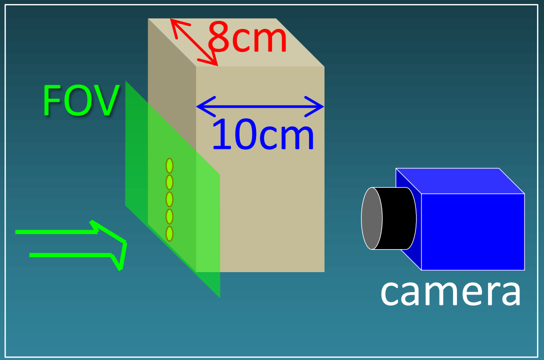
PIV Results in the Case of the Model (H=9cm)



Internal velocity fields and pressure variations acting on the building model (H=9cm)

PIV Results along the Front Face of the Model





Schematic view of PIV for the vertical plane along the front face of the model.

Internal velocity fields along the front face of the model and pressure variations (H=9cm)

Conclusions

1. In the case of the flow colliding with the wall, it was found that the vortex occurs in the bottom corner just after the tip collided, and the pressure near the bottom of the wall decreases due to the flow avoiding the vortex.
2. When the run-up water column falls down on the water surface, the impact pressure uniformly acts on the entire wall.
3. When the flow colliding with the wall reaches a steady state, the water in front of the wall almost stops. On the other hand, even though the flow colliding with the building model has a steady state, there is the large circulation near the bottom.
4. The flow separates up and down at the water surface height of the following flow. As a result, dynamic pressure acts near the branch point of the flow, so the pressure is greater than hydrostatic pressure.

Thank you for your kind attention!

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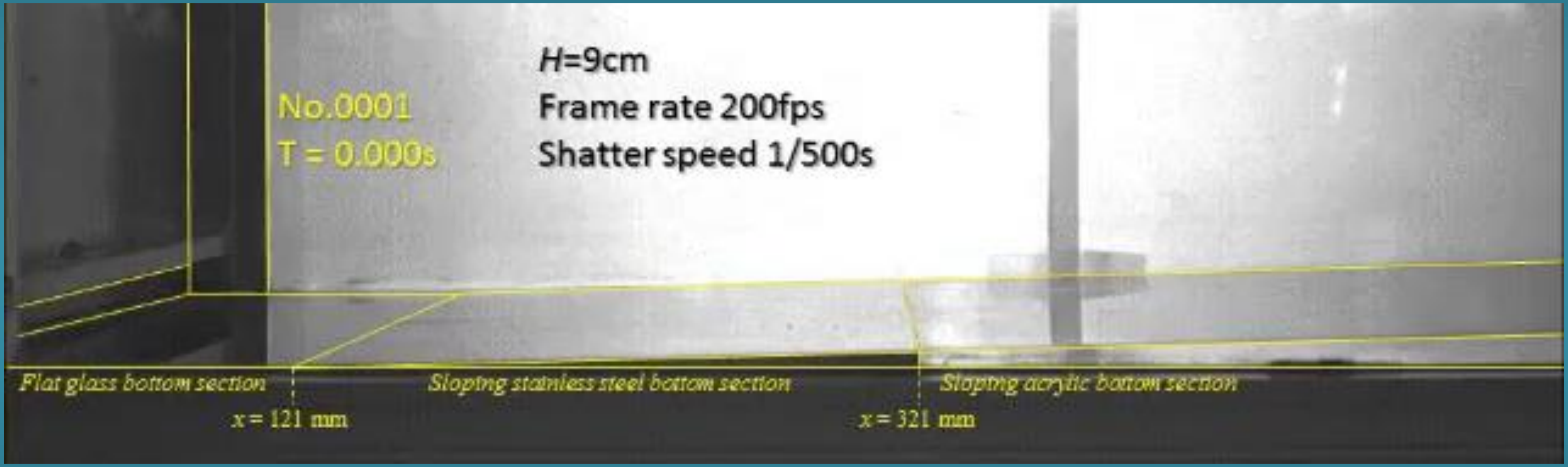
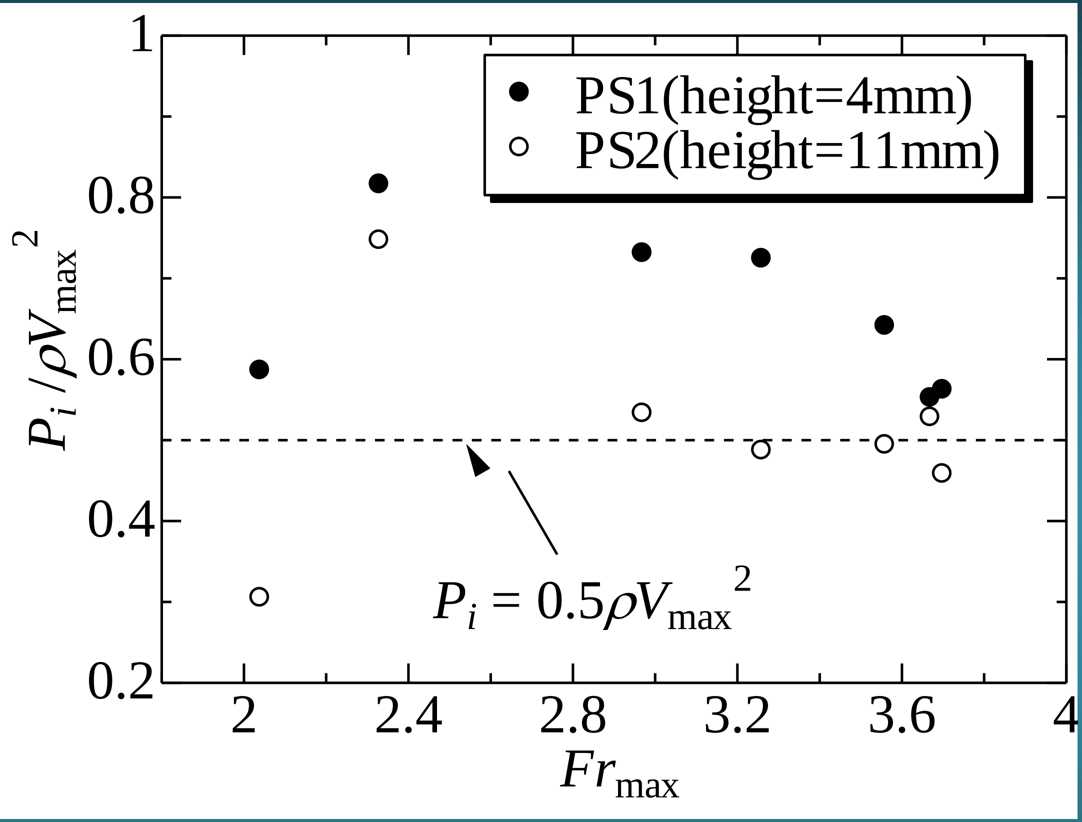
Video of the initial flow just after the gate opened

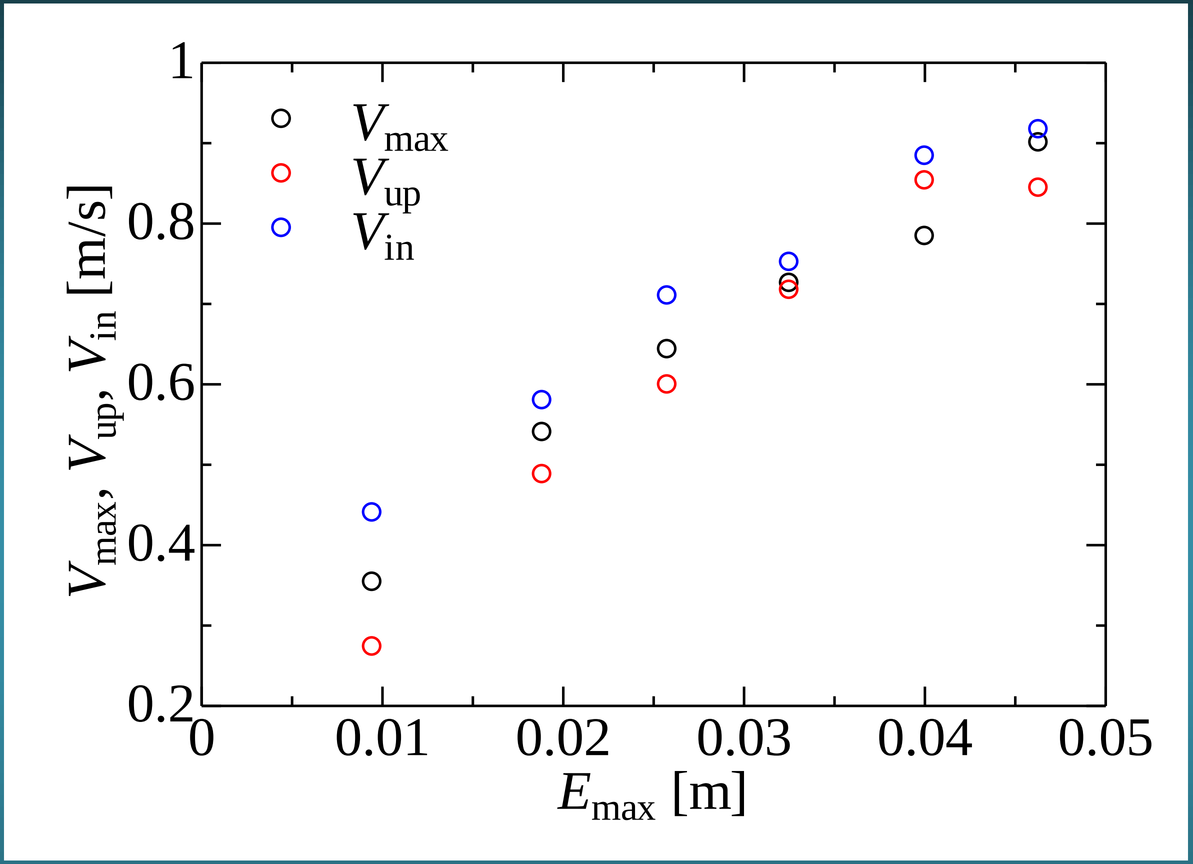


It is about 0.5 sec for 20 cm distance to lift the gate up.

Peak Pressure Values Evaluated by Impact Velocity



Three Kinds of Velocities vs Total Head



V_{max} is the velocity of the tip of the progressive flow at the wall.
V_{up} is the upward velocity along the wall calculating by the surface elevation.
V_{in} is the plunging velocity from the highest point assuming free fall.
E_{max} is the specific energy of the progressive flow at the wall.