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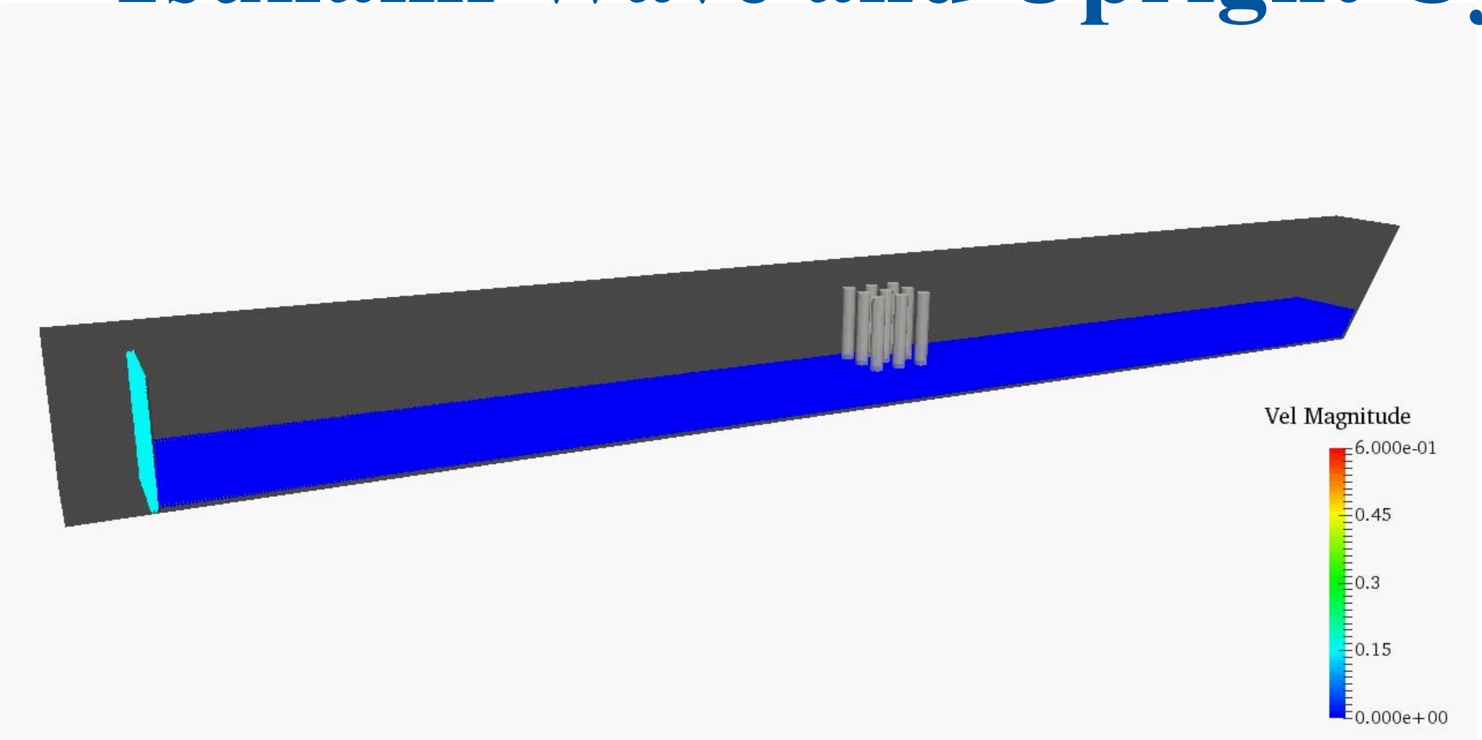
College of Water Conservancy & Civil Engineerin

SPH for the Interaction between Tsunami Wave and Upright Cylindrical Groups



Reporter: Jing-jun Li

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2018/9/27

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The First Part

Problem Description and Current States

Problem Description and Current States

① May 1960, a strong earthquake in the south-central seas of Chile caused a huge tsunami, resulting in the death and disappearance of tens of thousands of people, all paralyzed terminals along the coast, and 2000000 homelessness.

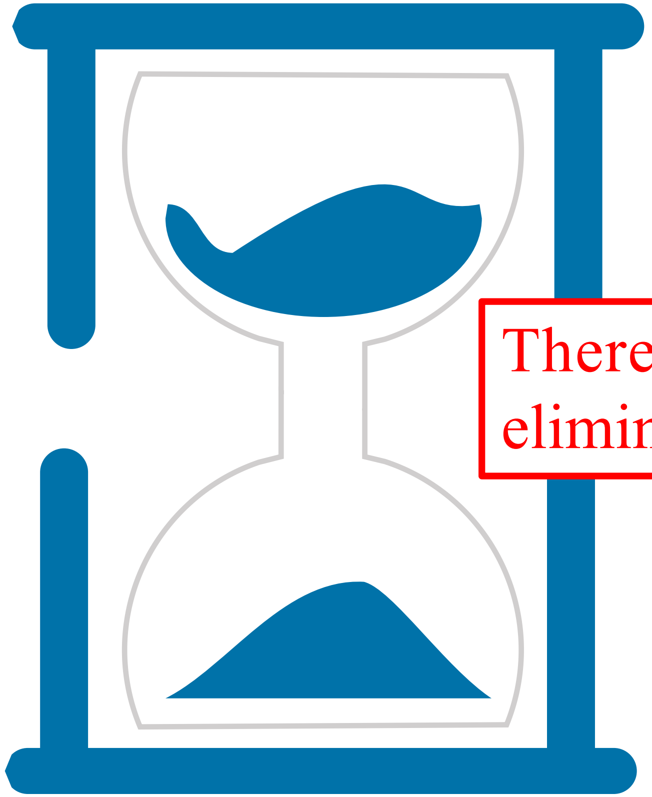
② Between September 1992 and July 1993, the tsunami attacked the Nicaragua, the Indonesian Islands and the Okushiri Island on the Pacific coast. The tsunami took 2,500 lives.

③ December 26, 2004 Indian Ocean tsunami. The tsunami was caused by the second strong earthquake and it has killed 156,000 people.

④ March 11, 2011, 9.0 earthquake occurred in Japan, triggered a huge tsunami, nearly 30,000 people dead or missing. Central Pacific countries are affected.

Problem Description and Current States

Research Status



2001 Chi-Wai Li， “A numerical study of three-dimensional wave interaction with a square cylinder”

2009 Jeng-Tzong Chen, “ Interaction of water waves with vertical cylinders using null-field integral equations ”

2011 Guanghai Gao, “ Modelling Open Channel Flows with Vegetation Using a

, rigid vegetation”

There are less literature on how to set up the building to eliminate the tsnuami.

2012 J. Westphalen， “Focused waves and wave–structure interaction in a numerical wave tank ”

2016 Ankit Aggarwala， “Irregular Wave Forces on a Large Vertical Circular Cylinder”

2017 Mohammad Sarfaraz, “SPH numerical simulation of tsunami wave forces impinged on bridge superstructures”

The Second Part

The Research Method

1. The Smoothed Particle Hydrodynamics (SPH)

By using DualSPHysics_v4.0

$$f(\vec{x}) \approx \sum_b W(\vec{x} - \vec{x}_b) f_b V_b$$

$$\frac{d\rho_a}{dt} = -\sum_b m_b (\vec{u}_b - \vec{u}_a) \cdot \nabla_a W_{ab}$$

$$\frac{d\vec{u}_a}{dt} = -\sum_b ma\left(\frac{p_a}{\rho_a^2} + \frac{p_b}{\rho_b^2} + \Pi_{ab}\right)\nabla_a W_{ab} + \vec{g}$$

$$\frac{d\vec{x}_a}{dt} = \vec{u}_a + \varepsilon \sum_b m_b \left(\frac{\vec{u}_a - \vec{u}_b}{\rho_{ab}}\right) W_{ab}$$

$$p = B\left(\left(\frac{\rho}{\rho_0}\right) - 1\right)^{\gamma}$$

$$\rho_a^{new} = \sum_b \rho_b \tilde{W}_{ab} \frac{m_b}{\rho_b}$$

$$\tilde{W}_{ab} = \left\{\psi_0(\vec{x}_a) + \psi_{1x}(\vec{x}_a)(x_a - x_b) + \psi_{1z}(\vec{x}_a)(z_a - z_b)\right\} W_{ab}$$

$$\psi_0(\vec{x}_a) = \begin{Bmatrix} \psi_0 \\ \psi_{1x} \\ \psi_{1z} \end{Bmatrix} = \left[\sum_b w_b(\vec{x}_a)[\Phi]V_I\right]^{-1} \begin{Bmatrix} 1 \\ 0 \\ 0 \end{Bmatrix}$$

$$[\Phi] = \begin{bmatrix} 1 & (x_a - x_b) & (z_a - z_b) \\ (x_a - x_b) & (x_a - x_b)^2 & (z_a - z_b)(x_a - x_b) \\ (z_a - z_b) & (z_a - z_b)(x_a - x_b) & (z_a - z_b)^2 \end{bmatrix}$$

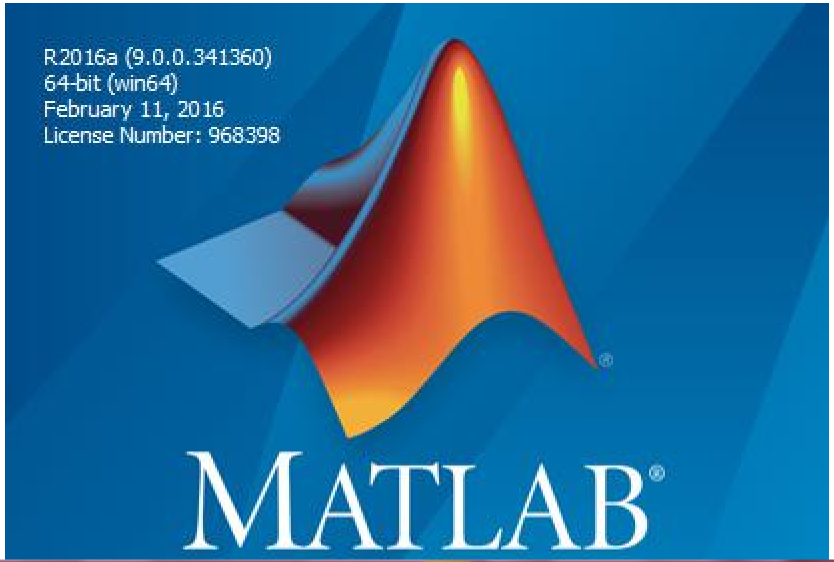
2. The motion of the wave maker (Goring.1978)

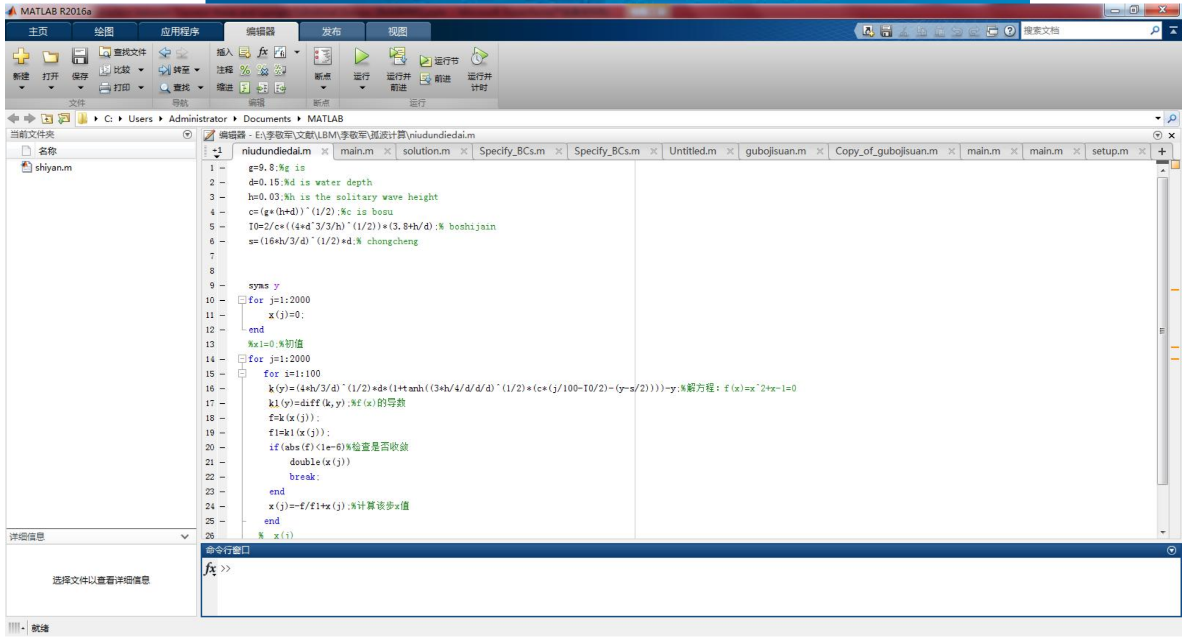
$$x_p(t) = \frac{a}{k_p}(\tanh \chi(t) + \tanh(\frac{k_p}{h}\lambda))$$

where $x_p(t)$ is the time history of the paddle location, t represents the time, a is the solitary wave height, k_p is defined as $(3a/4h)^{0.5}$, h is the still water depth, λ is $3.8/k_p$. The parameter $\chi(t)$ is calculated by using:

$$\chi(t) = \frac{k_p}{h}(c_w t - x_p(t) - \lambda)$$

in which c_w is $(g(h+a))^{0.5}$. It is clear that $x_p(t)$ appears in the above two equations and can be found by iteration methods such as Newton-Raphson.

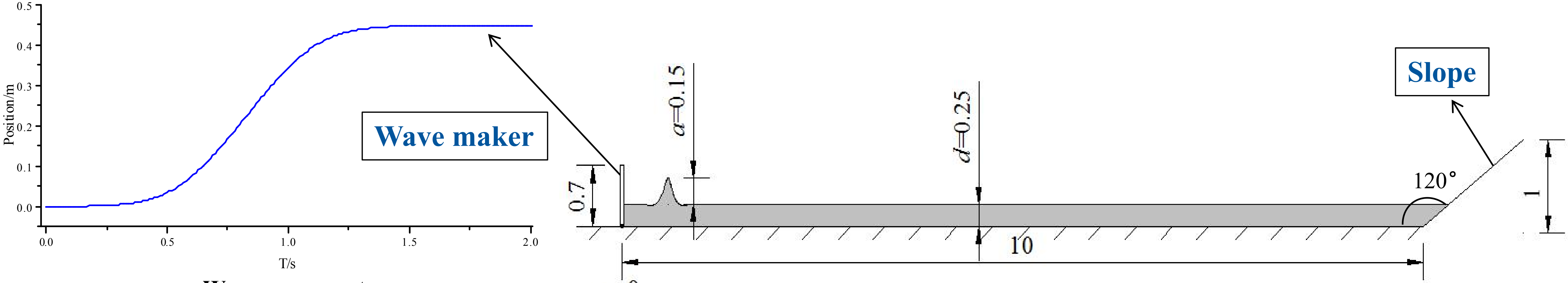




The Third Part

Validation of model and method

Validation of model and method

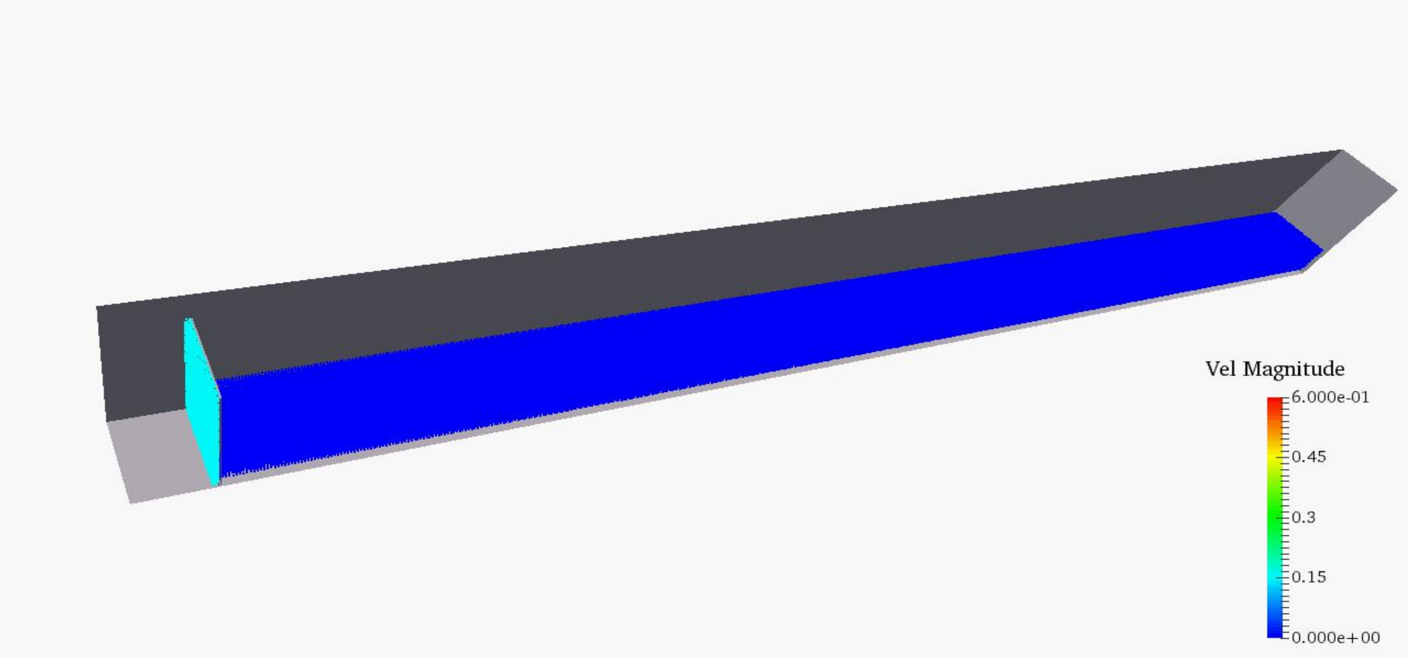


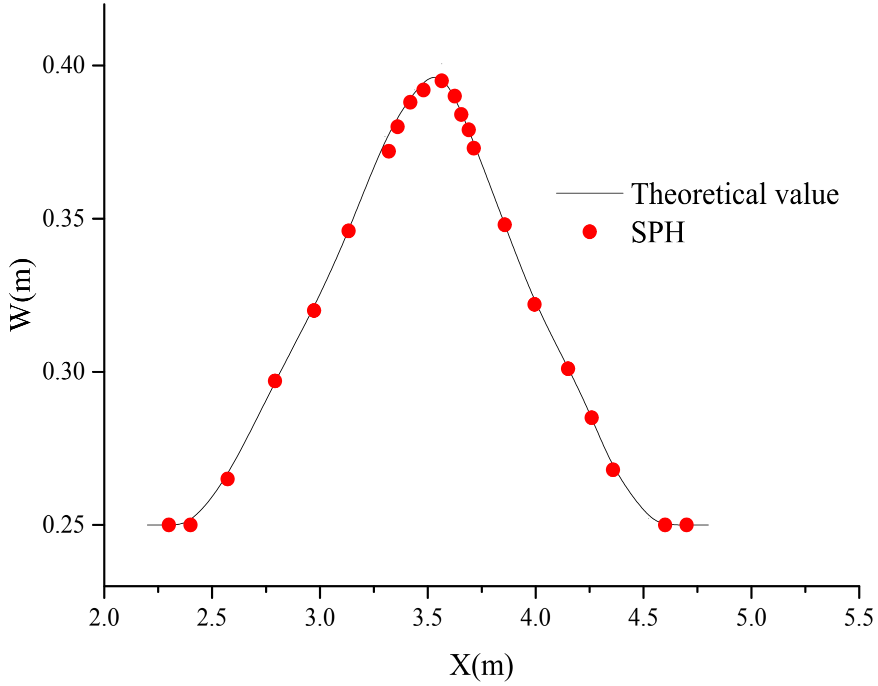
Wave movement

Model/m

The corresponding physical experiment was carried out by Zheng et al.[27] in a 3-D wave flume with piston wave maker in Harbin Engineering University (HEU). The wave tank length is L = 10 m, the water width is 0.7m and the water depth is d = 0.25 m. The solitary wave height is a = 0.15 m. In the SPH computations, the initial particle spacing is chosen to be 0.02 m and the time step kept constant as 0.00001s.

Validation of model and method



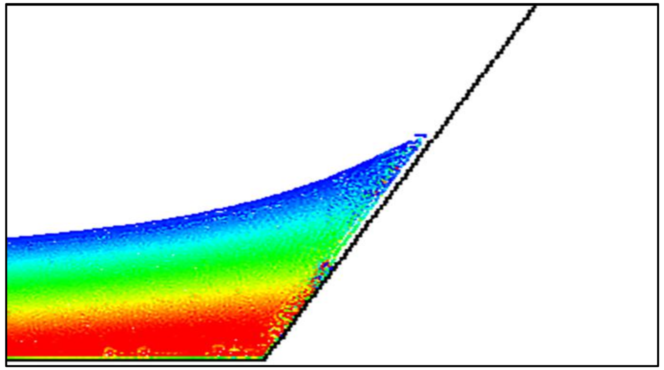


Comparison of numerical solutions and the analytical ones

This method can be used to trace the change of free surface in wave propagation. The numerical solutions is in good agreement with the SPH simulation. The result proves the correctness of wave making method and the accuracy and precision of SPH method in wave manufacture and transfer.

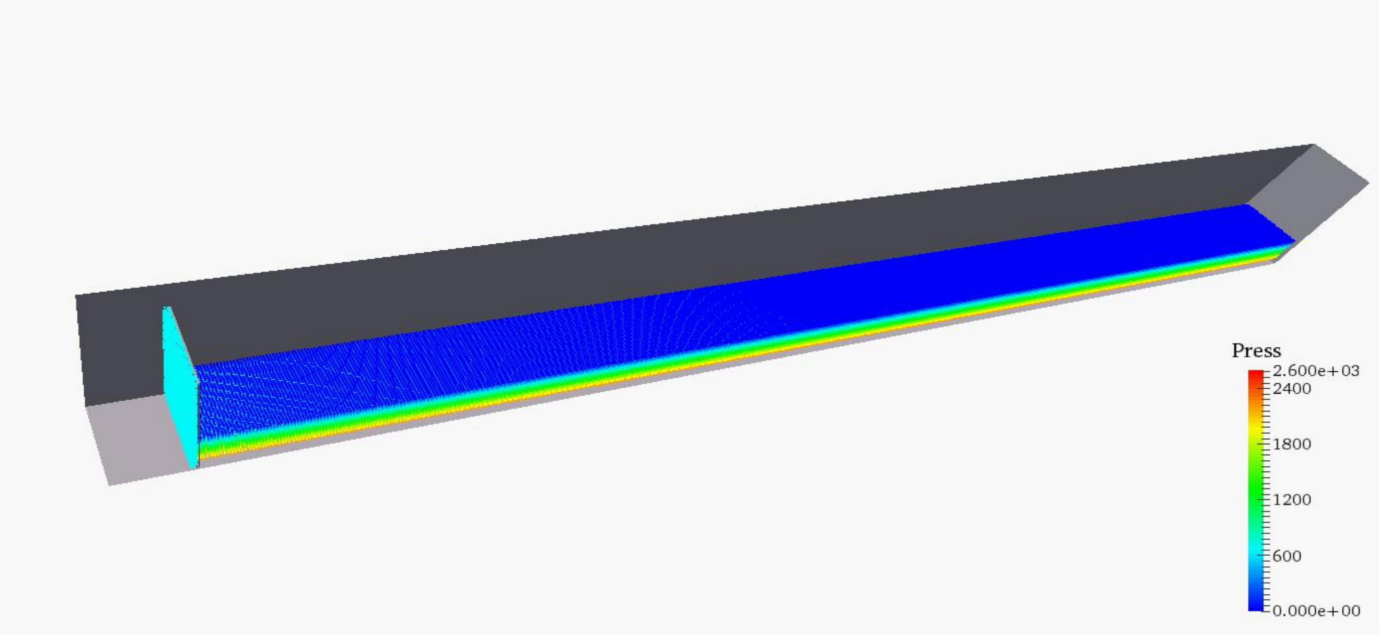
Validation of model and method

The section is selected along the centerline of the channel, and the cloud charts of pressure of the longitudinal section is plotted.



SPH **Experiment[27]**

The interaction between waves and slope

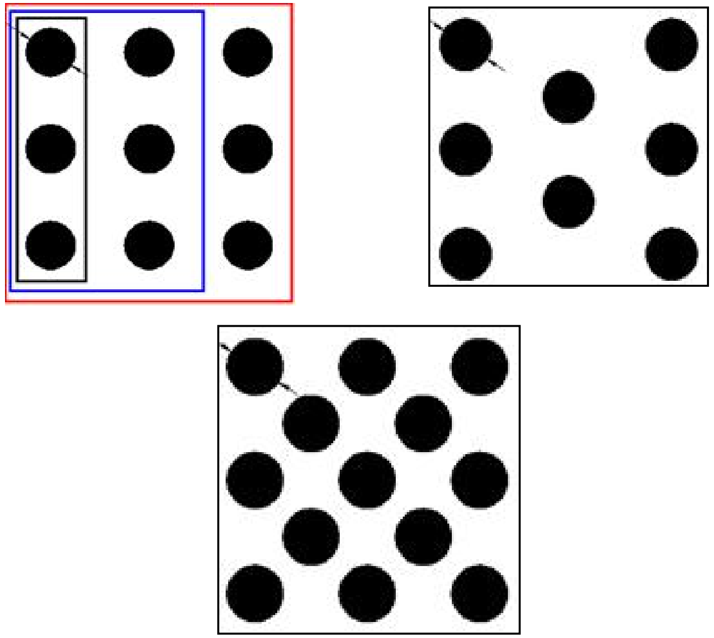


A snapshot of the computed wave profile with the experimental photo is be shown, including the pressure contour distributions in the fluid domain. It shows again that the wave elevation profile obtained by SPH can achieve a good agreement with the laboratory photograph, and the pressure distribution of wave field is quite stable.

The Fourth Part

Interaction between Tsunami Wave and Upright Cylindrical Groups

Interaction between Tsunami Wave and Upright Cylindrical Groups



01

Upright Cylindrical Groups

02

Different number of layers

03

Different arrangement

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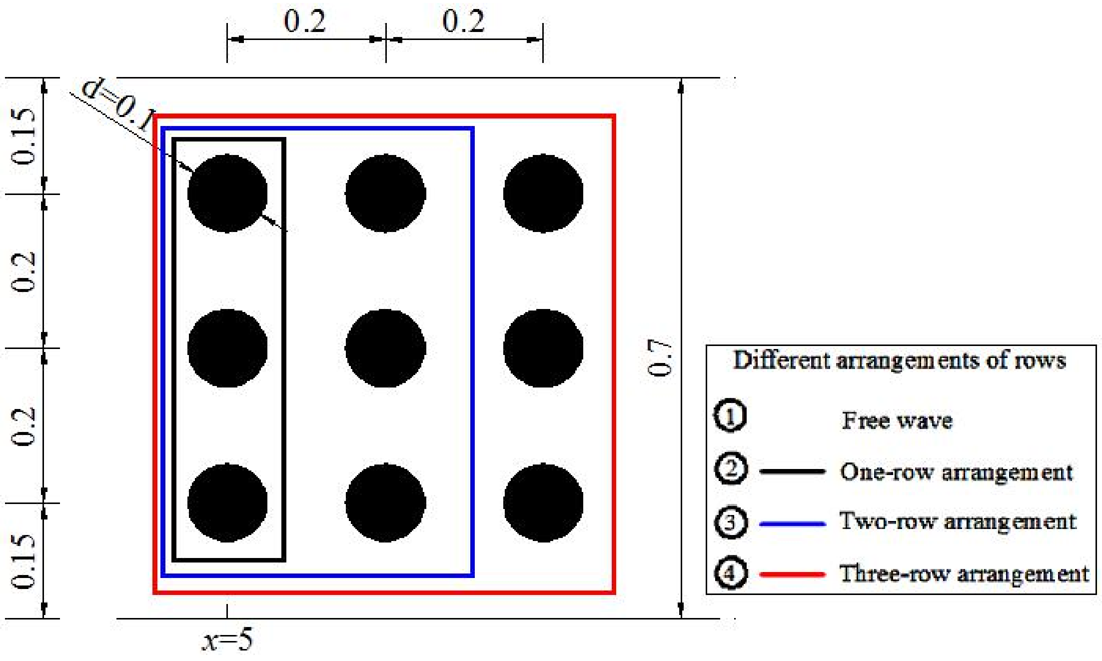
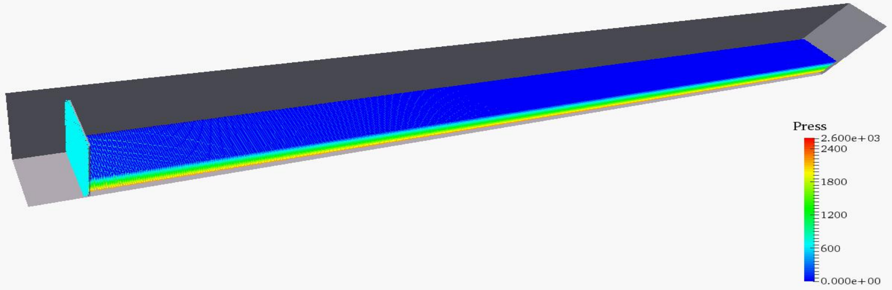
Different number of layers



Model size/(m)

In the case of rectangular arrangement, increase the number of rows of the cylinder

①



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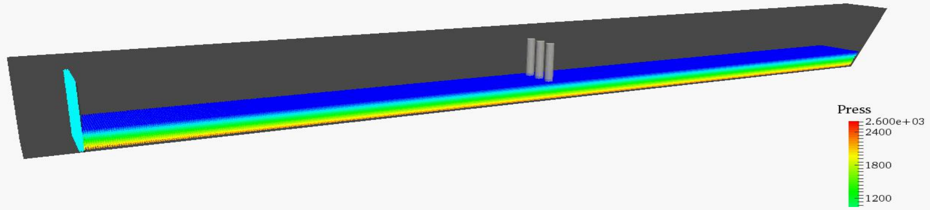

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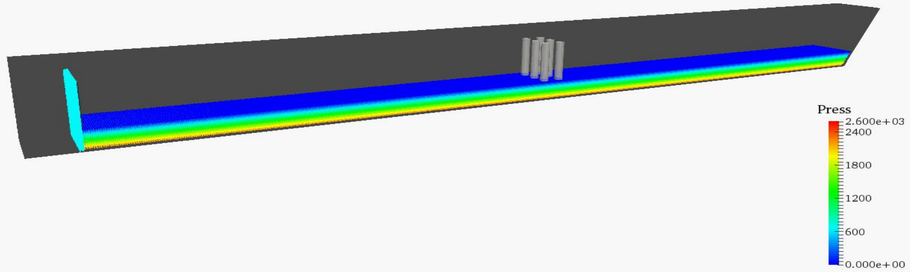

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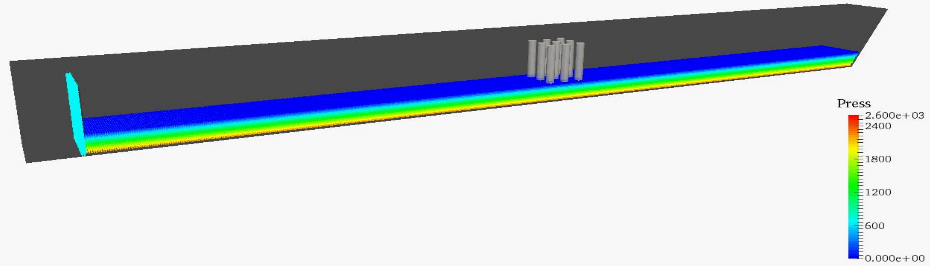
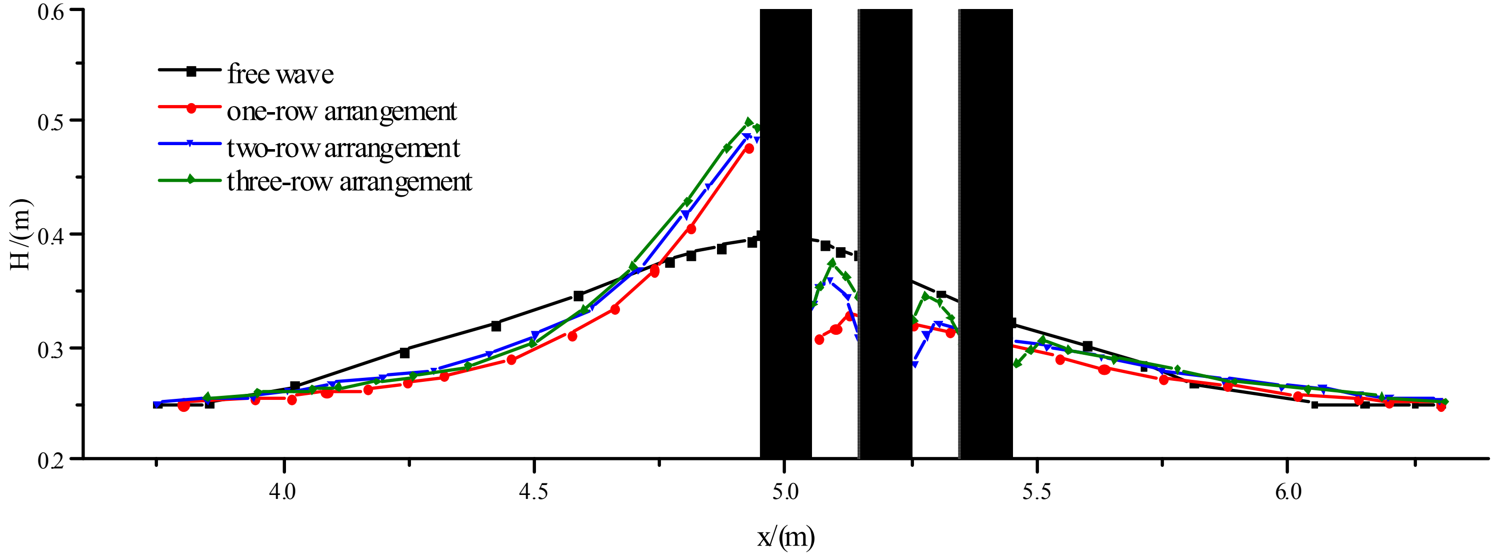
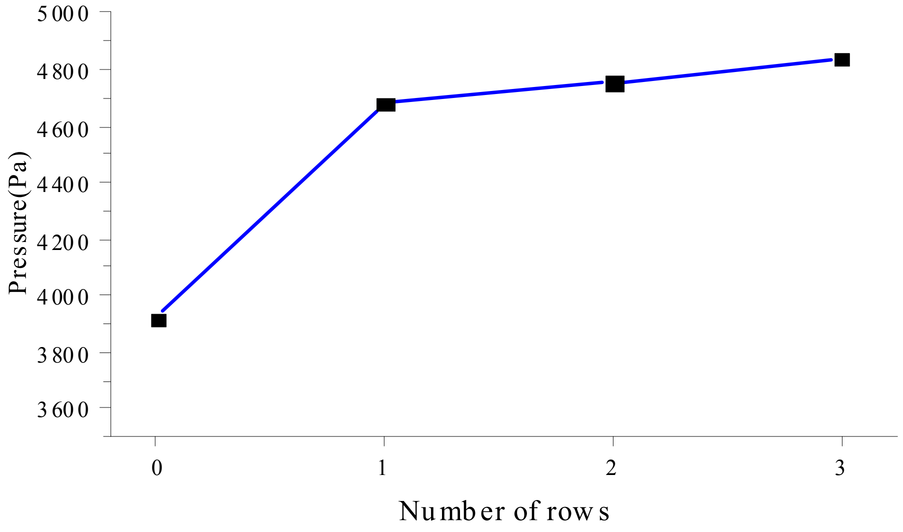


Interaction between Tsunami Wave and Upright Cylindrical Groups

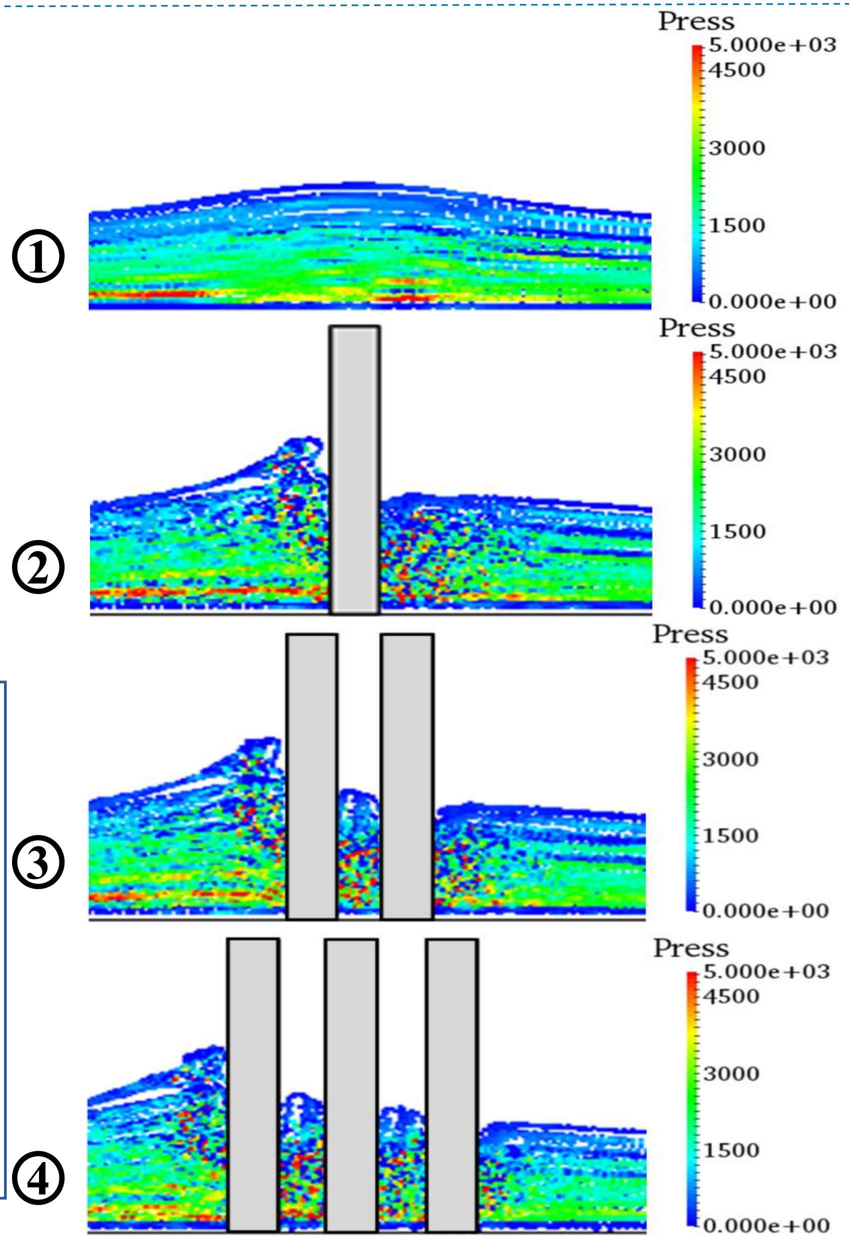


Wave and Upright Cylindrical Groups

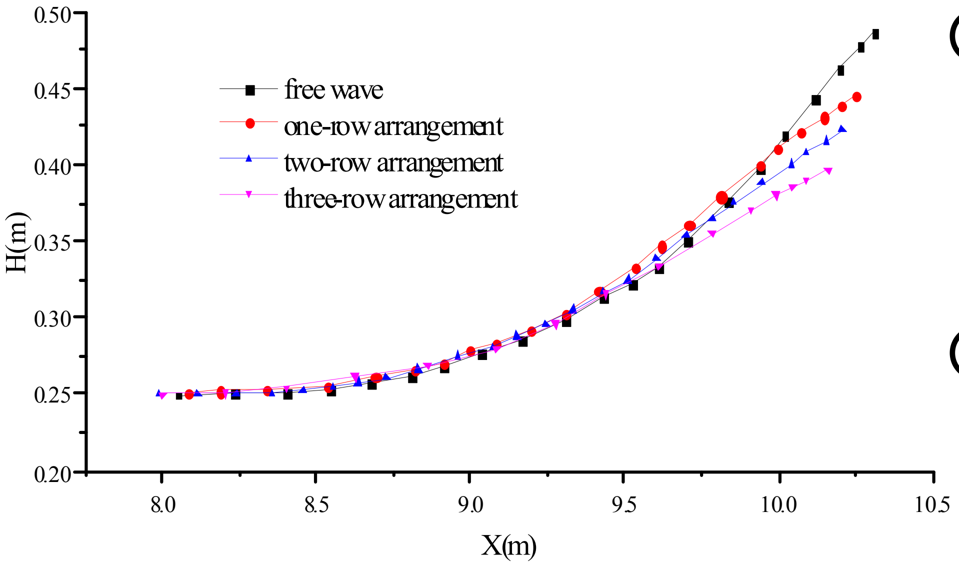


Pressure under different arrangements

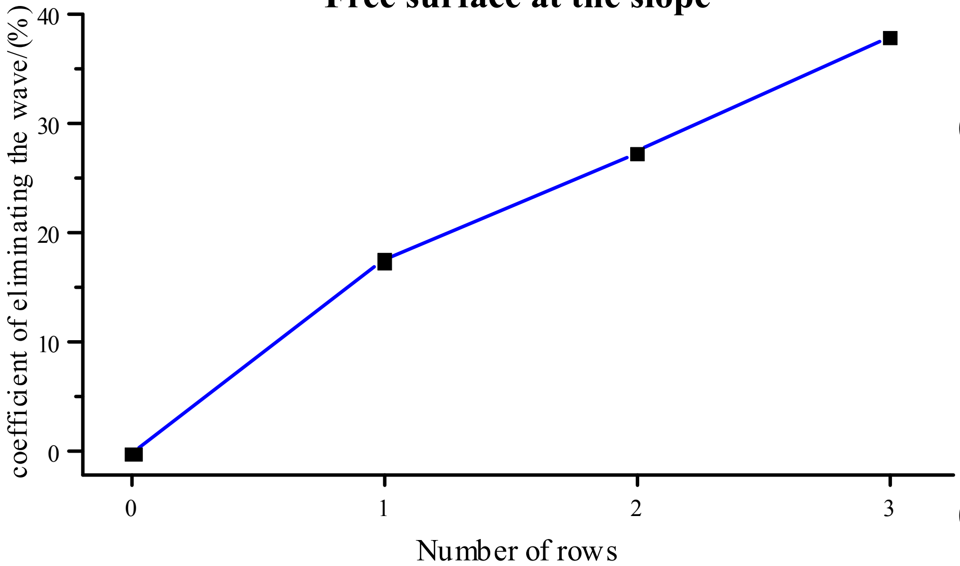
With the increase in the number of rows, the backwater effects of the cylinder group is more and more obvious, the water level before the column increased, the water pressure before the column also gradually become larger.



With the increase in the number of rows of the cylindrical groups, the climbing height of the wave gradually decreased and the coefficient of eliminating the wave is higher.

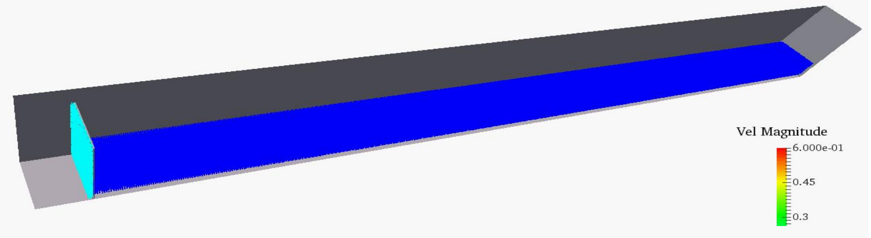


Free surface at the slope



The coefficient of eliminating the wave

①



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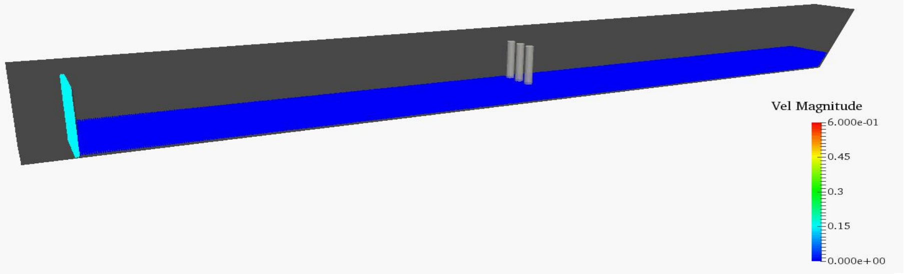

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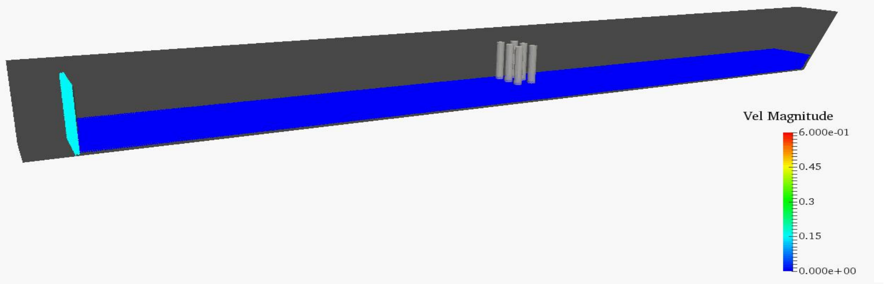

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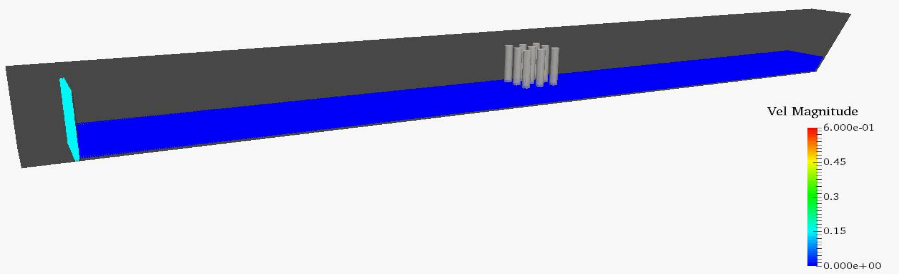
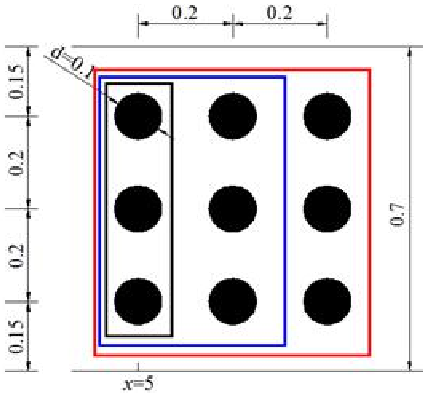
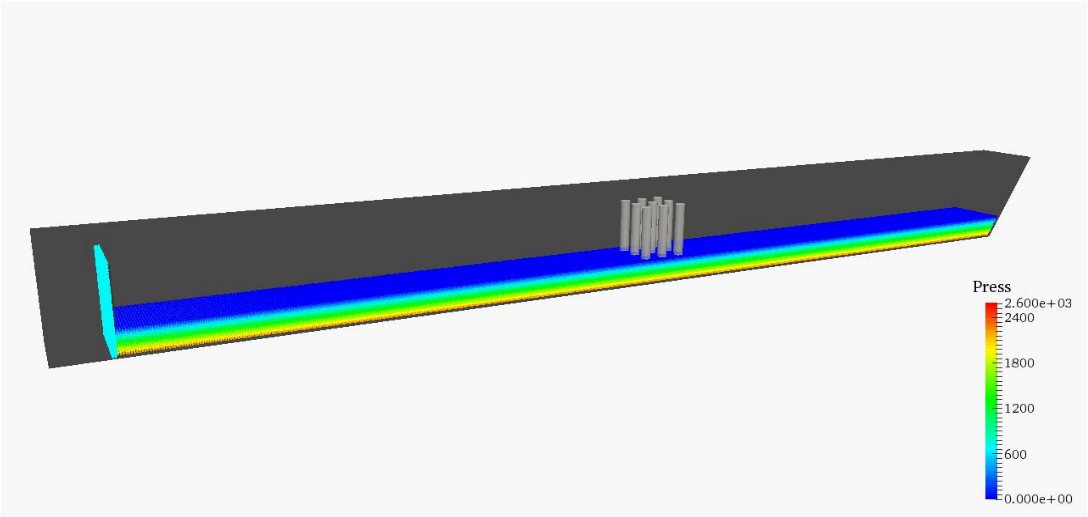


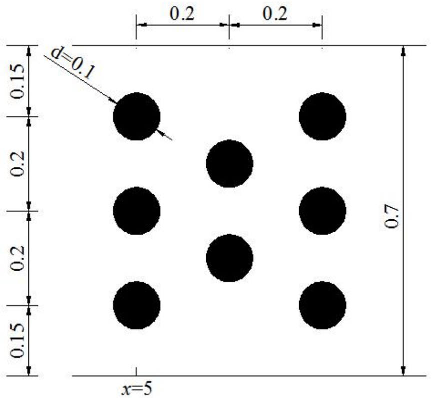
Different arrangement

The analysis of the cylindrical group layout as follows, there are rectangular arrangement, triangular arrangement and quincunx arrangement

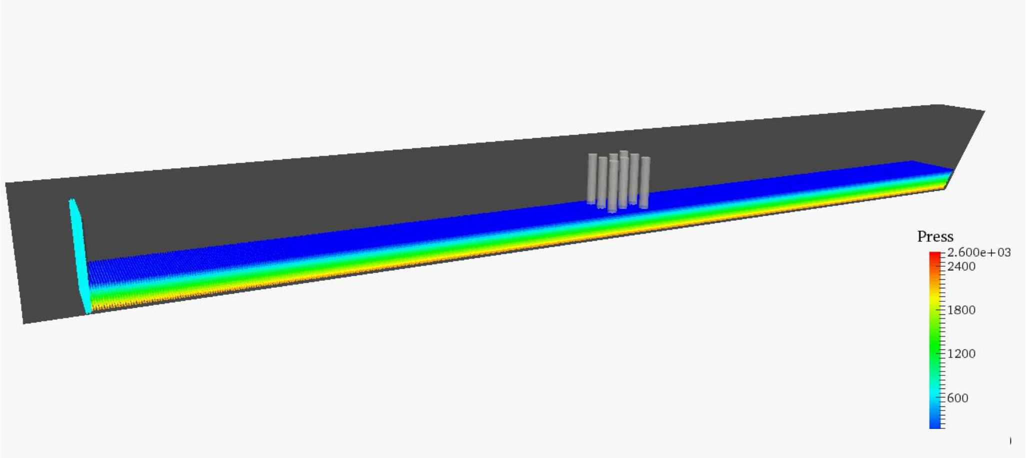


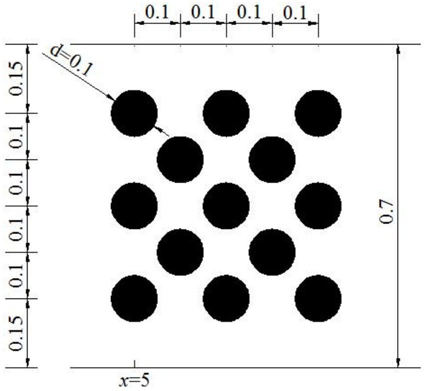
⑤ **Rectangular arrangement(m)**



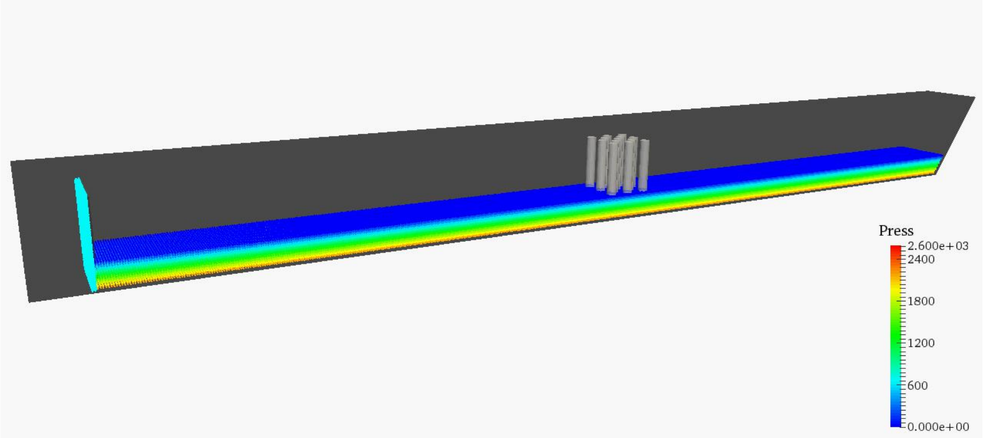


⑤ **Triangular arrangement(m)**





⑥ **Quincunx arrangement(m)**



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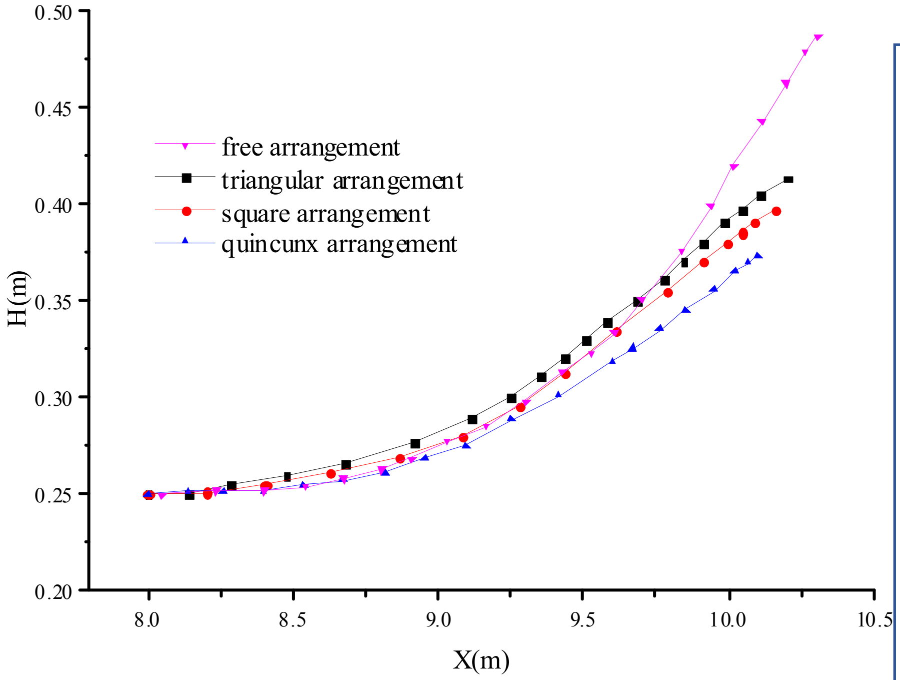
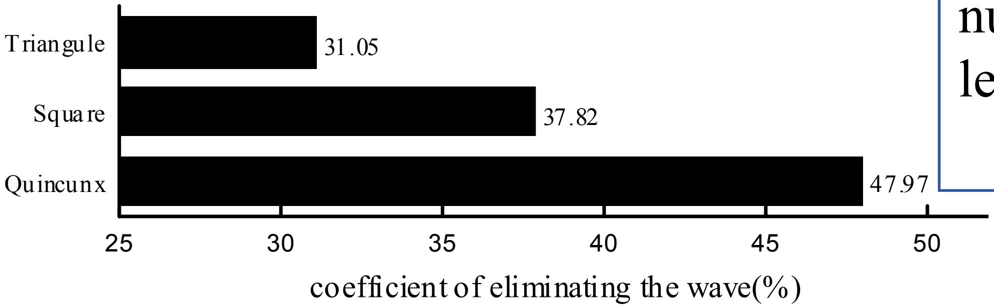


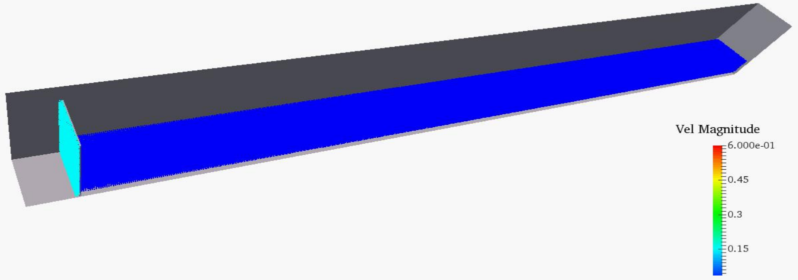
Free surface at the slope



The coefficient of eliminating the wave

In the case of the same area of the wave, the quincunx arrangement is the best, but The number of cylinders is the largest, there are as many as 13; square arrangement followed, the number is 9; triangular arrangement effect is poor, but the number of cylinders is the least by 8.

①



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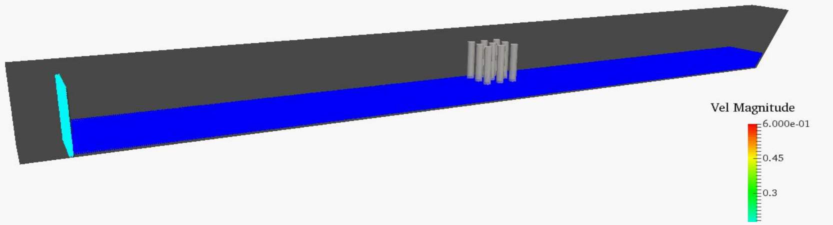

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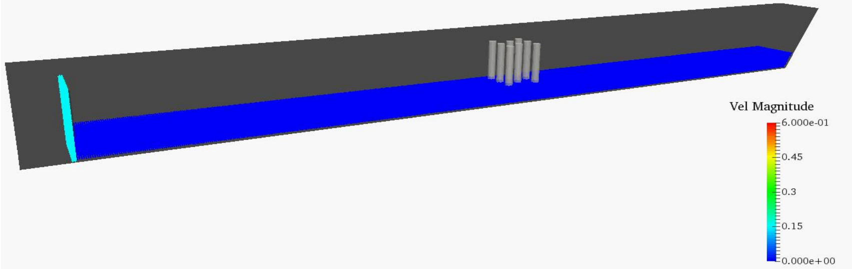

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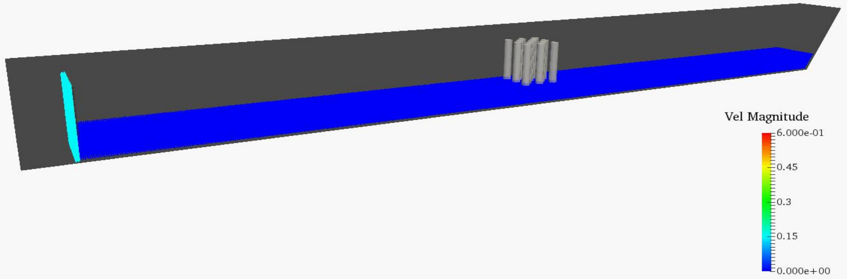

The Fifth Part

Conclusions

Conclusions

The model method is validated

The wave making process is well simulated through SPH. The calculated results of the height of the wave are found to be in a reasonable range compared with the experimental results. The numerical calculation verifies the accuracy of the SPH method for the simulated wave and the wave height after climbing on the slope.

Different number of layers of the upright cylindrical group

By using this method, this paper simulates the weakening effect of upright cylindrical group on the wave. The results show that the elimination of the wave group is getting better and better with the increase of the number of layers of the upright cylindrical group.

Different ways of the laying of the cylindrical group

In the same layout area, different ways of the laying of the cylindrical group to eliminate the effect of the waves is different. From the perspective of eliminating the waves, in turn from the quincunx arrangement, square layout, triangular layout of the anti-wave effect is gradually reduced.

Thanks

Reporter：Jing-jun Li