NUMERICAL INVESTIGATION ON THE PERFORMANCE OF A 'V' TYPE BREAKWATER

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Introduction

Breakwater is a common structure in coastal region, which is used to dissipate the energy from the sea and protect the structure and vessel near shore. Traditional breakwaters are effective, such as rubble mount, upright concrete caissons and so on, but they are more expensive in materials. For less cost, permeable breakwaters are paid more attention in recent years. Therefore, more and more novel type structures have been proposed. Neelamani and Rajendran investigated the wave transmission, reflection and dissipation characteristics of 'T' and '⊥' type breakwaters[1][2]. Günaydın and Kabdaşlı analysed the characteristics of 'U' and 'Π' type breakwaters in 2004 and 2007 respectively[3][4].

Recently, Computational Fluid Dynamics (CFD) simulation, as a new method differing from theoretical analysis and experimental measurement, can provide a comprehensive information about the flow field. More and more CFD software applied to fluid calculation are developed, for example, FLUENT, COMSOL, STAR-CCM+ and so on. Compared with the above, Open Field Operation and Manipulation (OpenFOAM) is an open source code written by C++, having a broad range of application including CFD, heat transfer, computational chemistry, even finance. OpenFOAM provides a multi-phase solver called Waves2FOAM, which can simulate wave propagation effectively.

In this paper, the character of a 'V' type breakwater will be discussed. Using the VOF model in OpenFOAM, 2D numerical simulation of regular waves through a 'V' type breakwater is carried out. In the present research, the performance of the breakwater is evaluated by measuring reflection and transmission coefficient.

Government equations

The numerical model is based on OpenFOAM, simulating two-phase incompressible flow of air and water. By secondary development of the CFD toolbox OpenFOAM, Jacobsen developed the Waves2Foam, a new utility to simulate wave propagation. The free surface is captured by the VOF method, and the continuity and momentum equations are solved using the finite volume method. The detailed information can be seen in the manual of Waves2Foam[5].

The continuity equation is as follows:

$$\nabla \cdot \mathbf{u} = 0 \tag{1}$$

The momentum equation is as follows:

$$\frac{\partial \rho \mathbf{u}}{\partial t} + \nabla \cdot \rho \mathbf{u}\mathbf{u}^T = -\nabla p^* + g \cdot (\mathbf{x} - \mathbf{x}_r)\nabla \rho + \nabla \cdot \mu_{tot} \nabla \mathbf{u} \tag{2}$$

The meaning of the above variables can find in the manual of Waves2Foam.

Numerical simulations

1. Model scale

According to the research of Günaydın and Kabdaşlı[3][4], the way of absorbing wave energy by the new type structure is cutting the orbits of water particles, so the breakwater should be set at the free surface. The position of breakwater is demonstrated by Fig.1 in detail. To cut wave more effectively, Günaydın suggested the horizontal length α_h should be greater than the horizontal orbit of water particles ($\alpha_h > \alpha = (H/2)\coth(2\pi h/L)$) and the vertical length α_v should be greater than the vertical orbit ($\alpha_v > \beta = H/2$).

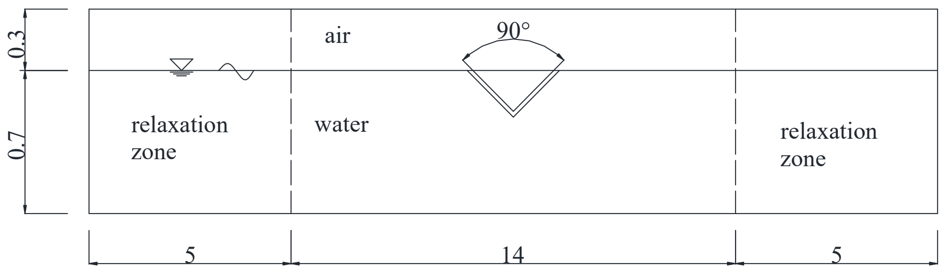

Figure 1: Sketch of the model

In the present study, the size of wave flume is 24m×1m×1m, and the characteristic of the regular wave is listed in the Table 1.

Table 1: The characteristic of wave

Height(m)	Period(s)	Depth(m)
0.05	1	0.7
0.10		
0.15		

Then, based on the wave parameters, the size of 'V' type breakwater can be calculated:

Table 2: The size of breakwater

Height(m)	α=$(H/2)\coth(2\pi h/L)$(m)	β=$H/2$(m)
0.05	0.0252	0.025
0.10	0.0503	0.05
0.15	0.0755	0.075

The horizontal length of the breakwater is set to 20 cm. By varying the angle of the breakwater, the vertical length can be determined.

2. Wave characteristics

In order to evaluate the performance of the breakwater, it is indispensable to measure the reflection and transmission coefficients. According to the two coefficients, the dissipation coefficient of energy can be calculated. These parameters are given below.

Reflection coefficient:

$$C_r = \frac{H_r}{H_i} \tag{3}$$

Transmission coefficient:

$$C_t = \frac{H_t}{H_i} \tag{4}$$

Dissipation coefficient:

$$C_I = \sqrt{1 - {C_r}^2 - {C_t}^2} \tag{5}$$

where H_i is the incident wave height, H_r is the reflection wave height and H_t is the transmission wave height. The incident and transmission wave height can be separated by the method presented by Goda and Suzuki[6].

Results and Discussion

Three different angles are chosen in the study, 60°, 90° and 120°. In the simulation, the bubbles are generated between the two plates, causing wave energy dissipation of wave energy. At first, the surface is calm. When the first wave contacts the structure, a jet is generated front the structure. After a second, the wave reaches the back plate, and an inverted jet prevents the propagation of waves. Lasing for a while, some bubbles occur between two plates, and it is the main reason of energy dissipation. The following figure shows the generation of the bubbles.

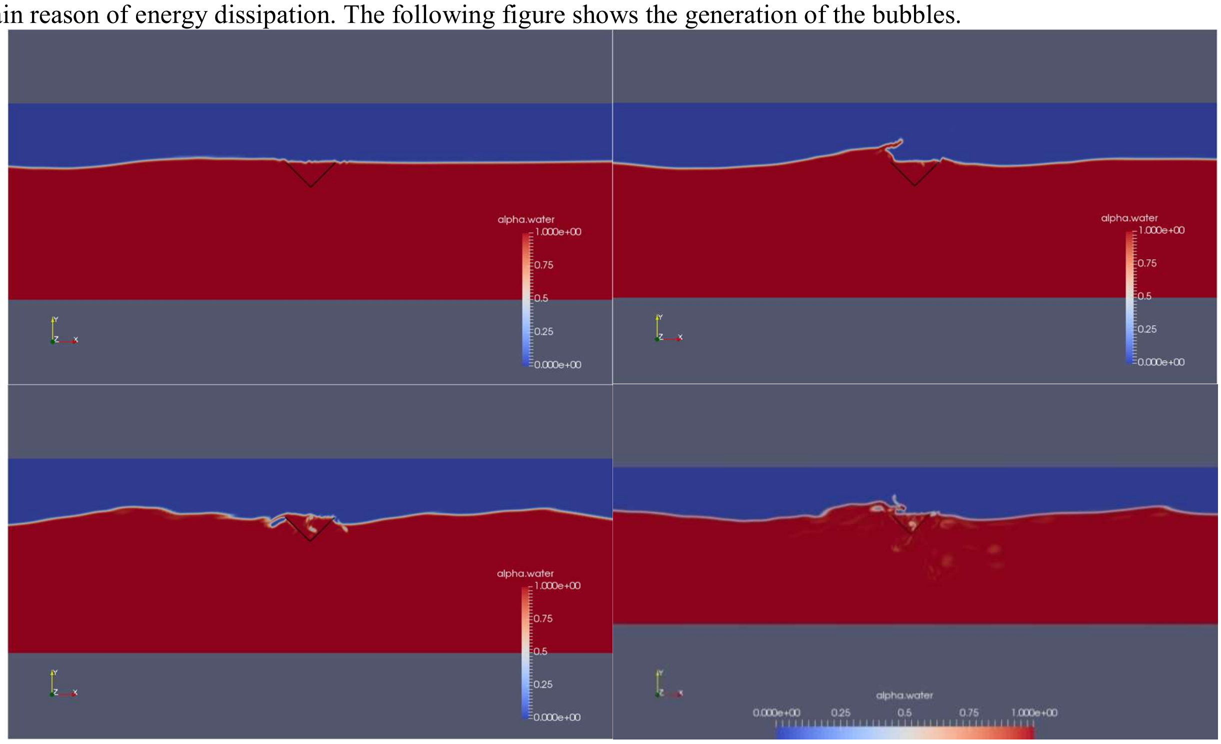

Figure 2: wave propagation between the two plates

Using the two-points separation method, the reflection and transmission coefficients can be calculated readily. After the simulation, the wave height of the front and back of the structure can be obtained by the Waves2Foam utility. On the basis of two-points separation method, the reflection wave and incident wave is separated through the wave height measured. Setting the inlet as origin, the breakwater is at 12 meters, so the wave height at 7, 8 and 16 meters is measured. The results of the case of angle 60° under wave height of 0.15m are as follows.

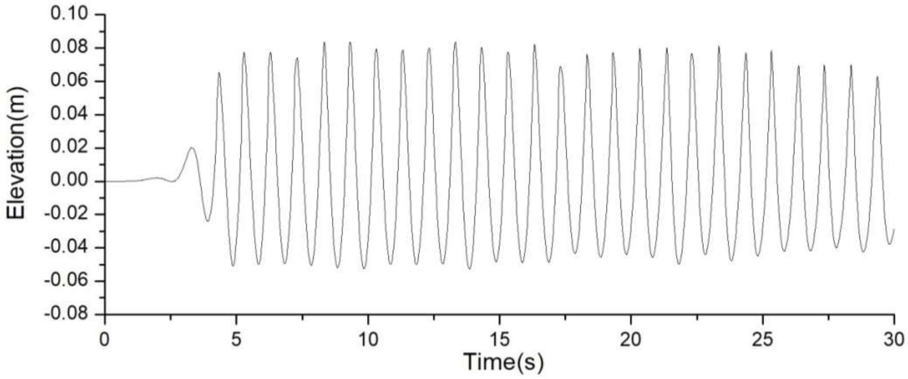

Figure 3: Surface Elevation (7m)

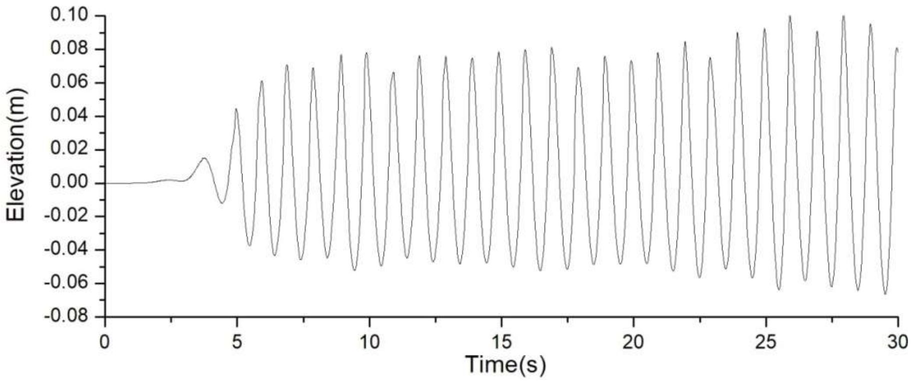

Figure 4: Surface Elevation (8m)

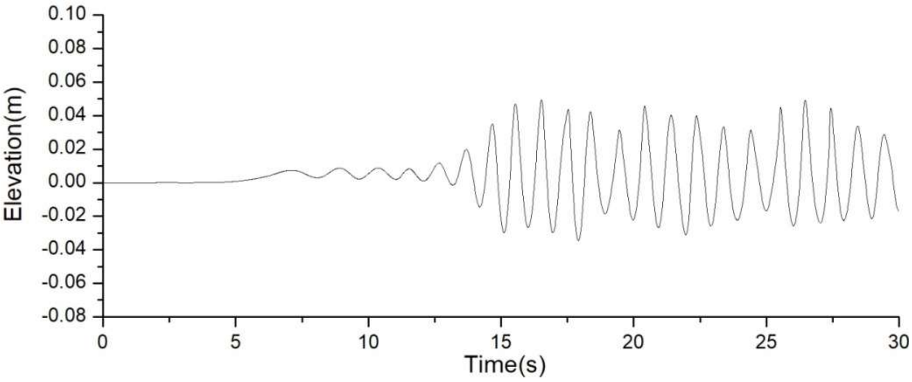

Figure 5: Surface Elevation (16m)

Table 3: The coefficients of simulations

	Angle(degree)	Reflection coefficient	Transmission coefficient	Dissipation coefficient
H=0.05m	60	0.732	0.261	0.629
	90	0.671	0.305	0.675
	120	0.713	0.386	0.621
H=0.10m	60	0.778	0.211	0.591
	90	0.784	0.264	0.561
	120	0.847	0.275	0.455
H=0.15m	60	0.509	0.222	0.832
	90	0.532	0.232	0.814
	120	0.559	0.184	0.809

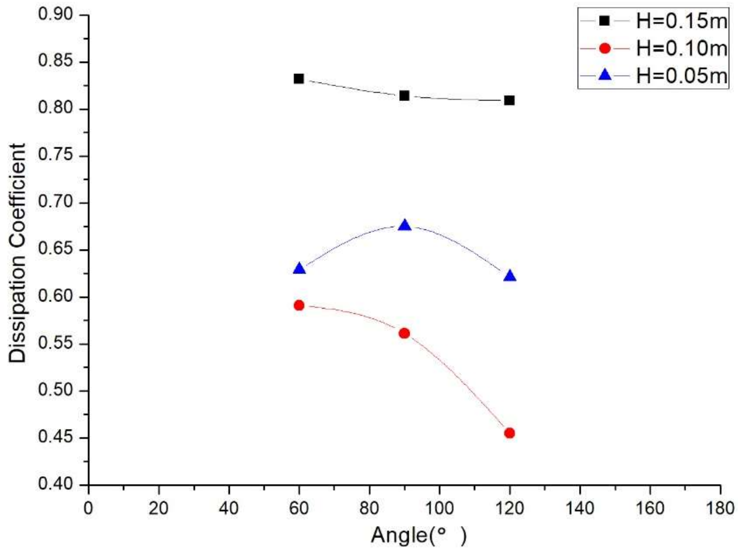

Figure 6: Dissipation coefficient

In the result, the dissipation coefficient of wave height of 0.05m and 0.1m is lower than 0.15m. With the angle of 90°, the vertical length of structure is 0.1m, which is double than β of the breakwater under the wave height of 0.1m. Between the two plates, two whole water orbits are remained. The structure cannot effectively cut the orbit of water particles, so the breakwater under the wave height of 0.1m has a poor performance. It is same under the wave height of 0.05m. The vertical length is 1.33 times than β under the wave height 0.15m, which is not integer times than β, so the dissipation coefficient is the larger than the other cases. The dissipation coefficient have the same property under other angles. The distance of two plates is shorter, namely the angle is smaller, the appearance of reverse jet is earlier and more frequent, so the dissipation coefficient is larger. With the increasing of angle, the dissipation coefficient decreases.

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