II－29　Tsunami Energy Dissipation in Mangrove Forest

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1. Introduction

Tsunami has caused huge casualties and fatalities in many countries, which are surrounded by tectonic plates. Historically, such as in South East Asia countries, in the last decade, thousands of people died due to their residential place were swashed by tsunami. Meanwhile, in those countries, the coastal vegetation named Mangrove is heavily vegetated. This natural protection is mostly recommended because of their very economy, effectiveness, and also for the environment reservation.

Several studies on tsunami passing through the vegetation have been reported. In the previous study, by using a hydraulic experiment as well as a numerical calculation, the effectiveness of the vegetation as a buffer zone to reduce the tsunami energy was investigated, and it was concluded that mangrove reduce the tsunami energy sufficiently.

However, in the previous studies, the effect of the model width and the water depth on tsunami energy dissipation has not been discussed in detail. Also, the drag coefficient (Cd) value under the group of pile condition is not still well understood. Therefore, to understand that contribution on tsunami energy dissipation, the study under such several conditions above is required.

In this study, the hydraulic experiment of the tsunami dissipation due to the mangrove model is performed under several conditions. Then, by using one dimensional numerical calculation with leap-frog scheme, the Cd values are calculated from the experimental data. The correlation between Cd with Re is discussed.

2. Experimental Set-up

Hydraulic experiments on tsunami energy dissipation in mangrove forest were carried out in an open channel with 26 m length and 0.8 m width as shown in Figure 1.

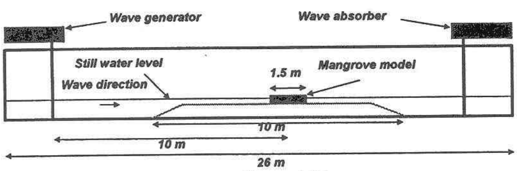

Figure 1 Channel Diagram

A model of beach and wetland, which is made of wooden panels, is set at the center of wave flume as illustrated in Figure 1. Mangrove model, which is 1.5 m long, is located at the center of the wetland. Measuring points were arranged at three locations as shown in Figure 2.

The Rhizophora Apiculata was selected as a model of mangrove, since it is popular and heavily vegetated in

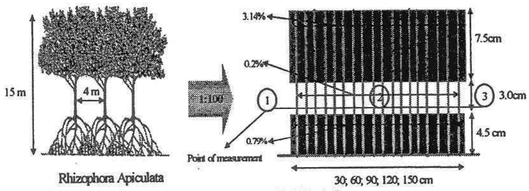

Figure 2 Prototype & Model

tropical country[5] (see also Figure 2-left side). The mangrove model dimension is adopted from the prototype condition in Indonesia. The height of the mangrove is assumed around 15 m and the diameter of the tree is about 20 cm.

While survey data is not available, the several field observations show that the spacing of the mangrove trees ranges widely. As for such above species, the tree spacing varies from 2 to 5 m, and in the present experiment, 4 m spacing of trunk is selected. The model of whole part of mangrove (roots, trunks, and leaves) is made of cylindrical bamboo with diameter (ϕ) 1.8-2 mm. The density of roots, trunks, and leaves is assumed 0.8%, 0.2%, and 3% respectively. The model width is 30, 60, 90, 120, and 150 cm.

Regarding to the channel's dimension and wave generator condition, the scale was 1:100, thus the dimension of the mangrove forest's model and its all part (roots, trunks, and leaves) is as shown in Figure 2.

The experiments were performed under several conditions. The incident wave height was designed from 15 mm to 40 mm, with 5 mm increment. To describe the effects of the water depth due to the tide, the model was run under three conditions of water depth, (6.5, 8.0, and 9.5cm).

3. Results and Discussion

The experimental results, as depicted in Figure 3a-c below, show the wave height decay ratio (Ht/Hi, where Ht is transmitted wave height, Hi is incident wave height) decrease proportionally with the model width.

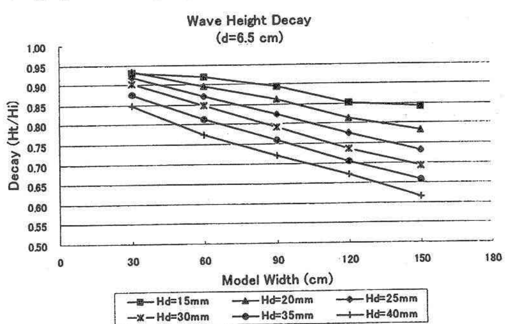

Figure 3a Wave Height Decay

As for 30 cm model width, the wave height decay ratio is around 0.85 to 0.95. The wave height decay rate decrease proportionally to the model width increase, down to around 0.63 to 0.85, which is depending on the water depth, and wave height.

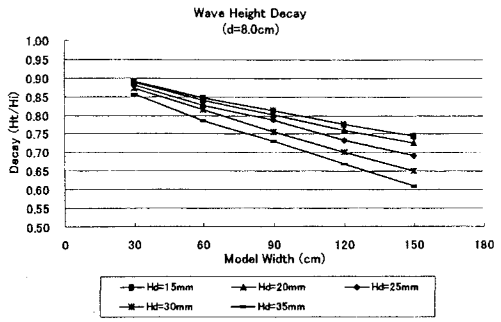

Figure 3b Wave Height Decay

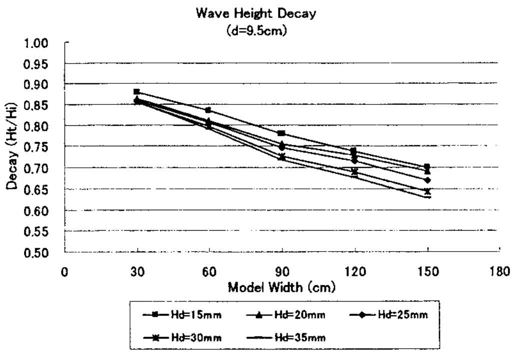

Figure 3c Wave Height Decay

By comparing the three graphs above, it can be concluded that the wave height decay ratio is influenced by the incident wave height. When the incident wave height is higher the wave height decay is also higher.

Meanwhile, regarding to the influence of water depth, in the deeper of water the influence of the incident wave height to the wave height decay ratio tend to small. Therefore, the correlation line is more convergent.

To obtain the Cd value, one-dimensional numerical calculation with the leapfrog scheme was used. The momentum equation which is included the resistance model based on Morison equation is written below[2,3,4]:

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{D}\right)+gD\frac{\partial \eta}{\partial x}+\frac{gn^2M|M|}{D^{7/3}}+\frac{Cd}{2}\frac{Ao}{\Delta X\Delta Y}\frac{M|M|}{D^2}=0$$

where: M is discharge flux; $D\ (=h+\eta)$ is the total depth, h is the still water depth; η is the water elevation, Cd is the drag coefficient; n is the Manning roughness coefficient; Ao is the projected area of vegetation; g is the gravitational acceleration

In this study, the incident wave height is much greater than the diameter of pile; therefore drag coefficient (Cd) predominates over to the inertia coefficient (Cm) [1]. So that, drag coefficient (Cd) is included in the calculation.

By using above model, Cd value can be adjusted to get the best fit of wave height decay ratio between numerical and experiment data. The calculation was carried out under each condition of the experiment.

Figure 4 shows the correlation between drag coefficient (Cd) and Reynolds number (Re), in which the Cd value slightly decreases as Re increases. The regression line is described as Cd=0.5818e^(-0.00034Re); as for 15mm to 40 mm wave height and 6.5cm to 9.5cm water depth, the Cd value gradually decrease from 0.50 to 0.38.

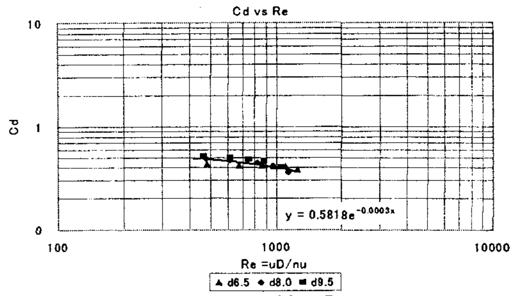

Figure 4 Cd vs. Re

By comparing the above Cd values to the Cd value for single pile, which is around 1.0 to 1.3[1], the Cd value in this study is small. It is caused by the effect of group of cylinder as a mangrove model. The spacing among the piles is small; the wake of each pile will affect the velocity acting on the pile, which is located behind. It means that, excluding the most front pile; all piles will be in wake area. This condition might bring the horizontal particle velocity decrease resulting in the forces decrease. One more possible reason is the fact that the velocity near leaves part is much smaller than that of the other parts. Those complicated factors lead to the decreasing of the Cd value.

4. Conclusion

The hydraulic experiment as well as the one-dimensional numerical calculation on the tsunami energy dissipation due to the mangrove model resistance has been carried out. The graphs of wave height decay ratio were obtained. Based on the experiment result, the mangrove model significantly reduces the tsunami by approximately 35%. By using numerical calculation with leapfrog scheme, together with the experiment data under several conditions, the data set of Cd value in this experiment were obtained which is ranging from 0.38 to 0.50.

References

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