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Experimental Study of Wave Reflection in Breakwater Overtopping Catcher Model

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Abstract. Breakwater overtopping catcher model is a breakwater or shore protection model, which can accommodate or catch wave overtopping. This breakwater model is different from most other conventional breakwater models, at the back of this breakwater model, an opening is made to form a reservoir. This reservoir serves to collect overtopping wave, which is then collected and released back to the sea through an energy conversion process. How many waves overflow at the peak of the breakwater model is strongly influenced by several factors, one of which is the wave characteristics. This research was carried out experimentally to determine the characteristics of the waves, especially the influence of wave steepness to the wave reflection coefficient. The experiment was carried out in a wave flume with regular wave generation. Variations of research carried out on variations in the model that is slope and freeboard and wave variations that is period and wave height. The results of the study show that the wave reflection coefficient decrease with the increase of wave steepness, it is also seen that steep slopes produce the largest wave reflection coefficient.

1. Introduction

The breakwater is a coastal protection building that works by dissipating wave energy. Whereas sea waves are one of the renewable energy sources that are very environmental friendly. These ocean waves energies have the potential to be harnessed, rather than being destroyed. Ocean waves as a source of renewable energy are always available and even abundant in island countries like Indonesia. This energy source should not be destroyed by a breakwater but should be utilized.

The use of ocean waves for energy conversion has been known for a long time as the wave energy converter (WEC). Wave energy converter is a device to convert ocean wave energy into electrical energy. At present, the number of WEC devices has been very large, and even some of the devices have already been applied, but the device which is then termed as a single stand wave energy converter requires a very expensive cost when applied. Therefore, the researcher considers an idea to reduce the high cost of the single stand WEC with the concept of integrating the breakwater with the wave energy converter.

The integration of WEC devices with other marine facilities has become common especially for near-shore applications. The main reason is triggered by better economic viability through cost-sharing on construction, installation, maintenance, and operation as aligned with the main issue faced especially by the current stand-alone WEC device [1].

The breakwater overtopping catcher model is a breakwater model that not only functions as a coastal protector but also functions as a wave energy converter. This breakwater model is different from most

other conventional breakwater models, at the back of this breakwater model, an opening is made to form a reservoir. This reservoir serves to collect overtopping wave, which is then collected and released back to the sea through an energy conversion process.

This paper aims to determine the characteristics of the waves, especially the influence of wave steepness to the wave reflection coefficient on the breakwater overtopping catcher model.

1.1 Wave Reflection Coefficient

Wave reflection is one form of wave deformation and is one of the important parameters in coastal or breakwater protection studies. When a wave comes and hits an obstacle or coastal structure, some of the wave energy will be reflected, some will be transmitted, and some will be destroyed (dissipation). To know how much a coastal structure material reflects waves, it is usually known from how much its wave reflection coefficient. The wave reflection coefficient can be calculated using the following equation [2, 3].

$$C_r = \frac{H_r}{H_i} = \sqrt{\frac{E_r}{E_i}} \quad (1)$$

The formula shows that the reflection coefficient is the ratio between the height of the reflected wave to the height of the incident wave, where the height of the reflection wave is symbolized by H_r and the height of the incident wave is symbolized by H_i . The reflection wave coefficient can also be the root of the comparison of the reflection wave energy to the incident wave energy.

1.2. Wave Steepness

The wave steepness is also one of the most important wave characteristics that can give an idea of an incoming wave that will hit a coastal structure. An incoming wave has a height and a wavelength, and the ratio between the height and the wavelength ($s_0 = H_m_0/L_0$) is known as the wave steepness. In general, when the wave steepness is about $s_0=0.01$ that it can indicate that it is a typical swell sea and when the wave steepness is about $s_0 = 0.04$ to 0.06 that it can indicate that it is a typical wind sea. Long-period waves are often be associated with the Swell sea, where the main parameter that affects overtopping is the period. Definition of wave steepness shown in Figure 1.

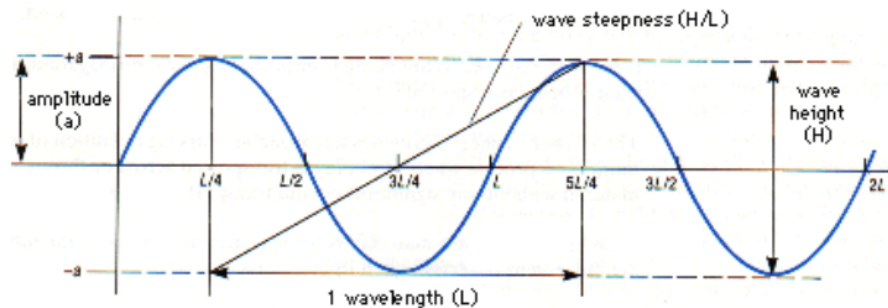


Figure 1. Definition of wave steepness [4]

Also, wind seas may become seas with low wave steepness if the waves break on a gentle foreshore. By wave breaking the wave period initially does not change much, but the wave height decreases. This leads to a lower wave steepness. A low wave steepness on relatively deep water means swell waves, but for depth limited locations it often means broken waves on a (gentle) foreshore [5].

2. Experimental Study

2.1. Experimental Facility and Equipment

This research is experimental research conducted in the hydraulics laboratory of the Civil Engineering Department Faculty of Engineering Universitas Hasanuddin. This experimental study carries out physical modeling where the scale used is 1:20 length scale. Breakwater building models are tested in a wave channel which has a length of 15 m and a width of 30 cm, the effective depth of the wave channel is 45 cm. The generator of the wave is a flap type. Wave making flaps create wave motion. The top of the flap is connected to the drive plate using a stroke and the bottom of the flap is a hinge. Flap movement is a rotational motion that is controlled through a rotary motion of the drive plate. This flap movement/flutter that raises the waves. The wave flume photo is shown in Figure 2.



Figure 2. Wave flume photos used in the study

The wave generators on the wave channel generated wave height in the range of 2-12 cm and wave periods in the range of 0.6 to 6 seconds. The wave generators generated the regular wave. By adjusting the stroke in several variations to change the magnitude of the flap deviation, the wave height can be varied. And by adjusting the rotational speed of the drive plate, the wave period (T) can be varied.

2.2. Physical Model

The breakwater overtopping catcher model is a breakwater model that not only functions as a coastal protector but also functions as a wave energy converter. This breakwater model is different from most other conventional breakwater models, at the back of this breakwater model, an opening is made to form a reservoir. This reservoir serves to collect overtopping wave, which is then collected and released back to the sea through an energy conversion process. The breakwater overtopping catcher model is in 1:20 scale length. The freeboard of the breakwater overtopping catcher model is varied with 3 variation which is 12.5 cm, 10 cm, 7.5 cm, and the slope of the breakwater overtopping catcher model is varied with 3 variation which is 0.5, 0.4, and 0.3 or 1:2, 1:2.5 and 1:3 respectively. The freeboard and slope variations (model parameters) are shown in Figure 3.

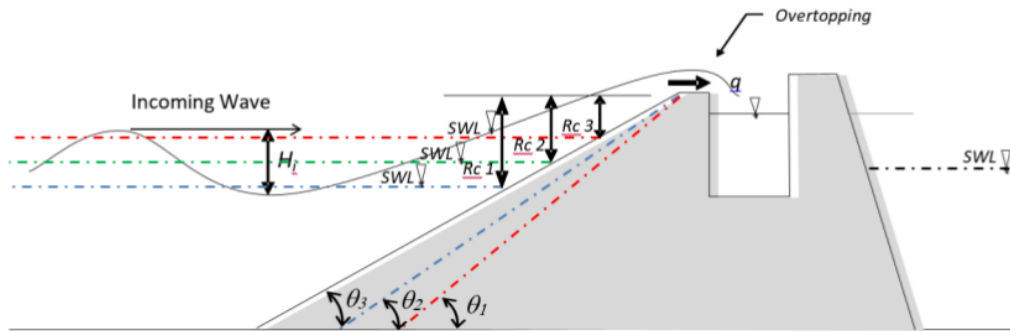


Figure 3. Illustration of slope variations and freeboard variations of the breakwater overtopping catcher model

The incoming wave height (H_i) varied with three variations which are 6 cm, 7 cm, and 8 cm. The wave period (T) which is directly related to the wavelength (L) also varied with seven variations which are 0.6 s, 0.7 s, 0.8 s, 0.9 s, 1.0 s, 1.2 s, and 1.3 s. The wave period and the incoming wave height (wave parameters) are presented in Table 1.

Table 1. The variation of wave parameters

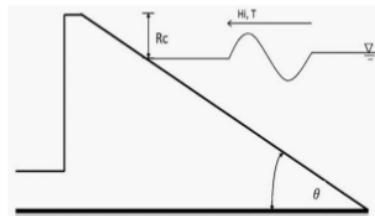
Incoming wave Parameters	Wave parameters variation
Wave Height (cm)	6 - 8
Wave Period (s)	0.6 - 1.3

3. Result

The experimental study carried out is summarised in Table 2. The test carried out with a smooth impermeable slope formed the reference case.

Table 2. Test condition summary

Model	Tan θ	Rc	H_i	T
1	0.5 (slope 1 : 2)	12.5 cm	3 variation	7 variation
		10 cm	3 variation	7 variation
		7.5 cm	3 variation	7 variation
2	0.4 (slope 1 : 2.5)	12.5 cm	3 variation	7 variation
		10 cm	3 variation	7 variation
		7.5 cm	3 variation	7 variation
3	0.3 (slope 1 : 3)	12.5 cm	3 variation	7 variation
		10 cm	3 variation	7 variation
		7.5 cm	3 variation	7 variation



Figures 5 (a)-(c) shown the resulting graph of the relationship between wave steepness and the wave reflection coefficient, with slope variations and freeboard variations on the breakwater overtopping catcher model.

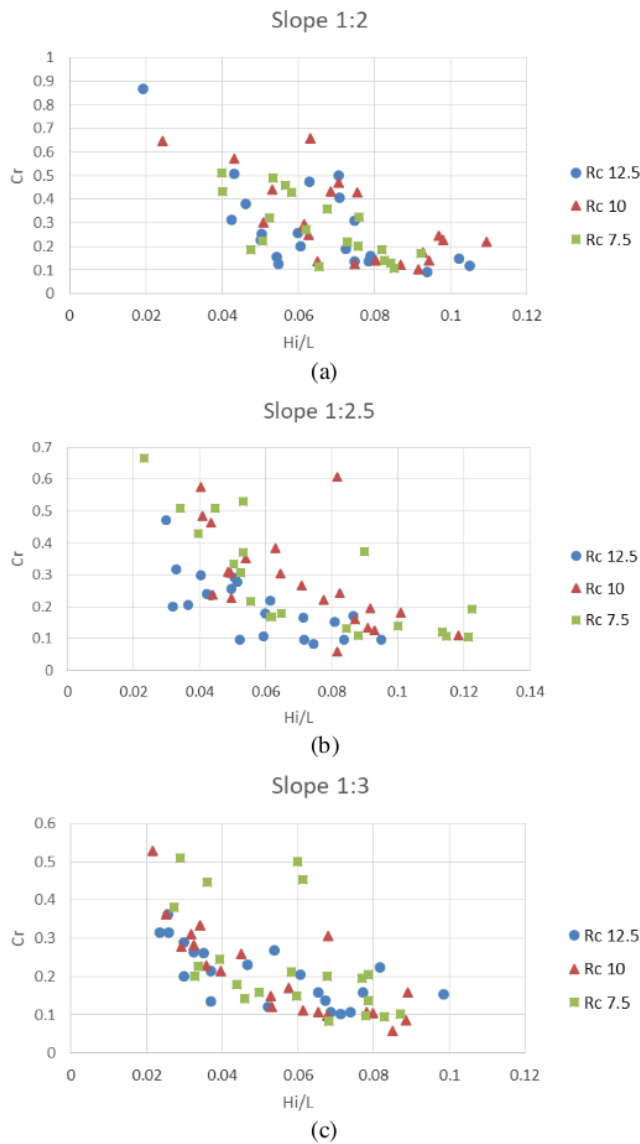


Figure 4. (a) Relationship between wave steepness and wave reflection coefficient for Rc 12.5 cm, Rc 10 cm, and Rc 7.5 cm for slope 1:2; (b) Relationship between wave steepness and wave reflection coefficient for Rc 12.5 cm, Rc 10 cm, dan Rc 7.5 cm for slope 1:2.5; (c) Relationship between wave steepness and wave reflection coefficient for Rc 12.5 cm, Rc 10 cm, dan Rc 7.5 cm for slope 1:3

From the chart in Figure a (slope 1 : 2), it appears that the wave steepness is in the range of values of 0.02 to 0.12 and the resulting reflection coefficient is in the range of values of 0.1 to 0.9. From the chart in Figure b (slope 1 :2.5), it appears that the wave steepness is in the range of values of 0.02 to 0.12 and the resulting reflection coefficient is in the range of values of 0.1 to 0.7. From the chart in

Figure c (slope 1 : 3), it appears that the wave steepness is in the range of values of 0.02 to 0.1 and the resulting reflection coefficient is in the range of values of 0.1 to 0.6.

4. Conclusions

A few conclusions can be drawn from figure 5 (a, b, c). Firstly, in all freeboard heights condition shown that large wave steepness value, results in a small wave reflection coefficient value, or it can be said that, wave reflection coefficient decrease with the increase of wave steepness. Secondly, it appears that the steeper the slope of the model, the larger the wave reflection coefficient produced. It can be seen that slope 1 : 2 produces the highest wave reflection coefficient values.

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