The effect of wave reflection coefficient to the breaker parameter on OWEC breakwater

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Abstract. OWEC breakwater is a coastal structure with an integrated concept of the breakwater and overtopping wave energy converter. This breakwater WEC concept (OWEC breakwater) model has a reservoir at the rear of the breakwater peak. This reservoir serves to catch and collect overtopping waves that overflow through the top of the breakwater. The amount of overtopping discharge is influenced by many factors, one of them is the characteristics of the incoming wave, including the characteristics of the breaking wave on the surface of the structure, named the breaker parameter. The effect of wave reflection coefficient to the breaker parameter on OWEC (overtopping wave energy converter) breakwater is investigated experimentally as a preliminary study. The study is carried out in wave flume with regular waves. The OWEC breakwater model is simulated with slope variations and freeboard variations. The result showed that most of the breaker parameter types obtained are plunging (0.4 < ξ < 2) and surging (ξ > 2), the result also showed that the higher the value of reflection coefficient, the higher the value of the breaker parameter.

1. Introduction

Most of the earth is the ocean. The ocean holds a lot of potentials, one of which is the wave. So far, the waves are always connected to the destructive force when they hit a coastal or a coastal building, but behind that, the waves can actually be used as a renewable energy source.

WEC (Wave Energy Converter) is a concept of utilizing wave energy for conversion. Many devices have been made to implement the WEC concept. But devices made specifically only for energy conversion, tend to be very expensive.

The breakwater is a coastal protection building that was built at a high cost that serves only as a wave energy destroyer, whereas with the potential of waves as a source of energy, the actual WEC concept can be integrated with breakwater with the aim of reducing expensive costs (cost-sharing on construction).

The concept of integrating WEC with breakwater has also been pretty much a research object for researchers, such as [1-4]. Most of the concepts of integrating WEC with breakwater use overtopping as its main mechanism. The use of overtopping in the concept of WEC and breakwater integration, then by researchers named OWEC breakwater (Overtopping Wave Energy Converter) breakwater.

OWEC breakwater is a coastal protection model with two functions, coastal protection, and wave energy converter. This breakwater WEC concept (OWEC breakwater) model has a reservoir at the rear of the breakwater peak. This reservoir serves to catch and collect overtopping waves that overflow through the top of the breakwater.

The most influential mechanism in this research on OWEC breakwater is overtopping discharge. The amount of overtopping discharge is influenced by many parameters, one of which is characteristics of
the incoming wave, including the characteristics of the breaking wave on the surface of the structure, which is called the breaker parameter.

Breaking waves is one of the most important phenomena that occur in coastal processes and coastal structures. Breaking waves can cause many negative and positive impacts. Negative impacts of breaking waves on the beach and the coastal structure can be coastal abrasion, sediment transport, scouring, high pressure on a structure that can cause damage, structure destruction and so on. The positive impact which is can be very advantages these days is if the breaking waves can be conditioned in such a way so that the large energy of the breaking waves (surging waves) can continue to crash upward with an overtopping mechanism and captured to be accommodated in the reservoir to be used as a wave energy converter.

Breaking waves on the coastal structure can be caused by two major things: the influence of waves and the influence of the geometry of the coastal structure. Based on the empirical formula, the influence of waves is the wave steepness, which is the ratio between the height of the incoming wave with the wavelength. The incoming wave is the wave that has not been affected by wave reflection.

In fact, a wave is one of the most difficult and dynamic phenomena, the wave that coming into the structure and crash the structure will produce wave reflection. The wave reflection in front of the structure can affect the incoming wave, which in turn affects the breaking wave. The aim of this paper is to determine the effect of wave reflection coefficient to breaker parameter of the breaking waves on the OWEC breakwater model.

1.1 Wave reflection coefficient

A wave that comes and hits the coastal structure, some of the wave energy will be transmitted, some will be destroyed (dissipation) and some will be reflected. According to the study, the wave reflection coefficient can be calculated using the following equation [5].

\[ K_r = \frac{H_r}{H_i} = \sqrt{\frac{E_r}{E_i}} \tag{1} \]

where \( K_r \) is the wave reflection coefficient which is a dimensionless parameter, \( H_r \) is the height of the wave reflection, \( H_i \) is the wave height, \( E_r \) is the energy of wave reflection, and \( E_i \) is the energy of incoming wave.

1.2 Breaker parameter

Breaker parameter or Iribarren number is a dimensionless parameter used to model several effects of (breaking) surface gravity waves on beaches and coastal structures. The parameter is named after the Spanish engineer Ramón Iribarren Cavanillas (1900–1967), who introduced it to describe the occurrence of wave breaking on sloping beaches. According to the research, the breaker parameter is defined as [6]:

\[ \xi = \frac{\tan \alpha}{\sqrt{\frac{H}{L_0}}} \tag{2} \]

where \( \xi \) is the breaker parameter or Iribarren number, \( \alpha \) is the angle of the seaward slope of a structure, \( H \) is the wave height, \( L_0 \) is the deep-water wavelength. The combination of structure slope and wave steepness gives a certain type of wave breaking, which is spilling, plunging, and surging, as shown in figure 1.

According to the study, for \( \xi > 2 - 3 \) waves are considered not to be breaking (surging waves), although there may still be some breaking, and for \( \xi < 2 - 3 \) waves are breaking [7].

Waves on a gentle foreshore break as spilling waves and more than one breaker line can be found on such a foreshore. Plunging waves break with steep and overhanging fronts and the wave tongue will hit
the structure or backwashing water. The transition between plunging waves and surging waves is known as collapsing.

The wavefront becomes almost vertical and the water excursion on the slope (wave run-up + run down) is often largest for this kind of breaking. Values are given for the majority of the larger waves in a sea state. Individual waves may still surge for generally plunging conditions or plunge for generally surging conditions.

| Diagram | Spilling breaker | Plunging breaker | Surging breaker |
|---------|------------------|------------------|-----------------|
| Breaking point | $\varphi = \frac{\tan \alpha}{\sqrt{H_e / L_0}} < 0.4$ | $0.4 \leq \varphi = \frac{\tan \alpha}{\sqrt{H_e / L_0}} \leq 2$ | $2 < \varphi = \frac{\tan \alpha}{\sqrt{H_e / L_0}}$ |
| $H_e / d_3 = 0.8$ | $H_e / d_3 = 0.8$ to 1.2 | $H_e / d_3 = 1.2$ |
| Wave overtopping** | $q = \frac{0.067}{\sqrt{h^2_{m0}}} \frac{1}{\sqrt{\tan \alpha}} \frac{1}{\gamma_s \gamma_o \gamma_f Y_f}$ | $q = \frac{1}{\sqrt{h^2_{m0}}} \frac{1}{\gamma_s \gamma_o \gamma_f Y_f}$ |

Figure 1. Breaker type classification [8].

2. Experimental study

2.1. Wave flume

The physical model test was carried out at Hydraulic Laboratory Faculty of Engineering Hasanuddin University in a 1:20 length scale. The wave channel has a length of 15 m and a width of 30 cm, the effective depth of the wave channel is 45 cm. The illustration of experimental study shown in figure 2.

Figure 2. The illustration of experimental study in wave channel.

The height of the incident wave height that can be adjusted on the wave channel is 2-12 cm, with periods ranging from 0.6 to 6 seconds. While the type of wave generated is a regular wave. The incident wave height can be varied by changing the rotation lever on the stroke plate whereas in the period setting can be adjusted by changing the speed of the “stroke” plate.
This breakwater research model with the concept of WEC (OWEC breakwater), carried out two kinds of variations, namely variations in the physical model, and variations in wave conditions. Variations on the physical model are by changing the height of the freeboard by three heights and changing the slope by three variations. Whereas in the variation of the wave condition, the incident wave height is varied three times and the length of the wave period is varied seven times.

2.2. OWEC breakwater physical model
The OWEC breakwater is the coastal protection model that is equipped with a reservoir at the top of the structure to collect water that overflows from the top of the structure (overtopping). The model is in 1:20 scale length. The freeboard of the OWEC breakwater model is varied with 3 variations 12.5 cm, 10 cm, 7.5 cm, and the slope of the OWEC breakwater model is varied with 3 variations 0.5, 0.4, and 0.3 as shown in figure 3 and figure 4.

![Figure 3. Sketch of freeboard variation.](image)

![Figure 4. Slope variation.](image)

Three variations of incident wave heights are 4 cm, 5 cm, and 6 cm. Seven variations of the wave period are 0.6 to 1.3 seconds.

3. Results
This study wants to examine how the effect of wave reflection in the form of dimensionless parameters (wave reflection coefficient) on the value of the breaker parameter generated in the OWEC breakwater model. By knowing the range of breaker parameter values that occur in this OWEC breakwater model, it can be seen the condition and type of breaking waves that occur on the slope of the model, which then indirectly affects the number of waves that will creep (run-up) and then overflow through the peak of
the breakwater. Figure 5 shown the correlation of the reflection coefficient and the breaker parameter with slope variations and freeboard variations on the OWEC breakwater model.

Figure 5. Correlation of reflection coefficient $Kr$ and breaker parameter $\xi$ in slope variations and freeboard variations.

The result shown in figure 5 is the higher the value of the reflection coefficient, the higher the value of the breaker parameter. Where the value of the breaker parameter obtained is in the range of the plunging breaker parameter type ($0.4 < \xi < 2$) and surging breaker parameter type ($\xi > 2$). The surging breaker parameter dominantly produced by $Kr > 0.2$ in all experimental conditions. The shape of the surging & plunging breaker type obtained in this experiment is shown in figure 6.
Figure 6. Phenomena of surging and plunging breaker type in the model.

4. Conclusions
Wave reflection has a significant effect on the breakers parameter. The greater the reflection wave coefficient, the greater the breaker parameter value. This means, the increasing of the surging occurrences, the increasing of overtopping discharges. The value of the breaker parameters are obtained in the range of the plunging breaker type parameters (0.4 <ξ <2) and surging breaker type parameters (ξ> 2). The surging breaker parameters (ξ> 2) are produced by Kr > 0.2 in all experimental conditions. In this condition, the wave energy captured is ultimately increasing due to the increase of overtopping discharge. The results of this preliminary experiment provide good prospects for the development of wave energy conversion through overtopping mechanisms. Further research will examine comprehensively the wave deformation in the OWEC breakwater and its effect on overtopping discharge.

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