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Experimental Study of the Relationship between Slope and Opening Height of OWC Type Wave Breaker Model on Wave Reflection

Riswal Karamma[1]*, A.Subhan Mustari[1], Mukhsan P.Hatta[1] , Silman Pongmanda[1], Ariningsih Suprapti[1] , St.Nur Rahmah[1], Muhammad Rifaldi Mustamin[2]
[1]Departement of Civil Engineering. Hasanuddin University, Indonesia
[2]Departement of Civil Engineering. State Polytechnic of Ujung Pandang, Indonesia
*Email: riswalk@unhas.ac.id

Abstract

Breakwater is a very effective wave dampening building to be used as a coastal protection against coastal abrasion by destroying wave energy before it reaches the coast. The working mechanism of the OWC type is the rise and fall of ocean waves which will push the air in the OWC column, then will rotate the turbine connected to the generator to produce electricity. This study aims to determine the effect of slope and opening height on breakwater on wave reflection. Then analyze the parameters that affect the amount of wave reflection and compare the resulting wave parameters. The method used was experimental based. The resulting wave characteristics consist of three depth variations, three period variations and three stroke variations. The research model used is an Oscillating Water Column (OWC) type breakwater with slope variations of 45°, 60° and 90° and open wall variations as high as 5 cm, 10 cm and 15 cm. The reading of the water level fluctuation is done electronically through the reading of the wave monitor.The results showed that the magnitude of the reflection coefficient is influenced by structural parameters, namely the slope and height of the model opening and hydraulic parameters, namely depth, period and wave height. The effect of the model slope on the reflection coefficient is that the greater the slope, the greater the reflection coefficient value. The effect of the model opening height is that the greater the opening height, the smaller the reflection coefficient value.

Keywords: Breakwater, OWC type Breakwater, Reflection Coefficient.

1. INTRODUCTION

Indonesia is the largest maritime country in the world. Indonesia's sea area reaches 6.4 million km2 or about 77% of Indonesia's national territory, with a coastline that stretches along 108,000 km [1]. The vast ocean area stores enormous energy. Therefore, the existing potential of ocean energy is expected to be utilized optimally, one of which is by converting the potential energy and kinetic energy contained in ocean waves into electrical energy [2].

Basically, the working principle of technology that converts ocean wave energy into electrical energy is to accumulate ocean wave energy to drive a turbine generator [3]. Currently, various technologies have been developed to convert wave energy into power generation, including Oscillating Water Colums (OWC), Overtopping Devices (OTD) and Wave Activated Bodies (WAB). Some of these technologies can be placed on the shoreline, nearshore or offshore and some can be applied to breakwater structures. Such as the caisson- type breakwater built in 1989 at Harbor Wall, Sakata Port, Japan which works as a breakwater as well as an electrical energy generator [4].

The review of wave reflection is one of the important aspects in coastal building planning, including in breakwater planning for wave energy utilization in this study. This is because wave reflection can cause fluctuations in sea level that can affect the amount of wave energy generated which will later be utilized as a power plant [5].

2. METHODS

The research was conducted at the Hydraulics Laboratory, Department of Civil Engineering, Faculty of Engineering, Hasanuddin University. The method used is physical modeling experimentally in the laboratory. The type of breakwater used is the OWC type with a model scale of 1:20. The model is made of acrylic material with model length = 30 cm, bottom width = 100 cm, top width = 30 cm and model height = 35 cm, adjusted to the size of the available wave flume.

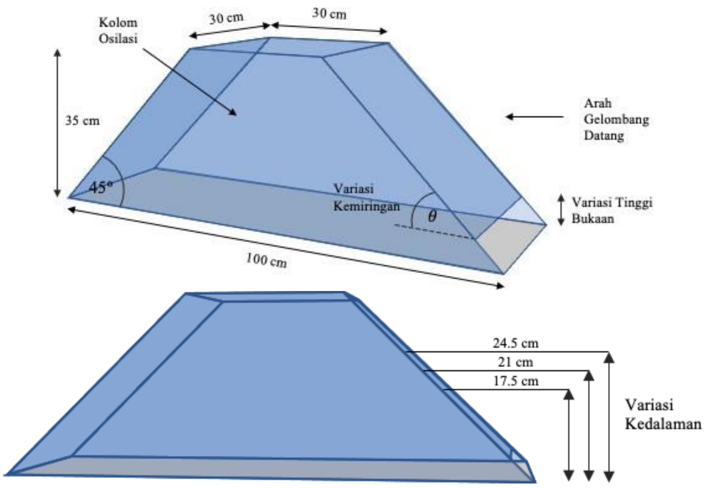


Figure 1. Test Model of OWC Type Breakwater

The position of the model in the wave flume and the measuring equipment can be seen in Figure 2. The model is placed in the center of the wave flume, at the front of the model there is a wave generating machine that supplies incident waves with a certain height and period. At the back of the model is a wave absorber to reduce the influence of waves on the wave flume.

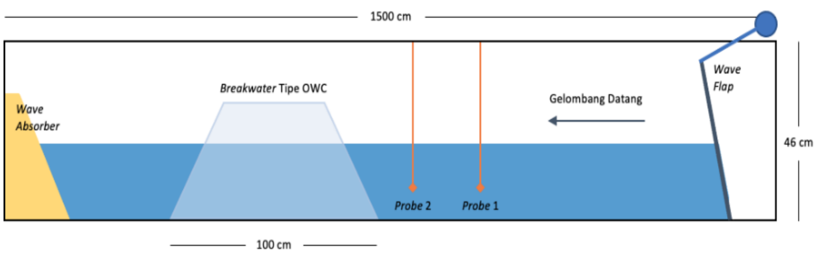


Figure 2. Test Model of OWC Type Breakwater

The breakwater structure parameters used are varied based on the slope of the structure and the opening height at the front of the breakwater. The hydraulic parameters such as depth and period are also varied. The variation of structural parameters and hydraulic parameters can be seen in the following table.

Table 1. Research Parameters

Parameter Description			
Notation	Definition	Parameter Type	Research Variations
d	Water Depth	Hydraulic Parameters	17.5 cm 21 cm 24.5 cm
T	Wave Period	Hydraulic/Wave Parameters	1.3 seconds 1.4seconds 1.5 seconds

Parameter Description			
Notation	Definition	Parameter Type	Research Variations
θ	Slope	Structure Parameters	45° 60° 90°
Hb	Opening Height	Structure Parameters	5 cm 10 cm 15 cm

Wave height data was collected using a replica model of a breakwater placed in the center of the wave flume. The wave generating machine used is a flap type with the bottom of the flap in the form of a hinge and the top of the flap connected to the drive disk using a stroke. The amount of flap deviation was adjusted according to the stroke scale and the wave period was adjusted by rotating the period variator on the main engine. Wave height readings were taken using a wave probe set in front of the model at ½ and ¼ wavelength, corresponding to the wave depth and period. The duration of data collection was set by adjusting the frequency and number of waves on the oscilloscope application. Furthermore, data collection was started by pressing the 'wave make start' button on the control panel, then starting the recording on the oscilloscope application when the wave stabilized or a few moments after the wave was generated. After the graph appears on the oscilloscope application, the recording is stopped and the machine is turned off by pressing the 'wave maker stop' button on the control panel. After that, the wave height data readings were then analyzed to determine the wave reflection [6].
Wave height analysis is required to determine the reflection coefficient. It can be calculated from the ratio between the reflected wave height and the incident wave height [7].

3. RESULTS AND DISCUSSION

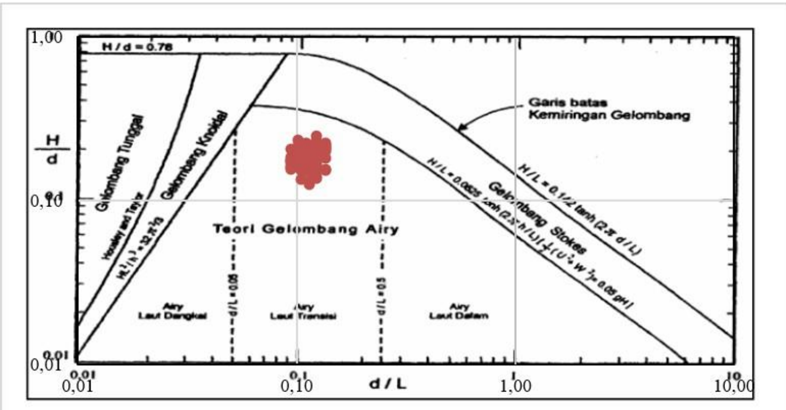


Figure 3. Wave Data Distribution

The distribution of wave data in this study is in the transitional sea wave area. The data obtained is then analyzed through several stages. The wave theory used is linear wave theory or small amplitude wave theory (Airy Wave Theory). The results of the analysis of the influence of wave parameters and breakwater structure parameters on reflection waves will be presented in the form of tables and graphs.
In this research, wavelength data is used to determine the location of the wave probe in the wave flume. Determination of the wavelength value is obtained through the iteration method of the wavelength equation using a function of period (T) and water depth (d) [7]. The wavelength (L) taken is the nth data with an error value close to zero.

Table 2. Wavelength Data (L)

d (cm)	T (seconds)	L0 (cm)	L (cm)
	1.3	263.640	181.859

d (cm)	T (seconds)	L0 (cm)	L (cm)
24.5	1.4	305.760	198.765
	1.5	351.000	215.487
21	1.3	263.640	170.970
	1.4	305.760	186.439
	1.5	351.000	201.762
17.5	1.3	263.640	158.451
	1.4	305.760	172.405
	1.5	351.000	186.246

From the experimental results and recording of wave height at each observation location point, the maximum and minimum amplitude values in front of the model were taken. 1000 data were recorded with a time base of 0.1 seconds, a frequency of 20 Hz and a recording duration of 100 seconds.

In this study, the wave height data of each probe is calculated based on the maximum and minimum amplitude height respectively and then summed up. The negative minimum amplitude must be solved to get the wave height value for each wave probe [8].

The data on wave probe 1 is used to determine the maximum wave height (Hmax) and the data on wave probe 2 is used to determine the minimum wave height (Hmin). The following table presents the wave height data on model M-1 (θ = 45° and Hb = 5 cm).

Table 3. Wave Height Data (H)

d (cm)	T (seconds)	Probe 1			Probe 2		
		αmaks (cm)	αmin (cm)	Hmaks (cm)	αmaks (cm)	αmin (cm)	Hmin (cm)
24.5	1.3	3.1053	-3.5270	6.6323	0.7560	-1.5262	2.2822
	1.4	2.8486	-3.0675	5.9161	0.7133	-1.2948	2.0081
	1.5	2.6995	-2.7818	5.4814	0.9091	-1.1524	2.0615
21	1.3	3.5537	-2.7822	6.3359	0.6409	-1.3485	1.9894
	1.4	3.0775	-2.8440	5.9215	0.8380	-1.0482	1.8862
	1.5	2.6780	-2.9101	5.5882	0.4376	-1.1702	1.6078
17.5	1.3	2.8482	-2.6624	5.5106	0.5989	-1.2065	1.8055
	1.4	3.0454	-2.3180	5.3634	0.8823	-0.8512	1.7335
	1.5	2.6565	-2.2152	4.8717	0.4765	-0.9280	1.4045

The maximum wave height (Hmax) and minimum wave height (Hmin) data are used to calculate the incident wave height (Hi) and reflection wave height (Hr) [9]. The following table presents the data of incident wave height (Hi) and reflected wave height (Hr) on model M-1 (θ = 45° and Hb = 5 cm).

Table 4. Data of Wave Height and Reflected Wave Height

d (cm)	T (seconds)	Hmak (cm)	Hmin (cm)	Hi (cm)	Hr (cm)
24.5	1.3	6.6323	2.2822	4.4573	2.1750
	1.4	5.9161	2.0081	3.9621	1.9540
	1.5	5.4814	2.0615	3.7714	1.7100
21	1.3	6.3359	1.9894	4.1627	2.1732
	1.4	5.9215	1.8862	3.9039	2.0176
	1.5	5.5882	1.6078	3.5980	1.9902
17.5	1.3	5.5106	1.8055	3.6580	1.8525
	1.4	5.3634	1.7335	3.5484	1.8150
	1.5	4.8717	1.4045	3.1381	1.7336

The degree of an object's ability to reflect waves is called the reflection coefficient (Kr). The reflection coefficient (Kr) is expressed as the ratio between the reflected wave height (Hr) and the incident wave height (Hi) [10]. The following table presents the results of the calculation of the reflection coefficient (Kr) on model M-1 (θ = 45° and Hb = 5 cm).

Table 5. Calculation Result of Reflection Coefficient

d (cm)	T (seconds)	Hi (cm)	Hr (cm)	Kr
24.5	1.3	4.4573	2.1750	0.4880
	1.4	3.9621	1.9540	0.4932
	1.5	3.7714	1.7100	0.4534
21	1.3	4.1627	2.1732	0.5221
	1.4	3.9039	2.0176	0.5168
	1.5	3.5980	1.9902	0.5531
17.5	1.3	3.6580	1.8525	0.5064
	1.4	3.5484	1.8150	0.5115
	1.5	3.1381	1.7336	0.5524

The basic concept of dimensional analysis is to simplify the number of separate variables included in a particular physical system into a smaller number of dimensionless variable groups. The dimensional analysis used is the Langhaar matrix method. Mathematically, the reflection coefficient produced in this study is a function of the following parameters:

$$K_r = f\left[\frac{H_b}{d} ; \frac{H_b}{H_i} ; \frac{H_i}{L}\right] \tag{1}$$

The parameter Hb /d is the ratio between the model opening height (Hb) and depth (d). The following table presents the calculation results of the Hb/d parameter on model M-1 (θ = 45° and Hb = 5 cm).

Table 6. Parameter Calculation Results H /d_b

Hb (cm)	d (cm)	T (seconds)	H /db
5	24.5	1.3	0.2041
	21	1.4	0.2381
	17.5	1.5	0.2857

The parameter H Hb/i is the ratio between the model opening height (Hb) and the incident wave height (Hi). The following table presents the calculation results of the H /Hbi parameter on model M-1 (θ = 45° and Hb = 5 cm).

Table 7. Parameter Calculation Results H /H_{bi}

Hb (cm)	d (cm)	T (seconds)	Hi (cm)	H /Hbi
5	24.5	1.3	4.4573	1.1218
		1.4	3.9621	1.2620
		1.5	3.7714	1.3258
	21	1.3	4.1627	1.2012
		1.4	3.9039	1.2808
		1.5	3.5980	1.3897
	17.5	1.3	3.6580	1.3669
		1.4	3.5484	1.4091

	1.5	3.1381	1.5933

The parameter Hi /L, also called wave steepness, is the ratio between the incident wave height (Hi) and wavelength (L). The following table presents the calculation results of the wave steepness parameter (Hi /L) on model M-1 (θ = 45° and Hb = 5 cm).

Table 8. Calculation Result of Wave Steepness Parameter (H_i /L)

d (cm)	T (seconds)	Hi (cm)	L (cm)	H /Li
24.5	1.3	4.4573	181.859	0.0245
	1.4	3.9621	198.765	0.0199
	1.5	3.7714	215.487	0.0175
21	1.3	4.1627	170.970	0.0243
	1.4	3.9039	186.439	0.0209
	1.5	3.5980	201.762	0.0178
17.5	1.3	3.6580	158.451	0.0231
	1.4	3.5484	172.405	0.0206
	1.5	3.1381	186.246	0.0168

The discussion for the results of this study is in the form of a graph which will be explained as follows.

1. Relationship of Parameter H_b /d to Reflection Coefficient (Kr)

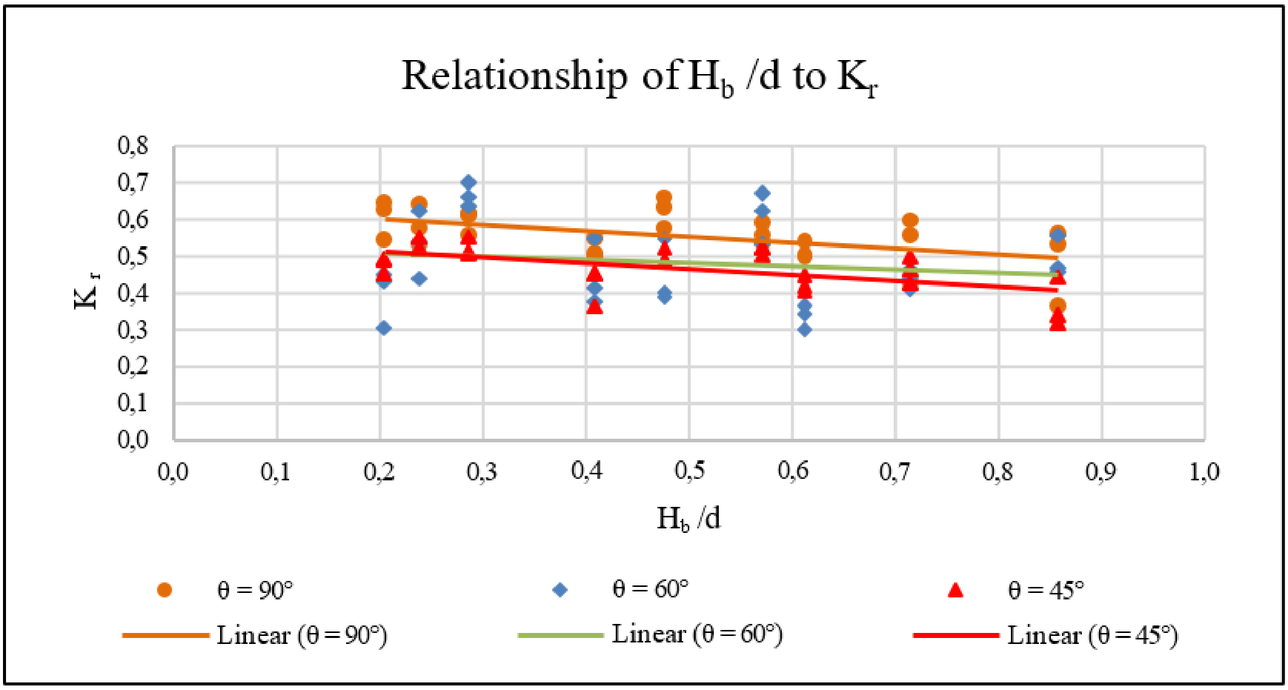


Figure 4. Relationship Graph of Hb/d to Kr

In the graph above, it can be seen that as the parameter Hb /d increases, the value of the reflection coefficient (Kr) will decrease. For the effect of slope (θ), the greater the slope (θ) or the more upright the breakwater model used, the greater the value of the reflection coefficient (Kr).

2. Parameter Relationship of H_b /Hi to Reflected Wave Height (Hr)

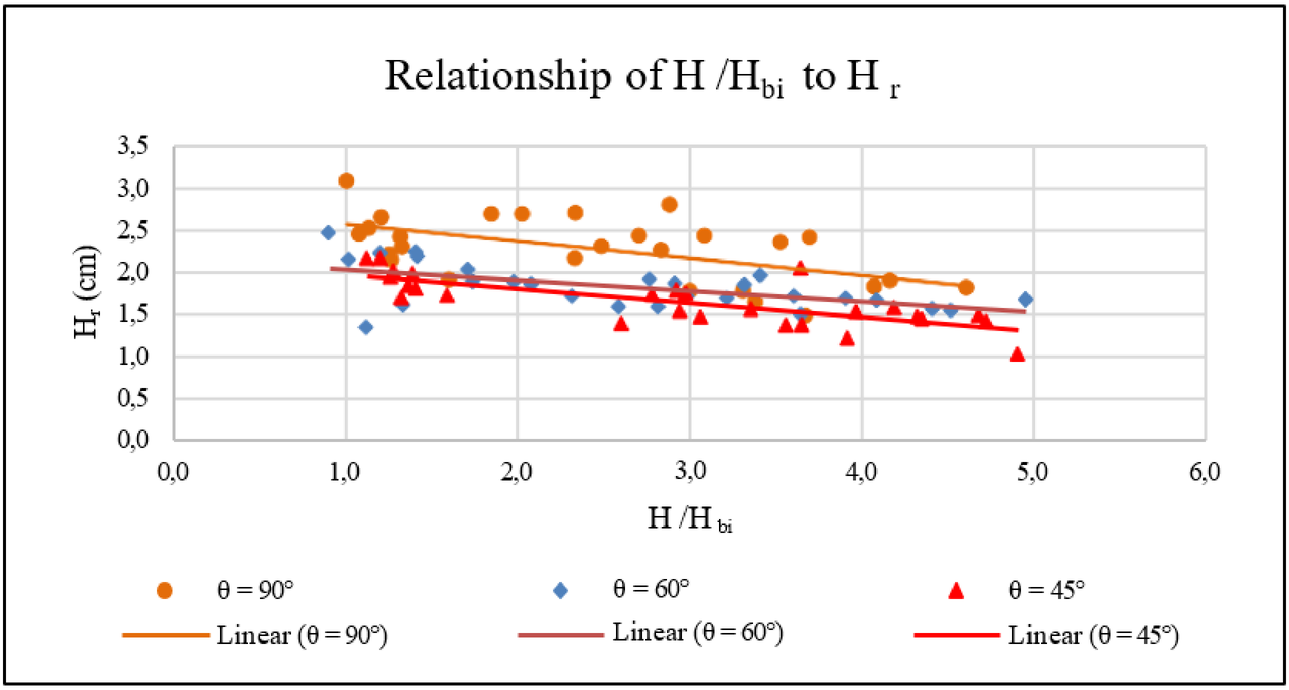


Figure 5. Relationship Graph of H /H_{bi} against Hr

In the graph above, it can be seen that as the parameter Hb /Hi increases, the value of the reflection wave height (Hr) will decrease. For the effect of slope (θ), the greater the slope (θ) or the more upright the breakwater model used, the greater the value of the reflected wave height (Hr).

3. Relationship of Wave Steepness Parameter (H_i /L) to Reflection Coefficient (Kr)

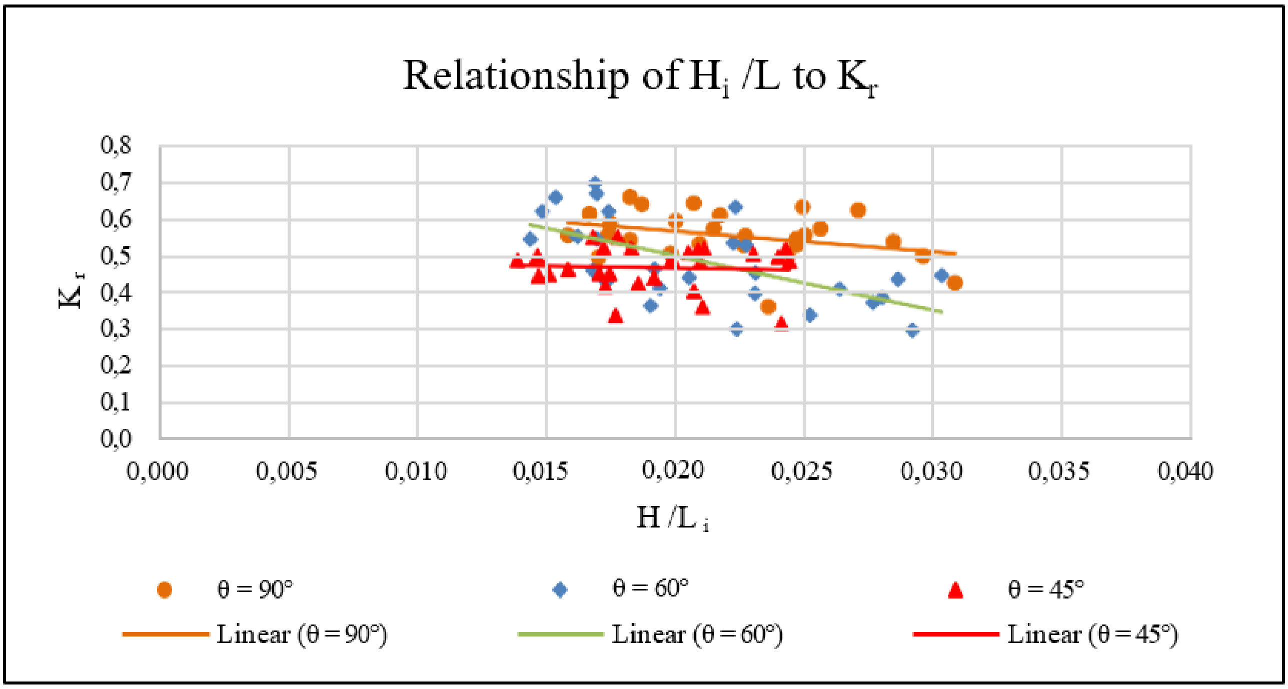
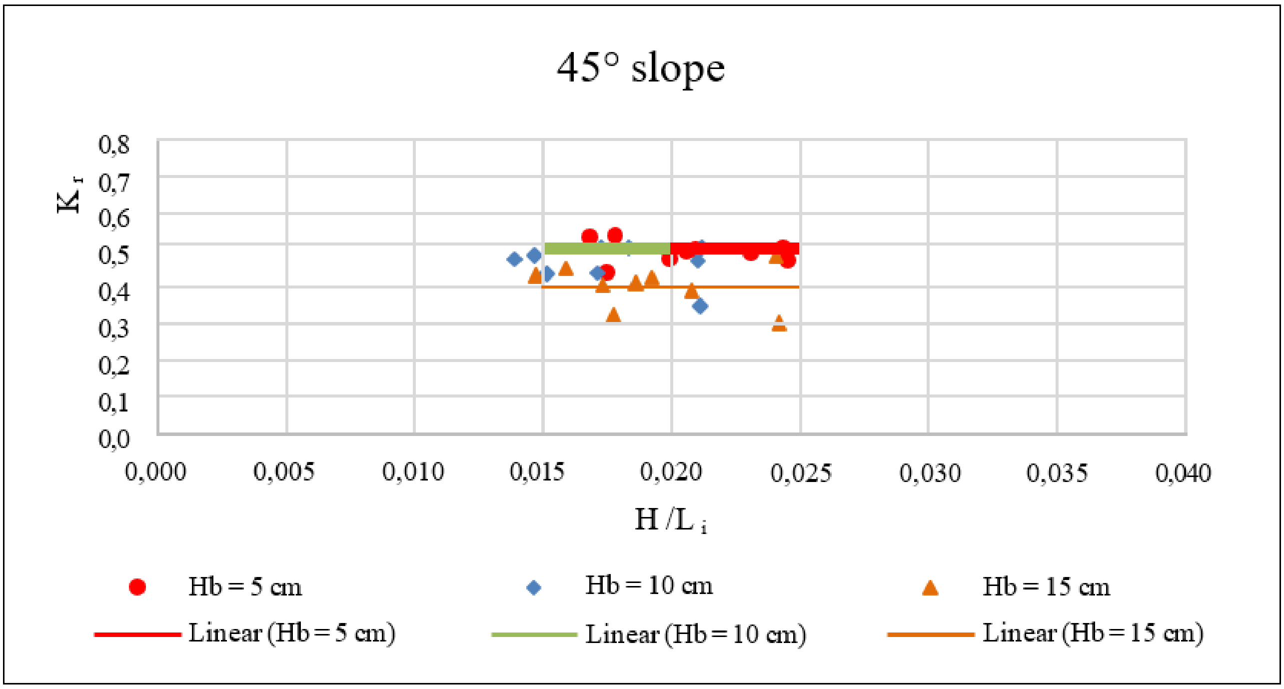
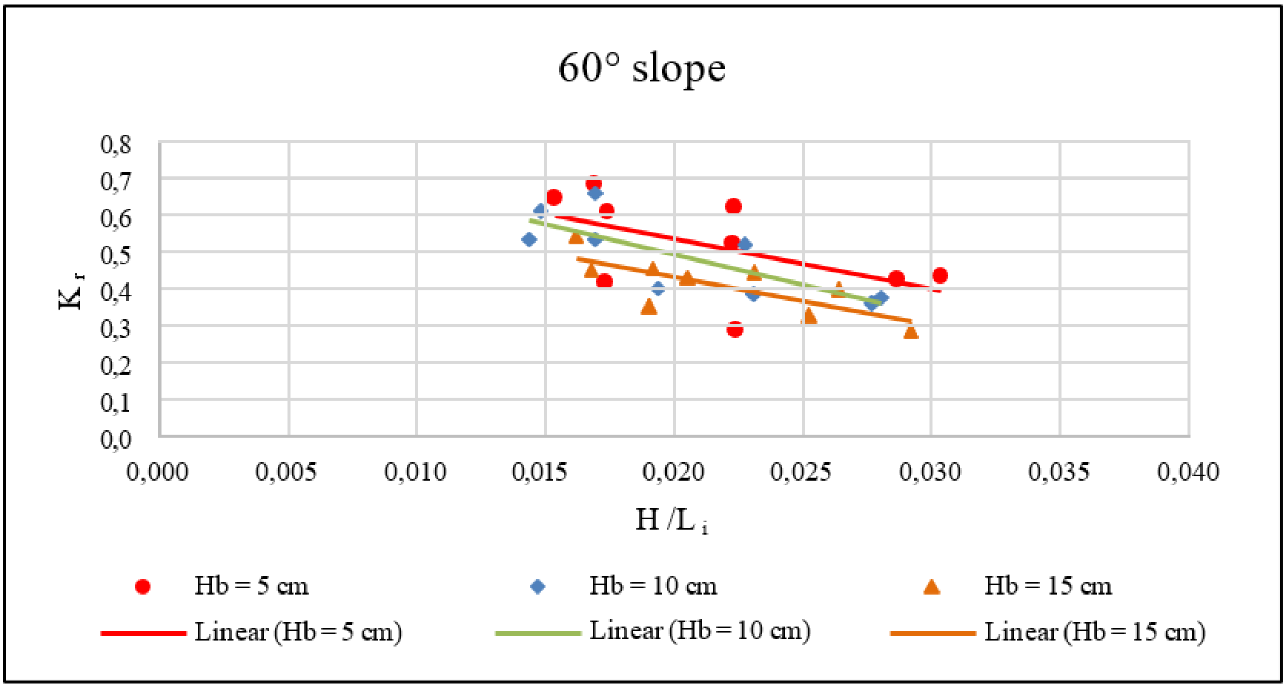


Figure 6. Relationship Graph of H_i /L against Kr

In the figure above, it can be seen that with the increasing value of wave steepness (Hi /L), the value of reflection coefficient (Kr) will decrease. For the effect of slope (θ), generally the greater the slope (θ), the greater the value of the reflection coefficient (Kr). But there is a change for slope (θ) = 60° and slope (θ) = 45°. At slope (θ) = 60° the reflection coefficient (Kr) value is greater than slope (θ) = 45° until it reaches the wave steepness (Hi /L) value of 0.0225. After passing this value, the reflection coefficient (Kr) value at slope (θ) = 60° is smaller than slope (θ) = 45°.





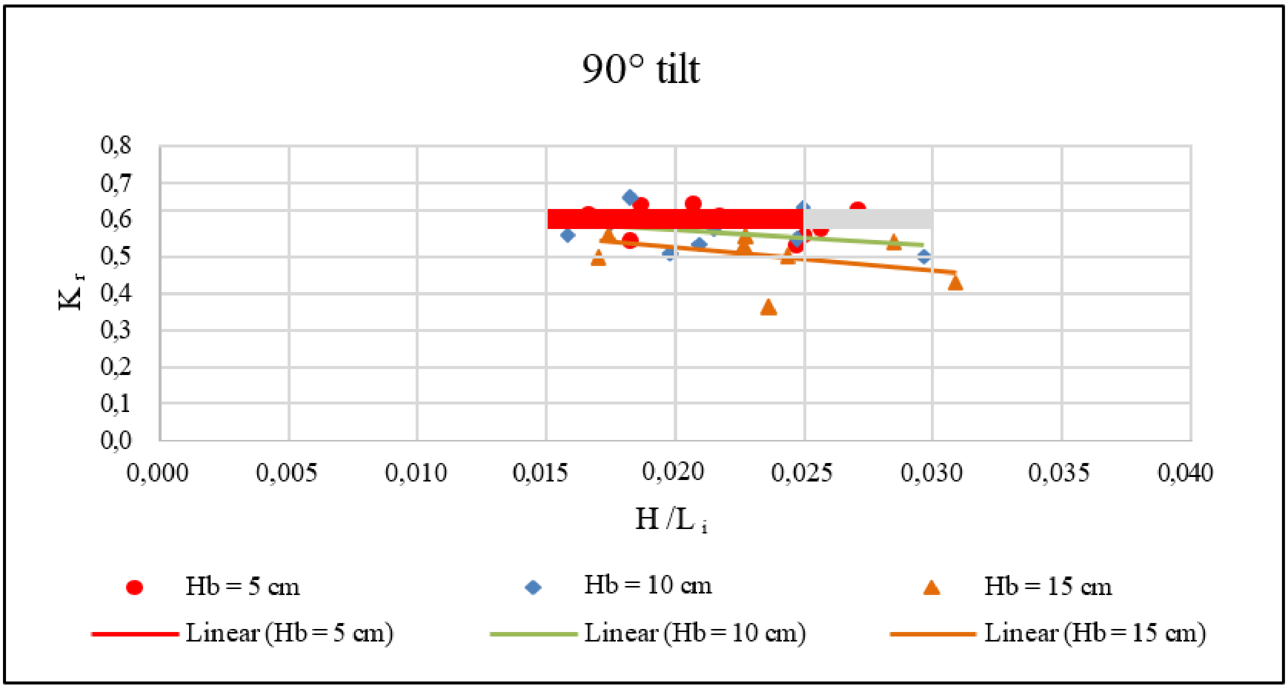


Figure 7. Relationship Graph of H_i /L against Kr in Each Model

In the figure above, it can be seen that with the increasing value of wave steepness (Hi /L), the value of reflection coefficient (Kr) will decrease. For the effect of opening height (Hb), the smaller the opening height (Hb) of the model used, the greater the reflection coefficient value (Kr). The amount of reflection value on each model is as follows:

- model M-1 (θ = 45° and Hb = 5 cm) ranged from 45-55%,
- model M-2 (θ = 45° and Hb = 10 cm) ranged from 36-52%,
- model M-3 (θ = 45° and Hb = 15 cm) ranged from 32-50%,
- model M-4 (θ = 60° and Hb = 5 cm) ranged from 30-70%,
- model M-5 (θ = 60° and Hb = 10 cm) ranged from 38-67%,
- model M-6 (θ = 60° and Hb = 15 cm) ranged from 30-56%,
- model M-7 (θ = 90° and Hb = 5 cm) ranged from 53-64%,
- model M-8 (θ = 90° and Hb = 10 cm) ranged from 50-66%,
- model M-9 (θ = 90° and Hb = 15 cm) ranged from 36-60%.

4. CONCLUSION

Based on the research results, it can be concluded that:

1. Parameters that affect the magnitude of wave reflection. For structural parameters such as slope (θ) and opening height (Hb) of the breakwater. As for wave parameters such as depth (d), period (T) and wave height (H).
2. The effect of slope (θ) and opening height (Hb) of the model on the reflection coefficient (K_r), viz:
   a. The effect of the slope (θ) of the model on the reflection coefficient (K_r) is that the greater the slope (θ), the greater the value of the reflection coefficient (Kr).
   b. The effect of the opening height (H_b) of the model on the reflection coefficient (K_r) is that the greater the opening height (H_b), the smaller the reflection coefficient value (K_r).

REFERENCES

[1] Cintya Fandani, Rivaldi David Maulana, Helen Purnomo, Natasya Shaherani, Robby Hilmi Rachmadian, and Tasya Khairunisa, Pengembangan Fitur 360^o Virtual Tour Berbasis Virtual Reality (VR) PadaAplikasi Banyuwangi Tourism Sebagai Upaya Peningkatan Kualitas PromosiPariwisata Kabupaten Banyuwangi, no. July. 2020. [Online]. Available: https://www.researchgate.net/publication/353338612

[2] I Made Adi Sayoga and Made Nuarsa, "Pemerataan Energi Gelombang Laut Dengan Sistem Berpiston Aksi Ganda," Din. Tek. Mesin, vol. 3, no. 2, pp. 106–110, 2013.

[3] S. R. Utami, "Studi Potensi Pembangkit Listrik Tenaga Gelombang Laut dengan Menggunakan Sistem Oscillating Water Column (OWC) di Tiga Puluh Wilayah Kelautan Indonesia," Dep. Tek. Elektro Fak. Tek. Univ. Indones., 2010.

[4] H. Al Imran, M. Arsyad Thaha, Mu. P. Hatta, B. Bakri, Nenny, and Kasmawati, "Pengaruh Tinggi Gelombang Terhadap Tekanan Pada Pompa Gelombang Tipe Pelampung," Ranc. bangun, vol. 07, no. 2, pp. 42–46, 2021, [Online]. Available: https://journal.unismuh.ac.id/index.php/hidro/article/view/6011

[5] R. Karamma, A. Ashury, N. Karim, and A. Almunawir, "Studi Laboratorium Disipasi Dan Refleksi Gelombang Pada Susunan Pipa Sebagai Pemecah Gelombang," Ris. Sains dan Teknol. Kelaut., no. c, pp. 28–33, 2019, doi: 10.62012/sensistek.v2i1.13082.

[6] A. Kusumastuti, "Pengenalan Pola Gelombang Khas dengan Interpolasi," CAUCHY J. Mat. Murni dan Apl., vol. 2, no. 1, pp. 7–12, 2011, doi: 10.18860/ca.v2i1.1803.

[7] B. Triatmodjo, Teknik Pantai. Yog: Beta Offset, 2016.

[8] F. Akbarrizky, R. Munadi, and H. Walidainy, "Perancangan dan Pengujian Antena Microstrip Circular Patch Array Dua Elemen untuk Aplikasi Wimax 2,3 GHz," J. Komputer, Inf. Teknol. dan Elektro, vol. 2, no. 4, pp. 21–28, 2017.

[9] M. K. Humairah, S. Widada, and R. Widiaratih, "Simulasi Model Fisik Efektivitas Pemecah Gelombang Tetrapod Dan Dolos," J. Tek. Hidraul., vol. 13, no. 1, pp. 17–26, 2022, doi: 10.32679/jth.v13i1.660.

[10] A. O. P. Putra, H. D. Armono, and Sujantoko, "Pengaruh Elevasi Muka Air Laut Pada Koefisien Transmisi dan Refleksi Composite Breakwater," J. Tek. ITS, vol. 2, no. 1, pp. G47–G51, 2013, [Online]. Available: http://ejurnal2.its.ac.id/index.php/teknik/article/view/3106