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EFFECT OF FREEBOARD HIGH ON WAVE REFLECTION ON ZIGZAG MODEL WCSP-DS BUILDING

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ABSTRACT

The Wave Catcher Shore Protection Dual-Slope (WCSP-DS) model in this study is a model of a dual function beach building as a beach protector and a catcher of wave energy, which has two walls, namely upright and inclined walls with an angle of 45°. The WCSP-DS building also has a reservoir at its top to accommodate wave runoff (overtopping). This study aims to determine the reflection in front of the model with variations in the freeboard height of the Wave Catcher Shore Protection Dual-Slope (WCPS-DS) building in a zigzag position. The test was carried out using a 1:20 scale 3D physical model at the Coastal and Environmental Engineering Laboratory, Faculty of Engineering, Hasanuddin University, Makassar. Simulation and data acquisition were carried out in a wave basin measuring 15 meters long, 10 meters wide using a regular wave generation system and the wave height data on the wave probe was recorded automatically. The simulation was carried out with 5 variations of freeboard height on 3 variations of waves, namely wave height and period and 3 variations of water depth. The results showed that there was a significant effect of freeboard height, wave steepness and water level position on WCSP-DS vertical wall height or water depth relative to the wave reflection coefficient in front of the model. The value of the reflection coefficient (Kr) in the relationship between freeboard height and water depth (Fb/d) at a depth of 0.4 meters (d/z = 1.143) ranges from 0.42 – 0.74, at a depth of 0.35 meters (d /z = 1) ranged from 0.44 – 0.74 and at a depth of 0.3 meters (d/z = 0.857) ranged from 0.35 – 0.71.

Keywords: WCSP-DS; wave reflection; freeboard; relative water depth; model.

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INTRODUCTION

Indonesia, which is located on the equator, surrounded by two oceans, namely the Indonesian Ocean and the Pacific Ocean, has promising potential as a new energy source. renewable energy (EBT) and has not been used optimally. One of the environmentally friendly renewable energy sources available with large reserves and high availability is wave energy. Ocean waves in addition to having a large enough energy potential that can be utilized also have a large destructive power if not controlled. To change the destructive power of waves into renewable energy sources, innovation and engineering are needed. Many studies have been done to convert the energy produced by ocean waves. The Tapered Channel or commonly known as TAPCHAN is WEC's first invention with the concept of sinking type overtopping, concentrating rising ocean waves into the reservoir through an overtopping mechanism. Wave Dragon is an invention with the concept of overtopping WEC with a floating type. The physical form of the Wave Dragon provides additional capabilities in addition to being an energy converter, as well as a wave absorber (Mustapa. M, 2017)

The Wave Catcher Shore Protection Dual-Slope (WCSP-DS) model in this study is the same as the WEC concept, which is a dual function beach building model as a beach protector and a catcher of wave energy. This WCSP-DS building has a reservoir at the top to accommodate wave runoff (overtopping). And has a combined wall, namely the upright and sloping side walls with an angle of 45°. Energy conversion buildings with dual slopes can increase wave energy (Puspita, 2020)

The efficiency of the model can be increased by engineering wave deformation (Puspita, 2020). To get the performance in this study, engineering was carried out at the position of the zigzag-shaped placement with the hope that it would function as a wave center that could increase the wave height. This study aims to determine the reflection in front of the model with variations in the freeboard height of the Wave Catcher Shore Protection Dual-Slope (WCPS-DS) building in a zigzag position. is wave reflection. (Puspita, 2020).

The relative depth of the ocean that changes from deep water to shallow water, then the propagation of the wave when it hits a building some of its energy will be reflected (reflection), partly transmitted (transmission), and partly destroyed (dissipation) depending on the type of coastal structure (smooth or rough surface). , impermeable or pass water), the characteristics of the incident wave (period, wave height and water depth) and the geometry of the building (slope, elevation and width of the crest of the building).

In this study using the theory of small amplitude waves (Airy) in transitional water conditions in accordance with the existing research conditions. The theory of small amplitude waves is derived from the Laplace Equation and at the boundary conditions the surface is obtained from the Bernoulli equation, assuming that the value of y at the surface is the same as the water level at rest, so that y = 0 is approximately the same as at y = η, so that the velocity is obtained wave propagation (C), wavelength (L) and deep sea wavelength (L_0) as follows:

$$C = \frac{gT}{2\pi} tanh \frac{2\pi d}{L} \quad \text{…. (1)}$$

$$L = \frac{gT^2}{2\pi} tanh \frac{2\pi d}{L} \quad \text{…. (2)}$$

$$L_0 = 1{,}56\, T^2 \quad \text{…. (3)}$$

With:

C = speed of wave (m/s)
g = gravity (9.81 m/s²)
T = wave period (seconds)
d = water depth (meters)
L = wavelength (meters)
L_0 = deep sea wavelength (meters)

Natural and artificial barriers will experience reflection either total or partial reflection when hit by waves. If the reflection is perfect or the incident wave is completely reflected, then the height of the wave in front of the barrier is twice the height of the incident wave and is called a standing wave. If the reflection is not perfect, then the height of the wave in front of the barrier will be less than twice the height of the incident wave and in this case it is called a partial standing wave. Reflection wave is a form of wave deformation. The wave reflection parameter is expressed in the form of the reflection coefficient (K_r) which is the ratio between the reflection wave height (H_r) and the incident wave height (H_i) or the ratio of the roots of the reflected wave energy (E_r) and the incident wave energy (E_i).

$$K_r = \frac{H_r}{H_i} = \sqrt{\frac{E_r}{E_i}} \quad \text{…… (4)}$$

With:

K_r = reflection coefficient
H_r = reflection wave
H_i = incoming wave
E_r = reflection wave energy
E_i = incoming wave energy

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For maximum and minimum water level elevation for partial standing waves (Paotonan.C, 2006) as follows:

$$H_i = \frac{H + H_{min}}{2} \quad \text{.... (5)}$$

$$H_r = \frac{H + H_{min}}{2} \quad \text{.... (6)}$$

With:

H_{max} = maximum wave height
H_{min} = minimum wave height

The basic concept of modeling with the help of a model scale is to reshape the problems or phenomena that exist in the prototype on a smaller scale, so that the phenomena that occur in the model will be congruent (similar) to those in the prototype. The similarity in question is in the form of geometric congruence, kinematic congruence and dynamic congruence (Yuwono, 1996).

Geometric congruence is a similarity where the shape in the model is the same as the prototype shape but different in size. The comparison between all length measurements between the model and the prototype is the same. Geometric congruents can be expressed in the form:

$$n_L = \frac{L_p}{L_m} \quad \text{.... (7)}$$

$$n_h = \frac{h_p}{h_m} \quad \text{.... (8)}$$

With:
n_L = long scale
L_p = prototype length
L_m = model length size
n_h = high scale
h_p = model length size
h_m = model length size

Dynamic congruence is a similarity that meets the criteria of geometric and kinematic congruence, and the ratio of the forces acting on the model and prototype for all flows in the same direction is the same.

$$n_t = \frac{t_p}{t_m} \quad \text{.... (9)}$$

With:
n_t = time scale
t_p = prototype time measure
t_m = model time measure

Dynamic congruence is a similarity that meets the criteria of geometric and kinematic congruence, and the ratio of the forces acting on the model and prototype for all flows in the same direction is the same.

$$n_t = \frac{t_p}{t_m} \quad \text{.... (10)}$$

With:

n_t = length scale

L_p = prototype length

L_m = model length

Dimensional analysis is needed to make it easier to analyze experimental data that can be used to design physical modeling as desired. Dimensionless numbers are used to express the relationship between parameters and are used to describe research results. To determine the dimensionless number can be done by dimensional analysis. From the dimensional analysis, dimensionless variables will be obtained which will be the reference in describing or presenting the results of the experiment. Some of the methods commonly used for dimensional analysis are the Basic Echelon Method, Buckingham Method, Rayleigh Method, Stepwise Method and Langhaar Method (Yuwono, 1996). This study uses the Langhaar method to explain hydraulic phenomena.

In planning the breakwater building in the coastal area, accurate calculations are needed. so that this breakwater building functions properly and can last a long time. according to the design life is expected to reach 25 years from manufacture. After the end of the design life, additional materials are needed in accordance with the concepts and calculations according to the real work steps (Satriadi I, 2017; Ginanjar B, Hariati F, 2015; Astuti GYD, Hariati F, 2016).

The dimensions of the breakwater adjust to the wave conditions and the water flow through the existing building. High water discharge requires high breaking structures as well. The quality of the breakwater building and the water discharge that follows it depends on the conditions in the field. It is this field condition that must be taken into account in planning the breakwater building, its dimensions, sizes, raw materials and types are planned (Erwanto Z et al, 2021; ALam MP, Lutfi M, 2016; Imamuddin MI, Larasati L, 2021; Budion A, 2014).

RESEARCH METHODS

Location and Type of Research

The research was conducted at the Coastal and Environmental Engineering Laboratory, Faculty of Engineering, Hasanuddin University, Makassar. This research is an experimental physical modeling under artificial conditions, arranged based on the literature related to the research.

Wave pools, wave generating units and Wave Probes

The wave basin used has dimensions of 15 m long, 10 m wide and 1.2 m high with an effective channel depth of 0.87 m, at the end of the channel there is a wave absorber that functions to absorb and reduce wave reflections. Equipped with a wave generator and wave maker. The wave motion is created by the wave making flap, connected to the pressure pump, the transfer of energy occurs by providing a push against the piston. The piston presses against the flap so a wave can occur. The movement of the flaps is connected to the computer to produce the desired wave height. The wave generator and wave maker can be seen in Figure 1. In this study, eleven wave probes were used to measure the height of water level fluctuations. The wave probe was calibrated before testing which became the reference for the running results.

(a) (b)

Figure 1. Wave basin (a), wave generator and wave maker (b) (Source: Lab LK, 2021)

Research design and modeling

The parameters studied in the wave reflection study are the height of the incident wave (Hi), the height of the reflection wave (Hr) and the reflection coefficient, varying the freeboard height (Fb), water depth (d) and wave period (T). To obtain the relationship between parameters to the value of the reflection coefficient (Kr) of waves used Non-dimensional Parameters (NDP).

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This model is based on the concept of a beach protector which is also a wave catcher. The construction of the model is made of 2 mm iron plate, the model is made based on the smooth surface of the Froude number. The model and the dimensions of the model can be seen in Figure 2.

The determination of the geometry scale is adjusted to the ability and capacity of the wave basin in the laboratory which is compared to the prototype size. This study uses an undistorted model. In the undistorted model, the geometric shape between the model and the prototype is the same but differs in size by a certain size ratio or scale. The geometric scale ratio is defined according to equations (7) and (8).

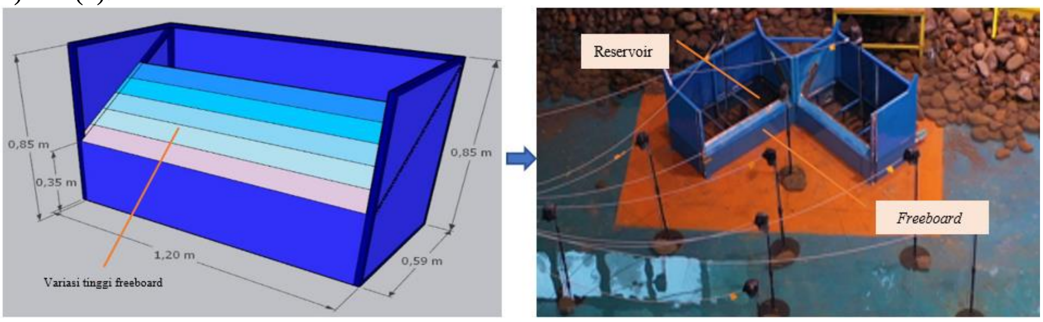

Figure 2. Model and model dimensions (Source: Lab LK, 2021)

Data collection procedure

The position of the model placement in the wave basin and the wave probe equipment can be seen in Figure 3. The model is placed near the wave absorber, at the front of the model there is a wave generator engine that supplies incoming waves with a certain height and period, there is also a probe measuring the height of water level fluctuations in the wave basin. 11 points in front of the model for wave height measurement.

Broadly speaking, the data collection procedure is as follows:

1. After the model is placed in the wave basin, then filled with water until it reaches the specified elevation, then data collection can be carried out.
2. Before running the model, calibration of the tool is carried out. Wave probe calibration is carried out by determining the upper and final limits that can be captured by the wave probe, calibration is carried out before the test is carried out at each measurement point at each change of height variation in water depth.
3. After all components are ready, the wave simulation begins by inputting frequency and amplitude data and running time on a computer connected to the wave maker. Then to generate a wave by pressing on the control panel on the wave generator and recording the probe simultaneously. The wave maker creates waves according to the input amplitude data. The wave probe records high fluctuations in water level according to the running time that has been inputted on the computer.
4. High water level fluctuations on the probe at the front eleven points of the model are stored automatically on the computer.
5. The placement of the probe changes according to changes in depth and period variations.
6. Procedures 3 to 5 are repeated according to variations in height, wave period and water depth as mentioned in figure 3 and table 1.

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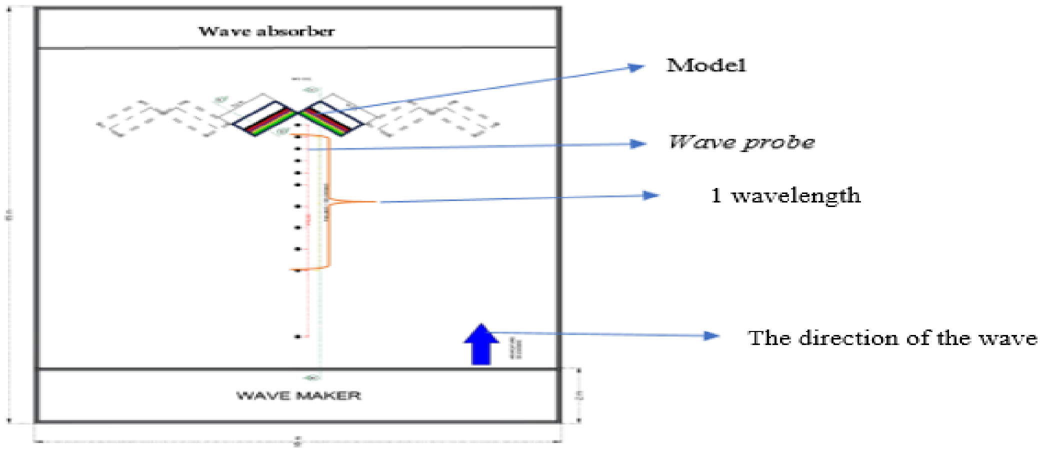

Figure 3. Model layout on the pool and probe position (Source: Data processing, 2021)

Table 1. Model simulation design

Model	**Freeboard (Fb) (m)**	**d (m)**	**T (S)**	**H (m)**
WCSP D-S I	Fb 1	3 variation	3 variation	3 variation
	Fb 2	3 variation	3 variation	3 variation
	Fb3	3 variation	3 variation	3 variation
	Fb 4	3 variation	3 variation	3 variation
	Fb 5	3 variation	3 variation	3 variation

(Source: Data processing, 2021)

RESULTS AND DISCUSSION

Wave height

From the results of running data on each probe, the average wave height of each probe is taken, then from the average height the maximum wave height (Hmax) and minimum wave height (Hmin). From the maximum and minimum wave heights, using equations (5) and (6), the incident wave height (Hi) and the reflection wave height (Hr) are obtained which will be used to obtain the reflection coefficient (Kr). For the initial wave height (H1), the wave height value is taken at the placement of the probe in front of the wave maker.

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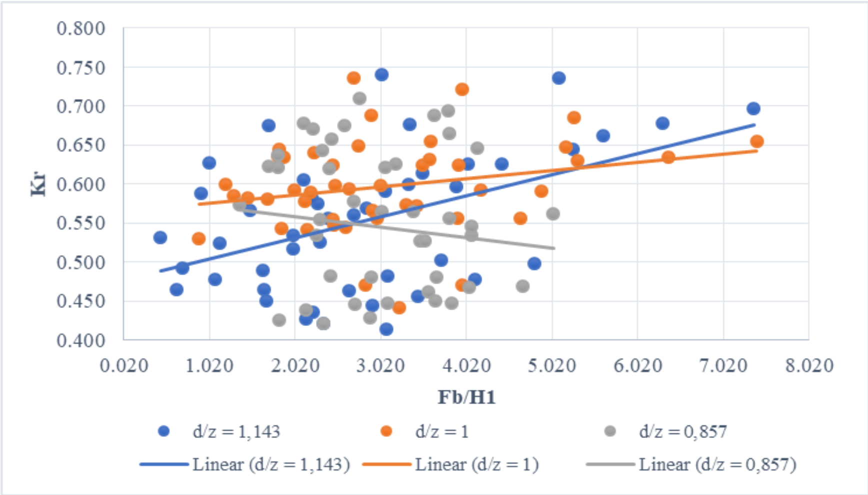

Figure 4. Graph of the relationship between Fb/H1 and Kr Source: (Results of data processing, 2021)

Based on Figure 4. it can be concluded that: for d/z = 1.143 and d/z = 1, the value of Kr increases with the increase in the value of Fb/H1, or the value of Kr decreases with the decrease in the value of Fb/H1. The position of the water level elevation at d/z = 1.143 is above the model's vertical wall and at d/z = 1 the water level elevation is parallel to the model's vertical wall. At that position, the larger the H1 value, the smaller the Kr value, because the initial wave (H1) will overflow up the slope of the model and enter the reservoir. For d/z = 0.857, the value of Kr gets smaller with increasing the value of Fb/H1, or the value of Kr gets bigger with decreasing value of Fb/H1. The position of the water level elevation at d/z = 0.857 is in the upright wall position of the model, the larger the initial wave (H1), the greater the value of Kr, the first incoming wave hits the model wall and then enters the reservoir.

Effect of NDP= (Fb/H1), (Fb/L) and (H1/L) on Kr

To obtain the relationship between parameters to the value of the wave reflection coefficient (Kr) used Non-dimensional Parameter (NDP).

Effect of NDP = (Fb/H1) on Kr

The effect of the relative depth of the model on the graph of the relationship between Fb/H1 and the reflection coefficient (Kr) for each variation in water level (d) is presented in the form of a graph of the relationship between the freeboard height and the initial wave height (Fb/H1) and the reflection coefficient value (Kr). Where Fb/H1 as the X-axis variable and Kr as the Y-axis variable are shown in Figure 4.

Effect of NDP = Fb/L on Kr

The effect of the relative depth of the model on the graph of the relationship between Fb/L and the reflection coefficient (Kr) for each variation in water level elevation (d) is presented in the form of a graph showing the relationship between the freeboard height and the wavelength (Fb/L) and the reflection coefficient (Kr). Where Fb/L as X-axis variable and Kr as Y-axis variable are shown in Figure 5.

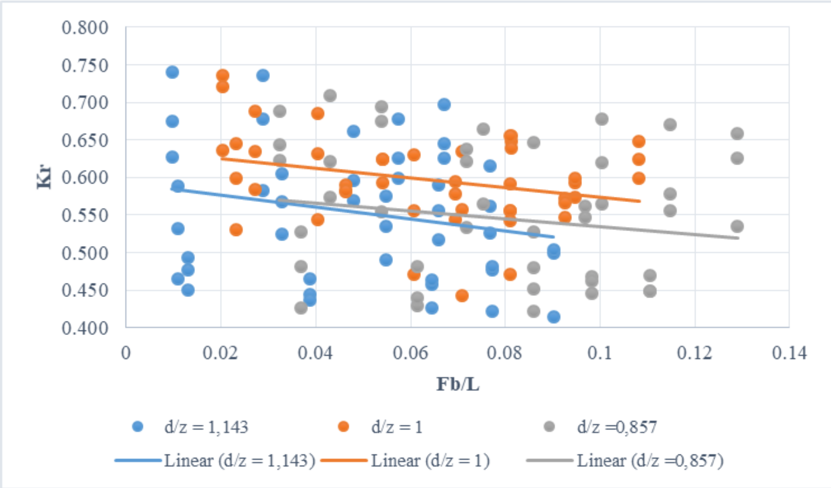

Figure 5. Graph of the relationship between Fb/L and Kr Source: (Results of data processing, 2021)

From Figure 5 it can be concluded that: the trend resulting from the reflection coefficient of all configurations is decreasing. The value of the reflection coefficient is getting smaller with the greater the value of Fb/L. The larger the wavelength (L), the greater the reflection coefficient (Kr).

Effect of NDP= (H1/L) on Kr

The effect of the wave parameter on the reflection coefficient (Kr) is used for the dimensionless parameter of the steepness of the wave (H1/L). The effect of freeboard height versus water depth on the graph of the H1/L relationship with the reflection coefficient (Kr) for each depth value (d) is presented in the form of a graph which is the relationship between wave steepness (H1/L) and the reflection coefficient (Kr). Where H1/L as X-axis variable and Kr as Y-axis variable for freeboard height variation (Fb), as shown in Figure 6, Figure 7 and Figure 8.

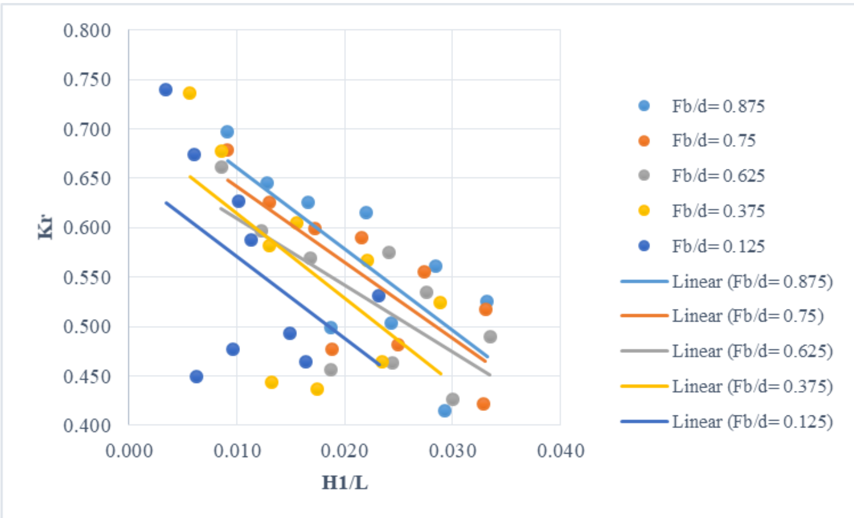

Figure 6. Graph of the relationship between H1/L and Kr at d=0.04 m Source: (Results of data processing, 2021)

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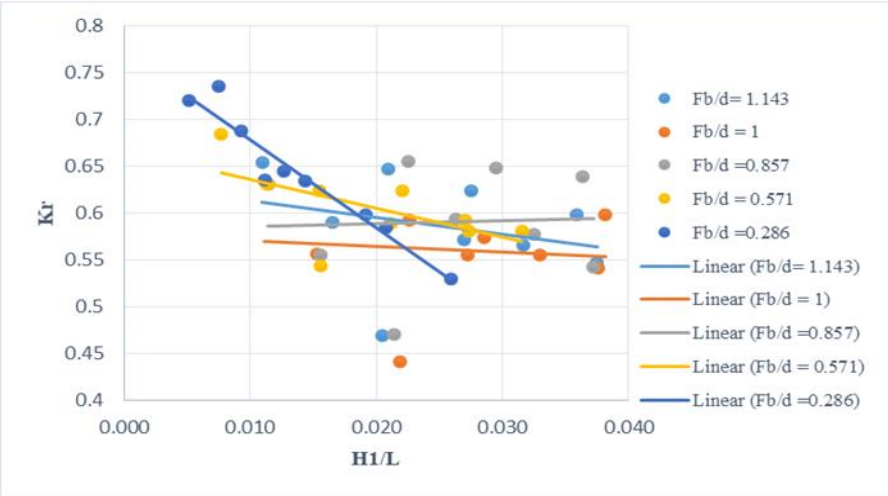

Figure 7. Graph of the relationship between H1/L and Kr at d=0.35 m Source: (Results of data processing, 2021)

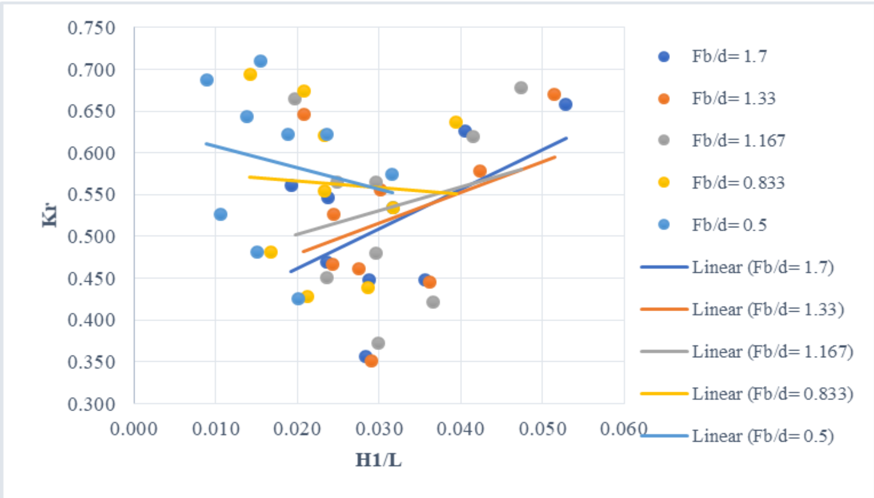

Figure 8. Graph of the relationship between H1/L and Kr at d=0.3 m Source: (Results of data processing, 2021)

Based on Figures 6, 7 and 8 which show the relationship between Kr and H1/L for several freeboard heights versus depths, it can be concluded that in Figure 6 the trend resulting from the graph of the relationship between H1/L and Kr at a water level elevation of 0.4 meters is decreasing. The greater the value of H1/L, the smaller the value of Kr, the greater the value of L, the greater the value of Kr. In Figure 7 the trend resulting from the graph of the relationship between H1/L and Kr at a water level of 0.35 meters is decreasing, but at Fb/d = 0.875 the trend is straight/linear, and tends to rise. In Figure 8 the trend resulting from the graph of the relationship between H1/L and Kr at a water level elevation of 0.3 meters decreases at Fb/d = 0.833 and Fb/d = 0.5, the greater the steepness of the wave (H1/L) the lower it is. reflection coefficient value (Kr). At Fb/d = 1.167, Fb/d = 1.33 , and Fb/d = 1.7 the trend resulting from the graph of the H1/L relationship to Kr is increasing, the greater the steepness of the wave (H1/L) the greater the value reflection coefficient (Kr). When the reflection coefficient (Kr) decreases, the waves that hit the walls of the structure will overflow into the reservoir, more than when the reflection coefficient (Kr) is larger, it can be seen in Figure 9.

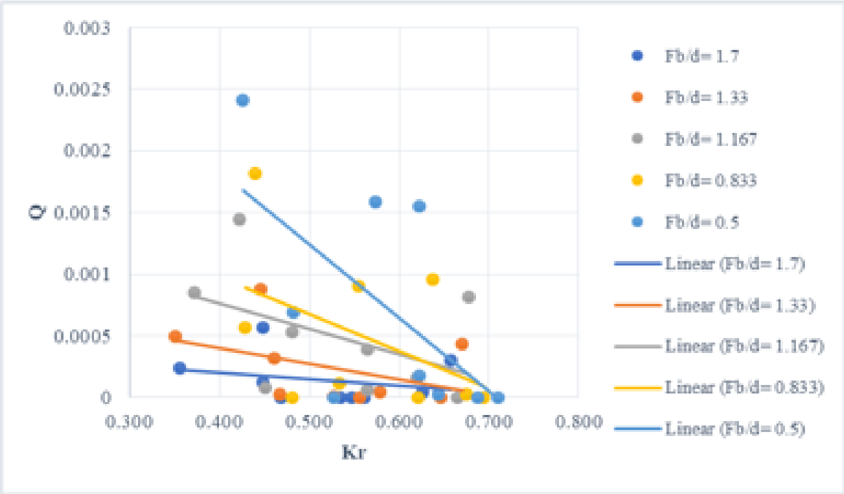

Figure 9. Graph of the relationship of Kr to Q at d = 0.3 m Source: (Results of data processing, 2021)

In Figure 9 it can be seen that the smaller the value of the reflection coefficient, the greater the wave runoff that enters the reservoir.

CONCLUSION

From the research that has been done, it can be concluded that: freeboard height, wave steepness and water level position on the vertical wall height of WCSP-DS or relative water depth, have a significant effect on the wave reflection coefficient in front of the model. The value of the reflection coefficient (Kr) in the relationship between freeboard height and water depth (Fb/d) at a depth of 0.4 meters (d/z = 1.143) ranges from 0.42 – 0.74, at a depth of 0.35 meters (d /z = 1) ranged from 0.44 – 0.74 and at a depth of 0.3 meters (d/z = 0.857) ranged from 0.35 – 0.71. Further research needs to be done to examine the wave force on the stability of the model.

NOTATION LIST

Fb Freeboard
z Model vertical wall height
d Water depth
H1 The wave front height of the wave maker
Hi wave height is coming
Hr Reflection wave height
Hmax Maximum wave height
Hmin Minimum wave height
Cr Reflection coefficient
H1/L The steepness of the wave
L Wavelength

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