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Experimental Study of Perforated Concrete Block Breakwater

Tamrin, Saleh Pallu, Herman Parung, Arsyad Thaha

***Abstract*--** **Perforated concrete block is a new form of breakwater that has similar function like coral reef and artificial breakwater, so the purpose of this research is to investigate how a perforated concrete block works as a breakwater protector structure toward the reduction level of wave height. The result showed that the perforated concrete block is one of breakwater types that could be used to muffle the wave height, and the use of perforated concrete block as a breakwater could reduce the wave height in the protected area and this could be developed into one of economic and eco-friendly breakwaters because the large pores of the concrete block could be used as a home of marine biota and it also reduces the volume of concrete using.**

***Index Term*—** **Perforated concrete block, economic and eco-friendly breakwaters**

I. INTRODUCTION

The damage of coastal area is commonly caused by the high waves that reach the coast which is caused by the bad weather and the damage of coral reef or mangrove that act as a natural wave damper. so, it is required to have a design of coastal protector that has a high security level and economic, thereby, one thing to be considered in the design of coastal protector is the availability of sufficient material for the construction workability.

Initially, man thought that the armour stone layer of the breakwater construction required large-sized stone, however as the amount of large-sized stone had decreased, so the breakwater construction is switch into artificial stone that was made according to the concept of the creator that leaded to a new fact that the stability of the breakwater was not only determined by the weight of the stone but it was also highly determined by the interlock of the stone.

In the construction development of breakwater itself, this type of breakwater hadn't overcome the environmental effect, it was also hard to carry out in a region that didn't have enough quarry, so a new form of wave damper that's economic, eco-friendly, and could be widely produced is needed to be taken into consideration, so that in this research it is emphasized that an investigation of perforated concrete block needs to be done because the application of perforated concrete block could reduce the volume of concrete using and it is not harmful for the environment because the large pore could act as the home of marine biota.

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Since Jarlan (1961) had first suggested it, porous breakwater had been widely used to reduce the wave force that reached the front part of vertical wall breakwater (Quinn, 1972). One of the important characteristics of a porous breakwater is that the wave energy will break if it hits the front part of the permeable and porous vertical wall breakwater (Quinn, 1972). In addition to that, the upcoming wave will continue to hit the pore, this will reduce the wave reflection in front of the breakwater structure. Initially, porous breakwater is a breakwater structure that is adopted from caisson type of breakwater whose front wall facing the sea is formed a hole and the back part is made to be permeable, another parameter such as wave height, period, regularity of waves, waves direction, and the depth of water are also taken into account. The wave pressure on the porous wall is less than the solid wall, as Bergmann and Oumeraci (1998) found. A research had also been done by Armono and Hall (2002) for wave transmission in submerged breakwater that was made of artificial reefs/ hollow Hemispherical Shape Artificial Reefs (HSAR). The investigation regarding the porous breakwater had been done by Ariyarathne (2007), in line with the result of the research done by Kondo (1979), Suh, et al. (2001) dan Hagiwara (1984). Rageh dan Koraim (2009) who investigate a vertical wall breakwater with horizontal slots in which result of the research derived a conclusion that a vertical wall breakwater could dissipate the arriving waves up to 50 % with the placement of the breakwater at d/L = 0,25-0,35 where d is the depth of water and L is length of waves. Then, in 2010 Wurjanto et al. investigated the level of effectiveness perforated skirt breakwater (PSB) in the category of long wave and concluded that the higher the value of draft breakwater (s) the smaller the transmission coefficient could get (Kt) or the dissipation energy would be higher. As the Kt coefficient is smaller, the better the breakwater function is, from those results this research will develop three types of breakwater that are made of perforated concrete block called perforated concrete block , so that all of the concrete block will be the waves energy damper and it can be the home of marine biota to proliferate because this type of breakwater is similar to reefs, other than that, this type of breakwater will reduce the run-up to 95 % so that the cost of structure enhancement caused by run-up can be avoided.

The method that is used in this research is 2D laboratory method by using wave flume in the laboratory of Hydraulics and Coastal Engineering Hasanuddin University. The purpose of this research is to derive a perforated concrete block which works effectively to reduce the wave height.

II. LITERATURE STUDY

Wave characteristic that hits a barrier so partial of the energy will be dissolved through the friction process, turbulence, and the wave breaking, the rest will be reflected and transmitted. The distribution of the amount of wave energy that's reflected, dissipated, and transmitted depends on the characteristic of the arriving waves (wave height and period), coastal protection type (rough or smooth surface, permeable or impermeable) and the dimension also protection geometry (slope, elevation, and the barrier width) also the surrounding environmental condition (water depth and coastal base contour). The amount of waves that's dissipated 9Hd) is the arriving waves energy (Hi) reduced by the reflected and transmitted energy (Ht). The wave parameter according to Airy theory is the parameter based on the assumption of harmonic sinusoid (Triatmodjo, 1999), with few wave characteristics, those are the wave length (L), the complete description will be shown below. Several used notations are:

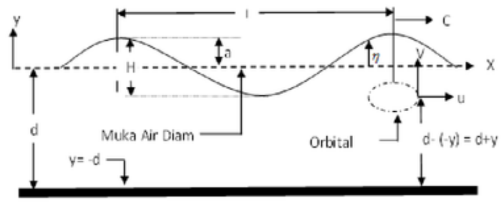


Fig. 1. Wave Airy Theory

d	: distance between mean water level and sea floor
η (x,t)	: fluctuation toward mean water level
a	: wave amplitude
H	: wave height = 2 *a*
L	: wave length
T	: wave period, time interval that's needed by water particle to return to the same point similar to prior point
C	: wave velocity = L/T
k	: wave index 2π/L
σ	: wave frequency 2π/T

The figure shows that the wave moves with the velocity of C in the water with depth of d. in this case, the moving element is just the water level form. Unlike the river basin in which the water (mass) particle moves in one closed orbit so that it doesn't move forward. A buoy in the sea will only move up and down following the wave and does not move (in the wave direction) from its origin point. Position of particle every moment of the orbit moves is given by horizontal coordinate (ξ) and vertical (ε) towards central orbit. The vertical velocity is u and v, and water level elevation towards the still water (x axis) in every point is η.

1. Water level profile

Water level profile is a function of space (x) and time (t) that has the following form

$\eta(x,t) = H/2 \ \cos(kx - \sigma t)$ ……………………………………………………..(1)

Equation (1) shows that water level fluctuation is periodic towards x and t, and it is included into sinusoid and progressive wave that moves stealthily in a positive x axis. Figure 1. is a form of wave from equation (1) in which the t value is $t_0 = 0$, $t_1 = T/8$, $t_2 = T/4$, $t_3 = 3T/8$; with T is wave period. The figure shows that according to the time alteration of wave in the direction of x axis with the velocity of L/T, L is the wave length, from left to right according to the time alteration.

2. Wave velocity and length

Speed (C) dan wave length (L) is given in the following equation.

$$C = \frac{gT}{2\pi} \tanh \frac{2\pi d}{L} = \frac{gT}{2\pi} \tanh kd$$

…………………………………………………………………..(2)

$$L = \frac{gT^2}{2\pi} \tanh \frac{2\pi d}{L} = \frac{gT^2}{2\pi} \tanh kd$$

…………………………………………………………………..(3)

Disperse equation is

$$\omega^2 = gk \tanh kh$$

…………………………………………………………………..(4)

simplification this equation can write

$$\frac{\omega^2 h}{g} = kh \tanh kh \text{ or } C = X \tanh X$$

…………………………………………………………………..(5)

X : $kh = \frac{2\pi}{L} h$

The wavelength can be calculated using the of Newton Raphson Method

$$\Delta x = \frac{C - X \tanh X}{\tanh X + \dfrac{X}{\cosh^2 X}}$$

…………………………………………………………………..(6)

X value is the value of X which has a small ΔX, so X is $\frac{2\pi}{L}$h

Table 1 application Newton Rapson method for calculation Length wave

C 1	X 2	xtanhx 3	tanh x 4	cos^2 x 5	X/COS^2x 6	C-XTanghX 7=1-3	TanhX+x/Csh^X 8=4+6	Delta X 9=7/8
0.180910092	3	2.9851643	0.9950548	101.3578	0.0295981	-2.80425417	1.024652865	-2.73678
	0.2632154	0.0677255	0.2573005	1.070897	0.2457896	0.11318462	0.50309016	0.224979
	0.4881942	0.2210456	0.452782	1.25788	0.3881088	-0.04013547	0.840890783	-0.04773
	0.4404645	0.1823653	0.4140294	1.206885	0.3649599	-0.00145516	0.778989322	-0.00187
	0.4385965	0.1809125	0.4124804	1.205023	0.3639736	-2.3666E-06	0.776454053	-3E-06

Calculation

2*3.14/L*h = X

2*3.14/L*4.1 = 0.438965

L value can write

L= 2.577312 m

II. METHODOLOGY

The basic rules of the modelling concept with model scale is to form back a problem or a phenomenon in a prototype in a smaller scale, so that the happening phenomenon in the model will be similar to the one exists in prototype. There are three criterions that's required fot the model according to the observed phenomenon characteristic, those are geometric similarity, kinematic similarity, and dynamic similarity. Geometric similarity is a similarity in which the form in the model is similar to the prototype but the size can be different. The comparison of the entire length of the model and the prototype is similar. In a perfect geometric similarity, the horizontal length scale and vertical length scale (is similar while in the distorted model, the length scale and height scale is not similar. Kinematic similarity is a similarity that fulfils the criterion of geometric similarity and the comparison between the velocity and current acceleration in two points in the model and prototype in the same direction is the same. Velocity scale is noted by nu, acceleration scale is noted by na, and time scale is nT. Dynamic similarity is a similarity that fulfils the criterion of geometric and kinematic similarity, and also the comparison between forces that work in the model and prototype for the entire current in the same direction is equal. In this research, it will be used the same length scale with height scale (undistorted models) by using Froude similarity. Dimensional number analysis method of dimensionless parameters is used to express the correlation between parameters and also used to describe the research result. To determine the dimensionless parameters it can be done with dimensional analysis. Few methods that's commonly used for dimensional analysis are Basic Echelon Method, Buckingham Method, Rayleight Method, Stepwise Method, and Langhaar Method. For this research, it is used Langhaar method because the variable affects less and this method is also ordered systematically. Langhaar method explains that hydraulic phenomenon model with n parameter Pi where i = 1,2,3, …………. n. if the parameter is ordered by m main element, then the product number of dimensionless parameters can be differentiated in the amount of (n-m). for hydraulic engineering, there are usually three main elements, those are Mass (M), Length (L), Time (T). Research with 2D physical modeling is done in Laboratory of Hydraulics and Coastal Engineering Hasanuddin University. The breakwater model that uses the placement od perforated concrete block s with 3 varied size. To derive the effect of several size towards the effectiveness of the usage, then it will be done a simulation with each three different heights (H) around 2 cm – 4.5 cm and with the period (T) around 1 seconds – 2 seconds, and also 3 varied water depths (d) those are 18.5 cm; 21.5 cm and 24 cm. to fulfill the scale requirement of all variables, then it is used geometric scale of 1:20.

Model of breakwater will be shown in the following figure:

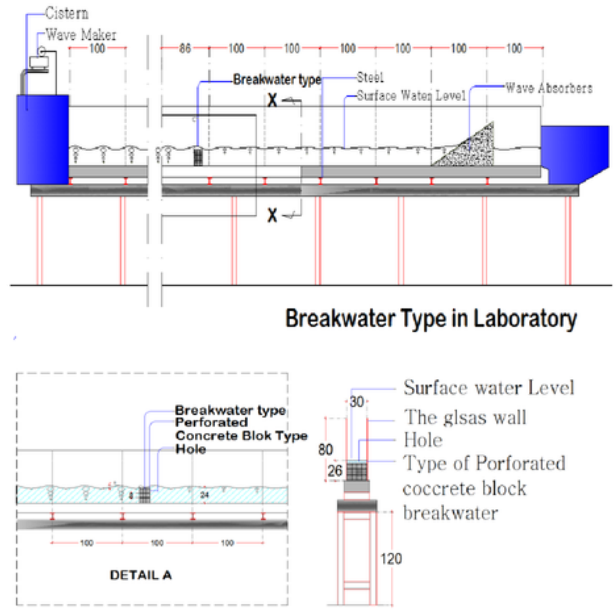
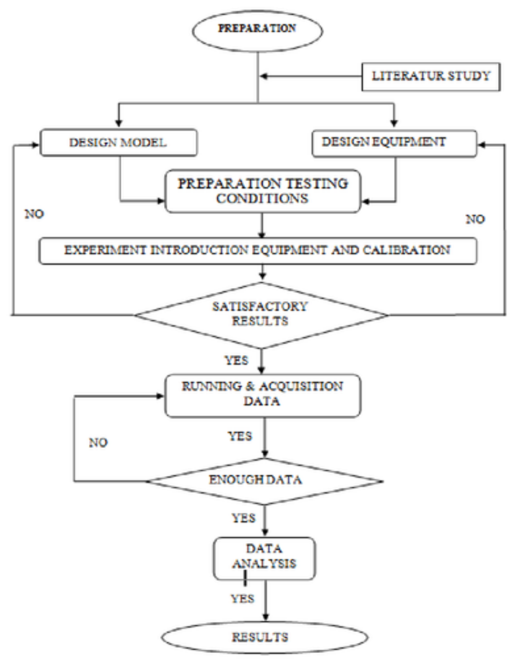


Fig. 2. Model of Breakwater Simulation

Schema implementation of testing perforated concrete block breakwaters



Dimention setup of perforated concrete block breakwaters

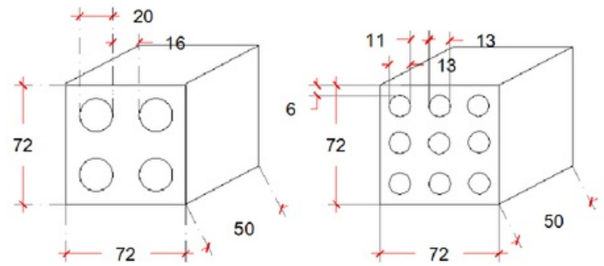


Fig. 3. Type of perforated concrete block breakwaters

III. DISCUSSION

With the addition of concrete block slots will reduce the wave height in reserve part of the breakwater in the structure because the wave energy will be absorbed by the concrete pores that will eventually reduce the wave height in the reverse part of the breakwater, this will be shown in the following figure:

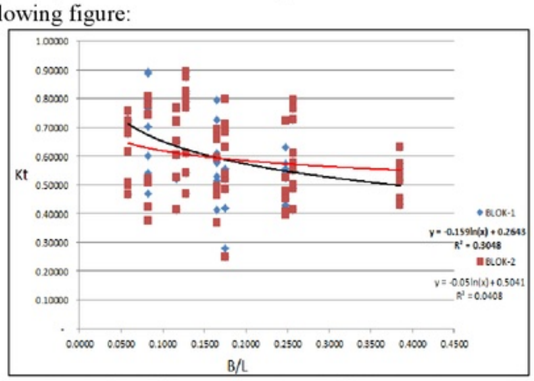


Fig. 4. Graph of the influence of slots length of B/L towards transmission coefficient (Kt)

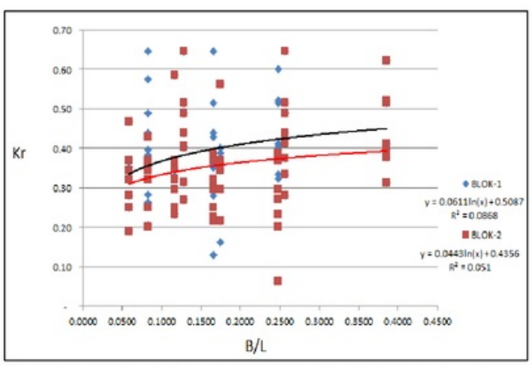


Fig. 5. Graph of the influence of slots length of B/L towards refraction coefficient (Kr)

Figure 4 shown kt values decrease if the value of B / L has increased, so the longer of the concrete block arrangement will make the transmission of wave height will be smaller and Figure 5 shown effects of B/L enlarges the reflection coefficient will be smaller and shrinking B/L will make the enlarged reflection

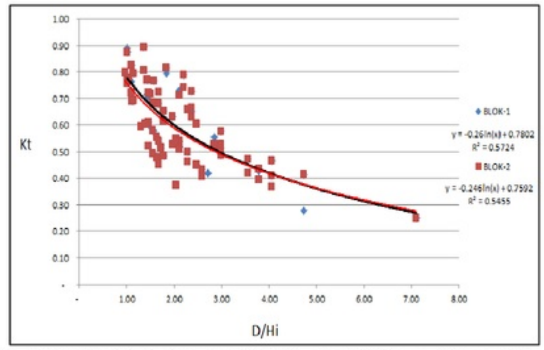


Fig. 6. Graph of the influence of slot diameter D/Hi towards transmission coefficient (Kt)

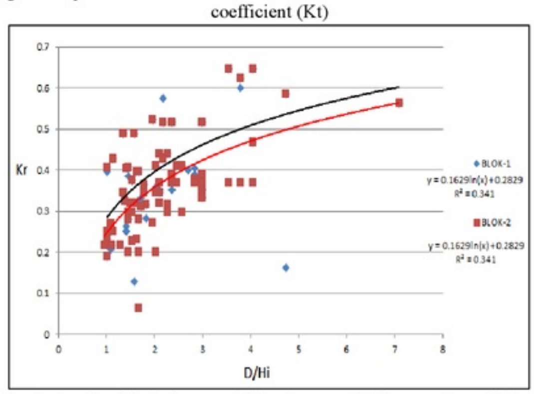


Fig. 7. Graph of the influence of slot diameter D/Hi towards coefficient

Kt and Kr is strongly influenced by the size of the hole diameter concrete block, as seen in Figures 6 and 7., As shown in the image above.

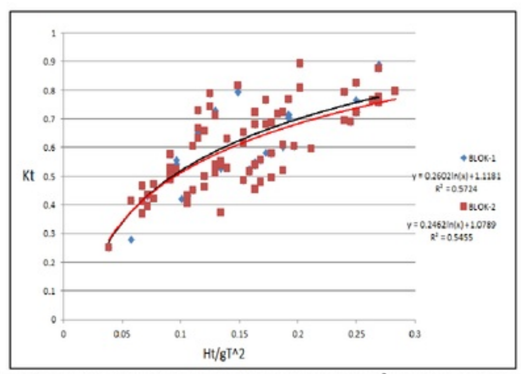


Fig. 8. Graph of the influence of wave slope Ht/gT^2 towards refraction coefficient (Kr)

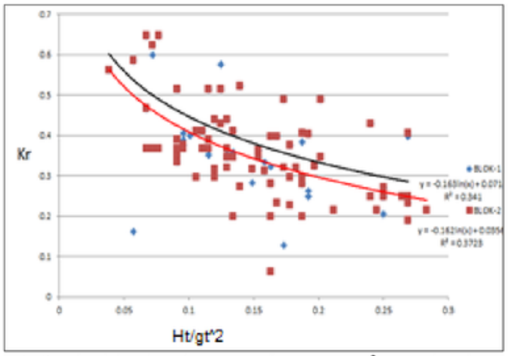


Fig. 9. Graph of the slots diameter influence Ht/gT^2 towards refraction coefficient (Kr)

The greater the value, the better the function Kt breakwater in reducing wave height, as seen in the function Ht/gt^2 where if Kt great then to Ht/gt^2 will be smaller.

According to the all figures shown above, it can be explained that the correlation between wave slope (B/L) Vs Kt, B/L Vs Kr, Ht/gT^2 Vs Kt dan Ht/gT^2 Vs Kr in the perforated concrete block slots can be explained in the following result:

1. If the amount of block row is higher then the pore slot (B) will be longer, this will increase the refraction coefficient and decrease the transmission coefficient, this shows that the length in concrete block slot will be longer then it will increase the dissipation in the concrete block, so the function of the breakwater will be better
2. If the pore slot diameter (D/Hi) is wider then the capability of dissipation of the concrete block will decrease, and the reflection in front of the breakwater will be smaller, however the transmission wave will be bigger, if the concrete block slot diameter (D/Hi) is getting smaller then the dissipation level of the breakwater will increase so that the transmission wave and reflection wave will be bigger
3. If in the same moment the value of Kt is high and the value of Kr is small, then the function of the breakwater will be better, this will happen if the slot diameter and the slot length is made ideal.

IV. CONCLUSIONS

1. Perforated concrete block will be developed to be one of the breakwater types that is eco-friendly, this is because the pore can be used as wave dissipater and it can be the home of marine biota to proliferate
2. A well placement of the perforated concrete block is required because the well placement will give the good effect of dissipation, because the influence of slot width towards the wave deduction level is not significant

V. FURTHER RESEARCH

1. It will be investigated further the influence of the effective diameter and length that can recommended in order to better the breakwater function.

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