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THE REDUCTION OF RUN-UP AND RUN-DOWN WITH PERFORATED BLOCK BREAKWATER

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ABSTRACT

Man took a step to protect the seashore using seawall or revetment as one of the concerns towards the condition of the seashore, but many shore protectors like seawall and revetment had been found broken. Its erosion affects the feet of the construction. One of damages caused by that is the high run-up and run-down when the wave attacks at revetment wall. So it is necessary to find a method that can reduce the result of run-up and run-down at the building structure, create an enhancement of the structure that is safe from the wave attack with the height of the structure, and also increase the cost. Run-up and run-down can be reduced in so many ways, such as the increased height of the structure; the wall can be made from rough material or to reduce the wave energy that can be obtained by having the wall with perforated block. Perforated breakwater is an alternative to reduce the wave energy and the idea of making this seawall or revetment made from porous block will be a solution to handle run-up at the seashore to protect the building structure and the hole of the porous concrete block will reduce concrete use and could be a proliferating place for marine biota. The purpose of this research is to investigate the performance of a perforated breakwater which is made of concrete block in order to reduce the run-up and run-down. A research with 2D physical modeling is conducted in the Coastal Engineering Laboratory of Hasanuddin University. Three different types of perforated concrete block that have the different diameter and porosity which are simulated with the different height, period, and water depth (*H, T, and d*). The parameter dimension of the models is using a geometric scale of 1:20. The result of the research shows that the parameter of the armor model which is represented by the model length (*B*), porosity (ζ), Irribaren number (*Ir*) and the wave steepness (*Hi/L*) is quite influential towards the reduction of *Ru* and *Rd*. As the model gets longer and the porosity values of the block gets bigger, then the bigger the reduction of *Ru* is. The relationship between *Ru* and *Rd* with *IrK* is presented in the form of a relationship of dimensionless parameter, where K is a function from ζ, *B/L,* and *Hi/L*. Therefore, the empirical equation that has been derived could be used to plan a prototype system for the coastal protection with perforated concrete block.

Keywords: run up, wave, perforated block.

INTRODUCTION

In line with the development of science and technology, it is important to develop the inshore zone to meet the human needs, either to support transportation or to support tourism and residential areas. In its development, the problem that often occurred is that the high waves so we need a safety to support the construction of the development to reach the expected plan.

The damage of the 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 was switch into artificial stone that was made according to the concept of the creator that leads 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 conduct 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 conducted 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.

Since Jarlan (1961) had first suggested it, perforated 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 perforated breakwater is that the wave energy will break if it hits the front part of the permeable and perforated vertical wall breakwater (Quinn, 1972). In addition to that, the upcoming wave will continue to hit the pores; this will reduce the wave reflection in front of the breakwater structure. Initially, Perforated 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

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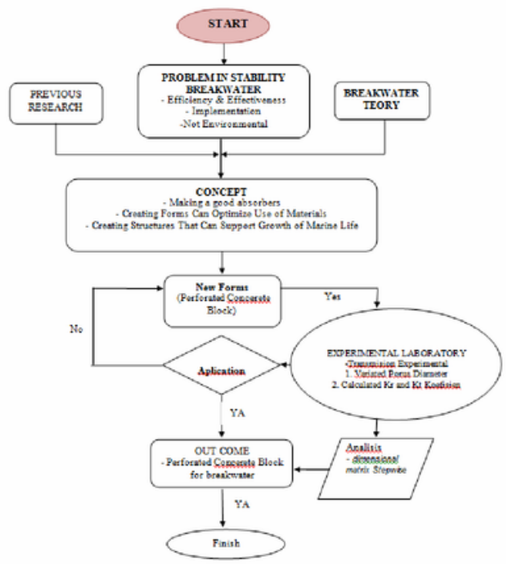
waves, waves direction, and the depth of water are also taken into account. The wave pressure on the perforated wall is less than the solid wall, as Bergmann and Oumeraci (1998) found. A research had also been done by Armono and Hall (2002) for wave transmission in submerged breakwater that was made of artificial reefs/ hollow Hemispherical Shape Artificial Reefs (HSAR). The investigation regarding the perforated breakwater had been conducted by Ariyarathne (2007), in line with the result of the research done by Kondo (1979), Suh, *et al*. (2001) and 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 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's used in this research is 2D laboratory method by using the 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.

METHODOLOGY

Concept of perforated concrete block for breakwaters can be show



The basic rules of the modeling 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 for 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 fulfills 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 fulfills 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, Rayleigh Method, Stepwise Method, and Langhaar Method. For this research, it is used Langhaar method because the variable

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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 of perforated concrete blocks 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:

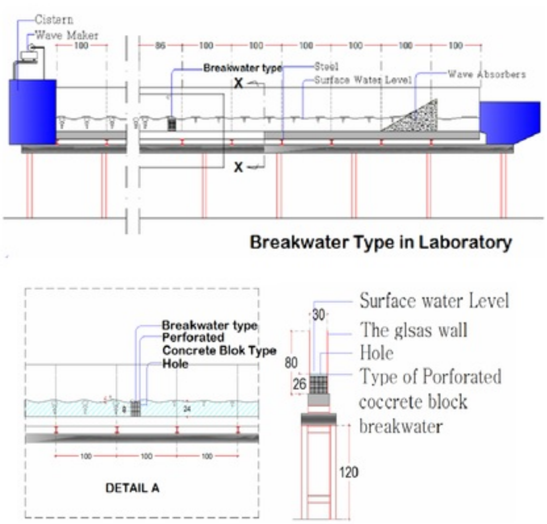
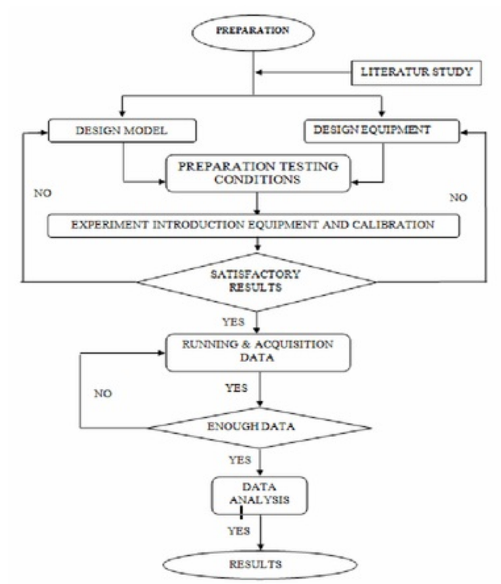


Figure-2. Model of Breakwater Simulation

Implementation scheme of perforated concrete block test for breakwaters



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:

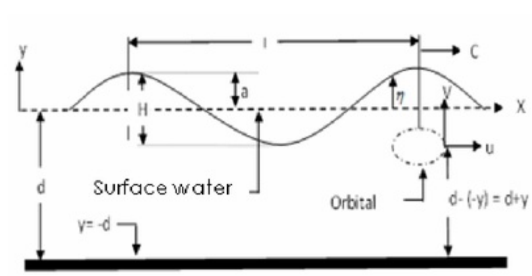


Figure-1. Wave Airy Theory.

d: distance between mean water level and sea floor

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$\eta(x,t)$: fluctuation toward mean water level
: 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 $2\pi/L$
σ : wave frequency $2\pi/T$

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

$$\eta(x,t) = H/2 \cos(kx - \sigma t) \qquad \text{.....(1)}$$

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 Error! Reference source not found; 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.

$$C = \frac{gT}{2\pi}\tanh\frac{2\pi d}{L} = \frac{gT}{2\pi}\tanh .kd \qquad \text{.....(2)}$$

$$L = \frac{gT^2}{2\pi}\tanh\frac{2\pi d}{L} = \frac{gT^2}{2\pi}\tanh .kd \qquad \text{.....(3)}$$

Disperse equation is

$$\omega^2 = gk\tanh kh \qquad \text{.....(4)}$$

This equation can be simplified as:

$$\frac{\omega^2 h}{g} = kh\tanh kh \text{ or } C = X\tanh X \qquad \text{.....(5)}$$

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

The wave length can be calculated using the of Newton Raphson Method

$$\Delta x = \frac{C - X\tanh X}{\tanh X + \frac{X}{\cosh^2 X}} \qquad \text{.....(6)}$$

X value is the value of X which has a small Error! Reference source not found. X, so X is

$$\frac{2\pi}{L}d = X \qquad \text{.....(7)}$$

Calculation wave length for T=1.45 S and d=0.24 m can be shown in the Table below

Table-1. Data of Calculated D/HI, KR, KT.

C	X	xtanhx	tanh x	cos^2 x	X/Cos^2x	C-XTanghX	TanhX+	Delta X
1	2	3	4	5	6	7=1-3	x/Cosh^X	9=7/8
							8=4+6	
0.454277127	2.000	1.928	0.964	14.154	0.141	-1.474	1.105	-1.333
	0.667	0.389	0.583	1.514	0.440	0.066	1.023	0.064
	0.731	0.456	0.624	1.636	0.447	-0.002	1.070	-0.001
	0.729	0.454	0.623	1.633	0.447	0.000	1.069	0.000
	0.729	0.454	0.623	1.633	0.447	0.000	1.069	0.000

With used equation 7 can be calculation length wave (L) is 2, 07 m

Table-2. Data of Calculated D/HI, KR, KT.

BLOK DIA SIZE	Length Wave Wave (L) cm	T (det)	Str Leght (B)cm	Hi	Kr	Kt	D/Hi
Size of Perforated is 1,6 Cm With Porositas Is 0.536	121.25	1.03	15.000	1.60	0.56	0.38	1.00
	121.25	1.03	10.000	1.63	0.54	0.43	0.98
	121.25	1.03	5.000	1.50	0.47	0.43	1.07
	121.25	1.03	15.000	2.60	0.35	0.52	0.62
	121.25	1.03	10.000	2.65	0.32	0.53	0.60
	121.25	1.03	5.000	2.75	0.27	0.51	0.58
	121.25	1.03	15.000	3.60	0.25	0.57	0.44
	121.25	1.03	10.000	3.60	0.25	0.71	0.44
	121.25	1.03	5.000	3.60	0.25	0.75	0.44
	129.23	1.45	15.000	1.85	0.35	0.22	0.86
	129.23	1.45	10.000	1.85	0.35	0.32	0.86
	129.23	1.45	5.000	1.90	0.32	0.32	0.84
	129.23	1.45	15.000	2.65	0.32	0.34	0.60
	129.23	1.45	10.000	2.75	0.27	0.45	0.58
	129.23	1.45	5.000	2.70	0.30	0.63	0.59
	129.23	1.45	15.000	3.55	0.27	0.72	0.45
	129.23	1.45	10.000	3.75	0.23	0.72	0.43
	129.23	1.45	5.000	3.75	0.20	0.72	0.43
	134.07	2.00	15.000	1.85	0.35	0.54	0.86
	134.07	2.00	10.000	1.80	0.39	0.44	0.89
	134.07	2.00	5.000	1.75	0.43	0.43	0.91
	134.07	2.00	15.000	2.25	0.56	0.24	0.71
	134.07	2.00	10.000	2.60	0.35	0.52	0.62
	134.07	2.00	5.000	2.80	0.25	0.71	0.57
	134.07	2.00	15.000	3.35	0.34	0.48	0.48
	134.07	2.00	10.000	3.45	0.33	0.59	0.46
	134.07	2.00	5.000	3.60	0.25	0.72	0.44

2. Run up and run down

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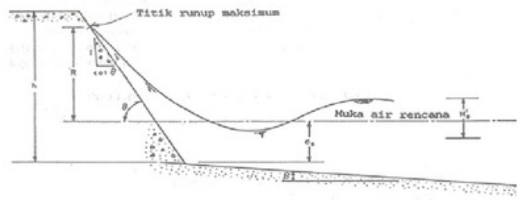

Figure-2. Wave Run-Up.

$$I_r = \frac{tg\theta}{(H/L_0)^{0.5}}$$

where:

I_r = Irribaren number
θ = Angele of breakwater
H = Wave height
L_0 = Wave length

DISCUSSIONS

With the addition of concrete block holes, it 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:

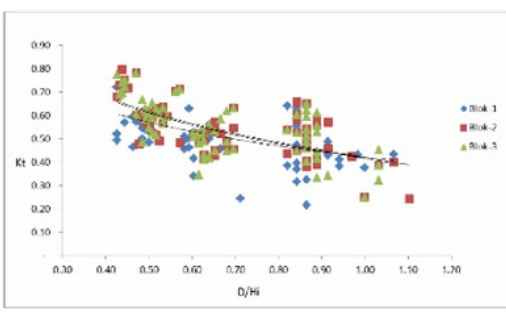

Figure-3. Graph of the influence of slot diameter D/Hi towards transmission coefficient (Kt).

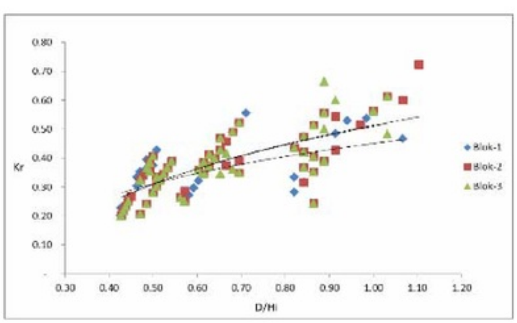

Figure-4. Graph of the influence of slot diameter D/Hi towards refraction coefficient (Kt).

Kt and Kr is strongly influenced by the size of the hole diameter concrete block, as seen in Figures 3 and 4., As shown in the image above.

Relationship between the irrabiren numbers towards Ru/H can be shown in the picture below.

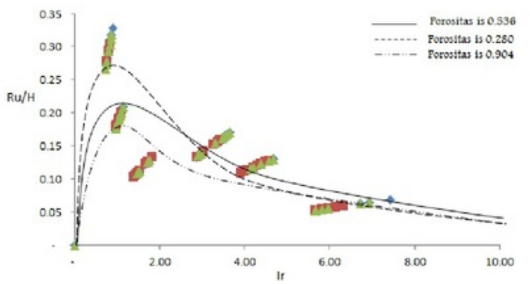

Figure-5. Graph of the Irrabiren number (Ir) towads Ru/H.

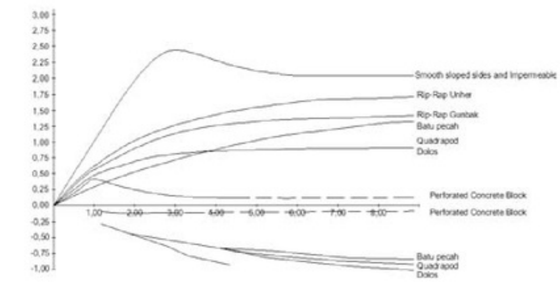

Figure-5. Graph of comparison of the run-up based on the material making up the breakwater.

As the the value of Ru/H is smaller, the function of perforated block breakwater in reducing run up and run down gets better, as seen in the graph above.

Between some materials that to compared perforated block breakwater break water showed the smallest value Ru/H.

CONCLUSIONS

I. Holes in the perforated blocks breakwater will give a significant effect of immersion on the run-up and run-down
II. High level of run-up and run-down reduction on the perforated breakwater blocks can reduce the breakwater excessive design which can certainly reduce the use of materials
III. Perforated concrete block breakwater will be developed to be one of the types of breakwater because the pore of perforated concrete block can reduce the wave height up to 80% and pore of the perforated concrete block can be the home of marine biota to proliferate.

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