The basic concepts of the sloping hollow breakwater model

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Abstract. The breakwater is a beach construction structure that is used to anticipate and control abrasion. The structure of the wave damper has experienced significant developments. One of the structures of the wave damper is a hollow wave breaker. Hollow breakwater has a varied model, besides minimizing wave of reflection, it is also expected to reduce transmission waves. The reason is because of its ability to absorb wave energy and to reduce the energy of incoming waves. This research is a preliminary simulation as the basis for determining the sloping hollow breakwater model. The study was conducted experimentally in a laboratory with the variables studied include the wave period (T), wave height (H), and wavelength (L). Variable water level (d) is arranged with variations of 21, 24, and 27 cm and the model parameters are cylindrical cavity volume (S), square cavity volume (P), and the slope of the breakwater (α). The results of research based on the theory of wave attenuation and previous studies of the hollow/porous shoreline protection model show that the holes and cavities in the proposed model are expected to work to capture the orbital wave flow and reduce their energy in the cavity through the turbulence process.

1. Introduction
The breakwater structure has experienced significant development, one of the wave damping structures is hollow and hollow breakwaters. Hollow breakwater has a varied model which in addition to minimizing wave reflection is also expected to reduce transmission waves, because of its ability to absorb wave energy and reduce the energy of incoming waves. Research on porous concrete blocks states that the hole, slot length, porosity of the concrete block surface, the number of blocks have a very big influence on the transmission and reflection coefficient values [1-4]. The transmission coefficient (Kt) decreases with the increase in wavelength and wave height, the reflection coefficient (Kr) increases with the increase in wavelength and wave height for the surface position, the increase occurs until a certain wavelength value then decreases for submerged cases [5-7].

With this foundation, this study wants to maximize the cavity by making a certain shape and volume of the cavity in the breakwater structure that is expected to increase resistance, so it is expected to be more effective in reducing incoming waves.

2. Characteristics of slopping hollow-side breakwaters
Research on tilted side breakwaters has been carried out with steel plates made rigid to eliminate the possibility of vibrations, experiments carried out with the tilt angle of structures $45^\circ$, $60^\circ$, $75^\circ$ and $90^\circ$ and made perforation 0%, 10%, 20%, 30%, 40% and 50%. The test results clearly show that the difference in the tendency of the breakwater structure with a slope of $60^\circ$ to $90^\circ$ has a very small effect on the relative wave increase compared to the slope of $45^\circ$ to $60^\circ$. This test also proves that the reflection on the beach wall with a slope of $45^\circ$ and $60^\circ$ is much greater than the slope of $60^\circ$, $75^\circ$, and $90^\circ$. The results also showed that increasing perforation had a marked effect in decreasing relative waves [8]. The definition sketch of the wave run-up model is shown in figure 1.

![Figure 1. Definition sketch of wave run-up model](image1)

Research on porous breakwaters has been carried out with the result that the reflection coefficient increases where a longer pipe is more efficient in reducing the reflection coefficient [9]. Submerged breakwaters in front of porous coastlines decrease the speed of waves on the sea wall and reflecting waves with variations in seawall width, seawall porosity, relative water depth, and wave steepness [10]. The breakwater functions will be better and if the diameter of the porous slot is wider, then the dissipation ability of the concrete beam will decrease, and the reflection in front of the breakwater will be smaller, but the transmission wave will be greater if the concrete block has smaller slot diameter [11]. Holes, slot lengths, the porosity of concrete block surfaces, the number of block blocks give a very big influence on the coefficient of transmission and reflection [12]. The porosity of the permeable outer layer helps to eliminate most of the wave energy, which in turn reduces the impact of the wave force on the inner rigid core of the submerged structure. Also, the increase in the friction coefficient of the hollow material is more effective than the increase in the thickness of the permeable outer layer for the dissipation of wave energy by submerged structures [13]. The schematic diagram for wave trapping when the wall is on the sloping bed is shown in figure 2.

![Figure 2. The schematic diagram for wave trapping when the wall is on the sloping bed](image2)
The composition of artificial corals with perforated hemispherical shapes (HSAR) has been investigated as a submerged composite breakwater. Smooth and perforated HSAR holes have hydraulic stability and produce a coherent vortex with the upward flow and provide a hiding place for fish. HSAR can also produce favorable whirlpools and turbulence, which are interesting characteristics for habitat structures because fish abundance is affected by whirlpools. Figure 3 shows the type of HSAR.

Figure 3. HSAR unit types

Research has been carried out by constructing a breakwater using a rubble mound base in conjunction with an HSAR unit, where, the HSAR unit is placed in a deeper location, to solve the problem of small stones that have accumulated so that part of the structure is buried on the seabed. This condition can reduce the efficacy of artificial reefs because cavity features at the bottom of Reef Balls that attract crawling marine organisms will be buried and covered with sediment [14]. Figure 4 shows the HSAR breakwater.

Figure 4. HSAR breakwaters

Dimension analysis is performed on the dimension variables that affect $K_t$ wave transmission:

$$K_t = \frac{H_t}{H_i} = f \left[ \frac{H_i}{gT^2}, \frac{h}{d}, \frac{h}{B} \right]$$

The nature of incoming and transmitted waves, placement of structures and geometries, namely: steepness of waves, wave transmission, depth of immersion, and proportion of reefs. The results obtained that the wave height is influenced by wave steepness, immersion depth, and reef geometry. Wave energy is reduced by an average of about 60%. The wave transmission equation obtained from the statistical analysis conducted is:

$$K_t = 1,616 - 31,322 \frac{H_i}{gT^2} - 1,009 \frac{h}{d} + 0,265 \frac{h}{B}$$

3. Results and discussion

The research carried out is to create a hollow oblique side breakwater model with model parameters in the form of cavity shape and volume. Some previous studies on porous breakwaters produce longer pipes that are more efficient in reducing the reflection coefficient. Submerged breakwaters in front of porous coastlines reduce wave velocity on sea walls and wave reflection with variations in seawall width, seawall porosity, relative water depth, and steepness of waves. The breakwater functions will be better and if the diameter of the porous slot is wider, then the dissipation ability of concrete beams will decrease, and the reflection in front of the breakwater will be smaller. Holes, slot lengths, the porosity of concrete block surfaces, the number of block blocks give a very big influence on the coefficient of transmission and reflection. The porosity of the permeable outer layer helps to eliminate most of the wave energy, which in turn reduces the impact of the wave force. The reflection on the beach wall with
a slope of $45^\circ$ and $60^\circ$ is much greater than the slope of $60^\circ$, $75^\circ$, and $90^\circ$. The results also showed that increasing perforation had a significant effect on decreasing relative waves.

Research that has been done requires a relatively long pipe, relatively many holes, a relatively large hole diameter that affects the decrease in the value of the reflection coefficient, transmission, and reduce wave energy. The number, length, and diameter of holes in the breakwater must be related to the volume of the hole itself, for this reason, the proposed breakwater with sloping and hollow sides, the proposed model is expected to solve the problem of small stones accumulating so that the breakwater can be buried or covered with sediment with a model of the front hole towards the incoming wave is relatively higher and the exit hole at the bottom is shown in figure 5.

![Figure 5. Model of the Sloping hollow breakwater structure](image)

In Armono, dimension analysis is carried out on four-dimensional parameters in the form of incoming and transmitted wave characteristics, structure, and geometry, namely: steepness of waves, wave transmission, immersion depth, and proportion of reefs by considering other parameters that are, the Reynolds number is constant, so in this study, the Reynolds number is used as a parameter of the cavity volume function, as well as the proportion of the breakwater as a parameter of the slope function, so that dimensional analysis is carried out on the dimensions of the wave steepness, wave transmission, depth, slope and cavity volume, the dimension variables that affect wave transmission ($K_t$) can be stated as equation 1.

$$K_t = \frac{H_t}{H_i} = f \left[ h, T, \rho_w, H_i, H_t, d, B, \mu, g \right]$$

(1)

$\rho_w, \mu$, is mass density, dynamic viscosity while $g$ is the gravitational acceleration. The matrix method produces the following $\pi$:

$$\frac{H_i}{h}, \frac{H_t}{h}, \frac{d}{h}, \frac{\mu T}{h}, \frac{g T^2}{h} = \pi_1, \pi_2, \pi_3, \pi_4, \pi_5, \pi_6, = 0$$

by combining $\pi$ obtained:
\[
\frac{H_t}{H_i} \frac{H_i}{gT^2} \frac{h}{B} \frac{h}{\sqrt{gH_i}} \mu/\rho_w = \frac{\pi_2}{\pi_1} \frac{\pi_3}{\pi_6} \frac{1}{\pi_3} \frac{1}{\pi_4} \sqrt{\frac{\pi_1 \pi_6}{\pi_5}}
\]

then the proposed equation is shown in equation 2.

\[
K_t = \frac{H_t}{H_i} = f \left[ \frac{H_i}{gT^2} \frac{h}{B} \frac{h}{\sqrt{gH_i}} \mu/\rho_w \right]
\]

Where \(K_t\) is a function of the parameters of wave steepness, breakwater slope, water depth, and cavity volume.

The variables studied to obtain the wave characteristics in designing the hollow oblique side breakwater model are the wave period (T), wavelength (T), wave height (H), water depth (d). The design of hollow and hollow slanted side breakwaters is based on several specifications:

a) The model is made of acrylic material with a scale model of 1: 20 that is made of cavities with square shapes and cylinders with certain cavity volumes.

b) Model width (B) is 30 cm the length of the top 20 cm, the length of the bottom 60 cm, and the height of the model (h) is 31 cm.

c) The model parameters studied were cylinder cavity volume (S), square cavity volume (P), and angle slope (\(\alpha\)). Variations in model parameters are shown in table 1.

**Table 1. Variation of model parameters**

| No. | Type of Variation            | Amount of Variation |
|-----|------------------------------|---------------------|
| 1.  | Cylindrical Cavity Volume (S)| 1 variation         |
| 2.  | Square cavity volume (P)     | 1 variation         |
| 3   | Slope (\(\alpha\))          | 3 variations        |

d) The wave parameters studied were wave height (H), wave period (T), and water depth (d) with variations of 27, 25, and 21 cm. The variation of wave parameters is shown in table 2.

**Table 2. Variation of wave parameters**

| No. | Type of Variation | Amount of Variation |
|-----|-------------------|---------------------|
| 1.  | Wave height (H)   | 3 variations        |
| 2.  | Wave period (T)   | 3 variations        |
| 3.  | Water depth (d)   | 3 variations        |

Preliminary simulations were carried out with variations in water depth (d) with variations of 21, 25, and 27 cm. Retrieval of wave height and wavelength observational data is measured and recorded at two points. Wave height measurements are carried out when the waves are generated under stable conditions, which is sometime after the waves are generated. Preliminary simulation results are obtained as in table 3.

**Table 3. Preliminary simulation results**

| Depth (D) (cm) | Variables      | Period (sec.) |
|---------------|----------------|---------------|
|               | (cm)           | 1.5 | 1.3 | 1.2 |
| 27            | Wave height (H)| 4.67| 4.75| 5.83|
|               | Wave length (L)| 233 | 204 | 184 |
| 24            | Wave height (H)| 4.56| 4.91| 5.15|
|               | Wave length (L)| 198 | 183 | 166 |
| 21            | Wave height (H)| 3.89| 4.09| 4.49|
|               | Wave length (L)| 192 | 187 | 159 |
4. Conclusion

a) Based on previous studies of hollow/porous coast protection models, it is known that cavities or porous are quite effective at absorbing waves.

b) Based on the theory that wave attenuation is strongly influenced by the friction medium through which the wave propagates, where the orbital velocity of the water particles in the wave will be reduced by the presence of friction.

c) The holes and cavities in the proposed model are expected to work to capture the flow of wave orbitals and reduce their energy in the cavity through the turbulence process.

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