WAVE HEIGHT REDUCTION THROUGH THE UNDER SURFACE PIPE STRUCTURE MODEL

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ABSTRACT

The model of the subsurface pipe structure is designed as a reducer of the height of an incident wave generated. Part of the wave will be reflected, and some will be transmitted through the pipe structure. Experiments on the calculation of reflection and transmission coefficients on the subsurface pipe structure model were carried out with variations in the depth of water in the flume. This experimental study aims to determine the effect of changes in incident waves on variations in water depth above the subsurface pipe structure (d-h = 0.0h; 0.1h; 0.2h). This research was conducted at the Hydraulics Laboratory of the Department of Civil Engineering, Faculty of Engineering, Hasanuddin University. Experimental laboratory research method using a wave generator flume with the characteristics of the generated waves consisting of 3 variations of the period (T=1.0 seconds, T=1.1 seconds, T=1.2 seconds) with three variations of water depth (d) which used, i.e., d=1.0h; d=1,1h and d=1,2h, where h is the height of the pipe structure. The results of this study indicate that the deeper water above the structure, the smaller the reflection coefficient and the greater the transmission coefficient.

Keywords: pipe structure, wave reflection, wave transmission.

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INTRODUCTION

Breakwaters have undergone many research developments, one of which is the structure of the porous breakwater. An essential characteristic of the porous breakwater is that the wave energy will break when it hits the permeable and porous front wall. The incoming wave will continue to pass through the existing hole, reducing the occurrence of wave reflections in front of the structure. A porous breakwater is a breakwater structure that takes the form of a caisson breakwater, the front wall facing the open ocean is given a hole, and the back wall is made impermeable. The submerged porous breakwater in front of the shoreline reduces the speed and reflection of waves on the seawall with variations in seawall width, seawall porosity, relative water depth, and wave steepness (Syamsuri *et al.*, 2022).

The porous or perforated breakwater is expected in addition to minimizing wave reflections. It can also reduce transmission waves due to its ability to absorb wave energy and reduce incident wave energy. If the wave energy passes through a surface, the wave energy will decrease as the friction surface increases. The porous breakwater is expected to reduce wave energy by using a pipe structure by making and designing models in the laboratory.

The model tested in this research aims to study the changes in reflection and transmission waves due to changes in water depth (water height) above the model. Therefore, it is necessary to test the model to compare differences and wave responses from various variations in water depth above the pipe structure (dh)/h

LITERATURE STUDY

The critical parameters to describe water waves are the wavelength, the height of the wave, and the depth of the water in which the wave propagates. Other parameters such as the effect of speed can be determined from the three primary parameters above, as for understanding the above parameters (Triatmodjo, 1993): Wavelength (L) is the horizontal distance between two successive peaks or highest points of waves. It can also be described as the distance between two wave troughs. The wave period (T) is the time required for two successive wave crests/troughs to pass a certain point. The velocity of the wave (celerity) (C) is the ratio between the wavelength and the period of the wave (L/T). When a water wave propagates at a speed of C, the water particles do not move in the direction of the wave propagation. The coordinate axis to explain the wave motion is at a depth of the calm water level. Amplitude (a) is the vertical distance between the crest/highest point of the wave or the trough/lowest point of the wave and the calm water level ($H/2$).

Wave deformation is a change in wave properties that occurs when a wave moves towards the beach. Changes commonly called wave deformation include Refraction, Diffraction, and Reflection (Triatmodjo, 1999):

a) Wave refraction is an event where the direction of the wave is deflected into shallow waters caused by some of the waves still propagating at the speed of deep-sea waves when they enter the shallow sea. In addition to affecting the waves' direction, refraction also dramatically affects the wave height and the distribution of wave energy along the coast. In the deep sea, where the seabed is very far from the surface, the influence of the seabed on the movement of waves is almost not existed. When the waves originating from the deep ocean go or move towards shallow waters where the sea depth factor becomes increasingly instrumental in their propagation, then if wave crest line and the top of the wave in shallower seas are observed, it will move slower than in the sea which results in the crest of the wave being deflected and trying to align with the contour line of the seabed/coast.

b) Wave diffraction will occur when the incoming wave is blocked by a barrier, a breakwater building, or small islands around it. As a result of being blocked, the incoming tide will bend around the end of the obstacle/barrier and enter the protected area behind it. In this case, energy transfer will occur in a direction perpendicular to the protected area. The phenomenon of wave diffraction is fundamental to be considered in the Planning of Ports and Breakwater Buildings.

c) Wave reflection is a wave that occurs when the incoming wave hits or blocks a wall or barrier, such as a breakwater. The reflection phenomenon can be found in harbor ponds. Different reflection coefficients can determine the reflection of waves for various types and types of buildings.

When a traveling wave passes through an obstacle, the wave will be reflected by the barrier. If the reflection is perfect or the incident wave is wholly 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. However, if the barrier has porosity or cannot reflect perfectly, then the wave height in front of the barrier will be less than twice the height of the incident wave, and in this condition, it is called a partial standing wave. An example of a partial wave event is a wave hitting the beach or a breakwater experiencing imperfect energy reflection.

If a wave undergoing imperfect reflection hits a barrier, then the height of the incident wave *Hi* will be greater than the height of the reflected wave *Hr*. The period of the incident and reflected waves is the same, so the wavelength is also the same (Syamsuri *et al.*, 2019). Because the reflection is not perfect, causing no actual node of the wave profile, to separate the height of the incident wave and the height of the reflected wave, Equations (1) and (2) obtain the maximum and minimum water level elevations for partial standing waves as follows (Dead *et al*, 1984:

$$\eta_{t\max} = \frac{H_i + H_r}{2} \qquad \text{... (1)}$$

$$\eta_{t\min} = \frac{H_i - H_r}{2} \qquad \text{.. (2)}$$

By eliminating equations (1) and (2), the equation obtained:

$$H_i = \frac{H_{\max} + H_{\min}}{2} \qquad \text{...................................... (3)}$$

$$H_r = \frac{H_{\max} - H_{\min}}{2} \qquad \text{...................................... (4)}$$

If the incident wave hitting the barrier is partially transmitted, the passing wave will experience the same thing as when it hit the barrier. If an obstacle blocks the transmitted wave, then the transmitted wave height *Ht* can be calculated by the formula:

$$H_t = \frac{(H_{\max})_t + (H_{\min})_t}{2} \qquad \text{.......................... (5)}$$

Furthermore, using Equations (3) to (5), the height of the incident wave, reflection, and transmission can be calculated.

The ratio between the height of the reflected wave and the height of the incident wave is described as the reflection coefficient (*Kr)*. At the same time, the ratio between the height of the transmission wave and the height of the incident wave is described as the transmission coefficient (*Kt)*.

The amount of dissipated wave energy is the energy of the incident wave minus the energy of the transmission and reflection waves (Horikawa, 1978). The energy loss coefficient is given the symbol $K_{d.}$ Then Equation (6) can be written:

$$K_r + K_t + K_d = 1 \qquad \text{...(6)}$$

$K_t = \dfrac{H_t}{H_i}$ = wave transmission coefficient ....(7)

$K_r = \dfrac{H_r}{H_i}$ = wave reflection coefficient ....(8)

K_d = wave energy loss coefficient

METHODOLOGY

A. Type of Research

The research was carried out at the Hydraulics Laboratory of the Department of Civil Engineering, Faculty of Engineering, Hasanuddin University in Gowa. The type of research used was experimental, where observations were made under artificial conditions, where these conditions were designed concerning the literature related to the research. Thus, experimental research is conducted by manipulating the object of research and the existence of controls. The aim is to investigate whether there is a causal relationship and how significant the causal relationship is by giving specific treatments to several experimental groups and providing controls for comparison.

In this study, two sources of data will be used, namely, primary data obtained directly from physical model simulations in the laboratory and secondary data, namely data obtained from the literature and the results of existing research, both those that have been carried out in the laboratory and carried out in other places related to porous breakwater research.

B. Parameters and Research Design

Before taking data, measure the water depth (*d*) which has been previously determined (adjusted for flume height), namely $d1$ = 1.0*h*; *d2*=1.1*h*; *d3*=1,2*h*, where h is the model height, with two variations of pipe diameter, namely *D7.5* = 7.5 cm and *D15* = 15 cm. For the surface roughness on the pore walls/pipe holes selected with four variations, namely without roughness (*K0*); coarse sand with a diameter of 0.3 - 0.5 cm (*K1*); gravel with a diameter of 0.7 - 0.9 cm (*K2*) and coral with a diameter of 1.0 - 1.2 cm (*K3*). Furthermore, for the placement of the model position on the wave channel, it must be in the proper position to be effective when the incoming wave or reflection wave is in front of the model.

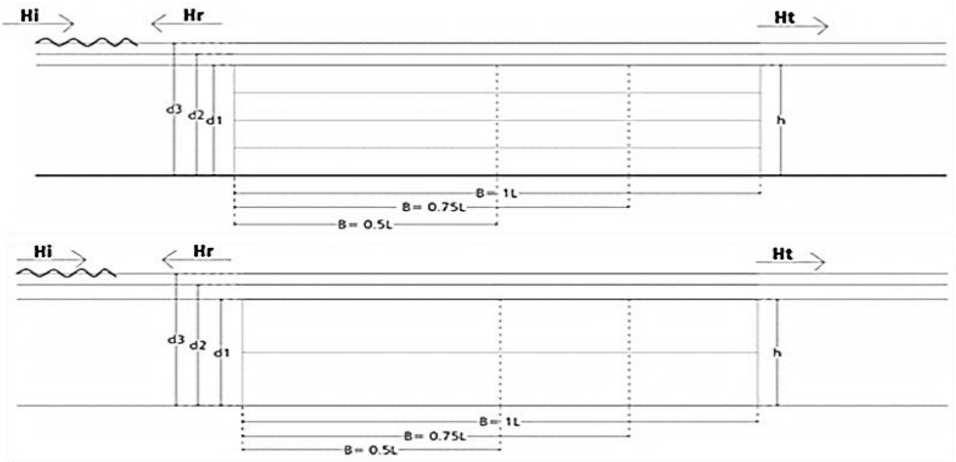

Figure-1. Variation of water depth (*d*) above pipe structure *D7.5* and *D15*.

The research procedure is to adjust the water level, namely the water depth *d1* = (30 cm); *d2* = (33 cm) and *d3* = (36 cm), then adjust the stroke distance on the flap into three varied strokes, namely 4, 5 and 6 and adjust the wave period variations, namely *T1* = 1.0 seconds, *T2* = 1.1 seconds and *T3*=1.2 seconds. Then calibrate each probe at every varied water depth, placing probe1 and probe2 in front of the model facing the wave while probe3 is behind the model. The distance between probes 1 and 2 was adjusted to *L*. (Goda, Y. Zusuki, 1976). Running begins with reading the wave height obtained from probe1, probe2, and probe 3, repeated with different periods (*T*) and strokes 4, 5, and 6 variations.

RESULTS AND DISCUSSIONS

A. Wave Height Analysis

Essential parameters to explain water waves include wavelength (*L*), wave period (*T*), and wave propagation speed (*C*). wavelength (*L*) and wave height (*H*) in the wave generation flume. The primary data obtained and observed in data collection is the reading of the upper and lower threads in each probe. The following are the results of the analysis of wave data calculations:

Wavelength is a function of depth (*d*) and period (*T*). In this study, the wavelength was obtained in 2 ways: the results of calculations and direct observations/ measurements on the wave generation flume. The wavelength is calculated according to the depth (*d*) = 0.36 m with a period (*T*) = 1.2 seconds. The results are:

L_0 = 1,56 (T^2) = 1,56 ($1,2^2$) = 2,246 m

$$\frac{d}{L_0} = \frac{0,36}{2,246} = 0,1602\ substituted\ \frac{d}{L} = 0,1917$$

where:

$\frac{d}{L_0} = \frac{d}{L}$ (Function table $\frac{d}{L}$ for increasing value of $\frac{d}{L_0}$)

$L = \frac{d}{d/L} = \frac{0,36}{0,1909}$ =1, 8858 m. So the wavelength (*L*) is = 1, 89 m

The incident wave height (*Hi*) in the wave generation flume occurs in front of the model. The Hi value is obtained from the *Hmax* and *Hmin* values division contained in probe1 and probe 2. The following are the results of the calculation of the incident wave height (*Hi*):

$$(Hi) = \frac{Hmax_{(probe2)} + Hmin_{(probe1)}}{2}$$

The reflection wave height (*Hr*) in the wave generation flume occurs in front of the model. The subtracted *Hr* value is obtained from the division of the *Hmax* and *Hmin* values found on probe1 and probe 2.

Following are the results of calculating the height of the incident wave (*Hi*):

$$(Hr) = \frac{Hmax_{(probe2)} - Hmin_{(probe1)}}{2}$$

While the transmission wave height (*Ht*) occurs behind the model, the *Ht* value is obtained from the division of the *Hmax* and *Hmin* values contained in probe 3. The following are the results of the calculation of the transmission wave height (*Ht*):

$$(H_t) = \frac{Hmax_{(probe3)} + Hmin_{(probe3)}}{2}$$

B. Effect of Sinking Depth (*d/h*) on *Kt* and *Kr*

In this study, there are several variations of parameters that affect one of them is the depth of sinking (*d/h*), namely the ratio between the depth of the water (*d*) and the height of the model (*h*) = 30 cm, where there is three varied depth of sinking, namely *d* = 1.2*h* (36 cm); *d*=1.1*h* (32 cm) and *d*=1.0*h* (30 cm). Figure-2 below shows the structure of the subsurface pipe with a diameter of 7.5 cm (*D7.5*) as shown below:

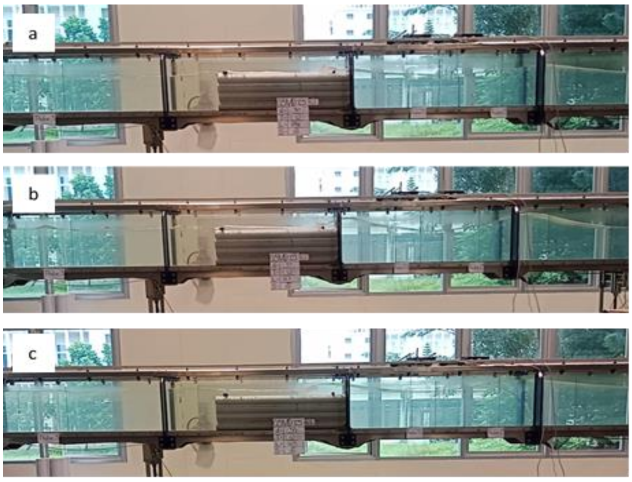

Figure-2. Pipe structure *D7.5* at *d*=30 cm (a); *d*=33 cm (b) and *d*=36 cm (c).

The results of the analysis of the effect of water depth above the pipe structure (*d-h*)/*h* on *Kt* and *Kr* in the *D7.5* model can be seen in Figure-3 below for changes in each different roughness (*K*):

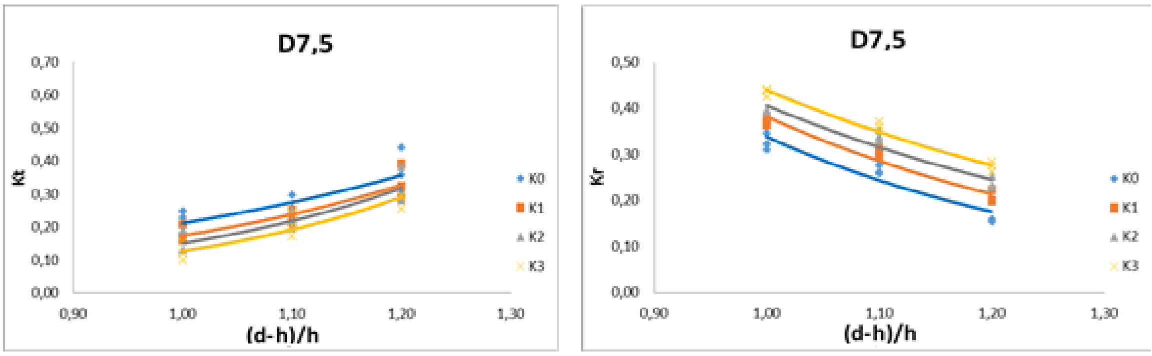

Figure-3. Effect of (*d-h*)/*h* on *Kt* and *Kr* in the *D7.5* model.

Figure-3 above shows that the transmitted wave experienced a significant increasing trend with increasing water depth above the pipe structure (*d-h*)/*h* in all roughness variations (*K*). The value of the transmission coefficient of the four variations of *K* looks different where the value of *Kt* for *K0* = 0.25 - 0.45; *K1* = 0.20-0.42; *K2* = 0.18-0.40 and *K3* = 0.16-0.37. This is because the higher the water level above the model, the larger the waves that are transmitted/transmitted. While the reflection wave shows the greater the depth of water above the pipe structure (*dh*)/*h*, the smaller the reflected/reflected wave is since the incoming wave is not completely or partially not impacted by the pipe structure so that it is small in reflecting waves in various variations of roughness even though they have the difference in *Kr* values of the four roughnesses (*K*). The value of the reflection coefficient of the four variations of *K* looks different where the value of *Kr* for *K0* = 0.12 - 0.30; *K1* = 0.15 – 0.35; *K2* = 0.17-0.37 and *K3* = 0.18-0.39.

Meanwhile, Figure-4 below shows the structure of the subsurface pipe with a diameter of 15 cm (*D15*) as shown below:

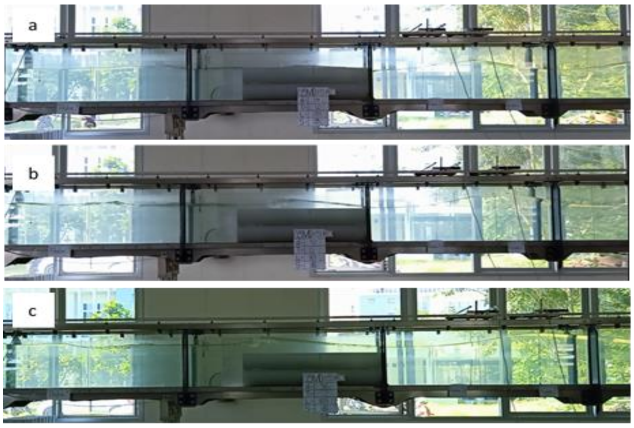

Figure-4. Pipe structure *D15* at *d*=30 cm (a); *d*=33 cm (b) and *d*=36 cm (c).

The analysis of the effect of sinking depth (*d/h*) on *Kt* and *Kr* on the *D15* model can be seen in the following graph for changes in the value of *Kt* and *Kr* values for each different roughness:

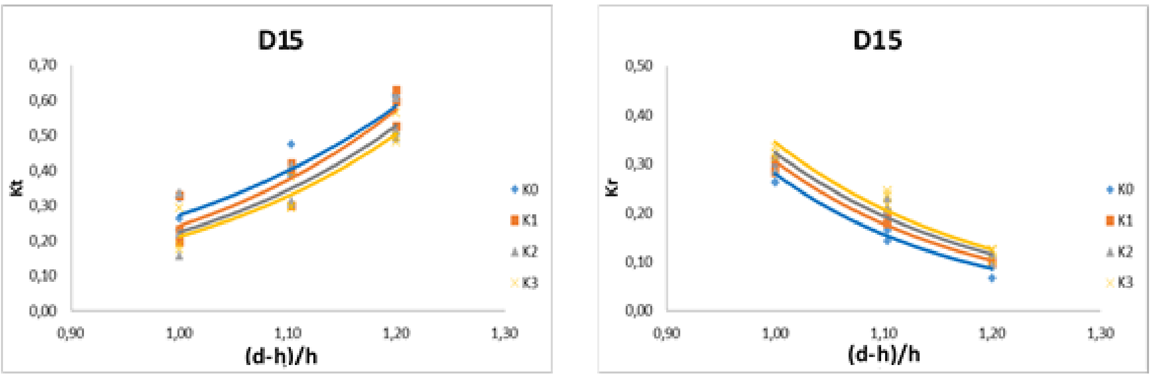

Figure-5. Effect of (*d-h*)/*h* on *Kt* and *Kr* on the *D15* model.

Figure-5 shows the difference in the transmission coefficient values for the four variations of *K*, where the *Kt* value for *K0* = 0.30 - 0.47; *K1* = 0.38 - 0.45; *K2* = 0.36 - 0.40 and *K3* = 0.21 - 0.38. This is because the higher the water level above the model, the larger the waves that are transmitted/transmitted. So that there is an increasing value of *Kt* as the water depth increases above the pipe structure. Meanwhile, *Kr* shows a trend where the greater the depth of water above the pipe structure, the smaller the reflected wave is due to the incoming wave not fully or partially not colliding with the pipe structure so that it is small in reflecting waves. The value of the reflection coefficient of the four variations of *K* looks different where the value of *Kr* for *K0* = 0.13 - 0.32; *K1* = 0.15 - 0.36; *K2* = 0.17 - 0.38 and *K3* = 0.21 - 0.39. When compared with two models of pipe arrangement with a diameter of 7.5 cm (*D7.5*) and a diameter of 15 cm (*D15*) concerning *Kt* and *Kr*, it can be seen that the small diameter pipe structure has a lower *Kt* value than the large-diameter model, but the *Cr* appears to be larger in the pipe structure with a small diameter than in the model with a large diameter.

CONCLUSIONS

Based on the study results, it was shown in the two models with different diameters that the resulting transmission wave was strongly influenced by changes in water depth above the pipe structure, where the higher the water above the pipe structure, the larger the transmission wave. At the same time, the height of the reflection wave decreases when the water level above the pipe structure increases.

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