Wave reflection and transmission test with pipe wall roughness and without roughness on the perforated breakwater

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Abstract. Waves towards the shore that have a porous breakwater building will experience reflection and transmission, to determine the height of reflection and transmission wave is needed a study by the process of generating waves on the flume with a porous breakwater building, the effect of wave changes in its propagation requires an experiment in the laboratory. This study was aimed to determine the height ratio of reflection and transmission wave by using a model of pipe structure as a wave reducer by adding the friction plane of the roughness of the walls in the pipe. A method of laboratory experiment on the wave generation flume has several variations consisting of 3 periods (T; 1.0 seconds, T; 1.1 seconds, T; 1.2 seconds) and 3 water depth (d) are 15, 30 and 36 cm, stroke to regulate the flap motion that determines the wave height (H) as a wave generator that is 4, 5 and 6 by comparing the model that uses pipe wall roughness and without roughness. The result of testing in indicates that the height of reflection wave (Hr) and transmission (Ht) is strongly influenced by the period (T). If the period increases, Hr and Ht significantly decrease, the height ratio of reflection wave using pipe wall roughness is greater than without roughness. However, it inversely proportional to the height of transmission wave (Ht) were a model using pipe roughness is more efficient to reduce Ht than a model without pipe roughness.

1. Introduction

Planning of shore building as carried out in a model of experiment or laboratory, it is necessary to predict the characteristics of the waves as a reference in research using a porous breakwater building research model [1]. In this study, a wave reducer experiment was carried out on a flume equipped with wave generation by engineering a porous breakwater building that is adding pipe wall roughness, it is expected that in addition to minimizing wave reflection, it is also to reduce transmission waves, because its ability to absorb wave energy and reduce wave energy coming on the rough surface of the pipe wall passed by wave energy. Therefore, to reduce the wave energy by using a porous breakwater structure can be done by making a model in the laboratory.

Wave generation to determine the characteristics of wave propagation with various wave period variation, one of them is wavelength, maximum and minimum wave height with 3 different types of depth, then testing a model with a variety of periods, strokes at three different depths are conducted in order to determine how large the effect of ratio between a model with pipe wall roughness (K3) and
without roughness \( (K0) \) both to the steepness of the wave \( (Hi/L) \), reflection wave height \( (Hr) \) and transmission wave height \( (Ht) \).

2. Method of research

2.1. Model design

The research was conducted at the Hydraulic Laboratory of the Department of Civil Engineering, Faculty of Engineering, Hasanuddin University of Gowa. The type of is experimental by designing a model with basic material is \( \Omega 4" \) (14 cm) pipe arranged horizontally from the direction of coming waves with the dimensions of the model are 28 cm in width (adjusted for flume width), 28 cm in height and 184 cm (1L) in length and comparing a model without pipe wall roughness \( (K0) \) and a model with pipe wall roughness \( (K3) \) by adding friction plane roughness to the inner wall of the pipe from gravel material (0.8 cm grain diameter) as shown in figure 1.

2.2. Flume and wave generation unit

Wave flume equipped with a wave generator device made from a steel frame with a glass wall where at the end of the flume is equipped with wave reducer, several parameters of the dimensions of the flume with a length of 15 m, width 0.3 m and height 0.8 m with effective depth of flume 0.46 m, equipped with computer with wave reading software that is directly recorded with the output of wave height reading of \( Hmax \) and \( Hmin \) (see figure 2).

Figure 1. Model without roughness \( (K0) \) and roughness \( (K3) \).

Figure 2. Flap-type wave generation flume (wave flume).
Flat-type wave generator as equipped with a generator consists of a water pump engine that regulates the supply of water entering the flume according to the desired water depth, the main engine as a motor that is directly connected to rotating the pulley, a pulley device with a round-shaped dimension continuously rotating to regulate disk rotation time as a reference in regulating the expected wave period, pulley are connected directly to strokes which have some distance variation functions to move the flap in forward and backward in the flume tank as a wave generating device.

2.3. Parameter and research design

Significant variables of research to determine the characteristics of the waves are 3 wave period variation, stroke variation used to regulate flap motion namely 4, 5 and 6 with 3 water depth variation used i.e \( d = 15, 30 \) and 36 cm.

In general, the procedure of the research procedure is:

1. Adjust the water level in the depth \( d = 15 \text{ cm}, 30 \text{ cm} \) and \( d = 36 \text{ cm} \) by using a water pump machine from the water reservoir then flowed into the flume until it reaches the desired and specified depth, then adjust the distance of stroke at flap into 3 stroke variations i.e 4, 5 and 6 and adjust the wave period variation i.e \( T_1 = 1.0 \) seconds, \( T_2 = 1.1 \) seconds and \( T_3 = 1.2 \) seconds.

2. Turn on the PC, wave monitor and eagle daq and install each probe1, probe2, and probe3 at the designated position.

3. Calibrate each probe in each different water depth that is 15, cm and 36 cm.

4. Probe 1 is positioned at the front from wave-comcoming direction while probe 2 is positioned at the front of the wave-comcoming direction model and probe 3 is positioned at the back of the wave-comcoming direction model.

5. Distance between probe 1, 2 and 3 are adjusted according to the wavelength (L), observation or calculation of the water depth and wave period.

6. After all, components are ready, running starts by generating waves by turning on the engine in the wave generator unit.

7. Wave height readings are obtained from the readings of each probe1, probe2, and probe3 which then send the results to a computer with a special application of wave height readings.

Procedures 1 to 7 are re-performed with different wave periods (T) and the stroke is changed to 4, 5, and 6. Following figure 2 shows one variation of period and strokes at a certain water depth to collect or record wave data from probe1, probe2 and probe3 below:

![Figure 3. Date retrieval of the wave at the position of probe1, probe2, and probe3.](image)

2.4. Calibration and placement of probe position

Determination of wave height value can be known through measurements with 3 probes, the probe is a detection device that is mounted on the wave flume which is a sensor to detect the received wave amplitude then sent to the amplitude for reading as an amplitude, to determine and get the wave height data then previously performed calibration at each probe by encountering the peak of the wave at each probe point, each probe has 7 points i.e 3, 2, 1, 0, -1, -2, -3 and then the distance from the probe encounters is a wavelength. Every change in depth must be re-calibration of probe due to the
difference of energy in each depth that can influence the probe reading, the steps to do calibration are the same as the previous depth [6]. Figure 3 shows the positioning of three probes for data retrieval of wave height.

![Figure 3](image)

**Figure 3.** The positioning of three probes for data retrieval of wave height.

**Figure 4.** The positioning of probes 1, 2 and 3 on wave generation flume.

### 3. Results and discussion

#### 3.1. Wavelength calculation

The calculation result of data processing for wavelength characteristics is calculated by the function of $d/L$ for adding $d/L_0$ (by interpolation). The parameter shown in table 1 was calculated according to the equation in [2]. Complete data on wavelength characteristics based on the calculation with variations can be seen in the following table 1.

#### Table 1. The wavelength at $d$ 15 cm, $d$ 30 cm, and $d$ 36 cm.

| Wavelength | T (sec) | d (meter) | $L_0$ (meter) | $d/L_0$ | $d/L$ | L (meter) | $L/2$ |
|------------|---------|-----------|---------------|---------|-------|-----------|------|
| 1.0        | 0.15    | 1.560     | 0.0962        | 0.1353  | 1.108 | 0.554     |
| 1.1        | 0.15    | 1.888     | 0.0795        | 0.1227  | 1.222 | 0.611     |
| 1.2        | 0.15    | 2.246     | 0.0668        | 0.1109  | 1.353 | 0.676     |
| 1.0        | 0.30    | 1.560     | 0.1923        | 0.2186  | 1.372 | 0.686     |
| 1.1        | 0.30    | 1.888     | 0.1589        | 0.1908  | 1.573 | 0.786     |
| 1.2        | 0.30    | 2.246     | 0.1335        | 0.1695  | 1.769 | 0.885     |
| 1.0        | 0.36    | 1.560     | 0.2308        | 0.2513  | 1.433 | 0.716     |
| 1.1        | 0.36    | 1.888     | 0.1907        | 0.2173  | 1.657 | 0.828     |
| 1.2        | 0.36    | 2.246     | 0.1603        | 0.1919  | 1.876 | 0.938     |

#### 3.2. Data of wave height

The result of data retrieval of coming wave height ($H_i$), reflection wave height ($H_r$) and transmission wave height ($H_t$) are obtained from the average value of $H_{max}$ and $H_{min}$ for each stroke change, probe 1 recording data of coming wave height ($H_i$), Parameter is shown in table 2 was calculated according to equation in [3]. probe 2 recording data of reflection wave height ($H_r$) and probe 3...
recording data of transmission wave height (\( H_t \)) in 3-period variation (\( T \)) i.e 1.0 seconds, 1.1, seconds and 1.2 seconds with three depths (\( d \)). The results of data processing at a depth of 15, 30 and 36 cm with some variations in this research can be seen in Table 2.

Table 2. Wave height at \( d \) 15 cm, \( d \) 30 cm, and \( d \) 36 cm.

| No | Dept h (d) | Perio d (T) | Wave length (L) | Without Roughness (K0) | Roughness 0.8 (K3) |
|----|------------|-------------|-----------------|------------------------|-------------------|
|    |            |             |                 | Hi (cm) | Ht (cm) | Hi/L | Hi (cm) | Hr (cm) | Ht (cm) | Hi/L |
| 1  | 15         | 1.0         | 110.8           | 2.4166 | 0.63257 | 0.2402 | 0.0237 | 1.8751 | 0.9715 | 0.3560 | 0.0184 |
| 2  | 15         | 1.0         | 110.8           | 3.1290 | 0.91646 | 0.5576 | 0.0307 | 2.8326 | 1.1088 | 0.4547 | 0.0278 |
| 3  | 15         | 1.0         | 110.8           | 3.7616 | 1.13233 | 0.4633 | 0.0369 | 2.9580 | 1.0710 | 0.4933 | 0.0290 |
| 4  | 15         | 1.1         | 122.2           | 2.4451 | 0.12235 | 0.4332 | 0.0214 | 2.3140 | 0.5326 | 0.4118 | 0.0203 |
| 5  | 15         | 1.1         | 122.2           | 2.9979 | 0.37422 | 0.4633 | 0.0263 | 2.3653 | 1.2313 | 0.4676 | 0.0207 |
| 6  | 15         | 1.1         | 122.2           | 3.6135 | 0.34442 | 0.5405 | 0.0317 | 2.9808 | 1.0318 | 0.4761 | 0.0261 |
| 7  | 15         | 1.2         | 135.3           | 2.4508 | 0.20423 | 0.4161 | 0.0184 | 1.6414 | 1.0245 | 0.3432 | 0.0123 |
| 8  | 15         | 1.2         | 135.3           | 2.6901 | 0.56155 | 0.3946 | 0.0202 | 2.2399 | 0.8695 | 0.3603 | 0.0168 |
| 9  | 15         | 1.2         | 135.3           | 3.5280 | 0.42991 | 0.4504 | 0.0265 | 2.6502 | 0.7438 | 0.3989 | 0.0199 |
| 10 | 30         | 1.0         | 137.2           | 6.2512 | 0.10211 | 1.1729 | 0.0447 | 4.6592 | 1.2612 | 0.6315 | 0.0333 |
| 11 | 30         | 1.0         | 137.2           | 8.3691 | 0.06696 | 1.2471 | 0.0598 | 5.5940 | 1.2391 | 0.8014 | 0.0400 |
| 12 | 30         | 1.0         | 137.2           | 9.6690 | 0.47530 | 1.2471 | 0.0691 | 8.1354 | 0.3708 | 1.0614 | 0.0581 |
| 13 | 30         | 1.1         | 157.3           | 5.8131 | 0.11904 | 0.8279 | 0.0377 | 4.1772 | 0.8306 | 0.5891 | 0.0271 |
| 14 | 30         | 1.1         | 157.3           | 6.9231 | 0.37795 | 1.2312 | 0.0450 | 4.9659 | 0.4280 | 0.7218 | 0.0322 |
| 15 | 30         | 1.1         | 157.3           | 8.5298 | 0.52639 | 1.1039 | 0.0554 | 5.5502 | 1.5520 | 0.9393 | 0.0360 |
| 16 | 30         | 1.2         | 176.9           | 5.2288 | 0.11824 | 0.7960 | 0.0317 | 3.4324 | 1.3765 | 0.5838 | 0.0208 |
| 17 | 30         | 1.2         | 176.9           | 6.1782 | 0.53783 | 0.8597 | 0.0374 | 4.3525 | 1.0999 | 0.6952 | 0.0264 |
| 18 | 30         | 1.2         | 176.9           | 7.5950 | 0.19751 | 1.0243 | 0.0460 | 5.4917 | 1.6572 | 0.8491 | 0.0333 |
| 19 | 36         | 1.0         | 143.3           | 6.2038 | 1.15803 | 3.2802 | 0.0434 | 4.6902 | 0.7941 | 2.6132 | 0.0328 |
| 20 | 36         | 1.0         | 143.3           | 9.2308 | 0.80644 | 3.5726 | 0.0646 | 5.2058 | 0.4559 | 3.1075 | 0.0364 |
| 21 | 36         | 1.0         | 143.3           | 10.9772 | 0.34638 | 3.8010 | 0.0768 | 6.4865 | 2.2057 | 3.1888 | 0.0454 |
| 22 | 36         | 1.1         | 165.7           | 6.2869 | 0.12875 | 3.6731 | 0.0381 | 4.5738 | 0.1123 | 2.1015 | 0.0277 |
| 23 | 36         | 1.1         | 165.7           | 8.0832 | 0.54993 | 4.0934 | 0.0490 | 5.4553 | 0.7239 | 2.8050 | 0.0331 |
| 24 | 36         | 1.1         | 165.7           | 9.8628 | 0.47029 | 4.3035 | 0.0598 | 6.3867 | 0.9160 | 3.1248 | 0.0387 |
| 25 | 36         | 1.2         | 187.6           | 7.4512 | 0.39847 | 2.8873 | 0.0405 | 4.2412 | 0.2971 | 1.4528 | 0.0230 |
| 26 | 36         | 1.2         | 187.6           | 8.9647 | 0.11189 | 3.5177 | 0.0487 | 5.4886 | 1.0010 | 2.8050 | 0.0298 |
| 27 | 36         | 1.2         | 187.6           | 9.1476 | 0.19504 | 3.6731 | 0.0497 | 5.7880 | 1.0416 | 3.2436 | 0.0315 |

3.3. Effect of roughness on (\( H_r \)) and (\( H_t \))

Simulation result as depicted in graph of data processing on table 2 can be seen a comparison between models using the pipe wall roughness (K3) and without roughness (K0) has different interval values of \( H_r \) and \( H_t \) at three depths as shown below:
As figure 5 appears that the greater of \( d \) value, \( H_r \) tends to decrease, on the contrary, that \( H_t \) tends to increase by increasing \( d \) value. This means that the greater of depth, the generated reflection will decrease but the generated transmission will increase. The parameter shown in figure 5 and figure 6 was calculated according to the equation in [5]. Comparison between models using pipe wall roughness (\( K_3 \)) \( H_r = 0.9 - 0.7 \) cm is greater than without roughness (\( K_0 \)) \( H_r = 0.4 - 0.25 \) cm, but the transmitted wave (\( K_3 \)) \( H_t = 0.1 - 1.9 \) cm is smaller than a model without roughness (\( K_0 \)) \( H_t = 0.1 - 3.0 \) cm. This means that the effect of pipe wall roughness effectively minimizes the transmission wave.

The following shows the changes in \( H_r \) and \( H_t \) values on the three period variations by comparing the two models.

The tendency of \( H_r \) and \( H_t \) decreases with increasing \( T \) value, seen in figure 6 above, it shows that the greater of period the reflection and transmission wave height decreases, the comparison between models using pipe wall roughness (\( K_3 \)) \( H_r = 0.9 - 0.8 \) cm is greater than without roughness (\( K_0 \)) \( H_r = 0.5 - 0.3 \) cm, but the transmitted wave (\( K_3 \)) \( H_t = 0.9 - 1.3 \) cm is smaller than a model without roughness (\( K_0 \)) \( H_t = 1.7 - 1.9 \) cm. This means that the effect of pipe wall roughness is effective in reducing waves and minimizing wave transmission (\( H_t \)) in each increase a period.

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**Figure 5.** Relationship of \( H_r \) and \( H_t \) with depth (\( d \)).

**Figure 6.** Relationship of \( H_r \) and \( H_t \) with period (\( T \)).
3.4. Effect of roughness on \((\text{Hi}/\text{L})\)

As a result of data processing in the form of the graphic shows the relationship of the steepness of waves \((\text{Hi}/\text{L})\) with periods \((T)\) and depth \((d)\). Parameter is shown in figure 7 was calculated according to the equation in \([4]\). to the comparison of models with pipe wall roughness \((K3)\) and without roughness \((K0)\).

![Figure 7](attachment:figure7.png)

**Figure 7.** Relationship of \(\text{Hi}/\text{L}\) to depth \((T)\) and period \((T)\).

Figure 7 shows that the effect of period and water depth on the steepness of wave has decreased significantly, if the condition of period \((T)\) is larger, then the decrease of the steepness of the wave \((\text{Hi}/\text{L})\) will also be smaller, this shows that the steepness of the wave at the water depth \((d)\) 15 cm is smaller than \((d)\) 30 cm and smaller than \((d)\) 36 cm, caused by large water depths, wave height, and wavelength is greater from small water depths. The calculation results of a comparison of two models to water depth \((d)\) and period \((T)\) experienced a decrease change in \(\text{Hi}/\text{L}\) and the significant difference value.

4. Conclusions

Based on the laboratory experiments in this study, it can be concluded, the resulting waves in the form steepness of the wave \((\text{Hi}/\text{L})\), reflection wave height \((Hr)\) and transmission wave height \((Ht)\) are strongly influenced by period \((T)\) and water depth \((d)\). Reflection wave height \((Hr)\) and transmission wave height \((Ht)\) have significant differences between two models where a model with pipe wall roughness \((K3)\) is more efficient in reducing waves than a model without roughness \((K0)\) both for changes in depth \((d)\) and period \((T)\).

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