The Effect of Hanging Sheet Pile Breakwater’s Draft Relative on Wave Transmission Coefficient \((K_t)\) in Irregular Wave

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Abstract. Breakwater is a structure that builds parallel to the coast, and located within some distance from the coastline. The breakwater that is currently and widely used is Rubble Mound Breakwater; a large dimension coastal structure with also come in high price. Due to this matter, a Hanging Sheet Pile type breakwater can be one of good solution. This research was conducted at Ocean Technology Laboratory, Faculty of Engineering, Universitas Hasanuddin, in a flume thank with 1:25 model scale, and equipped with wave generator and probes as measurement apparatus. The purpose of this study is to identify the effect of wave parameters \((H_i/gT^2)\) and structure parameters (draft relative, s/d) on fluctuated wave transmission coefficients produced. The waves are in the form of irregular waves that generated using JONSWAP spectrum. There were 5 variations in wave height \((H)\) and wave period \((T)\), while variations of structure in the form of draft \((s)\) are in 3 variations. The results of this study indicate that the value of \(K_t\) will decrease when \(H_i/gT^2\) value increase; so that the greater the value of s/d, the smaller value of \(K_t\) will be.

1. Introduction 

Indonesia as an archipelago located between two continents and two oceans, definitely have several problems due to its very long coastline. For that fact, beach protection against wave energy is a must. Beach protection system often used in Indonesia is breakwaters. The most important sea wave parameters commonly used in ocean wave analysis are wave height and wave period. Based on the wave height, the probability distribution of ocean waves can be determined; while with the wave period, the shape of the ocean wave spectrum can be determined.

Wave transmission \((K_t)\) is the ratio between the passings through sheet piles breakwater wave parameters to the incoming wave parameters. The wave height and period imposed on the model are used as variables that determine the magnitude of the wave transmission coefficient [1].

That parameter is very important in the planning of sheet pile breakwater. Therefore, it is necessary to conduct studies related to the effects of waves through the sheet pile structure before being applied to the actual conditions as breakwaters on the coast and harbor.

The subject of the study is to find out the influence of wave parameters such as wave height \((H)\) and wave period \((T)\) on sheet pile in a certain draft; by determining the effect of \(H_i/gT^2\), as wave steepness, on the magnitude of the wave transmission coefficient \((K_t)\) and the effect of draft relative \((s)\) to the value of the transmission coefficient \((K_t)\) which occurs on the hanging sheet pile.
2. Literature Review

Waves that travel from the deep to shallow water will experience a change in shape due to changes of sea depth. The more towards the beach, the wave crest will be sharper and the valley will be flatter. This phenomenon causes waves to break. Waves can be divided into several types. Among them are wind waves generated by the blowing of the wind at sea level, tidal waves that generated by the attraction of celestial objects, especially the sun and moon to the earth, and tsunami waves that occur due to volcanic eruptions or earthquakes in the sea [2].

2.1. Wave spectrum

The nature of ocean waves is random, both magnitude and direction, so that the nature of random wave energy is difficult to measure. Random waves are a combination of several sinusoidal waves with varying length and periods. The intensity of random wave components is generally expressed in the form of an amplitude density spectrum, wave energy density or commonly abbreviated as a wave energy spectrum.

In wave energy spectrum analysis, it is necessary to record wave data for 15-20 minutes. The principle of wave spectrum analysis is to describe an irregular wave into an arrangement of regular waves of various frequencies and wave heights [3]. The mostly single parameter spectrum that most commonly used is the Pierson-Moskowitz [4] which is based on significant wave height or wind speed. In addition there are several commonly used dual parameter spectrums.

2.2. Wave transmission

Wave transmission is the residual wave energy that occur after passing through the wave restraint structure [5]. The parameters are expressed as a comparison between the transmitted wave height \( H_t \) and the incoming wave height \( H_i \) or the root of the transmission wave energy \( E_t \) with the incoming wave energy \( E_i \).

\[
H_t = \frac{H_{\text{max}} + H_{\text{min}}}{2} \quad (1)
\]

\[
K_t = \frac{H_t}{H_i} = \left( \frac{E_t}{E_i} \right)^{1/2} \quad (2)
\]

The transmission coefficient is the ratio between the transmission wave height and the incoming wave height. From the energy function, the transmission energy is the root function of the comparison spectral wave energy transmission with the spectral wave energy coming. The smaller the wave reduction produced the greater the transmission coefficient [6].

2.3. Sheet Pile

Sheet pile is a relatively thin vertical wall that serves to hold the soil and to hold water into the excavation hole. Sheet pile is currently widely used in jobs such as retaining walls, excavation of excavation cliffs, buildings in ports, and dam construction.

Sheet pile is not suitable for holding very high soil because it will require a large area of large pile material. In addition sheet pile is also not suitable for use in soils that contain lots of rock, because it makes it difficult to erect. Sheet pile types can be distinguished according to the material used. The sheet pile material is various for example wood, reinforced concrete and steel.
3. Results and Discussions

After all wave spectrum variations and model scenarios are tested on wave flume, the results are then analysed in order to get an idea of what and how the effectiveness and response of various wave spectrums due to the reduction of transmission and wave reflection. For this research, JONSWAP wave spectrum will be used due to its common use in Asia, mainly in Indonesian waters and in some other places which are very similar surroundings [7].

1. Effect of Wave Steepness ($H_i/gT^2$) on the Transmission Coefficient ($K_t$) for Draft Variation ($s$), with the provision of a gap width of 0.005m. To present the magnitude of the draft ($s$) relationship with the transmission coefficient value ($K_t$), the $H_i/gT^2$ dimensionless parameter is used which represents the wave characteristics. If the $H_i/gT^2$ value is the X-axis and the transmission coefficient ($K_t$) is the Y-axis variable, then the graph will be obtained as follows:

![Figure 1](image1.png)  
**Figure 1.** The relationship of $H_i/gT^2$ with $K_t$ for draft 0.50m

![Figure 2](image2.png)  
**Figure 2.** The relationship of $H_i/gT^2$ with $K_t$ for draft 0.75

![Figure 3](image3.png)  
**Figure 3.** The relationship of $H_i/gT^2$ with $K_t$ for draft 1.00
Figures 1 to 3 shows that an increasing wave steepness, \( \frac{H_i}{gT^2} \), will cause a decreasing value of the transmission wave energy coefficient, \( (KE_t) \). This indicates that the steeper the waves come in front of the sheet pile breakwaters model, will cause a shrinking ratio of wave height behind and the front of the model. This phenomenon occurs because a wave with a large steepness occurs significant turbulence in front of the model and causing a decrease in wave height passing the model relative to the incident wave height. But note that the distribution of data for all is relatively large. For all the values of s/d are shown in Figures 5 to 7, for the \( \frac{H_i}{gT^2} \) less than 0.01, the decreasing of \( KE_t \) due to the increasing of \( \frac{H_i}{gT^2} \), is significant. Meanwhile on the value of \( \frac{H_i}{gT^2} \) greater than 0.01, the increasing of \( \frac{H_i}{gT^2} \) is relatively have a small effect on the changing of \( KE_t \).

Based on the graphs on the pictures above, it can be concluded that with the increase of \( \frac{H_i}{gT^2} \), the \( K_t \) will decreases; this will consistently occur in each test with different variations of draft (s). For draft 0.50, wave steepness (\( \frac{H_i}{gT^2} \)) values ranging from 0.000 – 0.0250 with a range values of \( K_t \) between 0.8 – 0.40. For draft 0.75, wave steepness (\( \frac{H_i}{gT^2} \)) values ranging from 0.000 – 0.0250 with range values of \( K_t \) is between 0.84 - 0.31 and for 1.00, wave steepness (\( \frac{H_i}{gT^2} \)) values ranging from 0.000 - 0.0250 with range values of \( K_t \) between 0.79 - 0.31. This means that the steeper the incoming wave, the better the sheet pile will be in reducing the wave; or the smaller the wave transmission value (\( K_t \)) will be. The influence of wave steepness (\( \frac{H_i}{gT^2} \)) on large \( K_t \) in the range \( \frac{H_i}{gT^2} \) < 0.005, can be seen from the significant change in \( K_t \). Whereas for the \( \frac{H_i}{gT^2} \) range > 0.005, the effect of \( \frac{H_i}{gT^2} \) is relatively insignificant so that the \( K_t \) value tends to shrink gradually followed by the enlargement value of the \( \frac{H_i}{gT^2} \).

2. The effect of s/d on the transmission coefficient (\( K_t \)). To presents the relationship of draft (s) and the relative depth (d) then the variable is based on s/d to \( K_t \), then the graph are as follows:

![Figure 4](image-url). The relationship of \( \frac{H_i}{gT^2} \) with \( K_t \) on each draft variations

Based on the graphs on previous pictures, it can be concluded that the relationship pictured in draft (s) and relative depth (d) as dimensionless numbers (s) to the value of \( K_t \). Where the greater the value of s/d, the more declined the trend of \( K_t \). This can be seen in the value up to 1.00 giving the smallest trend of \( K_t \) compared to the value up to 0.50 and up to 0.75. The decrease in the value of up to \( K_t \) tends to be drastic in the range \( \frac{H_i}{gT^2} \) < 0.005, then in the range of 0.005 < \( \frac{H_i}{gT^2} \) < 0.025, the decreases tends to be gradual.

But from these experiments, there are some things that make the value of s/d against \( K_t \), not always have a constant value, while \( \frac{H_i}{gT^2} \) increases. This can be seen from the trend lines that coincides one another.

1. For 0.75 and 1.0 that coincide, the trend in which this event can be caused by several things, including: The model approach was not perfect so that the results obtained did not match expectations.
2. The wave damping behind the model is imperfect, so that the transmitted wave can be reflected back towards the model. This is what causes wave resonance events between the incoming wave and the transmitted wave.

For the range $0.020 < H_i/gT^2 < 0.025$ where the frequency of waves are large due to the small wave periods and higher wave heights, causes the generated waves to be more steep. So that in this range the incoming waves will be more dissipated, both in partially and whole, due to the instability of the water particle movement during wave propagation. This can be seen from the tendency of the $K_t$ line to move almost in straight line, since most of the incoming wave energy has been dissipated.

4. Conclusions

1. The greater the wave steepness ($H_i/gT^2$), the smaller the transmission coefficient ($K_t$) will be, where the effect of wave steepness ($H_i/gT^2$) on $K_t$ are significant on $H_i/gT^2 < 0.005$.

2. The transmission coefficient ($K_t$) will decrease by the increasing value of $s/d$ equal to 1.00. This means that the greater the draft relative ($s$), the better structure functioning in transmitting waves.

References

[1] Murali, K., & Mani, J. (1997). Performance Of Cage Floating Breakwater. ASCE.
[2] Triatmodjo, B. 1999. Coastal Engineering. Beta Offset: Yogyakarta.
[3] Yuwono, N. 1982. Coastal Engineering. Teknik Sipil UGM: Yogyakarta.
[4] Chakrabarti, 1987, Hydrodynamics of Offshore Structure, Computational Mechanics, Cornell University.
[5] USACE, 2002, Coastal Engineering Manual, Washington, D.C.
[6] Bleck, M., & Oumeraci, H. (2001). Wave Dampening And Spectral Evolution At Artificial Reefs. 2, pp. 1062-1071. Proceedings of The International Symposium on Ocean Wave Measurement and Analysis (WAVES 2001), ASCE.
[7] Muis Alie, M., 2016. The Effect of Symmetrical and Asymmetrical Configuration Shapes on Buckling and Fatigue Strength Analysis of Fixed Offshore Platforms. s.l., International Journal of Technology (IJTECH).