Damage Value of Wave Breaker Protection Coating That was Placed by Organized and Raised Due to Wave Attack

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ABSTARCT

Protective layer of crushed stone material has been widely used in flexible breakwaters to protect the coast from damage. The formulation of the problem in this study is: does crushed stone material as a protective layer of breakwater which is placed in an arranged manner will give a smaller damage value than that which is placed in a random way when it gets attacked by waves? The purpose of this study was to determine the amount of damage to the protective layer of the breakwater which was placed in an arranged and randomized manner due to wave attack. For this purpose a model of the sloping side breakwater structure is made. The main tool used in this research is a wave channel equipped with a wave generator, a wave height measuring device, a computer equipped with a wave synthesizer program. The protection layer stability test was carried out with a wave attack duration of 100 minutes, at a depth of water in front of the leg of the breakwater of 13 cm on the model scale. The damage to the protective layer is calculated based on the ratio of the protective layer material that has moved from its place to the material affected by the wave attack. The results showed that the protected layer of crushed stone which was placed in an arranged manner had a smaller damage value when compared to the protected layer of crushed stone which was placed randomly at the same wave height attack.

Keywords: *damage, layer of protection, waves, arranged, scrambled.*

1. INTRODUCTION

Indonesia is an archipelagic country with the fourth longest coastline in the world. The coast has enormous and diverse potential that can be used as an area for agriculture, fisheries, ports, tourism, commerce and industry, settlements, sports venues, mining, airports and nature reserves. Due to its position directly facing the sea, the coastal area can also be a source of large ocean wave energy, so it is possible that it can be managed and utilized to support economic activities in the area. With the increasingly intensive use of coastal areas for various purposes, humans intentionally or unintentionally damage the coastal area by destroying the natural defenses of the beach, such as coral reefs, beach sand and existing mangrove trees. Besides that, coastal areas in Indonesia also suffered a lot of damage due to the influence of chain wave attacks, sediment transport, and ocean currents that cause coastal erosion. The existence of disturbances to coastal areas, especially those caused by natural factors, such as wind, waves and ocean currents, the coast needs to be protected from damage. One of the human efforts to protect coastal areas against the dangers of damage, especially those caused by natural factors, is to build breakwaters. The breakwater building functions to protect the beach from wave attacks by reducing wave energy towards the coast. The amount of wave energy that is attenuated (crushed, reflected and transmitted), depends on the characteristics of the wave (wave height and period). It also depends on the type of breakwater structure (porosity and roughness), structure geometry (slope) and local environmental conditions such as water depth, breakwater contours and beach bed (Dalrymple, Losada and Martyn 1991, in Dirgayusa, 1997). Sloping breakwater is one type of breakwater that is quite widely used and has been built in various coastal areas in Indonesia. An important requirement for breakwater buildings is that the structure of the building, especially the protective layer, must remain stable, not easy to move and move when exposed to wave attack. Breakwater strength can be designed by using the right protective layer material, it can be natural stone material or artificial concrete material, especially to keep it stable, not easy to move when hit by waves. The stability of the protective layer is influenced by many parameters such as wave duration, wave spectrum shape, wave height, wave period, water depth in front of the breakwater, weight of the protective layer material, slope of the front side of the breakwater, shape and roughness of the protective layer material, porosity and placement, protective coating material.

One of the properties of the protective coating material that is important for calculating the strength and stability of the protective layer of the breakwater is the coefficient of stability of the protective layer Kd (damage coefficient). The properties of the protected layer material represented by the Kd coefficient include shape, roughness and the degree of interlocking. The Kd coefficient is still widely studied in relation to the number of waves, wave height and period, differences between regular and irregular waves, wave spectrum, water depth in front of the breakwater leg and the position/placement of the protective layer material on an ordered or random breakwater.

In the publication of this research, one problem is formulated, namely: "Is the broken stone material as a protective layer for the breakwater that is placed in an arranged manner when it gets attacked by random waves will give a smaller damage value than the one placed at random?"
In general, the purpose of this research is to find out how much damage the protective layer of broken rock breakwater is that is laid out in an arranged and randomized manner. This research will also look for the magnitude of the coefficient of stability of the protective layer (Kd) due to the attack of random waves that have broken before reaching the breakwater structure. The selection of irregular waves that have broken before reaching the breakwater structure is intended to bring the research results closer to the reality that occurs in the field.
The results of this study are expected to provide benefits and useful information for the purposes of designing the sloping side of the breakwater structure using a uniform protective layer of crushed stone.
LITERATURE REVIEW
Slope Side Breakwater. From the point of view of the type of structure, breakwaters are generally divided into three parts, namely inclined side breakwaters, rigid breakwaters, and semi-rigid breakwaters. The sloped side breakwater has flexible properties because it can be adapted to irregular bathymetric conditions and easily adapts to subgrade settlement. The damage caused by the wave attack is not sudden (not fatal). Even though some of the stones fell, the building could still function. The damage that occurs is easily repaired by adding protective stones to the landslide.
Sloping breakwaters are generally built in layers, with the outermost layer being the armor layer and the innermost being the core. Between the protective layer and the core layer is the filter layer. The protective layer serves as a protection for the breakwater structure from wave attack. Because of that the protective layer material is composed of the largest and heaviest protective stone so that it remains stable against wave attacks. The deeper the breakwater structure, the smaller the size of the stone used and should not be washed through the pores/cavities of the outer layer. Excessive discharge of the core layer from the filter layer and protective layer will cause settlement of the filter layer and protective layer and the instability of the protective layer which results in damage to the breakwater structure. [1]
The cross-sectional shape of the sloping side breakwater is trapezoidal with the peak width usually meeting the criteria for being able to accommodate at least 3 units of protective layer material. The width of the base will increase as the depth of the sea increases. At greater sea depths, the volume of buildings will increase so that the cost of constructing a breakwater will also increase. Therefore the inclined side breakwater which is also called flexible breakwater only attracts at not very great ocean depths. [2]

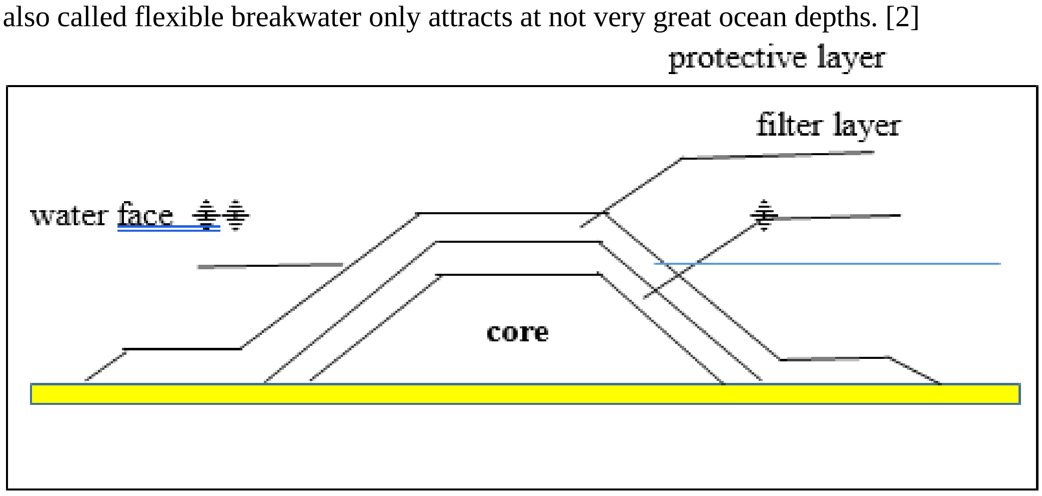

Figure 2.1. Slope side breakwater structure

Breakwater Structure Damage.
One type of damage to the breakwater structure identified by Jensen is the type of damage to the protective layer. The cause of damage to the protective layer is due to the displacement of the protective layer material from its original position. The protective layer material moves due to the operation of excessive wave forces, especially during wave run-down and run-up [3]
Meanwhile, Bruun [4] stated that damage to the protective layer can also be caused by being attacked by plunging waves, concentrated wave trains, erosion at the foot of the breakwater, and incompatibility of the materials used.
There are several formulas that can be used for the design of the protective layer of the breakwater structure, including those proposed by Hudson and Radianta Triatmadja [5]. Each formula has discrepancies in the parameters used so that there are differences in several respects. Hudson's formula uses the significant wave height (Hs) or H10 as the design wave height. Triatmadja put forward his formula by taking into account the wave height before breaking and after breaking (Hd or Hs) and the water depth at the foot of the breakwater (d).
Winarno [6] in his research stated that the duration of the wave affects the level of damage to the protective layer. Winarno's research was strengthened by Agung (1999) in his research which concluded that the longer the duration of the wave attack on the breakwater structure, the greater the damage value of the breakwater protective layer.

There are several parameters related to the protective layer material that need attention, namely: the density of the protective layer material (ρs), the coating coefficient (KΔ), the porosity coefficient (n) and the stability coefficient (Kd). Coating coefficient (KΔ), indicates the degree to which the protective layer materials combine together in a layer. This coefficient is important to determine the size of the layer thickness. The porosity coefficient (n) is important to determine the amount of stone (armor unit) in the armor layer. While the stability coefficient (Kd) is a reflection of various properties. These properties include the shape and roughness of the material, the degree of interlocking and the way in which the protective layer is arranged or scrambled.

The types of materials that make up the protective layer are generally divided into two, namely artificial materials and natural materials in the form of crushed stone. Artificial material was created to obtain a better value for the stability of the protective layer so that the breakwater is not easily damaged. These materials include: tetrapod, dolos, concrete cubes, akmon, tribar and others.

Several researchers have used artificial materials and have succeeded in drawing some important conclusions, including:

a. Tantrawati, [7], used gamapod and tetrapod as a protective layer material. The protective layer gets attacked by random waves (irregular wave) in the state of the wave has not broken. The conclusions obtained from Tantrawati's research are: The amount of protective layer material per unit area affects the stability of the protective layer. The duration of the wave attack affects the price of the stability coefficient (Kd).

b. Sulistyawati [8], used a mixed layer of protective material (gamapod and crushed stone). The breakwater model is subjected to random wave attack with a Bretschneider spectrum. The test is stopped when the waves have broken. The conclusions obtained in this study are: in general the mixed protective layer will give a higher Kd value than the Kd value of the gamapod protective layer. The duration of the wave attack affects the magnitude of the resulting gamapod Kd value if the wave follows the Rayleigh distribution.

Several variables that need to be considered in the design and affect the stability and damage of the protective layer of the breakwater include: gradation of the protective layer, spectrum shape and wave group, wave duration, breakwater slope, wave height and significant wave period, weight of protective layer material and placement of protective layer material.

Legawa [9] stated that the placement of the material is a variable that affects the stability and level of damage to the protective layer. The placement of the arranged material is intended to obtain better interlocking properties between the protective layer materials so that the protective layer will be more stable, not easy to move from its original position when receiving wave attacks. Displacement of the protective layer from its original position will cause damage to the structure

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2. METHODS

3.1. Protective Coating Material Stability Formula.

By modifying the Irribaren formula (1938), then Hudson (1953) proposed the Kd formula as follows:

$$K_a \; \frac{H_s^3}{W_s{}^3 \cot} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

Where: H = design wave height
θ = angle of the slope of the building
Kd = coefficient of stability of the protective layer
Δ = relative density of the protective layer unit = (ρs/ρw – 1)
Ws = weight of protective layer
γs = specific gravity of the protective layer unit

So far the determination of the grain weight of the protective layer (Ws) of the breakwater is based on the Hudson formula (equation 3.1). By paying attention to the wave forces acting on the breakwater structure and the formula proposed by Hudson, some variables that need attention are:

1. weight (W) and density (ρs) of the protective layer material,
2. Frictional and interlocking forces which are influenced by the shape and layout of the material,
3. Density of water (ρw),
4. the slope angle of the breakwater building (θ),
5. Significant wave height (Hs) influenced by spectrum and duration.

Triatmadja [5], proposed adding a variable to Hudson's formula (3.1) so that the new formula applies to broken waves. The variable is the water depth in front of the leg of the breakwater with the notation (d). The Triatmadja formula to calculate the weight of the protective layer material (Ws) is formulated as follows:

$$W_s \; \frac{H_s^2 d_a}{K_d \;{}^3 \cot} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

In equation (3.2), Hd is the wave height at the location before it breaks and (d) is the water depth in front of the toe of the breakwater when the water is calm (SWL).

3.2. Representative Wave

For the purposes of calculating the weight of the breakwater protective layer, as well as for the planning of coastal structures, it is necessary to select the height and period of individual waves that can represent a wave spectrum. These waves are known as representative waves. If the wave height of a record is ordered from the highest value to the lowest, it will be possible to determine the wave height Hn which is the average of the highest (n) percent of waves.

With such a form will be able to express the characteristics of natural waves in the form of a single wave. For example, H10 is the average height of the highest 10% of waves from the recorded waves. The most widely used form is H33, which is the average height of 33% of the highest value of recorded waves which is often referred to as significant wave height (Hs). The same method can also be used to obtain the period of the wave (T).

3.3. Hypothesis

From the results of the literature review and the theoretical basis above, the following hypothesis is drawn:

"That the protective layer material that is placed in a good arrangement will increase the stability of the protective layer and give a smaller value of damage to the protective layer when the protective layer is placed randomly".

3. RESULT AND DISCUSSION

4.1. Research Limits

a. The orthogonal incident wave is perpendicular to the breakwater. b. The waves that attack the breakwater are random waves.

c. Wave attack duration is set at 100 minutes (scale model)

d. The protective coating material tested is crushed stone. e. The slope of the breakwater is 1: 2 (cot α= 2).

f. The protective layer material is placed in an arranged and random manner on the wave channel that is already filled with water

g. The stability of the protective layer and the observed damage were only the front of the breakwater structure, the rear was not observed.

h. The depth of water in front of the leg of the breakwater in calm water (SWL) is d = 13 cm (on the model scale).

4.2. Modeling.

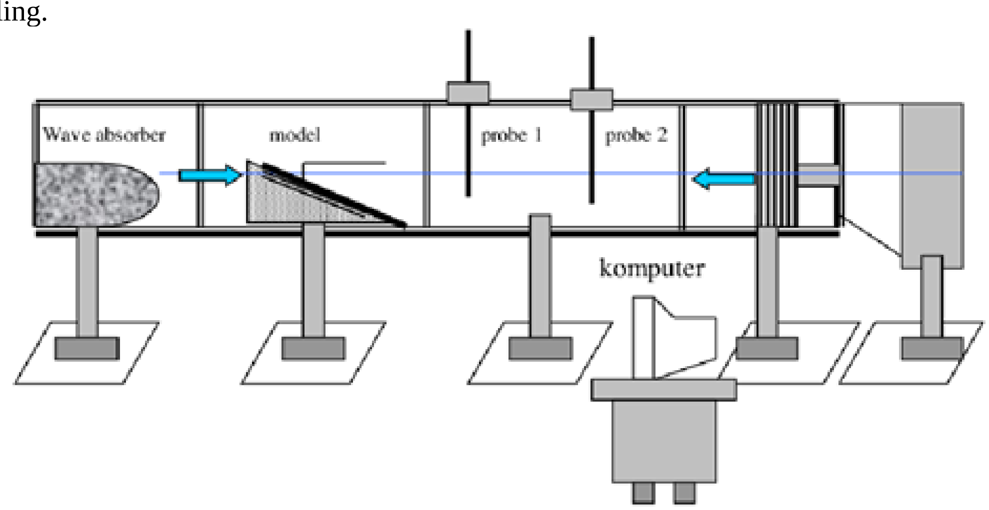

Figure 4.1. Place the Model in the wave channel

In this study, a model scale of 1: 50 was used. The use of the model scale was intended to compare with the conditions of the prototype. In accordance with the basics of model scaling, the value of the scale for the non-distortion model with the Froud number congruence is obtained as follows:

1. Wave height scale = nH = 50
2. Scale length = nL = 50
3. Depth scale = nd = 50
4. Time scale = nt = 7.07
5. Speed scale = nv = 7.07
6. Volume scale = nvol = 125,000

4.3. Amount of protective coating material

The amount of protective layer material for a certain area is calculated using the
Jensen formula (1984) as follows:

$$N = c.n. \left(1 - \frac{P}{100}\right) V^{-\frac{2}{3}} A$$

N is the amount of material area A,

- A is the area containing the protective layer material in 1 lane (15 x 50) cm2,
- c is the form factor taken 1 (one)
- n is the number of layers taken 2 layers

- P is the porosity (40 taken because the rock is broken)
- V is the volume of the protective layer material (seed).

4.4. Protective coating test

The main tool used in this research is a wave channel equipped with a wave generator, a wave height measuring device, a computer equipped with a wave synthesizer (WS) program, see Figure 4.1.

Testing of the stability of the protective layer was carried out with a wave attack duration of D=100 minutes, at a water depth of d=13 cm with several tests to obtain a significant amount of data. The damage to the protective layer is calculated based on the ratio of the displaced crushed stone protective layer material to the material affected by the wave attack, both layered and randomly placed protective layers. The magnitude of the coefficient of stability of the protective layer is calculated using the Triatmadja [5] formula, to be consistent with the research limits

4.5. Damage Classification

The classification of damage used in this study follows the results of research on the hydraulic model of the Baai-Bengkulu island port conducted by the Ministry of Sea Transportation in collaboration with the Engineering Affiliation Bureau, Faculty of Engineering UGM. Armor with 0-2% damage is classified as very little damage. Damage
3% damage classification is slight. 5% damage is classified as moderate damage. Damage of 7% and above is classified as a lot of damage.

Wave Height

Wave height data obtained from the analysis of random waves through the wave synthesizer program package. The wave height data obtained is the digit data of the water level and the standard deviation. With the equation Hs = 4.σ it will be obtained the magnitude of the significant wave height (Hs) on the prototype in meters. In this study using a 1:50 scale model, the wave height of Hs in the model is:

Hs = 4σ :50 x 100 = 8σ. The wave height Hs = 8σ is then used to calculate the stability coefficient of the breakwater protective layer using equation (3.2):

$$W_r = \frac{\gamma_s H_d^2 d}{K_d \Delta^3 \cot\theta}, \quad \text{and} \quad K_d = \frac{\gamma_s H_s^2 d}{W_s \Delta^3 \cot\theta}$$

Armor Damage Rate.

In this study the level of damage to the protective layer is calculated by the percent (%) of damage, namely the ratio between the amount of material that moves and the material that is affected by the wave attack. The amount of material affected by wave attack is assumed to be in the area between + 1.5 Hs and -1.5 Hs calculated from the calm water level, as shown in Figure 5.1.

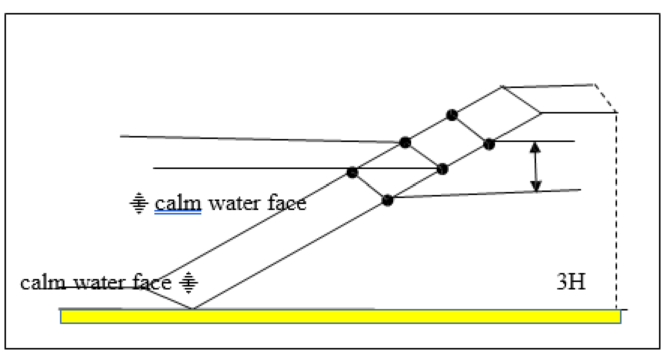

Figure 5.1.The area affected by waves as high as 3Hs

To calculate the percent (%) damage to the protective layer, some data are needed, namely:
1. Data Hs = 8σ (is the standard deviation of wave height)
2. The upright position of the breakwater that was hit by the wave = 6.708 cm
3. Number of stones in one layer = 105 units
4. Materials hit by waves as high as 3Hs = 3 x 8σ = 24σ
5. Amount of material hit by wave attack = (24σ)/6,708 x105 (units)

From the available data, it can be calculated that the percent (%) of damage = n/(∑material) x 100%, where (n) is the number of stones that move in one test duration. Percentage of damage is presented in the form of a graph of the relationship between percent of damage (%) with wave height for water depth d = 13 cm and duration D = 100 minutes (figures 5.2, 5.3 and 5.4).

Figures (5.2, 5.3 and 5.4) show, the higher the wave that attacks the breakwater protective layer, the greater the damage to the protective layer that occurs, both the crushed stone protection layer which is placed randomly or in an orderly manner. At the same wave height, namely Hs/d = 0.6, identical to Hs = 7.8 cm (model scale), the amount of damage to the protective layer placed in a random way reaches ± 10% (figure 5.2). Meanwhile, the amount of damage to the protective layer that was placed by arranging the damage was smaller, namely ± 3% (figure 5.3).

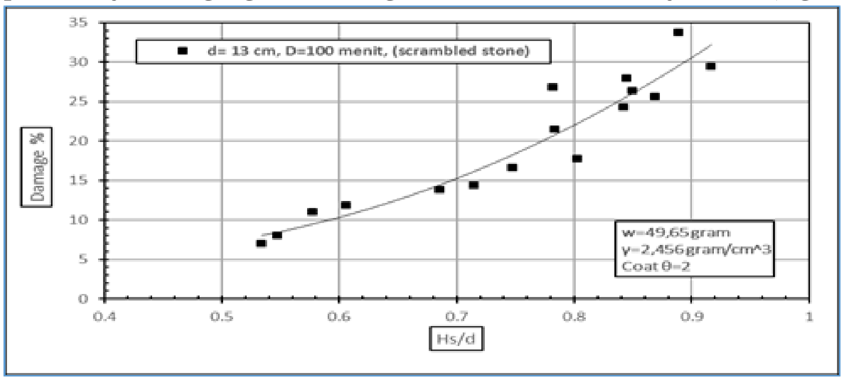

Figure 5.2.Graph of the relationship between wave height (Hs/d) and damage crushed stone protection layer was randomized at wave duration
D = 100 minutes and water depth d=13 cm (model).

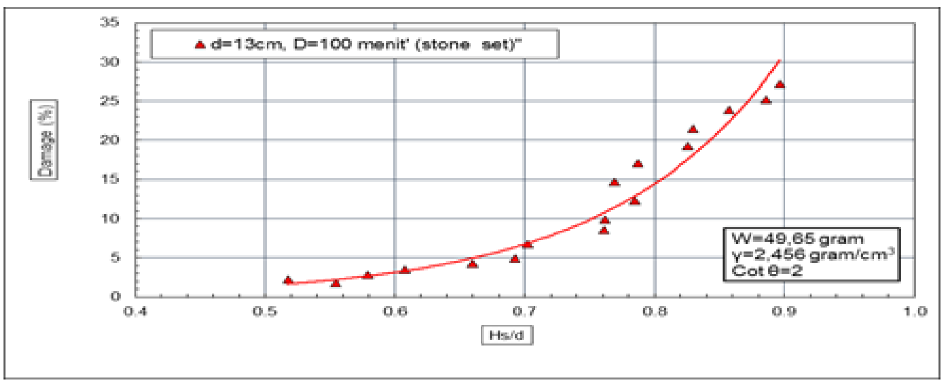

Figure 5.3. The relationship between wave height (Hs/d) and layer damage crushed stone guard set at wave duration D = 100 minutes and
water depth d=13 cm (model).

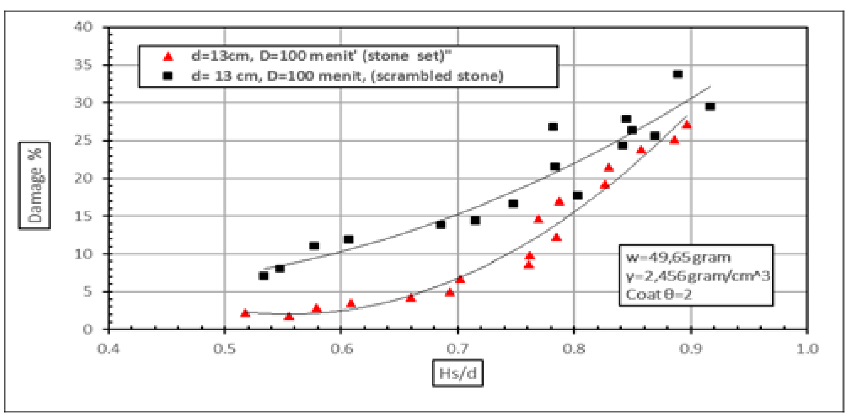

Figure 5.4. Graph of the combined relationship between wave heights (Hs/d) with damage to the crushed stone armor layer are randomized and arranged by duration wave D = 100 minutes and water depth d = 13 cm (model).

From Figures 5.2, 5.3 and 5.4, it can be concluded that the protective layers that are placed in a well-arranged/arranged way will have better strength to lock each other up so they are not easily moved or damaged when hit by waves. Meanwhile, the protective layer which is placed randomly will cause the interlocking strength between the protective layer material is not good so that the protective layer easily moves from place to place or is easily damaged when hit by a wave attack.

The Relationship Between Damage To The Coating With The Coefficient Of Coating Stability Protector (Kd).

The results presented in Figure 5.5 state that the Kd value, for example, is taken as 8, with the duration of the wave attack (D) = 100 minutes, the value of damage to the protective layer is ± 5% for the layered protection layer and ± 13% for the scrambled protective layer. From the results of the research presented in Figure 5.5, it can be concluded that at the same Kd the layer of protection that is arranged will be more stable so that it gives a smaller damage value than the layer that is placed randomly.

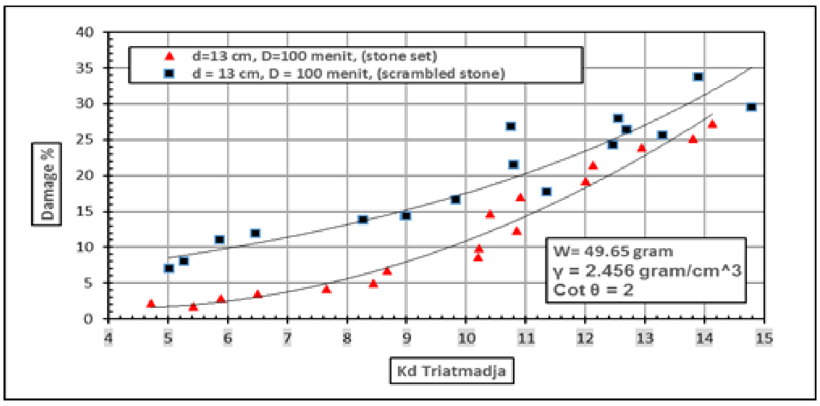

Figure 5.5. The relationship between Kd Triatmadja and damage to the inner layer of protection (%) at wave duration D=100 minutes and water depth d=13 cm (model)

Table 5.1. The value of the damage to the crushed stone layer which is laid out in a randomized manner at the same wave height.

Water depth (d) (model scale)	Wave height Hs/d = 0.6	Damage (%)	
		Stones set	Stones scrambled
13 cm	Hs = 7,8 cm	±3%	±10 %

Table 5.2. The value of the damage to the crushed stone layer which was laid out in an arranged and randomized manner at the same Kd value.

Kd Triatmadja formula	Damage (%)	
	Stones set	Stones scrambled
8	±5 %	±13%

4. CONCLUSION

1. The protective layer of crushed stone which is laid out in an arranged manner will have better interlocking strength so that it gives a smaller damage value of ±3% when compared to the damage of the protective layer of crushed stone which is placed randomly of ±10% at height. the same wave (Hs/d = 0.6).
2. At the value of the coefficient of protection layer Kd = 8 using the Triatmadja formula, the protected layer of crushed stone placed in an arranged manner has less damage ±5% when compared to the damage of the protected layer of crushed stone which is placed randomly by ±13%.

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