3rd Malikussaleh International Conference on Multidiciplinary Studies 2022 (3rd MICoMS 2022)

IINTERNATIONAL CONFERENCE PROCEEDINGS 00045 (2022) | DOI: https://doi.org/10.29103/micoms.v3i.209
E-ISSN: 2963-2536

A Study Coastal Protection Using Stones Crushed and Tetrapod (Case study at Ujong Blang Beach)

Teuku Muhammad Ridwan[1] Abdul Jalil[2,*]

[1,2] Universitas Malikusaleh
[*]Corresponding author. Email: abduljalil@unimal.ac.id

ABSTRACT

Ujong Blang Beach and Jagu Beach are in Lhokseumawe City. The purpose of this study was to plan a breakwater along the coast of Ujong Blang as an alternative for coastal protection. This includes specifying the details of the breakwater layers and calculating the dimensions of the breakwater. Applying the Hudson method to obtain the diameter and weight of stones grains. The protective layer material uses crushed stones and tetrapods. The results of the analysis obtained breakwater dimensions obtained based on a slope of 1: 2. The results of the analysis that have been obtained are made in the drawing 2D as a result of designing rock mounds with a slope of 1: 2. Breakwaters are planned in a position to protect the coast from waves. The planned breakwater height is 6.32 meters so it has the same elevation and crest dimensions, but the material volume will change less due to the lower contour differences in the sea.This type of breakwater is suitable for Ujong Blang beach, because it will have a good effect on the tourism business. The number of protected layer grains on a slope of 1:2 has a material use of 0.23 tons of tetrapods and a peak width of 3.5 meters.

Keywords: *Breakwaters, Hudson Methods, Tetrapods, Crushed stones.*

1. INTRODUCTION

Breakwaters are often used to protect beaches and infrastructure from wave attack. Breakwaters can be divided into three types according to the principle of wave attenuation: reflection type and breakwater, reflection type and friction type [1]. The rubble mound type breakwater is a simple and widely used type of reflection breakwater, and it absorbs wave energy mainly by incident wave energy. Many studies have been carried out to investigate the resistance of the rubble mound breakwater.[2] proposes a new box-type breakwater with superstructure arranged near free surface.[3] study physical model tests wave overtopping at rubble mound breakwaters, including breakwaters with a crest wall, breakwaters with a berm, and breakwaters with a crest wall and a berm.

Gelombang tinggi pada akhir tahun 2020 dan 2021 telah menghantam pantai Ujong Blang dan melimpah melewati pemecah gelombang. Karena gelombang tinggi yang sering terjadi akhir ini, maka penting untuk diajukan suatu alternatif pelindung pantai Ujong Blang. So that there is a protective layer that is important for strength and breakwater stability. The characteristics of the protective layer material are represented by the K_D coefficient including shape, roughness and degree of interlocking. The coefficient K_D is widely used in relations with the number of waves and period. There is a difference between regular and irregular waves, waves spectrum, water depth in front of the breakwater and position of the protective layer material on a regular or random breakwater.

2. METHODS

The research was conducted at Ujong Blang Beach, Lhokseumawe City. The study area was taken along the coast about 2 km and 1 km to the sea. Some important data needed for this analysis include bathymetry and topography, wind data, wave data.

2.1. Topography and Bathymetry

The bathymetry and topography research area is located on the coast of Ujong Blang and the Malacca Strait. This area is in the Sub-district of Banda Sakti with a beach area of approximately 60 ha **Error! Reference source not found.**.

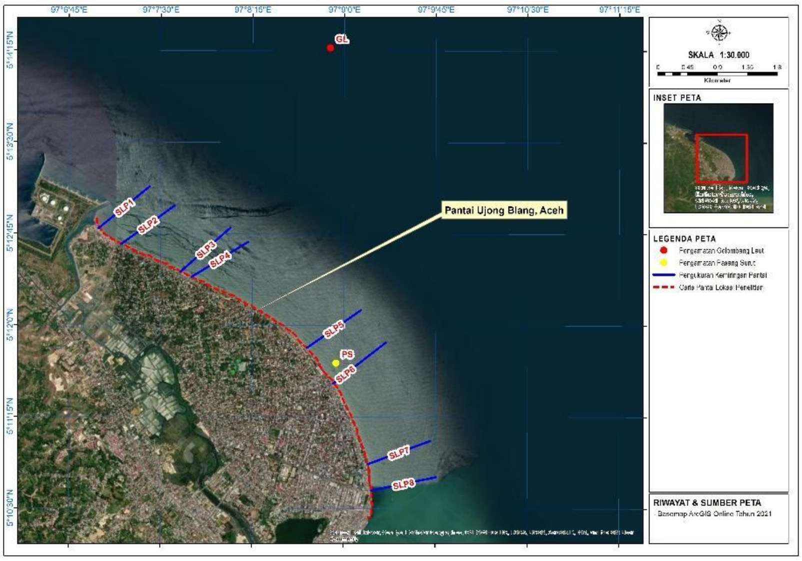


Figure 1 Study area at Ujong Blang beach

2.2. Wind Data

Wind data was taken for 27 years, from 1995 to 2022 at the Malikussaleh station. Data were obtained from the Malikussaleh BMKG Station with coordinates at (*N*) 05°13'33" latitude and (E) 096°56'55" longitude with an altitude of 28 m above sea level. Processing of wind direction and speed data using WRPLOT version 8.2.

2.3. Wave Data

Sea wave data is taken from the Geospatial Information Agency (*BIG*) for 25 years with a recording period from 1995 to 2020. The Admiralty method is a harmonic method used to calculate two harmonic constants, namely amplitude and phase difference in a short span of time (29 days). The output generated in the Admiralty method includes the amplitude (*A*) and phase (g^0) of each component of the tides and the elevation of several important water levels. The tidal components generated from the admiralty method include 9 main tidal components, namely: M_2, S_2, N_2, K_1, O_1, P_1, M_4, MS_4, and K_2. While the elevation (Chart Datum) values generated from this data processing include: MSL, HWL, HHWL and LLWL. In subsequent processing, the amplitude value (*A*) is used to determine the Formzhal value (*F*), so that the types of tides at the research location will be obtained.

$$Z_0 = S_0 - (H_{M2} + H_{S2} + H_{K1} + H_{O1}) \quad (1)$$

Based on harmonic tidal terms, the relative importance of the diurnal and semidiurnal tidal constituents is expressed in terms of a form factor:

$$F = \frac{(H_{K1} + H_{O1})}{(H_{M2} + H_{S2})} \quad (2)$$

The tides may be roughly classified as shown in ***Error! Not a valid bookmark self-reference.***.

Table SEQ Table * ARABIC 1. *F* number based on harmonic tidal conditions**.**

2.4. Wave Celerity and Period

The speed of wave propagation is called wave celerity, *C*. The distance traveled by the wave during one wave period is equal to one wavelength. The wave speed is related to the period and the wavelength.

$$C = \frac{L}{T} \quad (3)$$

C = wave celerity (m/s), L = wavelength (m), and T = period (s).

a) Shoaling coefficient (K_s)

K_s is termed the shoaling coefficient. Values of K_s as a function of d/L and d/L have been tabulated in Tables C-1 and C-2 shown in [4].

$$K_s = \sqrt{\frac{n_0 L_0}{nL}} \quad (4)$$

Gravity waves can be classified according to the depth of the water through which they travel. The following classifications are made based on d/L quantities and limit values are taken as shown in Table 2 below.

Table SEQ Table * ARABIC 2. Classification of magitude d/L

b) Refraction coefficient (K_r)

The methods of refraction analyses are based on Snell's law. The direction of wave arrival at a depth of 3 meters is calculated by the Equation (5).

$$\sin\alpha = \frac{C}{C_0}\sin\alpha_0 \quad (5)$$

and coefficient refraction as follow.

$$K_r = \sqrt{\frac{\cos\alpha}{\cos\alpha_0}} \quad (6)$$

c) Height wave breaking

Analysis of high wave breaking was analyzed using a manual shore protection manual procedure [4].

$$\frac{H_0^{'}}{gT^2} \quad (7)$$

d) The breaking wave depth

Analysis of depth wave breaking was analyzed using a manual shore protection manual procedure [4].

$$\frac{H_b}{gT^2} \quad (8)$$

2.5. Wave Run-up

When a wave hits a structure, it will rise to the surface of the building (run up). The planned elevation of the structure depends on the allowable run up and runoff [5]. The wave run up is as follow.

$$\frac{R_u}{H} \quad (9)$$

For more information on this equation, see [5].

2.6. Rubble Mound Breakwaters

Rubble mound breakwaters is designed using an empirical the Hudson formula:

$$W = \frac{\gamma_r \times H^3}{K_D \left(S_r - 1\right)^3 \cot\theta} \quad (10)$$

where *W* is the weight of the rubble stone, γ_r the density of the rubble stone, S_r is the ratio of the density of crushed stone to the density of the sea water, θ the slope angle of the rubble mound, *H*, the incident wave height, and K_D the stability coefficient.

2.7. Crest Width of Rubble Mound Breakwaters

The minimum width of the rubble mound can be designed as follows.

$$B = nk_\Delta \left[\frac{w}{\gamma_r}\right]^{1/3} \quad (11)$$

Where *B* is the crest with of rubble mound, *n* is the number of stones ($n_{minimum}$ =3), K_Δ = layer coefficient, w is the grain weight of the protective stone, γ_r = density of stone.

3. RESULT AND DISCUSSION

3.1. Topography and Bathymetri

The bathymetry and topographic map of the research location can be seen in **Error! Reference source not found.**. The study area is estimated to be 60 ha as shown in Figure 1. Bathymetry and topography data were collected by observing along the coast of Ujong Blang 100 m towards the mainland and 1 km towards the sea or reaching a depth of ≤ 40 m. The blue lines are SLP1, SLP2, SLP3, SLP4, SLP5, SLP6, SLP7 and SLP8 which are the coastal slope profiles of station 1, station 2, station 3, station 4, station 5, station 6, station 7 and station 8. The water depth at each station with a beach slope is shown in **Error! Reference source not found.**. The measurement of the distance from the coast to the sea coast for all stations is 1000 meters.

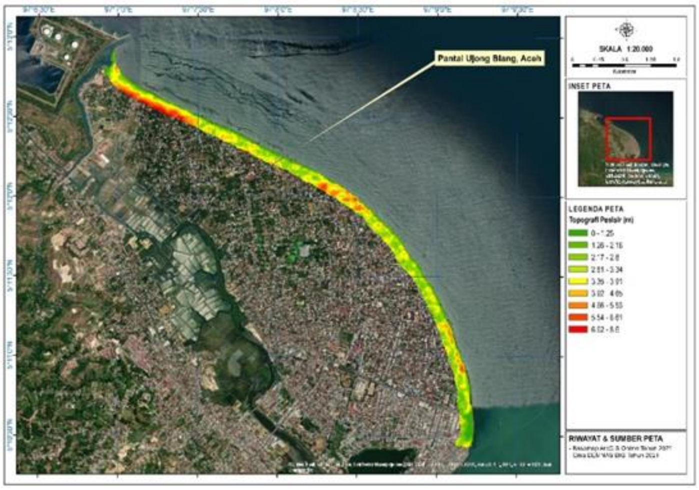
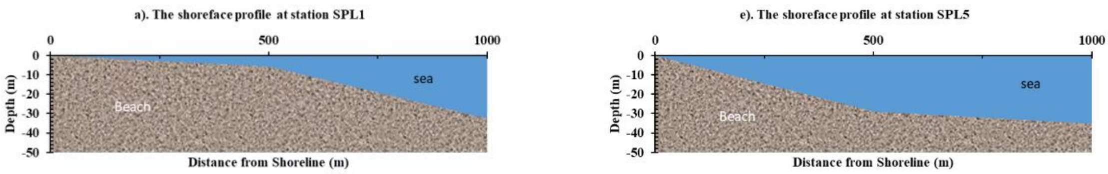


Figure 2 Topography of Ujong Blang Beach



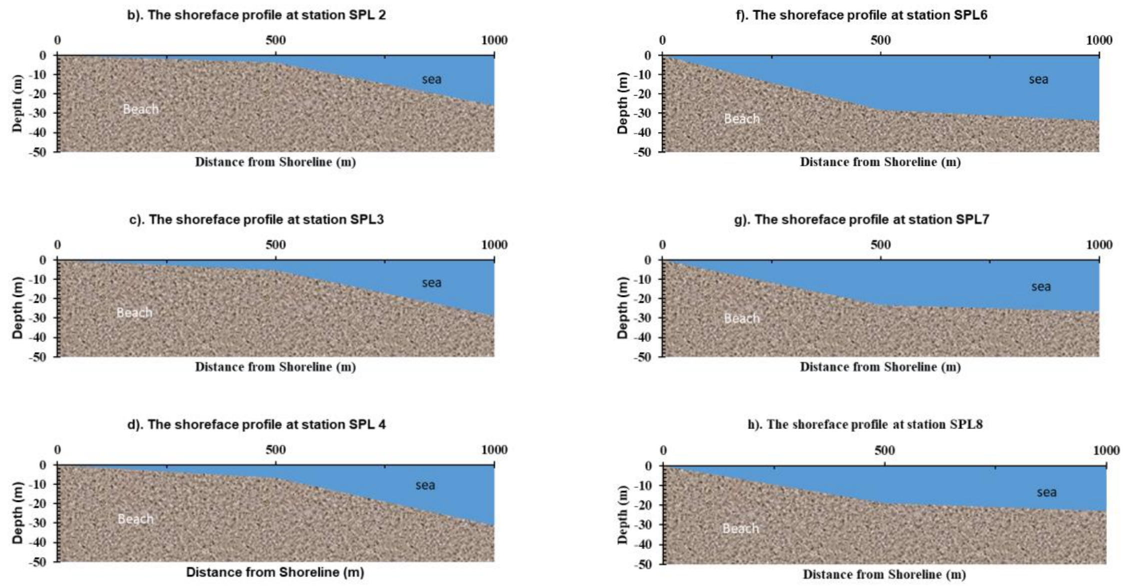
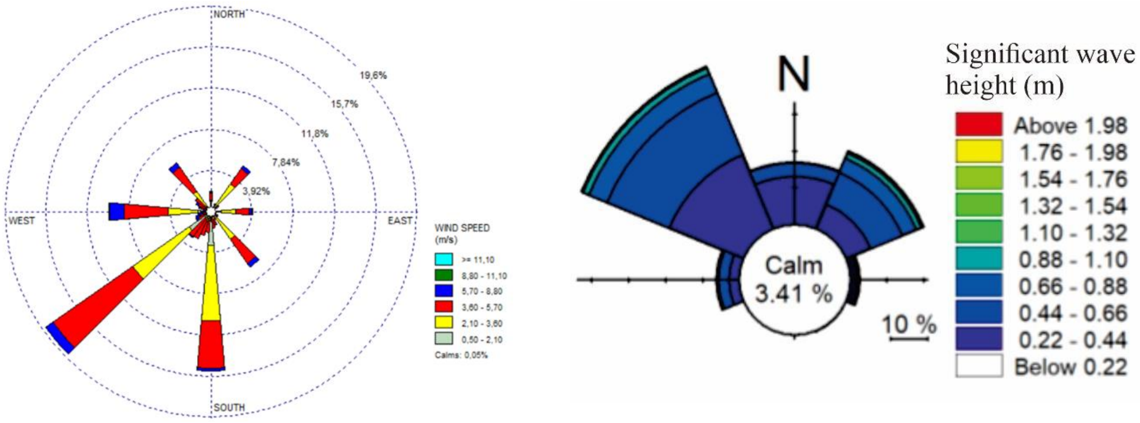


Figure 3 The shoreface profile at Ujong Blang Beach

3.2. Wind Analysis

The layout of the breakwater to be planned is based on wind and wave directions. Wind speed direction and significant waves towards Ujong Blang beach are shown in **Error! Reference source not found.** as follows:



a) Windrose b) Wave rose of significant wave-height

Figure 4 Direction of wind and significant wave. a). windrose at shoreface profile. b). Significant wave.

A general view of the wind climate at *SW* and the siginificant wave at NW direction are shown in the wind rose of **Error! Reference source not found.**a, the wave rose of **Error! Reference source not found.**b.

3.3. Wave Analysis

3.3.1. Tidal Harmonic Analysis with the Admiralty Method

Data processing methods use the Admiralty method, which is a calculation to find the amplitude (*A*) and phase difference (g^0) from observational data for 15 or 29 (days of observation) and the mean sea level (S_0) which has been corrected. Analysis of Ujong Blang beach tides using data with a range of 25 years.

Then calculations are carried out for the second 15 days observation from January 1 2020 to January 15 2020. Data for calculating the harmonic waves for 2020 can be seen in **Table 2**.

ble SEQ Table * ARABIC 3. Results of analysis of wave data using the Admiralty method for 2020.

3.3.2. Tidal Parameters

It is usual to refer to harmonic tidal constituents rather than tidal constants when presenting the results of an analysis [6]. The results of the tidal harmonic analysis in **Table 2Table 2** will be used to calculate the datum reference datum (Chart Datum).

ble SEQ Table * ARABIC 4. Chart Datum, a form factor and Tidal form for 2020.

3.3.3. Significant Wave in 2010 – 2020

The height of the significant waves is the average of the highest third of the waves, H1/3 (33%). Significant waves can be used as input to calculate the wave run-up height of the structure. The run-up height can be used to determine the design crest elevation of the breakwater. For breakwater planning purposes, it is necessary to select individual wave heights and periods that can represent the wave spectrum. This wave is known as a representative wave [5]. The wave height of a recording is sorted from the highest to the lowest value or vice versa, it will be possible to determine the H_n value which is the average of n percent of the highest wave height. This wave can be expressed as a characteristic of natural waves in the singular. Example H_{10} is the average height of the highest 10% waves of a wave chart. The most used wave height is H_{33} or the average height of the highest 33% of recorded waves which is also known as significant H_s waves.

The results of the analysis obtained the maximum wave height H_{max} = 2.01 m, and the maximum period, T_{max} = 6.15 seconds. Wave height 10% (H_{10}) = 0,925 m, Period 10% (T_{10}) = 5,216 second, significant wave height (H_s) or 33% (H_{33}) = 1,109 m, Period 33% T_{33}=5,294 second. Wave height 100% (H_{100}) is the average wave H_{100}=0,474 m and T_{100} = 4,533 second.

3.3.4. Significant Wave in 2010 – 2020

Analysis of the equivalent transformation of wave height in deep water using equation (3) and the results are wave height (H_0) = 1,109 m, Period (T) =5,294 detik, direction of incoming waves (α) = 45º, and the depth (d) = 3 m.

a) Coefficient shoaling (K_s)

L_o = 1,56 x T^2 = 1,56 × $(5,294)^2$ = 43,72 m

$$C_0 = \frac{L_0}{T} = \frac{43,72}{5,294} = 8,258\ m/s$$

$$\frac{d}{L_0} = \frac{3}{43,72} = 0,069$$ Then, from the Tabel L-1, we find n = 0,8645

Error! Reference source not found. Tabel L-1 [5], we can find:

$$\frac{d}{L} = 0,1130$$

$$L = \frac{3}{0,1130} = 26,548 \text{ (transitional, } \frac{1}{25} < \frac{d}{L} < \frac{1}{2})$$

$$C = \frac{L}{T} = \frac{26,548}{5,294} = 5,015\ m/\text{det}$$

To calculate the shoaling coefficient, find the value of n using the Tabel L-1 based on the d/L_0 value above, and get n=0,8645. or deep sea n_0 value is 0,5, so the shoaling coefficient is.

$$K_s = \sqrt{\frac{n_0 L_0}{nL}} = \sqrt{\frac{0,5\times 43,72}{0,8645\times 26,548}} = \sqrt{\frac{21,86}{22,949}} = 0,952$$

b) Refraction coefficient (K_r)

Refraction can be calculated analytically at the shoreline, using Snell's law directly [7].

$$\sin\alpha = \frac{C}{C_0}\sin\alpha_0 = \frac{5,015}{8,258}\sin 45^\circ = 0,429 \quad \text{maka } \alpha = 25,40^\circ$$

The refraction coefficient can be obtained as follows.

$$K_r = \sqrt{\frac{\cos\alpha}{\cos\alpha_0}} = \sqrt{\frac{\cos 25,40^\circ}{\cos 45^\circ}} = \sqrt{\frac{0,903}{0,707}} = 1,130$$

Then treated to get the equivalent wave height. (H_o')

(H_o') = $K_s \times K_r \times H_o$ = 0,952 × 1,130 × 1,109 = 1,193 m

c) Breaking wave height

H_o' = 1,193 m

$$\frac{H_0'}{gT^2} = \frac{1,193}{9,81\times 5,294} = \frac{1,193}{51,934} = 0,0229$$

From **Error! Reference source not found.** entering with H_0'/gT^2 = 0.00229 and intersecting the curve for a slope of 1:20 (m = 0.05) result in H_b/H_0 = 1.0. Therefore.

d) Breaking wave depth

$$\frac{H_b}{gT^2} = \frac{1,193}{9,81\times 5,294^2} = 0,0229$$

and entering Error! Reference source not found. for m = 0,05. and, $\beta = \frac{d_b}{H_b}$

$$\frac{d_b}{H_b} = 1,47$$

The depth at breaking.

$$d_b = 1,47 \times 1,193 = 1,754\ m$$

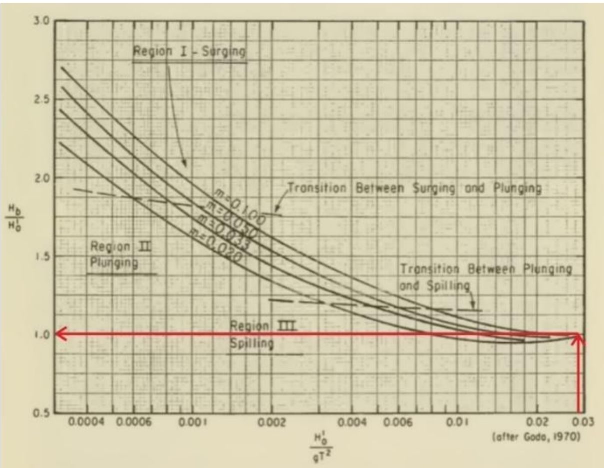


Figure 5 Determination of breaking wave height [7]

From **Error! Reference source not found.**, the minimum depth at breaking is β = 1,47 for m = 0,05, $(d_b)_{min} = \beta \times H_b$ = 1,47 ×1,193 = 1,754m. The breaking is H_b = 1,193 m and d_b = 1,754 m.

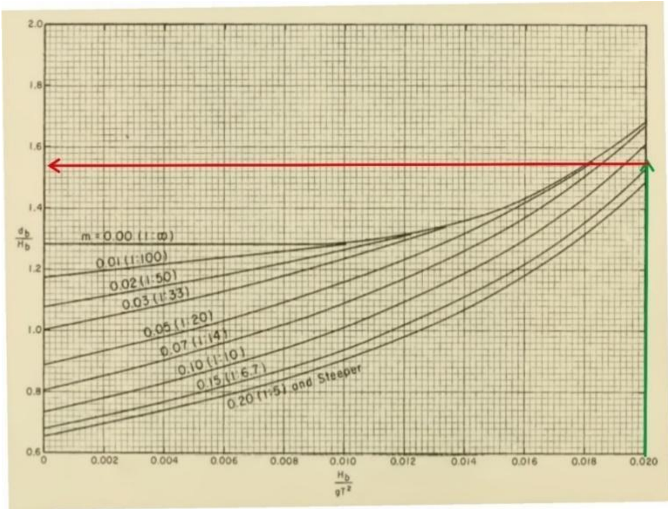


Figure 6 Dimensionless depth at breaking versus breaker steepness [7].

3.4. Model Breakwaters

The determination of the breakwater model must be in accordance with environmental conditions, calm waters, and development plans. The planning conditions considered are wind, tidal height, waves, and water depth and seabed conditions.

To protect the beach and overcome the problem of sediment transport at Ujung Blang beach, it is planned to use a breakwater construction. The construction of the breakwater uses a sloping beach building type. The construction is divided into two parts, namely the head and body. It is planned to build a breakwater using natural stone as a protective layer because natural stone material with a certain weight in large quantities can easily be obtained around the beach location. For the protective layer and the core part of the breakwater construction, natural stone materials are used.

The breakwater construction is made in several layers, where the bottom layer has a smaller diameter and rock weight than the top layer. This is because the topmost layer is directly exposed to waves, so it must be composed of piles of stones that are large in diameter and heavy. The following parameters for the analysis of the breakwater structure are significant wave height (H_{33}) = 1.109 m, Period (T_{33}) = 5.294 second, depth of breakwaters = -2,0 m from LW, tidal elevation HWL = + 2,61 m, MWL = + 2,44 m and LWL = ± 0,00 m. Datum = ± 0,00 m, density of crushed stones (γ_r) = 2,65 t/m^3 and density of seawater (γ_w) = 1,025 t/m^3.

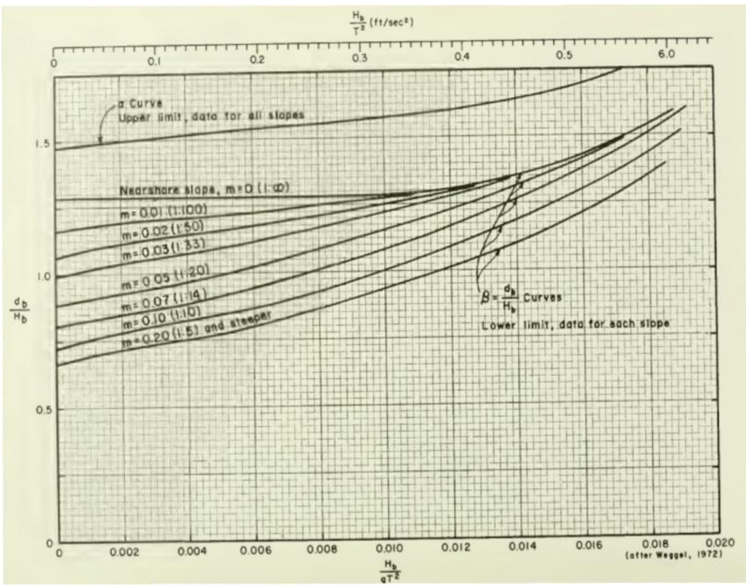


Figure 7 Determination α and β versus $\frac{H_b}{gT^2}$ [7]

3.4.1. Design Breakwater

The design slope of the breakwater is 1:2Panjang gelombang :

$$L_0 = 1{,}56 \cdot T_{33}^2$$

$$= 1{,}56 \times (5{,}294)^2 \quad = 43{,}721 \text{ m}$$

The Iribaren number is obtained in the curve of **Error! Reference source not found.**.

$$I_r = \frac{Tan\ \theta}{\left(H / L_0\right)^{0,5}}$$

$$I_r = \frac{0.5}{\left(1,76 / 47,721\right)^{0,5}} = \frac{0,5}{(0,0369)^{0,5}} = \frac{0,5}{0,192} = 2,604$$

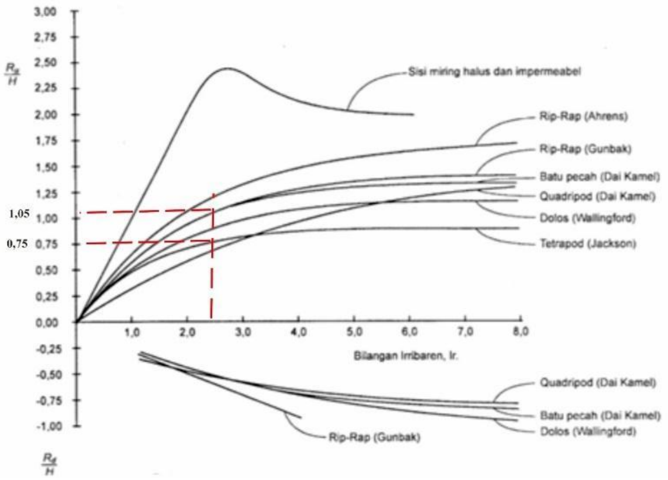


Figure 8 Comparison of runup and rundown for different types of hypotenuse

a. For the protective layer with crushed stone construction at I_r = 2.604, the Run-up value is obtained according to the wave Run-up graph [5].

$$\frac{R_u}{H} = 1,05$$

R_u = 1,05 × 1,76 = 1,848 m

The crest elevation of the breakwater is obtained with a free height of 0.5 m and is calculated below

El_{puncak} = HWL + R_u + 0.5

= 2,61 + 1,848 + 0,5

= 4,958 m ≈ 5,0 meter.

The height of the breakwater is at a depth of 2.0 meters below the lowest sea level (LWL):

$H_{breakwaters}$ = Breakwater crest elevation – Seabed elevation

= 5,0 – (- 2,0) m = 7,0 meter

b. For protective layer with tetrapod construction; I_r = 2.604, the run-up value is obtained according to the wave run-up chart [5].

$$\frac{R_u}{H} = 0,7$$

Then, R_u = 0,7 × 1,76 = 1,232 m

the crest height of the breakwater and the free height is 0.5 m

El_{crest} = HWL + R_u + 0.5

= 2,61 + 1,232 + 0,5

= 4,32 m ≈ 4,3 meter.

The height of the breakwater at a depth of 2.0 meters below the lowest water level (LWL): (LWL):

$H_{breakwaters}$ = El_{crest} – Seabed elevation

= 4,32 – (- 2,0) m = 6,32 meter

3.4.2. Grain Weight of Protected Coatings and Crushed Stones

The grain weight of the cover rock is calculated using the Hudson formula [8] as follows:

a. Crushed stone protection K_D = 4

$$W = \frac{\gamma_r \times H^3}{K_D\left(S_r - 1\right)^3 \cot\theta} = \frac{2,65 \times 1,76^3}{4 \times \left[\left(2,65/1,03\right) - 1\right]^3 \times 2} = \frac{14,447}{31,137} = 0,464 ton$$

Stone diameter

$$D = 2 \times \sqrt[3]{\left(\frac{3}{4} \times \frac{W/\gamma_r}{\pi}\right)} = 2 \times \sqrt[3]{\left(\frac{3}{4} \times \frac{0,464/2,65}{\pi}\right)} = 0,241 m = 24 cm$$

For the protective layer of tetrapods (K_D =8)

$$W = \frac{\gamma_r \times H^3}{K_D\left(S_r - 1\right)^3 \cot\theta} = \frac{2,65 \times 1,76^3}{8 \times \left[\left(2,65/1,03\right) - 1\right]^3 \times 2} = \frac{14,447}{62,274} = 0,232 ton$$

b. The crest width of the breakwater

Breakwater crest width for n=3 (minimum)

$$B = nk_\Delta \left[\frac{w}{\gamma_r}\right]^{1/3} = 3 \times 1,15 \left[\frac{2,5}{2,65}\right]^{1/3} = 3,384 m$$

c. Layer thickness

$$t = nk_\Delta \left[\frac{w}{\gamma_r}\right]^{1/3} = 2 \times 1,15 \left[\frac{2,5}{2,65}\right]^{1/3} = 2,256 m$$

d. The number of protective stones

The number of protective stone grains per unit area ($10m^2$) is

$$N = Ank_\Delta \left[1 - \frac{P}{100}\right]\left[\frac{\gamma_r}{w}\right]^{1/3} = 10 \times 2 \times 1,15 \left[1 - \frac{37}{100}\right]\left[\frac{2,65}{2,5}\right]^{1/3} = 14,774 \approx 15$$

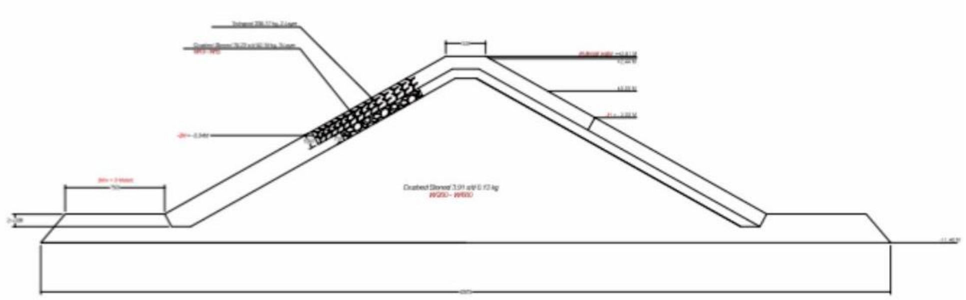


Figure 9 The result of the design of the breakwater protective layer

Headings may be numbered or unnumbered ("1 Introduction" and "1.2 Numbered level 2 head"), with no ending punctuation. As demonstrated in this document, the initial paragraph after a heading is not indented.

4. CONCLUSION

The description of the discussion can be concluded as follows:

1) Breakwaters are planned in a position to protect the coast from waves. The planned breakwater height is 6.32 meters so it has the same elevation and crest dimensions, but the material volume will change less due to the lower contour differences in the sea..

2) This type of breakwater is suitable for Ujong Blang beach, because it will have a good effect on the tourism business.

3) The number of protected layer grains on a slope of 1:2 has a material use of 0.23 tons of tetrapods and a peak width of 3.5 meters

AUTHORS' CONTRIBUTIONS

AJ performed the analysis data and mapping. TMR conducted the data analysis as well as provided wave data. All authors read and approved the final manuscript.".

ACKNOWLEDGMENTS

The authors would like to express their gratitude for the support given by the Lector Scheme Reseacrh Fund, as well as the LPPM of Universitas Malikussaleh.

REFERENCES

[1] Sawaragi, T., 1995. *Coastal Engineering- Waves, Beaches, Wave-Structure Interactions*. Tokyo: Elsevier.

[2] Liang, J., Chen, Y., Liu, Y. and Li, A., 2022. Hydrodynamic performance of a new box-type breakwater with superstructure: Experimental study and SPH simulation. *Ocean Engineering*, 266, p.112819. https://doi.org/10.1016/j.oceaneng.2022.112819.

[3] van Gent, M.R.A., Wolters, G. and Capel, A., 2022. Wave overtopping discharges at rubble mound breakwaters including effects of a crest wall and a berm. *Coastal Engineering*, 176, p.104151. https://doi.org/10.1016/j.coastaleng.2022.104151.

[4] CERC, 1984a. *Shore Protection Manual 1, US Army Coastal Engineering Research Center*. Washington.

[5] Triatmojo, B., 1999. *Teknik Pantai*. Yogyakarta: Beta Offset.

[6] Pugh, D. and Woodworth, P., 2014. *Sea-Level Science: Understanding Tides, Surges, Tsunamis and Mean Sea-Level Changes*. Second edition ed. United Kingdom: Cambridge University Press.

[7] CERC, 1984b. *Shore Protection Manual 2, US Army Coastal Engineering Research Center*. Washington.

[8] Triatmojo, B., 2010. *Perencanaan Pelabuhan*. Yogyakarta: Beta Offset.