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Wave Analysis Of Breakwater Building Structure In North Kalimantan

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Abstract

Natural factors in the form of large sea waves occur on the beach located in Tanjung Aru Village, East Sebatik District, Nunukan, North Kalimantan, causing the beach This area is experiencing a decline in the coastline or what is commonly referred to as coastal erosion. In connection with these conditions, there has been a *breakwater detached* as an effort to solve this problem to protect coastal areas that are experiencing erosion. But before that, it is necessary to conduct a wave analysis of the design of the *breakwater detached* to be built. Based on the calculation analysis that has been done, the significant wave height (Hs) is 4,361 meters and the significant wave period (Ts) is 11.173 seconds. The pressure wave force *(P)* is 27.001 tons and the moment *(Mp)* is 92.612 tonmeters. Wave height measurements need to be carried out every month throughout the year in order to obtain a more representative picture of wave height. In addition, planning for the construction of *breakwater* needs to be considered again, especially on the dimensions of the *breakwater structure.* Moreover, the condition of the sea waves is fully developed.

Keywords: Wave, Breakwater Detached, North Kalimantan

1. Introduction

Indonesia, which is an archipelagic country, has a coastline of more than 81,000 km. Coastal areas in Indonesia have undergone rapid changes, so the coastal area management program is an activity that must receive serious attention. The coastal area is an area that is always changing. Changes in the characteristics of the coastal area occur due to the combination of several forces acting, including wave and wind forces. The beach is a moving area, because every change in these forces is always followed by a change in the beach. Coastal damage occurs as a result of processes and changes in force that occur.

Waves are a major factor in determining the layout of ports, shipping lanes and coastal structures. Planning of coastal buildings must know or pay attention to the direction of knowing the height of the breaking waves that occur in the building. Ocean waves can be generated by the wind (wind waves), the attraction of the sun and moon (tidal waves), volcanic eruptions, or earthquakes at sea (*tsunami*), moving ships and so on. Wind speed allows the causes of natural phenomena, namely erosion, abrasion and sedimentation. Waves can also generate energy to form beaches, cause currents and *transport* in the direction perpendicular to the coast and parallel to the coast, and cause forces acting on coastal structures.

The beach is an area on the edge of the water that is affected by the highest tides and the lowest low tides. Very long coastal areas, human activities, and development activities in coastal areas as well as natural factors such as waves, tides, and currents can have a negative impact on coastal areas by causing erosion and coastal sedimentation. Natural factors in the form of large sea waves occur on the beach located in Tanjung Aru Village, East Sebatik

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District, Nunukan, North Kalimantan, causing the coast in this area to experience a coastline decline or what is commonly referred to as coastal erosion. If left unchecked, coastal erosion can cause enormous losses by destroying residential areas and existing facilities in the area. In connection with these conditions, a *breakwater detached* as an effort to protect the coastal area that is experiencing erosion. Coastal protection can be done in a natural way and the construction of a coastal protection structure. The purpose of making coastal protection is to avoid coastal erosion. But before that, it is necessary to have a wave analysis of the design of the *breakwater detached* to be built.

2. Materials and Methods

Location

Location of this research is in East Kalimantan, Tanjung Aru Village, East Sebatik District, Nunukan.

Data Collection Method The

Method used to collect data is secondary data in the form of wind data, tidal data and wave data, literature in the form of articles, journals and the internet or publications from various sources related to research.

Data

Analysis Fetch analysis and to find out wave data, *hindcasting* which followed the method described in SPM (*Shore Protection Manual*).

Research Flowchart Research

Flow chart is depicted in the figure below to facilitate and direct the course of research.

Fig. 1. Location of Wave Analysis on Breakwater

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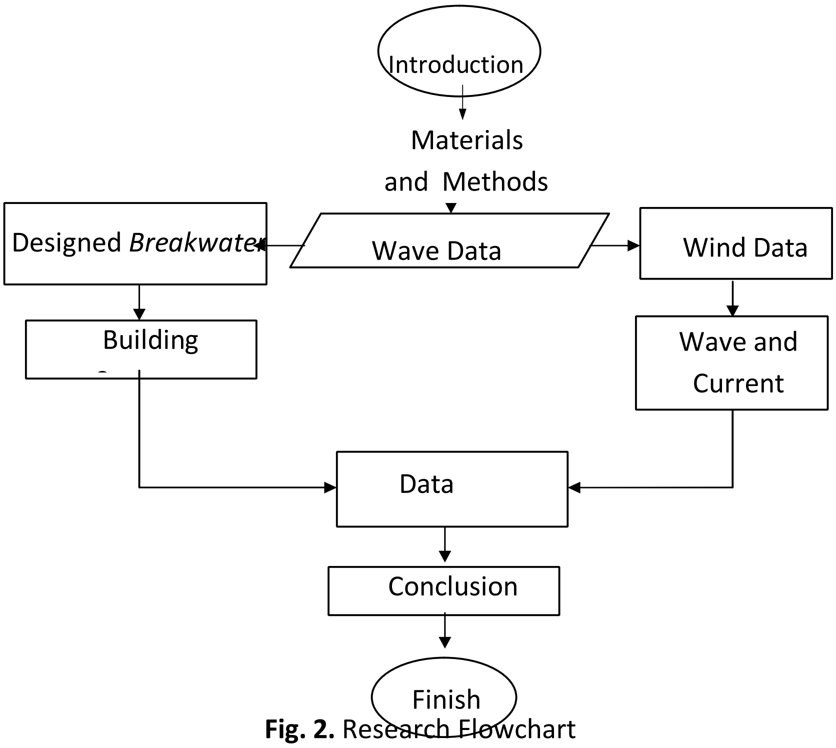

Fig. 2. Research Flowchart

3. Results

Wave Prediction with Return Period *is* Method Weibull. The calculation of the return period uses the significant wave heights that have been sorted in the table. The calculation results can be seen below.

Table 1. Sorted Significant Wave Heights

Year	H33
2008	3.286
2017	2.584
2020	2.505
2006	2.195
2007	2.194
2013	2.146
2011	2.035
2009	1.867
2012	1.784
2014	1.642
2010	1.630
2016	1.530
2019	1.259
2018	1.258
2021	0.839
2015	0.796
2022	0.545

Table 2. Wave Height of the Weibull

Return Period Tahun	yr	Hsr m	τnr	τr	H_{sr}-1.28τ_r m	H_{sr}+1.28τ_r m
2	0.613	1.678	0.458	0.286	1.311	2.044
5	1.886	2.293	1.067	0.667	1.439	3.147
10	3.041	2.851	1.674	1.046	1.513	4.190
25	4.753	3.679	2.588	1.617	1.609	5.749
50	6.164	4.361	3.347	2.091	1.685	7.038

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100	7.662	5.085	4.153	2.595	1.764	8.407

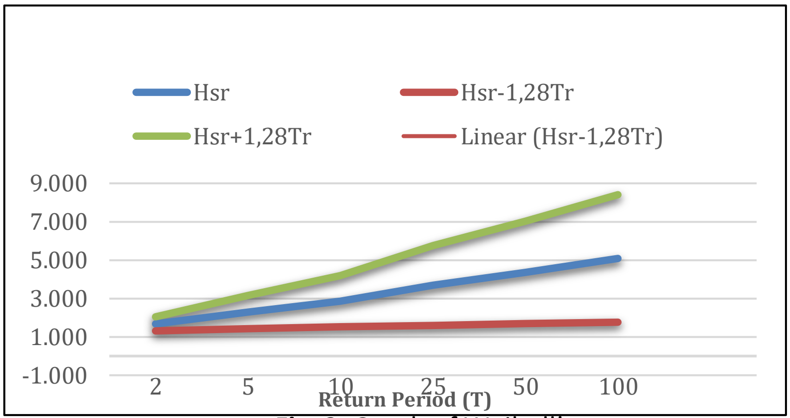

Fig. 3. Graph of Weibull's

From the results of the determination of the wave return period above, the significant wave height from the next 2 years to 100 years is getting higher. This data becomes more accurate because it has been tested with an 80% confidence interval. Where the value of the significant wave is in the specified confidence interval (Hs value - 1.28σr and Hs value +1.28σr). So that the data can be used as a reference in the construction of coastal protection structures. The wave height of the 50-year return period used is the wave height using the *Weibull* , which is 4,361 meters with a wave period of 11,173 seconds.

Tidal Data

Observations were carried out on September 19 to October 3, 2010. Based on the results of data analysis, it was found that the tidal type is mixed tide tends to be double, meaning that in a day there are two high tides and two low tides but high and low tides. the period is different. And also obtained the planned elevations:

Table 3. Elevation of Tidal Beaches in Tanjung Aru Village, Nunukan, North Kalimantan

Elevasi	Calculation	Results (cm)
HHWL	S0+(M2+S2+K2+K1+O1+P1)	499.822
MHWL	S0+(M2+K1+O1)	365.294
MSL	SO	238.530
MLWL	S0-(M2+K1+O1)	111.766
LLWL	SO-(M2+S2+K2+K1+O1+P1)	-22.761

Calculation of Refraction

The refractive coefficient is calculated based on the value of the wave propagation speed and the angle of incidence of the wave. The value of the refraction coefficient obtained from the calculation is 1 m/s. You can see the formula below.

$$Lo = 1{,}56\,T^2$$

$$L_0 = 1{,}56\,(11{,}173)^2 = 194{,}754\,m \quad \rightarrow \quad C_0 = \frac{L_0}{T} = \frac{194{,}754}{11{,}173} = 17{,}430\ \mathrm{m/d}$$

$$\frac{d}{L_0} = \frac{0{,}2}{194{,}754} = 0{,}0010 \ \rightarrow \ \frac{d}{L} = 0{,}012 \ \rightarrow \ L = \frac{0{,}2}{0{,}012} = 16{,}66\,m$$

$$C = \frac{L}{T} = \frac{16{,}66}{11{,}173} = 1{,}491\,m/d$$

$$\sin\alpha = \left(\frac{C}{C_0}\right)\sin\alpha_0 = \frac{1{,}491}{17{,}430}\sin 0^o = 0^o$$

$$Kr = \sqrt{\frac{\cos\alpha_0}{\cos\alpha}} = \sqrt{\frac{\cos 0^o}{\cos 0^o}} = 1\,m/d$$

Calculation of Equivalent Wave Height Wave

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Height in the deep sea is calculated based on the value of wave height, coefficient of refraction and coefficient of siltation. The wave height in the deep sea (H0) is 4,361 meters. Furthermore, the equivalent wave height value (H'0) is 10.898 meters.

$$H' = K_s \times K_r \times H_0$$

$$K_s = \sqrt{\frac{n_o L_o}{n\, L}} = \sqrt{\frac{0,5 \times 194,754}{0,9972 \times 15,625}} = 2,499$$

Coefficient shoaling (Ks) at sea in the value of n_0 is 0.5

From the calculation of the coefficients above, the equivalent wave height (H') is obtained as follows:

$$H = K_s \times K_r \times H_o$$

$$= 2,499 \times 1 \times 4,361 = 10,898\, mS$$

Calculation of the Height and Depth of Breaking Waves Based on the Direction of the Waves Coming (Hb and db)

In the modeling that has been carried out, it can be seen that the highest wave height occurs from the east. So that the calculation of breaking waves is carried out for the direction of the incoming wave from the east. The beach which is located in Tanjung Aru Village is a beach that stretches from south to north. The direction of the waves comes from the east (Angle to the perpendicular to the coast, o = 0°). The breaking wave height is 4,841 m and the breaking wave depth is 5,989 m.

Calculation of Breakwater Detached

The type of breakwater is detached breakwater with a slope of 1:2. The structure uses crushed stone material. From the wave height modeling, the wave height value at the building site is 2.227 m and is at a depth of (d) 1.75 m from the LWS.

Behind *breakwater* is formed by a button, so that it is obtained:

Distance from the design water level elevation = 6,025 m. The distance from the shoreline to the breakwater is 300 m, length Breakwater = 480 m Distance between breakwaters = 384 m.

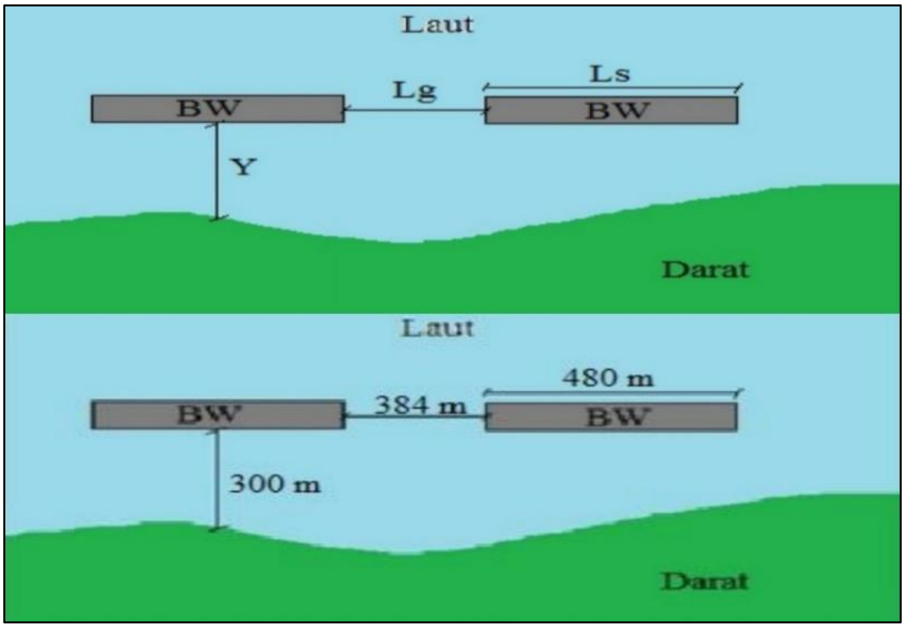

Fig. 4. Detached Breakwater

Wave Length and Height

From the previous calculations, the following values are known:

Significant wave height (H_s) = 4.361 m

Significant wave period (T_s) = 11,173 s Deep

Sea wave length (L_0) = 194.754 m

Equivalent wave height (H'_0) = 10,898 m

Then the following calculations are carried out:

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$$\frac{H'_0}{L_0} = \frac{10,898}{194,754} = 0,055$$

$$\frac{d}{L_0} = \frac{1,75}{194,754} = 0,0089$$

Next calculate the wave depth value using the following equation:

$$d_{bw} = d + 6,025 \times H_{\frac{1}{3}}$$

$$= 1,75 + 6,025 \times \frac{1}{30} \times 4,361$$

$$= 2,625\ m$$

The maximum wave height (H_{max}) is obtained using the following formula:

$$H_{max} = 1,8H$$

$$= 1,8 \times 4,361$$

$$= 7,84 \text{ m}$$

Wave Pressure

Known based on the function d method /L.

$\frac{d}{L_0}$	$\frac{d}{L}$	$\frac{2\pi d}{L}$	tanh $2\pi d/L$	sinh $2\pi d/L$	cosh $2\pi d/L$	K_s	K	$\frac{4\pi d}{L}$	sinh $4\pi d/L$	cosh $4\pi d/L$	n
0	0	0	0	0	1	∞	1	0	0	1	1
0.0001	0.00399	0.0251	0.0251	0.0251	1.0003	4.467	0.9997	0.0501	0.0502	1.001	0.9998
0.0002	0.00564	0.0355	0.0354	0.0355	1.0006	3.757	0.9994	0.0709	0.0710	1.003	0.9996
0.0003	0.00691	0.0434	0.0434	0.0434	1.0009	3.396	0.9991	0.0868	0.0869	1.004	0.9994
0.0004	0.00798	0.0502	0.0501	0.0502	1.0013	3.160	0.9987	0.1003	0.1005	1.005	0.9992
0.0005	0.00893	0.0561	0.0560	0.0561	1.0016	2.989	0.9984	0.1122	0.1124	1.006	0.9990
0.0006	0.00978	0.0614	0.0614	0.0615	1.0019	2.856	0.9981	0.1229	0.1232	1.008	0.9987
0.0007	0.01056	0.0664	0.0663	0.0664	1.0022	2.749	0.9978	0.1327	0.1331	1.009	0.9985
0.0008	0.01129	0.0710	0.0708	0.0710	1.0025	2.659	0.9975	0.1419	0.1424	1.010	0.9983
0.0009	0.01198	0.0753	0.0751	0.0753	1.0028	2.582	0.9972	0.1505	0.1511	1.011	0.9981
0.0010	0.01263	0.0793	0.0792	0.0794	1.0031	2.515	0.9969	0.1587	0.1594	1.013	0.9979
0.0011	0.01325	0.0832	0.0830	0.0833	1.0035	2.457	0.9965	0.1665	0.1672	1.014	0.9977
0.0012	0.01384	0.0869	0.0867	0.0871	1.0038	2.404	0.9962	0.1739	0.1748	1.015	0.9975
0.0013	0.01440	0.0905	0.0903	0.0906	1.0041	2.357	0.9959	0.1810	0.1820	1.016	0.9973
0.0014	0.01495	0.0939	0.0937	0.0941	1.0044	2.314	0.9956	0.1879	0.1890	1.018	0.9971
0.0015	0.01548	0.0972	0.0969	0.0974	1.0047	2.275	0.9953	0.1945	0.1957	1.019	0.9969
0.0016	0.01598	0.1004	0.1001	0.1006	1.0050	2.239	0.9950	0.2009	0.2022	1.020	0.9967
0.0017	0.01648	0.1035	0.1032	0.1037	1.0054	2.205	0.9947	0.2071	0.2086	1.022	0.9964
0.0018	0.01696	0.1065	0.1061	0.1067	1.0057	2.174	0.9944	0.2131	0.2147	1.023	0.9962
0.0019	0.01742	0.1095	0.1090	0.1097	1.0060	2.146	0.9940	0.2189	0.2207	1.024	0.9960
0.0020	0.01787	0.1123	0.1118	0.1125	1.0063	2.119	0.9937	0.2246	0.2265	1.025	0.9958
0.0021	0.01832	0.1151	0.1146	0.1154	1.0066	2.093	0.9934	0.2302	0.2322	1.027	0.9956
0.0022	0.01875	0.1178	0.1173	0.1181	1.0069	2.070	0.9931	0.2356	0.2378	1.028	0.9954
0.0023	0.01918	0.1205	0.1199	0.1208	1.0073	2.047	0.9928	0.2410	0.2433	1.029	0.9952
0.0024	0.01959	0.1231	0.1225	0.1234	1.0076	2.026	0.9925	0.2462	0.2487	1.030	0.9950
0.0025	0.02000	0.1256	0.1250	0.1260	1.0079	2.005	0.9922	0.2513	0.2539	1.032	0.9948
0.0026	0.02040	0.1282	0.1275	0.1285	1.0082	1.986	0.9918	0.2563	0.2591	1.033	0.9946
0.0027	0.02079	0.1306	0.1299	0.1310	1.0085	1.968	0.9915	0.2612	0.2642	1.034	0.9944
0.0028	0.02117	0.1330	0.1322	0.1334	1.0089	1.950	0.9912	0.2660	0.2692	1.036	0.9942
0.0029	0.02155	0.1354	0.1346	0.1358	1.0092	1.933	0.9909	0.2708	0.2741	1.037	0.9939

Fig. 5. The d/L function for increasing the value of d/Lo

Coefficient of wave pressure:

$$a_1 = 0,6 + \frac{1}{2}\left\{\frac{\left(\frac{4\pi d}{L}\right)}{sinh\left(\frac{4\pi d}{L}\right)}\right\}^2$$

$$= 0,6 + \frac{1}{2}\left\{\frac{0,1587}{0,1594}\right\}^2$$

$$= 1,09$$

$$\frac{d_{bw} - h}{3d_{bw}}\left(\frac{H_{max}}{h}\right)^2 = \frac{2,476 - 0,5}{3 \times 2,476}\left(\frac{7,84}{0,5}\right)^2$$

$$= 65,40$$

$$\frac{2d}{H_{max}} = \frac{2 \times 1,75}{7,84} = 0,446$$

$$a_2 = min\left\{\frac{d_{bw} - h}{3d_{bw}}\left(\frac{H_{max}}{h}\right)^2, \frac{2d}{H_{max}}\right\}$$

$$= min\{65,40 : 0,446\} = 0,851$$

$$a_3 = 1 - \frac{d'}{d}\left\{1 - \frac{1}{cosh\left(\frac{2\pi d}{L}\right)}\right\}$$

$$= 1 - \frac{6,025}{1,75}\left\{1 - \frac{1}{1,0031}\right\} = 0,989$$

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So from the calculation results, we get a value of a_1= 1.09, a_2= 0.851, and a_3= 0.989

Next, the wave pressure will be determined:

$$p_1 = \frac{1}{2}(1+\cos b)(a_1 + a_2 cos^2 b) g_0 H_{max}$$

$$\frac{1}{2}(1+\cos 0{,}824^o)(1{,}09 + 0{,}851\, cos^2 0{,}824^o)\ 1{,}03 \times 7{,}84 = 3{,}995\ t/m^2$$

$$P_2 = \frac{P_1}{cosh\left(\frac{2\pi d}{L}\right)}$$

$$= \frac{3{,}995}{1{,}0031} = 3{,}982\ t/m^2$$

$$P_3 = a_3 \times p_1$$

$$= 0{,}989 \times 3{,}995 = 3{,}951\ t/m^2$$

So, from the calculation results obtained the value of P_1= 3.955, P_2= 3.982, and P_3= 3.951. Then calculate the upward pressure using the following formula:

$$P_u = \frac{1}{2}(1+\cos b) a_1 \times a_3 \times g_0 \times H_{max}$$

$$= \frac{1}{2}(1+\cos 0{,}824^o) \times 1{,}09 \times 0{,}989 \times 1{,}03 \times 7{,}84 = 8{,}704\ t/m^2$$

From the calculated wave pressure, namely P_u= 8,704 t/m^2, then the wave force and moment generated by the wave against the foot of the building can be calculated as follows:

The maximum elevation at which the pressure wave acts.

$$h^* = 0{,}75(1+\cos b)H_{max}$$

$$0{,}75(1+\cos 0{,}824^o)7{,}84 = 11{,}75$$

$$d_c^* = min\{h^*: d_c\}$$

$$= min\{11{,}75: 2\} = 2$$

$$P_4 = P_1\left(1 - \frac{d_c}{h}\right)$$

$$3{,}955\left(1 - \frac{2}{11{,}75}\right) = 3{,}281\ t/m^2$$

So, the maximum elevation of the wave pressure distribution to sea level is h = 11.75 and the value of P_4= 3.281 t/m^2. Furthermore, the wave force and moment can be calculated.

$$P = \frac{1}{2}(P_1 + P_3)d' + \frac{1}{2}(P_1 + P_4)d_c^*$$

$$= \frac{1}{2}(3{,}955 + 3{,}951) \times 5 + \frac{1}{2}(3{,}955 + 3{,}281) \times 2 = 27{,}001\ t$$

$$M_p = \frac{1}{6}(2P_1 + P_3)d'^2 + \frac{1}{2}(P_1 + P_4)d' \times d_c^* + \frac{1}{6}(P_1 + 2P_4)d_c^{*2}$$

$$= \frac{1}{6}(2 \times 3{,}955 + 3{,}951)5^2 + \frac{1}{2}(3{,}955 + 3{,}281)5 \times 2 + \frac{1}{6}(3{,}955 + 2 \times 3{,}281)2^2 = 92{,}612\ tm$$

So, the pressure wave force (*P*) is 27.001 tons and the moment (*Mp*) is 92.612 tonmeters.

4. Conclusions

Based on the calculation, it is found that the significant wave height (Hs) is 4,361 meters and the significant wave period (Ts) is 11.173 seconds. The pressure wave force *(P)* is 27.001 tons and the moment *(Mp)* is 92.612 tonmeters. Wave height measurements need to be carried out every month throughout the year in order to obtain a more representative picture of wave height.development planning, *breakwater* necessary to pay attention to the structure *breakwater.* Moreover, the condition of the sea waves is fully developed.

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