Analysis of Breaking Wave Characteristic To Prevent Shoreline Damage

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Analysis of Breaking Wave Characteristic To Prevent Shoreline Damage

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Abstract - *The existence of the beach naturally, where there is a dynamic interaction between water and wind and its constituent materials, causes the vulnerability of the beach to changes in the form of damage to coastal areas. Changes in the coastline and damage are dominated by the breaking waves and natural conditions of the beach. Research into the characteristics of breaking waves and the effects of their dynamism on the occurrence of coastal damage needs to be done.*

Analysis of the characteristics of breaking waves on the coast of Atep Oki using wind data for 11 years (2001-2011) obtained fetch along 785.68 km and height of breaking wave by 1,723m at a maximum depth of 1.94m with uprush and back rush wave effect on shoreline displacement of 21.62m and plunging as the breaking wave type with surf similarity coefficient > 0.4. Indicated that the beach has the potential for damage so that prevention can be done by, among others, making beach safety buildings.

Keywords - *breaking wave characteristics, shoreline damage*

I. INTRODUCTION

The problem that occurs on critical beaches is that there can be abrasion on some of the coastline so that the area of fishing or population activities along the coast is decreasing, residential land and roads as a means of transportation are also disrupted. Damage to coastal areas is often affected by natural factors such as coastal currents, coastal sediment transport, changes in sea level rise, and ocean waves. Ocean waves are usually generated by many things, for example, by wind, tides, currents, and others. As protection against the beach can be made, a beach safety building is one of the alternative treatments. The planning of beach safety buildings required some parameters of breaking waves as well as other wave characteristics. Wave transformation, when on its way closer to the coastline, will experience a change in direction and wave height until the wave breaks. The rise and fall of water levels due to the waves and their approach towards the coast affect the boundary between water and land, where this has the potential to cause coastal damage. Waves coming from the sea to the coast cause fluctuations in the water level in the coastal area against the still water level.

The effect of breaking waves and their reach towards the coastline can cause damage to the coastline. In analyzing wave characteristics used the hindcasting method. The basis of this method is to use historical data on wind speed and direction to get wave height and period in the past to then statistically analyze and serve as the basis for design planning, specifically calculate historical wave generation. Ocean waves are not always running at constant depths. Linear waves do not change at constant depth as long as energy loss is not taken into account. In reality, the bottom of the ocean waters is not always constant. The sea varies so much in-depth that it can be said that the ocean waves must have changed in their propagation from the deep to the shallow water or otherwise. The wave transformation by wave shoaling, refraction, and diffraction where waves can experience changes in height and length as well as their direction and wave tendency to spread through limited fissures from deep water to the point break then the wave height begins to decrease because of energy dissipation. The sudden decrease in the wave height is used to define the breaking point and determines the breaking parameters like Hb,db. The breaking wave may have one of several shapes as it breaks**.** The breaker type is a function of the beach slope m and the wave steepness H/L**.** These may be combined into a ratio, usually called the surf similarity parameter.

II. RESEARCH LOCATION

The research site is located on the beach of Atep Oki Minahasaregency with geographically located in coordinates 01^{0}08'30.6" N- 125^{o}01'21.8" E and administratively included in the territory of the North Sulawesi Province, Indonesia.

This location can be shown in Fig.1.

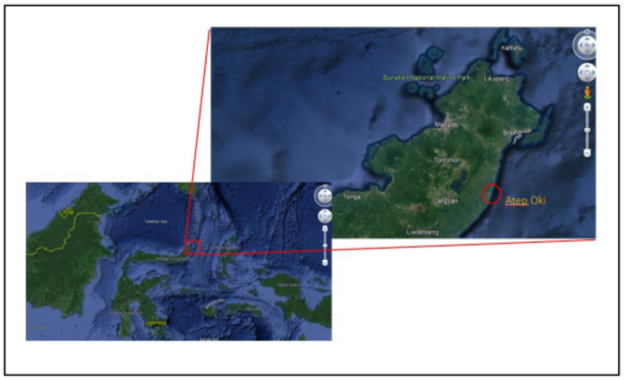

Fig. 1Research Location

III. RESEARCH METHODS

The calculation of the magnitude of the wave begins from the depiction of fetch, where fetch is the distance of the wave formation propagation from the beginning of its generation. Usually limited by the shape of the land around the sea, where the longer the fetch distance, the greater the height of the wave. Fetch is effectively used in wave forecasting to determine the height, period, and duration of waves. This fetch effective length calculation is done using the help of topographic maps of locations with a considerable scale so that it can be seen the islands or land that affect the generation of waves in a location.

The average effective fetch is as follows(Triatmodjo,2012):

$$F_{eff} = \frac{\Sigma X_i Cos\alpha}{\Sigma Cos\alpha} \quad (1)$$

Fetch (Xi) calculations from various possible directions are shown in (Fig. 2). below.

Fig. 2 Fetch of Atep OkiBeach

A. Fetch effective calculations

The main wind direction is determined as the central line using a map of the Atep Oki coastal area and in calculations made the angle from the centerline towards the right and left of the fetch line at an interval of 22.5°, then measure fetch until it touches the land or the final boundary of the map then multiplied by the scale of the map. Determination of fetch points taken on the position of the deep sea from the location of the waters reviewed because waves generated by wind form in the deep sea of water, then propagate towards the coast and break while the waters were getting shallow near the coast.

B. Wind analysis

The wind data analyzed is data on the magnitude of daily maximum wind speed and direction with an interval of 11 years data obtained from the BMKG Winangun wind data source. The wind maximum to be used in the calculation of significant wave height is first corrected to obtain the stress-wind factor value (wind-stress factor).

C. Calculation of refraction coefficient

Refraction is a deflection of the direction of the wave when entering shallow waters. The stage in determining the refractive coefficient starts from the calculation of the angle of coming waves then determines the depth to determine the change in wave height and maximum wave period. The relationship between maximum wave height and wave period can be seen in (Fig. 5).

Based on the graph in (Fig. 5), it can be calculated the period of waves in the deep sea. The refraction coefficient can be calculated by the equation:

$$K_r = \sqrt{\frac{Cos\alpha_0}{Cos\alpha}} \quad (2)$$

where:

α: the angle between the wave crest and the shoreline

α_0: the angle between the deepwater wave crest and the shoreline

D. Calculation of shoaling coefficient

The shoaling coefficient or the siltation coefficient is calculated by the formula:

$$K_s = \sqrt{\frac{n_0 L_0}{nL}} \quad (3)$$

.

where:

n_0: deep-sea coefficient (0.5)L_0: deep-sea wavelength

H_0: deep water wave height

n: the form of $\frac{1}{2}\left(1 + \frac{2kd}{Sinh\ 2kd}\right)$

Wave height $H=H_0.K_r.K_s$

E. Breaking wave calculation

Determine the value of H'_0 and H_b, with use-value of refraction coefficient Ks, obtained H'_0 then H_b value obtained from the plot between the value of H'_o / gT^2 and the slope of the beach (m) in the graph of Fig.3. Hb is breaking wave height.

Breaking waves are an effect of wave transformation in the surf zone area. The wave may continue to dissipate energy to the shoreline or, if the water depth again increases as in the case of a barred beach profile, the wave may cease breaking, reform, and break again on the shore. The transformation of wave height through the surf zone impacts wave setup, runup, nearshore currents, and sediment transport (CEM,2002).

By using graphs of the relationships between H'_0/gT^2 and Hb/H'_0 and the slope of the beach (m), we obtained a high value of breaking waves H_b.

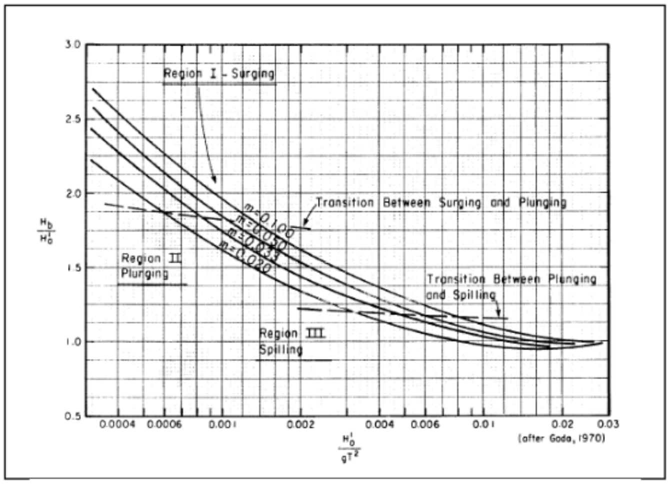

Fig. 3 Breaking Wave Calculation Graph (sourceCEM,2002)

Waves approaching the coast increase in steepness as water depth decreases. When the wave steepness reaches a limiting value, the wave breaks, dissipating energy and inducing nearshore currents and increasing in mean water level. The surf zone is the region extending from the seaward boundary of wave breaking to the limit of wave uprush. Within the surf zone, wave breaking is the dominant hydrodynamic process. As a wave approaches a beach, its length L decreases, and its height H may increase, causing the wave steepness H/L to increase. Waves break as they reach a limiting steepness, which is a function of relative depth d/L and the beach slope tan β (CEM,2002). The breaking waves type is one of the major factors for the determination of wave forces affecting beaches and coastal structures.

Breaker type refers to the form of the wave at breaking, may be correlated to the surf similarity parameter ξ_b..(Battjes 1974)

$$\xi_b = \frac{m}{\sqrt{H_b/L_0}} \quad (4)$$

Equation (4) gives some of the classifications of breaker where the wave propagates landward as follow:

-Spilling breakers occur when $\xi_b < 0.4$

- Plunging breakers when $0.4 < \xi_b < 2.0$

- Surging/Collapsing breakers when $\xi_b > 2.0$

Waves break shoaling towards the land, the movement of water towards the land as uprush while towards the sea as a back rush. Uprush and backlash are important phenomena in sediment transport on the coast. Depending on the slope of the bottom of the water and the condition of the breaking waves, the beach will experience erosion or accretion. This is a factor for the damage to the coastline.

Wave Setup

Wave setup is a phenomenon of the peak elevation of the average water level of MSL caused by wave action. Wave setup that occurs can be a clue to the potential for damage to the coastline where the shoreline displacement is indicated by displacement Δx.
Conveying both energy and momentum in the wave direction takes place when waves approach the shoreline. As long as breaking waves take place, the wave energy dissipates, as is evident from the turbulence generated. For some locations of beach safety, the oscillating component of wave setup is relevant.

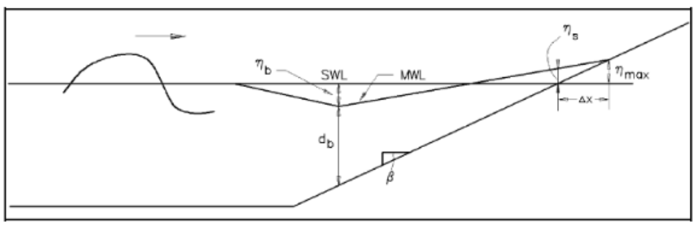

Fig. 4 Definition skets of Wave Setup (source CEM,2002)

Refer to Coastal Engineering Manual (CEM), equation (5) and (6) explain the shoreward displacement of shoreline and the cross-shore balance momentum, and equation (7) explain the breaker depth index.
Equation (10) gives setup at the still water shoreline. To calculate the maximum setup and position of the mean shoreline, the point of intersection between the setup and beach slope must be found. The first term in this equation is setdown (η_b) at the breaking point, and the second term is set up across the surf zone. For higher breaking waves, d_b will be greater, and setup will be greater as well. The transfer of wave-related momentum to the water column during wave breaking causes an increase in water level within the surf zone.

$$\Delta_x = \frac{\eta_s}{\tan\beta - \frac{d_\eta}{d_x}} \quad (5)$$

$$\frac{d_\eta}{d_x} = \frac{1}{1+\frac{8}{3\gamma_b^2}} \tan\beta \quad (6)$$

$$\gamma_b = b - aH_b/gT^2 \quad (7)$$

(breaker depth index)

a and b are empirical functions of the slope of the coast, and tanβ is the term for beach slope.

$$a = 43.8\left(1 - e^{-19\tan\beta}\right) \quad (8)$$

$$b = \frac{1.56}{\left(1+e^{-19.5\tan\beta}\right)} \quad (9)$$

setup on Stillwater shoreline:

$$\eta_s = \eta_b + \left(\frac{1}{1+\frac{8}{3\gamma_b^2}}\right) h_b \quad (10)$$

$$\eta_b = -\frac{1}{16}\gamma_b^2 d_b \quad (11)$$

The term used in equations (5) to (11) can be explained by Fig.4

IV. RESULTS AND DISCUSSIONS

Effective fetch calculations for the main direction:

Some of the fetch's depictions selected the largest fetch are the north-east's main direction. The results of fetch calculations obtained an effective fetch length of 785.68km.

Table 1. Effective Fetch Calculation

Direction	Angle α (^{0})	Fetch (mile)	Fetch (km)	Cosα	Fcosα	F_{eff}(km)
	-20	0	0	0.94	0	
	-15	20.9	33.63529	0.966	32.489	
	-10	22.8	36.693043	0.985	36.136	
	-5	25	40.2336	0.996	40.08	
Northeast	0	1755	2824.3987	1	2824.399	785.68
	5	794	1277.8191	0.996	1272.957	
	10	770	1239.1949	0.985	1220.369	
	15	743	1195.7426	0.966	1154.999	
	20	206	331.52486	0.94	311.531	

In this calculation, maximum wind speed is used. This is so that extreme wave conditions can be obtained. The maximum wind to be used in the calculation of significant wave height is first corrected to obtain the stress-wind factor value.

Calculation of wind voltage factors:

Wind data to be used for high forecasting and wave periods must be corrected against elevation, stability, location effect, and drag coefficient to obtain wind stress factor (U_A). Wind data used for coastal building planning is the maximum daily wind data that will cause maximum wave height.

With hindcasting method obtained high and period of deep-sea waves H_0=1.4721m, T_0=4.4513 second. Waves break from the calculations obtained 0.7m to 1.723m from the variation of beach slope m.

Table 2. Breaking Wave Calculation

No	H'o	H'o/gT^2	m	H_b/H'o	H_b
1	1.472	0.0076	0.0806	1.17	1.723
2	1.472	0.0076	0.0662	1.15	1.692
3	1.492	0.0077	0.0531	1.14	1.701
4	1.513	0.0077	0.0413	1.12	1.694
5	1.453	0.0072	0.0312	1.1	1.598
6	1.063	0.0053	0.0102	1.04	1.106
7	0.876	0.0043	0.1250	1.37	1.2
8	0.494	0.0029	0.0500	1.42	0.701

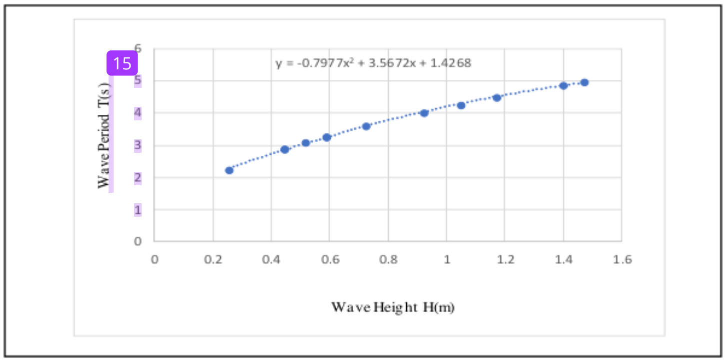

Fig. 5. Relationship between Height and Wave Period Maximum

Equations that are obtained from graphs of relationships between Wave Height (H) and Wave Period (Ts) it is used to calculate the waves period of Ts in the deep sea.

The equation is $y=-0.7977x^2+3.5672x+1.4268$

Potential damage indications to the coastline where the occurrence of shoreline displacement is indicated by displacement Δx. (Δx: is the shoreward displacement of the shoreline)

Table 3.MeanWater Surface Elevation

No	a	b	*CEM formula II-4-5 breaker depth index* $\gamma_b = b - aH_b/gT^2$	breaker depth $d_b = \frac{H_b}{\gamma_b}$	*mean water surface elev about SWL* $\eta_b = -\frac{1}{16}\gamma_b^2 d_b$
1	34.329006	1.29172	0.987419	1.744953	-0.106333
2	31.348591	1.223507	0.950796	1.779561	-0.100547
3	27.829651	1.151235	0.908383	1.872557	-0.096573
4	23.815963	1.078144	0.873100	1.940214	-0.092439
5	19.588353	1.010218	0.854787	1.869471	-0.085372
6	7.7165678	0.857316	0.814779	1.357424	-0.056322
7	39.725965	1.434642	1.198443	1.001299	-0.089883
8	26.860743	1.132739	1.022490	0.685581	-0.044798

Table 4. Setup of Stillwater Shoreline

No	*setup of stillwater shoreline* $\eta_s = \eta_b + \left(\frac{1}{1+\frac{8}{3\gamma_b^2}}\right)h_b$	$\Delta_s(=\eta_b+\eta_{max}) = 0.15d_b$ $S_w(=\eta_s) = 0.19\left[1-2.82\sqrt{\frac{H_b}{gT^2}}\right]H_b$	formula II-4-23 CEM $\frac{d_\eta}{d_x} = \frac{1}{1+\frac{8}{3\gamma_b^2}}\,tan\beta$
1	-0.084753	0.211470	0.021579
2	-0.083786	0.212212	0.016760
3	-0.084024	0.214490	0.012548
4	-0.083258	0.217832	0.009182
5	-0.078662	0.214879	0.006710
6	-0.054288	0.176560	0.002033
7	-0.046126	0.149874	0.043757
8	-0.030716	0.095973	0.014082

Table 5. Shoreward Displacement of Shoreline

No	$\Delta_x = \frac{\eta_s}{tan\beta - \frac{d_\eta}{d_x}}$	$\eta_{max} = \eta_s + \frac{d_\eta}{d_x}\Delta x$
1	3.582974	0.288788
2	4.292335	0.284153
3	5.289291	0.280861
4	6.782121	0.280102
5	8.774199	0.273755
6	21.619015	0.220514
7	1.844768	0.230596
8	2.672007	0.133600

Based on formula (4), there is a relationship between the slopes of the beach (m) with surf similarity coefficients (ξ_b) and shoreward displacement of the shoreline (Δx). When the smaller the beach slope, the higher the shoreward displacement of the shoreline, as can be seen in Fig.7.The condition of land soil plays an important role in this phenomenon. In Fig.6, where there is a relationship between beach slope and surf similarity, it can be seen that the value of surf similarity is more than 0.4, the graph area is plunging, and less than 0.4 the graph area is spilling. The research location shows that the breaking wave of plunging tipe occurs in the location. As the name implies, the wave crest runs ahead of the main body of the wave and plunges forward violently. Table 5. This shows that the shoreward displacement of shoreline reaches 21.6 m landward, which this enough longer of distance to process of damage of shoreline.

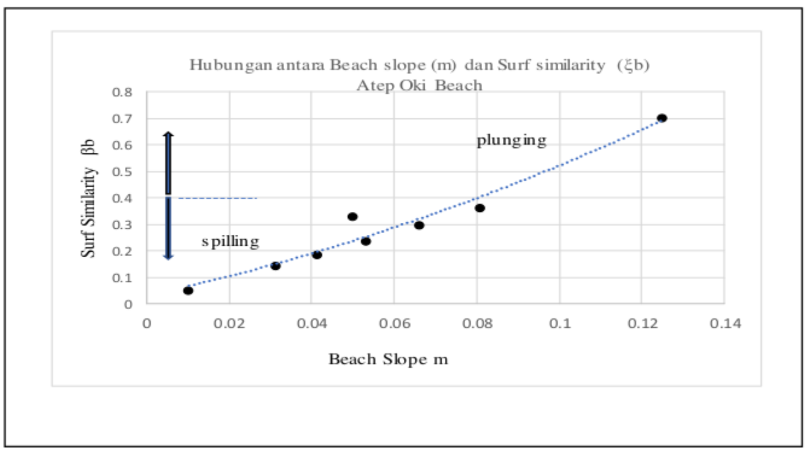

Fig. 6. Graph of Relationship between surf similarity (βb) and Beach slope (m)

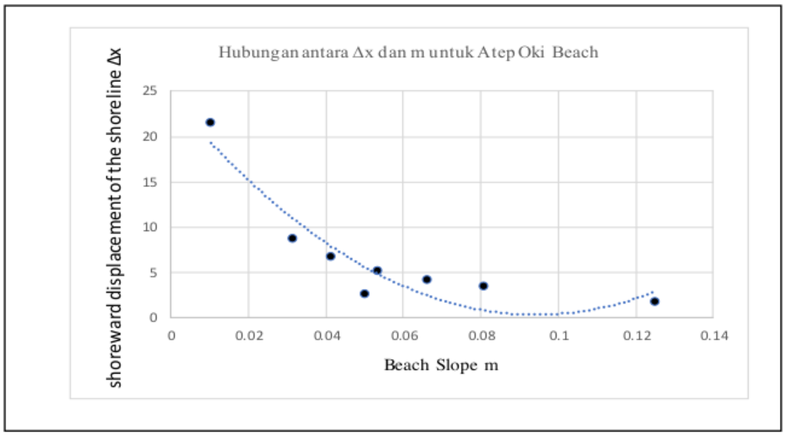

Fig. 7. Graph of relationship between shoreward displacement of shoreline (Δx) and Beach slope (m)

Classification of breaking waves in its spreading towards the coast according to Battjes (1974) in Introduction of Coastal Engineering and Management, W.Kamphuis (2000), the character of spilling and plunging breakers:

Spilling breakers occur on flat beach slopes, for steep waves or both when $\xi_b < 0.4$; therefore, when the sea, which consists of steep waves, breaks on a flat sandy beach, the breakers are predominantly spilling breakers. Portions of the wave crest appear to break gently (spill). Several wave crests may be breaking simultaneously, giving the appearance of several rows of breaking waves throughout the braking zone. Such beaches are often called dissipative beaches.

Plunging breakers occur on steeper beaches and/or for flatter waves when $0.4 < \xi_b < 2.0$. The wave crest runs ahead of the main body of the wave and plunges forward violently. They are, for example, predominant when swell breaks on the flat sandy beach.

In Fig. 6., it can be explained that the beach slope is increasing, then surf similarity is increasing too. Atep Oki beach conditions where surf similarity leads to the type of plunging breaking waves, when $\xi b > 0.4$

In Fig. 7., it can be explained that the beach slope decreases, then the shoreward displacement of shoreline is higher, indicating that Atep Oki beach has a rather steep beach condition with large uprush and back rush movements. From Fig. 6. and Fig. 7. , it can be said that Atep Oki beach has the potential for coastal damage; with the show occurring, the type of plunging waves with a displacement of the shoreline is quite long. To prevent coastal damage, the displacement area of the breaking waves can be made alternative beach safety buildings.

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V. CONCLUSION

Analysis conducted on the characteristics of breaking waves on the coast of Atep Oki using wind data during 11 years (2001-2011) fetch obtained along 785.68 km and breaking wave height by 1,723m at a maximum depth of 1.94m with uprush and back rush wave effects on shoreline displacement of 21.62m as well as Plunging breaking wave types with surf similarity parameters > 0.4. This indicates that the beach in some parts is rather a steep slope with a large uprush and back rush movement so that potential damage to the beach, for the prevention of damage to the coastline, among others, by build beach safety buildings.

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