Wave Analysisi in near Shoreline for Coastal Morphology in Mouth of Kali Porong Sidoarjo

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Abstract: The wave is one of the important parameters in the dynamics of seawaters. Waves can cause energy to form the beach, sorting sediments, causing the flow and transport of material sediments (sediment transport). This research was conducted to find out the characteristics of the waveform that occurs around the mouth of Kali Porong. This study uses data from the meteorological station of Cape Wind Silver during the period of 5 years from the year 2011 – 2015 with the fetch direction of the dominant East. The calculation of the length of the fetch effectively amounted to 161968.65 meter with the significant wave height H1/3 and (significant wave period) T1/3 is 1.26 meters and 7.35 seconds. As for looking for refraction, shoaling and the surge broke the researcher looking for using three slices that represent characteristics of an existing wave on site research. In this research obtained for Slice 1 high waves broke 1.5459 meters with a depth of wave broke of 1.8989 m, Slice 2 high waves broke 1.5458 meters with a depth of wave broke of 1.9181 m, Slice 3 high waves broke 1.5458 meters with a depth of wave burst of 1.9578 m.

1 INTRODUCTION

The Kali Porong (Porong River) canal is one of the Brantas River in Mojokerto, flows eastward and empties in the Madura Strait. Figure 1 shows Location Study of the Coast around the Mouth of the Kali Porong. The River is limiting Sidoarjo Regency Pasuruan. This River is the river an artificial Canal used aliases to redirect a portion of the flow of the Brantas River that empties in Surabaya. Kali Porong has two streams namely River Sedati (KP. 100) with DAS of 406.7 Km2 and River Kambing (KP. 148) with DAS of 196.6 Km2. The basic conditions are an irregular river without large stones and shrub. The natural geology of the Valley River Porong contains volcanic rocks such as the piedmonte grumosol, latosol, mediteran and alluvial. In November 2006, the Government set Sidoarjo mud caused by Porong Mud disaster in May 2006 is thrown through River Porong to be streamed to the sea in the Madura Strait. This has to be one of the causes of the occurrence of a change of the coastline around the mouth of the porong times (Mustain, et.al, 2010, 2017, 2018).

In addition to the extra mud from the river one of the factors that also affect very large changes in the coastline that is ocean waves. Waves can be caused by energy to form the beach, sorting sediments, causing the flow and transport of material sediments (sediment transport) base towards the shore, offshore, and along the coast as well as cause the forces acting on the building of the coast. So the wave data is indispensable in planning coastal buildings (such as a jetty, of Groin, seawall, breakwater, reclamation etc.), determining the layout of the Harbour, cruise and flow management of the marine environment, and marine and recreation area determination aquaculture in the coastal area (Sugianto, 2010). Because of the importance of the wave data for coastal structure planning and coastal changes to the feature, then this research needs to be done to find out the characteristics of the wave itself. Characteristics of waves that will be searched in this study i.e. the refraction of waves and wave shoaling which broke out. Therefore, the data from the study can be used for further research needs in order to improve the development and to estimate the possible happens in the beach area.

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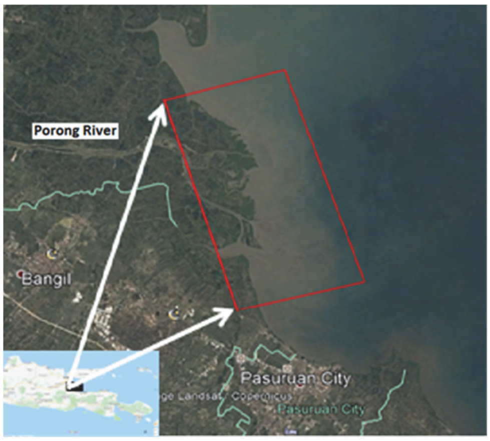

Figure 1: Location Study of the Coast around the Mouth of the River Porong (Google earth, 2018).

2 THEORITICAL BACKROUND

2.1 Wind Driven Wave

The ripples on the surface water will be generating by wind driven forces. The bigger of wind blowing will produce the bigger and the longer of the ripples as well. For the continuous of the wind, blowing the ripples will become the wave. The high and the wave period will depend on the wind velocity (U), time blowing (t), and length of Fetch (F). The length of Fetch need the long enough distance due to enough energy from the wind to drive then to transfer to the water to become the wave. Fetch formulation have been given by Triatmojo (1999):

$$F_{eff} = \frac{\sum X_i \cos \alpha_i}{\cos \alpha_i} \tag{1}$$

where:

Feff = Fetch effective

Xi = Length of fetch

αi = Deviation on either side of the wind direction

Using the angles added up to, 6o to 42o on both side of wind direction, then the wave parameters could be calculated by deep-sea wave forecasting formulas:

$$H_0 = 5.112\ x\ 10^{-4}\ x\ Ua\ x\ F_{eff}^{0.5} \tag{2}$$

$$T_0 = 6.238\ x\ 10^{-2}\ x\ [(F\_eff\char`^2)/UA]^{\frac{1}{3}} \tag{3}$$

Where UA is the wind stress factor. These wave parameters could be used to determine the Hrms, Trms, H01/3, and T01/3 using the formulation below;

$$H_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} H_i^2} \tag{4}$$

$$H_{01/3} = 1.416\ x\ H_{rms} \tag{5}$$

$$T_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} T_i^2} \tag{6}$$

$$T_{01/3} = 1.42\ x\ T_{rms} \tag{7}$$

2.2 Refraction and Shoaling Waves

To calculate the refraction wave we could use the formulation from the illustration of orthogonal wave. Figure 2 illustrates the orthogonal wave. These formulations are based on the fluxed conservation. There are;

$$\begin{aligned} P0\ &=\ P\ =\ Constant \\ n0\ B0\ E0\ C0\ &=\ n\ B\ E\ C \end{aligned} \tag{8}$$

Where:

$$E\ =\ wave\ energy\ (E = \frac{\rho\ g\ H^2}{8}) \tag{9}$$

$$n = \frac{C_g}{C} = 0.5\left(1 + \frac{2kd}{\sinh 2kd}\right); n_0 = 0.5 \tag{10}$$

Then we could write;

$$0.5 B_0 \frac{\rho g H_0^2}{8} C_0 = nB \frac{\rho g H^2}{8} C \tag{11}$$

$$\frac{H}{H_0} = \sqrt{\frac{L_0}{2nL}}\sqrt{\frac{B_0}{B}} = K_s K_r \tag{12}$$

Where;

H0 = height wave in deep sea

H = height wave in site area

L0 = length wave in deep sea

L = length wave in site area

B0 = wide of orthogonal wave in deep sea

B = wide of orthogonal wave in site area

Ks = Shoaling coefficient

Kr = Refraction coefficient

2.3 Breaking Wave

The change of bathymetry near shoreline from the offshore direction, normally create the slope so steeply to the shoreline. This will change the wave properties due to this slope, the wavelength become shorter then, before and wave high so become higher. The ratio between high wave to the length wave is called by wave steepness. The reduction of wave steepness is automatically will reduce the wave stability. When the wave stability become lest then the minimum, then the wave will automatically break. This case normally is called the breaking wave. The wave stability has the formulation (CERC, 1984) of:

$$H_{\max} = 0.095 e^{4m} L_b \tanh\left(\frac{2\pi d_b}{L_b}\right) \quad (13)$$

$$H_{\max} = d_b 0.65 e^{3.5m} \quad (14)$$

Where;

Hmax = the maximum wave height before breaking (m)

Lb = the wave length when breaking wave in site location (m)

Db = the depth of the position of breaking wave in site location (m)

3 DATA COLLECTION

3.1 Bathymetry

Bathymetries map data required to perform the analysis of refraction, shoaling and changing coastline. For the analysis of refraction, existing bathymetries map was divided into several slices, then to calculate coefficients of refraction and the characteristics of the breaking wave. As for the analysis of the changes of coastline, the existing map first divided into a smaller number of slices. Then done the measurements to get the initial Y-value (the distance from the zero point to the shorelines early). Next, the initial Y-results used in the calculation to get the Y-end in every step of the time to illustrate the changes in the coastline at the site of the study.

3.2 Wind

Wind data used in this research is the wind data from the meteorological station of Tanjung Perak during a period of 5 years from the year 2011 – 2015. Wind direction will be stated in the form of eight parts of the wind direction with the speed in knots. Before the wind data logging results using WRPLOT, first data is stored in the form of excel with the first column containing format date data. The second column contains the Moon, the third column contains the year, fourth column contains, and then the fifth and sixth column contains the direction and speed of the wind. After that, wind data will be processed using the program WRPLOT to get the dominant wind direction and the number of occurrences of the wind according to the direction and phase.

3.3 Wave

Wave data is necessary to know the quantity and behaviour of waves heading toward the beach. Wave data is used based on the conversion of wind data on surface and land near the location of the research.
In the propagation of a wave to the beach, the waves undergo a process of change in characteristics such as height wave and long wave from Pratikto (1996). Winds that blow across the surface cause disruption on the surface of the water, the ripples with the appearance of small waves on the surface of the water. When the wind speed increases, the ripple will be even greater when the wind blows continuously then it will be making waves.

Characteristics of waves include form, height and period of a wave that is formed depends on the influence of wind speed (U), wind gusts (t), the length of the fetch (F), as well as the direction of the wind. Fetch can be defined as the length of the wave generation area in the direction of the oncoming wind, generally limited by the land surrounding the area of wave generation. The length of the fetch influence on characteristics of wave, when fetch is getting longer it will be formed waves with periods of great.

In the form of irregular power, generation areas, then the calculations can be done effectively fetch and then the results will be used to predict the characteristics of waves in the deep ocean.

4 RESULT

4.1 Wind

Wind data analysis is conducted to find out the dominant wind direction and the number of occurrences of the wind according to directions. After wind data obtained, then wind data processed to be classified. The classified data shows the genesis Wind around the coast of the estuary of Kali Porong for year period of 2011-2015 in the shape of event frequency and percentage respectively.

It also can be seen that the dominant wind direction blows from the southeast with the number of events 13927, with a percentage of 31.785% of all events in a period of 5 years. The data above can be presented in the form of a rose wind. Figure 2 shows the Rose of the Wind (Tanjung Perak of Maritime Meteorology Station (2011 - 2015).

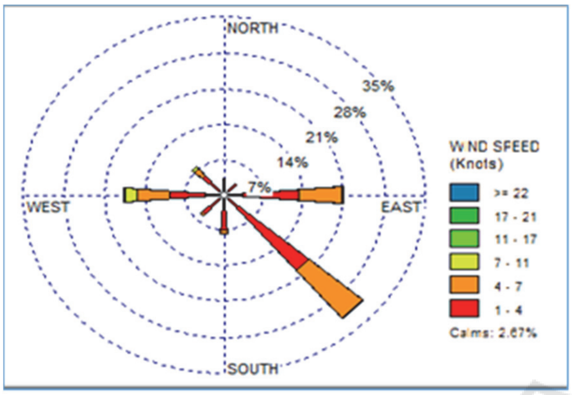

Figure 2: Rose of the Wind (Tanjung Perak of Maritime Meteorology Station 2011-2015).

4.2 Fetch

After the analysis of wind, data and the direction of the dominant wind are obtained, and then the fetch length is calculated (length of wave generation area). Fetch will be longer, a wave with a large period will be formed. In this research, the biggest fetch become the dominant wind direction. Therefore, this calculation uses the fetch of the dominant east direction. When the waveform generation area is irregular, then for effective fetch calculation can be done equation (1) below (Triatmojo, 1999):

$$F_{eff} = \frac{\Sigma X_i \cos \alpha}{\Sigma \cos \alpha} = 161968.65m \qquad (15)$$

With:

Feff = fetch effective

Xi = fetch-th line length

αi = deviation on both sides of the wind direction, dominant by using an increment of 6 ° to an angle of 42 ° on both sides of the dominant wind direction.

Figure 3 shows the map for Effective Fetch Length Calculation. Fetch effective calculation results have be presented in table 1.

Table 1: Fetch Effective calculations.

a	cos a	X_i (km)	X_i cos a
42	0,74	117,05	86,98
36	0,81	140,47	113,64
30	0,87	126,10	109,21
24	0,91	173,90	158,86
18	0,95	250,00	237,76
12	0,98	250,00	244,54
6	0,99	250,00	248,63
0	1,00	250,00	250,00
6	0,99	250,00	248,63
12	0,98	127,32	124,54
18	0,95	111,67	106,20
24	0,91	97,54	89,10
30	0,87	73,32	63,50
36	0,81	70,84	57,31
42	0,74	66,51	49,43
∑	**13,51**		**2188,35**
F_{eff} =	**161,97 km**	**161968,65**	**m**

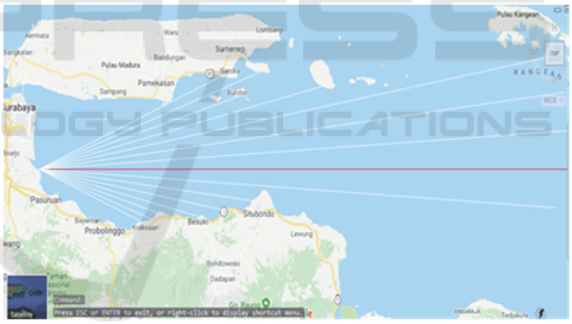

Figure 3: Map for Effective Fetch Length Calculation.

The value of α0 is the dominant wind direction, where the study uses the second dominant wind direction (East) because the fetch is greater than the direction of the first dominant wind direction. Xi is the distance from the study location to the nearest land. Likewise for other angles. After obtaining the distance for each angle, the effective fetch from the calculation using equation (1) is 161.96865 km. The next step is to change the data from the land recording (UL) to the sea wind speed data (Uw) to find the value of RL that can be obtained by plotting UL values into the characteristic graph. Then to calculate the H0, T0, Hrms, Trms, H1/3, T1/3, could be used the formulation of 2 till 7. Table 2 and 3 show the result of the calculation.

Table 2: The calculation of H0 and T0.

U_L	U_L	R_L	U_W	U_A	315 ⁰		
Knots	**m/s**		**m/s**	**m/s**	**F eff (m)**	**H_0 (m)**	**T_0 (s)**
4	2,06	1,68	3,46	3,27	161968,65	0,67	4,83
7	3,61	1,47	5,30	5,52	161968,65	1,14	5,74
11	5,67	1,31	7,42	8,35	161968,65	1,72	6,58
17	8,76	1,13	9,89	11,90	161968,65	2,45	7,40
21	10,82	1,05	11,36	14,10	161968,65	2,90	7,82
22	11,33	1,04	11,78	14,75	161968,65	3,04	7,94
					∑	8,88	32,37

Table 3: The calculation of Hrms (Significant wave height) and T1/3 (Significant wave period).

90 ⁰		**$H_{0\ 1/3}$(m) = 1.42 x Hrms**		
N	**n x H_0^2 (m)**	Hrms	**$H_{0\ 1/3}$(m)**	**n x T_0^2 (s)**
28889	13068,81			673878,62
12342	15925,85			406869,50
1361	4021,12			58972,88
52	311,64	0,8840	1,2553	2845,52
0	0,00			0,00
0	0,00			0,00
42644	33327,41			1142566,52
Hrms	0,88404		**Trms**	5,1762
			$T_{0\ 1/3}$ (s)	7,3502

From the calculation results in Table 2, the values of H1/3 and T1/3 are 1.26 meters and 7.35 seconds, next for analysis of; Refraction, Shoaling, and Breaking Waves. To perform analysis of refraction, shoaling, and breaking waves used calculations in Excel programs.

4.3 Breaking Wave

For analysis of; shoaling, refraction, and breaking waves the input and assumptions used are one (1.0). The wave data used is significant wave data obtained from wind wave forecasting (Table 2). Coastal slope is obtained from the height difference between contours being reviewed divided by the distance between the depth contours obtained from the bathymetry map, which is then processed in the AutoCAD system. The wave direction of calculated result is from the Southeast. The seabed contour is considered parallel to the coastline.

The study area have been divided become three slices in order to calculate the slope. These calculated slopes for each slice are; 0.0064, 0.0046, and 0.0018. The largest distance of breaking wave from these three slices is around it that about 1200 meter from the shoreline perpendicular to the offshore direction.

5 DISCUSSION

Regarding to the East of dominant wind direction, the distance as fetch effective for this direction is limited to 250 km as a maximum fetch due to no boundary such as island. The result of H1/3 and T1/3 are 1.26 meters and 7.35 seconds is a typical for the Madura Strait. Annually, this dominant wind will create the wave that furthermore to produce the near shoreline current that have parallel direction to the shoreline. This current normally called long shore current. In this case, of shoreline profile, the long shore current will flow from South to North direction.

Related to the breaking wave, the slope of bathymetry causes the range of distance where the breaking wave wills accordance. This research area have been divided become three slices. These slopes for each slice are; 0.0064, 0.0046, and 0.0018. The distance furthest of breaking wave from these three slices is around 1200 meter from the shoreline perpendicular to the offshore direction. On the other hand, the nearest distance of breaking wave from these three slices is gradually difference the bigger of slope the nearest distance. The largest slope, i.e. 0.0064 makes nearest distance of breaking wave of 200 meter from the shoreline perpendicular to the offshore direction. While the smallest slope, i.e. 0.0018 makes shortest distance of breaking wave of 680 meter from the shoreline perpendicular to the offshore direction as well. This information may useful for related stakeholders, for instance; to designer of coastal eco-truism planning, to local fisheries for finding the certain fish (Mustain, et.al, 2015; Mustain, 2016; Fauzi, et.al, 2017; Mustain, et.al, 2018).

6 CONCLUSION

The results of the analysis and calculations have been carried out; some conclusions can be drawn as follows:

1. The dominant wind direction in the study used in the effective fetch calculation is the east dominant

direction with the effective fetch value in this research location at 161.96865 km.

2. Significant wave height H1/3 and (significant wave period) T1/3 at the location of this study is 1.26 meters and 7.35 seconds.

3. The height of the breaking wave for slice 1 is 1.5459 meters with a breaking wave depth of 1.8989 m; the height of the wave breaking for slice 2 amounting to 1.5458 meters with a breaking wave depth of 1.9181 m, the breaking wave height for slice 3 is 1.5458 meters with a breaking wave depth of 1.9578 m.

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