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Longshore Current Characteristics in Madura Strait

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Abstract

Bathymetri became the important factors affected the stability of the ocean waves. Wave instability due to the depth changes will form breaking waves. After breaking waves came, longshore current were occurred in coastal. It is very important when studied sediment transports and its effected on the beach stability. This research aims to know the characteristics of the longshore current which is formed due to the breaking waves in Madura Strait. Wind Data during August 2008-2013 is obtained from BMKG Surabaya and became the main material in this study. Wind Data are analyzed and converted into wave parameters and calculated breaking wave and longshore currents as well as the sediment transport. Results showed the relative small longshore currents (0.865-0.918 m/s) with direction from West to East amount 15^0 (according to the angle of breaking waves) allegedly caused relative wave height and period, and the second parameter is assumed similar for all points is caused the conversion of wind data. Direction of longshore current is formed from West to East amount 15^0 (according to the angle of breaking waves). Longshore sediment transport is 0.30-0.36 m^3/s, linear with the magnitude of the wave energy flux, so the height and angle of breaking waves into a decisive factor in sediment transport

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Keywords: breaking waves, longshore current, wind

1. INTRODUCTION

Coastal environment in Madura straits has degradated and caused the building damage due to coastal protective abrasion, sea sand mining, retrieval of coral, and mangrove destruction [5, 6]. Erosion is one problem as the result of damage to the protective beach. The erosion occurs depends on the sediment transport, especially along the coast,

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was caused by the waves. Waves are generated by wind, so it was used to understand the wave characteristics. Longshore currents became important indicators in coastal sediment transport studies. The breaking waves has formed as a result instability waves due to depth. The breaking waves depends on angle, form, and depth [1, 4, 7].
Waves Characteristic in Madura Straits are relatively small [4]. This is due to the speed blowing small relative to the duration of which is not long. The dominant wind are flew from East and Southeast. The Madura island becomes wind barrier that coming from the East, so fetch is formed short. The SE is determined as the baseline data for forecasting waves. Longshore currents becomes an important factor in studying coastal sediment transport. Some equations were developed and considered the influence of it. Measurement are used some equipment as a method. The weakness of any equipment are covered by other equipment, so it will better if uses some equipment or methods in measuring the coastal sediment transport, in particular involving currents along the coast. These studies combine several instruments to measure longshore sediment transport [8].
Wind data is converted to wave using the SMB method [1, 7] and the result is wave parameters. Furthermore, longshore current and sediment transport is calculated [6]. The movement of longshore sediment has influenced beach stability [4, 6], as shoreline changes, particularly in the Madura Straits [4]. This research was conducted to know the longshore current characteristics in Madura Straits.

2. METHOD

The research were occured in Madura Straits during August-September 2013. It is seven station (Fig. 1) and considering the coastal morphology. The main material is used wind data in August 2008-2013 and obtained from BMKG Tanjung Perak, Surabaya. Wind data is processed using a WR-plot, then calculated using wave forecasting method (called SMB) [1, 6, 8]. SMB results wave parameters and use to calculate longshore current and coastal sediment transport. Analysis of waves transformation have done by determining the wave equivalent to determine depth of reference (reference). Wave height calculated using the equation:

$$H_1 = H_0 K_s K_r \quad (1)$$

where Ks and Kr is a shoaling and refraction coefficient is calculated by the equation:

$$K_s = \sqrt{\frac{C_{go}}{C_{gi}}} \quad (2)$$

$$K_r = \sqrt{\frac{\cos\theta_0}{\cos\theta_1}} \quad (3)$$

Analysis of breaking waves based on [1, 8] that the waves begun break up when the wave height reached 0.78 to the depth and the waters or:

$$Hb = \gamma\ b\ db \quad (4)$$

The influence of wave transformation (shoaling and refraction) are calculated based on wave equation [1, 8]:

The group velocity of breaking wave $C_b = C_{gb} = \sqrt{gd_b}$ (5)

Breaking waves $\sin\alpha_b = \sqrt{g\frac{H_b}{\gamma_b}\frac{\sin\alpha_1}{C_1}}$ (6)

The equation used to calculate the longshore currents [1, 6, 7] are:

$$V = 1.17\ (g.Hb)^{1/2} \sin a_b . \cos a_b \quad (7)$$

With: V is the longshore current velocity, g is gravitational acceleration (m^2/s), Hb high breaking waves (m), and a_b breaking waves angle (degrees).
The movement of longshore sediment transport is calculated using the formula [6, 7]:

$$Qs = K.P_1^n \quad (8)$$

$$P_1 = \frac{\rho g}{8} Hb^2\ C_b\ \mathrm{Sin} a_b\ \mathrm{Cos} a_b \quad (9)$$

Where:

Qs : longshore sediment transport (m^3/day)
Pi : wave energy flux at breaking waves (Nm/s/m)
ρ : mass of sea water (kg/m^3)
Hb : high breaking waves (m)
Cb : celerity of breaking wave (m/s) = √ gdb
a_b : the angle of breaking waves
K, n : Constants
G : gravitational acceleration ($m/second^2$)

To calculate longshore sediment transport using CERC [1, 7] as follows:

$Qs = 0.401\ P_1$ ………………………………………………………………………………………. (10)

Fig 1. The station and the location

3. RESULTS AND DISCUSSION

Wind direction during August 2008-2013 shows South-East and East. Either the predominant wind direction considerate for calculating fetch effectively base on determine the maximum distance for the ocean waves formation according to the maximum speed of dominant wind. Fetch value (64 km) is used to analyze the characteristics of wind-wave is the South-East considerating wind direction from the East, fetch effectively is shorter through the Mainland.

Wind data conversion is using the SMB method [1, 7] (**Table 1**) is used by Southeast wind direction (135^0), beach slope (0.033-0.050), and based on H_0 and T according to the wind data for five years (August 2008-2013). The result has showed similar for all station. The magnitude of wind speed measurement were affected the wind factor value (UA). These conditions affected the wave parameters. Wave height and period generated is affected by the wind, include: wind speed (U), durations, wind direction, and fetch [1, 7].

The waves was formed by the wind is strongly influenced by the conditions and forms of coastal waters. The existence of ocean barrier will affect the length of the fetch that is formed, thus affecting the formation of wave [6].

Wave height and period will affect the energy of waves. Wave height and period is affected by the wind that includes wind speed, durations, wind direction, and fetch. High breaking waves is 0.867-0.952 m and the angle is 15^0 (Table 2). Breaking waves occurs at 0.9 m depth. Depth is 700-1500 m from the coastline. The substrate is sand and muddy [5] and affects to sediment transport.

Longshore currents is formed relatively similar for all stations (0.918-0.865 m/seconds), indicating the longshore current speed is formed a small relatively. This is due to high waves and period has been small relatively, and the second parameter is assumed similar for all points caused the conversion of wind data. Direction of longshore current is formed from West to East amount 15^0 (according to the angle of breaking waves).

Longshore currents is tended to increase with increasing coastal corner of wave, but this speed will be reduced at a time when the wave has exceeded 60-70 degrees. Achieve of longshore current maximum shortly after the wave breaks and diminishes at a time when the current is moving towards the coast, until it reaches zero speed at a time when the current reaches the coastline. Increased speed of longshore current is influenced by the effects of breaking waves shortly. The loss of the wave energy is proportional to the longshore currents [6]. The wave energy flux (Pi) shows the range 0.7361-0.9093 Nm/d/m (**Table 2**). The magnitude of it is affected by the height and angle of the breaking wave that are formed. In this study, the high value of breaking waves affect the magnitude of the energy flux wave caused the value of the angle breaking waves that are formed for all research locations.

.**Table 1**. Characteristics of waves

Station	Waves Parameters					Waves Characteristic									
	d	H_0	T	α_o	m	L_0	C_0	L	C	n	α	Kr	Ks	H	H'_0
1	1.5	0.8	4.5	135	0.033	31.59	7.02	16.44	3.65	0.90	21.59	0.87	1.03	0.72	0.70
2	1.3	0.8	4.5	135	0.033	31.59	7.02	15.19	3.38	0.92	19.88	0.87	1.07	0.74	0.69
3	1.4	0.8	4.5	135	0.033	31.59	7.02	15.64	3.48	0.91	20.49	0.87	1.05	0.73	0.70
4	2	0.8	4.5	135	0.050	31.59	7.02	18.60	4.13	0.87	24.60	0.88	0.98	0.69	0.71
5	1.8	0.8	4.5	135	0.050	31.59	7.02	17.55	3.90	0.89	23.13	0.88	1.01	0.71	0.70
6	2.3	0.8	4.5	135	0.050	31.59	7.02	19.55	4.35	0.86	25.96	0.89	0.97	0.69	0.71
7	2.5	0.8	4.5	135	0.033	31.59	7.02	20.43	4.54	0.85	27.21	0.89	0.96	0.68	0.71

Table 2. Characteristics of breaking waves, longshore currents, and sediment transport

Station	Hb	db	αβ	V	Pi	QS
	(m)	(m)		(m/s)	(Nm/d/m)	(m^3/s)
1	0.872	0.959	15	0.869	0.7486	0.30
2	0.867	0.954	15	0.865	0.7361	0.30
3	0.869	0.956	15	0.866	0.7405	0.30
4	0.952	0.952	15	0.913	0.8944	0.36
5	0.947	0.947	15	0.908	0.8795	0.35
6	0.958	0.958	15	0.918	0.9093	0.36
7	0.892	0.981	15	0.888	0.7996	0.32

Longshore sediment transport is range of 0.30-0.36 m^3/s (Table 2). The magnitude of sediment transport will be linear with the size of wave energy flux, so the height and angle of breaking waves into a decisive factor in sediment transport. Some locations in the study suffered abrasion and sedimentation [5] which showed that the beach is always on condition of balance.

An understanding of longshore currents is very important to study the dynamics of the beach, particularly about concept of sediment cell. This concept is important to know the movement of sediments, and important influential factor is the current parallel beach that formed as a result of the breaking waves [2].

4. CONCLUSION

High breaking waves is 0.867-0.952 m and the angle is 15^0. It occurs at 0.9 m depth. The substrate is a sand and muddy. Longshore currents is formed relatively similar for all stations (0.865-0.918 m/s), indicating the longshore current speed is formed a small relatively. This is due to high waves and period has been small relatively, and the second parameter is assumed similar for all points is caused the conversion of wind data. Direction of longshore current is formed from West to East amount 15^0 (according to the angle of breaking waves). Longshore sediment transport are 0.30-0.36 m^3/s, linear with the magnitude of the wave energy flux, so the height and angle of breaking waves into a decisive factor in sediment transport.

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