Sustainable Coastal Protection in Pasuruan City: Jetty Structure in Rejoso Estuary

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Abstract. Rejoso Estuary has an unstable river mouth and threatens the existence of residents in the surrounding area. The rainy season, marked with high water discharge and river water overflows, affects flood in residential areas located around the coast. It happens due to sediment deposits formed closes the flow of the river to the sea. This study aims to find out an alternative, by processing data such as location maps, wind speed data, tidal data, current velocity, and sediment transport. From the calculation results, the researcher obtained the amount of longshore sediment transport amounting to 205837.7 m$^3$/year with the rate of perpendicular sediment transport of the coast which was 677915.27 m$^3$/year. The jetty is planned as the main alternative in this study to concentrate the flow of river water on a predetermined path to the sea, and to anticipate sedimentation due to sediment transport along the coast. The jetty was planned to be installed on the left and right of the estuary with a depth of 1.2 meters and length 25 meters. In this study, the jetty was considered quite effective to protect the estuary from the backwater effect and sedimentation which could cause flooding in the city area.

Keywords: estuary, jetty, sediment

1. Introduction
East Java is one of the provinces that having several coastal areas, both in the north and the south. This coastal area is rich in natural resources with economic value, used for ports, tourism, etc. It is possible for the beach to experience various damage caused by natural factors, as well as factors from coastal area users. One of the estuaries in East Java is Rejoso which is located at ±3000 meters from the center of Pasuruan and has a river mouth known as the Rejoso River, located on the border of the villages of Rejoso and Lekok.

In the rainy season, high water overflow occurs due to the obstruction of the flow of river water to the sea, caused by sediment transport along the coast settling right at the mouth of the river, in which the river water overflows, threatening existing facilities and infrastructure in the Pasuruan area. The longshore sedimentary material is driven by waves, entering and settling in the estuary, later causing then settles and causes the sand tongue to occur. Thus, it is necessary to plan the appropriate protections to withstand sediment transport along the coast to prevent deposited sediment in the estuary.
Based on the background as outlined above, this study questions about (1) Reviewing area in the Rejoso River Pasuruan estuary, (2) Calculating sediment transport (3) Installing jetty planning analysis.

This study aims to plan coastal buildings to reduce sediment deposition caused by longshore sediment transport to protect the settlements around the estuary from sea water waves. With the existence of the safety building, it is able to anticipate the sedimentation that occurs due to the influence of sea waves. While the benefits of this study are (1) Providing an understanding of coastal protection buildings, especially building jetty, (2) Understanding the character of waves, tides and sedimentation in the estuary of the Rejoso River. (3) Revealing the effects of making a coastal protection in the form of a river in the Rejoso estuary area, (4) Providing a reference in learning about coastal protection buildings.

1.1 Literature Review

1.1.1. Beach Overview
There are two terms about coastline in Indonesian which are often confused with their use, such as the coast and shore. Coastal is a land area on the edge of the sea exposing the influence of the sea such as tides, sea breeze and seepage of sea water. While the shore is an area on the edge of the water which is affected by the highest tide and lowest tide, the coastline is the boundary line between the land and sea water, where the position is not fixed and can move according to the tides and coastal erosion that occurs.

A. Wave. Waves in the sea can be generated by wind (wind waves), attraction of the sun and moon (tides), volcanic eruptions or earthquakes in the sea (tsunami), and so forth. Waves can generate energy to form the coast, giving rise to the flow and transport of sediments in a perpendicular direction and along the coast, causing forces acting on coastal structures. Tides are also an important factor because it can cause strong currents, especially in narrow areas, for example in bays, estuaries and river estuaries. In addition, tide and low tide elevation is also important for planning coastal buildings.

B. Small Amplitude Wave Theory. In general, waveforms in nature are very complex and difficult to describe mathematically because non-linear, three-dimensional and has a random shape (a wave series has a different height and period). Some theories only describe simple waveforms with natural wave approaches. The simplest theory discusses the theory of small amplitude waves introduced by Airy in 1985, often called as Airy waves.

C. Hindcasting Waves. Hindcasting waves are an upcoming wave forecasting technique that uses wind data in the past. Wind data can be used for estimate the height and period of waves in the sea due to the occurrence of ocean waves most affected by the wind. In the wind blast area, an event of wind will transfer energy to water. The initially calm water surface will be disrupted and small wave ripples arise above the water surface, as a result of tension caused by the speed of the wind on the sea surface. With increasing wind speed, ripples will become large and eventually will form waves. The longer the wind blows, the bigger the waves are formed. Hindcasting waves will produce an estimate of the height (H) and period (T) of the wave due to the presence of wind with a certain magnitude, direction, and duration.

D. Calculation of Fetch. Fetch is a sea wave generator area which is limited by the land surrounding the sea. In the analysis of wave forecasting, the initial work is performed to know the duration of the fetch from each direction of the wind that might generate waves.
E. Surface Wind Estimation. Wind data used for wave forecasting is data at sea level at the generation site. The first step in analyzing wind data, is conducted get the value of Wind Stress Factor (UA), to be used in conducting wave forecasting.

F. Formation of Deep Sea Waves. In limited fetch conditions, the wind blows constantly long enough for the wave height to reach equilibrium at the end of the fetch. The duration and the wave conditions are limited by the length of the wind blowing.

G. Wave Deformation. In wave propagation from deep waters to shallow waters, the wave will experience a change in height, direction, speed and wavelength caused by silting and refraction process wave. Refraction and the effect of sitation, diffraction, wave reflection, and breaking waves will determine the wave height and pattern (shape) of the wave crest line somewhere in the coastal area.

H. Sedimentation and Erosion. River estuaries can be divided into three groups depending on the dominant factors that influence it. In an estuary, these three factors work simultaneously, but usually one of them has a more dominant influence than the other. Sedimentation is an unexpected deposition process that occurs outside the coastline (river mouth).

I. Dominated by Sea Waves. This type of estuary is characterized by large sediment transports along the coast each year. In this type the estuary is usually covered by a sand tongue with sedimentation patterns. Large waves on sandy beaches can cause sediment transport (sand), either in a perpendicular direction or parallel / along the coast. Of the two types of the transport, the longshore sediment transport is the most dominant formation. Sediment transport can move into the mouth of the river as the wave conditions are calm, settling the sediment. The larger the wave, the greater the sediment transport occurs.

J. Dominated by the River. This estuary type characterized by river discharge each year is large enough resulting in debit as the main parameter of the estuary formation in the sea with relatively small waves. The river carries sediment transport from the uppermost large enough.

K. Tidal Dominant. This type of estuary is characterized by considerable tidal fluctuations. If the tidal height is large enough, the volume of tide entering the river is very large. The water will accumulate with water from upstream of the river. At low tide, the huge volume of water flows out over a period of time depending on the type of tide. Thus, the current velocity during low tide is large enough, which is potential to form a river mouth.

L. Coastal Sediment Transportation. Coastal sediment transport is sedimentary motion in the coastal area caused by waves and currents. Coastal sediment transport results in changes in shoreline both in the form of accretion and erosion. Coastal sediment transport can be in the form of longshore sediment transport and perpendicular sediment transport of the coast. Longshore sediment transport has a longshore average direction; whereas, perpendicular coastal sediment transport has an average direction perpendicular to the coast.

M. Longshore Sediment Transportation. Long shore transport is caused by turbulent sediments when the wave breaks, then moves are carried away and the components of the waves are parallel to the coast. At a point on the beach, the sediments come and go away (transported). If the transported sediments are greater than the sediments that come, beach erosion will occur. Beach upright sediment is divided into two parts of : the transport of sediments to the offshore direction such as those that occur during a storm, and heading towards the coast (onshore) as occurs during waves. Sediment
transport towards the deep sea occurs quickly and sediment will form a bar that will function to reduce wave.

1.2. Coastal Protection Technical Review.
The main purpose of coastal protection and protection is to secure and protect: a.) People who live along the coast from the threat of waves or floods; b.) Public facilities along the coast; c.) Coastal areas against the threat of coastal erosion; d.) Pollution of the coastal environment that can damage coastal biota.

A. Protection with Soft Structures. Nature generally provides an effective natural coastal protection mechanism. The examples of protection with soft structures include sand nourishment, beach recycling (beach passing), and beach drainage (beach drains).

B. Protection with Hard Structures. Protection of the beach with a harder structure consists of protection along the coast, which is perpendicular to the beach. Protecting the coastline for example breakwaters, seawalls and revetments becomes a coastal protection commonly seen in Indonesia. This building consists of structures that are directly attached along the coastline, or near and parallel to the coast for coastal protection from wave attacks. Whereas protection is perpendicular to the beach, such as in groin and jetty.

C. Jetty building. Jetty is a beach perpendicular building that is placed on one or both sides of a river mouth which functions to prevent river overflows by coastal sediment deposits. During the deposition process it is usually accompanied by turning the river mouth in the same direction as the direction of sediment transport along the coast. Prevention estuarine closure is divided into countermeasures for ship traffic (long jetty) and countermeasures for mouth closure which causes flooding (short jetty).

1.3. Building Type

A. Fix / Rigid Structure. The types of immovable construction that have a massive, structure and the advantages of ease and speed in installation, cheaper construction prices and lower maintenance costs. Meanwhile, the shortcomings lie in a more complicated planning procedure, if a sudden and total disaster occurs, it is difficult to repair [1].

B. Flexible Structure. The types of movable construction which have advantages and conveniences in planning. The structure is relatively simple, a high stability factor, because it can absorb most of the wave energy that hits the surface of the building, and the building is still functioning despite heavy damage, and is easy to repair. Meanwhile, the shortcomings lie in the availability of material (rock material) in a large amount of volume for the required diameter and quality (usually requires large quantities of large rocks) [1].

C. Detailed Construction. The construction part of the guide building and the wave barrier at the outlet of the river estuary can be broadly divided into two main parts, including the main construction part and the protective construction part.

D. Calculation of Weight of Protective Stone Grains. The head part of the building requires a heavy protective stone larger than the building's arm. This is because the building head can receive wave attacks from various directions. The KD value for the building head part is smaller than the KD value in the building's arm. The weight of protective stone is calculated by the formula of Hudson and Jackson 1962 [3].

On a sandy beach, the making of jetty which scours far enough into the sea can cause obstruction of sediment transport along the coast. As a result, sediments that move from the left will be blocked by jetty, leading to precipitation in the area. The area to the right, the waves that come in an angle to the
coastline cause a current along the coast. The current can carry sediment. However, there is no sediment supply in this area, because the sediment moving from the left is blocked by the building. As a result, the beach on the right side of the jetty will experience erosion.

2. Methods

2.1 Data Collection Survey
Secondary Data includes:
• The last 11 years wind speed data (2001-2011) from the Meteorology, Climatology and Geophysics Agency (BMKG).
• Aerial photos from Google Earth 2010 software.
• World map of Microsoft Encarta 2009 software.

Primary data: The survey was conducted by visual observation and interviews with the people who live around the estuary of the Rejoso river.

2.2 Secondary Data Analysis

2.2.1 Wind Data. For wave forecasting, wind data is required. The data are from a minimum of daily data in 10 years, and the wind data are obtained in the last 11 years. The wind data is taken from BMKG. Wind data consist of speed, direction and duration. Wind speed is expressed in units of knots, where 1 knot = 1 nautical mile / hour, 1 nautical mile = 6080 feet (feet) = 1853.18 m and 1 knot = 0.515 meters / second. Wind direction is expressed in 8 directions of the wind (North, Northeast, East, Southeast, South, Southwest, West, and Northwest).

2.2.2 World map. In wave forecasting, it is necessary to understand the effective fetch length of each main direction. To do fetch measurements, Microsoft Encarta software is utilized to have world map facilities and distance gauges. To facilitate the depiction, the researcher utilize AutoCad software.

2.2.3 Aerial Photos. An aerial photograph of the Google Earth software is required to determine the measured shoreline position.

2.3 Primary Data Analysis

2.3.1 Damage Assessment and Coastal Protection Technical Planning. Based on the survey conducted, it is apparent that the problems that occur around the mouth of the Rejoso river which are often subjected to sand deposition.

2.3.2 Flow Measurement Data. Current measurement is intended to get an overview of ocean currents in locations, such as the dominant speed and direction of the current.

3. Results and Discussions

3.1 Frequency Analysis
Based on the analysis of the frequency distribution of wind speeds that have been carried out, it is revealed that in January, February, March and April the dominant speed is West and North. The biggest wind speed in the West is in January with a percentage of 51.3% dominantly occurring between 1-5 knots, followed by the second largest wind speed in April with a percentage of 32% dominant occurring between 1-5 knots. Whereas the largest wind speed in the North direction is in March with a percentage of 39.7% dominantly occurring between 1-5 knots followed by the second largest wind speed in February with a percentage of 37.1% dominant occurring between 1-5 knots.
3.2 Calculation of Broken Waves

The calculation is conducted to determine the value of $H'o$ and $H_b$: (From table A-1 Bambang Triatmodjo "Ports" get $H / H_o '$values based on the value of $d / Lo$) [2].

$$d / Lo = 0.0453; H / H_o ' = 1.042$$

Then: $H'o = Ho / (H / Ho ') = 1.0703 / 1.042$

a. 1,027 m

Thus:

$$H'o / gT^2 = 1.0703 / (9.81.376292) = 0.0077$$

The value of $H_b$ is obtained from the plot between the value of $H'o / gT^2$ and the slope of the beach (m) from the graph of "Determination of the Height of Broken Wave (page 96), Coastal Engineering, Bambang Triatmodjo" [2].

The plot on the graph for $H'o / gT^2 = 0.0077$ and $m = 0.2$, obtained $Hb / Ho = 1.025$ and $Hb = 1.053$ m. Thus: $Hb / gT^2 = 1.053 / (9.81.3.76292) = 0.0076$, obtained $db / Hb = 0.82$ and $db = 0.863$ m

3.3 Analysis of Sediment Transport

3.3.1 Longshore Sediment Transportation. Calculation of longshore sediment transport is carried out by using the CERC method. The parameters are obtained based on previous calculations. By accumulating the amount of sediment transport every month for one year, the recapitulation of total longshore sediment transport is 205837.70 m$^3$ / year from the North and Northwest, but the transportation of sediments is more dominant, from the North. The northern direction of sediment transport is 203650.17 m$^3$ / year, with the largest sediment transport occurring in December, which is 32508.37 m$^3$ / year, and the lowest is in March which is 218.11 m$^3$ / year. Whereas the northwest direction of sediment transport is 2187.53 m$^3$ / year, with the largest sediment transport in April, which is 503.71 m$^3$ / year and the lowest is in August.

3.3.2 Upright Straight Beach Sediment Transportation. From the calculation of sediment transport perpendicular to the coast, by accumulating the amount of sediment transport every month for one year, the total recapitulation of upright coastal sediment transport is 677915.27 m$^3$ / year originating from the North, with the largest sediment transport in January, which is 78042.98 m$^3$ / year and transportation the lowest sediment in July is 31097.98 m$^3$ / year.

3.4 Building Layout

To determine the location of the safety building, building layout is performed to understand the wave conditions and coastal currents at the location of the study. To prevent the accumulation of sediments in the estuary area, it is necessary to make jetty on both sides of the river mouth, and add two series of jetty on the east coast of the river estuary, and to anticipate damage to the coastal area of Estuary Rejoso, considering that there are settlements along the coast.

4. Conclusion

At the mouth of the Rejoso river, sand deposition forms when waves and dominant currents deposit sediments form a longitudinal plain and result in the closure of river mouths. Since the research location included sandy beaches, the closure of the estuary resulted in sand spit in the estuary, the estuary type was dominated by ocean waves and wind.

- The maximum height and wave period that occurred in 2001 to 2011 was in February 2001, with a height of 1,070 m and a period of 3,763 seconds originating from the North. Likewise, the dominant wave originates from the North.

- By using the CERC (Coastal Engineering Research Center) method, the maximum longshore sediment transport rate is obtained, which is equal to 205837.70 m$^3$ / year originating from the North.
Besides, the maximum perpendicular beach sediment transport rate is also obtained, which is equal to 677915.27 m³/year from the North.

- The alternative problem solving for the Rejoso river estuary is conducted by using a protective beach in the form of jetty, because the area is not the port area where the ship is anchored. There are only small boats that are often used by fishermen for their survival. Thus, the construction is easier and more economical.
- Jetty is built on both sides of the river mouth, coupled with two jetties on the coast east of the river mouth to prevent the accumulation of sediment due to sediment transport which is much greater than the river discharge.
- In the jetty in the river estuary, overtopping is expected to occur, especially when the storm takes place to be considered for planning the type of construction, although overtopping is not too large. A damage inventory study in the Rejoso area is needed to find out more about coastal damage that will occur in a certain period of time.

References
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