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Numerical Simulation for Identifying Shoreline Erosion in the Vicinity of Runway Platform of Sultan Mahmud Airport, Kuala Terengganu, Malaysia

[1]Yuyun Hidayat, [2]Subiyanto, [2]Mohammad Fadhli Ahmad, [2]Mustafa Mamat,
[3]Aceng Sambas and [4]Sudradjat Supian
[1]Department of Statistics, Fakultas Matematika dan Ilmu Pengetahuan Alam,
Universitas Padjadjaran, Bandung, West Java, Indonesia
[2]School of Ocean Engineering,Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia
[3]Department of Mechanical Engineering, Universitas Muhammadiyah Tasikmalaya,
Tasikmalaya, West Java, Indonesia
[4]Department of Mathematics, Fakultas Matematika dan Ilmu Pengetahuan Alam,
Universitas Padjadjaran, Bandung, West Java, Indonesia

Abstract: In this study, the formula of longshore sediment transport rate is applied to identify shoreline evolution around of runway platform of Sultan Mahmud Airport, Kuala Terengganu, Malaysia. This formula was developed based on phenomena of fluid movement through the sediment particle. The sediment with high permeability become more loose, this causes sediment easily to move. Based on the simulation result by using this formula, shoreline profile around this airport occur an erosion and accretion. The accretion occurs on the north side of this airport. The average accretion in this area during the 1 year is 4.75 and 23.56 m during 3 years. The erosion occurs on the south side of this airport. The average erosion in this area during 1 year is 5.43 m while the erosion becomes worst when the simulation is done for 3 years that is equal to 20.21 m. It is required an effective coastal management and coastal protection in order to minimize this erosion in the future.

Key words: Accretion, erosion, longshore sediment transport, permeability, effective, management

INTRODUCTION

The coastal zone is the intersection area between the sea and land. This area is important because the number of people living around this zone is increasing. The United Nations has stated that there are more than 75% of the world's populations live in around coastal regions in 2004. Intergovernmental Panel on Climate Change (IPCC) report that around 1.2 billion people live in coastal regions in 2007 globally. This number is estimated to increase around 1.8-5.2 billion by 2080 due to a combination of population growth and coastal migration (Parry and IPCC, 2007). The population increases led to the development of infrastructure and buildings around the coastal zones. Today, coastal zone has become an attraction for the human population as they provided many functions such as recreation, trading, transportation, residential and rich marine resource. The increases of human activities in the coastal zone are confronted with coastal hazard. The most significant problem associated with the coast is coastal erosion. Erosion threatens the coastal population and leads to loss of properties along the coastlines. Some examples of coastal erosion caused by human activities such as coastal erosion on the Tangierc Harbour caused by breakwater structure (Serdati *et al*., 2004; Serdati and Anthony, 2007), erosion on the Northeast Bohai Sea (China) with an average retreat rate of 2.6 m per year during 1986-2003 due to dams on the Luan River (Xuo *et al*, 2009).

The most affected coastline erosion is the South China Sea border which that has been stated by Husain *et al.* (1995) that 30% of Malaysia's coastline is experiencing erosion. Terengganu coastline has bad erosion during monsoon season but the erosion is limited to only certain sections. The greatest erosion was occurring on the north side of the runway platform of Sultan Mahmud Airport Kuala Terengganu. From the visual observation, the offset changes from the original position of the shoreline due to erosion was more than 10 m during 2010, 2011 and it is believed that the offset becomes more in 2013 and 2014 (Ahmad *et al*., 2014).

Comprehensive coastal zone management and erosion control require a reliable and practical tool for identifying shoreline changes. In order to optimize shore protection, an efficient tool is required such as mathematical models.

Corresponding Author: Subiyanto, Department of Mathematics, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Padjadjaran, Bandung, West Java, Indonesia

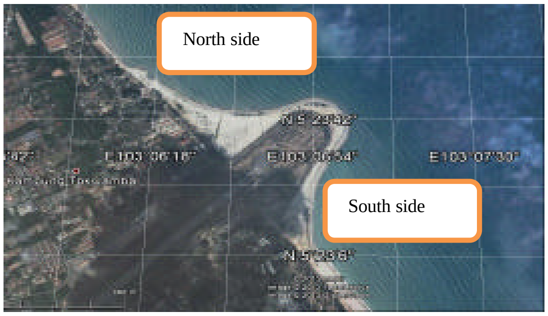

Fig. 1: Area of study

The mathematical model is a reliable and efficient predictive tool for protection and management coastal areas. Many researchers use mathematical models to predict shoreline change in the coastal engineering project (Grijm, 1965; Mehaute and Soldate, 1978; Miller and Dean, 2004; Hoan, 2006; Kim and Lee, 2009). The main objective of this study is to identify the shoreline erosion nearby of the runway of Sultan Mahmud Airport, Kuala Terengganu by using numerical simulation. The simulation was undertaken by solving a mathematical model of shoreline changes. The mathematical model is solved by using the formula of longshore sediment transport. The results were validated with data from satellite images.

Area of study: The study area extends from South to North Sultan Mahmud Airport for about 4 km as shown in Fig. 1. The shoreline in this area is classified as being critical by the local authorities. The main causes for this problem are the dynamic physical process in the area and human activities. The coastal area around Sultan Mahmud Airport was characterized by the Northeast monsoon with semidiurnal tides and the highest wave occurs during November-March where the average of wave angle is 60°-70° from the north with the wave high is more then 3 m and a tidal range is about 2.04 m from mean sea level (Ahmad *et al*., 2014).

MATERIALS AND METHODS

The methodology used in this study based on a numerical method which was introduced by Subiyanto (2015). This numerical method solves the partial differential equation of shoreline changes model (Subiyanto *et al*., 2013). The mathematical form of shoreline changes can be written as follows:

$$\frac{\Delta y}{\Delta t} = -\frac{1}{(d)}\left(\frac{\partial Q}{\partial x}\right) \quad (1)$$

Where:

- y = The shoreline position (m)
- x = The longshore coordinate (m)
- t = The time (sec)
- Q = The longshore sediment transport (m^3/year)
- d = The active depth (m) which equal the beach berm height (D_B), plus the closure depth (D_C)

The mathematical term of the longshore sediment transport rate in the coastal area can be expressed by an appropriate bulk longshore sediment transport rate formula that relates the movement of sediment to the incident wave conditions (Inman and Bagnold, 1963; USACE, 1984; Kamphuis, 2002).

The formula of longshore sediment transport rate that used in this study as follows (Reeve *et al*., 2004; Subiyanto, 2015; Longuet-Higgins, 1970):

$$Q_{New} = 1.88\times10^{-6}\left(\rho_s - \rho\right)\pi\frac{\alpha^2}{C_B}(d)^2 \exp\left(1.31\left(\frac{\ln(d)}{\ln(2)}\right)\right) sgH\frac{\sin(2\theta)}{\mu_0} \quad (2)$$

Where:

- Q_{new} = The new longshore sediment transport (m^3/year)
- ρ = The density of the water (kg/m^3)
- ρ_s = The density of the sediment (kg/m^3)
- C_B = A constant friction coefficient that in the general case is dependent on the flow and sediment properties
- α = The constant between 0.3 and 0.6
- d = Geometric mean grain size (mm)
- s = The local bottom slope
- g = Acceleration due to gravity (m/sec)
- H = The significant wave height at breaking (m)
- θ = The wave angle at breaker
- μ_0 = The maximum horizontal bottom orbital velocity of the waves at the breaker zone (m/sec)

In this study, a numerical scheme for solving this problem where the angle of incoming wave breaking is not assumed to be small but it is expanded by using Trigonometric identity (Subiyanto, 2015). It starts from the discretization of the partial differential equation of shoreline position by using backward time approach and the partial differential equation of longshore sediment transport by using the forward space approach. The combination of the partial differential equation of shoreline position and longshore sediment transport discretization has produced a matrix of partial differential coupled and it solves by using MATLAB code. In order to identify shoreline erosion in Sultan Mahmud Airport Kuala Terengganu coastline, this numerical model is applied in this area.

In order to validate the numerical results in this study, the quantitative comparisons in Sultan Mahmud Airport Kuala Terengganu coastline are performed between simulation and measurement shoreline position regarding the scatter of the calculation points around the line of exactly the shoreline positions. As a measure of scattering, the quantitative results of shoreline position can be calculated by using standard error of estimated as follows (Douglas *et al*., 2006):

$$S_{est} = \sqrt{\frac{\sum_{i=1}^{N}\left((y_N)_i - (y_A)_i\right)^2}{N-2}} \quad (3)$$

Where:

N = The number of the shoreline position data points

y_N = The numerical result

y_A = Measurement result

Perfect prediction in shoreline position is practically impossible. What is needed then, is a measure that describes how precise the prediction of shoreline position from measurement results based on shoreline position from numerical results or conversely how inaccurate the estimate might be. This measure is called the standard error of the estimate. The standard of the estimate is based on squared deviations between each shoreline position from measurement results y_A and numerical results y_N. Remember that the regression line represents all the value of shoreline position from numerical results y_N. If, S_{est} is small, this means that the data are relatively close to the regression line and the numerical method can be used to predict the shoreline position with little error. If, S_{est} is large, this means that the data are widely scattered around the regression line and the numerical method will not provide a precise estimate of shoreline position.

RESULTS AND DISCUSSION

The simulation of the shoreline erosion in Sultan Mahmud Airport, Kuala Terengganu coastline is performed in an area of 3km in the longshore direction is divided into 87 grid points with the width of each grid point is 35 m and 1.4 km in the cross-shore direction (seaward) from baseline. This coastline consisted of very well-sorted sediment with an average grain size is 0.22 mm and slope is 0.005 m. The wave condition is used in these simulations based on field data collected. The average significant wave height ranging from 1.72 m and 2 m/sec in group velocity at the breaking point with the obliquely incoming angle 60° respect to the shoreline is used in this simulation (Ahmad *et al*., 2014). All of these values

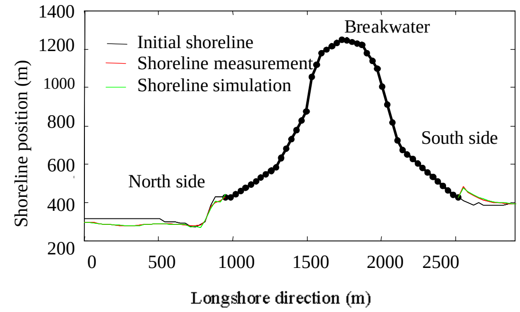

Fig. 2: Numerical result of shoreline changes nearby Sultan Mahmud Airport, Kuala Terengganu coastline

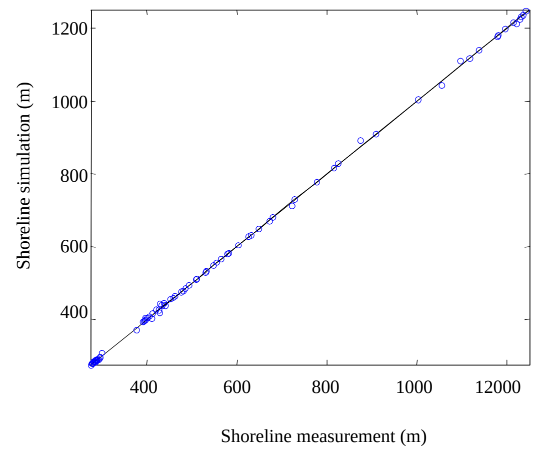

Fig. 3: The standard of estimated from the numerical result; error of estimated = 4.64%

are placed at the offshore boundary in the computation area. This simulation is validated by using image satellite. The numerical validation is shown in Fig. 2 and 3.

Figure 2 shows the shoreline changes nearby Sultan Mahmud Airport, Kuala Terengganu coastline. In this figure is compared between shoreline position based on measurement and simulation. The standard error of estimated from this simulation is shown in Fig. 3. The figure shows that the standard error of estimated from this simulation is 4.64%. This value indicates that the shoreline position based on simulation are relatively close to the regression line and the numerical method can be used to identify the shoreline changes nearby Sultan Mahmud Airport, Kuala Terengganu coastline especially erosion in the north of this airport. In order to identify erosion in Sultan Mahmud Airport Kuala Terengganu coastline, it is simulated shoreline changes in duration time 1 year indicates by the red line and 3 years indicates by the green line. The initial simulation is started from 2010. The simulation result is presented in Fig. 4 and 5.

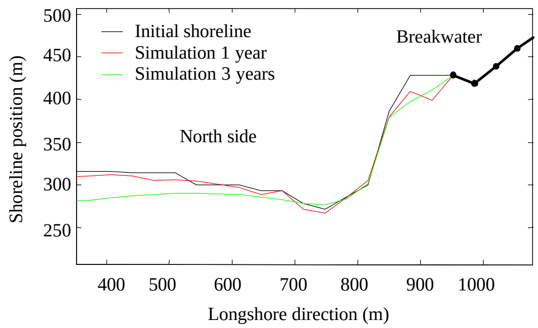

Fig. 4: Erosion around the North of runway extension Sultan Mahmud Airport Kuala Terengganu

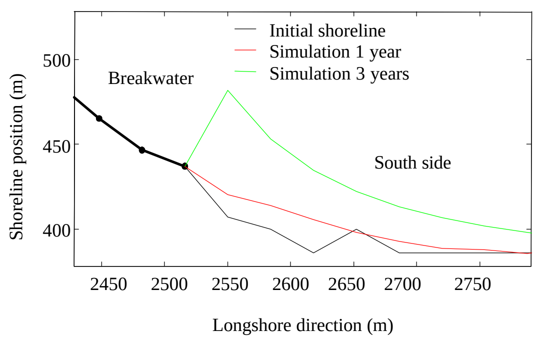

Fig. 5: Accretion around the South of runway extension Sultan Mahmud Airport Kuala Terengganu

Figure 4 shows that the north side of runway extension Sultan Mahmud Airport Kuala Terengganu occurs erosion. Based on the result, the average erosion in the area during 1 year is 5.43 m. The erosion more becomes worst when the simulation is performed during 3 years that is 20.21 m.

Based on Fig. 5, accretion occurs on the south side of Sultan Mahmud Airport Kuala Terengganu. The average accretion in this area during the 1 year is 4.75 m and 23.56 m during 3 years.

CONCLUSION

Based on the results of current study, it is concluded that erosion and accretion were occurred because of runway Sultan Mahmud Airport Kuala Terengganu. This result is confirmed by Philips (1985) that the net longshore sediment transports occurred towards the north of peninsular Malaysia. According to this statement the net of longshore sediment transport will be changed due to the runway Sultan Mahmud Airport Kuala Terengganu. Where south side of this Airport occurs an accretion and erosion occurs on the north side of this Airport. This erosion is getting worse over time, so that it is required an effective coastal management and coastal protection in order to minimize this erosion in the future.

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