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Placement of geotextile tubes as coastal management of way hawang seashore area at Bengkulu Province

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Abstract. Way Hawang Beach, one of coastal tourist attraction, located in Way Hawang Village, Maje, Kaur Regency, Bengkulu Province is suffering from erosion. The regular erosion speed is approximately 2 to 3 meters/year, taking the distance from Way Hawang coastline to West Sumatra Causeway which around 250 meters. Efforts to eradicate abrasion on Way Hawang Coast are mostly carried out using coastal protective structures. One of the breakwater structures that can reduce wave energy is geotextile tubes, which is a low-threshold breakwater structure. Geotextile tubes create a synthetic barrier along shorelines and beaches to help control erosion. Geotextile tubes placement plays an important role in the overall protection system performance. The geotextile tubes are simulated in the abrasion and accretion positions on the Way Hawang coast. The simulation results indicated that the position between abrasion and accretion are the most effective position to manage and to avoid erosion in Way Hawang coast's area at Bengkulu Province.

1. Introduction

One of the provinces in Indonesia is Bengkulu which is located on the southwest coast of Sumatra. The length of the coast is about 576 km, bordering the Indian Ocean in the western part of Bengkulu Province and has a 550 km long national road. This national road is called the West Sumatra Causeway which is the only land transportation route between districts in Bengkulu Province and is used to reach West Sumatra and West Lampung [1]. The function of the West Sumatra Causeway is very vital, heavy vehicles cannot be passed if this road is damaged and will significantly disrupt the economic acceleration of the Bengkulu population. Apart from being very important infrastructure used for traffic services, goods, agricultural products, mining, plantations and oil distribution, Bengkulu's population, the majority of whom are agrarian, trusts severely on agricultural products and requires land transportation via this national road [2].

This West Sumatra causeway is extremely defenceless to being eroded by ocean water starting from the Indian Ocean which takes very resilient hydrodynamics and sea waves to erode the road barriers. Coastal abrasion that erodes roads has a severe value, where the regular erosion rate is 2 meters/year and occasionally up to 3 meters/year [2]. Figure 1 shows the abrasion at South Kaur District, Bengkulu Province. Residents' settlements in the coastal area of South Kaur District, Kaur Regency are threatened with abrasion. The reason is that the distance from the beach to the road and residents' houses is only a few meters. This makes residents hope that the local government can immediately build the coastal protection structure. Some blisters have been managed by the Ministry of PUPR. However, abrasion remains to transfer to other parts of the coast, so a comprehensive clarification is desired to address this problem [3-7].

Figure 1. Abrasion at South Kaur District, Kau Regency, Bengkulu Province

Way Hawang Beach is approximately 250 meters away from West Sumatra Causeway. This tourist attraction is in Way Hawang, Maje, Kaur Regency, Bengkulu Province. Way Hawang coastal area is experiencing abrasions. Efforts to eliminate abrasion on the Way Hawang Coast are mostly carried out using coastal protective structures, including breakwater structures [8-10]. One of the breakwater structures that can reduce wave energy is geotextile tubes, which is a low-threshold breakwater structure. Geotextile tubes create a synthetic barrier used along shorelines and beaches to help control erosion (see Figure 2). Geotextile tubes placement shows a useful responsibility in the performance of the complete safety scheme [11]. In this study, geotextile tubes were simulated in the position of abrasion and sedimentation on the Way Hawang coast. The simulation results indicated that the position between abrasion and sedimentation was the most effective position to manage and to prevent abrasion in Way Hawang coast's area of Bengkulu Province.

Figure 2. Geotextile Tubes

2. Materials and Methods

2.1. The study area

Way Hawang Village is in Kaur Regency, Bengkulu Province. The latitude of Way Hawang is 4.8632° South and longitude is 103.4360° E. Figure 3 shows Way Hawang Village and coastal area which was taken from Google Earth platform [12] and Batu Jung is in the middle of Way Hawang Beach which is a tourist spot. The research site was in the coastal area of Way Hawang.

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Figure 3. Way Hawang Village and coastal area from Google Earth Engine

2.2. The forecasting of wave height on Way Hawang Beach

Wind data used for wave forecasting is sea level data at the generation site. This data was gained from direct measurements above sea level or measurements on land near the forecasting setting which was then transformed into wind data at sea. The results of processing wind data collected from the Bengkulu wind recording station from 2011-2020, with statistical analysis data, were used to calculate the hour and direction of wind deception. The maximum wind comes from the South, directly from India Ocean.

The calculation of waves, generated by the wind, was done by hindcasting [14]. The basic principle of this method is to estimate the wave height and period calculated from wind data and effectively fetched using empirical methods. The maximum wind speed was used in the calculation, which was intended to analyse the extreme conditions of the waves. The visualisation of wave height [15] at Way Hawang Beach can be seen in Figure 4. The maximum wave height at Way Hawang Beach arises from the South directly from Indian Ocean.

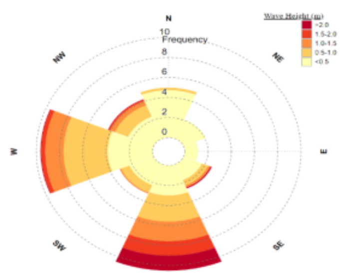

Figure 4. Wave rose of Way Hawang coastal area

The design wave height is the wave height of a certain return period at the location of the coastal protection structure, where the wave has transformed during its propagation from the deep sea. The wave data used is the period and wave height which is the result of a 10-year wind data hindcasting process. Furthermore, extreme wave analysis was carried out in the form of various return periods for each direction [16] and the 50-year return period wave height will be modelled using SMADA software [17]. The design wave height is 6.39 m from the results of this wave transformation model.

Furthermore, tides are an oceanographic physical phenomenon that needs to be studied as an effort to understand the circulation pattern of seawater masses. This tidal parameter generally determines the movement of water from midday to daily period depending on the type of tide that occurs in these waters. From the observation results, tide measurements are also used to determine the water level elevation.

The Mean High-Water Level, Mean Sea Level, and Mean Low Water Level at Way Hawang Beach are 1.08, 0.72, and 0.35 meters, respectively.

2.3. Design of Geotextile Tubes

The design and location of geotextile tubes was determined based on wave data. The result of forecasting wave height for the 50-year return period stands $H_{50} = 6.39$ m; therefore, the wave height (H), wave period (T), and the wavelength in the deep waters (L_0) are obtained as follows:

$$H = 33\%\ H_{50} = 2.1 \text{ m}$$
$$T = 3.88\sqrt{H} = 5.63 \text{ second}$$
$$L_0 = 1.56\ T^2 = 49.52 \text{ m.}$$

Furthermore, the height of breaking wave is 2.4777 m at the depth of the breaking wave is 2.7255 m.

The coastal protection structure using sand-filled geotextile tubes material at Way Hawang Beach has dimensions of 2 m high, a base width of 4.2426 m and a cross-sectional area of 6.2575 m^2. The geotextile tubes can be seen in Figure 5, where P_h is the pressure caused by waves (a combination of hydrostatic pressure and dynamic pressure) and P_p is the passive pressure caused by water pressure behind the structure. The geotextile tubes structure is stable against overturning, shear forces, and soil bearing capacity; therefore, it is in a stable and safe condition.

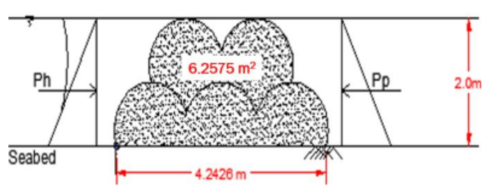

Figure 5. Geotextile tubes at Way Hawang Beach

2.4. Numerical Modelling System of Shoreline Change

The initial position of Way Hawang's shoreline is firstly done as an input by making the grids at a certain distance accordance to the long coastline that will be simulated. Data on the position of the Way Hawang's shoreline can be acquired from Google Earth Pro engine to AutoCAD application [18]. The distance between the grids is 66.3 m with 86 grids as shown in Figure 6. Wave data is the result of daily wind data processing in the form of wind speed and direction using a hindcasting program. The wave parameters obtained are the period, height and direction of the incoming wave. The number of wave data generated in one year is 8760 data.

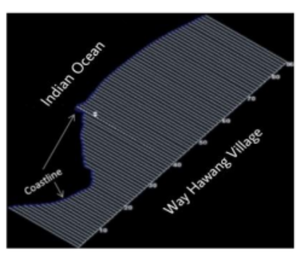

Figure 6. Grid of the Way Hawang Coastline

The prediction of shoreline change can be obtained using numerical method over a given period. A numerical model called GENESIS (GENEralized model for SImulating Shoreline change) [19], is used to calculate shoreline changes caused mostly by sea wave. This model is based on the one-line theory, which assumes that the beach profile remains unchanged, thus allowing shoreline change to be uniquely described in terms of shoreline position. The central task of this model is to simulate the shoreline response to constructions situated on or near the shore. GENESIS generally means that a simple user interface allows the system to be affected in a variety of situations involving the number, location, and combination of coastal protection structures. If all the input data needed for shoreline change prediction is obtainable, then the program will run through the START file. All comments in the START file are filled in according to the existing input and as required by GENESIS. The START input is also carried out, for conditions without or with the geotextile tubes.

3. Results and Discussion

Due to wave load, the shoreline at Way Hawang beach has changed. Figure 7 presents the shoreline change at Way Hawang coastal area. It can be seen from Figure 7 that the abrasions occur at grid 10-30 and the accretions occur at grid 30-50.

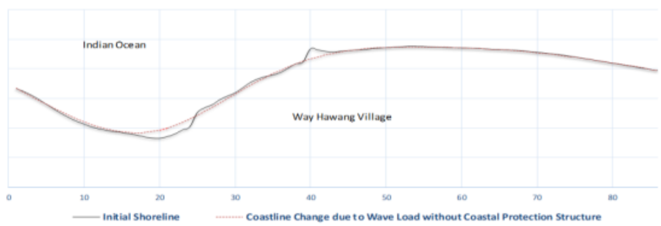

Figure 7. Coastline change at Way Hawang Beach due to wave load without coastal protection structure

The next step is to analyse the position of the most effective geotextile tube structure in order to minimise the occurrence of changes in the Way Hawang coastline. Three plans for the placement of geotextile tube structures were analysed. The placement of the geotextile tube structure at the location of the occurrence of abrasion and sedimentation was based on the results of coastline change analysis without the presence of a coastal protective structure. The first location was geotextile tube structure placement on grids 10 to 30 (the occurrence of abrasion), the second location was on grids 30 to 50 (occurrence of sedimentation), and the third location was on grids 10-50 (occurrence of abrasion and sedimentation). Figure 8 shows the coastline change due to the placement of the geotextile tube structure on the Way Hawang coast.

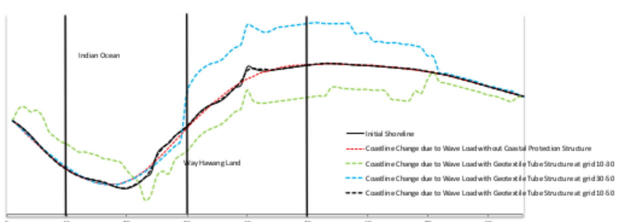

Figure 8. Shoreline change due to wave load with and without geotextile tube structure

The results of shoreline changes without the presence of a coastal protective structure and shoreline changes with the placement of geotextile tube structures at three different locations show that the average width of the occurrence of abrasion or sedimentation is as follows,

1. Abrasion width 0.2184 m where there is no coastal protection structure
2. Abrasion width of 2.7021 m for placement of geotextile tube structures on the grids 10 to 30
3. Abrasion width of 2.3252 m for placement of geotextile tube structures on the grids 30 to 50
4. Abrasion width of 0.0373 m for placement of geotextile tube structures on the grids 10 to 50.

The most effective placement of geotextile tube structures at the Way Hawang Beach is on the grids 10 to 50.

4. Conclusions

Shorelines are certainly dynamic and abrasion cycles are often a significant feature of their ecological character. Winds, waves and currents have normal forces that simply transfer sand and unconsolidated soil in shore areas, so that the position of the coastline changes rapidly. Development in coastal areas can increase erosion problems; this necessitates a great deal of effort to manage the problem of shore erosion and to return coastal function, to adapt both short- and long-term transformations caused by human activities, natural disasters and sea level rise.

Way Hawang coastal area at Kaur Regency, Bengkulu Province is experiencing abrasions. Efforts to eliminate abrasion on the Way Hawang Coast are mostly carried out using coastal protective structures. Erosion problems are exacerbated when preventive measures (i.e. selection of hard or soft structures) are inappropriate, inappropriately planned, constructed, or maintained and if effects on nearby shores are not carefully assessed. The geotextile tubes were simulated in the position of abrasion and sedimentation at Way Hawang coastal area. The simulation results indicated that the position between abrasion and sedimentation are the most effective position to manage and to prevent abrasion in Way Hawang coast's area of Bengkulu Province. Further research is how to maintain and retrofit the geotextile tubes at the coastal area.

Acknowledgments

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