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Stability and Placement Analysis of Geotube to Prevent Existing Shoreline at Pisangan Coastal Area in Karawang

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Abstract. Pisangan coastal area in Karawang has currently suffered from abrasion, and almost 3.5 km of land area has been covered by the sea. Abrasion has led to the destruction of settlements, farms, highways, and tourist area requiring the offshore breakwater to mitigate them. The appropriate breakwater to the circumstances of Pisangan coastal area is geotube. In this study, geotube is designed and stability of geotube is analyzed. The stability analysis of geotubeis determined by the stability against overturning, sliding, and bearing capacity. There are three positions of geotube is simulated to obtain the lessen shoreline change from abrassion. The result shows that the geotube attains the safety factor against overturning force, sliding force, and also the bearing capacity. The placement of geotubeat the occurrence of abrasion is the most effective position to cope and prevent the shoreline at Pisangan coastal area.

Introduction

Coastal structures have become very expensive to build and maintain. Shorelines are continuously being eroded, and due to the sea level rise, this problem gets worse. Consequenlty the cheaper materials for construction coastal structures are required.

Geotextile used for soil and sand containment in various types of containers have been used for several decades. The possibilities of geotextile use in coastal engineering are considerable. A breakwater constructed from sand filled geotextile tubes (geotube) could be a practicable alternative to more conventional rubble mount breakwaters in cases where temporary protection is required or rock is not obtained and too difficult to transport to the site.

Pisangan coastal area in Karawang, Indonesia has continuouslyeroded. To prevent the shoreline at Pisangan coastal area, the geotube is designed to ensure stability against overturning, sliding, and bearing capacity in the subsoil. In addition, the placement of geotube is simulated by three different positions to obtain the most effective placement to manage and prevent shoreline at Pisangan coastal area.

Forecasting Shoreline Change at Pisangan Coastal Area

Wind data for the prediction of waves normally obtained through direct observation through the fetch (wave formation region) which is assumed to have the speed and wind direction are relatively constant from observations on the ground. Wind direction and speed of the daily maximum will be used to predict the maximum wave height that can be generated in the wind over a certain time period [7].

The calculation of wave can be generated by wind and is done by hind casting method. The basic principle of this method is to estimate the wave height that is calculated from the wind speed, the effective fetch, and duration by using empirical methods. In the calculation of the maximum wind speed is used, which is intended to analyze the extreme conditions of the wave. Wind direction is expressed from the direction of the wind. It is treated similarly to the wave, where the wave is expressed from the direction of the wave [6]. The wind velocity used in this study is obtained from Tanjung Priok's station during the years of 2000-2011. The effective fecth is determined based on the location of shoreline study, i.e. Pisangan's beach in Karawang, Jawa Barat Province, Indonesia.

Assuming that the wind was blowing with 6 hour duration was obtained waves to wind speed varies. The wave height estimation for the return period in 50 years is 3.22 m.

The prediction of shoreline change can be obtained using numerical method ove a given period [2]. The initial position of Pisangan's shoreline is firstly done as an input by making the grids at a certain disctance accordance to the long coastline that will be simulated. The distance between the grid is 20 m with the amount of grid number is 41. The other input data is D_{50} = 0.10, i.e.the mean grain size which corresponds to 50% finer, from Pisangan's coastal area. The output of shoreline change for Pisangan's coastline can be seen in Fig. 1.

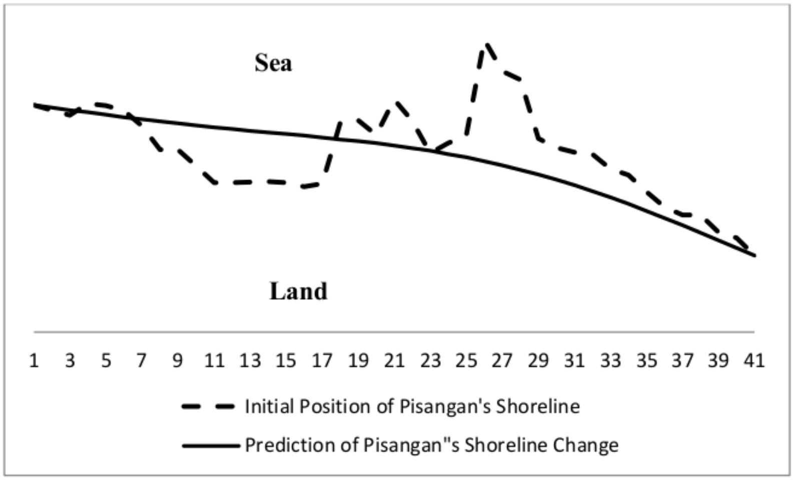

Fig. 1. Shoreline change prediction for Pisangan's Coastline

Fig. 1 shows the prediction of Pisangan's coastline change. It can be seen that the abrassion occured at grid 18 untill 40 and the sedimentation occur between grid 7 and 17. To prevent the shoreline change at Pisangan's coastal area, the suitable breakwater is urgently needed.

Geotube at Pisangan Coastal Area

Geotextile tubes (Geotube) are long, cylindrical hydraulically filled geotextile tubes that are permeable to water but not to sand. Geotube is generally filled with sand size range from 0.5 to 4.0 diameter and from 25 up to 100 m [4]. Geotube is replacement for conventional rubble mound breakwater. The reasons for replacing classic material, such as gravel, rock and concrete, include the unavailability of common materials, a reduction in the quantities required, improved functionality, simplified execution and a reduction in execution time. All of these advantages could lead to lower construction costs. The maintenance costs of the structure during the service life must also be taken into consideration [5].

The cost benefit of a structure increases with an increase in the isolation of the construction site. Local material and low-skilled labour can be used, rather than transporting all the required construction materials and labour to the construction site. Compared to traditional construction methods the application of geotextile sand filled elements may add considerable operational advantages to the execution of marine works and may offer attractive financial opportunities. The main advantages of geotextile systems when compared with traditional methods, including prefabricated concrete units, are reduction in work, use of local material, equipment and low-skilled labour, and no need for heavy construction machinery [3].

The important factor in the election of Geotubeallows waves hit the beach. Furthermore, the primary material used is the availability of materials around the job site. The Geotube filling with sand is designed to prevent Pisangan's coastline with height is 1.20 m, width is $B = 4.98$ m and the cross section area is $A = 4.82\,m^2$ (Fig. 2).

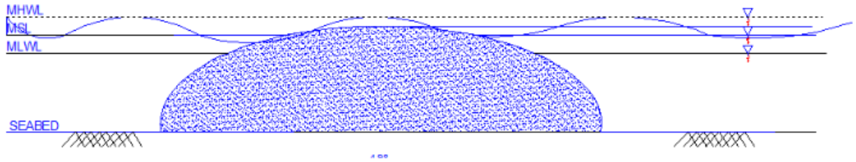

Fig. 2. Geotube at Pisangan's coastal area

Stability Analysis of Geotube at Pisangan's Coastal Area

Based on the wind data, the prediction of wave height and wave period for a return period of over 50 years are H_0 = 3.22 m dan T = 5.2 second, respectively. The wave length is obtained $L_0 = 1.56\times T^2$ = 42.18 m and the wave number is $k = 2\pi/L_0$ = 0.15. As wave passing through the breaker zone and assuming that the coefficient of refraction is 1, the equivalent wave height can be determined as $H'_0 = K_r\times H_0$ = 3.22 m.

Wave propagates towards the shore changes due to the effects of changes in the ocean depths. The influence of the depth of the sea began to be occured at a depth of less than a half times the wave length. Based on the bathymetry of Pisangan coastal area, slope of the beach is obtained 1:28.64 and the wave breaking height is H_b = 3.22 m. The depth at breaking wave is determined by d_b/H_b = 1.21 or d_b = 3.88 m.

Before reaching thebeach, thewavesundergo a process of refraction (change of direction of the waves) and shoaling (change in length and wave height). In addition, the wave at a certain depth through a phase of the wave broke before reaching the beach, so the waves on the beach are smaller than the waves off the coast. For the purposes of design of geotube, the wave height at the layout of the structure is taken H = 0.6 m and the water depth is d = 1.1 m.

Geotube's stability is influenced by the forces acting on the structure and its own weight. Pressure distribution on Geotube can be seen in Fig. 3, where P_{hd} is the pressure wave (a combination of hydrostatic pressure and dynamic pressure at the seabed and the mean sea level) as follows:

$$P_{hd} = \rho g H + \frac{\rho g H}{2}\frac{\cosh k(d+y)}{\cosh(kd)} = 9447.54 \text{ kg/m} \quad (1)$$

and P_p is the passive pressure caused by water pressure behind the geotube, i.e., 6113.10 kg/m.

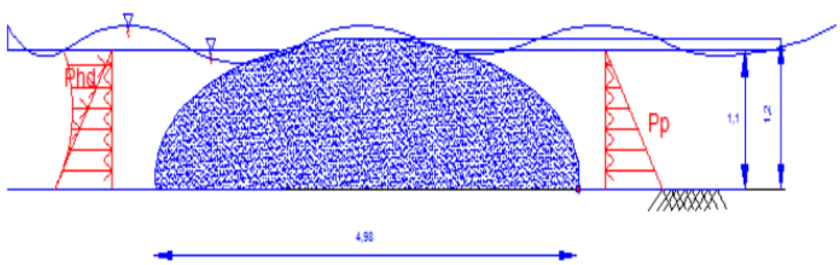

Fig. 3. Pressure distribution on geotube

The overturning stability is affected by the pressure on each side of the cause of geotube tend to rotate in the legs. Point O is the point of the leg of geotubes are used to obtain the value of overturning moment (Fig. 4).

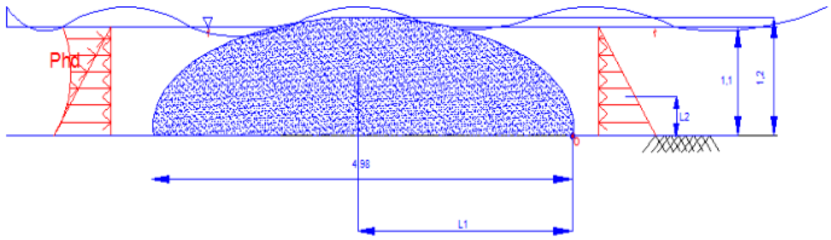

Fig. 4. Overturning Point of Geotube

The moment of the Geotube depends on hydrodynamic moment, i.e.,

$$M_h = \frac{\rho g H^2 L_0}{16T}\left(1+\frac{2kd}{\sinh(2kd)}\right) = 2503.33 \text{ kg}, \quad (2)$$

where $T = 3.88\sqrt{H} = 3{,}01$ second. Hydrostatic moment is $M_p = P_p \times L_2 = 2241.47$ kg with $L_2 = 0.34$ m. Moment due to its own weight is:

$$M_w = W_{geotube} \times L_1 = A\gamma L_1 = 21603.24 \text{ kg}, \quad (3)$$

where $\gamma = 1800$ kg/m^3 is the mass density of Geotube and $L_1 = \frac{4.98}{2} = 2.49$ m. The sum of moments at the toe of Geotube that constibute to its stability is

$$\sum M_{resisting} = M_p + M_w = 23844.71 \text{ kg}, \quad (4)$$

and the sum of the moments at the toe of Geotube that tend to cause overturning is $\sum M_{overturning} = M_h = 2503.33$ kg. The safety factor against overturning is:

$$FS_{overturning} = \frac{\sum M_{resisting}}{\sum M_{overturning}} = 6.81 \quad (5)$$

The stability of Geotube against overturning is reached, since the safety factor of overturning is greater than two [1].
Stability against sliding is achieved, if the safety factoris reached the following conditions:

$$FS_{sliding} = \frac{\sum P_R}{\sum P_D} \geq 1.5 \quad (6)$$

where $\Sigma P_R = W_{geotube}\tan\phi' + Bc' + P_p$ is the force resisting sliding along the wall base and $\Sigma P_D = P_h$ is the force driving sliding along the wall base, $\phi' = 25.68^o$ is the angle of friction of soil and $c' = 833.33$ kg/m^2 is cohesion of soil at Pisangan's coastal area. The safety factor of sliding is obtained $FS_{sliding} = 1.53$. It can be concluded that the geotube is stable against sliding.
The safety factor for bearing capacity is achieved if:

$$FS_{bearing\ capacity} = \frac{q_{ult}}{\sigma_v} \geq 3 \quad (7)$$

where $q_{ult} = c'N_{c'} + 0.5B\gamma N_\gamma$ is ultimate stress and $\sigma_v = W_{geotube}$ is the vertical stress at the base, $N_{c'} = 26.46$ is the contribution of cohesion to the ultimate load bearing capacity, $\gamma = 530.25$ is the weight of soil, and $N\gamma = 9.36$ is the unit weight of soil to the ultimate load bearing capacity. The stability of bearing capacity is reached since the safety factor for bearing capacity is $FS_{bearing\ capacity} = 3.97$.

Placement Analysis of Geotube at Pisangan's Coastal Area

Based on the results of prediction shoreline change without coastal protection structure, the placement analysis of Geotube at Pisangan's coastal area are simulated on three different layout as follows:

a) Grid 18 to 40
b) Grid 1 to 24
c) Grid 6-29

The geotube is located 120 m from the initial shoreline position of Pisangan coastal area. The prediction of Pisangan's shoreline change due to placement of Geotube at grid 18-40, 1-24, 6-29 can be seen in Fig. 5.

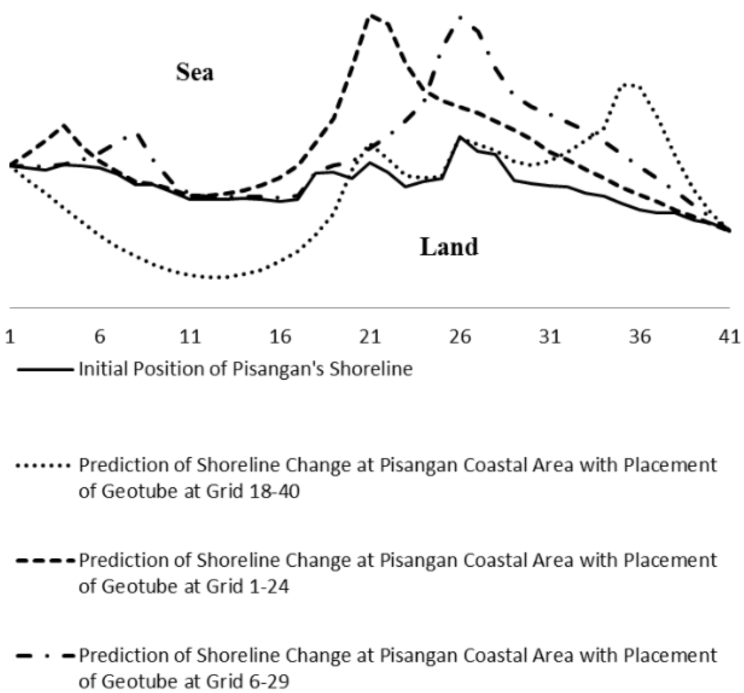

Fig. 5. Prediction of shoreline change at Pisangan's Coastal area with placement of geotube at grid 18-40, 1-24, and 6-29

The placement of Geotube at grid 18-40 shows the prediction of abrassion at Pisangan's coastal area occured at grid 1-20. The placement of Geotube at grid 1-14 and 6-29 do not occur abrassion along the Pisangan's shoreline.The maximum sedimentation ocurs at a distance of 67.3 m and 58.7 m from the initial position of Pisangan coastline due to placement of Geotube at grid 1-14 and grid 6-29, respectively. It can be concluded that the most effective position of Geotube is at grid 1-14 to prevent of Pisangan's coastline.

Conclusions

Pisangan's coastline has continuosly eroded due to the environment impact and also the human activities at the coastal area. Based on the prediction of wave force, the shoreline changes from abrassion and sedimentation. To prevent the existing shoreline of Pisangan's coastline, the geotube is designed and stability of Geotube is analyzed. The safety factors of stability are achieved against overturning, sliding, and bearing capacity. The simulation of three different placements of Geotube at Pisangan's shoreline are applied, i.e., the prediction of the occurence of abrasion, sedimentation, and between abrasion and sedimentation. The most effective layout of Geotube at Pisangan coastal area is at the location of the occurence of abrassion.

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