Soil properties and effects on sea dike instability in Hai Hau coast, Vietnam

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ABSTRACT

This research assesses the effects of soil properties on the sea dike in Thinh Long, Hai Hau coast, the north of Vietnam. The main soil layers in the sea dike body are silt soil and fine sand. From the results of the investigating and laboratory analyses, it can see that the fine sand layer has great effects on the land-side dike slope. That layer has low shear strength, leading to the sea dike has the high potential of failure at the high sea water level and tide. It requires the protected countermeasure for the land-side slope of sea dike. This paper suggests increasing the shear strength by designing soil component and compacted density. The cohesive force of body soil layer should higher 5 kPa. The high resistance material as geosynthetics should use to protect the sea dike.

Keywords: soil shear strength, the probability of sea dike’s stability, sea dike stability

1 INTRODUCTION

Hai Hau is the coastal district in Nam Dinh province, in the northern delta of Vietnam. In this area, there is no island and deposited terrains in offline, Hai Hau coastline are affected directly from all the sea energies from waves, tide, sea currents. The huge energy storm season often occurs and attack sea dike. In the past hundred years, the coastline erosion has been continually occurring with a quite high rate, ranged from 5 m/year to 30 m/year. The sea dike system was broken in several times. The dike system was must rebuild and recovered forward to land-side nearly kilometers from the beginning of the 20th century to nowadays. The current sea dike was recovered last time in 2006 and was broken in the storm season 2017, during Doksuri storm. The high tide and wave overtopping attacked the sea dike. More than 3 km of sea dike in Hai Hai, belong to Thinh Long, Hai Hoa communes (Fig. 1) Was broken. The sea water made about the 2 m flooding.

The coastal zone and sea dike in Hai Hau are interested in quite large numbers of researchers as well as government. There was much research, reports, analysis condition of geological, hydraulic dynamic as wave and tidal dynamic, give recommendations and suggest solving the problems of coastal erosion and sea dike instability (Zbigniew et al. 2002; Duc et al. 2007, 2012; Hieu et al. 2012; Yasuhara et al. 2013; Hieu 2015). Hai Hau coastal zone area also was study area in cooperation project between Ibaraki University and VNU University of Science from 2011-2014.

In this paper, the main objective is to analyze the stability of the sea dike’s the land-side slope with the current dike structure soil layer, the probability of the dike’ stability with the change of shear strength of body dike layer and sea water level.

Fig. 1. The broken sea dike in Hai Hau (Thinh Long) by overtopping waves.

2 STUDY METHODS

The data in this research includes the overview data from the previous researches, the monitoring station, and the field investigation and Geotechnical laboratory. In December 2017, after sea dike in Hai Hau area was broken in the typhoon No.10, Doksuri, the field investigation was carried out. The UAV (Unmanned aerial vehicle) equipment was used to take the photo of the coastal zone area and sea dike. In the broken sites of sea dike, collecting soil samples and determine soil properties in the Geotechnical laboratory in VNU University of Science, Hanoi.

The slope stability analysis is carried out by using the Monte Carlo simulation method available in the SLOPE/W (GEO-SLOPE program).

3 RESULTS AND DISCUSSION

3.1 Sea dike condition and problems

According to local government, before 2006 the sea dike had the elevation of only 3.5m, the top of the dike was 4m in width and without concrete covering. The seaside slope was reinforced by rock blocks, and the landside slope was not protected. The body dike was mainly compacted by fine sand and silt sand. In the land seaward, there was not revetment to break the waves and protect dike. In 2005, the dike was attacked and broken in some locations along sea shoreline in Nam Dinh by a strong storm in 26-27 Sept 2005.

In 2006, this dike was recovered and built with the elevation is up to about 5m above the sea water level. The configuration of sea dike in the case study as Thinh Long is shown in Fig. 2 based on investigated and testing results in the broken dike in Thinh Long.

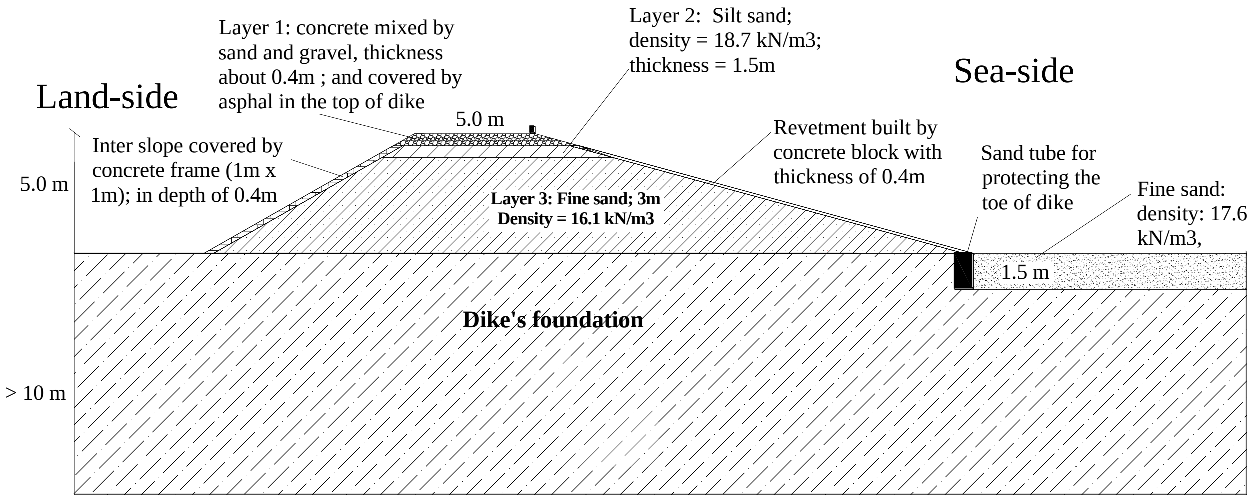

Fig. 2. The configuration of sea dike in Thinh Long, Hai Hau.

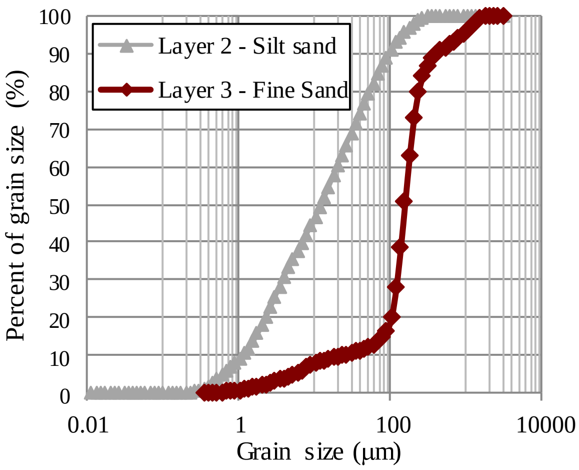

Fig. 3. The grain size distribution of soils collected in Thinh Long dike

Table 1. Soil properties of soil samples collected in the broken location in Thinh Long dike

Soil properties		Layer 2	Layer 3	Dike's foundation *
Coarse sand (%)	0.475 – 2 mm	0	0	
Medium sand (%)	2 – 0.425 mm	0	9.004	
Fine sand (%)	0.425 – 0.075 mm	13.033	76.515	
Silt (%)	0.075 – 0.005	83.302	14.378	
Clay (%)	<0.005mm	3.665	0.103	
LL		28.82		
PI		8.54		
Type of soil classification		ML	SM	
Natural water content (%)		13.83	5.59	
Natural density (kN/m^3)		18.7	16.1	16.9
Hydraulic conductivity (cm/s)		4.47 x 10^{-6}	2.44 x 10^{-5}	1.6 x 10^{-5}
Cohesion force (kPa)		22.44	2.24	15
Internal friction angle (°)		9.09	13.39	12

(* data for soil layer of dike's foundation was conferenced from Hieu, 2015)

Soil layer used for filling in dike body includes the following layers: The first filled layer in the top of the dike is the mixture layer of sand and gravel material with the thickness about of 0.4-0.5m. This layer is a part of the reinforcement layer and covered by gravel and asphalt of the road in the surface. The second layer is compacted layer of the mixture of silt sand, with a thickness of 0.15 – 0.5m under the first layer, this density is about 18.5 kN/m^3. However, the thickness of this layer changes and even missing in some locations in the broken cross-section. The third layer is fine and dense sand, about 1m from the surface to depth. This layer is the main body of the dike, as the filling layer that is often taken from near the dike's toe. Under the main dike's body layer is dike's foundation, with the content change from fine dense sand to silt sand component. Fig. 3 shows the grain size distribution and Table 1 shows the soil properties for soil collected in the body of the dike of broken location in Thinh Long area.

3.2. Probability of sea dike stability with change of sea water level

To evaluate the effects of various soils on dike stability, analyses were performed by using input data for the variation in shear strength. A probabilistic method and sensitivity analysis will be used to analyze sea dike stability. The slope stability analysis is carried out by using the Monte Carlo simulation method available in the SLOPE/W, GEO-SLOPE program (Eddleston et al. 2004). This method will be applied to analyzing the probability of stability of the land-side slope of the sea dike.

The stability of sea dike is significantly affected by the properties of the body layer as layer 3 – fine sand material. In this analysis, the shear strength is variable input data to analyze the probability of sea dike. In Thinh Long, the shear strength is only 2.24 kPa in cohesion force; and is 13.39 degree in friction angle. However, the shear strength may obtain higher value in other areas as shown in previous conferences. In Hieu (2015), the shear strength of body dike is 9 kPa in cohesion force and 25 degree in friction angle, and that is 15 kPa in cohesion force, and 12 degree in friction angle for the dike's foundation. That means the shear strength may range from small to high value, depend on the soil component and compacted density.

This paper analyses the probability of dike stability to see the effects of the factors of safety (FOS) by the changing of shear strength and the sea water level (SWL, H). The expected results may help to find out the suitable threshold of shear strength for dike stability. There are four cases of probability analysis with the change of the input range value of shear cohesion force.

Table 2. Cases for simulating the effects of cohesion force.

Case	Cohesion force for probability analysis			
	Mean (kPa)	Standard deviation (kPa)	Min Cohesion force (kPa)	Max Cohesion force (kPa)
Case 1	2.5	0.5	0	5
Case 2	5.0	1.0	0	10
Case 3	7.0	1.4	0	14
Case 4	7.0	0.4	5	9

The general results of the FOS of the land-side slope are shown in Fig. 4. It obviously indicates the effect of soil cohesion force to FOS. The FOS obtain higher value with the higher cohesion force and the lower SWL. At the current cohesion force, c = 2.5 kPa as shown from soil testing results in Thinh Long, the FOS has a quite low value when SWL at 0 m and 3 m. The FOS may be less than 1 and the sea dike will be a failure when the sea water level up to 5m.

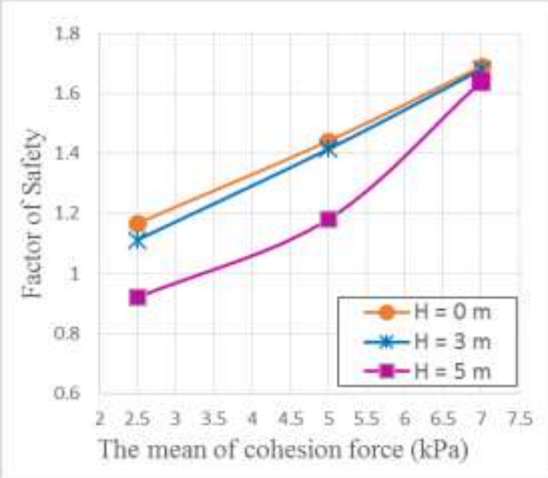

Fig. 4: Relationship of FOS and soil cohesion force at difference of the sea water level (H,m)

The results of the probability of sea dike stability for four case were built, and shown represent in Fig. 5 and 6 which are result for case 1 and case 4, respectively. In case 1, the mean of cohesion force is 2.5 kPa, and the range value of that is less than 5 kPa (from 0-5 kPa). The results of the probability of sea dike stability for four cases were built. Fig. 5 and 6 show the result for case 1 and case 4, respectively. In case 1, the mean of cohesion force is 2.5 kPa, and the range value of that is less than 5 kPa (from 0-5 kPa). The FOS is 0.89-1.5 for H=0m; 0,78 – 1.4 for H=3m; and 0.69-1.3 for H=5m. The probability of sea dike failure (FOS<1) are 20 %, 80 % to 98% when H is 0m, 3m, and 5m, respectively (Fig. 5). The probability of sea dike failure decreases with the higher mean cohesion force and large range value. That is only 20% when SWL at 5m in case of the cohesion force as 5 kPa, and reduce significantly and nearly can be ignored in other cases.

The probability of sea dike failure is small when the mean cohesion force is higher at 5 and 7 kPa (in case 2 and 3). However, FOS is still less than 1 when the cohesion force ranges in low value. In case 4 the FOS has not any percentage less than 1 when the cohesion force range from 5 to 9 kPa (Fig. 6). The FOS ranges in 1.4-2.3 for H=0m; in 1.4 – 2.2 for H=3m; and in 1.5-2 for H=5m. That mean the cohesion force of body soil layer of sea dike is at least higher than 5 kPa. To increase the shear strength of soil, soil component and compacted density are two way should be controlled and applied during building the sea dike.

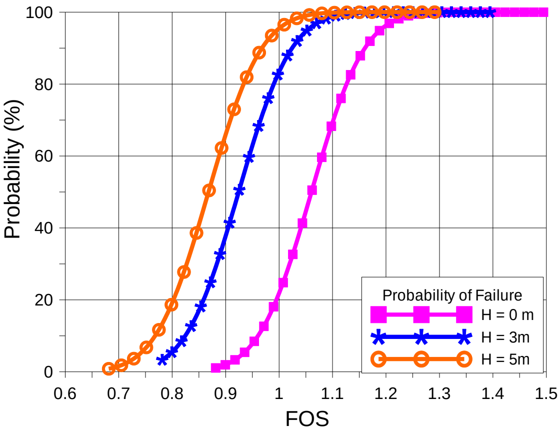

Fig. 5. Case 1 - Probability of FOS with c = 0-5 kPa and the difference of sea water level

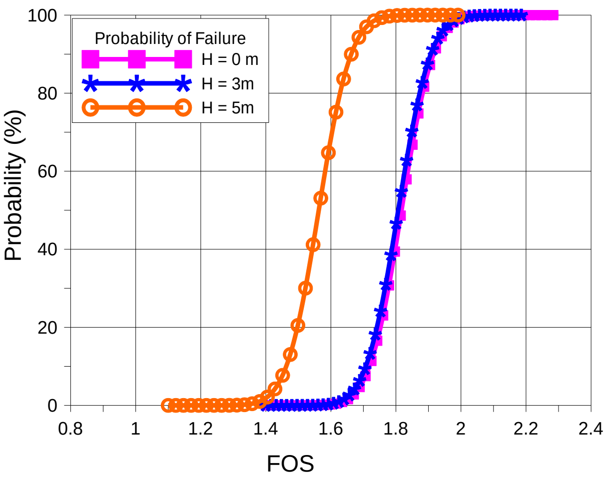

Fig. 6. Case 4 - Probability of FOS with c = 5-9 kPa and the difference of sea water level

4 CONCLUSIONS

This paper investigated the broken sea dike which happens in 2017. The following activities were done: investigating the dike structure, collecting soil sample, and determining soil properties, and analyzing the probability of the land-side slope stability. The result shows that the sand layer is the dike's body layer and has a great effect on the sea dike stability. Analyzing with the range of the shear strength, the land-side slope has a high probability of failure when the shear cohesion force less than 5 kPa. It is required having protected countermeasure for the land-side slope of a sea dike or increasing the shear strength as well as the cohesion force by designing soil component and compacted density during building the sea dike. The cohesive force of body soil layer is suggested higher 5 kPa, and the high resistance material as geosynthetics should be used to protect the sea dike.

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