Designed Coastal Dike to Counter Natural Disaster of Big Waves at Toseho Village

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Abstract. One of many cases of abrasion problems in the coastal areas in Toseho Village in South Oba subdistrict, North Maluku province. About thirty years ago, village residents have to evacuate to high land area due to abrasion damage that is caused by natural disaster of big waves from the pacific ocean. The abrasion progress is also triggered by deposit subsoil. By those problems, several families are still survived to stay because of living as fishermen, it is about 15 families. However, they do not have any construction to safe living under attacking natural disasters. Therefore, this study is proposed a design method using empirical way to design a dike for countering the natural disaster in recovery area land. The tidal waves investigated by using Global Positioning System (GPS) and subsoil properties observed by practically way along the coastline of residential. The coastal dike has to design by considering stability criteria such as bearing capacity and factor of safety, which are conducted by several empirical equations. Finally, the results of field investigation for cross section about 30 meters on perpendicular direction to the coastline for along 483 meters are obtained different ground level average 2.0 meters at the coordinate of 0°20'57.91"U and 127°39'17.30"T. The subsoil identified as silty and sands materials at the ground surface, which is parameter of loose density. The simulation results of empirical way are obtained ultimate bearing capacity of the subsoil  \( q_u \) of 31.2 t/m², factor of safety for overturning  \( F_s1 \) of 3.5 and factor of safety for sliding  \( F_s2 \) of 1.8. Then, factor of safety for bearing capacity of subgrade  \( F_s3 \) of 0.63, which is loaded by pressure at beneath the dike \( p \) of 49.74 t/m².

Keywords: Coastal dike, Recovery abrasion, Local resident, Toseho village

Introduction
Local people stayed from the year 1980 at Toseho village of subdistrict of south Oba in North Maluku Province. They were living along the coastline area as fishermen, which are homes built on the lowland area under attack by natural disasters such as big waves by the pacific ocean. The ground surface shows silty sand materials with loose density. However, local people residential was corrupted by natural disaster from year 1990. In recently year, the damage progress of local people residential is shown in Figure 1.
Figure 1 shows that in order to protect the abrasion damage of the subsoil, the local people were constructed a conventional dike by using coral stone material on the wooden pile installation, but that construction was broken due to big waves from the seashore. Soil investigation in the field used practical methods because this study is to apply empirical equations on elastic with a drained model for calculations.

![Figure 1. Recently residential condition in last year, 2019 (Photographer Suyuti, August 24th, 2019)](image)

The parameters are predicted based on field investigation such as cohesion $c$, internal friction $\phi$, and bulk density of soil on saturated $\gamma_{sat}$.

### 2. Fundamental theory

In order to design a robust coastal dike based on stability criterion at the Toseho village, this proposal is to calculate as below:

Faujan et al. reported the results of coastal dike on the soft soil ground at Akedetilou village using coral stone material. They found geometrical dike such as height of 3 m, width at the top of 1.6 m, slope at front of dike $n_1$ of 1.6 and behind $n_2$ of 1.0. The stability criterion reported factor of safety for overturning $F_{s1}$ of 1.35 that used coefficient friction between base of dike and ground $u$ up to 0.2. They were reinforced soft ground by using bamboo pile, which is used variation of spacing $s$ up to $3d$ (where $d$ = diameter of pile) [1].

Sabaruddin et al. reported results of stability research for an embankment on the very soft soil reinforced bamboo piles, where modeled by full-scale, which is varied vertical loading pressure with
concrete blocks and horizontal pressure it’s powered by hydraulic jack. They were have obtained coefficient friction $u$, of 0.22 [2].

Suyuti et al. worked research on modeling on how to calculate design criteria for river dike construction on soft ground using timber piles. They determined design criterion by conducting Finite Element Method-2D. They found the geometrical design of dikes such as height of 4.50 meters, the width at the top of 16.5 meters and slope of 1.5. In the simulations in FEM used Mohr-Coulomb material model for deformation elastic, and Cam Clay Model for calculating consolidation settlement of the soft ground beneath the construction [3].

2.1 Geometrical design of dike
The geometrical design of dike designed by following steps below

1) The width at top of dike construction is calculated by [4]

$$B_0 = \eta k_d (W_{cd}/\gamma_{cd})^{1/3}$$

where $\eta$ is number of stones, $k_d$ is the coefficient of protection layer, $W_{cd}$ is the weight of stone of construction (ton), $\gamma_{cd}$ is the bulk density average of dike materials (t/m$^3$).

2) Parameters of wave forces
Parameters of wave forces are calculated by using several empirical equationstoprovide the dynamic force of wave $R_m$ (ton), momentof dynamics wave $M_m$ (t.m), and hydrostatics force $R_s$ (ton).

2.2 Stability criterion of a dike
Stability criterion of the coastal dike is provided by following as

1) The stability of dike construction such as factor of safety for overturning $FS_I$ is calculated as[5].

$$FS_I = \frac{\sum_{i=1}^{n} MV}{\sum_{i=1}^{n} MH} > 2.0 \text{ (2)}$$

where $\Sigma MV$ is the total moment resistance due to vertical forces of coastal dike protection, $\Sigma MH$ is the total moment driving due to horizontal force due to waves, $n$ is the number of segment, and $i$ is an integers number.

The factor of safety for sliding at base of dike $FS_2$ is calculated as [5]

$$FS_2 = \frac{\sum_{i=1}^{n} \mu_s H_i}{\sum_{i=1}^{n} H} > 1.5 \text{ (3)}$$

where $\Sigma V$ is the total vertical forces, $\Sigma H$ is the total horizontal forces due to waves, $\mu_s$ is the coefficient of friction between base of dike and the ground surface.

2) Ultimate bearing capacity of soil foundation $q_u$ for width strip footing of the coastal dike is followed classical Terzaghi and Peck’s equation (1943). It can be written as [6]

$$q_u = cN_c + qN_q + \frac{1}{2} B_1 \gamma' N_p \text{ (4)}$$

Where $c$ is the cohesion of soil (t/m$^3$), $\gamma'$ is the effective bulk density of soil (t/m$^3$), $B_1$ is the width of dike foundation (m), $N_p, N_c, N_q$ are the capacity factors of soil.

Therefore, the factor of safety of the soil foundation $FS_3$ can be evaluated by

$$FS_3 = q_u/p_{cd} \text{ (5a)}$$

$$p_{cd} = \gamma_{cd} H_{cd} \text{ (5b)}$$

where $p_{cd}$ is the loading pressure of dike construction (t/m$^3$), $H_{cd}$ is the height of dike (m).

3. The methodology of the study
3.1 Surveying tidal waves
Coastal dike construction is placed at the behind of the breakwater construction. So, the priority study is focused on how to design height the coastal dike $H_{cd}$ on the ground for recovering area without any reinforcement. It is shown in Figure 2. Here, represented cross section by providing several parameters design such as HWL is high water level, MSL is mean sea level, and LWL is low surface level of waves. Therefore, authors have to survey tidal waves in field for setting up a height of dike, which are prepared three points.

![Diagram](image)

**Figure 2.** Schematics of coastal dike construction for countering natural disaster of coastal waves

### 3.2 Field Investigations

In order to prepare a proposal calculation using empirical equations for designing coastal dike construction, the steps of its process are explained by followings.

1) **Soil investigation**

Soil properties are investigated by using simple way to predict subsoil parameters such as cohesion $c$ (t/m$^2$), internal friction $\phi$ ($^\circ$), and bulk density on saturated $\gamma_{sat}$ (t/m$^3$). The dense of granular layer can be tested by plugging hoe on the ground surface.

2) **Coordinate of location**

Coordinate of location is surveyed by using General Positioning System on April 21st, 2020. In the field survey is obtained the three points are shown in Figure 3(a).

3) **Surveying tidal waves**

Tidal waves at a location are surveyed by also using GPS on April 21st, 2020. In the field survey is found the three points, which is represented one point as shown in Figure 3(b).

### 4. Results and discussions

#### 4.1 Results of parameters for calculations

From field survey for tidal waves on April 21$^{st}$, 2020, authors have found parameters of tidal waves such as HWL of 2.0 meters, MSL of 1.05 meters, and LWL of 0.1 meters. The geometric of embankment is found width $B_0$ of 2.0 meters, slope $n_1$ of 1v : 2h, slope $n_2$ of 1v:1h, height $H_{cd}$ of 3.5 meters, and width $B_1$ of 12.5 meters as well as space $S_0$ of 12.5 meters.
4.2 Results of calculations

The ground surface is identified as silty and sand layers with loose to medium density, bulk density on saturated $\gamma_{sat}$ of 1.75 t/m$^3$ [7, 8]. The calculation results of stability criterion such factor of safety for overturning $F_{s1}$, sliding $F_{s2}$, and bearing capacity $F_{s3}$ are listed in tables 1, 2 and 3 below. Table 1 shows the results that all of $F_{s1}$ is safety conditions.

Table 1. Results of stability of overturning for three points

| Cross section | The factor of safety $F_{s1}$ | Remark |
|---------------|-------------------------------|--------|
| Point-A       | 24.40 > 2                     | Safe   |
| Point-B       | 16.50 > 2                     | Safe   |
| Point-C       | 10.47 > 2                     | Safe   |

Table 2. Results of stability of sliding for three points

| Coefficient of friction $\mu_s$ | The factor of safety $F_{s2}$ | Remark |
|----------------------------------|-------------------------------|--------|
|                                  | Point-A | Point-B | Point-C |        |
| 0.20                             | 1.2< 1.5 | 0.9< 1.5 | 0.6<1.5 | All points not safe |
| 0.25                             | 1.5≤1.5 | 1.15<1.5 | 0.8<1.5 | All points not safe |
| 0.30                             | 1.8> 1.5 | 1.39<1.5 | 1.02<1.5 | Point-A (safe) |
|                                  |         |         |         | B and C (not safe) |

Table 2 shows that when used parameter of coefficient friction $\mu_s$ of 0.2 and 0.24 [8]. The factor of safety $F_{s2}$ is given not safe for all height of dike construction. Meanwhile, for height $H_{dc}$ of 3.5 meters gives the factor of safety $F_{s2}$ more than 1.5.

Table 3. shows that used silty sand parameter of coefficient internal friction of $\varphi$ of 10° for all heights of the dike. The factor of safety $F_{s3}$ for three points isobtained not safety. Meanwhile, for dike heights of $H_{dc}$ of 2.5 and 2.0 meters on the ground with $\varphi$ of 15° and safety factor $F_{s3}$ more than 2.0. Therefore, for all heights of dike construction on the ground with $\varphi$ of 20° and factor of safety $F_{s3}$ of 3.6 to 5.0.
Table 3. Results of stability of bearing capacity for three points

| Internal friction of soil $\phi$ for three points | Height $H_{cd}$ (m) | Bearing capacity $q_u$ (t/m²) | Factor of safety $F_s$ | Remark |
|--------------------------------------------------|----------------------|-------------------------------|------------------------|--------|
| 10°                                              | Point-A: 3.5         | 8.3                           | 0.9 < 2.0              | Not safe |
|                                                  | Point-B: 2.5         |                               | 1.1 < 2.0              | Not safe |
|                                                  | Point-C: 2.0         |                               | 1.3 < 2.0              | Not safe |
| 15°                                              | Point-A: 3.5         | 16.2                          | 1.8 < 2.0              | Not safe |
|                                                  | Point-B: 2.5         |                               | 2.2 < 2.0              | Safe    |
|                                                  | Point-C: 2.0         |                               | 2.6 < 2.0              | Safe    |
| 20°                                              | Point-A: 3.5         | 31.2                          | 3.6 < 2.0              | Safe    |
|                                                  | Point-B: 2.5         |                               | 4.2 < 2.0              | Safe    |
|                                                  | Point-C: 2.0         |                               | 5.0 < 2.0              | Safe    |

5. Conclusions
The research can be concluded geometrical design for dike such as width at top $B_0$ is 2 meters, slope at front of wave $n_1$ is 1v: 2h, the slope at behind of wave $n_2$ is 1v: 1h, height of embankment $H_{cd}$ of 3.5 meters, width at the bottom $B_1$ of 12.5 meters. In field investigation for cross section on perpendicular direction about 30 meters to the coastline are obtained different ground level about 2 meters, which is noted the coordinate of $0^o20'57.91"U$ and $127^o39'17.30"T$. The simulation results of empirical way are obtained ultimate bearing capacity of the subsoil $q_u$ of 31.2 t/m², the factor of safety for overturning $F_s1$ of 3.5 and factor of safety for sliding $F_s2$ of 1.8. Then, load pressure $p$ at beneath the dike due to wave and dike selves is given $p$ of 49.74 t/m². The factor of safety of bearing capacity is given $F_s3$ of 0.63 that is less than 1.0.

6. Acknowledgments
Authors would like to thanks the Soil Mechanics and Hydraulics laboratories of Study Program of Civil Department, Faculty of Engineering, Universitas Khairun for supporting this research.

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