Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

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To cite this article: Suyuti *et al* 2020 *J. Phys.: Conf. Ser.* **1569** 042042

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Bamboo Pile Installed Into Soft Ground to Increase Required Reinforcement Force for Coastal Dike

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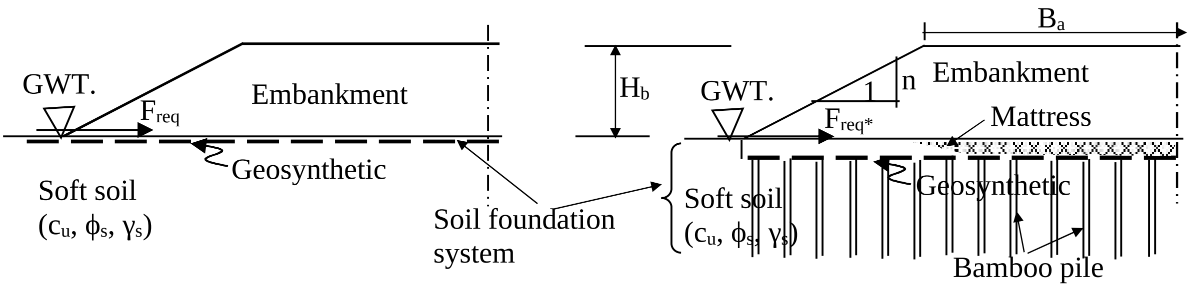
Abstract. There are three thousand kilometers of six thousand three hundred kilometers were occured abrasion in coastal area, in North Maluku. Those accidents caused by natural disaster such as big waves from seashore. In order to avoid that risk natural disaster for living safe, local government must to construct a dike. However that construction is often built on the deposit soft soils in lowlands. In which, a required stability of it's dike on the soft ground must be satisfied to support loads. Recently, the traditional way is mostly familiar to increase soil stiffness for embankments, which used local material such bamboo pile. It is pile material installed into soft ground before construct an embankment. Therefore, the study aims is focused on observation of the required renforcement force of the ground after installed with bamboo piles which investigated by full-scale test. Finally, the reliability performance of required reinforcement force of soft ground with bamboo pile, which is derived by several empirical equations.

Keywords: Bamboo pile, Soft ground, Required force, Coastal dike

Introduction

A deposit soil in lowland area is generally consisted of soft soil, peat soil and loose granular materials. The deposit material of lowland gives a stiffness of soil foundation for embankments. As consequency of that natural situation, a stability criterion is very weak to support loads from the embankment. This research is focused on how to predict an overall stability such safety factor of foundation of soft soil on thick layer. In order to evaluate it's safety factor (Fs), the required force (F_{req*}) on reinforcement system for soft soil is derived from the coefficient of friction μ_r.



a. Foundation soil with geosynthetic b. Proposed foundation soil system

Figure 1. Required force on reinforcement of soil foundation system using bamboo pile

where c_u, ϕ_s, γ_s are the cohesion undrained, the internal friction and the bulk density of submerged soft soil, respectively; GWT. is the groundwater table; F_{req} and F_{req*} are the required force on reinforcement without pile, and required force on reinforcement with bamboo piles, respectively. B_a and n are the width and the slope of embankment, respectively.

Figure 1 shows the reinforcement system, which is usually using for design construction of embankment on the soft ground. Therefore in Figure 1.b, the foundation soil system, which is used traditional method as foundation soil. The construction procedure of it's method included (i) installing bamboo pile, (ii) placing geosynthetic on the ground, and (iii) spreading and compactng mattress materials on geosyhthetic [1]. In which before installed pile, a mattress placed on the ground with same thickness of it's mattress and level of the ground.

In order to explain a maximum force of foundation of soft soil (P_{req*}) for embankments on soil foundation traditional, the research proposal is presented as follows.

2. Fundamental theory

Ministry of Public Works of Indonesia (M.P.W.) has published a traditional method of reinforced soft ground. They were reported that trial embankment on mattress with soft soil mixed by cement, and its spreading and compacting on timber pile installation, in which made by spacing s = 3d, length L = 4m, diameter d = 12cm) [2, 3]. On that construction way mentioned above, the safery factor (Fs) was increased more than Fs of 1.30, it is possible to design an embankment by a height (H_b) is targetted construction more than H_b of 3.0 m.

The implementation of the traditional reinforced soft soil for bank was investigated by implementing traditional reinforcement model that made by conducting full-scale test. Suyuti et al. reports that traditional reinforcement method was contained by installing bamboo pile (where worked by diameter d = 8.1 cm, length L = 1.0 m, spacing s = 3d), putting geo-bambo on the bamboo piles, and placing soil bags on the geo-bamboo that soil mixed with cement 10%, it was constructed with two layers of soil bags by implementing thickness 0.22 m, and very soft soil obtained soil consistency q_u = 10 kPa. They were reported that average of CBR field method was found about 4.86% [3].

Jewel presents a fundamental theory for a maximum force of foundation soil (P_{req}) of embankment fill on the geosynthetic without pile as expressed in Figure 1.a [4]. Then the maximum force (P_{req}) was defined that

$$P_{req} = P_{fill} + P_{found} \quad (1)$$

The research is focused on the maximum force on reinforced by bamboo (P_{req*}), it may be defined by [5, 6]

$$P_{req*} = P_{fill} + P_{found*} \quad (2)$$

$$P_{req*} = \frac{1}{2} K_a ¥_b H_b{}^2 + «_{r*} s_{u0} L_x \quad (3)$$

where, γ_b and H_b are the bulk density, and the height of fill embankment, respectively; s_{uo} and L_x are the undrained soil strength at the ground surface, and the distance from the embankment toe; μ_{r*} is defined by a coefficient of friction between base of embankment and mattress (soil bags) on the installation of bamboo piles on soft soil, K_a is the coefficient active of soil e,mbankment.

3. Methodology of Research

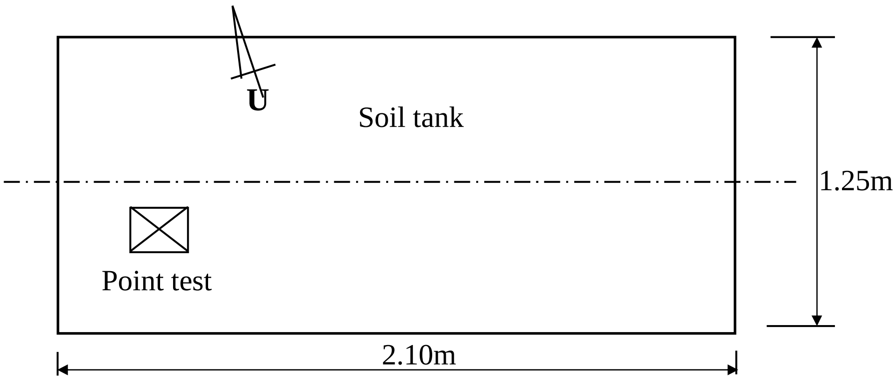
3.1 Using coefficient of friction μ_{r*}

The coefficient of friction μ_r taken into calculation for determining shear force stability (Fs_1) of coastal bank on the soft ground [7~ 8]. They were obtained Fs_1 of 0.45; 0.90 and 1.35 for variation values of friction μ_r of 0.10; 0.20; 0.30, respectively. However, those calculation results of Fs_1 above were not more than Fs of 1.50 as required in the guideline [2].

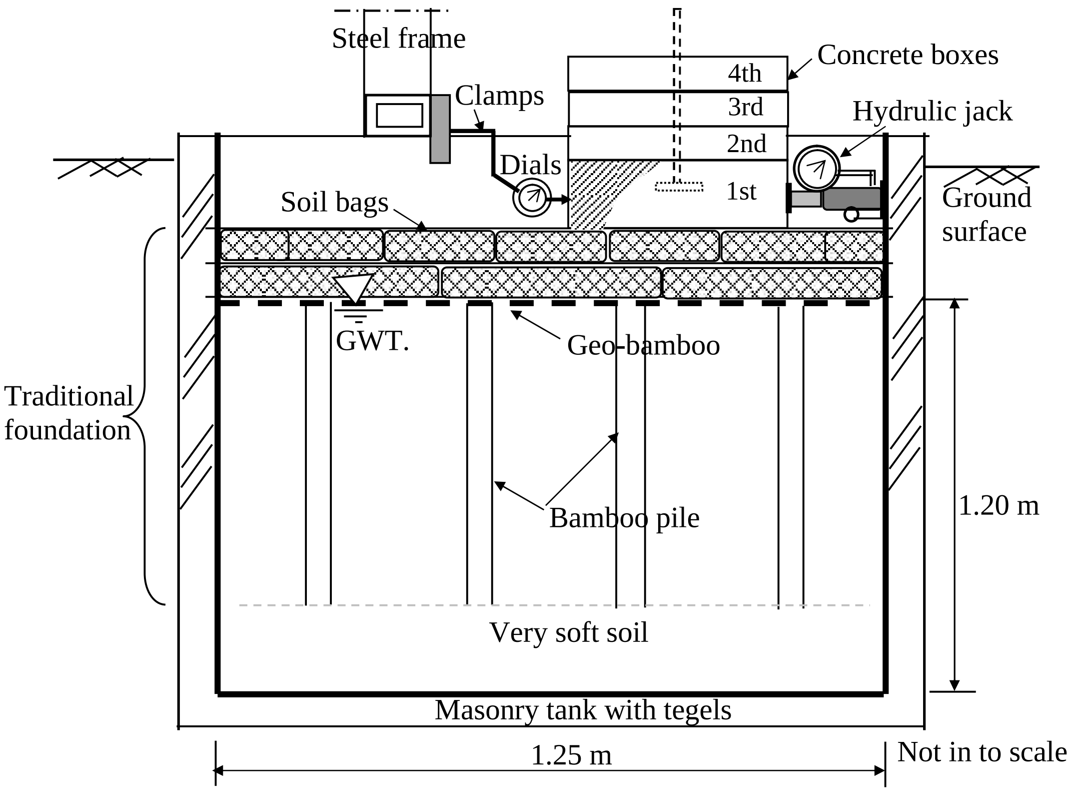
3.2 Working full scale tests

In order to observe a maximum force (F_{req*}), authors are provided full scale investigation by using construction mattress of soil bags on the installation pile of bamboo. This construction was contined model investigation of traditional way. The steps of working full-scale test are explaining follows.

1. Setting up investigation of horizontal force
   Model tests are setting up by placing concrete boxes on the mattress underlying very soft soil, a hydraulic jack 2.0 ton/m^2 placed at the front side of the concrete box to push horizontal direction pressure (where Grountwater table (GWT) is setting up as same level of the soft ground. Then, two dial geuges placed at behind side of the concrete boxes, it is hanged at the steel frame to monitor horizontal deformation as shown in Figure 2.



a. Top view of placing point test



b. Long section view of point-1 for working full scale test

Figure 2. Schematics of full scale test for the traditional foundation system

2. Processing full scale test
   Full-scale test method is prepared by powering static load from hydraulic jack on capacity 2.0 ton/m^2. The steps of the test method are (i) full scale investigated on two points, see Figure 2(a), (ii) powering static load agains the horizontal force by conducting hydraulic jack, (iii) investigating horizontal force (P_h), concrete boxes pushed by hydraulic jack to horizontal direction (see Figure 2), (iv) monitoring horizontal displacement by using two dial geuges, (v) staging static load (P_v) that used concrete boxes.

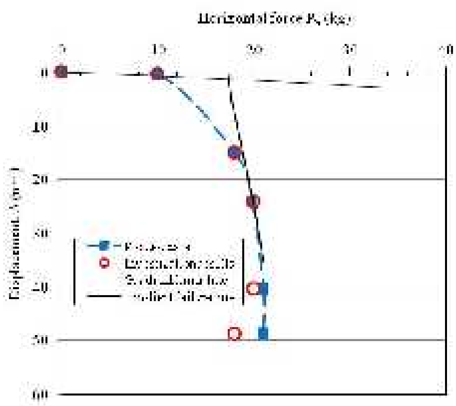
3. Figure out of full-scale tests
   The proposal research for designing required force on reinforcement of dike is provided by conducting full-scale test as Figure 3 below.

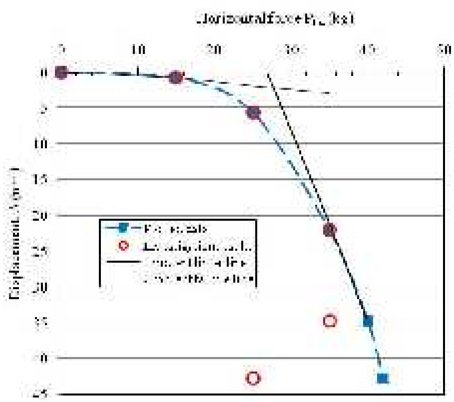
Figure 3. Observation of horizontal force under loading steps at the point-2 (July 1st, 2019)

4. Results and discussions

4.1 Calculating the coefficient of friction μ_{r*}

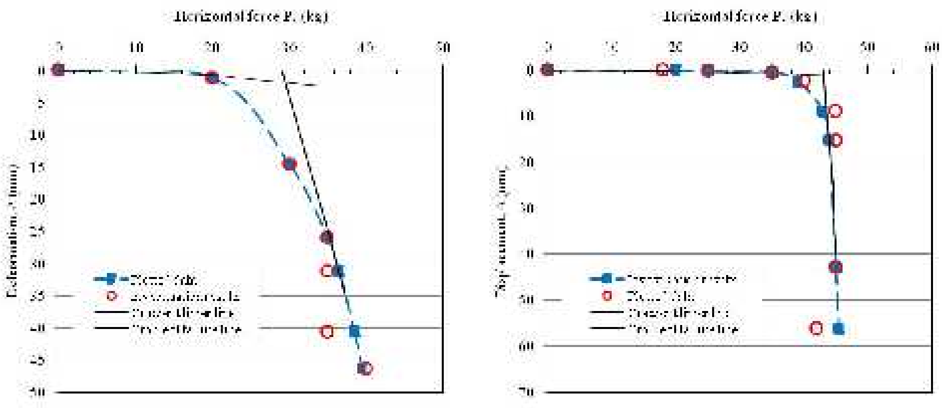
In order to calculate coefficient of friction μ_{r*}, the horizontal force batas (P_{hu}) for each loading step at two points are predicted by conducting graph of full scale dataset result. It is obtained in Figures of 4 and 5 as below [10].





a. Loading step 1st (obtained P_{hu} = 16.8 kg) b. Loading step 2nd (obtained P_{hu} = 28 kg)

Figure 4. Investigation results for loading 1st and 2nd steps



a. Loading step 3rd (obtained P_{hu} = 29.5 kg) b. Loading step 4th (obtained P_{hu} = 43 kg)

Figure 5. Investigation results for loading 3rd and 4th steps

4.2 Calculating the coefficient of friction

The dataset of horizontal force ultimate, the calculation results of coefficient of friction μ_{r*} is presented. The dataset of testing results as explained in figure 4. The calculation results of the coefficient of friction between mattress and concrete box on very soft soil with timber pile (μ_{r*}) is obtained μ_{r*} of 0.201.

4.3 Applying the coefficient of friction on the embankment

The values of coefficient of friction with variation for soil subgrade with bamboo and without bamboo pile are applied beneath the embankment that used traditional reinforcement. The embankment parameters used height H_b up to 4.50 m, bulk density γ_b of 19 kN/m^3, internal friction of soil ϕ_b of 35^o, slope of embankment n of 1.5, width at the top B_a of 16.5m [2]. Meanwhile, subgrade of soil used very soft soil cohesion with parameter c_u of 5 kN/m^2 [3].

5. Conclusions

The coefficient of friction of subgrade of very soft soil increased from μ of 0.1 for without pile untill μ_{r*} of 0.201 for with pile. The required force on reinforcement is also increased due to significant values of the coefficient of friction μ_{r*}. However, this model full-scale test is only limited on investigation that conducted by concrete box on the mattress. The results of μ_{r*} are influenced by frictional surface of the rigid concrete.

6. Acknowlegments

Authors would like to gratefully acknowledge the Ministry of Research, Technology and Education of Indonesia for supporting fund of the Competitive Research of Higher Education, Universitas Khairun in 2019. Authors like also to thanks to the Soil Mechanics Laboratory of Study Program of Department of Civil Engineering, Engineeering Faculty, Universitas Khairun for supporting this research.

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