International Journal of GEOMATE, Jan., 2020, Vol.18, Issue 65, pp. 102 - 109
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2020.65.59237
Geotechnique, Construction Materials and Environment

PREDICTED OVERALL STABILITY OF EMBANKMENT ON VERY SOFT SOIL REINFORCED BY BAMBOO PILES BASED ON FULL-SCALE TEST DATA

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ABSTRACT: Local government has built a coastal dike for countermeasurebig waves from the seashore in North Maluku.As consequence, the condition of the ground has consisted deposit very soft soils. As far as, a traditional foundation system such mattress and bamboo pile installed to increase bearing capacity of the soft ground. However, theIndonesian guidelines recommended to design embankment using trial data from the field test data,it is to difficult to applied by local engineers and government. Therefore, theproposal of research is a simple method using reasonable physical equations for predicting overall stabilityof dike on very soft soil based on full-scale tests on the traditional foundation, which modeled a mattress from soil admixed cement on the geo-bamboo,and its supported by bamboo piles. In which are modeled the mattress contained soil with cement 10%, thickness, D_m of 22 cm, bamboo pile installed by diameter, d of 8.1 cm, spacing, s of 3d, length, L of 1.10 m.In order to design the parameters of coefficient of friction α_p for overall stability, concrete blocks were placed on the mattress reinforced bamboo piles. Finally, the overall stability such factor of safety, Fs is found more than 1.2 for design height of embankment, H_b less than 1.0 m.

Keywords: Overall stability, Factor of safety, Embankment, Soft soil, Bamboo pile, Full-scale.

1. INTRODUCTION

Ministry of Public Works (MWP. 2014) reported that 3,000 kilometers of 6,300 kilometers occurred abrasion due to natural disasters such as big waves from offshore [1]. On the other,the lowland area consisted deposit materials of loose granular and soft soil. Indonesian locally has a traditional way to increase soil stiffness for soil foundation, which used local pile such bamboo, or timber. It is installed into soft ground before constructing embankment**.**

The technical design of traditional reinforcement has been taken a problem for implementing in the field, because its design method must be worked a trial, before construct rill embankment. The traditional reinforcement method is shown in Figure 1 [2, 3].

where B is width of the foundation; D_t is the depth of mattress; L_p, d_p, s are the length of pile, the diameter, and spacing of piles, respectively; γ_s, c_u, ϕ_s are the unit weight of saturated soil, the cohesion and the internal friction of soil, respectively; GWT. is the groundwater table.

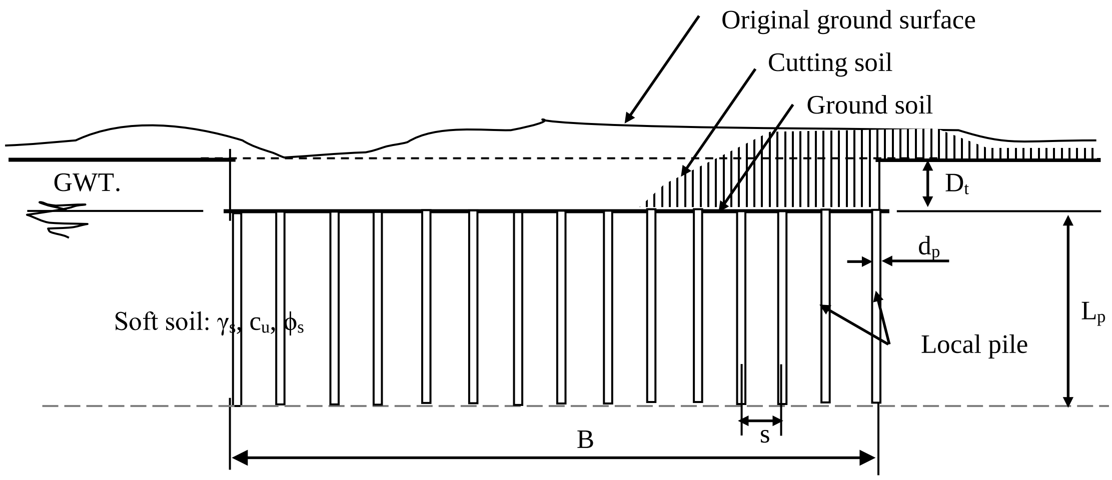


Fig.1 Cross-section of the traditional reinforcement method for embankments

There are natural and technical problems for constructing a bank on soft ground. Indonesian guidelines have been reported in how to construct a bank on the soft ground using bamboo piles, it is called traditional reinforcement method. However, that method is to difficult by local engineers and government based on requirement design for dike.

Plate loading test conducted to investigate the ratio of bearing pressure of soft clay reinforced by geo-bamboo to soft clay without reinforcementas well as ratio of footing settlement, S/B in model tests. The results of investigations were obtained the bearing capacity, q_r of 48 kN/m^2, and the ratio of footing settlement, S/B of 6% [4].

This research is focused on how to predict factor of safety, Fs of the dike based on full-scale data using bamboo piles its installed into soft ground. The safety factor is derived from several physical equations as explained below.

2. LITERATURE STUDIES

Palmeira et.al. (1998) presented an analysis of embankment on the soil foundation reinforced by geosynthetic (without pile) was reported on how to predict factor of safety, Fs. The empirical equation derived by following equilibrium role such a slip circle failure model. The undrained shear strength (s_u) of thick soft soil used increases with depth, z. The factor of safety is inserted a required force on the geosynthetic reinforcement in the calculation [5, 6].

Irsyam M. et al (2008) reported trial test for coastal embankment on soft clays with down depth 25 meters reinforced mattress bamboo and its supported by cluster bamboo piles located at Tambak Oso, Surabaya. The results of the trial of embankment height, H of 3.25 m haveobtained the factor of safety, Fs and vertical settlement by consolidation, S [7].

Suyuti et al (2018) reported mattress contained soil with cement on supported bamboo piles. From the full-scale test, the California bearing ratio, CBR-field was given CBR- field of 4.8%. This value was equal to the ultimate bearing capacity calculation for continues with width footing (q_u) = 48 kN/m^2 [8].

Therefore, the factor of safety, Fs of embankment on the traditional reinforcement method is expressed in Figure 2. It can be proposed by [6]

$$Fs = \frac{s_{u0}}{\gamma_b H_b}\left\{4 + \frac{\rho n H_b}{s_{u0}} + \sqrt{\frac{2(1+\alpha_p)\rho n H_b}{s_{u0}}}\right\} \quad (1)$$

Where B, H_b, n are the width, height, and slope of embankment, respectively; c_u, ϕ_s, γ are the cohesion, internal friction and unit weight of foundation soil; R_F is the required force, s_{u0} is the undrained shear strength of soil at the ground surface, ρ is rate of increase of undrained strength with depth.

The required force on the reinforcement system, R_F is defined by [9]

$$R_F = \tfrac{1}{2} s_{u0} \times B \times \alpha_p \quad (2)$$

Active force due to height of embankment, P_a is

$$P_a = \tfrac{1}{2}\gamma_b \times K_a \times H_b{}^2 \quad (3)$$

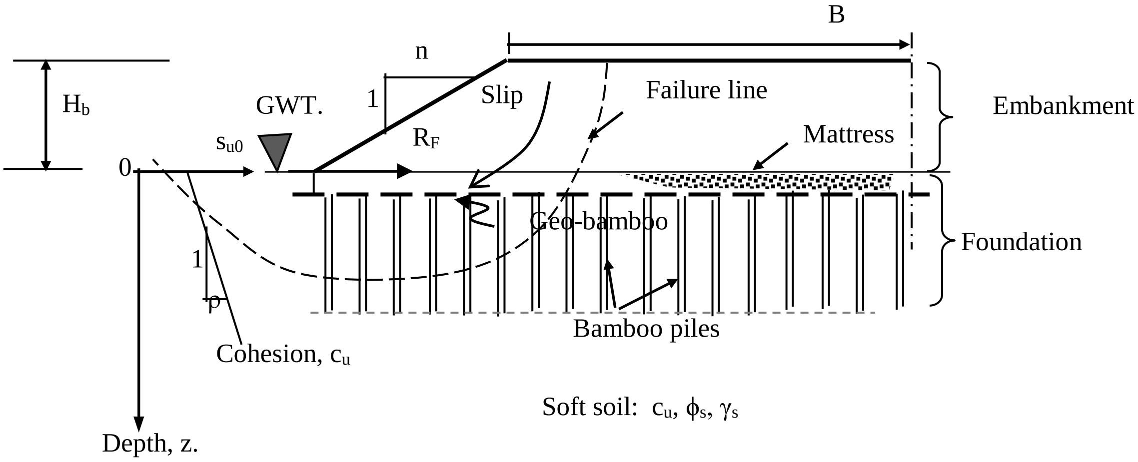


Fig.2 Cross-section slip circle failure of embankment on the soil foundation

$$K_a = \tan^2(45^o + \frac{\phi_b}{2}) \quad (4)$$

where α_p is a ratio between mobilized shear stress and undrained strength of soil with piles at the ground surface; K_a is the coefficient of active pressure of embankment; $\gamma_b$and ϕ_b are unit weight, and internal friction of soil embankment, respectively.

3. METHODOLOGY OF RESEARCH

3.1 Research Proposal Plan

In order to investigate the performance of the foundation installed bamboo piles, authors were provided a full-scale test by using a mattress reinforced by geo-bamboo on supported by bamboo piles. The illustration of research proposal plan is explained as shown in Figure3.

Figure 3 shows concrete made 5 (five) boxes, it is put on the mattress (soil bags admixed cement). Then, the horizontal force from the hydraulic jack is used to investigate the failure condition of the loading.

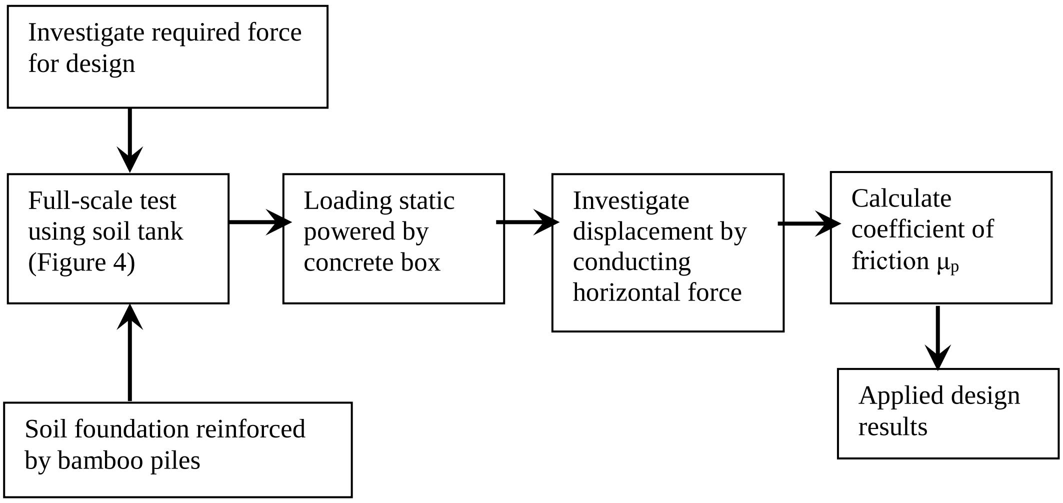


Fig.3 Schematics of the proposal for investigating mattress reinforced by geo-bamboo and bamboo piles

3.2 Full-Scale Test

Soil foundation reinforced bamboo piles included: (i) Filling down very soft soil material as subgrade, (ii) Installing bamboo pile into the subgrade; (iii) Laying geo-bamboo on top of bamboo piles; and (iv) Placing soils bags as mattress [7].It is expressed in Figures 4 and 5.

A full-scale test is set up by powering static-hydraulic jack placed at the wall of soil tank.

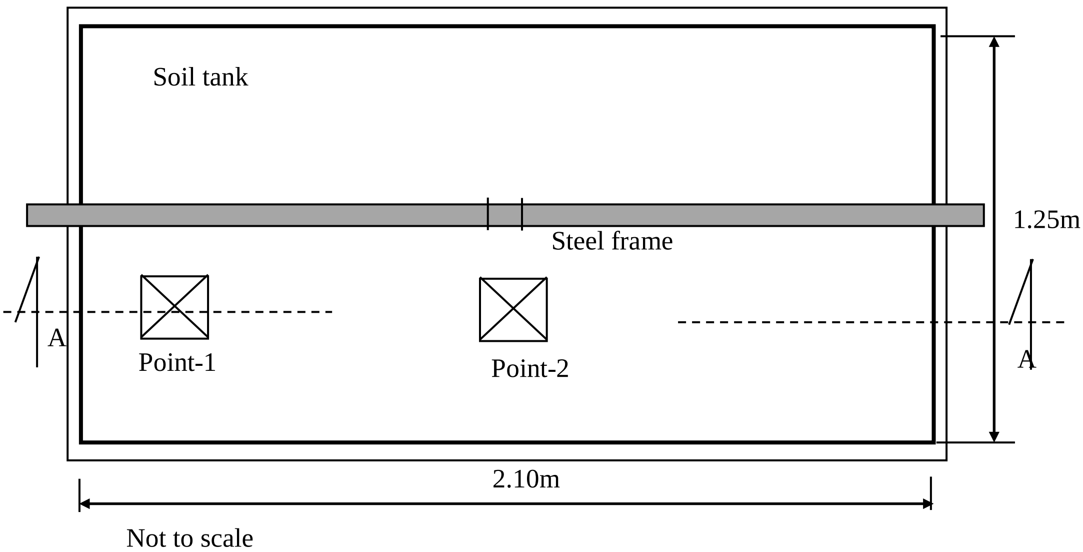


Fig.4 Top view of full-scale test for investigations

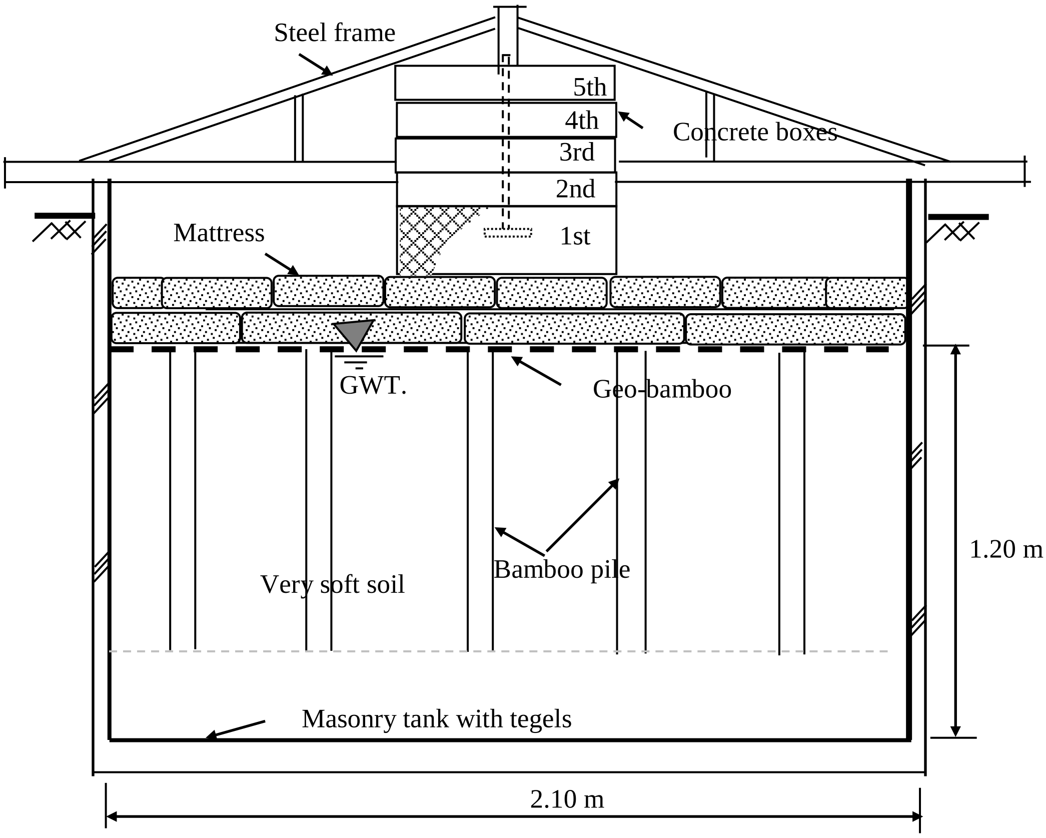


Fig.5 Long-section of the full-scale test by placing concrete boxes at point-2

Fig.6 Photo of investigation at the point 1

Fig.7 Photo of investigation at point 2

Figure 4 shows the detail of the layout full-scale test.While concrete boxes put on the mattress reinforced geo-bamboo and supported by bamboo piles, in which soil admixed cement 10% by thick 0.22 m, installed bamboo pile such diameter d of 8.1 cm, spacing, s of 3d, length, L_p of 1.10 m. Figure 4 shows the mattress uses on the traditional reinforcement system. These models were investigated two points, then to observe the correlation between normal load pressure (from concrete boxes) and shear load (hydraulic jack, the capacity of 2 ton).

Figure 6 and 7 shows the investigationviews at point 1 and point 2 respectively.

3.3 Full-scale test data

The observation of horizontal force by conducting a stage of loads for two points. The ultimate horizontal forces for each loading stage, $P_{hu}$are predicted by conducting the normal pressure from the concrete box, it can be estimated by following Figure 8 below [10, 11].
where : 0J is elastic zona, JK is plastic zona, KF is failure zona, P_{hu} is predicted an ultimate loading from the intersection of two lines at point U.

The cumulative weight of concrete boxes for loading stress is listed in Table 1.

The test results data are investigated by normal stress and shear force (by hydraulic jack) up to failure condition for both two points as expressed in Figures 9(a) and 9(b). Then static load started from first loading stage.

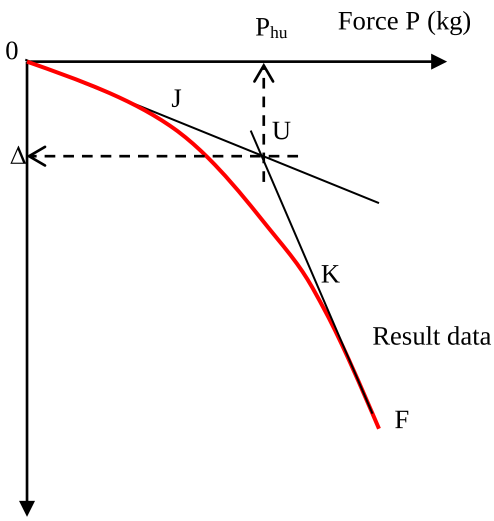


Fig.8 Estimatingthe ultimate horizontal force, P_{hu} based on results of investigation data

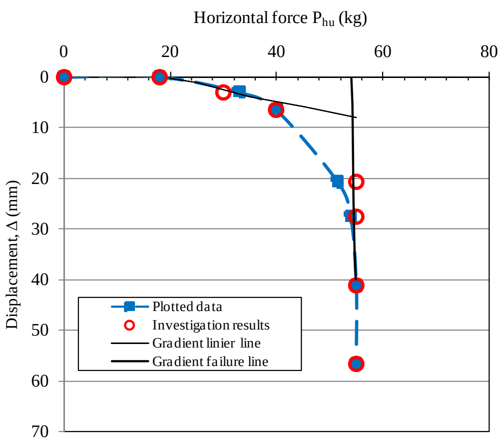
Table 1. The cumulative weight of the concrete box

Weight of each concrete box (kg)	Cumulative weight of concrete boxes (kg)	Loading stages
101	101	1st
47	148	2nd
53	201	3rd
54	255	4th
55	310	5th

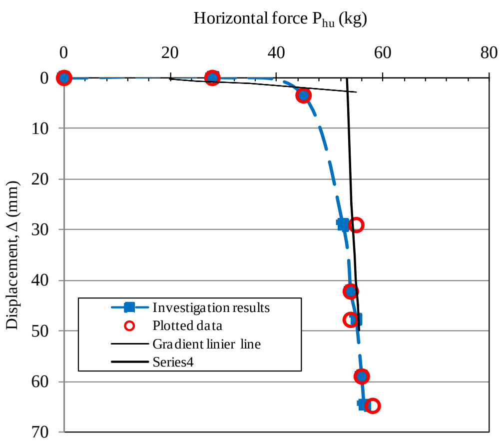
4. RESULTS AND DISCUSSIONS

4.1 Calculation of Investigation Results

In order to calculatethe coefficient of friction α_p, ultimate the horizontal force, P_{hu} for each loading stage of two points.



a. Loading stage of 5th at point-1



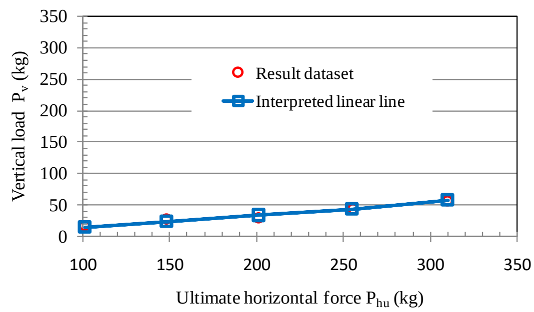
b. Loading stageof 5th at point-2

Fig.9 The correlation of horizontal force and horizontal displacement for each loading stage at the two points

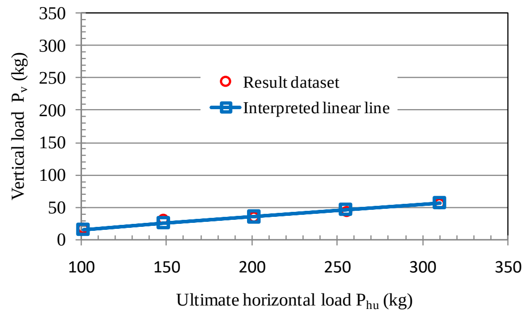
Figure 9 shows the results data of full-scale investigation.

4.2 Calculating the Coefficient of Friction

Based on the results data of the ultimate horizontal force as presented above in Figure 6. In order to calculate a coefficient of friction α_p for the mattress on the very soft soil reinforced geo-bamboo that supported by bamboo piles, the correlation between ultimate horizontal force and vertical load is shown in Figure 10 as below.



a. Graph results of point-1



b. Graph results of point-2

Fig.10 Relationship between horizontal force and vertical load

Table 2. Calculation results of the coefficient of friction α_p

Loading stage	The vertical force of boxes, P_v (kg)	Ultimate horizontal force, P_{hu} (kg)		The coefficient of friction, μ_p	
		Point-1	Point-2	Point-1	Point-2
1st	101	16.8	17.9	0.208	0.240
2nd	148	28.0	30.4		
3rd	201	29.5	35.0		
4th	255	43.0	44.0		
5th	310	57.0	55.0		

Therefore, to know the use of mattress performance as mentioned above, the coefficient of friction of two points is calculated as listed in Table 2.

4.3 Factor of Safety

Table 2 shows the coefficient of frictions,αp for two points, the average friction is obtained αp of 0.224. The factor of safety, Fs is emphasized for the circle failure model, which calculated by using overall stability theory.

Those empirical equationscan be applied for an embankment on very soft soil reinforced by the traditional reinforcement way. The simulation of this embankment was applied by using parameters of the subsoil are used cohesion, suo of 5 kN/m2, strength rate, ρ of 0.2 [6]. While the embankment designed parameters such slope, n of 1.5, the variation of height, H of 0.75 m to 2.0 m, the unit weight of soil, γ of 19 kN/m3, the internal friction, ϕ of 25o, width of embankment, B of 12.0 m [3].

The simulation results of a factor of safety, Fs are presented in Figure 11.

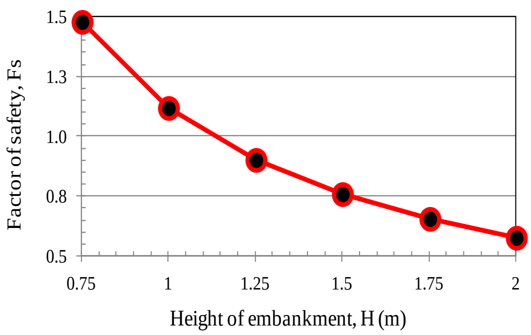


Fig.11 Relationship between height H and factor of safety Fs

The required force on the reinforcement, RF is found 13.4 kN/m. However, the active force due to embankment is given force, Pa of 23.4 kN/m for height, H less than 1.0 m.

The results of the trial of embankment height, H of 3.25 m in field.It is found design criterion such as the factor of safety, Fs of 1.6 and vertical settlement by consolidation, S of 54 cm [7].

A trial embankment data was reported that embankment (H of 3m) on soft soil reinforced bamboo pole – geotextile composite, it was found the total settlement about 58.8 m for 418 days [12].

The factor of safety is influenced by tension and capacity of reinforcement way. While the bamboo pole as the mattress can be reduced loads from embankment.

5. CONCLUSIONS

The factor of safety, Fs for embankment on very soft soil reinforced geo-bamboo and bamboo pile is found more than 1.20 for the height of embankment, H less than 1.0 m. The active force of embankment for the coefficient of friction µp of 0.224 is given Pa of 23.4 kN/m.

The height of embankment on soft soil reinforced bamboo pile as the mattress can be constructed more than a height H of 3m. The mattress also is placed to reduce the load pressures from embankment.

Those investigation results are affected by assuming thatthe surface of the concrete boxes model tests as a rigid material. However, it may change the value based on type of reinforcement.

6. ACKNOWLEDGMENTS

Authors would like to gratefully acknowledge the Ministry of Public Works, Technology and Education of Indonesia for supporting funds of the competitive research scheme of Higher Education, Khairun University in 2019. The authors also thank the Soil Mechanics Laboratory of Study Program of Civil Engineering, Faculty of Engineering.

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