The Effect of Pile Reinforcement To Bearing Capacity On Design Physical Modelling Of Residual Slope

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Abstract. Pile reinforcement in rows as slope reinforcement elements reduces lateral soil pressure through force is transfer to anchoring piles at a certain distance on the slope. The use of residual soil and embankment soil above with reinforced concrete piles is influenced by pile diameter, pile distance, the position of pile placement Lx/L = 0.75 with the slope ratio of the embankment to the determined residual soil. The test bath is 1.5 m long, 1 m wide and 1.5 m high. Loading is done by adding the load gradually until it reaches the load collapse on the slope modeling which is modeled as a strip footing by channeling the load from the load cell and looking for bearing capacity of the foundation. The problem studied was to find out the changes in the field collapsed on the embankment slope above the residual soil without and with reinforcement. The test results of experiment shown that utilizing of pile reinforcement on a slope have bearing capacity improvement, and the installation of strain gage on the pile to determine the strain and lateral deflection that occurs on the pile.

Introduction

From the geographical location, causing a large part of Indonesia's territory to have residual land and increasing development activities, many hills have to be turned into housing, agriculture, plantations and roads. Residual soil properties (soil due to weathering pile strength in rows as slope reinforcement elements reduces lateral soil pressure by transferring forces to anchoring poles at a certain distance on the slope. With the ability to reduce lateral soil pressure, slope stability is expected to increase.Plastic soil displacement on pole reinforced slopes in rows is influenced by distance between poles, pole diameter and pole length. The effect of the burden is still taken into account because the construction of buildings on the slopes can lead to structural failure. The pile is considered a passive pole in the unstable topsoil. Several studies on slope reinforcement in improving and increasing the stability of unstable residual soil slopes include: Tan, L.P., C.Y. Lee and T. Sivadass, 2008; Nilo Cesar Consoli et al, 2017; Vítor Pereira Faro1 et al, 2018; Bengt H. Fellenius et al, 2007; Jianhong Jia et al, 2014; Atefeh, 2014. Research on laboratory models for pile-reinforced slopes in rows using pile reinforcement mostly examines sand soil types with reinforced piles made of aluminum and steel piles (Mostafa A. El Sawwaf, 2004; Muthukkumaran K., 2004), Boominathan & Ayothiraman, 2007 with aluminum pole reinforcement on clay soil, Kavitha PE & Dr. Narayana K.P, 2012 with reinforcement of aluminum piles on sand soil. Whereas for research on laboratory models using residual soils it is very rare to do this because because in terms of the soil itself has a complex problem.

Bearing Capacity Improvement Analysis (BCI)

The influence of the existence of reinforcement using either pile or other reinforcement is described in the form of non-dimensional quantities commonly called BCI. Bearing Capacity Improvement (BCI) is a ratio that explains the comparison between the carrying capacity of the soil when given reinforcement with the carrying capacity without being reinforced (ratio that explains the limits of load before and after pile reinforcement). The value of BCI carrying capacity can be determined based on two things, namely carrying capacity during ultimate or BCIu (SM Marandi, 2008; PK Haripal et al., 2008; EC Shin et al., 2000; MJ Kenny et al. 1997) and the same carrying capacity or BCIs (A. Zahmatkesh et al., 2010; SM Marandi, 2008). BCI values ca be wrote as equation:

$$BCI_u = \frac{q_u(R)}{q_u} \tag{1}$$

Where :
qu (R) = ultimite bearing capacity with reinforcement
qu = ultimite bearing capacity without reinforcement

Material and Methods

Box Model and Footing

The box is made of fiber glass with a length of 1.5 m x width of 1.0 m x 1.5 m high. The base of the box is reinforced with a 1.4 cm thick steel plate while the back of the box uses a 4 mm thick plate, while the front side of the box uses 12 mm thick fiberglass. Stiffener plates were installed at the corners of the box using an angled steel strip 60.60.4., While the middle section was also given stiffener 40.40.4. For load retaining frames using WF 50.100.4 Boxes were made quite stiff in the hope that they could maintain field strain conditions . The use of fiberglass is expected to be observed and seen during preparation and testing. Pictures of boxes can be seen in the figure 1.

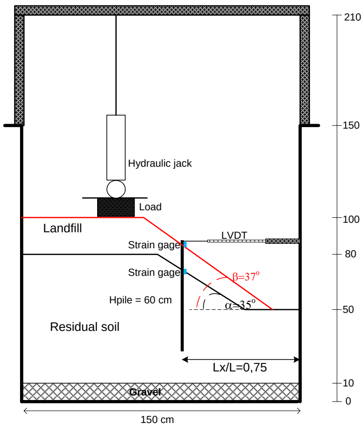

Figure 1. Experimental box

Procedure Experiment

The soil prepared as slope formation is put into a test box with a volume of 1,050,000 cm^3 divided into 7 layers for subgrade, then compaction with the principle of the weight of the soil volume to be achieved and with the help of hydraulic jacks, each layer of soil is checked water content and density as a control, then cut to slope 35^o. While 300,000 cm^3 is divided into 2 layers for landfill with each layer of 10 cm and compacted and cut slopes with variations of slope 37^o. The results of testing the water content and density are also checked. Then the strain gage is mounted on the pole with the position of the strain gage above and at the center of the pile, precisely located at the boundary between the subgrade and the embankment. The strain gage is associated with a strain meter so that the strain value can be measured. As for the installation of LVDT (Linear Variable Differential Transformer) at one end of the pole to find out the displacement of the pile and above the foundation to determine the decrease in the soil. Installation of strain gage, strain meter, dial gage, LVDT and the shape of the slopes that are ready to be tested is shown in Figure 1. Loading is evenly distributed using a hydraulic jack and is read by load cell. The measured variable in testing is a decrease in the foundation.

Sand Soil Test

Table 1. Residual Soil Physical Test Results

Model test parameters	Unit	Information
Water content (w_c)	%	64,401
γ_t	gr/cm^3	1,455
γ_d	gr/cm^3	0,98
Spesific gravity (G_s)		2,264
Degree of saturation (Sr)	%	93,6
Pore ratio (e)	%	1,558
Porosity (n)	%	0,609
Classification of USCS		Sandy silt (ML) with around 60% predominantly silt granules with low plasticity, low dry strength, fast dilution and low hardness; and about 40% contains sand
Classification of AASHTO		A-5 (Silt soil)
Classification of USDA		Vertisol soil
Cohesi (c)	kg/cm^2	0,071
Friction angle (ϕ)	^{o}	27,744

In this test there are tests without piles and 9 tests that use reinforcement. Variations of diameter (D) that used are: 2.5 cm, 3.175 cm and 3.81 cm; the distance between pile (S) are 10 cm; 11.5 cm and 12.5 cm; where as pile location on slope Lx / L = 0.75 and slope ratio between subgrade and embankment (with slope of subgrade α = 35^o) and slope of embankment (β) is 37^o, pile length 60 cm, 12 cm wide foundation.

Table 2. Variabel dalam Slope Model Test

No	Constant parameter	Independent variable	Exp.
1	Non reinforcement	b = 0,5 B	-
2	Lx/L = 0,75 α/β = 0,95 H/B = 5	D/B = 0,208; 0,265; 0,318 S/B = 0,833; 0,958; 1,042	row

Result and Discussion

To find effect of pile diameter and pile distance on the bearing capacity of the foundation, this test can be carried out using pile reinforcement with 2 variations in diameter, that used : 2.5 cm, 3.175 cm and 3.81 cm with locations on the upper slope (Lx / L = 0,75) with a pile length of 60 cm. The test results are shown from the BCI values in the figure 2, 3, 4, and 5.

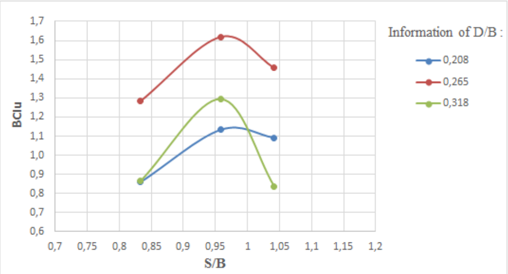

Figure 2. Relation between BCI_u and ratio pile spacing–foundation width different pile diameter

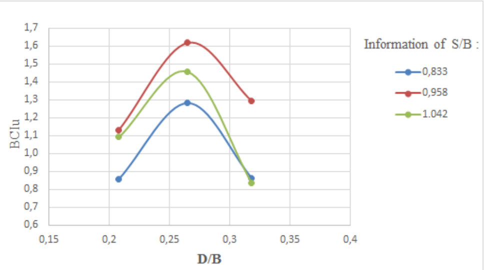

Figure 3 Relation between BCI_u and ratio pile diameter–foundation width with different space between pile

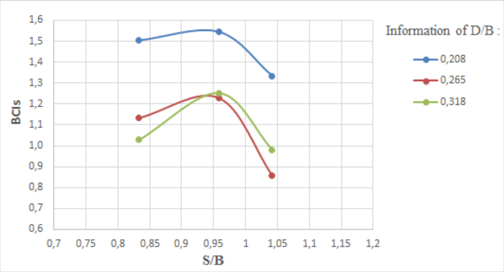

Figure 4. Relation between BCI_s and ratio pile spacing–foundation width different pile diameter

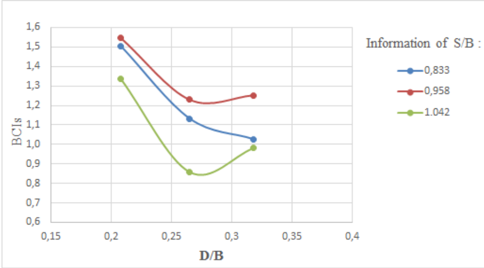

Figure 5. Relation between BCI_s and ratio pile spacing–foundation width different pile diameter

Conclusion

1. Slope reinforcement with pile reinforcement has a significant effect to increase the bearing capacity of the foundation.
2. The values of BCI_u on pile diameter reached the maximum point on 3.175 cm (11/4 ") and the maximum point on 11.1 cm as space between pile.
3. The values of BCIs on the pile diameter reached the maximum point on 2.54 cm (1") and the maximum point on 11.1 cm as space between pile.

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