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Numerical Analysis to Improve Soil Strength Using Bamboo Pile

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ABSTRACT

Soil reinforcement methods that is being developed recently. Considering into account the cost of relatively expensive, it is very necessary to try other alternatives that are cheaper and easily available around the construction site, for example the use of a bamboo pile as a soil reinforcement. Bamboo *Atter* is one kind of plant that grows abundantly in Indonesia and bamboo are very easy to obtain, and the price was relatively cheap. Bamboo does not require a long time to grow and produce great tensile strength. Tensile strength and compressive strength was higher than the bamboo wood is a material that is quite popular in the world of construction. Model testing is made of a steel drum tubes 60cm diameter with a height of 45cm ground soil. The soil very soft clay with high plasticity and swelling index. Tested by loading cell without bamboo reinforcement to know the dimensions of the ground failure at the beginning known reach 1,91mm. Pile bamboo made on actual diameter with varying heights of 10, 20 and 30cm and instilled in the soil models vertically. The results showed settlement can be reduced up to 70% on 5kN load.

Keywords: Bamboo Atter, pile, soil reinforcement, settlement.

1. INTRODUCTION

In Civil construction damage not only caused by the structure of the building factor, but also the condition of the ground on where the structure construct. The damage caused by large of settlement and very low of soil bearing capacity. Such as cohesive soil which containing of high water content. Therefore, it must be considered carefully regarding bearing capacity of the cohesive soil, whether need for improvement or soil stabilization to get the desirable soil properties so that the damage of construction can be prevented [1].

Soil stabilization to improve the bearing capacity of soil are developed fast recently, specially using eco natural material utilization. Bamboo is one kind of plant that grows abundantly in Indonesia so easy to find and the price is relatively low cost. It is only need for 3-5 years to grow and it could be used as structure materials. A lot of kinds of bamboo types are growth in Indonesia.

Characteristics of bamboo are excellent to use in construction, bamboo is a kind of strong material, straight shape, light, and easy to process. Bamboo in a round shape as used for the construction of houses, sheds, bridges, ladders, even to use as scaffolding.

Fig. 1 Soil Reinforcement Using Bamboo Pile Testing Model in Laboratory

Bamboo are recommended to be considered as a reinforcement material like a wood [2, 3]. Modeling and testing of bamboo as a soil reinforcement material is an interesting thing to be investigated in terms of the mechanical characteristics of bamboo has a tensile strength and compressive strength are very high. Modeling a bamboo as a pile on soil reinforcement is intended to determine the effectiveness of a bamboo pile to reduce the settlement that occurs in the soil due to axial force (loading test).

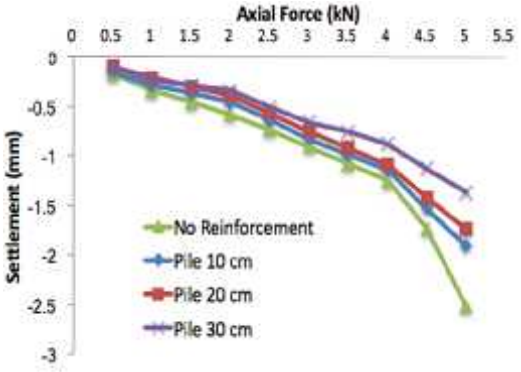

Fig. 2 Load-Displacement relationship by loading test

Plaxis software are used to analyzed and solve the geotechnical problems based on finite element method which relying on the accuracy of computation modelling calculation [4]. *Plaxis* calculation are expected given a result of numerical analysis that solved the geotechnical and model testing in the laboratory. The software is available in two kinds, there is 3D and 2D for modeling the material test [5].

2. METHODOLOGY

This research is to understand the physical and mechanical properties of bamboo materials, analyze the effect of the deep of bamboo pile to the settlement that occurred and analyze the behavior of the bamboo pile on the soil with numerical calculations. The physical characteristics of bamboo are tested in laboratories eco-material and physical characteristics of the soil tested in a laboratory soil mechanics, while models with reinforcement embankment will be tested by loading test in the laboratory.

Atter bamboo (Gigantochloa atter Kurz) or better knowing as Parring Bamboo in local Makassar people are using as pile bamboo in this research. This type of bamboo is used after preliminary characteristic testing which generate tensile strength and compressive strength better than other bamboo, very widely used as a structural material selection in construction development in Sulawesi Selatan. The physical properties and mechanical properties of bamboo testing in this study is based on ISO 22157-1 (2004) and ISO 22157-2 (2004). Soil used is a soft clay soil. Physical examination and mechanical as initial parameters based on ASTM and ISO standars.

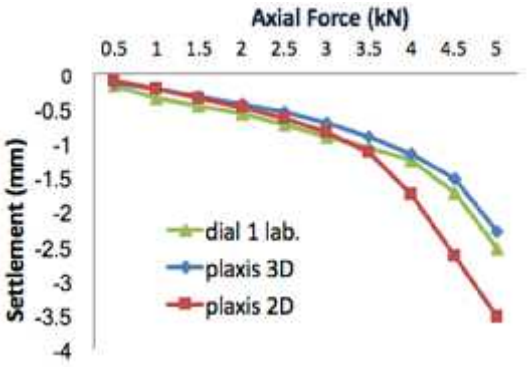

Fig. 3 Load-Displacement relationship soil without reinforcement

Soil reinforcement model test container with bamboo material in this study were made by using a cylindrical drum diameter of 60 cm and a height of 45 cm. Inside the container will then be filled with compacted clay material. Length of pile of bamboo used is made in three variations, that is 10, 20 and 30cm.

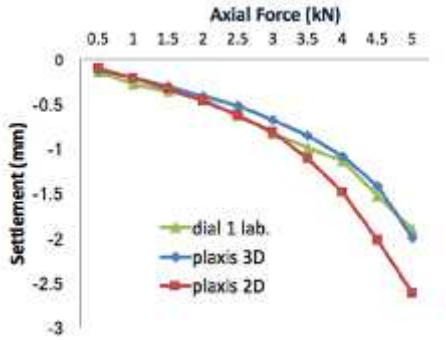

Fig. 4 Load-Displacement relationship soil with 10 cm bamboo pile

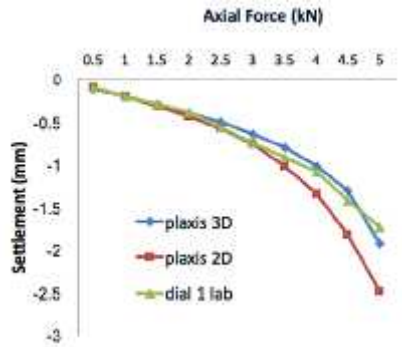

Fig. 5 Load-Displacement relationship soil with 20 cm bamboo pile

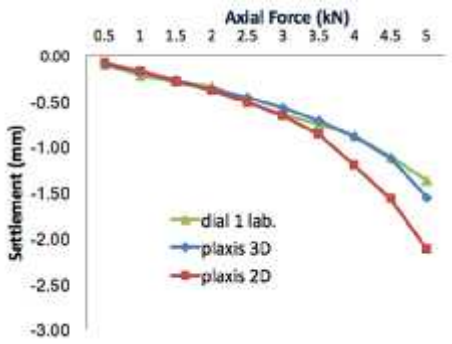

Fig. 6 Load-Displacement relationship soil with 30 cm bamboo pile

The test results of model in a laboratory will be analyzed the effect by using numerical analysis applications Plaxis 3D and 2D with Mohr-Coulomb analytical methods, which is consider of 5 parameters to analyze the soil model.

3. RESULTS AND DISCUSSION

Physical characteristics of soil performed is to classify the soil types used in this research. The results show that the Plasticity Index of the soil is 13, 38%. The value of the plasticity index classified as a high one. Unconfined compression test result shows that the soil could reach 2, 51 kg/cm^2 of load given, with 7 kN/m^2 of cohesion and $\square = 20{,}34^0$ of friction angle.

The tensile strength test of the bamboo according to the standard of bamboo testing materials ISO/TR 22157-2 "Bamboo-Determination of Physical and mechanical properties" and also following the test recommended by the previous research. The results of the tensile strength are 2989, 77 kg/cm^2 with 0,02 of strain, modulus of elasticity of the tensile is 14.649,88 MPa. The

compressive strength is the strength of bamboo against forces from the outside comes from parallel directions of fibers that tend to shorten or squeeze the bamboo simultaneously.

The results given 53, 04 – 65, 43 MPa of stress pressure. Flexural strength of bamboo is the ability of material against the forces which comes perpendicularly to the fiber axis. Bamboo samples are given roller supports in the both ends. The results show that flexural strength reaches 86,505 Kg/cm² for the bamboo sample with node, and the sample without node 43,253 Kg/cm².

A. Results of Bamboo Pile on Soil Testing

The bearing plate test was conducted on 4 samples, which is one soil sample without reinforcement bamboo pile, soil sample with 10 cm of bamboo pile, 20 cm of bamboo pile, and sample with 30 cm deep of bamboo pile as a soil reinforcement. Test results in the laboratory conducted then generate to the Load-Displacement relationship as follows;

By the test results, the soil without bamboo pile reinforcement has 2, 52 mm of settlement in the end of loading given until the soil has collapsed is 5 kN. Soil with 10 cm of pile bamboo settlement is 1.91mm. Soil with 20 cm bamboo pile reinforcement only has 1.74 mm of settlement. While the sample with 30 cm of bamboo pile has 1, 37 mm of settlement when given 5 kN of load.

The testing results analyzed, and it shows that the deeper of the bamboo pile approaches the soil with the stronger bearing capacity increases the strength of the soil in supporting the structural load above it.

From the graphs above, it can be compared between the Load-Settlement relationship generated in laboratory testing and the results of the numerical analysis of the Plaxis software.

Figure 3 to Figure 6 as it shows, it can be concluded that there are some similarities in behavior in soil samples when given a load samples without bamboo piles, to a sample with 30 cm of bamboo pole reinforcement, where the largest settlement occurs on the ground without bamboo reinforcement, whereas the smallest settlement occurred in the sample with bamboo pole reinforcement 30 cm (deepest).

In the graphs can also be seen other soil behavior where the sample given of 3.5kN of load, the soil began to be in the plastic area so that the settlement that occurs more extreme when compared to previous loading.

In addition, it can be seen that in the plastic area of the soil, the settlement value occurring in the laboratory test results, 2D Plaxis results, and the results of Plaxis 3D begins to occur where the settlement in Plaxis 2D calculation is more extreme than the results of laboratory tests and plaxis results 3D. The outputs generated by the 3D plaxis tend to remain close to the results of laboratory sample testing.

B. Shape of Deformation on Plaxis

On 2D Plaxis, bamboo pile in plane strain modeled with circular plate with 0.8

cm. while on 3D Plaxis, bamboo pile modeled as a single pile with 8 cm of outer diameter and 0.8 of thickness. Poisson ratio of bamboo used 0,30 kN/m3 taken from previous research. 30 cm diameter of bearing plate used a steel material.

The linear elastic perfectly-plastic Mohr-Coulomb model requires a total of five parameters, which are generally familiar to most geotechnical engineers and which can be obtained from basic tests on soil samples.

Table 1. Material data used in Plaxis Software with Mohr-Coloumb Analysis Method.

Indicator	Value
Types of Soil	Clay
Analysis Model	MC
Boundary Type	Undrained
γ_{sat} (kN/m^3)	20
γ_{unsat} (kN/m^3)	17.7
E (kN/m^2)	3838.41
ν	0.3
Cohession (kN/m^2)	7
Φ	20.34^0
ψ	0^0

Table 2. Bamboo material and Bearing plate input in Plaxis

Material	Bamboo	Steel Plate
Model types	Circular tube (3D) Plate (2D)	Floor (3D) Plate (2D)
Thickness/d(m)	0.008	0.025
Diameter (m)	0.08	0.3
Γ (kN/m^3)	6.6	78.5
E (kN/m2)	81147400 (E press)	210000000
N	0.3	0.3

From the figure 7, we could see the transformation of stress-strain which occurs in the soil as a result of axial force given into the bearing plate.

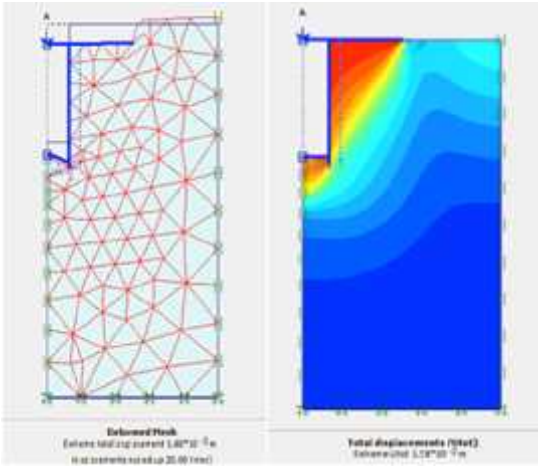

Fig. 7 Shape of Deformation on Plaxis 2D

Figure 8 shows the shape of deformations to the sample with bamboo pile reinforcement on numerical application Plaxis 3D. Colors graduation shows the shape of deformation as impact of force given to the soil by loading. Graphs below shows the relationship of load-displacement on soil samples, the colors graphs show as analyzing result of Plaxis.

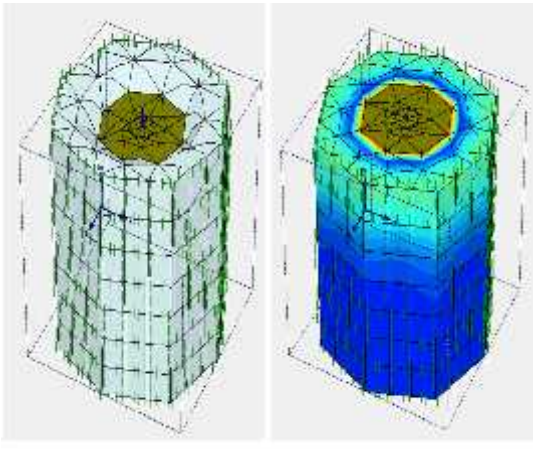

Fig. 8 Shape of Deformation on Plaxis 3D

4. CONSLUSION

Based on the research and analysis of the test results compared with the results of

numerical analysis software, it can be concluded several things as follows:

a. On the mechanical properties of Atter bamboo for bamboo with node, compressive strength is smaller than the compressive strength of bamboo without node. Based on the calculation of stress-strain pressure relationship in the laboratory, then in the modulus of elasticity of the whole bamboo pressure between 5494 - 8115 MPa.
b. Based on test results of loading test on soil using bamboo pile as reinforcement, it is concluded that the soil reinforced with 30 cm bamboo pile has the smallest settlement. More deeper the bamboo pile that becomes reinforcement in the soil clay, more small the settlement occurs. The result of the analysis leads to the soil which has deeper bamboo pile has a more high bearing capacity and also to the surface of the soil ground.
c. FEM analysis through 2D and 3D Plaxis program showed relatively harmonious results with laboratory test results on soil behavior with bamboo reinforcement, where the largest settlement occurred in soil samples without bamboo pile reinforcement, while the smallest settlement occurred on soil with bamboo pile reinforcement longest (30 cm)

To improve the knowledge quality of bamboo pile effect it is suggested to:

a. The test result from this research only shows the magnitude of the influence of pile bamboo, so it is needed for further study to know how the condition of soil characteristics around pile bamboo.
b. Further research on bamboo reinforcement of other types of soil material is required and carried out on a larger and more complex scale..

5. REFERENCES

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