Recent Trends in Civil Engineering and Built Environment Vol. 4 No. 2 (2023) 240-250

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

Improvement of Soil Bearing Capacity Using Bamboo Technology

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DOI: https://doi.org/10.30880/rtcebe.2023.04.02.027
Received 06 January 2022; Accepted 15 January 2023; Available online 20 July 2023

Abstract: In some cases, for construction, the engineering performance of the soil at the site may not meet the requirements according to the design. This factor can be identified during the site investigation phase of the project. Soil such as clay can be a hassle to deal with during and also after the construction as the settlement process can be lengthy and might be ongoing until the project is already finished. This will lead to problems to the structure such as cracking for buildings and also for pavements. This study will emphasise on the improvement of soil bearing capacity using other methods which are more sustainable. Bamboo is a viable alternative due to its physical and mechanical properties which can withstand a high degree of load without failing. In order to prove the suitability of bamboo to be used as a soil improvement option, an on-field test will be carried out to compare results of soil with bamboo and soil without bamboo.

Keywords: Soil Improvement, Bearing Capacity, Bamboo

1. Introduction

Soil improvements is the process of altering the mechanical and physical properties of a soil in order to improve its engineering performance to ensure the soil is more predictable for construction purposes. Soil improvement can either be a permanent measure or just temporary measure to able the construction of a facility. The main reason for soil improvements is to improve the shear strength of the soil to mitigate any slip failure and also improve the bearing capacity of the soil, usually done to soft soils such as clay and peat soil. Another reason for soil improvements is the prevent excessive settlement occurring during construction on reclaimed land. Some of the existing soil improvements is using geogrid, geotextile micro piles, and biomediated.

According to a study done by [1], bamboo is a good material to be used to implement soil improvement. Bamboo is a sustainable material as it has a high rate of regeneration therefore it will not face any shortage of supply. Bamboo is also a strong material and can withstand high load while not compromising its structural strength. Other than implementation of bamboo as geosynthetics such as geogrid and piles, bamboo can also be used as it is, by arranging the bamboo in grids.

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There are 3 main objectives of this study: (a) To test the strength of bamboo, (b) Tto conduct and on-field plate bearing test on soil with bamboo reinforcement and soil without soil reinforcement, and (c) To compare the results of both the plate bearing test. The type of bamboo used for this research is Gigantochola Scortechinii or known locally as *buluh semantan* as this type of bamboo is readily available in Parit Raja. Test site is choosen to be at RECESS, UTHM as the soil is already known to be clay soil and the index properties is already known according to [2].

2. Literature Review

This chapter will discuss further in detail the terminology related to the topic of research as well as referencing past studies done by researchers that relates to the topic. In any construction, the foundation is an important aspect of any given structure. The foundation is vital as it needs to support most of the load from the structure above.

According to [3], various research have been done and came to a conclusion that the bearing capacity and settlement can be improved by placing reinforcements in the ground. Therefore, the studies that have been done on the past related to the topic will be further discussed in this topic to enhance the understanding regarding bearing capacity, soil improvement, and bamboo.

2.1 Bearing Capacity

Bearing capacity is the capability of the soil to withstand and support the loads that is applied to the ground on top of it. The loads can either be a structure of a building or a construction of road. The bearing capacity mainly is dependent on the types of soil, the value of shear strength and also its density. Another factor for the bearing capacity is how deep the embedment of the load. The general idea is the deeper the embedment of the load, the greater the amount of load the soil can support, which means the higher the bearing capacity of the soil. When a load is applied to the soil, the soil moves downward. The vertical effective tension exerted on the earth is increased as a result of the load. As a result of this load, the vertical strain in the soil increases. The earth moves downhill as the vertical strain increases. Most structures do, in fact, settle over time. Unless there are changes in the drainage patterns around the building, extreme changes in weather, or other external influences, most building settlement happens during the first few years after construction. In expansive clay soils, the total volumechange is primarily attributable to the changes associated with each component phase.However, the interconnectedness of physical and chemical processes in the soil mass leads to complicated volume change mechanics. This volume change can be describedas a combination of hydraulic and mechanical processes, with the hydraulic part representing deformation caused by changes in water content due to weather conditions and the mechanical part representing deformation caused by changes in vertical stresses due to soil–structure interaction. [4] According to [1] in their report, in South Sumatera, peat soil has become a problem for construction and one of the ways to improve the bearing capacity is to use reinforcement method or physical stabilization.

2.2 Plate Bearing Test

The Plate Bearing Test (or Plate Loading Test) is an in-situ soil load bearing test that determines the ground's ultimate bearing capacity and expected settlement under a particular load. BS 1377 Part 9: 1990 is followed when performing the Plate Bearing Test. It entails loading a steel plate with a known diameter and documenting the settlements associated with each load increment. The load on the test plate is gradually increased until it begins to settle quickly.

According to [5], The plate bearing test is used in earthworks and foundation engineering, although it is most commonly used to verify the compaction of road and airfield earthworks. In other words, the test's goal is to determine the deformability of soils or rocks. The test enables the link to be established between the applied pressure and the displacements.

2.3 Clay soil

The Parit Raja area is made up of strata, primarily clay soil. Clay soils are characterised by fine-grained particles, low permeability, high compressibility, and low strength. Flooding is a natural occurrence that can occur on any land surface and is usually associated with low infiltration rates. Water infiltrates into the soil's subsurface, causing the bulk density to increase during infiltration and, as a result, the bulk density to decrease. [2].

According to [6], the clay soil located at RECESS has moisture content ranges from 23 percent to 69 percent, specific gravity ranges from 2.18 to 2.65, plastic limit ranges from 20 percent to 35 percent, liquid limit ranges from 37 percent to 66 percent, plastic ranges from 17 percent to 31 percent, and soil sensitivity ranges from 2.5 to 7.3 (m2/year). The size of the soil particles is smaller than 0.002mm. As a result, the soft clay must be stabilised prior to road construction on the ground.

2.4 Bamboo

The most common bamboo found in Peninsular Malaysia and around the world is Gigantochloa scortechinii (buluh semantan). It's one of the most accessible sources of wood to supplement what's available locally. Bamboo is similar to wood in that its mechanical properties improve when the moisture content lowers. In a study done by [7], bamboo is known to have a density of around 700-800kg/m³ and 60-70% of its total weight are consists of its fibres. Bamboo can also withstand high tension force compared to some types of wood while also having low to medium modulus of elasticity of about 35 – 70 kN/mm² depending on the diameter and the thickness of the outer wall of the culm.

The culm or internodes are the nodes that separate bamboo stems into parts. The nodes act to prevent the bamboo from buckling when it is bent. Bamboo culms can be hollow at times. Bamboo has greatest tensile flexural strength and stiffness due to cellulose fibre oriented down the length of the bamboo. As a result of recent bamboo studies, it can be stated that bamboo might be a sort of construction material because of its structure, which provides strength, stiffness, and ease of use. [8]

3. Materials and Methods

The process and methods of preparation of materials are listed in this chapter. The methodology discusses on the flow process of research and testing to achieve the main objectives of this study.

3.1 Materials

The materials required for this are Gigantochloa scortechinii (buluh semantan), which are cut down into 1m lengths and 0.8m lengths. As stated earlier the bamboo is collected from Parit Hj. Rais. Then the bamboo is left to dry for 7 days.

The test area is prepared at RECESS UTHM. The dimensions for both test area is 1.8m x 1.0m with a depth of 0.5m. Test area with bamboo is labelled as Test Area 1 and soil without the bamboo reinforcement is Test Area 2. Both test areas are excavated to ensure that both are considered disturbed soil.

3.2 Methods

Figure 1 shows the flowchart of the project.

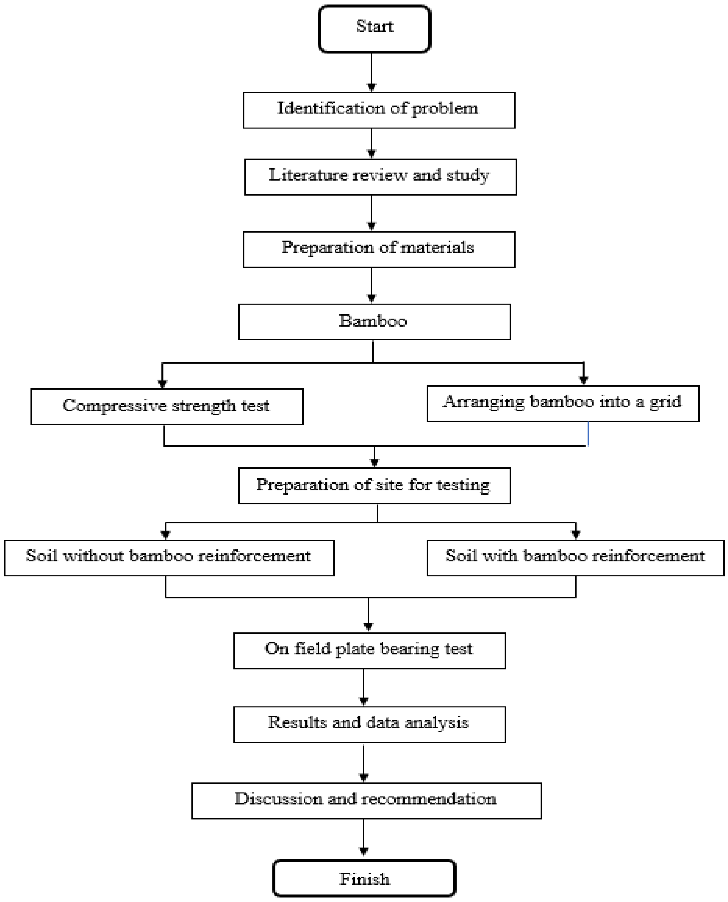

Figure 1: Flowchart for research

3.3 Materials

After collection of bamboo from Parit Hj. Rais, some bamboos are cut into 15cm lengths to be tested for its compressive strength test. 3 samples are made and tested to get the average reading of the compressive strength.

Figure 2: 3 samples of bamboo for compressive strength test

Other bamboos that were collected were arranged into a grid of 1m x 1.8m. The average size of the aperture of the bamboo is 22cm and the thickness is 18cm. the bamboos is tied together using rafia rope and placed at the base of Test Area 1.

Figure 3: Bamboo reinforcement

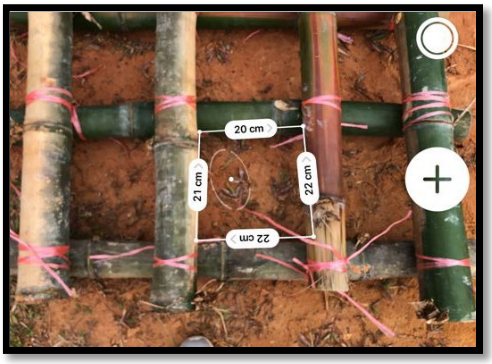

Figure 4: Aperture of bamboo reinforcement

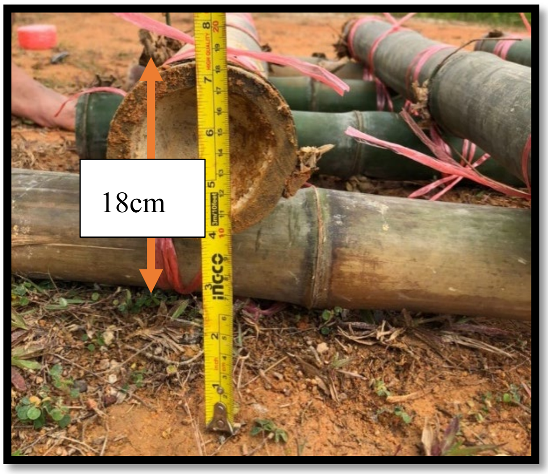

Figure 5: Thickness of the bamboo reinforcement

3.4 Compressive Strength Test

To determine the strength of the bamboo, a compressive strength test was done. The bamboo samples are prepared by cutting them into 15cm length. The thickness of the walls of the bamboo are chosen to be almost similar in size which is 1cm. 3 samples of bamboo was tested to get an average value of the strength of the bamboo. The standards used for this test in accordance with BS EN 1992-1-1. The data of the strength test is the visualized into a graph. Figure 6 shows bamboo sample B undergoing compressive strength test.

Figure 6: Compressive strength test

3.5 Preparation of Field-Testing Area.

The location for the testing will be done at Research Centre for Soft Soil, Universiti Tun Hussein Onn Malaysia (RECESS, UTHM). The site was chosen to be here because the type of soil is clay soil according to a study done by [9].

3.5.1 Soil With Bamboo

For testing area 1, site preparation must be done prior to the testing. The soil was excavated until a depth of 0.5m is achieved. After the desired depth is achieved, the bamboo reinforcement is placed at the base of the pit.

Figure 7: Excavation of soil

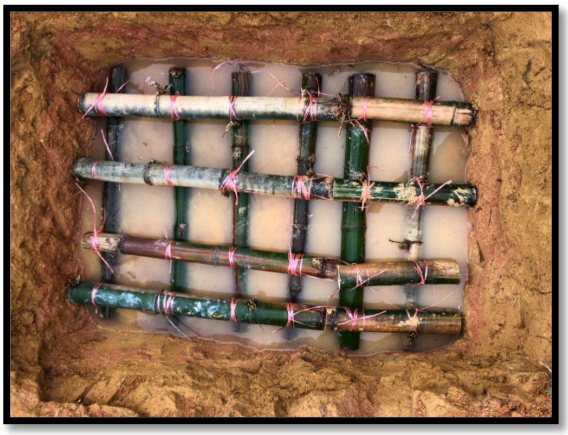

Figure 8: Bamboo reinforcement placed in the pit

After the bamboo reinforcement was placed at the base, the pit was then refilled with the clay soil and compacted. After that the testing area can proceed with the plate bearing test.

Figure 9: Test area 1 after compaction

3.5.2 Soil without bamboo

In order to achieve valid results, Test Area 2 was also excavated similar to Test Area 1. This ensures that the test areas are both disturbed soils.

Figure 10: Excavation of soil

Figure 11: Test Area 2 after compaction

3.6 Plate Bearing Test

The testing that was conducted is plate bearing test and in accordance with the British Standard (BS) 1377 part 9. The test was performed on the surface rather than in a shallow pit. The reaction load used was a mini excavator which adheres to the standards long as the load applied is in increments and not more than 95 kPa for each increment. The reaction load was placed near testing area 2, ensuring that the rear of the mini excavator is right above the testing area. Then the bearing plate was placed and moved in a circular motion so that the surface of the plate is in contact with the surface of the soil as much as possible. A 300mm plate was used to get a zone of influence underneath the ground of about 6 metres. A hydraulic jack was then placed on the plate along with the measuring instruments such as dial gauge to measure the settlements of the soil. The reaction load was applied in increments of 50, and the settlement reading was recorded when the reading is constant with a minimum holding time of 15 minutes for each increment of load. After applying the maximum load increments, unloading process was done in decrements of 100 bearing pressure until the pressure is 0. Settlement reading is completed when the bearing pressure is at 0. After completion, the mini excavator was then moved to Test Area 1 and the same steps of testing was repeated.

Figure 12: Plate bearing test setup at Test Area 2

Figure 13: Plate bearing test setup at Test Area 1

4. Results and Discussion

4.1 Compression Strength (CS) Test of Bamboo

Table 1: CS test results for bamboo sample A

Bamboo A (D = 70mm, t= 10mm)	Strain (%)	Load (kN)	Strength (mPa)
1	4	12.9	18.0
2	7.3	20.7	29.0
3	9.5	14.8	21.0
Average		**16.13**	**22.67**

Table 2: CS test results for bamboo sample B

Bamboo B (D = 60mm, t = 20mm)	Strain (%)	Load (kN)	Strength (mPa)
1	2.11	20.5	14.8
2	4.63	32.2	22.0
3	6.47	31.4	21.5
4	8.01	28.0	20.0
Average		**28.025**	**19.58**

Table 3: CS test results for bamboo sample C

Bamboo C (D = 70mm, t = 15 mm)	Strain (%)	Load (kN)	Strength (mPa)
1	1.48	1.14	2.0
2	4.22	21.4	31.0
3	5.0	24.4	34.8
4	6.94	16.5	24.0
Average		**15.86**	**22.95**

From the data of compressive strength of all 3 of the bamboo samples, it shows that bamboo sample C has the highest compression strength which is 22.95 MPa compared to bamboo A with 22.67 MPa and bamboo sample B with 19.58 MPa. Bamboo sample C has a wall thickness of 15mm which is higher than bamboo sample A with 10mm but lower than bamboo sample B with 20mm thickness. However, bamboo sample B has a smallest diameter, D = 60mm while both bamboo sample A and C have a diameter of 70mm. This data shows that the diameter and the thickness of the bamboo contributes to the strength of the bamboo.

4.2 Plate Bearing Test

The results for the plate bearing (PB) test are categorized into 2: (a) soil without bamboo reinforcement and (b) soil with bamboo reinforcement. The settlements for both of the testing area are recorded and compared. Table 4 shows the summary of the settlement for all 3 tests.

Table 4: Summary of settlement

Max settlement soil without bamboo reinforcement (mm)	Max settlement soil with bamboo reinforcement (mm)	Max settlement soil with bamboo reinforcement after 7 days (mm)
24.14	19.38	17.50

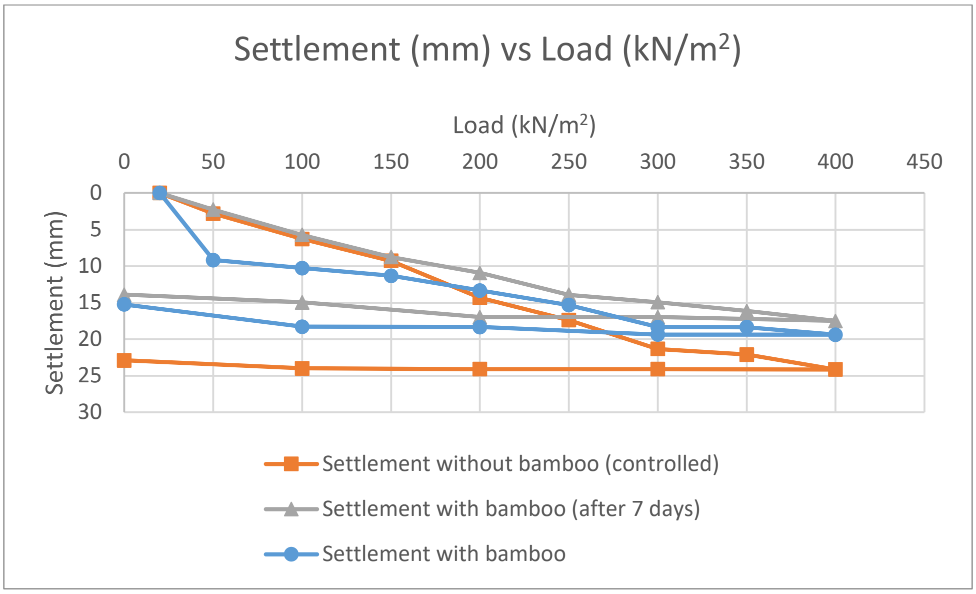

Figure 14: Settlement for soil with and without bamboo reinforcement

From the data, we can also say that all the tested soils have a bearing capacity of more than 400 kN/m^2 as both soil experience settlements not exceeding 25mm when maximum load is applied. With a factor safety of 2, the safe bearing capacity of the soils is 200 kN/m^2. Since the soil without bamboo reinforcement has a maximum settlement of 24.14mm which is already close to the 25mm limit, it has a lower bearing capacity than the soil with bamboo reinforcement which has a lower settlement. The soil with bamboo reinforcement also seems to stabilize even before the maximum load is applied compared to soil without bamboo which still has a high difference between the readings at 350 kN/m^2 and 400 kN/m^2.Discussions

5. Conclusion

Based on the results of the compressive strength test that has been conducted, it can be said that the first objective of this study has been achieved. The average strength of the *Gigantochloa Scortechinii* bamboo that was collected near Parit Hj. Rais has been determined to be 21.73 MPa. This also proves that the *Gigantochloa Scortechinii* or known locally as *buluh semantan* is comparable to timber which another material widely used in construction. From the results of the plate bearing test, it shows that bamboo is suitable to be used as reinforcement to increase the bearing capacity of the soil. Bamboo reinforcement was able to decrease the settlement by 29.58%. The bamboo reinforcement was also able to stabilize the soil earlier compared to soil without bamboo reinforcement. Furthermore, with the conclusion of both plate bearing test and comparing both of the results, the second and the third objective of this study has also been achieved.

5.1 Recommendations

Based on the results, there are several suggestions for improvements that could be considered in this study of soil improvement using bamboo technology.

i. It is recommended for future studies on this subject could consider integrating the usage of commercial geotextiles to be integrated with the bamboo reinforcement to further improve the soil.
ii. Ensure that prior and during testing, no rain occurs to prevent high moisture content within the soil which can cause the soil to become weak and invalidates the data.
iii. Conduct field density test to ensure that both the soils are compacted correctly and have similar density.

Acknowledgement

The authors would like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support.

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