RECENT TREND IN CIVIL ENGINEERING AND BUILT ENVIRONMENT
e-ISSN: 2773-5303

RTCEBE

Vol. 6 No. 1 (2025) 137-146
https://publisher.uthm.edu.my/periodicals/index.php/rtcebe

Bamboo Technology Improvement in Reinforcement of Embankment

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DOI: https://doi.org/10.30880/rtcebe.2025.06.01.015

Article Info

Received: 08 January 2024
Accepted: 15 April 2024
Available online: 6 May 2025

Keywords

Peat soil, settlement testing, bamboo reinforcement

Abstract

Peat soil known as problematic soil in construction industry and very fibrous due to the presence of a lot of degraded materials and organic matter, which makes it highly compressible, weak at shear strength, and low in bearing capacity. This property renders it unsuitable for use as a foundation or sub-grade since it would have a significant influence on deformation and settling if not properly handled. And lead to occur such as large settlement, failure of pre- and post-construction, and long-term effects in various ways. Bamboo high rate of biomass production and renewability in sustainably managed bamboo plantations are definitely important features. The behaviour of bamboo also helps in increasing its unit weight hence the shear strength and load bearing power. The objectives of this study are to measure settlement with and without load on the embankment over peat soil with reinforcement system by using bamboo technology. Bamboo is recognized as a potential natural reinforcing material for improvement and stabilization of soil. This study was then applied three different layers of loads which are each faced consist of 120 kg. Based on the outcome of peat soil settlement, *'Buluh Mengkawan'* that were knotted like a raft had contributed to acting as a potential for peat soil improvement technique, the settlement value had lowered till 0.0720 cm with three layers of load of 360kg on top. The bamboo had sunk 0.02 cm in 24 hours till 360kg loads and remaining constant for next 72 hours. This is due to shape of rectangular bamboo forms interlock to resist horizontal stress and enhance bamboo stiffness, resulting in an equally distributed vertical distribution of stress. Because it distributes modest embankment loads to peat soil, the void area of the bamboo, where air is trapped inside the bamboo, can give a buoyant effect. This research project contributes to the advancement of fundamental knowledge in the preparation of reinforcing works on peat soil. is compulsory.

1. Introduction

Soft soil is a type of soil that unsuitable for construction because it has a particle size less than 0.063mm. Soft soil known as problematic soil in construction industry. In this research, type of soil that been used is peat soil. Generally, peat soil is dark brown in colour meanwhile the physical of peat are spongy and fragile textures. Peat soil is very fibrous due to the presence of a lot of degraded materials and organic matter, which makes it highly compressible, weak at shear strength, and low in bearing capacity. This property renders it unsuitable for use as a foundation or sub-grade since it would have a significant influence on deformation and settling if not properly handled. And lead to occur such as large settlement, failure of pre-and post-construction, and long-term effects in various ways. Basically, peat is a type of soil that contains a lot of dead organic matter above 75%, it forms due to a lack of oxygen in waterlogged or poorly drained soil (Huat et al., 2014; O'Kelly, 2017).

Due to urbanization and industrialization, peat soil needs to be treated and improved to gain the standard strength for construction by increase its unit weight and shear strength and load bearing capacity. One of the effective techniques is by using bamboo technology as improvement of embankment. In this report, type of soft soil that being used is peat soil. Peat soil is obtained at Parit Nipah, Batu Pahat, Johor. Besides that, preloading and strengthening bamboo grids on peat are predicted to minimize compression and enhance peat soil carrying capacity. Preloading may be 2 applied by employing an embankment material that can accelerate compression, while to enhance bearing capacity owing to embankment load, a combination of bamboo grids can be used.

The laboratory modelling was done with two sample of peat soil medium supported by rafted layer of bamboo grid with diameter of 6.35 cm in short and long bamboo, a length of 150 cm in long bamboo, and 78 cm in short bamboo. The confinement of peat soil in a square pattern arrangement of bamboo increased its stiffness, while the tensile resistance of the horizontal ribs and compressive resistance of the vertical ribs of bamboo prevented excessive settlement. Apart from that, this research is expecting to reduce the deflection and settlement of bamboo grid and pile due to the load of embankment and in the end can increase the bearing capacity of peat soil.

2. Properties of Peat Soil in Embankment

Many academics, particularly engineers, have conducted physical studies of peat in order to ensure that any structures built on peat-based soil have a long lifespan once completed. (Edil, 2003). This section describes the physical and mechanical straits of peat soil that were researched for this study paper. According to Zainorabidin et al., (2018), Table 1.1 reveals that the parameters of peat soil vary greatly collected by previous studies. It also demonstrates that Malaysian peat soil varies according to geographical area. This is determined by the agricultural history of the area as well as the rate of rainfall.

Table 1 *Index properties of Parit Nipah peat (Zainorabidin et al., 2018)*

Parameters	Parit Nipah peat	Range
Moisture Content, %	635	236-784
Liquid Limit, %	252	220-417
Specific Gravity, G_s	1.34	1.27-1.56
Bulk Density kN/m^3	10.45	7.95-11.5
Organic Content, %	95.5	78.77-95.44
Fiber Content, %	37.8	40.97-63.77
Compression Index, C_c	1.48	0.9-1.5
Von Post Scale	H6	H5-H6

The organic content of peat soil contributes to its compressibility. Peat's degraded organic matter contains durable fiber and other fibrous components. As the embankment load is applied, these fibers tend to compress and rearrange, resulting in a decrease in soil volume and, as a result, settlement (Dikau et al., 2000). Furthermore, compared to other soil, peat soil has a large void ratio and lower density, which contributes to its compressibility and settling behavior (Lehman, 2002).

The high of water content of peat soil also influences settlement behavior. Water act as a lubricant between soil particles, allowing them to rebuild under load. Different settlement happens when specific layers, resulting in uneven settlement and associated structural problems (Hoyos et al., 2010).

3. Materials and Methods

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The procedure for soil preparation started with taken from the Parit Nipah area by digging the soil at 0.5m depth to get the origin and correctly peat soil. The best quality of peat soil needed is red brown in colour. Besides, it also must clean from any contaminant to ensure the best quality of soil. After that, all the soil was putted in sealed container to ensure that the soil's sample moisture content maintained.

Bamboo type of *'Buluh Mengkawan'* was prepared with diameter of 6.35 cm in short and long bamboo, a length of 150 cm in long bamboo, and 78 cm in short bamboo respectively. The bamboo then was tied to secure place like a raft. This type of arrangement of bamboo are able to increase its stiffness, while the tensile resistance of the horizontal ribs and compressive resistance of the vertical ribs of bamboo prevented excessive settlement.

Besides that, the two of laboratory testing was conducted which are Plate Load Test and Moisture Content Test to achieve the objectives of this study. Plate Load Test is aim to obtained behavior of settlement of peat soil. Meanwhile, Moisture Content Test is to quantify the water content in the peat soil relative to its dry weight.

Fig. 1 *Obtaining Peat Soil Sample from Parit Nipah*

Fig. 2 *Preparation of bamboo reinforcement*

3.1 Moisture Content Test

The aiming of ASTM D-2216-90 was to calculate the water quantity in a given amount of soil when it comes to dry weight. Apparatus needed for moisture content test were soil sample, a can, temperature-controlled oven and electronic scale. The primary objective of the moisture content test in peat soil sample is to quantify the water content in the soil relative to its dry weight. Furthermore, this information is important in various engineering field, as it influences the soil's engineering properties, stability, and behaviour. Figure 3.5 shows the apparatus that has been used for moisture content test.

For moisture content test procedure, the raw soil samples were prepared. Next, empty can were weighed by using electronic scale and the weight was recorded. Then, the moist soil samples were filled in the can and the weight of the can with wet soil were recorded. After that, can that fill with wet sample were placed in the oven with temperature 60 of degree Celcius and kept for 24 hours. The soil sample was removed from the oven after 24 hours. The container filled with the soil sample were weighed and then data was recorded. Then, the moisture content was calculated by using the following formula.

$$\text{Moisture Content (\%)} = \text{Initial Wet Weight} - \text{Final Dry Weight} / \text{Final Dry Weight} \times 100 \quad (1)$$

Fig. 3 *Process Obtain Moisture Content Data of Peat Soil Sample*

3.2 Plate Load Test

The plate load test is particularly crucial in understanding the soil's ability to support structures and infrastructures. In the context of peat soil, which is known for its high compressibility and low in strength, the plate load becomes especially valuable. The procedure involved applying loads to a rigid plate, and hard wooden board has been used which been placed on top of bamboo reinforcement. The test was performed with three layers of load applied for the peat soil which is each layer consist of 120kg load. The layering of loads allows for a more comprehensive analysis of how the peat soil responds to increasing settlement, lead to condition that structure might exert on the soil over time. The measurements of settlement taken during the test will provide valuable data. Additionally, the test observed potential settlement issues that cold impact the long-term stability and performance of structures built on peat soil.

Fig. 4 *Plate load test on peat soil in progress*

4. Results and Discussion

4.1 Moisture Content Test Results

From the result of moisture content test, the moisture content for peat soil sample is 79.54%. According to Zainorabidin et al., (2007), the range value of moisture content for peat soil in Parit Nipah from 236% until more 784%. This is because factors of weather conditions such as temperature or humidity influence the differences data of peat soil compare to previous research. Moreover, moisture content can vary with depth in the soil profile. In this study, the sample of peat soil was obtained at 0.5 m depth.

4.2 Plate Load Test Results

The plate load test was carried out on this study on a modest scale in the laboratory using a physical model. The study's findings were obtaining the settlement behavior on peat soil. This study was applied three different layers of loads which are each layer consist of 120 kg.

4.2.1 Settlement Test for Loads of 120kg

Table 2 and Figure 5 present a comprehensive of settlement measurements observed over 72-houe period when loads of 120kg was applied.

Table 2 *Results of Settlement Test for Loads 120 kg*

Day	Times (hours)	Settlement (cm)
1	24	0.0936
2	48	0.0890
3	72	0.0836

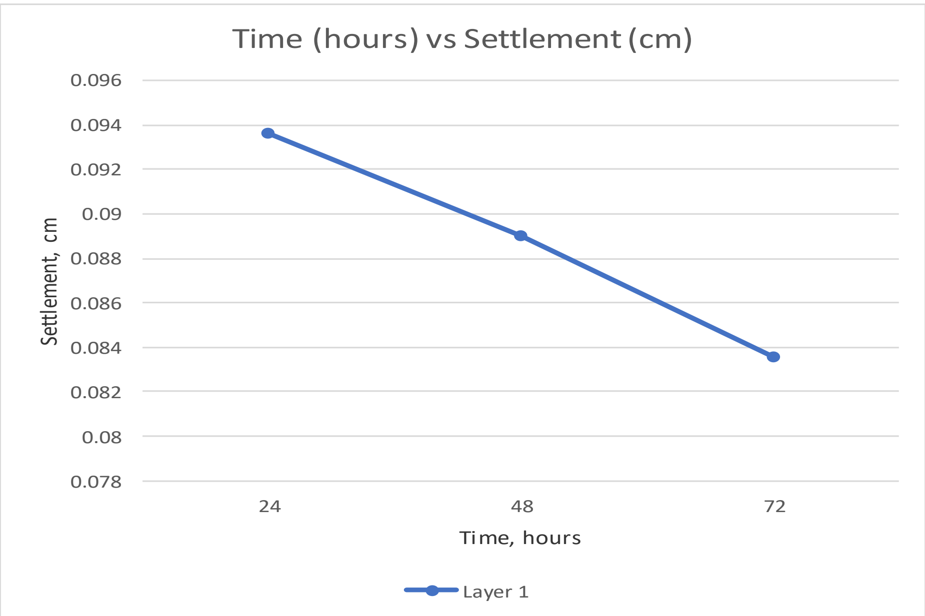

Fig. 5 *Graph of peat soil settlement for 120 kg loads*

The initial 24-hour interval indicates a settlement reading of 0.0936cm, reflecting the falling that occurred during this timeframe. Moving into subsequent 24 hours, a noticeable decrease is noted, with the settlement value at 0.089cm. This reduction suggested a potential shift in the settling process or factors influencing the observed settlement. The decline is much more obvious in the last 24-hour period, when the settlement value falls to 0.0836cm. The overall data from these three intervals suggests a slow and possibly increased settlement phenomena over a complete 72-hour time period. Evaluating these data in conjunction with other relevant factors, such as environmental conditions, might provide significant insights into the dynamics of the settlement process and assist in the development of acceptable measures or project improvements.

4.2.2 Settlement Test for Loads of 240kg

Table 3 and comprehensive measurements hour period 240kg was

Figure 6 present a of settlement observed over 72- when loads of applied.

Table 3 *Test for Loads* *Results of Settlement 240 kg*

Day	Times (hours)	Settlement (cm)
1	24	0.0952
2	48	0.0804
3	72	0.0804

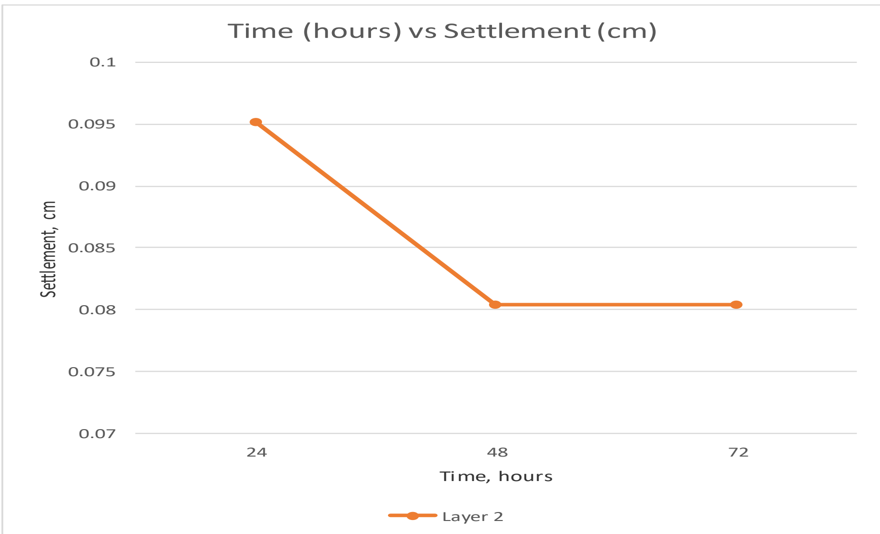

Fig. 6 *Graph of peat soil settlement for 240 kg loads*

The initial 24-hour interval indicates a settlement reading of 0.0952cm sinking 0.0116cm from continuity settlement of 120 kg, reflecting the falling that occurred during this timeframe. Moving into subsequent 24 hours, a noticeable decrease is noted, with the settlement value at 0.0804cm. This reduction suggested a potential shift in the settling process or factors influencing the observed settlement. The decline is much more obvious in the last 24-hour period, when the settlement value constant at 0.0804cm. If the settlement readings remain constant, it indicates that the rate of compression or consolidation has stabilized and that the soil is not settling further during the observed period. This might be due to a number of circumstances, including the soil reaching a state of equilibrium where compression activities balance out, or external variables impacting settlement such as loads or environmental conditions being relatively constant.

4.2.3 Settlement Test for Loads of 360kg

Table 4 and Figure 7 present a comprehensive of settlement measurements observed over 72-houe period when loads of 240kg was applied.

Table 4 *Results of Settlement Test for Loads 360 kg*

Day	Times (hours)	Settlement (cm)
1	24	0.0720
2	48	0.0720
3	72	0.0720

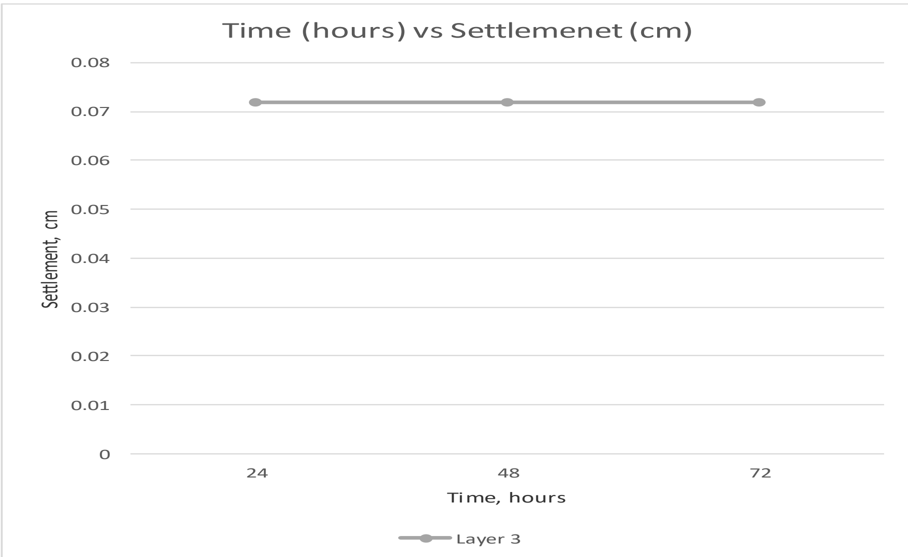

Fig. 7 *Graph of peat soil settlement for 360 kg loads*

The initial 24-hour interval indicates a settlement reading of 0.0720cm sinking 0.0084cm from continuity settlement of 240 kg, reflecting the falling that occurred during this timeframe. Moving into subsequent 24 hours, a noticeable constant is noted, with the settlement value at 0.0720cm. however, the next 24-hour period shows a striking observation that settlement value remains constant at 0.0720cm. Remarkably, this constancy maintain over the entire 72-hour duration, with no further settlement occurring. Furthermore, peat soils have potential adaptability or "creep" over time, in which the soil gradually adjusts to the applied load, resulting in a steady settlement reading.

4.3 Continuities Settlement of Peat Soil

Figure 8 shows the continuity settlement that means constant deformation or settling of soil caused by applied loads over time.

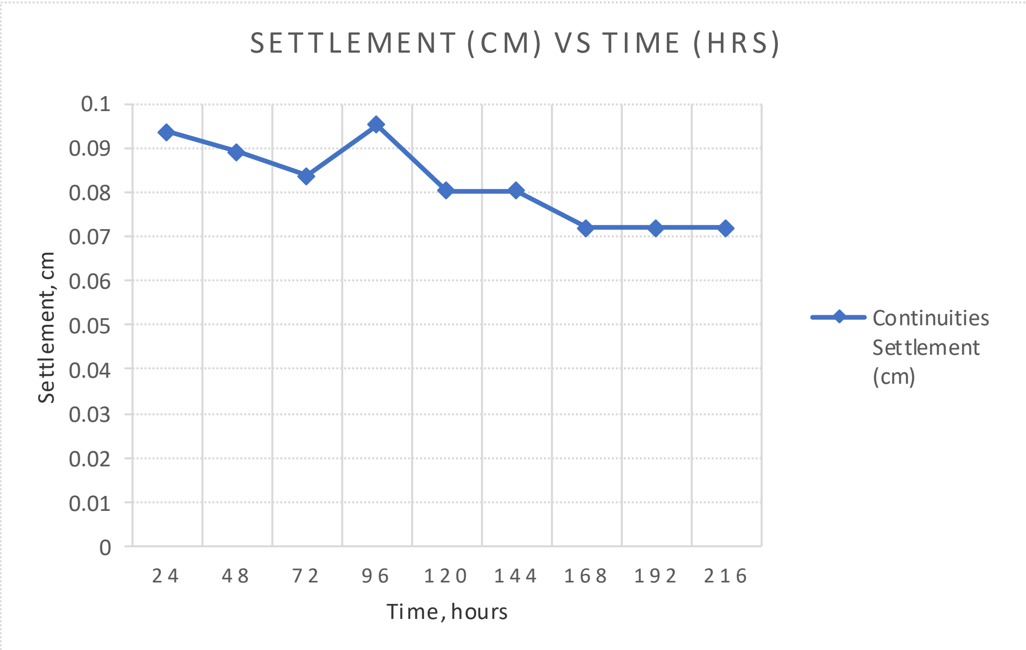

Fig. 8 *Graph of continuities settlement of peat soil*

The continuous settlement under subsequent layers of load might indicate that the peat soil has achieved an equilibrium condition, in which the deformation caused by the applied load has stabilized. It is critical to understand this data in the context of peat soil's particular characteristics, which are recognized for their excessive compressibility. The various layers of load may have caused different comes out of load on the soil, and the continuous settlement could indicate that the earth has responded to these loads without imposing greater sinking.

4.4 Summary of Peat Soil Settlement

Figure 9 shows the summary of peat soil settlement of 120 kg, 240 kg, and 360 kg together with bamboo reinforcement was applied.

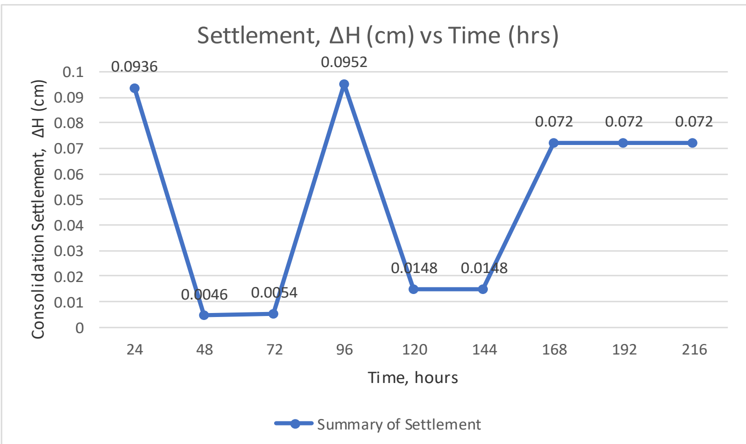

Fig. 9 *Graph of summary of peat soil*

The settlement value decreased till 0.0054 cm for first layer of 120kg loads. Meanwhile, the settlement decreased drastically till 0.0148cm after applying of 2 layers of 240kg loads. This decrease means that the strain that the foundation can bear on peat soil. This shows that adding more layers of loads can reduce the reading of soil settling. This imply that the bamboo reinforcement plays an important role in distributing and minimizing the settlement impact of additional loads besides potentially increase peat soil's load bearing capacity and overall stability.

5. Conclusion

Based on the outcome of peat soil settlement, *'Buluh Mengkawan'* that were knotted like a raft had contributed to acting as a potential for peat soil improvement technique, the settlement value had lowered till 0.0720 cm with three faced of load of 360kg on top. The bamboo had sunk 0.02 cm in 24 hours and remaining constant for next 72 hours. This is due to shape of rectangular bamboo forms interlock to resist horizontal stress and enhance bamboo stiffness, resulting in an equally distributed vertical distribution of stress. Because it distributes modest embankment loads to peat soil, the void area of the bamboo, where air is trapped inside the bamboo, can give a buoyant effect.

This experiment proves that potential practical of *'Buluh Mengkawan'* application as a reliable and sustainable solution for addressing challenges associated with peat soil in construction projects. However, further research and consideration of site-specific conditions are warranted to optimize and validate the effectiveness of this technique in diverse environmental contexts.

In summary, the objectives of this investigation were achieved through a comprehensive examination of settlement behavior in the with and without of loads, coupled with a focused analysis of the performance of bamboo technology as a viable reinforcement system for peat soil. The mattress of bamboo transferred the working load to the soil, changed the location of the critical failure surface, and provided uplift buoyancy force.

Acknowledgement

The authors would like to thank Research Centre of Soft Soil (RECESS), Universiti Tun Hussein Onn Malaysia and the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for providing facilities and guidance during the research work.

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