

Polymer-Peat Column as an Improvement of Soil Settlement

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DOI: <https://doi.org/10.30880/mari.2025.06.01.004>

Article Info

Received: 1 October 2024

Accepted: 30 November 2024

Available online: 15 January 2025

Keywords

Peat Polymer Column, peat soil settlement, stabilization, Vinyl Acetate-Acryl Copolymer (VAAC)

Abstract

This study evaluates the effectiveness of Polymer-Peat Columns (PPC) in stabilizing peat soil. The results indicate that PPC significantly reduces soil settlement, making it a viable solution for construction on weak soils. The study's objectives are to identify the performances of the PPC in a physical model study and to study the soil structure interaction between load, settlement and time. A physical model in this study is a method used to identify the performances of the PPC in a peat soil. The original peat soil was placed in a box of 30 cm x 30 cm x 30 cm as a soil bed allowing it to rest for 24 hours promotes homogeneity. Organic soils, have an inhomogeneous and anisotropic structure that differs greatly from inorganic soils, resulting in their peculiar engineering properties, which are usually not conducive for load bearing. The study highlighted the variations in settlement while employing PPC versus without PPC. Peat is a primary material and Vinyl Acetate-Acryl Copolymer (VAAC) is used as a stabilizer agent to improve soil settlement. Load tests were performed for data collection and analysis. The result of this study shows when maximum load in this study is applied to peat soil without PPC is 7.023 mm and 12 cm from the center shows 0.028 mm. The settlement increases at the beginning load with linear pattern, which is 1.25 kg to 5 kg with a comparatively small settlement, suggesting that the peat soil has an elastic behavior. While the result for settlement with PPC is 6.515 mm after applying load and 12 cm from the center is 0.024 mm. In contrast, peat soil without PPC experiences greater settlement due to its high compressibility and low shear strength, leading to increased deformation under load. Thus, VAAC is an effective chemical stabilizer that can reduce peat soil settlement. These findings support the adoption of VAAC as an effective solution for addressing settlement issues in peat soils, offering a viable approach for infrastructure development in areas characterized by these challenging soil conditions.

1.0 Introduction

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Peat soil presents considerable issues in building because of its poor shear strength, despite its high organic content, moisture level, and compressibility. Due to its properties, peat soil is considered as not suitable for construction purposes. A strong foundation is needed to support the entire structure. But, from the perspective of construction, peat is commonly considered a problematic deposit with poor geotechnical properties which require a stabilization process if it needs to be used to support any infrastructures. To address the challenges posed by this type of soil, innovative stabilization techniques are essential. One promising method is the use of Polymer-Peat Columns (PPC), which aims to enhance the mechanical properties of peat through the incorporation of polymers. This study investigates the effectiveness of PPC in reducing settlement and improving the structural integrity of peat soil. The polymer acts as a binding agent, creating a more cohesive and less compressible matrix within the peat. By reinforcing the peat with polymer, the PPC method seeks to increase shear strength, reduce compressibility, and provide a more stable foundation for construction. The primary aim of this study involves two key objectives. First, it seeks to evaluate the effectiveness of Peat Polymer Columns (PPC) in reducing soil settlement through a detailed physical model study. This involves assessing how well the PPC can stabilize peat soil and improve its load-bearing capacity. Second, the study aims to examine the interaction between the soil structure and various factors such as load, settlement, and time. This includes understanding how the soil responds over time under different loading conditions and how the PPC influences these dynamics to provide a more stable foundation. This research highlights the potential of PPC as a viable soil stabilization technique, particularly in regions with prevalent peat deposits. The results suggest that PPC not only enhances the physical properties of peat soil but also offers a practical solution for construction projects facing the challenges of building on weak and compressible soils.

1.1 Peat Behavior

Peat soil is a unique type of soil characterized by its unusual behavior and high organic content. This organic matter accumulates in layers and slowly breaks into peat in anaerobic (low oxygen) conditions [1]. The high moisture content of peat soil is one of its most distinctive features. Peat is saturated with water because it forms in wet settings, which fills the pores between the organic particles. Since peat has a high moisture content, it is prone to compression under stress due to its soft, spongy nature [2]. In addition, peat soil is highly compressible, yet it also has poor shear strength. This indicates that it is prone to erosion and slope instability since it is relatively weak when exposed to lateral forces or shear stress. While peat soil typically has a unit weight in the range of 800 – 1200 kg/m³, peat soil has a comparatively low unit weight [3]. For peat with an organic content of 75% and greater, the specific gravity is in the range of 1.3 to 1.8 with an average of 1.5. Peat soil is a highly compressive soil, which makes the soil have quite a high void ratio. According to [4], the range for void ratio in peat can vary from 5 to 15, and in fibrous peat, it can go up to 25.

1.2 Stabilization on Peat

Stabilization of peat is a crucial engineering challenge due to the soil's high organic content, excessive moisture, and low bearing capacity [5], it is unsuitable for most construction and agricultural applications in its natural state. When loads are applied to peat, its distinct properties are high compressibility and poor shear strength because of significant settlement and instability. For this reason, stabilizing peat is crucial to infrastructure development in areas where this type of soil is predominant. Peat is improved through a variety of processes, such as mechanical, chemical, and biological ones. Mechanical stabilization involves physically altering the peat structure through processes like compaction and the addition of reinforcing materials such as geotextiles or geogrids. On the other hand, chemical stabilization usually makes use of binders such as fly ash, cement, or lime to start chemical reactions that lower the moisture content of the soil and increase its ability to support loads.

By reacting with the moisture and organic materials in the peat, these binders form a more stable and rigid matrix. In contrast to mechanical and chemical approaches, biological stabilization is a less popular and more experimental method of improving soil qualities through microbial activity. Stabilizers for this study is an acrylic-based copolymer or vinyl acetate. VAAC is a unique type of soil stabilizer that may simultaneously manage erosion and dust [6]. VAAC increases the load-bearing capacity and decreases the compressibility of the peat structure by creating a flexible and resilient matrix inside it. By filling in the voids in the peat, this binding process lowers its porosity and enhances its overall stability. The application process involves the formation of a column that is cured for 14 days. In conclusion, the process of stabilizing peat is complex and essential to the development of infrastructure in areas rich in peat. Peat can be made into a more stable and dependable foundation material by using a chemical material, like the usage of VAAC, which will ensure the longevity and safety of construction projects.

1.3 Settlement Study of Peat Soil

Failures are classified into three types which are General Shear Failure, Local Shear Failure and Punching Shear Failure, depending on the type of bearing capacity of the different soil. [7] stated that punching shear occurred on peat soil settlement in deformation of the indicator's layer when the load applied on peat soil. Hence, the mechanism of settlement in peat soils is primarily driven by their high organic content and significant water saturation. When subjected to loads, peat undergoes large volumetric changes due to its highly compressible nature. Initially, the application of a load causes immediate settlement, as the water present in the peat's porous structure is expelled. This primary consolidation phase is followed by secondary compression, where the organic matter within the peat slowly decomposes and compresses further under sustained loading. The high void ratio in peat, coupled with its low shear strength, leads to substantial and prolonged settlement, as the soil structure rearranges itself to accommodate the applied stress. Furthermore, the presence of fibrous material in peat may increase stability problems by causing uneven and unequal settlement. Overall, the settlement in peat is a complex process influenced by both mechanical compression and the gradual breakdown of organic constituents, resulting in significant challenges for construction and infrastructure development on these soils.

2.0 Materials and Methods

2.1 Materials

The materials used in this study are peat as a soil bed, VAAC as soil stabilizer and Sand as a soil marker (passing 1.18 mm sieve) as shown in Fig. 1.

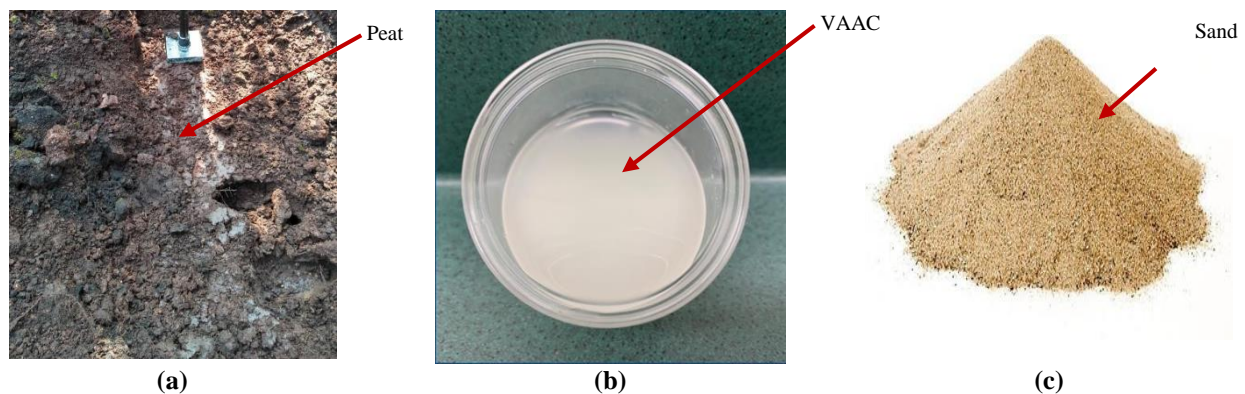


Fig. 1 Materials used (a) Peat; (b) VAAC, (c) Sand

2.2 Methods

A sampling of peat was carried out in Parit Nipah, Batu Pahat, Johor. For sampling, the priority of selecting the sampling area in an open area. The peat soil was placed in the box with size 30 cm x 30 cm x 30 cm after going through with the moisture content reduction process. Then, sand was put on top of peat soil for 1 cm. Throughout this study, the polymer VAAC was utilized to stabilize peat soil as a column. There were two sets of physical models which are the first model is Physical Model Without PPC and the second model is Physical Model With PPC. Two different locations for dial gauge were placed on both model's surface. PPC was cured for 14 days to enhance durability, address volume instability, improve mechanical qualities, and regulate permeability. Load tests were performed on Physical Model for data collection and analysis.

2.2.1 Sample Preparation

Peat was taken far from large trees surrounding it to avoid the disturbance of the sample from visible roots and branches. Larger material was removed from the peat soil, such as isolated roots, large fibre, and samples. The peat soil will be placed in the box with size 30 cm x 30cm x 30 cm after going through with the moisture content reduction process. Then, the peat soil bed is left in the box for 24 hours to make it homogeneous. In this study, sand was used as a soil marker to see the peat soil settlement. Sand was sieved before use and needed to pass 1.18 mm sieve. Throughout this study, the polymer VAAC was prepared with distilled water at a ratio of 1: 3.

2.2.2 Core Cutter Test

The purpose of the core cutter method is to determine the in-situ wet density and unit weight of peat soil. The mould must be weighed before starting the test. Measure the mould to calculate the volume of the core cutter. The mould is driven into the ground using a steel rammer. Getting a cylindrical sample of soil that precisely represents

the density and moisture content at the chosen depth. The soil sample-containing mould is next weighed to ascertain the overall mass. In order to make soil bed and put into the box the density and unit weight of the peat soil sample must be determined. The unit weight of the peat soil is 226 kg/m^3 .

2.2.3 Calibrate of Dial Gauge

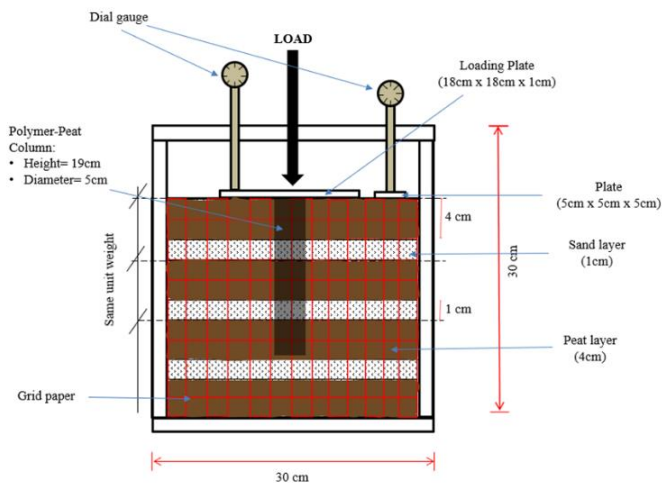
Calibration of a dial gauge ensures accurate measurements by comparing its readings with a standard device, such as a micrometer or gauge block. The process starts with setting the dial gauge to zero on a reference surface, then measuring known dimensions with the standard device and noting any discrepancies. Regular calibration adjusts for wear, environmental factors, and other variables, ensuring the dial gauge's reliability and precision in engineering and manufacturing tasks. Table 1 shows the calibration of dial gauge in this study.

Table 1 The calibrate of dial gauge

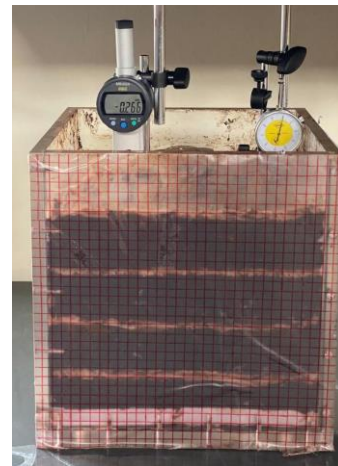
Reading	Dial Gauge (mm)	Ruler (mm)
1	20	20
2	30	30
3	40	40

2.2.4 Design

A single-column type was used in this study, and generating polymer-peat columns was a methodical procedure. To create a homogenous composition, peat and VAAC components were initially carefully combined in a precise ratio. The well combined material was then placed into a column-shaped container in order to begin the column curing process. A box that will be used in this physical model study has a dimension of 30 cm in length, 30 cm in width and 30 cm in depth with a transparent Perspex. [10]. Grid paper was attached at one side of the box to make it easier to see the pattern of the settlement of peat. The static loads were applied to the surface of the peat as in Fig. 2 (a). A loading plate with size $18 \text{ cm} \times 18 \text{ cm} \times 1 \text{ cm}$, is placed on the surface. The location of the dial gauge is as in Fig. 2 (b).



(a)



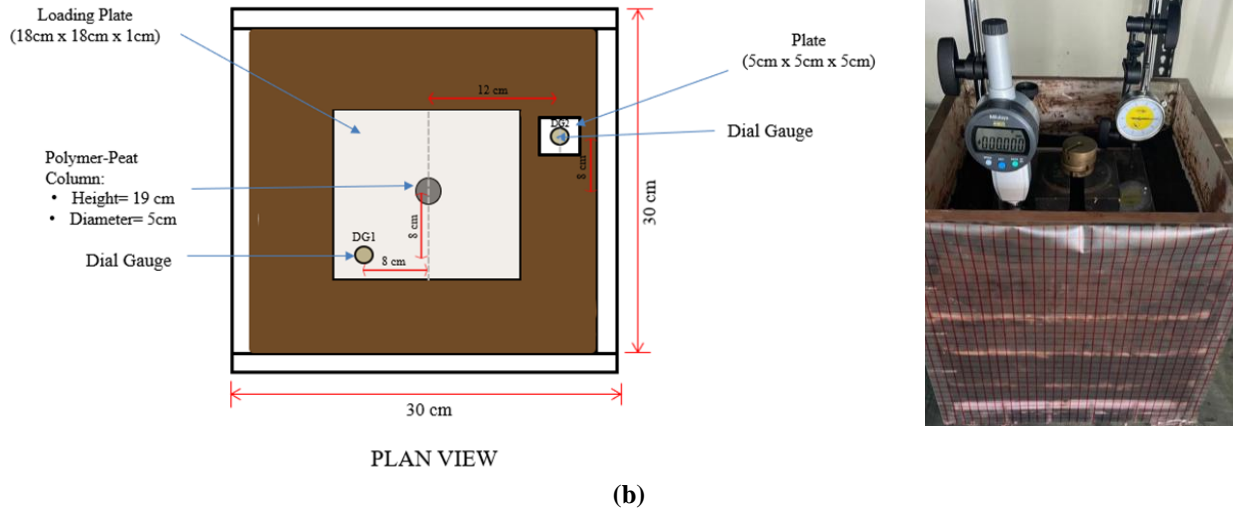


Fig. 2 Physical Model Study (a) Front View; (b) Plan View

2.2.5 Physical Model Study

2.2.5.1 Sample Formation

Larger material was removed from the peat soil, such as isolated roots, large fibre, and samples. The peat soil was placed in the box after went through the moisture content reduction process. The peat was placed in the 30 cm × 30 cm × 30 cm box for 4 layers. Sand was placed on top of peat for each layer, The peat has to be flattened and placed near to the Perspex in each layer. Then, the peat soil bed is left in the box for 24 hours. Organic soils, have an inhomogeneous and anisotropic structure that differs greatly from inorganic soils, resulting in their peculiar engineering properties [11], which are usually not conducive for load bearing.

The method for producing PPC involves combining peat and polymer substances to create a composite material with unique features. The moisture content in peat sample was reduced into the range of 50 % – 60 % by using an oven-dried method. The, 70% of VAAC (from weight of solid) were mixed with the soil. After carefully mixing the ingredients, polymer-peat mixes were put into PVC column and compacted it into 3 layers. This polymer-peat mixes were going through curing for 14 days in a room temperature. By using auger, the cylindrical hole was prepared and the PPC was installed.

2.2.5.2 Load Test

The static loads 1.25 kg, 2.5 kg, 5 kg, 10 kg, 20 kg were applied to the surface of the physical model. The dial gauge reading was recorded after application of each load at a time sequence of 0.25, 0.5, 1.0, 4.0, 8.0, 15, 30, 60, 120, 240, 480 and 1440 minutes.

3.0 Results and Discussions

3.1 Soil Time-Settlement

The soil time-settlement graph of various loads for dial gauge at the center is shown in Fig. 3. There are two graphs which are (a) time vs settlement graph and (b) load vs settlement graph. Fig. 3 (c) and (d) demonstrate how the graph's pattern changed as the load or time increased. The pattern of graph dropped drastically as it reached optimum time and load. This proves that as the load increases, the settlement value will decrease. This is because of the peat's high-water content, high permeability, low undrained shear strength, and high compressibility. If the incremental application of loads keeps increasing, the deformation curve gradually increases after some period before attaining its failure stress [13]. This results in immediate response of peat's settlement when load applied.

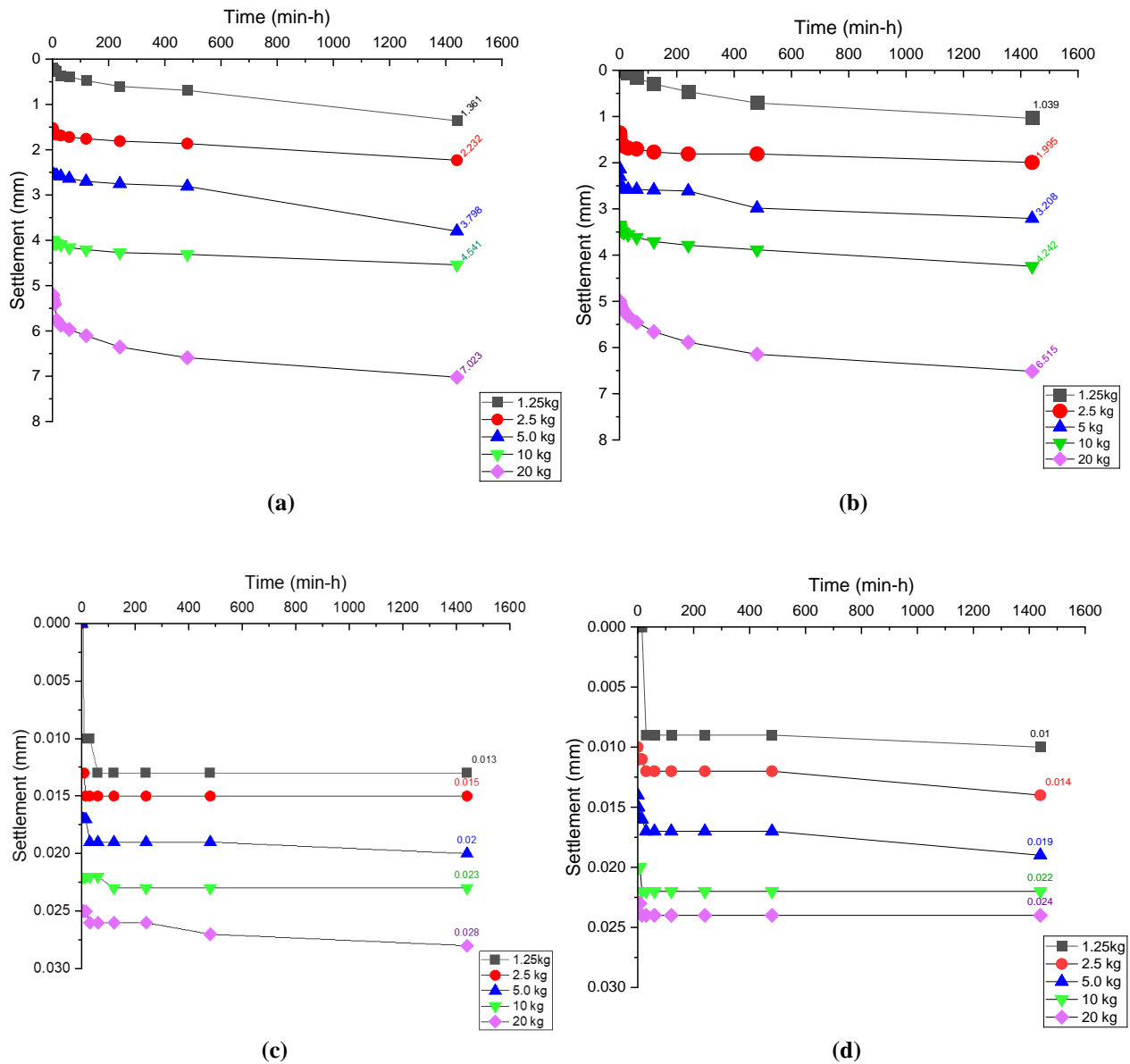


Fig.3 Peat Time-Settlement (a) without PPC; (b) with PPC at the center of the physical model study; settlement (c) without PPC; (d) with PPC at the 12 cm from the center of the physical model study

3.2 Soil Load-Settlement

Fig. 4 shows the relationship for a polymer-peat column between the load at 1440 minutes (24 hours), expressed in kilograms, and the settlement, expressed in millimeters at the center of the physical model study. Load values from 0 to 20 kg are displayed on the horizontal axis, and settlement values from 0 to 8 mm are represented on the vertical axis. The settlement increases at the beginning load with linear pattern, which is 1.25 kg to 5 kg with a comparatively small settlement, suggesting that the peat soil has an elastic behavior [14]. The graph begins to slope downward as the load increases from 10 kg to 20kg, signifying that the foundation or soil is about to undergo plastic deformation.

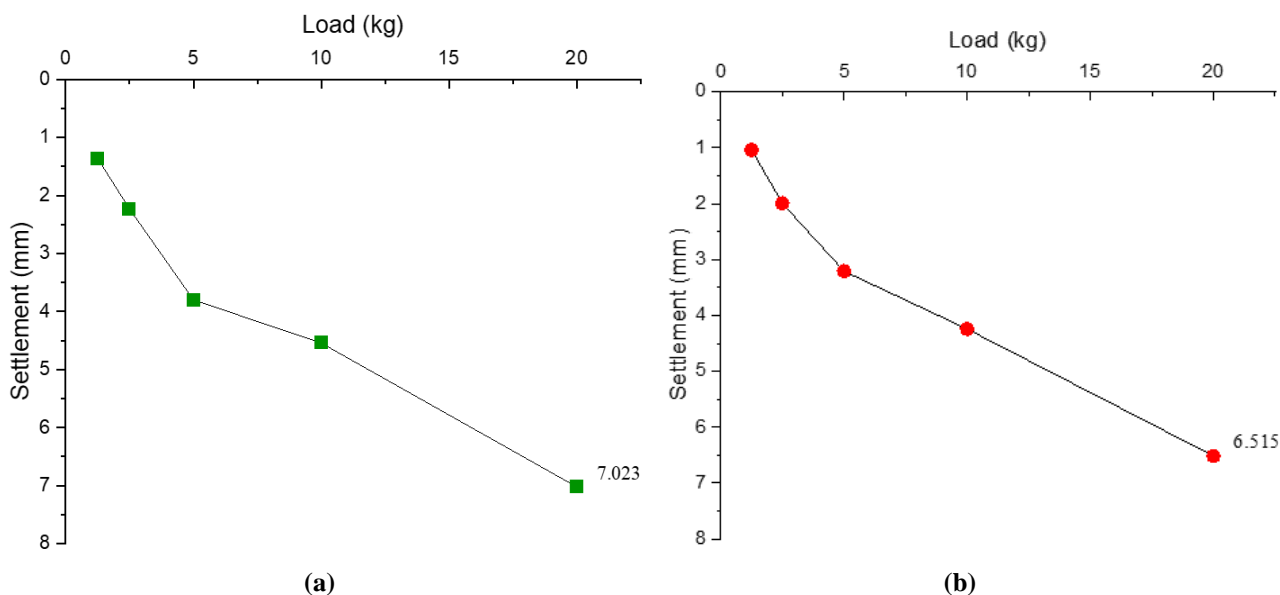


Fig. 4 Peat Load-Settlement (a) without PPC; (b) with PPC

4.0 Conclusion

This study demonstrates that Polymer-Peat Columns (PPC) significantly reduce peat soil settlement, providing a viable solution for construction on weak soils. The adoption of VAAC as a chemical stabilizer can effectively address settlement issues in peat soils. The data from the graph at maximum load (20 kg, 1440 minutes) without PPC is 7.023 mm higher than with applied PPC which is 6.515 mm. The data or graphs show the decreasing of 0.508 mm settlement at the maximum load (20 kg, 1440 minutes) after PPC has been added to physical model study. The chemical of polymer, VAAC has been proven as one of the chemical stabilizers that can decrease soil settlement of peat soils. The physical model study of PPC effectively key aspect of the solving problematic of peat soil with high moisture content, high compressibility and other else.

Acknowledgement

The authors would like to thank the Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia for its support. The authors also would like to express their sincere appreciation to their supervisor, Puan Siti Nooraiin Binti Mohd Razali for the support given throughout the duration for this research.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

This journal requires that all authors take public responsibility for the content of the work submitted for review. The contributions of all authors must be described in the following manner:

*The authors confirm contribution to the paper as follows: **study conception and design:** Nur Shaffa Syafwah Muhammad, Nur Adriana Nabila Mohd Hairul Azekey, Muhammad Aiman Azhar, Siti Nooraiin Mohd Razali; **data collection:** Nur Shaffa Syafwah Muhammad, Nur Adriana Nabila Mohd Hairul Azekey, Muhammad Aiman Azhar, Siti Nooraiin Mohd Razali; **analysis and interpretation of results:** Nur Shaffa Syafwah Muhammad, Nur Adriana Nabila Mohd Hairul Azekey, Muhammad Aiman Azhar, Siti Nooraiin Mohd Razali; **draft manuscript preparation:** Nur Shaffa Syafwah Muhammad, Nur Adriana Nabila Mohd Hairul Azekey, Muhammad Aiman Azhar, Siti Nooraiin Mohd Razali. All authors reviewed the results and approved the final version of the manuscript.*

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