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# Effects of Ordinary Portland Cement in Parit Haji Ali Peat Soil on Compression Strength

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**Abstract**

Peat is categorised as a soft soil due to its high porosity, extreme compressibility, high squeezability, and low shear strength. In recent years, adding Ordinary Portland Cement (OPC) to improve its properties and enhance its strength has been establish in several places. However, the optimum amount of OPC required to stabilised every peat is different depend on its properties. Therefore, there is a need to investigate the effects of OPC on Parit Haji Hali peat and find the optimum value of OPC required to stabilize the peat. The study meticulously examines the basic properties of raw peat soil, encompassing humification level corresponding to the H6 classification, moisture content (470%), organic content (97.238%), liquid limit (345%), specific gravity (1.247), fiber content (38%), and pH (3.86). Then, the unconfined compressive strength test were perform on treated samples with two different binder content (300 kg/m$^3$ and 350 kg/m$^3$) and different curing period (7,14 and 14 days) with a target of 50 kPa. Results indicate that the compressive strength of treated peat surpasses that of untreated peat, with the highest strength of 113.8 kPa achieved after a 28-day curing period at 350 kg/m$^3$ binder. The comparison of unconfined compressive strengths in treated peat with densities of 300 kg/m$^3$ and 350 kg/m$^3$ consistently demonstrates higher strength values associated with the increased binder density and curing period. The cement dosage 300 and 350 kg/m3 for Parit Haji Ali hemic peat was sufficient to achieve the target strength of 56.88 and 67.54 kPa at 7 days, respectively

## 1. Introduction

Peat soil, characterized by its abundance in organic matter resulting from plant breakdown or "humification," covers approximately 8% of the global land area. In Malaysia, this unique soil type spans 30,000 km$^2$, posing both challenges and opportunities for construction projects (Zainorabidin & Wijeyesekera, 2007). The distinctive properties of peat soil, including its dark brown to black color, high organic content, water retention capacity, and lightweight nature, categorize it as unsuitable for conventional geotechnical applications. Notably, histosol, moss, bogs, fen, and mires are often grouped under the same category as peat soil, emphasizing its prevalence and importance in various ecosystems (Afnan Ahmad, 2021).

Given its unsuitability as a foundation material for construction due to high porosity, compressibility, squeezability, and low shear strength, peat soil has traditionally been viewed as an unfavorable geotechnical material (Mohd Zambri & Md Ghazaly, 2018). The acidity, rapid subsidence rates, and substantial water content ranging from 500% to 2000% further contribute to its problematic nature in civil engineering applications, as highlighted by Yacob & Som (2020). However, the increasing demand for development in Malaysia, driven by economic growth, has led to the necessity of utilizing peat soil for construction, especially in areas where suitable and affordable lands are scarce.

In response to the challenges posed by peat soil, researchers have explored various stabilization methods, with a particular focus on cement-based stabilizing agents. Studies, such as those conducted by Mohammed K. H. Radwan (2021), have demonstrated that cement additives tend to enhance the compressive strength of treated peat soil. Additionally, Rahman et al. (2016) have proposed and validated the use of chemicals like cement and calcium for stabilizing peat soil, opening avenues for the exploration of alternative mixtures tailored to the unique properties of peat soil in Malaysia.

In recent years, ordinary Portland cement (OPC) has emerged as a promising stabilizing agent for peat soil. While existing research has explored its effectiveness, the lack of specific guidelines regarding the optimal OPC dosage for stabilizing different peat types remains a gap in knowledge. The study's objectives are first, to determine the basic properties of Parit Haji Ali peat soil, focusing on parameters such as moisture content, organic content, fiber content, liquid limit, specific gravity, and acidity; and second, to assess the unconfined compressive strength (UCS) of untreated and treated peat soil with the addition of OPC at different curing periods. The significance of this study lies in its potential to inform construction practices by offering insights into optimizing OPC dosage for enhancing both economic and strength aspects in peat soil stabilization (Rahman et al., 2016; Mohammed K. H. Radwan, 2021).

## 2. Methodology

This part outlines the research method used to study peat's geotechnical characteristics and the effectiveness of Ordinary Portland Cement (OPC) in enhancing their strength. The discussion encompasses the materials used, sampling location, sampling method and sample preparation including OPC and peat soil. A flowchart was produced to illustrate the whole process of the research in simpler way as shown in figure 1.

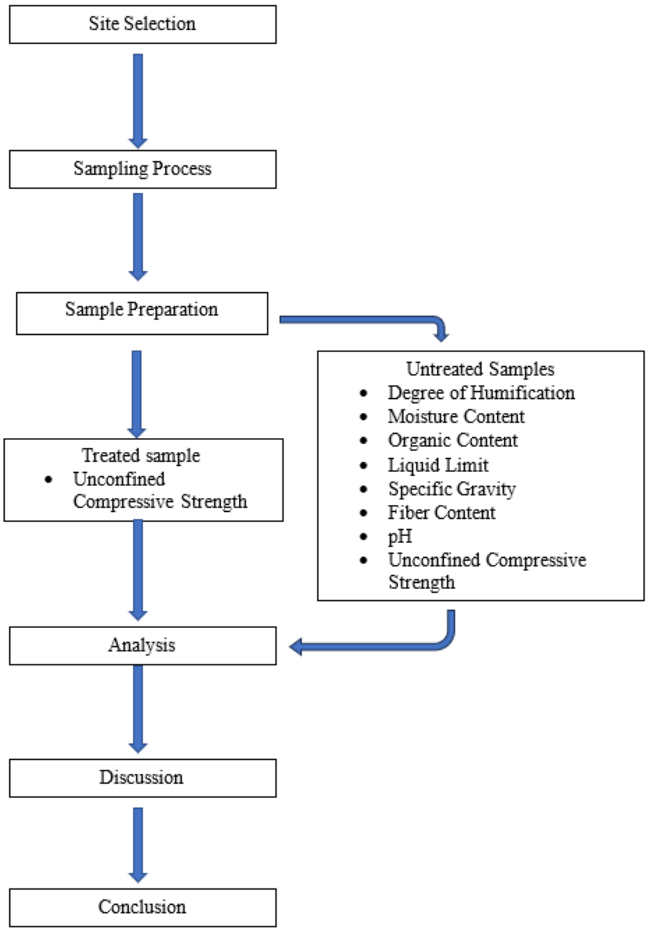


**Fig. 1** *Flowchart of methodology*

## 2.1 Sample preparation

The preparation of samples for this study involves the utilization of Ordinary Portland Cement (OPC) as a crucial stabilizing agent for peat. The primary material, peat soil, is sourced from Kampung Parit Haji Ali, Parit Raja, Johor. Given the delicate nature of peat soil, the sampling method is designed to minimize disturbance to its natural composition. The excavation process involves removing the top layer of soil to a depth of one foot, followed by a post-classification test to determine the peat's sapric, hemic, or fibric nature base on the criteria shown in table 1 and table 2. The level of humification was evaluated through visual examination, and an 80-kilogram sample was collected for further processing at UTHM. To avoid excessive disruption, the on-site procedures were minimized, ensuring a representative sample for accurate laboratory testing.

**Table 1** *The classification based on Von Post*

| ASTM | Classification of peat |
|---|---|
| H1 | Peat that has not broken down at all and lets out almost clear water. Plant stays easy to recognise. There is no vague matter. |
| H2 | Clear or yellowish water from almost undecomposed peat. Still recognisable. Not amorphous |
| H3 | Very slightly decomposed peat that emits muddy brown water but does not slide between fingers. No amorphous material, plant recognised. |
| H4 | Slightly degraded peat yields black, muddy water when |

| | |
|---|---|
| | squeezed. The plant remains are slightly pasty but not peaty. |
| H5 | When pressed, moderately degraded peat yields highly "muddy" water with a little amount of amorphous granular peat escaping between the fingers. Despite being hazy, the plant remains can be recognised. Pasty residue. |
| H6 | Medium-decomposed peat with a vague plant structure. One-third of peat slips between fingers when squeezed. Squeezing clarified the structure. |
| H7 | Highly decomposed peat amorphous with slight plant structure. Squeezing releases half the peat. Released water is black and almost pasty. |
| H8 | Amorphous peat with very little plant structure. Two thirds of peat slips between fingers when squeezed. Pasty water may leak. Roots and fibres resist degradation in the hand. |
| H9 | Decomposed peat without plant structure. It squeezes into a paste. |
| H10 | Decomposed peat without plant structure. Wet peat leaks when compressed. |

**Table 2** *The classification based on ASTM*

| ASTM | Classification of peat |
|---|---|
| Fiber content<br>(ASTM D1997) | Fibric: > 67% fibers<br>Hemic: 33%- 67% fibers<br>Sapric: < 33% fibers |
| Ash Content<br>(ASTM D2974) | Low Ash: Peat < 5% ash<br>Medium Ash: Peat 5%-15% ash<br>High Ash: Peat > 15% ash |
| Acidity<br>(ASTM D2976) | Highly Acidic: Peat < 4.5 pH<br>Moderately Acidic: Peat 4.5-5.5 pH<br>Slightly Acidic: Peat 5.5-7 pH |

The study employs sample molds with dimensions of 75 mm in height and 38 mm in diameter for assessing the Unconfined Compressive Strength (UCS). After a sun-drying phase, the peat undergoes crushing and sieving, with soil particles passing through a 2 mm screen collected for further processing. The quantities of materials used for treated peat samples at 300 kg/m$^3$ and 350 kg/m$^3$ are detailed in Tables 3, referencing Talib et al.'s (2015) research. Precision in material measurement was ensured, and a mandatory 10-minute blending session guarantees thorough mixing. The resultant material was evenly distributed into molds in a maximum of three layers, with a rigid metal retainer applied after each layer through 20 uniform taps. The molds containing the soil samples were submerged and allowed to undergo curing for durations of 7, 14, and 28 days, forming the basis for subsequent geotechnical analyses

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**Table 3** *Quantity of materials*

| Description | Data |
|---|---|
| Water content, w (%) | 470 |
| Bulk unit weight, γ bulk (kN/m3) | 9.76 |
| Total volume per sample, V ($m^3$) | 0.000196 |
| Dry unit weight, γ dry (kN/m3) | 1.71 |
| Dry weight of soil per sample, WS (kg) | 0.03362 |
| Weight of soil, WT (kg) | 0.192 |
| Cement content (%) | 100 |
| Weight of water per sample, WW (kg) | 0.158 |
| Weight cement per sample, $WB_1$ (kg)-300 kg/$m^3$ | 0.059 |
| Weight cement per sample, $WB_2$ (kg)-350 kg/$m^3$ | 0.069 |

## 2.2 Testing Instrument

The test for properties of peat soil was conducted by referring to *ASTM-D 2974* for moisture content, *ASTM-D2974-87* for organic content, ASTM-D1997 for fiber content, BS 1377 part 2: 1990: 4.3 for liquid limit, BS 1377 part 2: 1990: 8.3 for specific gravity and ASTM-D 4972 for pH value. The Unconfined Compressive Strength (UCS) test serves as a pivotal component in illustrating the compressive strength behavior of treated soil, aligning closely with the study's objectives. Specimens are meticulously extracted on the 7th, 14th, and 28th days of the curing process, adhering to the established guidelines outlined in ASTM D 2166. The evaluation of compressive strength for both treated and untreated peat soil samples is carried out employing an Unconfined Compressive Strength machine located at RECESS UTHM, as depicted in Figure 3. To minimize friction during testing, a layer of petroleum jelly is uniformly applied to the upper and lower plate surfaces before placing the specimen, a practice recommended by Shibi and Ohtsuka (2021). The test maintains a consistent strain rate of 1.27 mm/min, following the methodology detailed by Kolay and Aminur (2011), thereby ensuring reliability by subjecting a minimum of three samples to the testing procedure.


**Fig. 3** *UCS machine*

## 3. Result and discussion

The investigation into the physical properties of untreated hemic peat soil from Parit Haji Ali involved a comprehensive examination. The Von Post technique classified the peat as H6, indicating a moderately to severely degraded state with indistinct plant composition (N. Wahab et al., 2023). The peat's high flexibility, abundant fibrous material, and dark brown color led to its categorization as hemic peat soil. Moisture content analysis demonstrated a significant natural moisture retention, with an average of 470%, aligning with the inherent water-retaining ability of peat. The high organic content and large pore spaces within the soil structure enable it to absorb and retain water effectively (Abdul et al, 2018). The organic content, determined as 97.238%, indicated a substantial presence of organic matter, consistent with earlier studies. The reason for this high organic content is the accumulation of dead plant material in waterlogged, acidic environments where decomposition rates are slow. The waterlogged conditions inhibit the complete breakdown of organic matter by microorganisms, leading to its accumulation over time (Zainorabidin and Wijeyesekera's, 2007). The fiber content, assessed at 38%, fell within the expected range for hemic peat soil. Specific gravity, with an average of 1.23, reflected the low-density characteristic of peat, influenced by its degree of decomposition. The liquid limit analysis revealed a moisture content of 368%, while the pH value, averaging 3.86, confirmed the highly acidic nature of peat soil. This acidity results from the accumulation of organic acids produced during the partial decomposition of plant material in anaerobic (low-oxygen) conditions. As organic matter decomposes, organic acids are released, contributing to the soil's acidity (Wang et al., 2021). These findings provide a detailed understanding of Parit Haji Ali's peat soil, crucial for assessing its suitability for construction applications. Table 4 shows the summary of Parit Haji Ali peat soil properties.

**Table 4** *Summary of Parit Haji Ali peat soil properties.*

| Properties | Result |
|---|---|
| Organic content (%) | 97 |
| Water content (%) | 470 |
| Fiber content (%) | 38 |
| Liquid limit (%) | 368 |
| Acidity | 3.86 |
| Specific gravity | 1.247 |

### 3.1 Unconfined Compressive Strength (UCS)

The effect of Ordinary Portland Cement (OPC) on Parit Haji Ali peat with two different binder dosage and curing period were examined and summarize in table 5 and illustrate in figure 4. The results, depicted in Figure 4, showcased a clear trend of increased compressive strength with prolonged curing periods. This trend was consistent for both binder contents, indicating the positive influence of curing time on the treated peat's strength. The UCS values for the 300 kg/m$^3$ samples displayed a progressive increase from 56.88 kPa at 7 days to 106.3 kPa at 28 days. Similarly, the 350 kg/m$^3$ samples exhibited an upward trend, with strengths increasing from 67.54 kPa at 7 days to 113.8 kPa at 28 days.

**Table 5** *UCS result*

| Curing Period | Untreated (kPa) | Treated (kPa) | |
|---|---|---|---|
| | | 300 kg/m$^3$ | 350 kg/m$^3$ |
| 7 days | 15.24 | 56.88 | 67.54 |
| 14 days | 15.49 | 70.64 | 74.8 |
| 28 days | 16.06 | 106.3 | 113.8 |

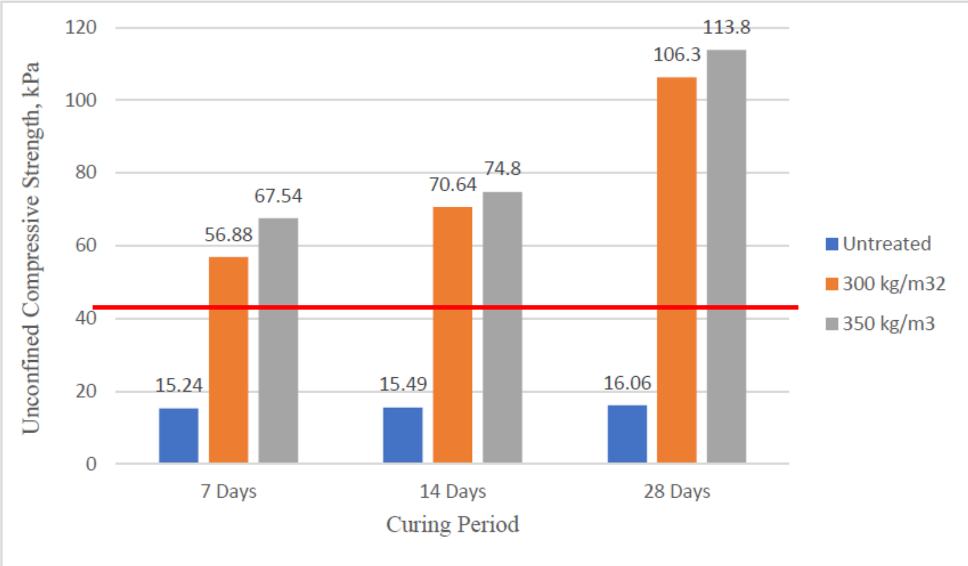


**Fig. 4** *UCS Comparison*

The important of binder density in influencing compressive strength was proved throughout the study. Higher binder content, represented by the 350 kg/m$^3$ samples, consistently resulted in superior compressive strengths compared to the 300 kg/m$^3$ samples. This phenomenon can be attributed to the increased volume of binder, which forms cementitious bonds with the soil particles. This process creates a network of interlocking crystals and bridges within the soil matrix, increasing cohesion and strength. As a result, the soil becomes more resistant to compression and deformation, leading to an increase in UCS (Mohd Zambri &Md Ghazaly, 2018). While higher OPC dosages generally lead to stronger stabilization due to increased cementitious material available for bonding soil particles, excessive amounts can result in undesirable effects such as excessive shrinkage, cracking, and increased project costs.

Peat is primarily composed of organic matter, which inherently has low strength and high compressibility. By mixing peat with OPC, the organic content of the soil mixture is reduced as the cementitious binder replaces some of the organic material. This reduction in organic content decreases the compressibility of the soil and enhances its load-bearing capacity, resulting in an increase in UCS (Gowthaman et al., 2022).

The substantial increase in compressive strength values after a 28-day curing period can be explained by the continued hydration process of cementitious materials, especially cement, used in the stabilization. Prolonged curing allows these materials to react with water, forming robust crystalline structures that contribute to the overall strength of the stabilized peat (Rahman et al., 2016). The binding effect of cement further enhances cohesion between soil particles, leading to increased density and stronger bonds over time.

Importantly, the observed compressive strengths for both binder contents surpassed the desired shear strength range for treated peat which is 50 kPa, as recommended by N. Wahab (2023). The results indicate that the stabilization process is highly effective in significantly improving the strength properties of peat soil, making it a promising solution for construction applications in challenging soil conditions. The study provides valuable insights into the intricate relationship between binder density, curing time, and the mechanical properties of treated peat, offering a robust foundation for engineering considerations in geotechnical applications.

## 4. Conclusion

In conclusion, the investigation into Parit Haji Ali peat soil conducted in this study has provided valuable insights into its physical, chemical, and mechanical characteristics. The soil, identified as hemic with a moderate degradation level, demonstrates noteworthy attributes such as an average moisture content of 47%, organic content of 97%, and a liquid limit of 368%. With a pH of 3.86, 38% fiber content, and a specific gravity of 1.247, these findings lay a solid foundation for comprehending the inherent qualities of peat.Furthermore, the study successfully illustrates the efficacy of cement as a stabilizing agent in enhancing the compressive strength of treated peat. Through Unconfined Compressive Strength tests, it is evidenced that both 300 kg/m3 and 350 kg/m3 binder densities undergo successful wet curing, surpassing minimum strength requirements. The treated samples achieve peak strengths of 106.3 kPa and 113.8 kPa, respectively, after 28 days.However, it is imperative to further analyze whether these achieved strengths meet the minimum values required for construction purposes. This evaluation will ascertain the practical applicability of cement-stabilized peat in geotechnical projects and determine its suitability for enhancing the mechanical properties of the soil. Therefore, while the study demonstrates promising results regarding the enhancement of peat soil's compressive strength through cement stabilization, additional consideration regarding its adequacy for construction needs is necessary for comprehensive decision-making.

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## Conflict of Interest

Muqri Marzuki, one of the authors, certifies that there is no conflict of interest related to the publishing of this journal paper and that there are no personal or financial ties that might improperly affect the content. Any possible financial or personal conflicts of interest that could have affected the research's findings or interpretation have been declared.

## Author Contribution

This journal mandates that every author assumes public accountability for the content presented in submitted work for review. Each author is required to articulate their contributions to the research in the following manner:

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