Review of consolidation test on peat soil of Batubara Regency Sumatera Utara Province

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Abstract. Organic soil is soil that has organic content which influences soil characteristic. Peat soil has high water content, high void ratio, low bearing capacity, and high compression so that settlement on peat soil is very large. It makes peat soil categorized as bad soil for construction. The purposes of this research were to know the index properties of peat soil, to determine the classification of peat soil, and to analysed the compression index ($C_v$) and coefficient of consolidation ($C_c$) by consolidation test with gradually loading from 0.5 kg, 1 kg, 2 kg, 4 kg, and 8 kg and immediately loading of 1 kg and 4 kg for 7 days. Peat soil Paya Pinang Plantation had 732.0 % water content ($w$), specific gravity ($G_s$) of 1.533, void ratio ($\varepsilon$) of 8.235, moist unit weight ($\gamma_{w}$) of 1.008 gr/cm$^3$, dry unit weight ($\gamma_d$) of 0.166 gr/cm$^3$. Based on ASTM D4427-92 (2002) peat soil sample had 22.424 % ash content, which classified as high ash peat and as slightly acidic peat with a pH greater than 5.5 and less than 7. The compression index ($C_v$) was 0.693 and coefficient of consolidation ($C_c$) was 0.275cm$^2$/sec.

1. Introduction
Almost similar to compost [1-5], peat soil is formed from the decomposed process of plants under anaerobic water-saturated conditions. Peat soil has high water content, low unit weight, low bearing capacity, and high compression so that settlement on peat soil is very large [6]. When a saturated compressible clay layer is subjected to a stress increase, the excess pore water pressure generated by loading dissipates gradually over a long time. There is secondary consolidation settlement in organic soil such as peat soil [7]. Terzaghi’s one-dimensional consolidation theory is a small strain theory, therefore both the coefficient of compressibility ($a_v$) and the coefficient of permeability ($k$) remain constant during the consolidation process. Then there is a unique relationship between the change in void ratio and the change in effective stress. This implies also that there is no secondary compression. [8]. This research was conducted to review the compression index and coefficient of consolidation from the consolidation test of peat soil Paya Pinang Plantation Batubara Regency regarding with the settlement of a shallow foundation.

2. Method
The research activities include index properties test of peat soil using undisturbed soil samples, disturbed soil samples, and consolidation tests. These activities were conducted in two different places, for index properties test were conducted in Soil Mechanics Laboratory, Civil Engineering Department, University of Sumatera Utara. And for consolidation test were conducted in the Laboratory of Lima Saudara company. The research samples were peat soil from Paya Pinang Plantation Batubara Regency. These samples were supposed to be representative of peat soil that was in Batubara regency,
Sumatera Utara province. One sample was used for the determination of ash content and organic content based on ASTM D2947-87 [9]. The gradually loading consolidation used 0.5 kg, 1 kg, 2 kg, 4 kg, and 8 kg while the immediate loading consolidation employed 1 kg and 4 kg for 7 days. Two types of soil samples can be obtained during subsurface exploration, undisturbed and disturbed samples. Thin wall tube was used for obtaining undisturbed soil samples. The thin wall tubes are commonly referred to as Shelby tubes. The undisturbed samples were used for the determination of shearing strength of soil. Hand auger boring was used to obtained disturbed sample. The shear strength determination of original soil by using direct shear test must use undisturbed samples. The investigation flowchart was given in Figure 1.

![Investigation Flowchart](image)

**Figure 1.** The investigation flowchart.
3. Result and discussion

3.1. Index properties data
Index properties of peat soil from Paya Pinang Plantation, Batubara Regency were presented in Table 1.

| No | Test                      | Result          | Physical properties of normal peat soil |
|----|---------------------------|-----------------|----------------------------------------|
| 1  | water content             | 732.000 %       | 110 %-1300 %                           |
| 2  | specific gravity          | 1.533           | 1.250 – 1.800                          |
| 4  | moist unit weight (γ_b)   | 1.008 gr/cm³    |                                         |
| 5  | dry unit weight (γ_d)     | 0.166 gr/cm³    |                                         |

3.2. Classification of peat soil
The result of ash content, organic content, and pH of peat soil were displayed in Table 2.

| No | Test             | Result       | Classification of peat soil based on ASTM D4427-92 (2002) [10] |
|----|------------------|--------------|--------------------------------------------------------------|
| 1  | ash content      | 22.424 %     | >15 % high ash-peat                                         |
| 2  | organic content  | 77.576 %     |                                                             |
| 3  | pH               | 6            | Slightly acidic                                             |

3.3. Mineral element of peat soil
Mineral elements of peat soil were presented in Table 3.

| Mineral element       | Units | Result |
|-----------------------|-------|--------|
| Silica (SiO₂)         | %     | 10.8   |
| Aluminum (Al₂O₃)      | %     | 0.02   |
| Ferum (Fe₂O₃)         | %     | 3.31   |
| Magnesium (MgO)       | %     | 0.16   |
| Califium (CaO)        | %     | 0.52   |
| Kalium (K₂O)          | %     | 0.25   |
| Natrium (Na₂O)        | %     | 0.38   |

3.4. Loading time influence toward water content in immediately loading
The time of loading versus water content curve in immediately loading was shown in Figure 2. It could be concluded that if the loading time increased then water content decreased sharply.
3.5. **Loading time influence toward moist unit weight in immediately loading**

The time of loading versus the moist unit weight curve in immediately loading was displayed in Figure 3. It could be concluded that if the load and loading time increased accordingly moist unit weight decreased sharply.

![Graph showing moisture content and unit weight](image)

**Figure 3.** Influence immediately loading toward moist unit weight.

3.6. **Loading time influence toward dry unit weight in immediately loading**

The time of loading versus dry unit weight curve in immediately loading was shown in Figure 4. It could be concluded that if the load and time of loading increased then dry unit weight increased.

![Graph showing moisture content and unit weight](image)
3.7. Correlation of time with settlement in gradually loading
Correlation of time with settlement on samples 1 and 2 in gradually loading was shown in Figure 5 and Figure 6. Both figures showed the same settlement trend which at early loading produced a large settlement and then produced a very small settlement in the remaining time.

Figure 4. Influence immediately loading toward dry unit weight.

Figure 5. Correlation of time with Settlement on sample 1 in gradually loading.

Figure 6. Correlation of time with settlement on sample 2 in gradually loading.
3.8. Correlation of time with settlement in immediately loading
Correlation of time with settlement on samples 3 and 4 in immediately loading was shown in Figure 7 and in Figure 8. Both figures showed the same trend of settlement which at early loading produced a large settlement and then produced a very small settlement in the remaining time.

![Figure 7](image1.png)
**Figure 7.** Correlation of time with settlement sample 3 in immediately loading.

![Figure 8](image2.png)
**Figure 8.** Correlation of time with settlement sample 4 in immediately loading.

3.9. Coefficient of consolidation ($c_v$) in gradually loading
The coefficient of consolidation ($C_v$) in gradually loading was shown in Figure 9.

![Figure 9](image3.png)
**Figure 9.** The curve of $C_v$ from sample 1 and sample 2.

3.10. Correlation of void ratio with effective pressure in gradually loading
The correlation of void ratio with effective pressure in gradually loading was shown in Figure 10. It could be concluded in loading condition that the void ratio decreased in concave upward shape of the compression curve, and in unloading condition, the void ratio was constant which meant no elastic strain at all.
3.11. Correlation of void ratio with time of loading

The correlation of void ratio with the time of loading was presented in Figure 11 and Figure 12. It could be concluded that \( C_v \) value was very large in the early loading, then became very small in the later time.

4. Conclusion

From the investigation outcome, it could be deduced that:

- Peat soil Paya Pinang Plantation, Batubara Regency had 732.0 \( \% \) water content \( (w) \), specific gravity \( (G_s) \) of 1.533, void ratio \( (e) \) of 8.235, moist unit weight \( (\gamma'_{b}) \) of 1.008 gr/cm\(^3\), dry unit weight \( (\gamma'_{d}) \) of 0.166 gr/cm\(^3\), 22.424 \( \% \) ash content, 77.576 \( \% \) organic content, and acidity / pH of 6.
Based on ASTM D4427-92 (2002), the peat soil was classified as high-ash peat with more than 15% ash.

Based on ASTM D4427-92 (2002), the peat soil was classified as slightly acidic peat with a pH between 4.5 and 6.5.

The compression index ($C_c$) was 0.693 and coefficient of consolidation ($C_v$) was 0.275 cm$^2$/sec. The compression index and coefficient of consolidation in peat soil were very large compared to compression index and coefficient of consolidation ($C_v$) of clay soil.

Peat soil Batubara Regency was poor soil for building construction because the compression index was very large so that it would experience a very large settlement.

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