Strength Characteristics of Pond Ash – Hydrated Lime Admixture Treated Peat Soil

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Abstract. Peat soil is identified as unsuitable soil to support the structure's foundation in original condition because it has the characteristics that make it fail when the excessive settlement occurred. It will give the effect of the building conditions because the substructure foundation building not safe to use for a long immersion period. Therefore, this study is to increase the strength of peat soil characteristics in an effective way using a low-cost budget. Each variant of 3, 6 and 9% of hydrated lime (HL) were mixed with 5% of pond ash (PA), at which PA is constant. Meanwhile, each variant of the 10 and 15% of PA was mixed with 3% of HL and tested in different soaking time (0, 3 and 7 days). The strength of the sample increases when the percentage of PA and HL increase during soaking time. 15% of PA sample shows the strength increased to the range of 16% at a 7-day soaking time compares to the natural peat soil. Meanwhile, the 9% of HL sample also shows the strength was achieved in the range of 32% in 7-day soaking time. It was analyzed that the PA and HL addition increase the strength of original peat soil.

1. Introduction
In construction industry, a serious problem that should be considered is the placement overloading structure for the long term, especially problematic. The problematic soil in the construction industry at present somewhat lacking, although it has become increasingly necessary for development reason. For this time, it is important to stabilize the peatlands before building the construction. Chemical admixture is one of the better alternatives for soil stabilization [1 & 2]. A study by [3], soil stabilization is one of the methods to improve ground for peat soil, to increase soil strength, to improve deformation properties and to save cost. For example, according to [4], the sodium silicate stabilizers have shown that the viscosity is less. In research by [5], they have studied the use of pond ash as a waste for “green sustainability” in the construction industry. In [1], [6] and [7] also mention the pond ash, which is product of power plant. For soil stabilization [8] explains that the peat soil has different physical properties as shown in Table 1. Therefore, using hydrated lime, fly ash, blast furnace slag or other “secondary product” can accelerate the reaction rate during stabilization.

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According to [1], [9] and [10], they also agree the addition of different admixtures of different amounts of pond ash on peat soil shows rise in the unconfined compressive strength results.

### Table 1. Physical Properties of Peat [8].

| Soil Deposits                        | Water Content (w, %) | In Situ Bulk Density (kN/m^2) | Specific Gravity (G_s) | Organic content (%) |
|--------------------------------------|----------------------|-------------------------------|------------------------|---------------------|
| Quebee fibrous peat                  | 370 - 450            | 8.7 - 10.4                    | -                      | -                   |
| Antoniny fibrous                     | 310 - 450            | 10.5 - 11.1                   | -                      | 65 - 85             |
| Co Offaly fibrous peat, Ireland      | 865 - 1400           | 10.2 - 11.3                   | -                      | 98 - 99             |
| Cork amorphous peat, Ireland         | 450                  | 10.2                          | -                      | 80                  |
| Cranberry bog peat, Massachusetts    | 759 - 946            | 10.1 - 10.4                   | -                      | 60 - 77             |
| Austria Peat                         | 200 - 800            | 9.8 - 13.0                    | -                      | -                   |
| Japan Peat                           | 334 - 1320           | -                             | -                      | 20 - 98             |
| Italy Peat                           | 200 - 300            | 10.2 - 14.3                   | -                      | 70 - 80             |
| America Peat                         | 178 - 600            | -                             | -                      | -                   |
| Canada Peat                          | 223 - 1040           | -                             | -                      | 17 - 80             |
| Hokkaido Peat                        | 115 - 1150           | 9.5 - 11.2                    | -                      | 20 - 98             |
| West Malaysia Peat                   | 200 - 700            | 8.3 - 11.5                    | 1.38 - 1.7             | 65 - 97             |
| East Malaysia Peat                   | 200 - 2207           | 8.0 - 12.0                    | -                      | 76 - 98             |
| Central Kalimantan Peat              | 467 - 1224           | 8.0 - 14.0                    | 1.50 - 1.77            | 41 - 99             |

2. Methodology

2.1. Materials

The peat soil from Johor is dark brown in color were extracted at 0.3 – 1 m depth below the ground level and considered as fully saturated soil has the potential in future development. The undisturbed samples were extracted using a thin-wall Shelby tube (or thin walled-sampler tube) size based on BS 1377 (1990) – 1 and ASTM standard to minimize the disturbance to the sample. Meanwhile, the disturbed samples were extracted using hand auger in very large quantity for related testing purposes. A few samples need to be prepared before the tests were conducted. The soil sample was to be dried in oven. Samples were dried in an oven and sieved in particles size beyond 2 mm. All the physical properties tests are stipulated according to BS 1377: 1990.

2.2. Mixture Materials

PVC pipe as shown in Figure 1a were used in this study. The 5% of the PA was mixed together in each of 3, 6 and 9% of HL, meanwhile the 3% of HL content was adopted in each 10 and 15% compositions of PA as shown in Figure 1b, c. Mixture samples ‘A’ until ‘F’ which are three (3) samples immersion period, namely 0-, 3- and 7-day. The immersion application is to applying natural state of the mixture samples when exposed to the peat’s natural water level at that location. For each immersion period, three (3) mixed specimens are required with a total of Forty-eight (48) specimens. Immersion samples extracted and ready for unconfined compressive strength (UCS) testing.

2.3. Unconfined Compressive Strength Test

The remolded peat for the untreated was also tested for UCS. The UCS test of the typical strain stress curves shown in Figure 2.
Figure 1. (a) PVC mold (b) Untreated peat sample (remolded) and (c) Treated peat sample

Table 2. Samples Labeled

| Label | Type of sample | Composition | Soaking time (days) | No. specimens |
|-------|----------------|-------------|---------------------|---------------|
|       |                | Pond Ash (PA) (%) | Hydrated Lime (HL) (%) | 0  | 3  | 7  |
| A     | Peat (remoulded) | - | - | 3 | - | - |
| B     | 5PA3HL         | 5% | 3% | 3 | 3 | 3 |
| C     | 5PA6HL         | 5% | 6% | 3 | 3 | 3 |
| D     | 5PA9HL         | 5% | 9% | 3 | 3 | 3 |
| E     | 10PA3HL        | 10% | 3% | 3 | 3 | 3 |
| F     | 15PA3HL        | 15% | 3% | 3 | 3 | 3 |

Figure 2. Stress-strain curves
3. Mechanical and Physical Characteristics

3.1. Characteristics Results

A several test results of physical characteristics (Table 3) was indicating that natural peat obtained from Jalan Rejo Sari, Senggarang, Batu Pahat, Johor. The mineral composition of PA samples in this study as shows in Table 4 and according to ASTM D 618-94 [11] it falls into the Class F coal category. Meanwhile, the HL contains calcium hydroxide (Ca (OH)₂) [12].

3.2. Unconfined Compressive Strength Test Results

From the results of the compressive strength test, the large stress-train curve was provided in Figure 3a, b, clearly increased with the increase of PA-HL in immersion period at 0-, 3- and 7-day. Increasing HL, the sample strength increased from 30 to 51.3 kPa. Meanwhile, for 0- and 3-day samples, they increased to 35.4 kPa and 38.9 kPa, respectively.

### Table 3. Summary of Peat Properties at Jalan Rejo Sari, Senggarang, Batu Pahat, Johor

| Characteristics                  | Values       |
|----------------------------------|--------------|
| Water content (w) (%)            | 588.96 - 814.6 |
| Decomposition LOI (N) (%)        | H3 – H6      |
| LOI (%)                          | 78.163       |
| Specific gravity, Gs             | 1.39 - 1.54  |
| OC (H) (%)                       | 98.8         |
| pH                               | 3.23         |
| MDD (Mg/m³)                      | 0.62         |
| OMC (%)                          | 42.31        |
| UCS (Untreated Remolded) (kPa)   | 30           |

### Table 4. Chemical and Physical Composition of PA

| Major element            | Value     |
|--------------------------|-----------|
| SiO₂                     | 46.3%     |
| Al₂O₃                    | 34.5%     |
| Fe₂O₃                    | 9.88%     |
| MgO                      | 0.91%     |
| CaO                      | 0.73%     |
| TiO₂                     | 5.95%     |
| SO₃                      | 0.31%     |
| P₂O₅                     | 0.05%     |
| Alkalis (Na₂O + K₂O)     | (0.098 + 0.84) % |
| SiO₂ + Al₂O₃ + Fe₂O₃     | 90.68%    |
| Specific Gravity         | 2.15      |
| Bulk Density             | 720 kg/m³ |

This increase was approximately 1.2 to 1.7 times the strength untreated peat (sample A). Figure 3b shows the compression strength (UCS) of 3% HL sample. The strength increases up to 65.4 kPa which is an increase of 2.2-time. Samples with a 0-day immersion time showed an increase in strength to 52.3 kPa which was 1.7 times natural soil. Meanwhile, with a 3-day immersion sample, its strength increased to 56.6 kPa which is 1.9 times the natural soil. This indicates additional material increased peat strength by comparing soaking durations as the strength is increased during immersion period.
3.3. Unconfined Compressive Strength Test Analysis

Over the immersion period, a series of graphs were generated based on their PA and HL contents. Figure 4a shows a series of graphs derived in three squares with characteristics features of samples B, C and D which contain 5% of PA and Figure 4b shows a series of graphs derived in two squares with different strengths of samples E and F with 3% of HL. In Figure 4a, sample B shows an increase in strength in early stage of immersion. Strength increased from 0% on day 3 to 101% on day 7. Sample C also showed a similar trend but reached a maximum strength of 24% on day 3 before increasing to 42% of day 7. Samples D has the same trend as sample C but with slightly different percentages. The strength increased 10% on the day 3 before increasing to 32% at the maximum strength of 51.3 kPa which was recorded using the sample on day 7 day.

![Figure 3a](#) Effect of different soaking time on UCS at 5% PA

![Figure 3b](#) Effect of different soaking time on UCS at 3% HL

![Figure 4a](#) Strength characteristics of treated peat (5% PA) subjected with soaking time.

![Figure 4b](#) Strength characteristics of treated peat (3% HL) subjected with soaking time.

In Figure 4b, sample E shows a similar pattern. It starts with a 42% increase on day 3 before dropping to 15% on the day 7. The strength of sample F decreased by 8% before increasing to 16% on day 7. Meanwhile, Figure 5 shows the trend graph of the $E_{50}$/UCS which is not consistent, but similar behaviour, especially in composition of 5PA3HL, 5PA9HL and 10PA3HL. The composition of 15PA3HL mix gives a higher value between 6 to 24, and the composition of 5PA6HL shows the lower value between 6.3 to 22.

4. Conclusions

It can be concluded that a longer immersion times lead better strength of the treated peat. The addition of hydrated lime and pond ash have shown the pozzolanic reaction were happening in the natural soil. When more samples a composition is made, the greater the potential increase and comparison of maximum strength values between the samples.
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