The effect of mixing peatland burning remains as fly ash and peat soil on its California Bearing Ratio value

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Abstract. Peat has been known for its high compressibility, low shear strength and high-water content. Moreover, when it comes to dry season, peat can easily be burnt leaving the large amount of carbon into the atmosphere also causes significant damage to peatland ecology. Based on these, peat burning remains are used as fly ash and it is expected to improve the strength of peat soils alongside to be environmentally safe. Laboratory tests were carried out according to that condition. A study on the influence of fly ash addition in peat soils was done by comparing the result from CBR (California Bearing Ratio). Different percentages of fly ash (i.e. 15, 20, and 25%) were added into peat soil at optimum moisture content amidst 5% of Portland cement for each sample with a variety of curing time of 2 hours, 1 day, 3 days, and 7 days. Changes were observed in specific gravity, acidity, and the microscopic structure. The CBR test results show that the peat gained strength due to the addition of fly ash, with the optimum result of 5.36% for unsoaked condition and 6.35% for soaked condition. Furthermore, according to the results, the peat soil can be used as a subgrade.

1. Introduction
Indonesia has a land area of 1,913,578.68 km² and peatland is about 10.8% from the total area. Peatland is distributed mainly in Sumatera, Kalimantan, and Papua. Due to population growth, substantial areas of peatland in Indonesia have been and presently are being reclaimed for construction, especially for roadway. Construction of road embankments could be hard because of its poor characteristic. Peat is a type of soil which has a high-water content and low pH level. It can be identified by its colour, which is black to dark brown, and its fibrous texture. Peat is an organic soil made up of partially decomposed process of vegetation. It is characterized with high compressibility and low bearing capacity. Moreover, it has a property of irreversible drying.

During dry season, peat can be easily ignited and once it started, fires are difficult to extinguish as they burn downwards. Besides, ignition on peatland is tougher to human’s health even to environment. There have been some improvements done on peat soil, such as preloading method and stabilization using additive, for example cement [1, 2], lime [3–5], and geopolymer [6]. Despite those methods can improve the strength of peat, they are considered not environmentally friendly. Due to that reason, materials from peatland ignition remains called fly ash used to enhance peat soil stability. It is expected to be environmentally friendly and reduce chemical waste that usually comes from additives using, considering in this research waste from ignition remains are used.
2. Characteristics of the materials

2.1. Soils used
Soil used in this study is peat soil that were collected as disturbed from Ogan Komering Ilir, South Sumatera. Peat soils represent the intense form of soft soil. It is identified as fibrous peat because it has 20% or more of fiber content. The soil has low pH level and is classified as peat soil with moderately acidic. Peat soil has inhomogeneous condition which can be seen from its fibers’ size and density that are not the equivalent in different places.

2.2. Fly ash
Fires in peatland are often caused by forest degradation or deforestation that is linked to its drainage. In South-east Asia itself, the peat fires can smoulder hectares in one period of dry season. In this research, fly ash formed from the ignition remains of peatland in Rokan Hilir, Riau is added into peat soil. It has acidity level of 6.30 and specific gravity value of 2.49. One of the differences between peat soil and burnt peat soil, or fly ash, can be seen from its crystallite structure which can be known from XRD test as seen in the figures below.

![Figure 1. XRD result of peat soil.](image1)

![Figure 2. XRD result of fly ash.](image2)

3. Research methodology
In this research, there were three things observed, such as:
- Physical changes, observed in specific gravity and acidity level (pH)
- Mechanical changes, observed in CBR value
- Microscopic changes, observed with Scanning Electron Microscopy (SEM)

3.1. Sample preparation and curing
The peat soil used in this research had moisture content of 300%. Therefore, it had to be air dried since the mixing process was done with lower moisture content, which is 120%, the optimum moisture content obtained from compaction test. It was done following ASTM 698-78 with standard proctor.

Three types of stabilized samples were prepared, namely:
- Type X: Peat soil is stabilized with 15% of fly ash material and 5% of Portland cement
- Type Y: Peat soil is stabilized with 20% of fly ash material and 5% of Portland cement
- Type Z: Peat soil is stabilized with 25% of fly ash material and 5% of Portland cement

The percentage of fly ash material and Portland cement achieved from peat soil’s dry density.

Peat soil and fly ash were mixed and stirred manually in a container. The mixture was left in an airtight container for a different curing time. Curing was applied to each sample for 2 hours, 1 day, 3 days, and 7 days. It was done thus the peat soil pores were filled with fly ash. After that, Portland cement was added to the mixture. Samples that had been mixed with Portland cement then being compacted with standard proctor.
3.2. California bearing ratio
The California Bearing Ratio test was performed after the curing process was done. It was conducted on both unstabilized and stabilized peat soil. The samples used were at a moisture content of 120%. The test was done in accordance with the procedures from ASTM D1883-16. There are two types of tests, unsoaked and soaked condition. The soaking period in order to examine the samples to be submerged in water and fully saturated is 96 hours. During this period, the swelling value is being examined.

4. Result and discussion
As can be seen in table 1, fly ash used in this study has a higher value of specific gravity, pH level, also nitrogen. However, the C-Organic, or carbon, contained in fly ash is lower due to ignition process. Compared to the properties of unstabilized peat soil, acidity of stabilized peat soil is reduced because of the addition of fly ash. Moreover, the specific gravity of it are higher. Both improvements in physical properties of stabilized sample are caused by the addition of fly ash that has higher specific gravity value as well as pH level.

Table 1. Properties of peat soil and fly ash.

| Properties       | Peat Soil | Fly Ash |
|------------------|-----------|---------|
| Specific Gravity | 1.83      | 2.49    |
| pH Level         | 4.10      | 6.30    |
| Ash Content (%)  | 35.91     | -       |
| Organic Content (%) | 64.09 | -       |
| C-Organic (%)    | 49.00     | 3.60    |
| Nitrogen (%)     | 3.47      | 6.10    |

Before CBR test began, compaction is occurred to unstabilized peat soil thus optimum moisture content and dry density of it could be known. The unstabilized peat soil has an optimum moisture content of 120% hence the dry density is 0.47 gram/cm³.

The California Bearing Ratio (CBR) is one of the engineering properties that is an important soil parameter used in design of pavements. The change in penetration test from CBR is shown in figure 3. Each graph represents results of unstabilized sample and stabilized samples with different curing time. There are three types of stabilized samples as can be seen in each graph. Those samples can be distinguished by its percentage of fly ash addition, which are 15% (type X), 20% (type Y), and 25% (type Z).
Figure 3. The result of California Bearing Ratio test.
The percentage of fly ash addition indicates different results in two hours and one day of curing time. In two hours of curing time, type Y shows the highest result in unsoaked condition and type Z in soaked condition. Whilst in one day of curing time, type Z shows the highest result in unsoaked condition along with type X for the soaked condition. Meanwhile, type Y has the highest result in three days of curing and type Z in seven days of curing in both conditions, which are unsoaked and soaked.

From the figure above, it shows that the unsoaked condition has more strength to withstand from the penetration. It may be caused by the inhomogeneous of peat soil. The structure of peat soil is the sum up of organic fibers, and it may be in difference sizes. Moreover, peat consists of macro and micro pores.

The chemical reactions occurred in this process of stabilization could strengthen the peat soil and make it gains considerable strength thus its load bearing capacity improved. In comparison to the unstabilized peat soil, the stabilized soil shows that it can endure more load. It may increase until about 150% from its initial strength with the addition of fly ash material and Portland cement.

Figure 4 shows the effect of curing period to CBR value. It represents that CBR value is decreasing along the curing period. The three type of samples mainly show the highest CBR value when the curing time was done in one day. It may be caused by the chemical reactions in one day are giving its best performance. CBR value of stabilized peat soil with Z mixed type shows the highest result for the unsoaked condition while the X mixed type shows the highest result for the soaked condition. The results show that the stabilization process, with the addition of fly ash, increase the general rating of the in-situ peat soil from very poor to fair.

![Figure 4. The effect of curing period to CBR value.](image)

During soaking process in California Bearing Ratio test, the reading of swelling is also conducted. The result obtained from swelling reading reveal that fly ash cannot prevent the samples from absorbing water, therefore the samples can swell for 11.53%, for the highest value, from its initial size despite the lowest swelling value is 1.88%.

The structure of unstabilized peat soil can be seen that it has pores between fibers. Microscopic observation results indicate that fly ash is filling the gap in between peat soil’s particles. It also shows that the higher percentage of fly ash given, the gap, or micro pore, in between soil particles is being decreased. It can be seen from SEM photos as shown in figure 5. There is a fewer macro cracks in the stabilized sample.
Unstabilized Peat Soil

Magnification of 5,000x

Magnification of 10,000x

Magnification of 20,000x

Magnification of 30,000x

Stabilized Peat Soil

Magnification of 5,000x

Magnification of 10,000x

Magnification of 20,000x

Magnification of 30,000x

Figure 5. SEM photos of unstabilized and stabilized peat soil.

5. Conclusion
In this research, stabilization on peat soil was done with the addition of fly ash which is formed from the ignition remains of peatland and Portland cement as a binding agent. From the result, fly ash can enhance the CBR value of peat soil from poor to good enough with the optimum result is 5.36% for uns soaked condition while for soaked condition is 6.35%. It is important to note that the effectiveness of fly ash addition is affected by curing period.

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