Analysis of shear strength clay using coconut shell charcoal powder as stabilization material

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Abstract. One type of soil that has weak bearing capacity is clay. One parameter that can be reviewed is the soil shear strength value in the form of cohesion value (c) and internal shear angle (φ). To increase the bearing capacity of the soil can be done using stabilization materials. In this research, coconut shell charcoal powder is used to increase the shear strength of the soil so that it does not become a waste and can be used as a stabilizing material because coconut trees are quite widely available on the island of Bangka. Variations in the addition of coconut shell charcoal powder are 5%, 10%, and 15% of the dry weight of the soil. Tests conducted in this study are sieve analysis, consistency limits, specific gravity, compaction, and direct shear test. The testing standard used is SNI. Soil classification using the USCS method. The value of shear strength of clay soil increased with the addition of the percentage of coconut shell charcoal powder from 26.844 kN/m² for clay soil to 59.845 kN/m² for clay soil with 15% coconut shell charcoal powder so that the coconut shell charcoal powder can be used as soil stabilization material.

1. Introduction
The soils is the main part of building construction because the ground is the bottom of building construction. So soils must have a good bearing capacity to withstand the burden that will be received from the building above. Not all types of soil have a good bearing capacity, one of which is clay soil. Clay soils are classified as fine-grained soils, so that these soils become weak soil bearing capacity. One of the soil bearing capacity parameters is the soil shear strength. The soil shear strength is influenced by the cohesion factor (c) and internal shear angle (φ) [1]. One way to increase the bearing capacity of the soil is by stabilization. Soil stabilization is a method to increase soil bearing capacity by increasing specific properties of the soil. One method that can be used by adding a mixing material as a stabilizing agent is, among others, by using coconut shell charcoal powder.

Ash or coconut shell charcoal powder can increase the bearing capacity of the soil, from previous studies have shown that mixing soil both clay soil, laterite soil, expansive soil, and cotton black soil with coconut shell material can provide a good effect to increase the strength or bearing capacity of the soil [2-12]. This is because coconut shell charcoal has a high amount of silica (SiO₂). The silica content serves to bind the soil grains. The other chemical elements present in the coconut shell charcoal are Al₂O₃, CaO, and Fe₂O₃, as shown in Table 1. All these elements are elements that are owned by cement
Cement is good binding material for binding material, such as in a concrete mixture. The content of chemical elements found in coconut shell charcoal can be seen in Table 1.

| No | Chemical Elements | Result Test (%) |
|----|-------------------|-----------------|
| 1  | Al₂O₃              | 18.6831         |
| 2  | CaO               | 5.4185          |
| 3  | Fe₂O₃             | 2.3993          |
| 4  | MgO               | 2.7813          |
| 5  | SiO₂              | 28.6142         |

Indonesia has many islands, including the Bangka Belitung Islands Province, which has many coconut plants. Part of the coconut fruit is the coconut shell, which has not been widely used by the community. At this time, the coconut shell is only used a small part, namely as charcoal for baking food. So that this coconut shell does not become a waste to the environment, the authors are interested in conducting this research. So that later this coconut shell can be more utilized for soil stabilization.

### 2. Research Method

The research was carried out in a laboratory. The research process is carried out with the initial stages is the study of literature followed by field surveys. Next is the preparation of materials and tools. The materials used for this research are clay and coconut shell charcoal powder. Clay is taken from the Reklamasi Village location, Bangka Regency, Bangka Belitung Islands Province. This location is a former tin mining area. Coconut shell charcoal powder as a stabilizing agent is obtained by manually combustion process. Combustion is carried out in a furnace in a large cave where the material to be charcoal is arranged in the cave, then the cave door is closed with bricks so that the air does not enter the evaporation process takes place. The combustion fire does not directly burn the coconut shell, therefore the furnace and the furnace laying the material apart so that only the hot steam enters the furnace and converts the material into charcoal. Coconut shell that has been burned turned into coconut shell charcoal. The next process is the destruction of coconut shell charcoal, then proceed with filtering using sieve no. 10. The result of filtering from crushed coconut shell charcoal is called coconut shell charcoal powder, which is used as a stabilizing agent with a percentage of 5%, 10%, and 15% of the dry weight of the soil.

The tools used are field water content testing tools, sieve analysis, consistency limits, specific gravity, compaction, and direct shear strength. Tests conducted in this study use the Indonesian National Standard (SNI) [15]. The soil classification used uses the USCS (Unified Soil Classification System) classification. The data used for soil classification are sieve analysis data and consistency limits (liquid limit and limit plasticity). Compaction testing using the modified proctor method. Data generated from compaction testing in the form of optimum moisture content (OMC) and maximum soil dry density (MDD). The optimum moisture content obtained is used as the water content when mixing clay soil with stabilizing material for the specimen of direct shear strength. From the direct shear strength test, value cohesion and internal shear angle data were obtained, both clay and clay soil with a mixture of coconut shell charcoal powder. Furthermore, the internal cohesion and shear angle values can be calculated, which will be compared as an analysis material. To find out whether this coconut shell charcoal powder can be used as a stabilizing agent, the value obtained from testing clay soil with a mixture of coconut shell charcoal powder is compared with the value from testing clay soil without stabilizing material. The final stage of this study is to conclude the analysis that has been obtained in accordance with research data. The process of making specimen and direct shear test is shown in Figure 1.
3. Result
After conducting several soil properties tests, namely field water content, sieve analysis, consistent boundaries, and specific gravity obtained data, as shown in Table 2.

Table 2. Soil property test material.

| No | Test                              | Unit | Result Test |
|----|-----------------------------------|------|-------------|
| 1  | Field water content              | %    | 31.832      |
| 2  | Sieve Analysis, for soil loose sieve no.200 | %    | 64.565      |
| 3  | Liquid Limit (LL)                | %    | 35.775      |
| 4  | Plasticity Limit (PL)            | %    | 20.461      |
| 5  | Plasticity Index (IP)            | %    | 15.314      |
| 6  | Specific gravity (Gs)            | -    | 2.632       |

Based on the filter analysis data, the liquid limit, plastic limit, and soil plasticity index from Table 2 can be determined by using the USCS standard, the soil is included in the CL group, which is an organic clay type with low to moderate plasticity [1].

From compaction testing using the modified Proctor method, it is found that the value of the maximum dry soil density (MDD) and the optimum water content (OMC). This value can be seen in Figure 2.
From Figure 2, it can be seen that the optimum moisture content (OMC) of clay is 18.259%, and the maximum dry soil density (MDD) is 1.762 gr/cm$^3$.

Based on the results of direct shear strength testing of clay and clay soil mixed with coconut shell charcoal powder (CSCP) with a percentage of 5%, 10% and 15%, the cohesion value and internal shear angle were obtained. This value can be seen in Figure 3 and Figure 4. From Figure 3 and Figure 4, it can be seen that the trend from the graph of cohesion value and internal shear angle in clay soil with a mixture of coconut shell charcoal powder shows an increase in value with an increasing percentage of coconut shell charcoal powder. Cohesion value of clay soil without stabilizing material is 12.534 kN/m$^2$, and this value is increasing with the increasing percentage of coconut shell charcoal powder, the highest cohesion value with the percentage of coconut shell charcoal powder 15% is 31.67 kN/m$^2$, meaning this cohesion value has increased equal to 252% of the cohesion value without stabilizing material.

The value of internal shear angle also increased from 21.105$^\circ$ for clay soil without stabilization material increased to 37.231$^\circ$ for clay soil with a mixture of 15% coconut shell charcoal powder, meaning the value of internal shear angle has increased by 176% of clay without stabilization material.

**Figure 2.** Relationship between soil dry density and water content

**Figure 3.** The effect of clay + CSCP mixture variation to the value of cohesion (c)
From the cohesion value and internal shear angle, the value of soil shear strength can be seen in Figure 5.

From Figure 5, it can be seen that the trend from the graph of soil shear strength values is increasing with an increasing percentage of coconut shell charcoal powder (CSCP). The soil shear strength value for soil without stabilizing material was 26.844 kN/m² increasing to 59.845 kN/m² with the addition of 15% coconut shell charcoal powder. This means that the value of the shear strength of this soil has increased by 222% of clay without stabilization material. The value of the soil shear strength is increasing because the cohesion value and the internal shear angle are increasing.

The value cohesion and internal shear angle value increased because the coconut shell charcoal powder contained silicate (SiO₂), which was high enough to be able to bind to the soil grains so that the bond between the soil grains became stronger. The content of other elements that affect the bonding of soil grains is Al₂O₃, CaO, and Fe₂O₃, all of which are elements contained in cement. Cement has a good ability to bind the mixture as in a concrete mixture. In addition, the gradation from the soil that has been mixed with coconut shell charcoal powder has changed because of the addition of a more coarse grading, because the coconut shell charcoal powder used is passed through sieve No. 10. This causes the ground shear to increase.

4. Conclusion
The value of shear strength of clay soil increased with the addition of the percentage of coconut shell charcoal powder from 26.844 kN/m² for clay soil without stabilization material to 59.845 kN/m² for clay...
soil with 15% coconut shell charcoal powder. This increase occurred at 222% so that the coconut shell charcoal powder can be used as soil stabilization material.

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