Utilization of Coconut Shell Charcoal to Improve Bearing Capacity of Clay as Subgrade for Road Pavement

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Abstract. Road construction on clay causes many problems with road damage because clay has a low bearing capacity and a large swelling value. The soil stabilization method was used to improve clay soil characteristics by adding cement, lime, fly ash, or other stabilizing agents. One of the stabilizing agents used in this study is coconut shell charcoal. The purpose of this study was to analyze the effect of adding coconut shell charcoal to the CBR value and the swelling index on clay soil. In this study, the coconut shell charcoal used was 0%, 4%, 8%, 12%, and 16% of the dry weight of the soil. The samples used were disturbed soil, and the curing period was 7 days. Testing the physical and mechanical properties of the soil (CBR and Swelling test) refers to the ASTM Standard. The results showed that the addition of coconut shell charcoal by 4% increased the bearing capacity and reduced the swelling index. An optimal CBR value of 14.69% was obtained for the addition of coconut shell charcoal by 4% with the unsoaked condition with a 7-day curing period. Whereas in the soaked soil condition, the optimal CBR value is 8.53% and the swelling value is 0.24%. Increasing the CBR value and decreasing the swelling value will cause the road construction layer to be more stable in supporting the load.

1. Introduction

The road is a means of connecting areas with one another. Along with the development of housing in the Kuranji watershed, especially in the area of Limau Manis, the need for roads has increased. The problem when planning the pavement road is the unstable subgrade condition due to its low bearing capacity and high swelling [1,2,3]. To overcome this problem, soil improvement can be carried out using chemicals or other additives [4,5].

Chemical stabilization is a process of adding certain chemicals to the soil so that a chemical reaction occurs, which causes the binds between the soil grains to improve. Stabilized agents that are usually used include portland cement, quicklime, and other added ingredients [6,7]. Besides stabilized agents can also be used in the form of rice husk ash, fly ash, coconut shell charcoal, sugar cane straw ash, etc [8,9,10,11,12]. In this study, coconut shell charcoal will be used as a stabilized agent, this is because in this area there is a lot of shell coconut waste and it has not been used optimally. Shell charcoal is charcoal made by a combination of coconut shells or shells. In the burning process of coconut shells which consists of very complex carbohydrates, it will cause a series of reactions, namely thermal decomposition and generate heat as a result of the decomposition of various molecular structures. At a temperature of 275 ° C, cellulose lingo begins to release H₂O and CO₂, besides that, charcoal and methane are also formed [13].

The results of previous studies indicate that the addition of coconut shell charcoal can increase the CBR value [14, 15, 16] and increase the value of the free compressive strength of the soil [17,18]. Based
on the results of the above research, coconut shell charcoal will be used as a stabilized agent in this study.

2. Research Location
Soil sampling was carried out in the Limau Manis area, Padang. Limau Manis is one of the areas that has rapid housing growth, so road infrastructure is needed. It's necessary to do soil classification to determine soil characteristics and analyze soil stability when used as a road subgrade. Soil sample testing was carried out at the Soil Mechanics Laboratory, majoring in Civil Engineering, Andalas University. All types of testing follow ASTM standards.

![Figure 1](image-url)  
*Figure 1. Soil sampling at Limau Manis, Padang.*

3. Materials and Methodology
The soil used in this study is a fine-grained soil located in the Limau Manis area, Padang. The soil condition used is disturbed soil which is taken using a hoe and then dried so that it can be broken into pieces using a hammer and sieved with a sieve No. 40 to test the physical properties of the soil. The added material used is coconut shell charcoal, which has passed filter number 100. In this study, coconut shell charcoal with levels of 4%, 8%, 12%, 16% of the dry weight of the soil was used. For the curing period, the sample used was 7 days. The soil specifications used are shown in Table 1.
Coconut shell charcoal used in this study comes from burning coconut shells. In the burning process of a coconut shell which consists of very complex carbohydrates, it will cause a series of reactions, namely thermal decomposition and generate heat as a result of the decomposition of various molecular structures. At a temperature of 275 °C, cellulose lingo begins to release \( H_2O \) and \( CO_2 \), besides that, charcoal and methane are also formed. In general, coconut shell has several characteristics as shown in Table 2 [19], while Table 3 shows the chemical composition of coconut shell charcoal [20].

| No. | Parameter                  | Percentage (%) |
|-----|----------------------------|----------------|
| 1.  | Water content              | 7.8            |
| 2.  | Ash content                | 0.4            |
| 3.  | Volatile material content  | 80.8           |
| 4.  | Carbon                     | 18.8           |

Table 3. Chemical composition of coconut shell charcoal

| Composition  | Content (%) |
|--------------|-------------|
| K\(_2\)O     | 45.01       |
| Na\(_2\)O    | 15.42       |
| CaO          | 6.26        |
| MgO          | 1.32        |
| Fe\(_2\)O\(_3\) dan Al\(_2\)O\(_3\) | 1.39 |
| P\(_2\)O\(_5\) | 4.64 |
| SO\(_3\)     | 5.75        |
| SiO\(_2\)    | 4.64        |

The types of tests carried out in this study include testing the physical properties of the soil including sieve analysis, specific gravity, Atterberg limits (liquid limit, plasticity limit, and plasticity index), and soil mechanical properties testing on original soil samples and soil that has been added with coconut shell charcoal. The type of mechanical testing performed is compaction test, California Bearing Ratio (CBR) with immersion and non-immersion conditions, and swelling test.

4. Results and Discussion

4.1 Physical characteristics of soil at Limau Manis

Based on the results of soil physical properties testing, the soil in the Limau Manis-Padang area is classified as fine-grained (clay), which is classified as OH soil, namely organic clay with moderate to high plasticity (USCS classification). Meanwhile, based on the AASHTO classification, the soil studied is included in the A-7-5. Based on the USCS and AASHTO classifications, this type of soil has a low
bearing capacity is not good when used as a road subgrade so that this land needs to be stabilized so that it can be used as a road subgrade.

Table 3. The Result of physical characteristics soil at Limau Manis.

| No | Type of Testing                             | Result  |
|----|--------------------------------------------|---------|
| 1  | Water content, $W$ (%)                     | 60.518  |
| 2  | Initial moisture content, $W_o$ (%)         | 19.106  |
| 3  | Unit weight, $\gamma$ (Gram/cm$^3$)        | 1.515   |
| 4  | Specific gravity, $G_s$                     | 2.591   |
| 5  | Liquid Limit, LL (%)                       | 58.409  |
| 6  | Plasticity Limit, PL (%)                   | 47.607  |
| 7  | Plasticity Index, PI (%)                   | 10.80   |
| 8  | CBR original with a soaked condition (%)   | 4.94    |
| 9  | Original soil swelling value (%)           | 0.52    |

4.2 Mechanical characteristics of soil at Limau Manis

4.2.1 The effect of adding coconut shell charcoal to the soil compaction

Figure 2 shows that the addition of coconut shell charcoal can increase the maximum dry density of the soil, the addition of 8% coconut shell charcoal causes the maximum dry density value of 1.175 grams / cm$^3$, but the addition of coconut shell charcoal of more than 8% results in a decrease in the maximum dry density of the soil. This is because the content of coconut shell charcoal in the soil is too much so that the soil grains cannot bind perfectly due to the uniform size of the coconut shell charcoal.

Figure 3 shows that the addition of coconut shell charcoal to clay soil causes a decrease in the value of the optimum water content, this is because coconut shell charcoal has water-absorbing properties (hygroscopic) so that water will be easily absorbed.

![Figure 2. Effect of adding coconut shell charcoal to the maximum dry weight ($\gamma_{dry}$ maximum).](image)
4.2.2 The effect of adding coconut shell charcoal to the CBR value

CBR is a way to assess the carrying capacity of the soil which is expressed in the form of a percentage of the ratio between the load required to penetrate a type of material to the load required to penetrate standard materials with the same depth and penetration speed.

Figure 4 shows that the addition of coconut shell charcoal with a content of 4% can increase the CBR value of clay soil but if the coconut shell charcoal content is more than 4% it causes a decrease in the CBR value of unsoaked and soaked. This is because when mixing the soil with coconut shell charcoal there is a reaction between coconut shell charcoal and clay when water is added, where the elements contained in coconut shell charcoal will form a reaction with clay soil which causes the formation of a hard and rigid soil mass so that the soil becomes hard and interlocking with each other. The strongest reaction was obtained at the addition of 4% coconut shell charcoal, whereas if more than 4% of the reaction between the soil grains decreased again, it was due to reduced reaction between soil particles and coconut shell charcoal. The CBR value obtained by adding 4% coconut shell charcoal content was 8.53% (CBR soaked) and 14.69% (CBR unsoaked).
4.2.3 The effect of adding coconut shell charcoal to the swelling value

Figure 5 shows that the addition of 4% coconut shell charcoal causes the swelling value to decrease to 0.24%. While the addition of coconut shell charcoal content of more than 4% is not effective because it causes the swelling value to increase again so that the soil becomes unstable and easily changes shape due to the influence of water. The addition of coconut shell charcoal of 4% can reduce the swelling value by 53.8% of the original soil swelling value.

![Figure 5](image.png)

**Figure 5.** Effect of adding coconut shell charcoal to the swelling value.

5. Conclusions

The addition of 4% coconut shell charcoal can cause the unsoaked CBR value to 14.69% and CBR soaked to 8.53% and reduce the swelling value of clay soil by 53.8% from the original soil. Based on this value, the optimal content of coconut coir to be used as an added material is 4% of the dry weight of clay soil.

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