Effect of addition of palm shell ash and asphalt emulsion for bearing capacity on clay soils

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Abstract. Soil stabilization is a method to improve soil properties either by mechanical means or by adding another material to the soil with the purpose is to increase the strength or bearing capacity of the subgrade to the construction built on it. Subgrade with low bearing capacity can cause damage or collapse of construction above it. In this study, the type of stabilized soil is clay. Repairing this subgrade by adding additive material to the clay using palm shell ash and asphalt emulsion with 8% of palm shell ash content as a dependent variable and emulsion asphalt of 3%, 6%, 9%, and 12% as an independent variable. The purpose of this step is to get the optimum mixture content as a stabilizing agent. Based on testing, the optimum mixture content is 8% palm shell ash+9% emulsion asphalt. The addition of this additive material can reduce water content by 13.23%, plastic index by 74.47%, and shrinkage by 43.75% during the 14 days curing period, and increase the bearing capacity of subgrade through CBR testing of unsoaked and soaked respectively each of 114.15% during the curing period of 14 days and 211.1% during soaking of 4 days after curing period of 14 days. Based on the result of testing, this addictive material can be used as a stabilizing material.

1. Introduction

Soil stabilization is a way to improve soil properties either by mechanical means or by adding an added material to the soil, to increase the strength or carrying capacity of the subgrade to the construction built on it [1]. Subgrade with poor bearing capacity can have an impact on the construction above which can cause damage or collapse of construction.

In this study, the type of stabilized soil is clay type by adding additive material to clay using palm shell ash and asphalt emulsion to reduce dependence on cement as a stabilizing material commonly used to save costs when viewed from the economic side of infrastructure development [2]. The purpose of this study is to determine and obtain several physical and mechanical parameters in stabilizing soil with palm shell ash and asphalt emulsions.

Soft clay is aggregates of microscopic and submicroscopic sized particles that originate from the chemical decomposition of rock constituents, and are plastic in moderate to wide water content intervals. In a dry state is very hard, and not easy to peel just with your fingers. Also, the permeability of clay is very low [3]. The materials used as stabilization are:
- Palm Shell Ash is a solid waste derived from palm shell incineration as fuel to produce steam in the process of palm oil mill [4]. The cohesive soil properties are changed with the addition of palm ash so that compaction will produce a high degree of compacting while there is also a bond between the binding material and cohesive soil particles [5]. The use of Palm Shell as a soil stabilization material can increase the compressive strength and shear strength and decrease the index value [6].

- Asphalt Emulsion is a type of asphalt consisting of hard asphalt, water, and emulsifiers, which at normal temperatures and atmospheric pressure are liquid. The function of the emulsifying material here is to change the asphalt particles so that the asphalt particles can mix with water [7]. Stabilization with asphalt is defined as a process when a certain amount of asphalt is mixed with soft or aggregate soil to form a stable soil condition as required as a subgrade. The stabilization material in the form of asphalt will increase cohesion between particles and soil bearing capacity and increase soil resistance to water [8]. The function of asphalt in soil stabilization using asphalt for fine-grained soils is a waterproof mixture, while for coarse-grained soils is a waterproof and binder mixture.

2. Research methodology

Subgrade sampling is taken from the Gedebage area, Bandung, West Java, because the land in the area is classified as a type of damaged soil that has high shrinkage and low bearing capacity. Therefore, an experiment was carried out using stabilization to strengthen the subgrade so that it could carry the burden of construction that stood on it. Furthermore, taking the material as a stabilization mixture are Palm Shell Ash and Asphalt Emulsion. Then do the physical and mechanical properties of clay that have not been or after mixed with stabilization materials which will then get the optimum variable from the stabilization material as shown in Figure 1 below.

![Figure 1. Research investigation methodology in the laboratory.](image-url)
3. Results and discussion

3.1. Test result of physical testing of subgrade
In this section, the results of testing the physical properties of soft soil and mixed soft soil soils consisting of grain size, density, and atterberg limit analysis are shown in Table 1.

| Index Properties | Symbol | Unit | Variable |
|------------------|--------|------|----------|
| Grain Size       | G      | %    | 0 1 2 3 4|
| 1.1 Gravel       |        |      |          |
| 1.2 Sand         |        |      |          |
| 1.3 Silt         |        |      |          |
| 1.4 Clay         |        |      |          |
| Density Test     | Gs     |      | 2.59 2.75 2.98 2.82 2.93|
| Atterberg Limit  |        |      |          |
| 3.1 Plastic Limit| PL     | %    | 38 41 25.87 49 27|
| 3.2 Liquid Limit | LL     | %    | 85 57 54.79 61 62|
| 3.3 Plasticity Index | PI | % | 47 16 29 12 35|
| 3.4 Shrinkage Limit | SL | % | 16 13 15.73 9 17|

3.2. Test result of mechanical testing of subgrade

3.2.1. Compaction. The optimum water content decreases with an increasing percentage of the mixture with a constant value of % Palm Shell Ash (PSA) and a value of % Asphalt Emulsion (AE) which increases as shown in Figure 2.

![Graph](image_url)

**Figure 2.** Relationship curve between addition% palm shell ash+ variation of% asphalt emulsion (ωopt).

The graph above shows that the increasing addition of palm shell ash and asphalt emulsion will reduce the water content in stabilization soil. ωopt on the soft soil by 31%, then when added with palm shell ash 8% as the dependent variable and asphalt emulsion as the independent variable by 3%, the ωopt
value becomes 30.40% as well as an increase in asphalt emulsion by 6% to 29.50%; 9% asphalt emulsion is 28.20 and 12% asphalt emulsion is 26.90%.

3.2.2. CBR testing. CBR test has another function besides measuring strength value of base soil which is a measurement to determine the layer thickness of compaction [9]. In the CBR mixed soil test, the stabilization material tested was the stabilization material with an optimum mixture of variable 3 with a percentage of 8% palm shell ash and 9% asphalt emulsion because the lowest plasticity index value was in mixture 3 which was 12%. The level of asphalt emulsion that is good as a stabilizing agent with the soil is around 6% -8% depending on the plasticity of the soil [10]. According to the Pavement Design Manual (MDP), the minimum CBR value for pavement is ≥ 6%. CBR results can be seen in Table 2.

| Technical Properties | Symbol | Unit | Variable | Value
|----------------------|--------|------|----------|------|
|                      |        |      | Soft Soil| Variable 3 |
| 1 Unsoaked           |        |      |          |        |
| 1.1 CBR Curing 0 day | CBRdesign | % | 4.1 | 3.15 |
| 1.2 CBR Curing 3 days | CBRdesign | % | - | 5.20 |
| 1.3 CBR Curing 7 days | CBRdesign | % | - | 6.45 |
| 1.4 CBR Curing 14 days | CBRdesign | % | - | 8.78 |
| 2 Soaked             |        |      |          |        |
| 2.1 CBR Curing 0 days | CBRdesign | % | 1.8 | 1.91 |
| 2.2 CBR Curing 3 days | CBRdesign | % | - | 3.35 |
| 2.3 CBR Curing 7 days | CBRdesign | % | - | 3.65 |
| 2.4 CBR Curing 14 days | CBRdesign | % | - | 5.6 |

The results of CBR Unsoaked testing of soft soil at 0 days are still higher when compared to a mixture of variable 3 but the CBR value increases with increasing curing time of 3, 7, and 14 days. And the best percentage value is CBR with 14 days curing with CBR value of 8.78% as shown in Figure 3.

For the Soaked CBR percentage test value, the mixed soil is immersed for 4 days. The soft soil at 0 days ripening has a small percentage compared to the mixture of variable 3 and tends to increase as well as increasing ripening time ie 3, 7, and 14 days. The best percentage value is CBR which is immersed 4 days after being cured for 14 days with a CBR value of 5.6% as shown in Figure 4.
Figure 4. Relationship curve of CBR value and soaked curing time on variable 3.

3.2.3. Swelling. In the implementation of building a road often encountered soil in a bad condition with high shrinkage properties that is expanding in wet conditions and shrinking when dry so that this also causes damage to the road structure that makes the road bumpy or cracked - therefore swelling value land must be known [11].

The testing of swelling is tested based on the optimum mixture value, which is mixture 3 which is shown as Table 3.

Table 3. Result swelling stabilization materials.

| Technical Properties | symbol | unit | Variable |
|-----------------------|--------|------|----------|
| 1 Swelling            | -      | %    | 3,37     |
| 1,1 Curing 0 day      | -      | %    | 3,72     |
| 1,2 Curing 3 days     | -      | %    | 2,29     |
| 1,3 Curing 7 days     | -      | %    | 1,96     |
| 1,4 Curing 14 days    | -      | %    | 1,47     |

The results of testing the development of the swelling volume of mixture 3 show a percentage value that decreases from the swelling value of soft soil from 0 days ripening to 14 days ripening. The decrease occurred from 0 days to 14 days by 41.6%. This means that increasing the number of curing days is better because it can reduce the development that occurs in the subgrade so that the optimum percentage of swelling occurs with the addition of 9% emulsified asphalt and curing time of 14 days.

4. Conclusion

From the description above, it can be concluded that:

- In compaction testing, the addition of palm shell ash and asphalt emulsion as a stabilizing material can reduce the water content by 13.23%, from the ωopt value of the soft soil by 31% to 26.90% when stabilized.
- The variable taken for CBR testing is variable 3 because it has the smallest plastic index value compared to other mixtures. The carrying capacity of soil stabilization also increases as can be seen from CBR testing. Unsoaked CBR value increased by 114.15% with a carrying capacity of 4.1% to 8.78% at 14 days. And CBR Soaked increased by 211.1% with the carrying capacity of soft soil by 1.8% to 5.6% on immersion 4 days after braking for 14 days.
- Swelling value on variable 3 also decreases with increasing curing time which is equal to 41.6% with the smallest swelling value of 1.47 at the curing time of 14 days.
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