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# Improvement of Clay Shale Soil Characteristics Using Asphalt Emulsion and Artificial Lightweight Aggregate Perlite

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**Keywords**
*Clay Shale, Soil Stabilization, Asphalt Emulsion, Artificial Light Weight Aggregate Perlite, Triaxial)*

**Abstract**
The present study investigates the effect of stabilizing clay shale soil using asphalt emulsion stabilizing material and artificial lightweight aggregate perlite. Clay shale soil is characterized by its low strength when exposed to the elements, particularly air and water. Clay shale soil is characterized by its low strength, high plasticity, and poor durability, which poses significant challenges in geotechnical engineering and road pavement applications. The objective of this study is to evaluate the optimum moisture content, maximum dry bulk density, Atterberg limits, and internal friction angle in the soil. The study systematically varies the curing time of the stabilized soil, with samples collected at 0 days, 3 days, 7 days, and 14 days. The findings indicate that the incorporation of asphalt emulsion and artificial lightweight aggregate leads to a reduction in plasticity and an augmentation in the internal friction angle. The most significant enhancement was observed in variation 1, which underwent a 14-day curing period. The internal friction angle prior to stabilization was 13,8°, and it increased to 21,8°.



## Introduction

It is evident that Indonesia's infrastructure development exhibits a consistent annual progression. This encompasses the construction of high-rise buildings, residential housing, roads, dams, and other infrastructure. Geotechnical science, the discipline that encompasses the study of the properties and characteristics of soil, plays a pivotal role in this development (Adisurya et al., 2022). Most buildings in Indonesia are constructed on poor-quality soil, such as clay shale. Clay shale is a type of soil that can cause problems, and it often leads to construction failures in Indonesia. The instability of clay shale soil is due to its tendency to deteriorate when exposed to air or water (Pratama, 2021). Instability in clay shale soil can occur even in flat areas. This raises many issues in the field of geotechnical engineering when planning infrastructure. (Yusuf et al., 2017). Clay shale is a type of expansive soil that increases in volume when it contracts with water (Somantri et al., 2018). Weathering, in general, can be defined as the process of rock transformation that occurs due to the influence of the atmosphere and water. These alterations can manifest as physical disintegration and chemical decomposition. In regions characterized by a tropical climate, such as Indonesia, this phenomenon manifests more frequently than in other climate types (Alatas et al., 2017).

The various geotechnical problems arising from clay shale soil highlight the importance of soil stabilization. Soil stabilization is an engineering technique that aims to improve and maintain certain properties of the soil so that it meets the required technical standards (Darwis, 2018). A plethora of studies have previously investigated the use of various materials in the field of soil stabilization, including but not limited to fly ash, cement, lime, waste, and plastic. The present study focuses on the stabilization of soil using two stabilization materials: asphalt emulsion and artificial lightweight aggregate perlite.

In the study by Pratama (2021), the challenges associated with the instability of clay shale in construction were explored, particularly emphasizing how its tendency to deteriorate when exposed to water or air leads to significant geotechnical problems in Indonesia. The research provided important insights into the nature of clay shale and its role in construction failures. However, the study was limited in offering practical solutions to mitigate these issues, particularly in terms of stabilization methods. The research predominantly focused on identifying and understanding the problem without exploring effective stabilization techniques, which left a gap in addressing the engineering solutions required for clay shale soil improvement.

Similarly, Yusuf et al. (2017) conducted a study that highlighted the instability of expansive soils, particularly clay shale, and its impact on infrastructure development. The research outlined the general characteristics of expansive soils, but it lacked a deeper investigation into specific soil stabilization techniques, such as the use of alternative materials like asphalt emulsion and artificial lightweight aggregate perlite. Their focus was more on the identification of problems related to soil instability, and less on exploring innovative methods for soil improvement.

The primary objective of this research is to evaluate the effectiveness of asphalt emulsion and artificial lightweight aggregate perlite as stabilization materials for clay shale soil in infrastructure projects. The benefit of this research is that it offers an alternative to traditional stabilization methods, contributing to the development of more resilient and sustainable infrastructure in Indonesia, especially in areas with expansive soils like clay shale. The findings can significantly improve the quality and longevity of construction projects in geotechnically challenging areas.

## Materials and Methods

Artificial lightweight aggregate perlite is a lightweight aggregate produced by heating materials such as terai, molten metal, clay, diatomaceous earth, fly ash, shale, slate, and loam (Darayani, 2018). The artificial lightweight material utilized in this study is composed of perlite. Perlite is a volcanic rock that undergoes expansion when subjected to heat, either gradually or rapidly. Perlite has been demonstrated to possess favourable pozzolanic properties, with an estimated global reserve of approximately 6,700 million tons (Calik & Sadoglu, 2014). The utilization of ALWA in the construction industry is currently employed as a substitute for natural aggregates in the production of concrete, particularly in the production of lightweight concrete. The utilization of ALWA in concrete has demonstrated efficacy in meeting the requisite strength demands of concrete without compromising its strength (Hao et al., 2022). A preceding body of research was conducted on subgrade soil and determined that the optimum level of 20% ALWA perlite was achieved (Rithani & Kumar, 2023). The mineral composition of artificial light weight aggregate perlite can be seen in Table 1.

**Table 1. Mineral Composition of Artificial Light Weight Aggregate Perlite**

| Testing | Testing Standards |
|---|---|
| Specific Gravity | (ASTM D-854-02, 2002) |
| Atterberg Limit | (ASTM D4318-17, 2017) |
| Water Content | (ASTM D2216-98, 2019) |
| Weight of Content | (ASTM D2216-98, 2019) |
| Dry Weight | (ASTM D2216-98, 2019) |
| Pore Value | (ASTM D2435, 2011) |
| Porosity | (ASTM D2435, 2011) |
| Compaction | (ASTM D1557-12, 2012) |
| Triaxial | (ASTM D4767-11, 2011) |

Asphalt emulsion stabilization material can be defined as a method in which a certain amount of asphalt is mixed with soft soil. The primary objective of incorporating asphalt is to establish robust soil conditions, a prerequisite for the construction of a base layer. The utilization of asphalt emulsion as a stabilization agent has been demonstrated to enhance the soil's resistance to water (Wicaksono et al., 2023). The appropriate asphalt emulsion content used to stabilize soil is 8% (Tarigan & Syahril, 2021).

The present study will examine the impact of asphalt emulsion and artificial lightweight aggregate perlite, which will be subjected to a curing process to ascertain the effect of curing duration on soil stabilization. Table 2 presents a comprehensive overview of the soil stabilization variations.

**Table 2. Soil Sample Composition**

| Sample Name | Sample Composition |
|---|---|
| Clay Shale | Clay Shale (100%) |
| Variation 1 | Clay Shale (91%), Asphalt Emulsion (8%), Artificial Light Weight Aggregate (1%) |
| Variation 2 | Clay Shale (90%), Asphalt Emulsion (8%), Artificial Light Weight Aggregate (2%) |
| Variation 3 | Clay Shale (89%), Asphalt Emulsion (8%), Artificial Light Weight Aggregate (3%) |
| Variation 4 | Clay Shale (88%), Asphalt Emulsion (8%), Artificial Light Weight Aggregate (4%) |

The testing standards used as guidelines for conducting research are as follows, can be seen in Table 3

**Table 3. Testing Standard in This Research**

| Testing | Testing Standards |
|---|---|
| Specific Gravity | (ASTM D-854-02, 2002) |
| Atterberg Limit | (ASTM D4318-17, 2017) |
| Water Content | (ASTM D2216-98, 2019) |
| Weight of Content | (ASTM D2216-98, 2019) |
| Dry Weight | (ASTM D2216-98, 2019) |
| Pore Value | (ASTM D2435, 2011) |
| Porosity | (ASTM D2435, 2011) |
| Compaction | (ASTM D1557-12, 2012) |
| Triaxial | (ASTM D4767-11, 2011) |

## Results and Discussions

### Clay Shale Index Properties

The test results of the index properties of clay shale soil, in the form of testing the specific gravity, atterberg limit, weight of content, pore value, water content, dry weight, and porosity of the soil can be seen in Table 4

**Table 4. Index Property of Clay Shale Soil**

| Number | Testing | Symbol | Unit | Value |
|---|---|---|---|---|
| 1 | Specific Gravity | Gs | - | 2.686 |
| 2 | Atterberg Limit | | | |
| | Liquid Limit | LL | % | 53.86 |
| | Plastic Limit | PL | % | 32.65 |
| | Plasticity Index | PI | % | 21.21 |
| 3 | Weight of content | $\gamma$ | gr/cm3 | 1.70 |
| 4 | Pore value | e | - | 1.34 |
| 5 | Water content | $\omega$ | gr/cm3 | 48.88 |
| 6 | Dry weight | $\gamma d$ | gr/cm3 | 1.14 |
| 7 | Porosity | n | - | 0.57 |

### Atterberg Limit Test

The summary of atterberg limit test result can be seen in Table 5, and the atterberg limit graphic can be seen in figure 1.

**Table 5. Summary of Atterberg Limit Test Result**

| Testing | Symbol | Value (%) | | | | |
|---|---|---|---|---|---|---|
| | | Clay Shale | Variation 1 | Variation 2 | Variation 3 | Variation 4 |
| Liquid Limit | LL | 53,52 | 38,14 | 38,75 | 39,91 | 41,13 |
| Plastic Limit | PL | 21,21 | 29,63 | 30,00 | 30,90 | 31,76 |

| Testing | Symbol | Value (%) | | | | |
|---|---|---|---|---|---|---|
| Plasticity Index | PI | 32,31 | 8,51 | 8,75 | 9,01 | 9,38 |

Preliminary findings, as indicated by the test results, suggest that the incorporation of ALWA stabilization material and asphalt emulsion into clay shale soil has led to a decline in the liquid limit value and plasticity index, while concurrently resulting in an increase in the plastic limit value. The maximum liquid limit value exhibited a 31.05% decrease in mixture variation 1, from 53.52% to 38.14%, indicating a substantial reduction in the proportion of liquid material. The maximum plasticity index value exhibited a significant decrease in mix variation 1, with a 279.67% reduction from the previous value of 32.31% to 8.51%. The decline in liquid limit value and plasticity index suggests that the soil becomes more stable, less plastic, and more resistant to the influence of water content.

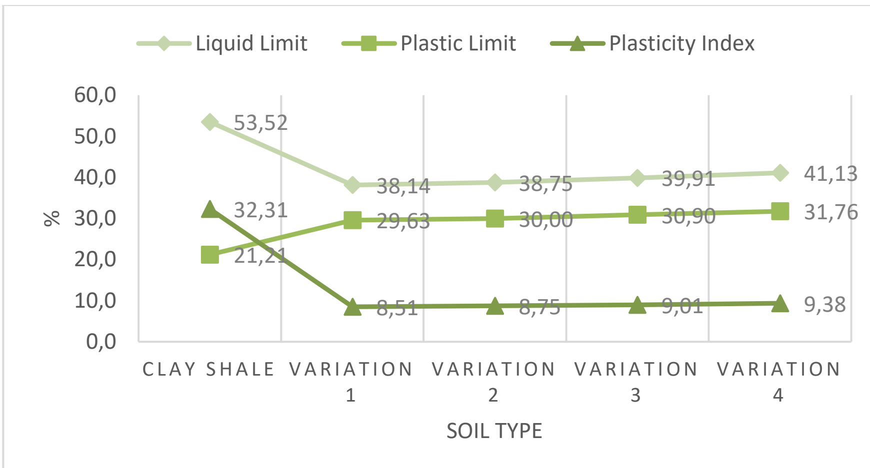


**Figure 1. Atterberg Limit Testing Graphic**

**Compaction Test**

In the domain of soil stabilization, soil compaction testing constitutes a crucial step in ensuring the optimal density and stability of the soil to support construction activities. This testing protocol involves the determination of the maximum moisture content and dry weight of the soil. The objective of this procedure is to facilitate the determination of the soil's suitability for construction purposes. The outcomes of the soil compaction testing are displayed in Table 6, and the soil compaction graphic can be seen in Figure 2.

**Table 6. Soil Compaction Test Results**

| Testing | Unit | Clay Shale | Variation 1 | Variation 2 | Variation 3 | Variation 4 |
|---|---|---|---|---|---|---|
| Optimum Moisture Content (wopt) | % | 28,80 | 26,83 | 27,79 | 27,97 | 28,33 |
| Maximum Dry Density (γdmax) | gr/cm3 | 1,34 | 1,41 | 1,39 | 1,37 | 1,35 |

The findings of the soil compaction testing indicated a decline in the optimal moisture content of clay shale soil. However, an increase in ALWA stabilization material resulted in an increase in the optimum moisture content. The maximum decrease in optimum moisture content was observed in variation 1, where the initial moisture content of 28.80% decreased to 26.83%. Furthermore, the results of soil compaction testing demonstrated an increase in maximum dry weight, from 1.34 g/cm$^3$ to 1.41 g/cm$^3$, in variation 1. However, the incorporation of ALWA levels resulted in a reduction of the maximum dry weight. An increase in maximum dry weight is indicative of denser soil particles, which can increase the soil's capacity to withstand structural loads.

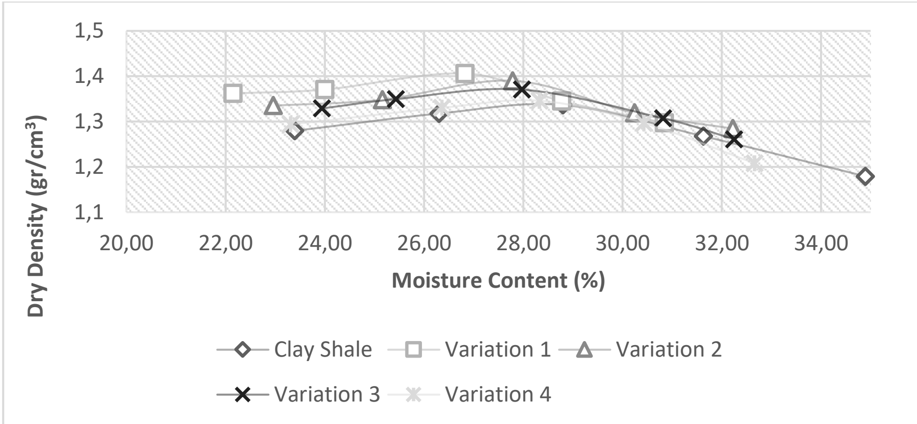


**Figure 2. Soil Compaction Graphic**

**Triaxial Test**

The triaxial test is a laboratory testing method used to evaluate the mechanical characteristics of soil, such as shear strength, deformation parameters, and soil strength under certain conditions. These parameters are obtained through the Unconsolidated Undrained Triaxial Test (Triaxial U-U). In this test, the soil sample is prevented from consolidating, and drainage of the soil is not permitted during the test. The internal friction angle values obtained from the triaxial test are presented in Table 7, and a graphical representation of the internal friction angle values is provided in Figure 3. The cohesion values obtained from the triaxial test are presented in Table 8, and the comparison graph of the cohesion values is presented in Figure 4.

**Table 7. Shear Angle Value in Triaxial Testing**

| Sample Name | Unit | Curing Time (days) | | | |
|---|---|---|---|---|---|
| | | 0 day | 3 days | 7 days | 14 days |
| Clay Shale | ° | 13,8 | - | - | - |
| Variation 1 | ° | 19,39 | 19,80 | 20,71 | 21,80 |
| Variation 2 | ° | 18,26 | 19,29 | 20,30 | 20,81 |
| Variation 3 | ° | 17,74 | 18,62 | 19,44 | 20,00 |
| Variation 4 | ° | 17,22 | 17,74 | 18,35 | 18,67 |

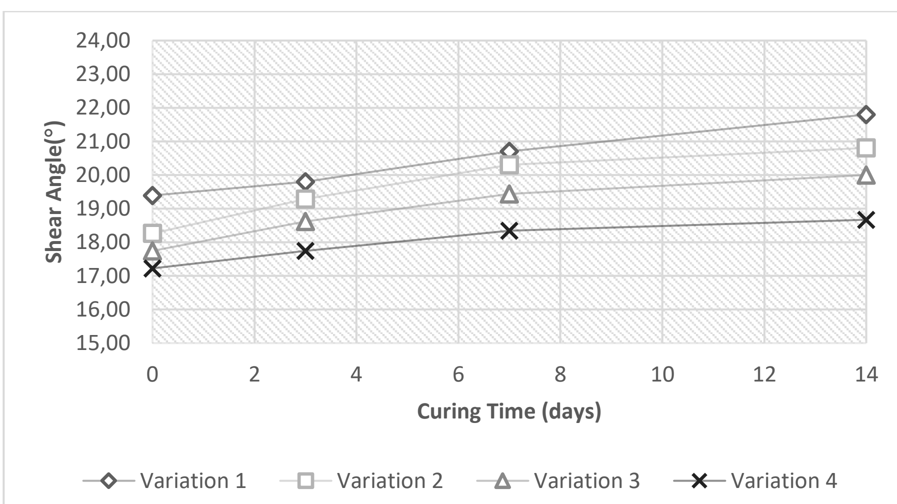


**Figure 3. The Effect of Curing Time on Shear Angle Value**

**Table 8. Cohesion Value in Triaxial Testing**

| Sample Name | Unit | Curing Time (days) | | | |
|---|---|---|---|---|---|
| | | 0 day | 3 days | 7 days | 14 days |
| Clay Shale | kg/cm2 | 0,770 | - | - | - |
| Variation 1 | kg/cm2 | 0,778 | 0,870 | 0,900 | 0,980 |
| Variation 2 | kg/cm2 | 0,720 | 0,777 | 0,830 | 0,881 |
| Variation 3 | kg/cm2 | 0,640 | 0,690 | 0,770 | 0,800 |
| Variation 4 | kg/cm2 | 0,600 | 0,620 | 0,710 | 0,732 |

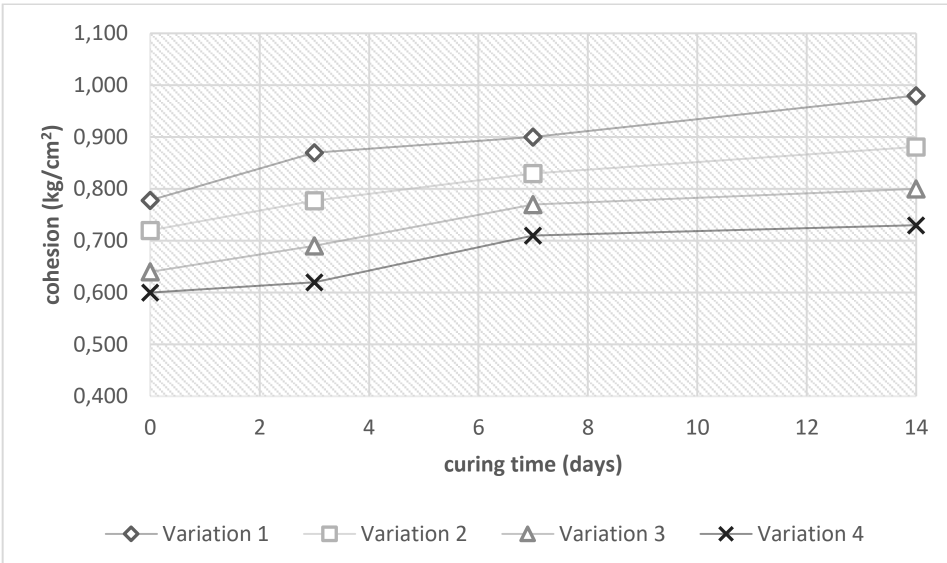


**Figure 4. The Effect of Curing Time in Cohesion Value**

The findings of the Triaxial U-U test on stabilized soil demonstrate a clear trend of increasing internal friction angle (φ) and soil cohesion (c) values as the curing time is extended (0, 3, 7, and 14 days). As the proportion of ALWA content in the mixture variations increased, there was a concomitant decrease in the internal friction angle and cohesion values. The maximum increase was observed in Variation 1, with an increase in the internal friction angle of 57.97% from the previous 13.8° to 21.8° after stabilization with a 14-day curing period. Conversely, the maximum increase in cohesion was observed in Variation 1, with a 27.27% increase from 0.77 to 0.98 after 14 days of curing. The maximum increase in Variation 1 indicates that the addition of stabilizing material strengthens the particle bonds between the soil particles.

## Conclusion

The application of stabilizing materials resulted in a decline in liquid limit and plasticity index values, accompanied by an increase in plastic limit values. These findings suggest an increase in soil stability in response to changes in water content. The maximum decrease in liquid limit value recorded was 31.05% in variation 1, while the largest decrease in plasticity index, 279.67%, was recorded in variation 1. This phenomenon signifies that the stabilized soil exhibits a reduction in plasticity and an increase in volumetric stability. From a mechanical perspective, the compaction process leads to a decrease in the optimum water content, which reaches its maximum in variation 1. This decrease is evident when the initial water content of 28.80% decreases to 26.83%. Concurrently, an increase in the maximum dry weight value from 1.34 g/cm$^3$ to 1.41 g/cm$^3$ was observed. The triaxial test results indicated a 57.97% increase in the internal friction angle, from 13.8% to 21.8%, in variation 1 with a curing time of 14 days. Concurrently, the cohesion value of the soil exhibited a 27.27% increase, rising from 0.77 kg/cm$^2$ to 0.98 kg/cm$^2$ in variation 1, with a curing time of 14 days. However, as the proportion of artificial lightweight aggregate increased, the internal friction angle and cohesion values decreased again. The utilization of a combination of asphalt emulsion stabilizing material and artificial lightweight aggregate has been demonstrated to enhance the performance of clay shale soil with respect to plasticity and mechanical strength. In this study, an optimal mixture ratio of 8% asphalt emulsion and 1% artificial lightweight aggregate was identified for stabilizing clay shale soil.

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