Stabilization to Plasticity Index by Deep Soil Mixing Using Vermiculite and Asphalt Emulsion

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ABSTRACT
The most likely happen problem on embankment construction is settlement and land deformation even sliding because of loads. Those failures can be caused by embankment fail or subsoil fail and the triggers are overloading loads, low bearing capacity also high compressibility of the soil. To avoid high risk of soft clay’s settlement, it is necessary to do improvement by increasing the stability using vermiculite and asphalt emulsion on Deep Soil Mixing method. Besides improving physical properties, stabilizat

ion is expected to increase soil’s resistance to load. Vermiculite is used to absorb excess water and increase soil volume, while asphalt emulsion is used to decrease soil plasticity index, it also acts as an adhesive substance. The decreasing of soil’s water content and particle bonding increase will also strengthen the stability of soil. Vermiculite varies from 3%, 5%, to 7%, and constant 8% of asphalt emulsion for all testing sample. This research is using soft soil by the classification corresponding to Unified Soil Classification System (USCS), a quantitative experimental physical testing method, and mechanical testing. It is resulting that the soil is a fat clay with high plasticity, and the optimum mixture is on 5% of vermiculite by decreasing 61.93% of the PI.

Keywords: Asphalt_Emulsion, Deep_Soil_Mixing, Soil_Stabilization, Subsoil, Vermiculite

1. INTRODUCTION

Soil has an important role on a construction system; it is as a construction’s foundation [1]. One of problems occur in soil is the slope failure due to deformation of soft soil as the subgrade. Sliding can be caused by the lack of particle’s bonding, high water content, extreme slope, and loads [2]. Therefore, these unfavorable properties need to be reduced by reinforcing, replacing soil or mixing with other materials [3].

One of the methods used in soil repair is Deep Soil Mixing (DSM). To change compressibility, bearing capacity, permeability, sensitivity to the fluctual change of water content, then repair treatment is planned using vermiculite to absorb water and asphalt emulsion as adhesive [4]. Fathurohman (2019) states cement on DSM for clay shale soil at Cisomang bridge generate high SF, swelling pressure 42.71%, PI decrease until 27.55%, and cohesion escalation [5]. Syahril (2011) reduces PI, increase (yd) and q at optimum asphalt emulsion 8% [6]. Hendry (2014) stabilized soil using vermiculite 2%, 4%, 6%, and 8% combined with 8% cement. That research proofs PI decrease and obtained the highest strength at 4% vermiculite [7]. Hendry (2019) also doing a research using Lapindo mud and asphalt emulsion and resulting PI decrease also q increase because addition of soil bonding by asphalt [8].

From literature review stated above, this research is trying to fill the gap by using different percentage of vermiculite (3%, 5%, 7%) and optimum asphalt emulsion 8%.

1.1. Expansive Soil

Most of soil’s mixture contains many variation of particle size. It may varies from >100 mm - <0.001 mm [9]. A condition where the soil contains mostly microscopic and sub-microscopic material size (<0.002 mm or 2 micron). Clay soil consist of montmorillonite, illite, and kaolinite on. Montmorillonite causes the soil to have very high absorption rate characteristic and increasing the chance of soil to expand that can harm the building on it [3] [9].

1.2. Stabilization Materials

1.2.1 Vermiculite

Vermiculite is an excess mineral from silica that has been heated on high temperature that vermiculite itself formed from magnesium aluminium silica. It has high content of silica and some properties such as light weighted material, non flammable, and high absorption
of water. From its capablility, it can be used to increase soil’s volume, absorbing excess water, drainage, and planting media. From the forming matter and it’s ability to absorb water, so it can be used as soil stabilization additive material.

1.2.2 Asphalt Emulsion

Asphalt emulsion is a soil asphalt dispersion result by water and emulsifying matter that changes the particle so it dissolved and creating a bond with water [10]. This material can also bond with other material and hardens after several range of time depends on its type.

2. RESEARCH METHOD

This research refers to the number of sliding cases and settlement on soft soil because of instability. Laboratory investigation purposed to obtain physical properties and soil classification, that can be figured on flowchart Figure 1.

![Research flow chart](image)

Figure 1. Research flow chart

The stabilization is done by mixing original soil with addition of Vermiculite that varies in percentage and constant Asphalt Emulsion, as be shown on Table 1. Both of original and stabilized soil are tested to obtain Index Properties of the soil and the values changes that following each of this requirement used as guide on Table 2.

### Table 1. Percentage of stabilization mixing

| Code  | Original Soil | Vermiculite | Asphalt Emulsion |
|-------|---------------|-------------|------------------|
| Variation 1 (V1) | ✓ | - | - |
| Variation 2 (V2) | ✓ | 3% | 8% |
| Variation 3 (V3) | ✓ | 5% | 8% |
| Variation 4 (V4) | ✓ | 7% | 8% |

### Table 2. Soil index properties test

| No. | Testing Name               | Testing Standard |
|-----|----------------------------|------------------|
| 1.  | Atterberg Limit Test       | ASTM D4318       |
| 2.  | Specific Gravity Test      | ASTM D854        |
| 3.  | Water Content Test         | ASTM D2216       |
| 4.  | Volume Weight Test         | ASTM D2216       |
| 5.  | Soil Classification        | AASHTO USCS      |

3. RESULTS AND DISCUSSION

3.1. Stabilization Materials Properties

3.1.1. Vermiculite

Material Vermiculite is used because of its ability to absorb excess water on the soil and high contain of Silica. The Silica can react and create bonding inside the soil. The properties can be depicted on Table 3 and Table 4.

### Table 3. Chemical contain of vermiculite

| Lab Num | 2055/20 | Method            |
|---------|---------|-------------------|
| % SiO₂  | 41.60   | Gravimetry        |
| % Al₂O₃ | 13.38   | ICP               |
| % FeO   | 6.29    | ICP               |
| % Fe₂O₃ | <0.001  | Volumentry        |
| % MgO   | 24.60   | ICP               |
| % H₂O   | 2.73    | Gravimetry        |

Remarks : The sample is analyzed from dry sample on (105-110°C) except H₂O.
### Table 4. Chemical properties of vermiculite from IPI Sunijaya

|          | %       |
|----------|---------|
| Silica   | SiO$_2$ | 35 – 41 |
| Alumina  | Al$_2$O$_3$ | 6 – 9.5 |
| Iron Dioxide | Fe$_2$O$_3$ & FeO | 6 – 9.5 |
| Titanium | TiO$_2$ | 0.6 – 1.4 |
| Dioxide  | MgO     | 21.5 – 25.5 |
| Lime     | C$_2$O  | 3 – 6   |
| Potash   | K$_2$O  | 3 – 6   |
| Water    | H$_2$O  | Varies  |
| PH Value |         | 8.5 s/d 10 |

### 3.1.2 Asphalt Emulsion

Asphalt Emulsion used is Slow Setting type CSS1 and according to the properties from PT. Hutama Prima as the producent and distributor the result testing as below.

### Table 5. Properties of asphalt emulsion

| Property                  | Unit | Method        | Result        | Standard Min | Max |
|---------------------------|------|---------------|---------------|--------------|-----|
| Residue by Evaporation    | %    | ASTM D-244    | 58.2          | 57           |
| Homogeny by Sieving 1000 | %    | ASTM D-244    | 0.02          | 0.1          |
| Viscosity at 25 Deg C     | sec  | ASTM D-244    | 22            | 20 – 100     |
| Particle Charge (+/-)     | %    | ASTM D-244    | +             | +            |
| Water Content             | %    | ASTM D-244    | 41.8          |              |
| Coating Ability           | %    | ASTM D-244    | 87            | 75           |
| Storage Stability 1 Day   | %    | ASTM D-244    | 0.84          | 1            |
| Solvent Content           | %    | ASTM D-244    | 0             |              |
| Cement Mixing             | %    | ASTM D-244    | 0.5           | 2            |
| Specific Gravity          | Gr/ml| ASTM D-70     | 1.012         | 1            |

### 3.2. Original Soil Properties

Table 6 shows the properties of original soil from Gede Bage, Bandung, East Java. From the following table, we can conclude that the soil can be categorized as high plasticity soil (PI>30).

### Table 6. Original soil physical properties

| Index Properties | Symbol | Unit | V1 (Original Soil) |
|------------------|--------|------|---------------------|
| Water Content    | W      | %    | 50.897              |
| Specific Gravity | Gs     | -    | 2.54                |
| Atterberg Limits | PL     | %    | 37.32               |
| Plasticity Index | LI     | %    | 85.41               |
| Activity Level   | AC     | %    | 48.09               |

Where:
- \( V_1 \) = Original Soil
- PL = Plastic Limit
- LL = Liquid Limit
- PI = Plasticity Index
- AC = Activity Level

### 3.3. Soil Grain Size Analysis

The aim of this analysis is to obtain soil gradation for soil classification purpose. The result can be shown on Table 7 and those data can be depicted on Figure 2.

### Table 7. Grain size analysis

| Sieve | Retained Weight | Percentage Retained | Passing |
|-------|-----------------|---------------------|---------|
| 10    | -               | -                   | 100.00  |
| 20    | 0.04            | 0.04                | 99.96   |
| 40    | 0.10            | 0.10                | 99.86   |
| 80    | 0.39            | 0.39                | 99.47   |
| 100   | 0.54            | 0.54                | 98.93   |
| 200   | 1.24            | 1.24                | 97.69   |
| pan   | 2.31            |                     |         |
The data on graphic above can be consideration to conclude that original soil used on this research has clay content 56% and categorized as silty clay with some amount of sand. The data results from this test can be used to classify soil.

3.4. Soil Classification

Soil classification on this research is done by using AASHTO method and USCS method. Both of them needs some specific original soil physical parameters to classify the soil.

3.4.1. Soil Classification by AASHTO Method

There are some parameters required to classify soil using AASHTO method, and those can be tabulated on Table 8 while original soil can be classified by the help of Figure 3.

Table 8. Original Soil Parameters Used for AASHTO Soil Classification

| Num. | Soil Parameter                      | Value   |
|------|-------------------------------------|---------|
| 1.   | Hydrometer (Passing Sieve Num. 200) | 97.69%  |
| 2.   | Liquid Limit (LL)                   | 85.41%  |
| 3.   | Plasticity Index (PI)               | 48.09%  |
| 4.   | Material                            | Clay Soil |

Figure 3. Soil classification AASHTO method
PI < (LL - 30) = 48 < (85 - 30) so the soil included on group A-7-5. General rating for subgrade defined as “Fair to Poor” hence the soil need stabilization act. Soil classification also can be assured from Figure 4 that showing correlation between PI and LL to determine classification area.

Figure 4. Correlation between PI and LL for AASHTO classification method

3.4.2. Unified Soil Classification System

Soil physical parameter needed to classify the original soil according USCS can be seen on Table 9.

Table 9. Original soil parameters used for USCS

| Num. | Soil Parameter                                      | Value        |
|------|-----------------------------------------------------|--------------|
| 1.   | Hydrometer (Passing Sieve Num. 200)                 | 97.69%       |
| 2.   | Liquid Limit (LL)                                  | 85.41%       |
| 3.   | Plastic Limit (PL)                                 | 37.32%       |
| 4.   | Plasticity Index (PI)                              | 48.09%       |

From the Hydrometer grain Analysis, percentage of grain size passing sieve number 200 is > 50% that is on 97.69% and can be concluded that the original soil is Fine-Grained Soil. As the PL and LL value from the table and the graphic below so it can be catagorized as Fat Clay (CH) or Clay with High Plasticity.

Table 10. Soil classification according to USCS

| % passing #200 | LL>60% | PI>0.73(L-20)% | USCS Symbol | USCS Name |
|----------------|--------|----------------|-------------|-----------|
| >50%           | Yes    | Yes            | CH          | Fat clay  |
|                | No     | No             | MH          | Elasit clay |
|                | Yes    | Yes            | CL          | Lean clay |
|                | No     | No             | ML          | Lean silt |

Figure 5. Soil classification according to USCS

Figure 6. Correlation between PI and LL on USCS

3.5. Stabilized Soil Physical Properties

Soil stabilization resulting this following data that shown on Table 11 below.

Table 11. Stabilized soil physical properties

| Index Properties | Symbol | Unit | V2  | V3  | V4  |
|------------------|--------|------|-----|-----|-----|
| 1. Water Content | w      | %    | 2.66| 2.70| 2.79|
| 2. Spesific Gravity | Gs | - | | | |
| 3. Atterberg Limits | PL | % | 50.63 | 59.20 | 58.20 |
|                  | LL | % | 75.87 | 77.47 | 77.21 |
|                  | PI | % | 25.24 | 18.27 | 19.02 |
| 4. Activity Level | AC | % | 0.55 | 0.40 | 0.41 |

Where:
V1 = Original Soil
V2 = Soil + 3% Vermiculite + 8% Asphalt Emulsion
V3 = Soil + 5% Vermiculite + 8% Asphalt Emulsion
V4 = Soil + 7% Vermiculite + 8% Asphalt Emulsion

From the data shown above, the value of Specific Gravity increases along the addition of stabilization matters. The value of PI decreases, by the addition of
stabilization matters, but starting to increase again on
the last variant (V4).

Comparison of original soil’s physical testing result
and stabilized soil can be depicted on following
graphics below. Figure 7 is showing the increasing
value of Specific Gravity along the increasing
percentage of Vermiculite. Soil with no addition to
Vermiculite has Specific Gravity value on 2.54, addition 3% of Vermiculite increase the value
until 2.66 and 5% is 2.70. The value keep increasing
until the last variation is 2.79.

![Figure 7. Relation between specific gravity and vermiculite percentage (%)](image)

The LL and PL value is evidently showing changes
between original soil compared with stabilized soil
mixing. The PL decrease extremely from the original
soil to 3% of Vermiculite and then increase a little bit
to the next 2 mixture. But the PL is increasing during
the increase of Vermiculite percentage. The relation
between both of the value can be shown on Figure 8.

![Figure 8. Relation between liquid limit and plastic limit](image)

From the LL and PI obtained from the Atterberg
Limit test, the value showing some reduction. PI of
original soil decrease from 48.09% to 25.24 on 3%,
18.27 on 5%, and increasing to 19.02% at 7%. The
graphic can be seen on Figure 9.

![Figure 9. Correlation between plasticity index and vermiculite percentage](image)

**4. CONCLUSION AND RECOMMENDATION**

Based from the physical laboratory testing of the
soils, the conclusion and recommendation can be
figured as the following points:

a. The soil used in this results is expansive clay
with high plasticity that has 50.89% of water,
2.54 specific gravity and 48.09% of Plasticity
Index.

b. Addition to Vermiculite and Asphalt
Emulsion can stabilize original soil by
decreasing the Plasticity Index and increasing
soil’s specific gravity.

c. Optimum percentage of Vermiculite is on 5%,
based on the lowest value of PI. That means
the mixture can reduce 61.93% of the PI from
48.09% into 18.27%.

d. The Plasticity Index drop might be caused by
chemical contents’ reaction from Vermiculite
and Asphalt Emulsion to stabilize the soil.

e. It is necessary to test mechanical properties to
acquire the soil strength to direct shear,
ultimate compressive strength and other
mechanical soil properties testing.

f. Further researches are needed to be done to
obtain the the most precise precentae of
Vermiculite and Asphalt Emulsion.

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