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, stabilization 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 (γd) and qu 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 qu increase because addition of soil bonding by asphalt [8].

From litterature 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 miscroscopic 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 absorbtion 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 alumunium silica. It has high content of silica and some properties such as light weighted material, non flammable, and high absorbtion

of water. From its cappability, 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.

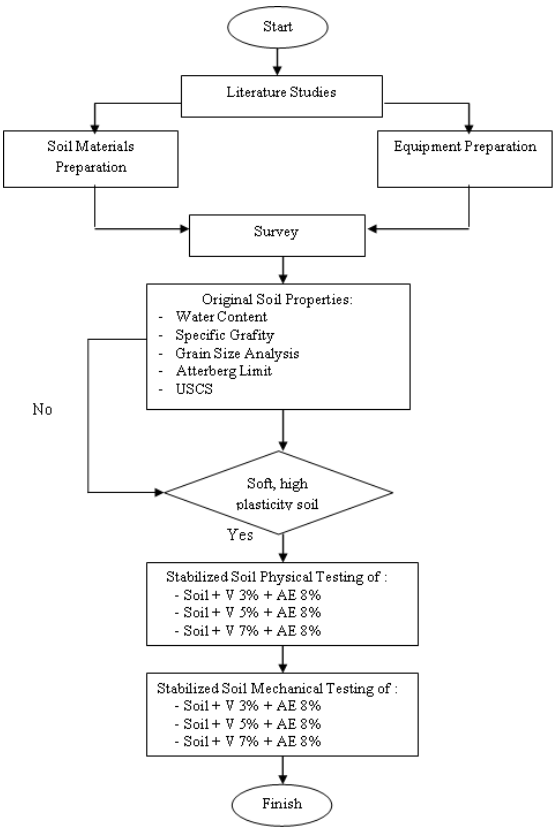

Figure 1. Research flow chart

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
Code	Vermiculite	
% SiO_2	41.60	Gravimetry
% Al_2O_3	13.38	ICP
% Fe_2O_3	6.29	ICP
% FeO	<0.001	Voulmetry
% MgO	24.60	ICP
% H_2O	2.73	Gravimetry

Remarks : The sample is analyzed from dry sample on (105-110°C) except H_2O.

Table 4. Chemical properties of vermiculite from IPI Sunijaya

		%
Silica	SiO_2	35 – 41
Alumina	Al_2O_3	6 – 9.5
Iron Dioxide	Fe_2O_3 & FeO	6 – 9.5
Titanium Dioxide	TiO_2	0.6 – 1.4
Magnesia	MgO	21.5 – 25.5
Lime	C_2O	1.5
Potash	K_2O	3 – 6
Water	H_2O	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	Standart	
				Min	Max
Residue by Evaporation	%	ASTM D-244	58.2	57	
Homogeny by Sieving no.20	%	ASTM D-244	0.02		0.1
Viscocity 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
Solven 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 catagorized as high plasticity soil (PI>30).

Table 6. Original soil physical properties

	Index Properties	Symbol	Unit	V1 (Original Soil)
1.	Water Content	W	%	50.897
2.	Spesific Gravity	Gs	-	2.54
3.	Atterberg Limits			
	Plastic Limit	PL	%	37.32
	Liquid Limit	LL	%	85.41
	Plasticity Index	PI	%	48.09
4.	Activity Level	AC	%	1.05

Where:
V1 = 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		

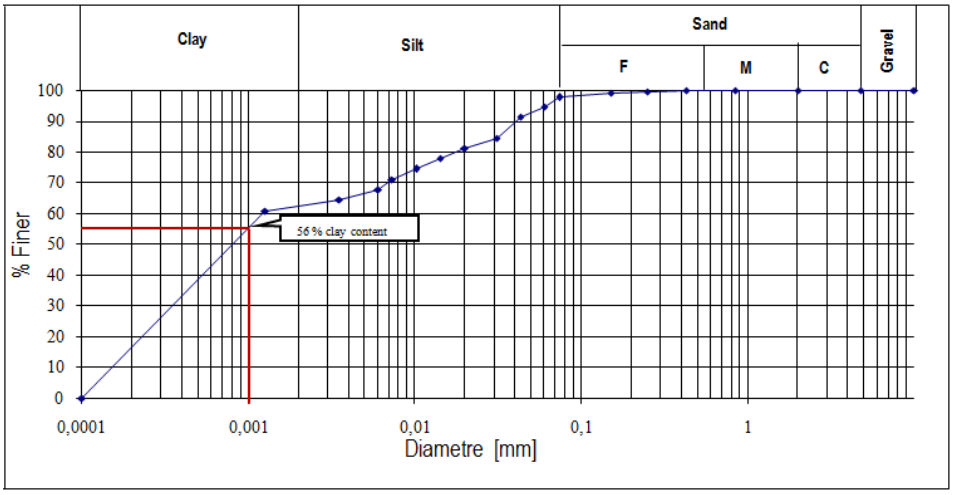

Figure 2. Distribution of grain size sieve analysis graphic

The data on graphic above can be consideration to conclude that original soil used on this research has clay content 56% and cataorized 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 clasify 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 tabled 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

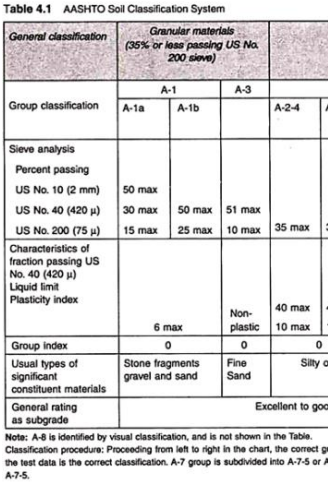

Table 4.1 AASHTO Soil Classification System

General classification	*Granular materials (35% or less passing US No. 200 sieve)*				
	A-1		A-3		
Group classification	A-1a	A-1b		A-2-4	
Sieve analysis					
Percent passing					
US No. 10 (2 mm)	50 max				
US No. 40 (420 μ)	30 max	50 max	51 max		
US No. 200 (75 μ)	15 max	25 max	10 max	35 max	
Characteristics of fraction passing US No. 40 (420 μ)					
Liquid limit				40 max	
Plasticity index	6 max		Non-plastic	10 max	
Group index	0		0	0	
Usual types of significant constituent materials	Stone fragments gravel and sand		Fine Sand	Silty c	
General rating as subgrade	Excellent to goo				

Note: A-8 is identified by visual classification, and is not shown in the Table.
Classification procedure: Proceeding from left to right in the chart, the correct g
the test data is the correct classification. A-7 group is subdivided into A-7-5 or A
A-7-5.

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 asured from **Figure 4** that showing correlation between PI and LL to determine classification area.

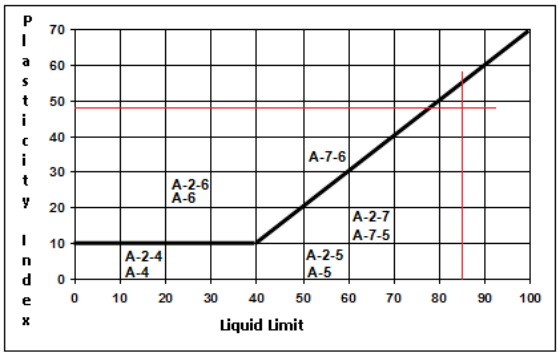

Figure 4. Correlation between PI and LL for AASHTO classification method

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(LL-20)%**	**USCS Symbol**	**USCS Name**
>50%	Yes	Yes	CH	Fat clay
		No	MH	Elastc clay
	No	Yes	CL	Lean clay
		No	ML	Lean silt

fine grained (more than 50% **smaller** than 63 µm BS or No.200 US sieve size (0.074 mm))	**Silts and Clays** (liquid limit less than 50)	Inorganic **silts**, silty or clayey fine sands, with slight plasticity	ML	Use plasticity chart
		Inorganic **clays**, silty clays, sandy clays of low plasticity	CL	Use plasticity chart
		Organic **silts** and organic silty clays of low plasticity	OL	Use plasticity chart
	Silts and Clays (liquid limit greater than 50)	Inorganic **silts** of high plasticity	MH	Use plasticity chart
		Inorganic **clays** of high plasticity	CH	Use plasticity chart
		Organic **clays** of high plasiticty	OH	Use plasticity chart
Highly organic soils		Peat and other highly organic soils	Pt	Use plasticity chart

Figure 5. Soil classification according to USCS

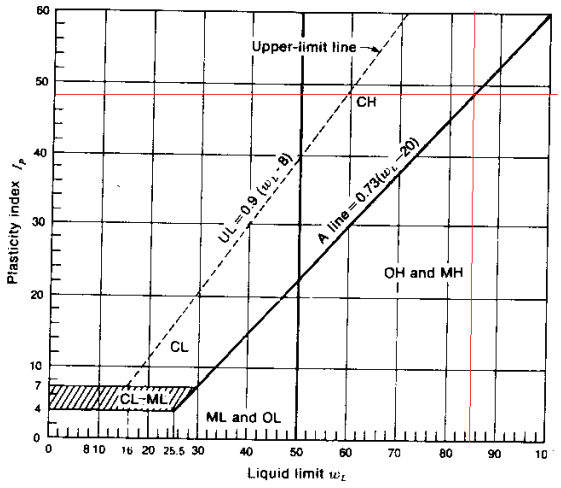

Figure 6. Correlation between PI and LL on USCS

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. Spesific Gravity	Gs	-	2.66	2.70	2.79
3. Atterberg Limits					
Plastic Limit	PL	%	50.63	59.20	58.20
Liquid Limit	LL	%	75.87	77.47	77.21
Plasticity Index	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.

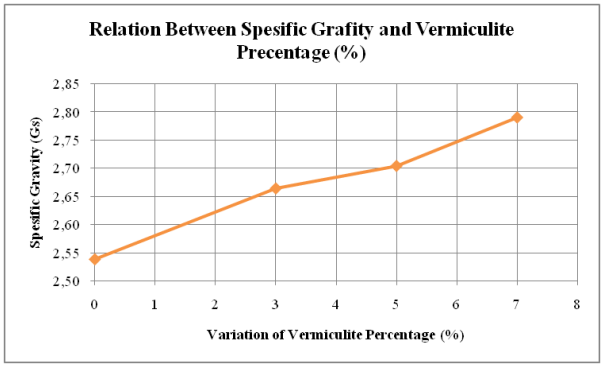

Figure 7. Relation between specific grafity and vermiculite percentage (%)

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.

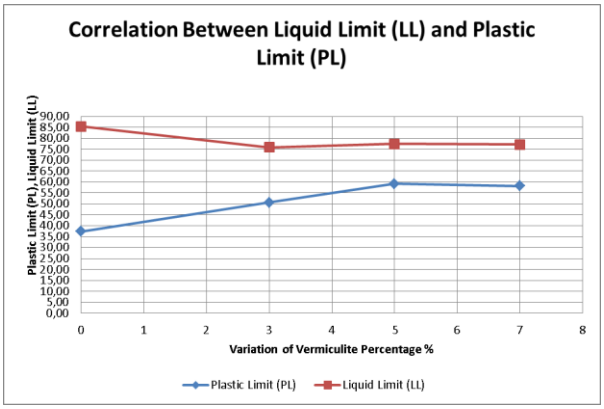

Figure 8. Relation between liquid limit and plastic limit

From the LL and Pl 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.

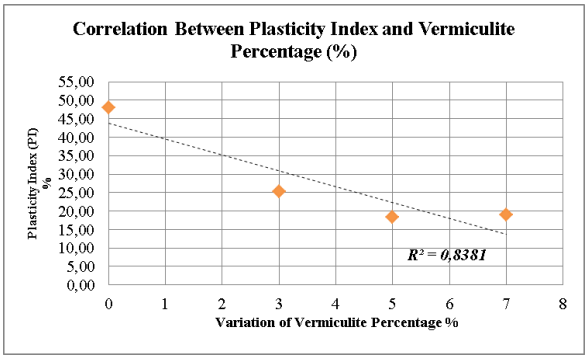

Figure 9. Correlation between plasticity index and vermiculite percentage

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 aquire 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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