Evaluation of Soil Stabilization from Marble Ash Powder and Asphalt Emulsion as Supporting Soil for Logistics Buildings

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ABSTRACT

This research focuses on improving the bearing capacity of soil by applying soil stabilization methods. Specifically, this research explores the use of a mixture of marble powder ash and emulsified asphalt to improve soil physical properties and increase soil bearing capacity to support logistics buildings such as lime or rice storage warehouses. This research was conducted in Cililin area which has soft clay soil that is unsuitable for construction. Tests were conducted in the laboratory using various compositions of marble dust ash (0%; 2.5%; 5%; 7.5%; 10%) and 6% emulsified asphalt. The tests measure the CBR (California Bearing Ratio) and UCS (Unconfined Compressive Strength) values of the soil. The tests measured the CBR (California Bearing Ratio) and UCS (Unconfined Compressive Strength) values of the soil. The test results showed a direct relationship between increasing marble ash composition with CBR and UCS values, with the highest design CBR value in the unsoaked method being 8% and the maximum q_u value being 1.676 kg/cm². However, the desired CBR value of >10% was not achieved in this study. To fulfill this requirement, future studies should consider compositions higher than 10% and for better results can use asphalt emulsion of more than 6%.

Keywords: Marble Powder, Ash, Asphalt Emulsion, Soil Stabilization, Soil Replacement, Clay.

1. INTRODUCTION

The Cililin area of West Bandung still has a large area of rice fields, where the rice fields tend to be expansive or can be said to have large shrinkage properties. Because of this condition, the soil in Cililin Subdistrict has decreased. So, this research was conducted with the approach of using the soil of Cililin Subdistrict, West Bandung, West Java and testing was carried out at the Bandung State Polytechnic Laboratory. A logistics building is a building that functions as a storage area for a product/good, such as rice. The place to store the results of the rice fields must be located not far from their origin to facilitate the farmers. So, it is necessary to improve the soil on the land to be built so that there is no significant land subsidence due to the load of rice that will be stored in the building. One solution to the problem is soil replacement, but the next problem is to dispose of the soil that will not be used. Therefore, an innovation that can be used is to add marble powder ash stabilization material or and asphalt emulsion to the soil to reuse the existing soil.

Marble Powder Ash is marble waste that has the same dominant element as lime. According to the results of research, it is explained that marble powder ash has a high content of Calcium Oxide (CaO) in it, with properties such as pozzolan if added to clay soil, it can bind particles in the soil so that it makes the soil hard [1]. The use of marble powder as a soil stabilization material is expected to be one of the cheap alternative materials to replace lime, supported by the relatively large supply of marble powder due to the lack of utilization of marble waste. The marble powder ash used came from a decorative stone craftsman in the Cipatat area, West Bandung Regency. Meanwhile, the function of emulsified asphalt for soil stabilization is as a water-resistant mixture for fine-grained soils, while for coarse-grained soils, emulsified asphalt functions as a water-resistant mixture and binder [2]. Emulsified asphalt used comes from a specialty store selling emulsified asphalt located in Riung Bandung. The main benefits of the research conducted to overcome the problems that occur in soft soil and provide alternative to soil improvement methods by using mixed materials that are included in the waste category to prevent environmental pollution, in this study, namely marble powder ash.

2. LITERATURE REVIEW

2.1 Clay

Clay is a soil that has microscopic and submicroscopic particles derived from the chemical decay of rock constituent elements and is plastic in the interval of moderate to wide water content. The shape of the particles is like a sheet that has a special surface so that it has properties strongly influenced by surface forces [3]. Clay soil comes from soil weathering through a chemical reaction process which will produce a colloidal-size. Particle arrangement with a grain diameter smaller than 0.002 mm (2 microns) [4].

2.2 Soil Replacement

Soil replacement is a method of improving the bearing capacity of soil by replacing compressible soil with better and more competent materials such as sand, gravel or crushed stone [5]. The use of this method can also reduce consolidation settlement. This method has advantages over other soil improvement methods, as it is more economical and takes less time to implement. However, there are still questionable cases based on experience, namely the problem of determining the thickness of the replacement soil [6].

2.3 Asphalt Emulsion

Emulsified asphalt is an asphalt mixture consisting of bitumen oil (petroleum bitumen), water and emulsifiers which at normal temperature and atmospheric pressure are liquid [7]. This emulsifier has a function as a modifier of asphalt particles, so that asphalt can mix with water which will immediately break after contact with aggregate or other mixing materials [8]. The function of asphalt in stabilization if used on fine-grained soil will be as a water proofing mixture, while if for coarse-grained soil as a water proofing mixture and binder (adhesion) [2]. Therefore, the purpose of mixing stabilization using asphalt is to increase inter-particle cohesion and soil bearing capacity and increase soil resistance to water.

2.4 Marble Powder Ash

Marble powder ash or marble waste is the result of marble processing/cutting. Marble waste comes from rocks that go through a metamorphic process or limestone Malihan, so it has constituent elements that are almost the same as lime. The content contained in marble waste shows that it has the highest content of Calcium Oxide (CaO) in it, which allows it to have properties such as pozzolan if added to clay soil, which can bind particles in the soil to form hard and stiff soil [1]. CaO is also a necessary compound in the chemical process with clay soil, which will produce high calcium ions that can bind and fill clay soil particles thereby reducing the attraction to water [9]. Marble waste in the market today has a relatively cheap price compared to lime [10]. It is likely that the use of marble powder as a soil stabilization material will be one of the cheap alternative materials, supported by the relatively large amount of marble powder supply due to the lack of utilization of marble waste. Therefore, the use of marble powder ash as stabilization is expected to reduce the amount of existing marble waste.

2.5 Reaction of Marble Powder Ash and Emulsified Asphalt with Soil

The reaction of soil with marble powder ash is based on the content of Calcium Oxide (CaO) contained in it. When CaO meets with H_2O (water) it will form $Ca(H_2O)$ (Calcium Hydroxide) which will emit heat, then it will bind CO2 (Carbon dioxide) to produce $CaCO_3$, if it reacts with water in the soil mixture it can reduce water absorption and is not easily dissolved in water. The pozzolanic properties contained in CaO will cause the reaction between particles to become mutually binding and strengthen the bond, which at the time of dehydration will form a reaction with the soil that causes the soil to become hard and stiff [11].

The reaction of soil with emulsified asphalt is slightly different from lime and/or cement (in this case marble powder ash). The reaction that occurs is that emulsified asphalt can be used as a water proofing mixture, in other words, it can withstand water from inside and outside that will enter so that it is not easy to shrink and develop too significantly. In grained soils, asphalt will bind the soil grains so as to increase soil stability where the asphalt will also fill the air voids of the soil and then there will be strong binding [8]. However, using asphalt emulsion as a stabilization material can also reduce the level of soil plasticity which will make the soil layer hard and can increase the bearing capacity of the soil. So with the properties of marble powder ash and emulsified asphalt which can also reduce the level of soil plasticity, the right composition is needed where the two materials will become a unit that can improve the bearing capacity of soil strength effectively and in accordance with the needs needed.

2.6 Composition Mixture

The basis of the composition used in this study is based on some previous research results related to stabilization with emulsified asphalt materials and or marble powder ash, looking at the effect of these materials on CBR and compressive strength (q_u) values. According to the results of research conducted by Dama et al (2021), the addition of emulsified asphalt in soil stabilization can affect the bearing capacity of the soil seen from the CBR results which show an increase in soil bearing capacity in the addition of 6% and 8% emulsified asphalt content with CBR values without soaking, namely 13.50% and 18.20%; soaking CBR values are 12.10% and 14.60% [12]. In the research of Wicaksono et al (2023) also obtained CBR results that increased with the addition of emulsified asphalt by 3%, 6%, and 10% with a value of 10.35%; 11.39% and the largest value of 12.08% [13]. Therefore, this research will use 6% asphalt emulsion judging from the CBR results obtained which are constant with a value of >10%. Previous research conducted by Setyono et al (2018) on expansive clay soil in the Citra Land Surabaya area, showed that the variation in the addition of marble powder 0%; 5%, 10%; 15%; 20%; up to 25% increased the CBR value with the highest value of 6.474% and the qu value peaked at the addition of 25% marble powder with a qu value of 1.734 kg/cm² [14]. Therefore, because the parameter to be used in this study is the desired qu value of >1 kg/cm², the limit of marble powder ash content to be used is 10% only, seen from the results of the study at 10% the qu value obtained is 1.078 kg/cm².

2.7 Compaction Test

Soil compaction is a process of strengthening and increasing the density of soil materials by reducing porosity and improving soil structure to make it more stable. This process aims to increase the bearing capacity of the soil and reduce unwanted soil settlement by determining the maximum dry weight (MDD) and optimum moisture content (OMC). The usual method in the field is grinding with heavy equipment, while in the laboratory it is by pounding or beating.

2.8 CBR (California Bearing Ratio)

CBR testing is conducted to assess the strength of the subgrade or other materials to be used for pavement construction, resulting in a ratio between the load required to penetrate a soil sample of 0.1"/0.2" and the load retained by a standard crushed stone of 3000 and 4500 lbs being considered to have a CBR of - 100%. The CBR value obtained is used to determine the required thickness of the pavement layer above the layer after the CBR value is determined. CBR testing can be done in the field and in the laboratory. CBR testing will be carried out based on specifications that are in accordance with soil replacement, which is classified as an optional backfill consisting of sandy clay or compacted material, and the CBR value that must be owned is at least 10% [15].

2.9 UCS (Unconfined Compressive Strength)

Unconfined Compressive Strength testing is used to determine the angle (Ø) of soil shear, soil cohesion, how strong the soil accepts the applied compressive strength until the soil separates from its grains and measures the soil strain due to the pressure. The compressive strength test is conducted on initial soil samples and non-initial soil samples. This unconfined compressive strength test is prioritized for clay and silt soil types because they have a high degree of saturation, the following types of unconfined compressive strength values in clay soil conditions can be seen in Table 1, which describes the value of unconfined compressive strength in clay soil [16].

Table 1 Unconfined Compression Strength Values

No.	Clay Soil Condition	q_u (kg/cm²)
1	Hard	> 4.00
2	Very Stiff	2.00 – 4.00
3	Stiff	1.00 – 2.00
4	Medium	0.50 – 1.00
5	Soft	0.25 – 0.50
6	Very Soft	< 0.25

2.10 Material Testing

Testing of additive materials carried out, namely testing the specific gravity of Marble Powder Ash, is useful for knowing the quality contained based on the strong absorption of the material, the lower the specific gravity contained, the greater the absorption of water for the material. The specific gravity of Marble Powder Ash in this test is calculated using Equation (1), where *Gs* is gravity specific, *W* is Weight (gr), V_1 is initial volume (ml), V_2 is final volume and *d* is density of water at 25°C

$$Gs = \frac{W}{(V_2 - V_1)d} \quad (1)$$

3. METHOD

The flowchart of this research shown in Figure 1, and explained in the following subsection.

3.1 Collection and Study of Secondary Data

The data obtained are data from previous studies whose research objects are in the same location as this study. The data taken is index properties testing data consisting of testing soil specific gravity, moisture content, atterberg boundaries, and grain size analysis on initial soil obtained from Antasya and Ikhsan [17].

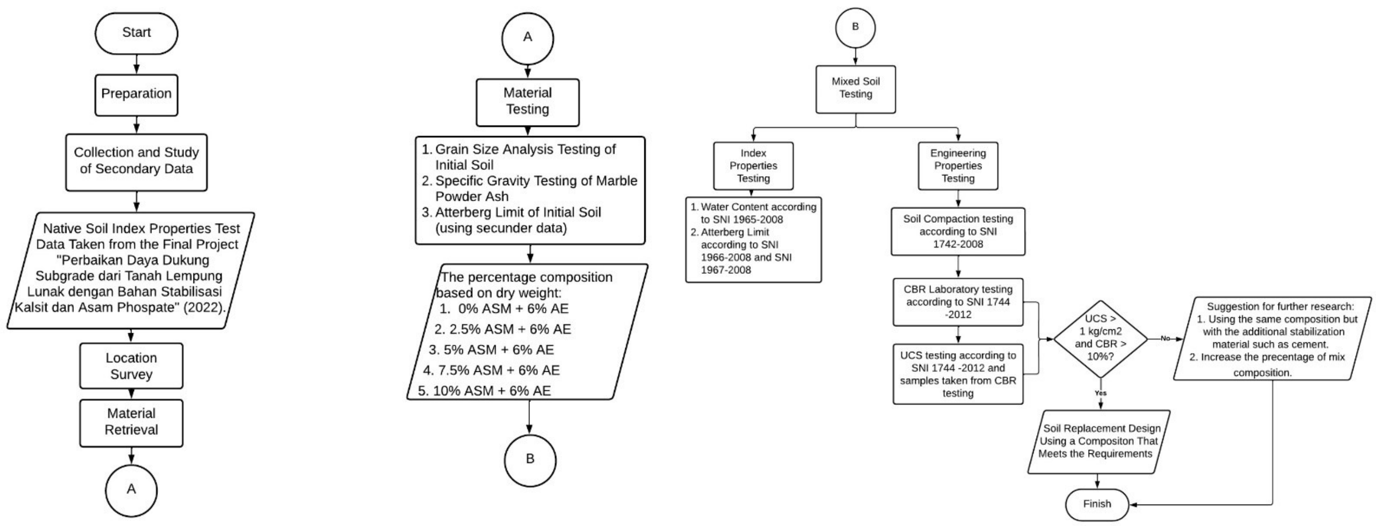

Figure 1 Research Flowchart

3.2 Soil and Additive Retrieval

Soil sampling for this research is planned to be taken in the Cililin area located at coordinates 6°55'40.38 "S 107°28'27.24 "E at a depth of 0.5-2 meters so that the soil obtained is initial soil. The method of taking soil samples is by peeling or cleaning 30-50 cm deep, so that the soil is protected from organic matter. Furthermore, the soil is dug using hoes and shovels, then put into plastic / sacks. The collection of additives, namely Marble Powder Ash, comes from a decorative stone craftsman Jl. Gunungmasigit, Cipatat District, West Bandung Regency, West Java, and Emulsified Asphalt is obtained from a specialty store selling Emulsified Asphalt located in Riung Bandung.

3.3 Determination of Stabilization Material Composition

Determination of stabilization material composition refers to previous studies that used the same stabilization material as this study. The composition of the emulsified asphalt mixture with 6% content was determined because in previous studies the addition of emulsified asphalt with this composition increased the bearing capacity of the soil and the mixture of marble powder ash with 0%, 2.5%, 5%, 7.5%, and 10% was determined because in that range, the CBR value and compressive strength of the soil increased.

The weight of the percentage of stabilization material added when mixing with soil is based on the weight of the soil when dry in each test of index properties and engineering properties with Equation (2). In this equation, W is weight of soil (gr) and $\%$ water is percentage of residual water in soil.

$$\text{Weight of added materials} = \frac{W}{1+\%\,Water}\,x\ \%\ Additive\ substance \qquad (2)$$

4. RESULTS AND DISCUSSION

4.1 Testing of Materials Used

Testing of additive materials carried out is testing the specific gravity (Gs) of Marble Powder Ash calculated using Equation 1 based on SNI 15-2531-1991. The results of the specific gravity test on marble powder ash can be seen in Table 2.

Table 2 Specific Gravity Testing Data of Marble Powder Ash

Sample Number		1	2
Weight (gr)	W	60.05	60
Initial Volume (ml)	V_1	0.7	0.6
Final Volume (ml)	V_2	23	229
Specific Gravity (Gs)		2.692	2.691
		2.6915	

4.2 Test Results on Soils with Additional Admixtures

4.2.1 Atterberg Limit

The Atterberg Limit test was conducted to obtain the Plasticity Index (PI) value. The results of the limit value and the comparison graph of the PI value in the entire Atterberg limit test can be seen in Table 3 and Figure 2.

Table 3 Recapitulation of Limit Values in Atterberg Limit Testing

No.	Soil Sample	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	Properties
1.	Initial soil	70,0%	35,9%	34,82%	High plasticity
2.	Soil + 6% AE + 0% ASM	45,14%	25,81%	19,33%	High plasticity
3.	Soil + 6% AE + 2,5% ASM	50,87%	33,11%	17,76%	High plasticity
4.	Soil + 6% AE + 5% ASM	48,63%	31,62%	17,01%	High plasticity
5.	Soil + 6% AE + 7,5% ASM	47,52%	30,77%	16,75%	Medium plasticity
6.	Soil + 6% AE + 10% ASM	42,66%	26,91%	15,75%	Medium plasticity

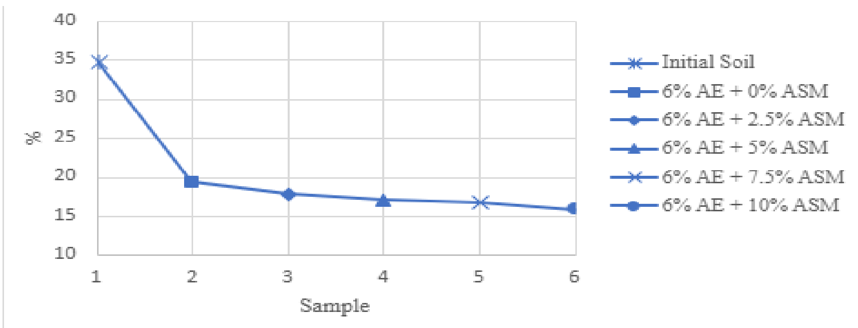

Figure 2 Comparison Chart of PI Values

4.2.2 Soil Compaction

Compaction testing of soil that has been mixed with stabilization materials is carried out to obtain the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) values. The results of all OMC and MDD values of compaction testing and soil compaction relationship graphs for each composition can be seen in Table 4 and Figure 3.

Table 4 Recapitulation of MDD and OMC Values of Soil Compaction Testing

No	Sample	*Maximum Dry Density* (ɣd) (gr/cm³)	*Optimum Moisture Content* (OMC) (%)
1	Initial soil	1.39	27.84
2	Soil + 6% AE + 0% ASM	1.20	41.5
3	Soil + 6% AE + 2,5% ASM	1.28	32
4	Soil + 6% AE + 5% ASM	1.29	32
5	Soil + 6% AE + 7,5% ASM	1.38	30
6	Soil + 6% AE + 10% ASM	1.38	29

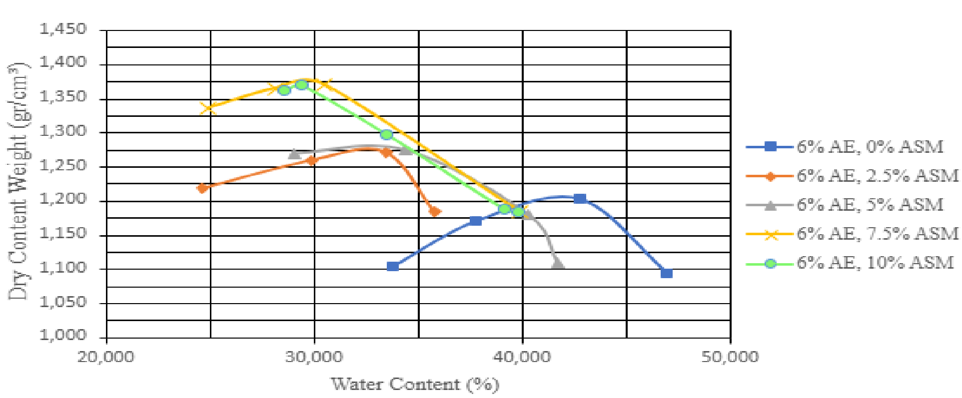

Figure 3 Compaction Relationship Graph of Whole Composition Soil

4.2.3 CBR

CBR tests carried out on initial soil and soil that has been mixed with stabilization materials are unsoaked CBR and soaked CBR. The overall design CBR value and its comparison in the unsoaked CBR and soaked CBR tests can be seen in Table 5 and Figure 4.

Table 5 Recapitulation of Unsoaked and Soaked Design CBR Values

No	Sample	CBR *Design Unsoaked (%)*	CBR *Design Soaked (%)*
1	Initial soil	3	1.83
2	Soil + 6% AE + 0% ASM	2.3	2.2
3	Soil + 6% AE + 2,5% ASM	3.8	3.7
4	Soil + 6% AE + 5% ASM	4.2	4
5	Soil + 6% AE + 7,5% ASM	6.2	6
6	Soil + 6% AE + 10% ASM	8	7.6

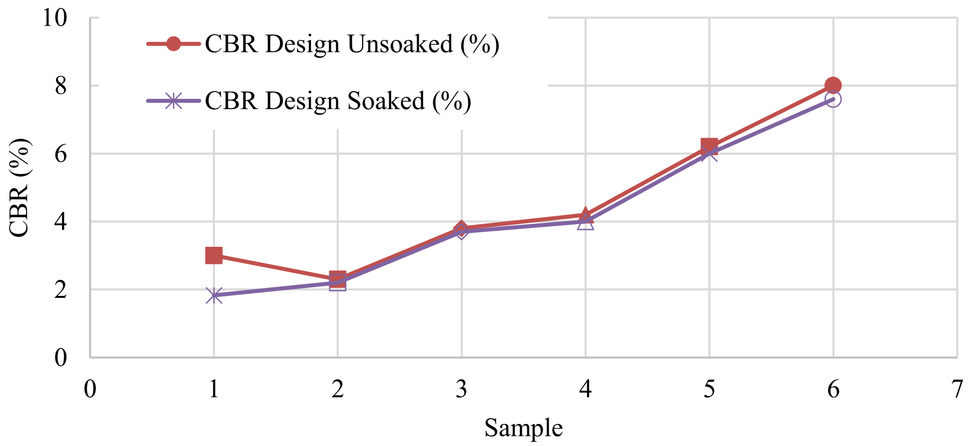

Figure 4 Comparison Chart of Unsoaked and Soaked Design CBR Values

From the table and graph above, it can be explained that the addition of marble powder ash to the sample increases the CBR value obtained. 2 methods that have been applied, the highest CBR value is obtained from the unsoaked method with a value of 8%.

4.2.4 UCS

UCS testing is carried out on the initial soil and soil that has been mixed with stabilization materials taken after the CBR test on each impact made to obtain the compressive strength value (qu). The results of the overall qumax value and its consistency in each sample taken from the CBR test with Soaked method results with 10x, 30x, and 65x impact can be seen in Table 6, Table 7, and Table 8.

Table 6 Recapitulation of qu_{maks} Value of 10x CBR Impact

No.	Sample	qu_{maks} [kg/cm^2]	Consistency
1.	Initial soil	0.299	Soft clay
2.	Soil + 6% AE + 0% ASM	0.357	Soft clay
3.	Soil + 6% AE + 2,5% ASM	0.317	Soft clay
4.	Soil + 6% AE + 5% ASM	0.325	Soft clay
5.	Soil + 6% AE + 7,5% ASM	0.482	Soft clay
6.	Soil + 6% AE + 10% ASM	0.581	Medium clay

Table 7 Recapitulation of qu_{maks} Value of 30x CBR Impact

No.	Sample	qu_{maks} [kg/cm^2]	Consistency
1.	Initial soil	0.299	Soft clay
2.	Soil + 6% AE + 0% ASM	0.345	Soft clay
3.	Soil + 6% AE + 2,5% ASM	0.456	Soft clay
4.	Soil + 6% AE + 5% ASM	0.539	Medium clay
5.	Soil + 6% AE + 7,5% ASM	0.735	Medium clay
6.	Soil + 6% AE + 10% ASM	1.193	Stiff clay

Table 8 Recapitulation of qu_{maks} Value of 65x CBR Impact

No.	Sample	qu_{maks} [kg/cm^2]	Consistency
1.	Initial soil	0.299	Soft clay
2.	Soil + 6% AE + 0% ASM	0.576	Medium clay
3.	Soil + 6% AE + 2,5% ASM	0.590	Medium clay
4.	Soil + 6% AE + 5% ASM	1.181	Stiff clay
5.	Soil + 6% AE + 7,5% ASM	1.627	Stiff clay
6.	Soil + 6% AE + 10% ASM	1.676	Stiff clay

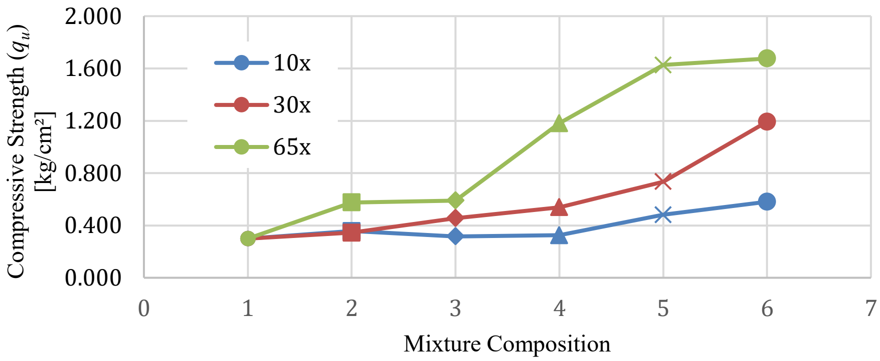

Figure 5 Comparison Chart of q_u Values of All Mix Compositions

4.2.5 Composition of Soil Mixture with Stabilization Materials in the Field

Soil composition and percentage of stabilization materials used in the field are calculated in volume units. Then the composition needed if the soil is 1 m³ is as follows.

MDD of initial soil = 1.39 gr/cm^3 = 1,390 kg/m^3
OMC value of stabilized soil = 29%
Original field moisture content = 15%
Soil = $1\ m^3 = 1390\ kg$
Water = $29\% - 15\% = 14\%$
= $1{,}390\ kg \times 14\% = 194.6\ kg = 194.6\ L$
Asphalt Emulsion = $1{,}390\ kg \times 6\% = 83.4\ kg = 83.4\ L$
Marble Powder Ash = $1{,}390\ kg \times 10\% = 139\ kg$

4.3 Recapitulation of Test Results

A recapitulation of the test results can be seen in Table 9.

Table 9 Recapitulation of Test Results

No	Soil Properties		Initial Soil *)	Soil + 6% AE + 0% ASM	Soil + 6% AE + 2.5% ASM	Soil + 6% AE + 5% ASM	Soil + 6% AE + 7.5% ASM	Soil + 6% AE + 10% ASM
1	Plasticity Index (PI)		34.82%	19.33%	17.76%	17.01%	16.75%	15.75%
2	Optimum Moisture Content (OMC)		27.84%	41.5%	32%	32%	30%	29%
3	Maximum Dry Density (MDD)		1.39	1.2	1.28	1.29	1.38	1.38
4	California Bearing Ratio (CBR)	Unsoaked	3%	2.3%	3.8%	4.2%	6.2%	8.0%
		Soaked	1.83%	2.2%	3.7%	4.0%	6.0%	7.6%
5	Unconfined Compression Strength (UCS) [qu maks]	10x Impact	0.299	0.357	0.317	0.325	0.482	0.581
		30x Impact		0.345	0.456	0.539	0.735	1.193
		65x Impact		0.576	0.59	1.181	1.627	1.676

Description:
*) From Final Project "Perbaikan Daya Dukung Subgrade dari Tanah Lempung Lunak dengan Bahan Stabilisasi Kalsit dan Asam Phosphate" (2022).
AE: Asphalt Emulsion
ASM: Marble Ash Powder

5. CONCLUSIONS

Based on the recapitulation of the test results of initial soil and soil mixed with stabilization materials, the value obtained increases with the higher percentage of stabilization materials added. It can be concluded that the addition of emulsified asphalt and marble powder ash as stabilization materials can increase the bearing capacity of the soil and can improve the soil but with a note that it must use the correct composition to meet the requirements for logistics buildings. The research that has been done has not yet met the requirements for logistics buildings, so for the next research, it can add more compositions so as to achieve the optimal composition.

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