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STABILIZATION OF EXPANSIVE SOIL USING MARBLE POWDER AND PHOSPHORIC ACID AGAINST PHYSICAL PROPERTIES AND *SEM-EDS TESTS*

***A. M. Nuno*[1,*]*, Syahril*[2]

[1]Department of Infrastructure Engineering, Politeknik Negeri Bandung, Bandung, Indonesia
[2]Department of Civil Engineering, Politeknik Negeri Bandung, Bandung, Indonesia
**Email: ambrosio.martins.mtri21@polban.ac.id*

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ABSTRACT

The Gedebage region faces a myriad of challenges, including road deformations, swelling of roads and bridges, and cracks in drainage foundations, buildings, and asphalt concrete. To address these issues, a comprehensive analysis of soil physical properties was conducted at the POLBAN soil mechanics laboratory, along with chemical tests at the POLMAN laboratory. The primary objective was to understand the physical properties and mineral composition of Gedebage soil and develop effective soil management strategies. Soil stabilization was employed as a method to enhance infrastructure resilience in Gedebage. Marble powder waste (MPW) was utilized in varying concentrations (2.5%, 4%, 5.5%, and 7%) along with 4% phosphoric acid (PA) to optimize the solution. MPW filled soil pores and improved cohesion, while PA reduced moisture content, enhanced particle bonding, increased load-bearing capacity, and minimized soil volume changes. Initial soil tests revealed a high plasticity index (PI) of 54.20%, indicating Gedebage, expansive clay soil nature with significant potential for expansion and plasticity. The AASHTO classified it as "A-7-6", and the USCS classified it as "CH." Stabilization experiments demonstrated that the most effective combination was the original soil + 7% MPW + 4% PA, resulting in a PI of 16.03% and an activity level (Ac) of 0.48. AASHTO classified this combination as "A-2-6," and the USCS as "CL." Furthermore, MPW oxygen, silica, and aluminum content exhibited potential for pozzolanic reactions, while PA reacted with soil mineral cations likes: Ca, Fe, Al dan Phosphor, forming a water-resistant layer. MPW and PA effectively improved the expansive clay soil's ability to withstand moisture-induced changes. This study serves as a foundation for further investigations into the mechanical properties of Gedebage soil, focusing on bearing capacity and stability, using MPW and PA in civil and infrastructure foundation applications.

Keywords: Soil; Stabilization; Marble_Powder_Waste; Phosphoric_Acid; SEM_EDS
Paper type Research paper

INTRODUCTION

There are many problems in the Gedebage area, such as road deformation, settlement of roads and bridges, cracks in drainage foundations, buildings and asphalt concrete. Therefore, it is necessary to take soil samples in these areas in order to be able to experimentally test the physical properties in the POLBAN soil mechanics laboratory, and carry out the chemical tests in the POLMAN laboratory. Through this test, we can find out what kind of impact it caused and find ways to overcome it, since this area is a residential area and rice fields. One thing that needs to be done is to stabilize the soil with other materials such as waste marble powder and phosphoric acid. And got done stabilization in 2 ways that is stabilization original soil with addition characteristic physical the soil more Good from another location called stabilization mechanics and stabilization with additive materials other for get new minerals to use for reduce flower shrink from soil the called stabilization chemical [1].

The purpose of this study was to determine the properties and characteristics of the soil in the Gedebage area and to implement a method of treating it with stabilizing material for waste marble powder of 2.5%, 4%, 5.5% and 7% at 4% phosphoric acid for all variation so that it can withstand construction and infrastructure and be strong and stable. While the SEM-EDS test aims to determine in detail the effect of which mineral content is affected, so that when soil is stabilized with MPW and PA, the property index decreases, the activity level decreases and the bearing capacity of the soil increases.

MPW is a waste product from marble production, it is white color, fine-grained, enhances soil stability, can fill soil pores and increase soil cohesion and PA is a clear-colored chemical liquid that evaporates, playing a role in reducing soil moisture content, increasing bonds between particles, while increasing the load-bearing capacity and reducing the possibility of changes in soil volume.

A Scanning Electron Microscope (SEM) instrument is designed to observe the surface structure of test objects at high resolution, While Energy Dispersive X-ray Spectroscopy (EDS) is a method for analyzing the elemental composition on the surface of test objects. The SEM-EDS method can be used in this study to analyze the changes in soil microstructure and mineral composition before and after MPW and PA stabilization. It's hoped that the SEM-EDS test will provide detailed information on changes in soil microstructure due to the contribution of MPW and PA, which may affect soil material composition, which has changes from high to low soil physical properties, the optimal variation is 7% MPW + 4%PA it was selected to evaluate the significant impact.

LITERATURE

carrying capacity soil clay with very high-water content range to water pollution, power support soil and strong high shear under conditions soil dry whereas power support soil low on condition high water content. Then there is a number of study earlier state that degradation this no will stop before soil reach level stable or balanced [2]. Percentage marble 0%, 10%, 15% and 20% gain mark index its plasticity compared soil original experience decreased, from 60% to 57.53% (10% MPW), 55% (15% MPW) and 52.27% (20% MPW) [3]. According to [4] application mixture Phosphoric Acid (PA) solution used are 4.5%, 7.5%, 10.5% and shell ash Coconut Palm oil (ABKS) as much as 8% for all sample can lower mark index plasticity (PI), for example in mixtures third (ABKS 8% + 10.5% PA) index plasticity from soil original (47%) fell to 9% and fulfill condition mark minimum Index plasticity (PI). Whereas according to study [5] Percentage ash volcanic 6%, 8% and 10% and acid 10% phosphate value index plasticity For soil original get 48% incl very high development so done testing physical with a stabilizing material until variation third proven can lower PI value to 14.22%. In research [6] stabilization soil clay with addition of mineral acids phosphate with varying percentages start from 2.5%, 5%, 7.5%, 10% and 12.5% worked lower mark index plasticity, because addition of mineral acids capable phosphate tie with details soil clay initial IP percentage of 39.4% to 9.43% in variations last and also the result classification soil original with AASTHO method included group A-7-5 is are clays soil which is not Good change soil become soil group A-2-5 is a fine loamy granular soil.

From the several references above, the purpose of this research is to the Atterberg limits of soils, classification analysis soil use USCS (Unified Soil Classification System) method, AASHTO classification and *Scanning Electron Microscope* (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS) methods are used for analyze structure micro to use know soil mineral content Gedebage before and after done stabilization with Marble Powder Waste (MPW) and AF. Stabilization with addition of Marble Powder Waste (MPW) and Phosphate Acid (PA) in the soil expansive Gedebage with the percentage of MPW 2.5%, 4%, 5.5% and 7% meanwhile Phosphate Acid (PA) 4% for all variation.

MATERIALS AND TOOLS

Clay soil

Clay soil formed during hoarding as consequence from reaction chemistry, which can form group particle colloid with size grains > 0.002 mm (2 microns). Particle soil clay arranged in the plates with surface certain. Because it's style surface influential real to type clay (Darwis, 2017).

Clay minerals can see no only from size particles, such as feldspar and quartz particles, though arranged from more particles small, however no can called clay universally, particles this no can cause soil plasticity. Change characteristic physical and mechanical soil expansive governed by the dominant mineral group within soil (Chen, 1975).

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In the Atterberg Limit test, using criteria [7] For determine potency development soil expansive seen in detail in Table I.

TABLE I. TERMS DEVELOPMENT DETERMINED FROM PI VALUES (DAS ET.AL, 1995)

Swelling Rate	Index plasticity	Index shrinkage
Low	< 12	<15
Currently	12–23	15–30
High	23–30	30–40
Very high	>30	>40

According to [8] level liveliness soil is combination between mark index plasticity and percentage fraction clay with formula equation 1. To find out the activity value is correlated with the potential for soil development as shown in Table II.

$$Ac = \frac{PI}{CF} \quad (1)$$

With Ac = Level liveliness soil,
PI = Index plasticity (%) and
CF = Percentage Fraction clay (%)

TABLE II. CORRELATION OF ACTIVITY LEVEL AND SWELLING POTENTIAL (DPU PD T-10-2005-B, 2004)

level of liveliness	Potency development
< 0.75	Not active
0.75 – 1.25	normal
>1.25	active

Stabilization soil

Stabilization soil consists from repair characteristics existing soil such shape for get filling soil conditions technical location development. Another meaning of stabilization soil is repair condition soil and then take exact steps for solve identified problem [9]. With additions material additive expected can lower mark index plasticity (PI) and power hammer soil.

Stabilization chemistry is repair held soil with add material fluid chemistry specific to the soil so that happen bond between soil with mixed materials, so produce material new with characteristic more technical good. Stabilization done For change composition soil or properties soil to afford enhancement Power support soil [10].

Kindly general, based on [11] state that global classification mechanism stability soil can distinguished into two types, namely:

1. Soil improvement is something type stabilization target soil _ For increase or maintain capacity and yield repair in a manner efficiency in accordance with condition technical with using additive materials (Materials chemistry), mixing soil, drying or distribution dynamic to in layer soil.
2. Soil reinforcing is one type stabilization target soil for strengthen or maintain quality soil in accordance with condition technically desired, with fully as material addition to in soil you want strengthened.

Classification soil

Classification soil is method determination and identification type soil in a manner systematic for determine suitability with use certain. Classification soil also for investigation more carry on about condition soil and determination properties mechanic like compaction , strong press , strong shear , consolidation and others (Bowles, 1989) .

When planning a construction, properties classification soil need done research so you can know cause strength soil. Classification method use USCS (*Unified Soil Classification System)* method. Classification use USCS method is determined by the following parameters: Size grain passing

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pebbles filter No. 3 fixed is in the filter Number 4, and the sand that escaped filter No. 4 fixed is in the filter Number 200, loose clay and silt filter No. 200, Coefficient *uniformity* (Cu) and *Atterberg* Limits [13].

Classification soil use AASHTO method is defined by parameters like following : index Group (GI) where percentage get away sieve no.200(F), index plasticity (PI), liquid limit (LL), dominant type of soil material and classification group soil such as : Very good subgrade soil until both A- 1, A- 3 and A- 2, meanwhile soil normal until bad A-4, A-5, A-6 and A-7 AASHTO system according to the tables and graphs of AASHTO M 145 or ASTM D 3282 [14].

SEM and EDS Testing on Original Soil, MPW and PA

Purpose of testing this is for now contained mineral content in the material to be used. If fulfill already meet what is expected so testing will proceed in step furthermore However If Not yet fulfil condition so must looking for material or suitable material composition element from material swell, Marble Powder Waste (MPW) and Phosphate Acid (PA). Analysis microstructure use Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray spectroscopy (EDS) for determine soil mineral properties and other materials based on results testing [15].

SEM-EDS testing was carried out POLMAN Materials laboratory Bandung with use tool brand SEM Hitachi SU3500 with EDAX Octane Pro. With help EDS tool for now composition chemistry on the sample.

Marble Powder Waste (MPW)

Marble Powder Waste (MPW) price relatively cheap. MPW is generated from cutting marble expected can replace chalk as material stabilizer economical soil. However, study about waste powder marble This as material stabilizer soil still very limited. MPW used originate from Padalarang, Bandung Barat Regency. Physically, Marble Powder Waste (MPW) is fine white in color and has a specific gravity of 2.79. The grain size of the Marble Powder Waste is very fine which 100% of the granules pass through the sieve number 200 with a diameter of 0.08 mm.

Phosphoric Acid (PA)

Phosphoric acid is type fluid clear, no smelly and easy evaporate. Hope it's phosphate Acid can reduce inside water level soil and lowered level development on soil, because sour phosphate reacts fast form bonded aluminum compounds with soil.

Phosphate organic and non- organic found in soil. Form solution compound organic is solution Calcium, Iron, Aluminum and Fluorine. Phosphate organic contain originating substance from plants and microbes, consists from sour nucleic acid, phytin and phospholipids [16]. Because that is stabilization soil expanded clay is very important for repair soil. Addition material chemistry fluid sour phosphate interact with deep mineral cations for form compound new to the soil and forming layer hard as well as No late in water. To find out the specifications common to products material phosphoric Acid (H_3PO_4) in Table III.

TABLE III. SPECIFICATIONS PRODUCT SOUR PHOSPHATE [17]

Specification	Phosphoric Acid
Form	Liquid, no colored
Formula Molecule	H3PO4
Molecular Weight	98 gr/mol
Point boil	158 °C at 1 atm
Density	1.685 gr/cm3
Point Melted	42°C
Specifics Gravity	1.67
Solubility g/L at 25 °C	
Purity	75%

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METHOD

Samples were taken using a hand drill with a 30 cm long, 3-inch diameter sampling tube, and the sampling point was cleaned and dug to a depth of 20 cm to avoid contamination. Install the tube on the end of the drill, then rotate it by hand to a certain depth, and slowly remove the sample, when the tube is full of sample, and lift it up, covered with plastic, the soil sample will not be disturbed. Physical property tests were carried out on the original soil and at the Soil Mechanics Laboratory of Bandung State Polytechnic Institute. Physical property tests performed include tests for water content, soil bulk density, specific gravity, specific gravity, and Atterberg limits. After testing is completed, the next step is to analyze the results of soil laboratory tests, including analysis of soil category type and soil classification using USCS and AASHTO methods to determine soil behavior. After analyzing and classifying, it turns out that the soil is classified as highly plastic soil type and cohesive clay soil type based on the table (Hardiyatmo, 2010), therefore determining the stabilizing material with MPW percentage of 2.5%, 4%, 5.5% and 7 % and PA 4% for all blend options, this percentage is based on previous studies such as [18][6][19][20]. After stabilizing the lowest PI value in this option, we decided to conduct a SEM-EDS study as the best option to find out what mineral composition is contained so that we can reduce the PI value from initially high to low. Tests performed use method like shown in Table IV and stages study shown in Figure 1.

TABLE IV. TEST TYPES AND STANDARDS TEST USED

No.	Test Type	Standard Testing
1.	Atterberg limit testing	ASTM D4318
2.	Specific gravity test	ASTM D854 - 58
3.	Test the moisture content	ASTM D2216 - 71
4.	Classification soil	AASHTO and USCS
5.	SEM-EDS chemical test	Hitachi SU3500 SEM manual book with EDAX Octane Pro

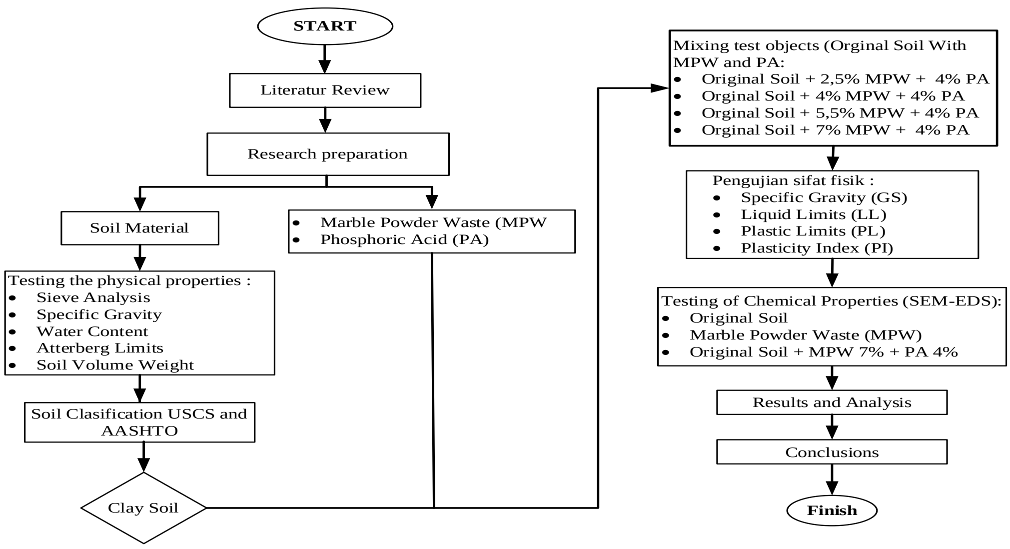

Figure 1 Flow Chart Testing

RESULTS AND ANALYSIS

Physical Properties Test For soil original

Results of Sieve Analysis Tests and Measures Original Soil Details

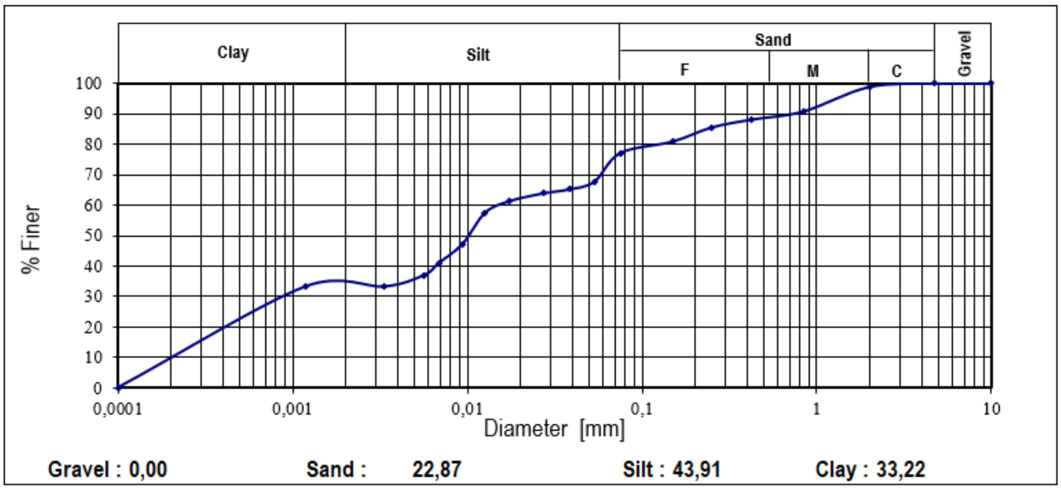

Figure 2 Sieve Analysis Test Graph

Testing hydrometer use SNI-3423-2008 standard. Analysis results filter obtained size grain 0.00% gravel (G), 22.87% sand (S), 43.91% silt (M) and 33.22% clay (C).

Results of Atterberg Limits

Atterberg limit testing includes testing of shrinkage limit, plastic limit and liquid limit. In this study, Atterberg's limit test was conducted on natural soil. Below are the results of Atterberg's limit test. For in more detail see in Table V.

TABLE V. ORIGINAL SOIL ATTERBERG LIMIT TEST RESULTS

No.	Properties index	Symbol	Unit	Value
1.	Water content		%	26,62
2.	Specific gravity	GS		2.65
3.	Atterberg limits			
3.1.	Shrinkage Limit	SL	%	5,039
3.2.	Liquid limit	LL	%	77,92
3.3.	Plastic Limit	PL	%	23,72
3.4.	Plasticity Index	PI	%	54,20
4.	Activity Level	Ac = PI/C	%	1,63

From the results of the tests that have been carried out, the original soft soil has a Plasticity Index value of 54.20% with an LL value of 77.92% and a PL of 23.72%. The level of soil activity (AC) of 1.63% is obtained from the percentage of clay fraction divided by the value of the plasticity index. In Table 5 base on [21] Table 5 describes soil plasticity and development potential, therefore it is concluded that the soil is a cohesive clay soil with high plasticity and development potential, including an active soil.

$$GI = (77.13-35) \times \{0.2 + 0.005(77.92-40)\} + 0.01 \times (77.13-15) \times (54.20-10) = 43.87$$

Based on the index value this soil group is included in the very bad subgrade class

From the results of the Atterberg limit test, analysis grain and hydrometer test then can classify soil original based on AASHTO and USCS methods like following.

Classification soil original with AASHTO method

Analysis filter soil original including category soil silt - loam Because pass filter no. 10 = 98.89%, percentage get away filter no. 40 = 88.16% and percentage soil pass sieve no.200 = 77.13% more big of 35%. Results table classification soil original with AASHTO method in view based on Table VI.

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TABLE VI. SIEVE TEST RESULTS PLOTTED TO THE AASHTO FOR ORIGINAL SOIL

General Classificaation	Granular Materials (< 35% or less passing 0,075 mm (no. 200))							Silt- Clay Materials (> 35% passing the 0,075 mm (no. 200))			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5/A-7-6
Sieve Analysis (% passing)											
2,00 mm (no. 10)	50 max	-	-	-	-	-	-	-	-	-	-
0,425 mm (no. 40)	30 max	50 max	51 min	-	-	-	-	-	-	-	-
0,075 mm (no. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing											
0,425 mm (no. 40)											
Liquid Limit (LL)	-	-	-	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity Index (PI)	6 max		N.p.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min
Group Index (G)	0		0	0		4 max		8 max	12 max	16 max	20 max
Usual types of significant constituent materials	stone fragments, gravel and sand		fine sand	Silty or clayey gravel and sand				Silty Soils		Clayey Soils	
General rating as a subgrade	Excellent to good							fair to poor			

Note:
Group A-7 divided up A-7-5 and A-7-6 depending on the plastic limit(PL)
i.e. PL > 30, Classification A-7-5 ;
i.e. PL < 30, Classification A-7-6 ;
Np = Non plastic ;

From the results of the plastic limit (PL) = 23.72% more small 30% and (GI) = 43.87, then results analysis system AASHTO classification for soil Gedebage, Bandung Barat, Jawa Barat, Indonesia, classified in classification group A-7-6 (43.87) with soil material type argillaceous global assessment as soil base fair to poor. With graphics classification procedure AASHTO index plasticity and liquid limit plotted in picture 3.

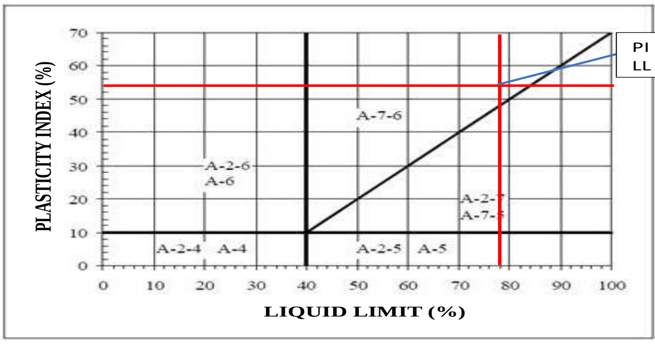

Figure 3 Graphic Classification Soil Original with AASHTO

Classification soil use USCS standard (Unified Soil Classification System)

The criteria used in the classification soil with USCS standard is seen from size grain get away sieve no.200, Liquid limit (LL) and index plasticity (PI). Based on hydrometer test results details escaped soil sieve 200 (0.075 mm) is 77.13%, which means soil original belong soil grained fine whereas LL value (liquid limit) = 77.92%, PI = 54.20% see detailed results in Table VII and plotted on the USCS correlation chart between LL and PI in Figure 4.

TABLE VII. SOIL CLASSIFICATION WITH USCS STANDARD

% Passed #200?	LL > 50%?	PI > 0.73 (LL-20%)?	USCS Symbol	USCS Name
>50%	Yes	Yes	CH	Clay Fat (Fat clay)
		No	MH	Silt (Elastic Silt)
	No	Yes	CL	Lean Clay
		No	ML	Lean Silt

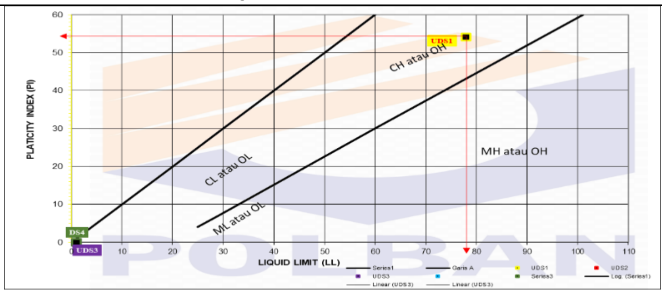

Figure 4 Graphic classification of original soil using the USCS method

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From the results analysis grouping soil original with USCS standard, got said that soil original belongs in soil clay fat with symbol CH (High plasticity clay).

Recapitulation results of physical properties testing for original soil

TABLE VIII. RECAPITULATION RESULTS ON THE ORGINAL SOIL

No.	Properties index	Symbol	units	Value Original Soil
1.	Size details			
1.1	Gravel	G	%	0.00
1.2	sand	S	%	22.87
1.3	Silt	M	%	43.91
1.4	Clay	C	%	33,22
2.	Specific gravity	Gs	-	2.65
3.	Water content		%	26,62
4.	Atterberg Limits			
4.1.	Liquid limits	LL	%	77,92
4.2.	Plastic limits	PL	%	23,72
4.3.	Plasticity index	PI	%	54,20
5.	Activity Level (Ac)	PI/C		1.63
6.	Index Group	GI		43,87
7.	AASHTO (fair to Poor)	A-7-6		
8.	USCS (High plasticity Clay	CH-OH		

Based on Table VIII, all initial results of soils are summarized in accordance with the objectives of soil research, including expansive clays with high plasticity and active soils, when used as a subgrade, including poor soils. Meanwhile, the soil classification based on the AASHTO method is included in group A-7-6 (fair to poor), and the USCS method includes a type of inorganic clay soil with high plasticity – fat clay (CH). Therefore, it is necessary to stabilize it with Marble Powder Waste (MPW)and Phosphoric Acid (PA).

Stabilization Soil Testing

Physical Properties Test for Soil Stabilization

After done testing characteristic physical soil original so soil the categorized as soil level very high development and done analysis with method classification AASHTO soil in figure 2 and USCS in figure 3 included soil argillaceous currently until bad with symbol CH (clay plasticity high), so need done stabilization with additional MPW material 2.5%, 4%, 5.5% and 7% meanwhile 4% PA solution for all variant for repair characteristics soil the. Then done testing characteristic physical such as the Specific gravity (Gs) test, analysis Atterberg filter and limits (LL, PL and PI), AC (activity soil) with objective for repair type soil argillaceous tall become soil argillaceous currently become low. Then results testing soil stabilization laboratory can plot in Table IX.

TABLE IX. SOIL STABILIZATION PROPERTIES INDEX TEST RESULTS

No.	Properties index	Symbol	units	Mixed Variant `				
				OS	I	II	III	IV
1.	Size details							
1.1	Gravel	G	%	0.00				
1.2	sand	S	%	22.87				
1.3	Silt	M	%	43.91				
1.4	Clay	C	%	33,22				
2.	Specific gravity	Gs	-	2.65	2.59	2.54	2.50	2.47
3.	Water content		%	26,62				
4.	Atterberg Limits							
4.1.	Liquid limits	LL	%	77,92	64,62	53,54	42.03	33,47
4.2.	Plastic limits	PL	%	23,72	21.97	19.70	18.54	17,44
4.3.	Plasticity index	PI	%	54,20	42.65	33,84	23,49	16.03
5.	Activity Level (Ac)	PI/C		1.63	1.28	1.02	0.71	0.48

Note: TA = original soil (clay soil)
Variation 1 = TA+2.5%MPW + 4%PA
Variation 2 = TA+4%MPW + 4%PA
Variation 3 = TA+4.5%MPW + 4%PA
Variation 4 = TA+7%MPW + 4%PA

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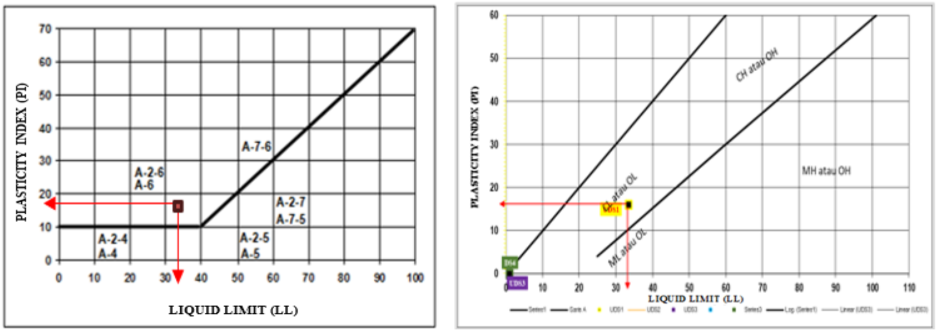


(a) (b)

Figure 5. (a) Graphic Of the AASTHO Method and (b) Graph of the USCS Method.

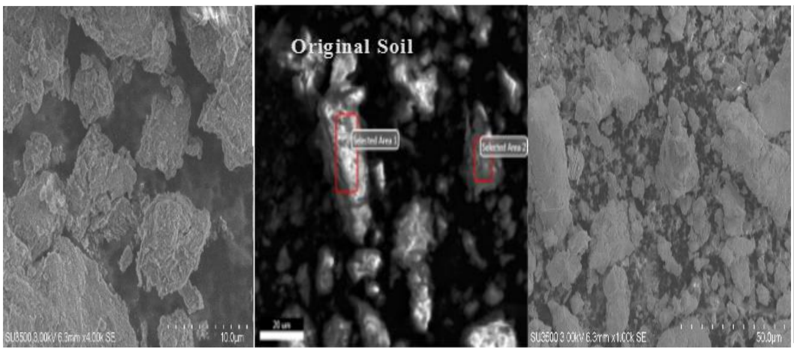
$$GI = (0{,}00-35) \times \{0.2 + 0.005(33{,}47-40)\} + 0.01 \times (0{,}00-15) \times (16{,}03-10) = -6{,}762$$

Based on the results of soil stabilization in table 9 the original soil has a very high level of development after stabilization up to variant 4 being the current level of development due to the influence of the plasticity index percentage while for table 5 the original soil is categorized as active soil, after the soil is stabilized the soil is included normal soil category because the Group Index value (GI) is -6.72 = 0 and is influenced by the property index value divided by the percentage of clay (C) the level of soil activity (Ac).

Soil after stabilization with MPW and PA up to variation 4 soil classification based on table 9, has become a granular material with classification group A-2-6 and reduces soil plasticity from CH to CL, because it is influenced by MPW and PA values that have filled the pores the soil becomes denser, reduces the water content of the soil, reduces the development potential so as to increase the carrying capacity of the soil to be effective and efficient. Based on the AASTHO method seen in Figure 5a and the USCS method shown in Figure 5b.

SEM and EDS testing

SEM and EDS test in the laboratory Polytechnic material testing Manufacturing Bandung (POLMAN) with type SEM & EDS (Scanning Electron Microscopy and Energy Dispersive Spectrometry*)* testing. The test results are original soil Gedebage seen as in Figure 6, 7, 8 and composition chemistry seen in Table X.



Original Soil Gedebage		
Element	A1. Weight %	A2. Weight %
C K	8.15	12.88
O K	38.38	49.20
AlK	12,49	14.17
SiK	47.12	17.37
TiK	0.62	0.43
FeK	5.81	5.95

(a) (b) (c) (d)

Figure 6. Original Clay soil with: (a) 10µm Magnification, (b) 20µm Magnification, (c) 50µm Magnification and (d) Mineral Percentage

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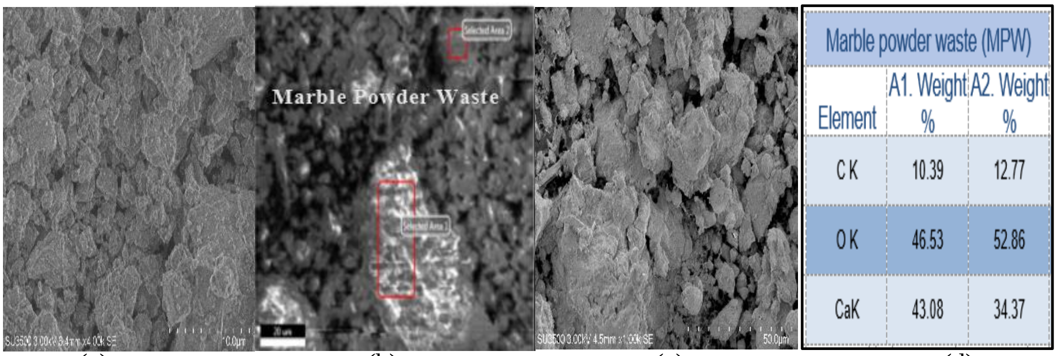
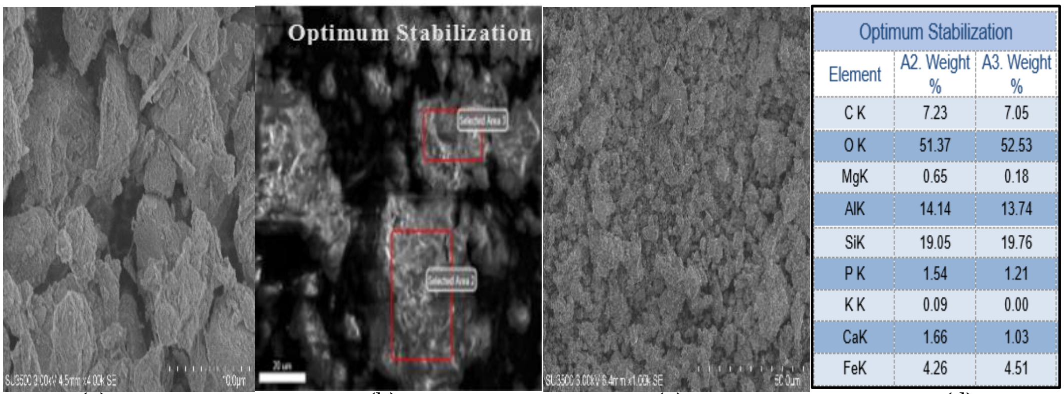


(a) (b) (c) (d)

Figure 7. Marble Powder Waste with: (a) 10µm Magnification, (b) 20µm Magnification, (c) 50µm Magnification and (d) Mineral Percentage



(a) (b) (c) (d)

Figure 8. Optimum Stabilization with: (a) 10µm Magnification, (b) 20µm Magnification, (c) 50µm Magnification and (d) Mineral Percentage

TABLE X. RESULTS OF CHEMICAL TESTING OF NATIVE SOIL, MPW AND OPTIMUM STABILIZATION (SEM-EDS) AT THE LABORATORIUM POLMAN

No	Mineral content	Average Percentage		
		Original Soil	Marble Powder Waste (MPW)	Optimum Stabilization 7% MPW + 4% PA
1.	Oxygen (O)	37,50	49,695	51,95
2.	Silicon (Si)	32,25	0,00	19,405
3.	Carbon(C)	10,52	11,58	7,14
4.	Aluminum (Al)	13,33	0,00	13,94
5.	Ferron (Fe)	5,88	0,00	4,385
6.	Calcium (Ca)	0,31	38,725	1,345
7.	Titanium (Ti)	0,22	0,00	0,00
8.	Phosphorus (P)	0,00	0,00	1,375
9.	Magnesium (Mg)	0,00	0,00	0,415
10.	Potassium (K)	0,00	0,00	0,09
	Total	100	100	100

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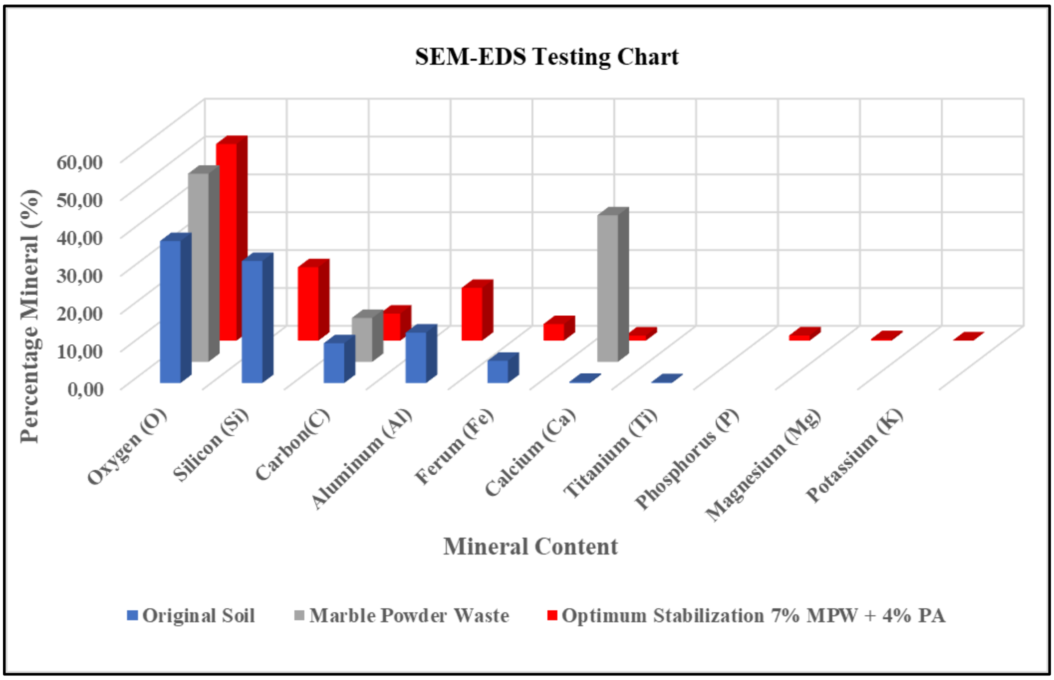

Figure 9. Graphic Sem-Eds Testing On TA, MPW and Optimum Stabilization (TA+MPW7%+ PA4%)

From the results analysis Table 9 and Figure 9 on testing Photo *Scanning Electron Microscopy and Energy Dispersive Spectrometry* (SEM *and* EDS) in both materials, marble powder waste and phosphoric acid, it shows that the most dominant element is oxygen because oxygen can affect the adhesion of clay particles in the soil. When oxygen is available in sufficient quantities, the surface of the clay particles can oxidize. Meanwhile, the element silica (Si) and the element aluminum (Al), based on [22] these results show that marble powder waste can fulfill the requirements to be used as a material that can form a pozzolan reaction, namely when calcium hydroxide ($Ca(OH)2$) in the soil reacts with silica compounds (Si) and aluminum compounds (Al) found in marble powder waste to form a binding reaction, namely calcium silicate or aluminate silicate (C-S-H) while phosphoric acid based on [23] it will react with cations from soil minerals and form inorganic compounds with Ca, Fe, Al and F so as to produce a layer that is hard and difficult to dissolve in water. So, the conclusion is that marble powder waste and phosphoric acid are very binding with clay (dense) soil so that the soil layer is hard so water is difficult to dissolve in it.

Discussion

In Table XI below This is recapitulation soil original and soil repair with a mix of MPW and PA on variation 4 uses the AASTHO method and the USCS method.

TABLE XI. RECAPITULATION RESULTS AASTHO AND USCS METHODS.

	Parameter	Original Soil	Soil Stabilization
Atterberg Limit	F	77,13	0
	LL	77,92	33,47
	PL	23,72	17,44
	PI	54,2	16,03
	GI	43,875	-6,762
Classification Method	AASTHO	A - 7 - 6	A - 2 - 6
	USCS	CH or OH	CL or OL
	Material Type	Clay Soil	Clay and Sand
	Evaluation	Moderate to bad	Very good to bad

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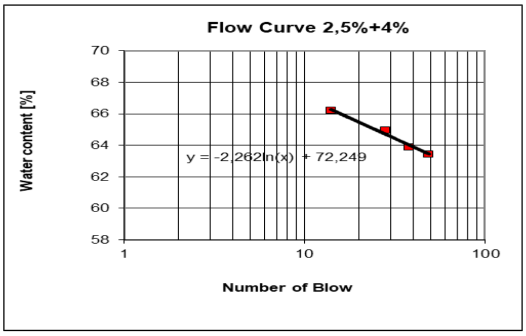
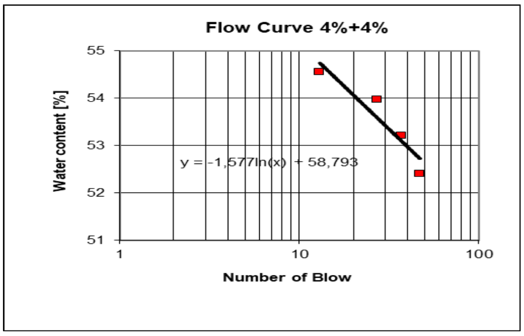
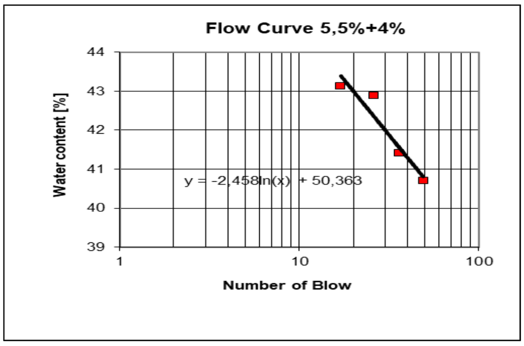
In Figure 7 (a), (b), (c) and (d) shows *Atterberg limit* test chart seen from amount beats (x) than percentage water content (y) for all variation mix.



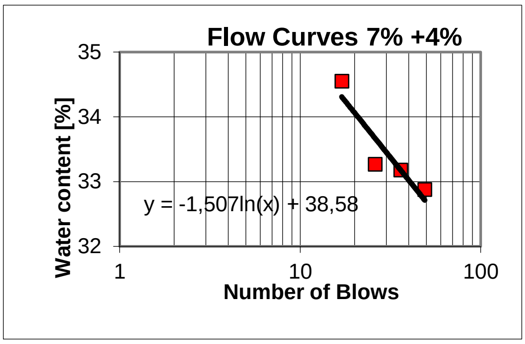
a. Variation 1



b. Variation 2



c. Variation 3



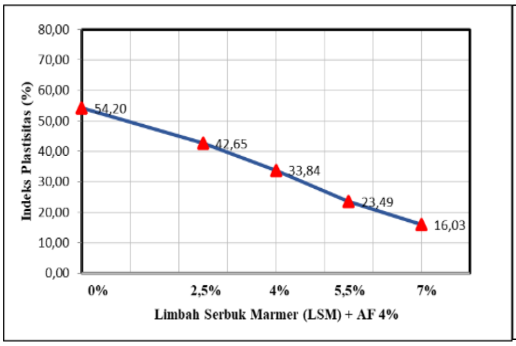
d. Variation 4

Figure 7 (a), (b), (c) and (d) Amounts knock compared with water content

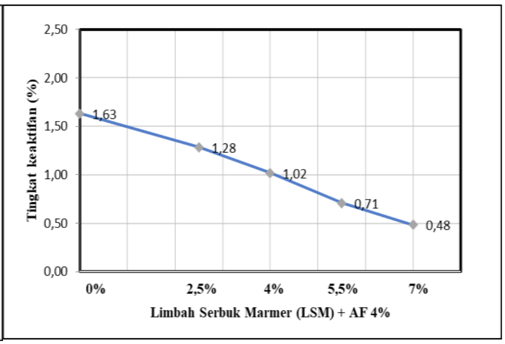
Table XII and Figure 8 show results Atterberg limit and level testers activity soil (AC) which was before stabilized and after done stabilization on all variation.

TABLE XII. ATTERBERG LIMITS AND ACTIVITY (AC) TEST RESULTS

Mixed Type			Atterberg Limits				Activity level (Ac)
Clay soil Expansive	MPW (%)	PA (%)	(LL)	(PL)	(LS)	Index Plasticity (PI)	
100%	0	4	77,92	23,72	5.04	54,20	1.63
100%	2,5		64,62	21.97	5,16	42.65	1.28
100%	4		53,54	19.70	5,64	33,84	1.02
100%	5,5		42.03	18.54	5,68	23,49	0.71
100%	7		33,47	17,44	5.99	16.03	0.48



(a)



(b)

Figure 8. (a) Percentage Index Plasticity and (b) Percentage of Soil Activity Level

In Table XII and figure 8 can show that testing soil original before do stabilization with PI = 54.20% based theory table 1 incl soil very high development, after done mixture with both materials

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on the Original Soil + MPW 7% + PA4% decreased PI values up to 16.03% and incl soil development medium.

CONCLUSION

From this research it can be concluded that the results of physical properties testing and SEM and EDS tests on the addition of marble powder waste and phosphoric acid to Gedebage soil are as follows:

From the results of the tests that have been carried out, Gedebage soil has a Plasticity Index value of 54.20% with an LL value of 77.92% and a PL of 23.72%. The level of soil activity (AC) of 1.63% is obtained from the percentage of soil particles that pass the 0.002 mm (no. 200) (F) sieve divided by the value of the plasticity index (PI). In accordance with Hardiyatmo, 2002 it was concluded that Gedebage soil is an expansive clay soil that has high expansion potential, high plasticity and cohesion, including active soil. Based on the index value, this soil group is included in the very poor alkaline soil class with the AASHTO classification method including A-7-6 and the classification method according to the USCS category on High Plasticity Clay (CH or OH). From these results it is stabilized with MPW 2.5%, 4%, 5.5%, 7% while PA is 4% so that the optimum value is at 7% MPW + 4% PA with a Plasticity Index (PI) of 16.03%, activity level (Ac) 0 .48, the AASHTO classification includes A-2-6 and the USCS classification includes CL or OL. Meanwhile, elements of silica (Si) and elements of aluminum (Al), based on [22] these results indicate that marble powder waste can meet the requirements for use as a material that can form a pozzolanic reaction, namely when calcium hydroxide (Ca(OH)2) is present in the soil. reacts with silica (Si) and aluminum (Al) compounds found in marble powder waste to form a binding reaction, namely calcium silicate or aluminate silicate (C-S-H) while phosphoric acid based on [23] will react with cations from soil minerals and form inorganic compounds. with Ca, Fe, Al and F to produce a layer that is hard and difficult to dissolve in water. So, in conclusion marble powder waste and phosphoric acid are strongly bound to clay (solid) soil so that the soil layer is hard so that it is difficult for water to dissolve in it.

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