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by Rama Kusuma

INFLUENCE OF MARBLE POWDER WASTE ON THE STABILISATION OF CLAY

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***Abstract*— Soil is the basic material of construction, be it building construction or road construction which often causes problems if it has poor characteristics. Problem soil characteristics and less favourable when used as the basis of construction include high plasticity, low shear strength, large volume changes, and large potential for shrinkage. Various methods are to improve the strength of the soil, including stabilisation using added materials.**

This study aims to determine the soil classification based on the USCS classification system and determine the value of the free compressive strength of the addition of marble powder waste with the optimum water content of each mixture. Soil samples were taken from Jalan Masjid Priyayi Village, Kasemen District, Serang City. Variations of marble powder waste were 0%, 7%, 17%, and 27%, with a curing time of 0 days, 7 days, 14 days, and 28 days. The soil tests carried out include sieve analysis, soil density, moisture content, atterberg limit, soil compaction, and unconfined compressive strength tests.

From the study results, it was found that the soil classification was included in the OH type according to the USCS classification system, namely organic clay with high plasticity. The highest Unconfined Compressive Strength (UCS) value obtained from the addition of marble powder waste was at a level of 7% with 28 days of curing, which was 3,427 kg/cm².

***Keywords*— stabilisation; UCS; marble powder waste.**

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I. INTRODUCTION

The subgrade, which has the properties of clay-type soil, has swelling and shrinking behavior according to changes in water content. If the clay dries, it will shrink, and a crack occurs; the soil will swell if the clay is exposed to rainwater.[1]. This condition causes instability in pavement construction, resulting in cracked and bumpy road construction [2]. In 2020 around 21.5% of Road Construction conditions in the Banten area are not good.[3].

Masjid Priyayi Village Road, Kasemen District, Serang City, is right beside the river and has potholes, as shown in Fig 1. We can see the research location on Google Map with coordinates 6°04'56.4"S 106°11'26.4"E as on Fig 2.

Fig.1 Masjid Priyayi road conditions.

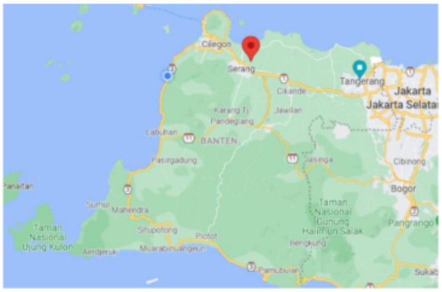

Fig.2 Masjid Priyayi road Location at 6°04'56.4"S 106°11'26.4"E

The results of the Dynamic Cone Penetrometer (DCP) test at that location showed an average CBR value of 1.967%, which did not meet the requirements for the CBR value for road pavement, which was at least 5%.[4] Therefore it is necessary to strive for soil improvement, and all actions to change the original properties of the soil to be adapted to construction needs are soil stabilisation efforts. There are soil stabilisation methods, namely chemical stabilisation, mechanical stabilisation.[5]. For chemical methods, one of them uses lime as an alternative material that is often used for soil stabilisation [6] and carbide waste [7].

Indonesia in 2019 had a total of 1,252,830 m3 of excavated materials in the form of marble.[8]. Processing of the marble excavated material and producing finished products also produces waste, one of which is marble powder, which contains CaO or lime compounds with 53.59%.[9]. The reuse of powdered waste is one of the efforts to preserve the environment in Indonesia

The soil stabilisation method using waste has previously been carried out using steel slag [10] using variations of 0%, 5%, 10%, 15%, 20%, curing time 0, 3, 14, 28 days, then by setyono [11] with marble powder waste added, the variation is 0, 5, 10, 15, 20, 25%. Furthermore, Mary Rebekah [12] added marble dust waste material, variations of 3, 6, 9, 12, 15 %, curing time 3, 7, 14 days. Based on several research conditions, the Priyayi Mosque village road in Serang City uses marble powder with variations of 0%, 7%, 17%, and 27%, with curing times of (0,7,14,21,28) days following the concrete age pattern.

Soil is a layer between subsoil and bedrock that has soft mineral deposits. There are several types of soil, including soil that is glued together by material so that it has hard properties similar to a hard rock called rock. While soil is very easy to take, it is excavated by hand and simple equipment. [13]. Soil is formed due to changes in weather, vegetation over a long time, and terrain conditions. It takes knowledge of the original properties of the soil, grain size, colour, texture, and consistency of the soil in question to be able to describe the soil. The soil is briefly divided into two parts based on the mechanical analysis results: coarse-grained and fine-grained. Terzaghi, [14]. Soil can be defined as weathered organic material elements and solid material elements that are separated from one another accompanied by empty space filled with liquid and gas above.

Soil is defined as a material consisting of aggregates (granules) of solid minerals that are not bound to each other (chemically bonded) and of weathered organic matter (which is solid particles) accompanied by liquids and gases that fill spaces. Empty between the particles above it.[15].

B. Clay Soil

Clay mostly consists of microscopic and sub-microscopic particles in the form of flat plates.[15]. Clay soils are characterised by very low permeability plasticity with a very wide range of water content, which are composed of very small particle aggregates that cannot be seen with the naked eye, which originate from the chemical decomposition of rock elements, are fine-grained, harden in a dry state and are hardened in dry conditions. Soft when wet.[14]

C. Soil Classification

Soil classification is a way to determine the soil type so that soil properties are obtained.[16]. Generally, soil classification is based on particle size obtained from sieve analysis (and sedimentation tests) and plasticity. The Unified Soil Classification System and AASHTO (American Association of State Highway and Transportation Officials) are often used.

D. Soil Stabilization

Soil stabilization is the process of increasing the cohesion, the frictional force between soil grains and thereby increasing the soil's ability to resist force loads or withstand construction loads on it.[17]. According to Bowles, [18] also stated that If the soil in the soft field is easy to shape, has an inappropriate Atterberg limit value, and other soil properties that are not suitable for the construction work, then the soil must be stabilised.In principle, soil stabilisation is an effort to improve poor soil quality. Bowles states how to carry out stabilisation can consist of one of the following actions:

1) Compactable soil
2) Adding certain materials for cohesion or soil shear resistance
3) adding materials to the soil that can cause chemical and physical changes to the soil.
4) Lowering the groundwater level
5) Replacing bad soils.

E Marble Powder Waste (MPW)

Marble waste is waste from the marble stone industry, produced from the sawing or carving process shaped by hand so that the fragments are gravel. Some are in the form of sand. According to Setyono. [11]. The research results of PT. Sucofindo Jakarta (Table 1) states that the composition of marble waste is:

TABLE 1
MARBLE POWDER WASTE(MPW) CONTENT ELEMENT

No.	Compound	MPW (%)
1	CaO	52,69
2	CaCO3	41,92
3	MgO	0,84
4	MgCO3	1,76
5	SiO2	1,62
6	A12O3 + Fe2O3	0,37

F. Unconfined Compressive Stength Test (UCS)

The unconfined compressive strength is the stress concentrated on the test object that collapses or when the strain reaches 15%. [19].

The UCS method is used as a reference in research to obtain the value of the unconfined compressive strength of soils containing clay or silt. The purpose of the UCS test is to determine the strength of the soil in receiving a given compressive force until the soil is separated from the grain and measure the soil strain caused by the compressive force.

An unconfined compressive strength test was carried out on the original soil sample and the stabilised soil sample of marble waste and then measured its strength against the value of the Unconfined compressive strength to determine the strength of the sample as shown in table 2.[12]

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TABLE 2
CONSISTENCY OF CLAY IN TERMS OF UNCONFINED COMPRESSIVE STRENGTH

Consistency	q_u (kPa)
Very Soft	Less than 25
Soft	25 – 50
Medium	50 – 100
Stiff	100 – 200
Very Stiff	200 – 400
Hard	Over 400

II. *MATERIAL AND METHOD*

This study obtained soil samples from Masjid Priyayi road, Kasemen District, Serang City. Soil samples taken were a soil that was on the side of the road, namely between the road and the river. In taking soil in the field, first, dig the soil to a depth of approximately 5-10 cm from the ground surface. Then after being dug up, the soil is taken, which is then put into a container which in this study used a sack that had been prepared. The samples that have been put in sacks are then taken to the Civil Engineering Laboratory of Untirta, Cilegon.Marble powder waste (Figure 3) was collected at PT Jaya Abadi Granitama (Figure 4) located in Cikande, Serang Regency, Banten Province.

Fig.3 Marble Powder Waste

Fig.4 Marble Factory.

The soil that had been taken from Jalan Masjid Priyayi Village was then tested in the form of a physical soil test. This study included an analysis of the grain size (SNI 3423-2008).[20], water content (SNI 1965-2008).[21].,Unit Weight, soil density, plastic limit (SNI 1966-2008).[22]., and liquid limit (SNI 1967-2008).[23]. Testing the physical properties of the soil is to determine the physical properties of the soil that will be needed to classify the soil using the USCS classification system.

After physical testing of the soil, proceed with compaction testing using a standard proctor test. In addition to testing the original soil, they also tested the compaction of the soil. Each variation of the mixture was 0%, 7%, 17%, and 27% marble powder based on the dry weight of the soil. The aim is to obtain the maximum dry density of the soil and the optimum moisture content in the original and mixed soils. The soil used in the compaction test was air-dried for several days and marble powder with 0%, 7%, 17%, and 27% variations.

It was making a UCS test sample with a sample size of 30 mm diameter and 72 mm height made from each variation of soil compaction. After the soil sample was made, it was put into a tightly closed plastic bag to be curing period according to the specified time, namely 0 days, 7 days, 14 days, and 28 days for UCS testing.

An unconfined compressive strength test was obtained from the soil compaction test, which was sampled—then removed with a jack or something like that. Check Unconfined compressive strength by controlling the strain.

After conducting data analysis and calculations are complete, then conclusions can be drawn from this research.

III. RESULTS AND DISCUSSION

A. *Soil Physical Test Results*

Soil physical testing in this study included analysis of grain size, plastic limit, specific gravity, soil density, and liquid limit. Soil physical testing is carried out to determine the physical properties of the soil that will be needed as data for the classification of the research soil. All soil physical testing was carried out at the Civil Engineering Laboratory of Untirta.

1) *Analysis of Grain Size*

The soil grain size analysis results on Jalan Masjid Priyayi Village, Kasemen District, Serang City are included in the category of fine-grained soil because the soil that passes the filter No. 200 is more than 50%, according to the USCS soil classification system. According to the USCS soil classification, the resulting data shows that Jalan Masjid Priyayi Village, Kasemen District, Serang City is a fine-grained soil with a percentage of pass through the No. sieve. 200 reached 52.2%.

2) *Soil Water Content (w)*

Testing the soil water content (*w*)on Jalan Masjid Priyayi Village, Kasemen District, Serang City are 42.04%.

3) *Soil Unit Weight* (γ)

The value of soil unit weight (γ) on the Priyayi mosque road soil is 1,978 gr/cm^3.

4) *Specific Gravity* (G_s)

The soil-specific gravity test has been carried out according to the soil mixture with each variation of marble powder waste. The results of the test are in table 3.

TABLE 3
Specific Gravity (G_s) in Each Mix

MPW %	Gs
0%	2,65
7%	2,622
17%	2,605
27%	2,581

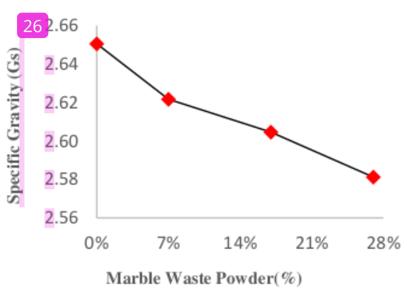

Fig 5. Graph of Specific Gravity Value for Each Mixture

Based on the graph results in Figure 5 from the tests carried out, the soil is included in organic clay. The decrease in the value of soil-specific gravity (Gs) was due to a change in the volume of clay grains which became larger due to the clotting reaction. Solid grain volume weight (γ_s) is the ratio between dry soil weight (Ws) and soil grain volume (V_s); if the value of (W_s) remains, the value of (V_s). Increases, then the value of s will decrease. While (Gs) is the ratio between the weight of the volume of solid grains (γ_s) and the weight of the volume of water (γ_w), if the value of s decreases while the value of w remains, then the value of Gs will also decrease.[24].

5) *Liquid limit (LL)*

Based on the data obtained in table 4, soil mixture with each variation of marble powder waste, it can be seen that the liquid limit value decreases as the marble powder waste content increases. The liquid limit value is used to find the plasticity index value for soil classification.

TABEL 4
LIQUID LIMIT VALUE ON EACH MIXTURE

MPW %	**Liquid limit (%)**
0%	62
7%	56
17%	50
27%	48

6) *Plastic Limit (PL)*

Based on the data obtained, it can be seen in table 5 that the plastic limit value increases with the increase in the content of marble powder waste as a soil mixture. The plastic limit value is used to find the plasticity index value used for soil classification.

TABLE 5
PLASTIC LIMIT VALUE ON EVERY MIXTURE

MPW %	**Plastic limit** (%)
0%	32,76
7%	35,09
17%	36,39
27%	37,44

7) *Plasticity Index (PI)*

Based on the data obtained in table 6, soil mixture with each variation of marble powder waste , it is known that the plasticity index value has decreased, we can see in Figure 6 as the content of marble powder waste increases, which means that the addition of marble powder waste has a good effect on the soil plasticity index value on Masjid Priyayi Village Road, Kasemen District, Serang City.

TABEL 6
IP VALUES ON EVERY MIX

MPW %	Plasticity Index (PI)
0%	29,24
7%	20,91
17%	13,61
27%	10,56

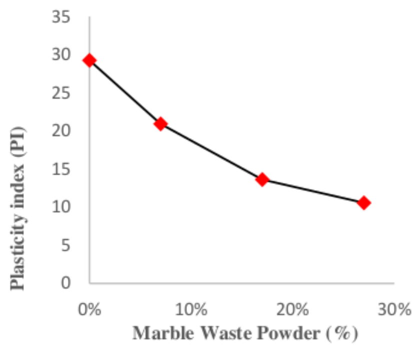

Fig 6. Variation of PI with the percentage of MWP

The addition of marble powder waste is 27% because it has an IP value of 10.56%, and soil with the addition of 17% marble powder waste because it has a value of 13.61%. Besides these requirements, the stabilised soil can be used for subgrade following applicable requirements. The pattern of decreasing the plasticity index value was similar to the study of marble dust on black cotton soil.[25]. The value of the Plasticity Index continues to decrease due to cation exchange which causes flocculation in the clay soil, which reduces the thickness of the clay particle layer.[26].

8) *Soil Classification*

The following table 8 is the result of testing the physical properties of the original soil:

TABLE 8
SOIL PROPERTIES OF SOIL MASJID PRIYAYI VILLAGE ROADS

Property	Value
Grain Size Analysis	52.2%
Water Content (w)	42,04%
Unit Weight (γ)	1,978 gr/cm^3
Specific Gravity (Gs)	2.65
Liquid limit (LL)	62%
Plastic Limit (PL)	32,76%
Plasticity Index (PI)	29,24%
Optimum Moisture Content (w_{opt})	24%
Dry Density γ_{dry}	1,40 gr/cm3

Data from the results of the analysis of plasticity index ,grain size analysis, liquid limit, and plastic limit, were then entered into the USCS soil classification system table. The soil on Jalan Masjid Priyayi Village, Kasemen District, Serang City is classified as OH soil, organic clay with high plasticity.

9) *Soil Compaction*

The compaction test results are obtained from the compaction graph, namely the relationship between dry density and water content, which forms a parabolic curve. The Maximum Dry Density (MDD) $(\gamma_d)_{maks}$ and Optimum Moisture Content (OMC) (w_{opt}) each mixture were obtained, as shown in Table 9.

TABLE 9
SOIL COMPACTION TEST RESULTS FOR EACH VARIATION OF MWP

MPW %	W_{opt} (%)	$(\gamma_d)_{maks}$ (gr/cm^3)
0%	24,0	1,40
7%	25,0	1,36
17%	27,4	1,34
27%	29,0	1,31

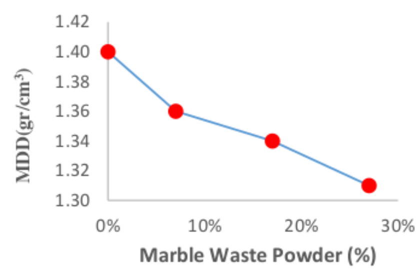

Fig.7. Variation of MDD with the percentage of MWP

In Figure 7 the decrease in the MDD value is due to a change in the total volume of clay which becomes larger due to the clotting reaction so that the number of pores in the soil increases. Density (γd) is the ratio between the dry weight of the soil (Ws) and the total volume of wet soil (Vt); if the value of Ws remains constant while the value of Vt increases, then the value of d will decrease. Therefore, the greater the addition of marble waste, the greater the decrease in the value of MDD.

The effect of adding Marble Powder Waste to the soil is that it can increase the value of the optimum water content and reduce the MDD weight.[27]. This is probably due to the process of mineral exchange between layers.[28]

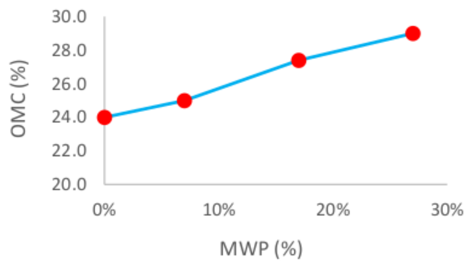

Fig. 8 Variation of w_{opt} with the percentage of MWP

The increase in the value of the optimum water content (w_{opt}) can be seen in Figure 8. When clay is mixed with marble waste and then given water, a segmentation process (binding) will occur, causing clumping, and the water content in the soil will also increase. The water content (w) is the ratio between the weight of water (Ww) and the weight of dry soil (Ws) and multiplied by 100% if the Ww value increases, while the Ws value remains, then the wc value will increase. Therefore, the greater the addition of marble waste, the greater the increase in the value of the OMC.

10) Unconfined Compressive Strength Test (UCS) Results

The unconfined compressive strength test object is a flat surface pressed up by a UCS tool until a collapse occurs or a maximum decrease of 15% of the height of the test object before being pressed. The data obtained from the UCS is then calculated and analysed. The results of the calculation and analysis of the value of q_u in kg/cm^2 with added marble powder waste can be seen in Table 10 of the curing period below:

TABLE 10
RECAPITULATION OF THE VALUE OF QU ON THE ADDITION OF MARBLE POWDER WASTE AND CURING PERIOD

Specimen Name	Unconfined Compressive Strength (kg/cm2)			
	0 day	7 days	14 days	28 days
CS+0% MWP	0,749	1,090	1,273	1,467
CS+7%MWP	2,393	2,727	3,060	3,427
CS+17%MWP	2,100	2,510	2,750	3,026
CS+27%MWP	1,897	2,280	2,453	2,880

Note: CS, clay soil; MWP, marble waste powder.

From Table 10. The unconfined compressive strength increases due to the process of formation of cement compounds (calcium silicate hydrate) which comes from the chemical reaction between calcium carbonate in marble powder waste, water and soil. [29]. the test results show that the addition of marble powder waste affects the compressive strength of the soil. The optimum qu value at the addition of 7% marble powder waste and decreased at the levels of 17% and 27%; this is due to the agglomeration reaction that occurs when it exceeds the optimum level causing the granules to become uniform and their strength to weaken as shown in Figure 9.

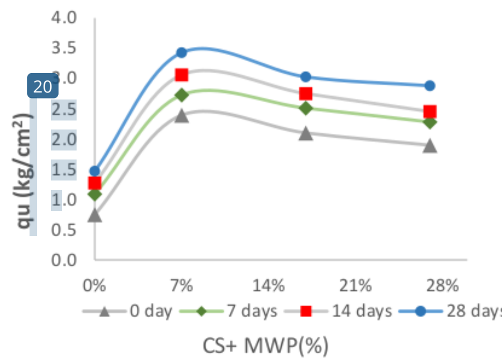

Fig 9. the effect of increasing the MWP mixture on the UCS (q_u) value

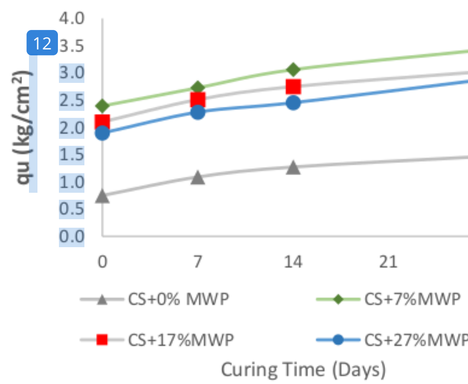

Fig 10. effects of MWP and curing time on unconfined compressive strength of mixtures

From the recapitulation data of the previous qu value, it can be concluded that either the addition of marble powder waste given or the curing time will affect the qu value. The effect is in the form of an increase in the value of qu (soil strength) obtained from the curing time and the addition of marble powder waste. It is proven by the curing time for 28 days, and the addition of 7% marble powder waste produces a qu value of 3,427 kg/ cm^2 (CS+7%MWP). The qu value increased from 0.749 kg/ cm^2 at a percentage of 0%, and a curing time of 0 days can be seen in Figure 10. It can be concluded that the addition of marble powder was optimum at 7% variation and decreased at 17% and 27% variations. However, the decrease in value at 17% and 27% variation was not lower than that of the original soil. The decrease in UCS value was due to insufficient moisture content to maintain the pozzolanic reaction to obtain further strength. [30],[31],[32].

Based on Table 2 shows the qu value of the soil at Masjid Priyayi Village road, Kasemen District, Serang city before mixing marble powder waste of 0.749 kg/cm^2, including medium consistency with a qu value of 0.5 - 1 kg/cm^2 and the qu value increased after mixing 7% marble powder waste. Becomes 3,427 kg/cm^2, which is included in very stiff consistency with a qu value of 2 - 4 kg/cm^2. So it can be concluded that marble powder waste has an effect on the soil stabilisation process because it can increase the value of qu, which was originally entered into medium consistency to very stiff. The effect of using optimum water content in each mixture on the value of free compressive strength is to make the value of qu more objective because the water content used in each mixture is the optimum water content in each mixture.

IV. CONCLUSION

The conclusions from the research and testing carried out for soil stabilisation using marble powder waste on clay on Masjid Priyayi road, Kasemen District, Serang City are has a soil type classified as organic clay OH (USCS standard), which has a plasticity index of 29.24% including soil types with high plasticity.

In the unconfined compressive strength test, the marble powder waste can increase the value of the unconfined compressive strength, which was originally in the original soil condition of 0.749 kg/ cm^2 classified as medium consistency, at a percentage of 7% added material with a curing time of 28 days to 3,427 kg/ cm^2 classified in very stiff consistency which is the optimum qu value, at the percentage of 17% added material with a curing time of 28 days to 3,026 kg/ cm^2 is classified as very stiff consistency, at 27% added material with a curing time of 28 days becomes 2,880 kg/ cm^2 classified as very consistency stiff.

In this study, marble powder waste can affect the physical properties of clay. This is indicated by a decrease in the value of the soil plasticity index in the original soil condition by 29.24%, which includes high plasticity pure clay, at 7% of added materials the plasticity index value to 20.91%, at 17% of added materials the plasticity index value to 13.61%. At 27% of added materials, the plasticity index value became 10.56%, which is the lowest plasticity index and belongs to the silty clay with medium plasticity.

In this study, taking into account the requirements that apply to the subgrade from the qu value and the plasticity index value, what can be used for subgrade improvement is the use of 17% added material where the qu value is 3.026 kg/ cm^2, and the plasticity index is 13.61%. Meet the specified requirements.

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