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STABILIZING PEAT SOILS BY USING MARBLE ASH AND POLYESTER RESIN SOLUTION

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Abstract

This research aims to measure the bearing capacity of peat soil through the stabilization of polyester resin and marble ash.The highway alignment that is made sometimes has to pass through peatland areas, so it is necessary to stabilize the soil so that its carrying capacity meets the requirements. Peat soil is known as soil with very high pore numbers and water content so that the soil's carrying capacity is low (California Bearing Ratio (CBR) < 6%). In this research, peat soil was taken at a depth of ± 1 m in Tanoh Manyang village, Teunom subdistrict, Aceh Jaya district.The stabilizer used is marble ash which comes from marble/limestone cutting waste in the South Aceh Polytechnic Industrial laboratory and a polyester resin solution purchased from a building materials shop as a binder.The tests carried out were on the physical and mechanical properties of peat soil after being mixed with soil stabilization materials based on Indonesian national standards (SNI).The results of the compaction test, the wopt value decreased from the original soil wopt value of 68.0% to 13.0% at a mixture percentage of 30% and the maximum dry bulk density (ɣd) decreased from the original soil ɣd value of 0.68% to 0.66% at a mixture percentage of 5 %.Then increase the mixture percentage from 10% to 30% from the original soil ɣd 0.68% to 1.18%.The research results showed that there was an increase in the CBR value due to the addition of stabilization materials.The CBR value of the original soil without soaking was 1.50% to 4.50% at a mixture percentage of 30% and the CBR value of the original soil soaking was 1.4% to 5.4% at a mixture percentage of 30%. However, the use of marble ash at a percentage of 30% and a 10% polyester resin solution has not been able to improve the CBR. It is recommended to add a percentage of marble ash greater than 30%, so that a CBR of > 6% is obtained.

Keywords: Stabilization, CBR, Peat Soil, No Soaking, Marble.

1. INTRODUCTION

Soil is the most widely used material in the construction, especially roads. However, not all land can be used as road construction material. In this research, the soil used was peat soil. Peat soil is a heterogeneous mixture of organic substances buried in water-saturated conditions, its color ranges from yellow to dark brown, depending on the level of decay. Peat soil has quite high organic content and generally occurs from a mixture of fragments of organic material originating from fossilized plants. Literature studies show that peat soil has accumulated cumulatively since 20,000 years ago [1].

Based on data from the Aceh Agricultural Technology Assessment Center (BPTP Aceh), the area of peat land in Aceh Province currently reaches 150,000 Ha spread across Aceh Jaya, West Aceh, Nagan Raya, South Aceh and Aceh Singkil [2].

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The soil must be hard in accordance with technical requirements, so that the soil needs to be stabilized. Soil stabilization is a method used to change or improve the nature of the subgrade so that it is expected to obtain better quality and fall within the requirements for subgrade use with a minimum CBR value of 6% [3].

The stabilizing agents used in this research are marble ash/waste which is leftover from the processing of marble rock. Utilization of marble ash to reduce acid levels in the soil which can affect road pavement. Currently in South Aceh Regency, the marble industry is being developed, because there is a large amount of marble found in South Aceh Regency, specifically on Mount Kerambil weighing 3,431,000 tonnes which has not been mined. As a result of the development of the marble industry, there is a lot of marble waste in the form of powder from marble cutting that is not utilized. The composition or content contained in marble ash/waste is mostly lime [4][5]. Apart from marble ash as a stabilizing agent, a polyester resin solution was also added as an adhesive, to bond the test materials, namely peat soil and marble ash itself [6].

The sample material is tested for physical and mechanical properties, compaction testing. The level of soil compaction is measured from the dry volume weight of the compacted soil. When water is added to soil that is being compacted, the water will function as a wetting agent (lubricant) for the soil particles. Because of the presence of water, the soil particles will more easily move and slide against each other and form a denser/denser position.

For the same compaction effort, the dry volume weight of the soil will increase if the water content in the soil (when compacted) increases [7]. Meanwhile, CBR testing is an empirical method for assessing soil deformation under loading. The CBR value is calculated at penetrations of 0.1 and 0.2 inches by dividing the load on each penetration by the standard load [8]. The aim of the research is to measure the bearing capacity of peat soil through the stabilization of polyester resin and marble ash. Bearing capacity measurements were carried out using the laboratory CBR test method. The benefit of this research is as reference material for researchers in developing the use of methods to improve soil bearing capacity with the addition of marble ash and polyester resin solutions. Provides additional knowledge for readers and can also reduce waste resulting from marble processing at marble cutting factories.

2. LITERATURE REVIEW

2.1 Soil Stabilization

Soil stabilization is an effort to improve the properties of the original soil, so that soil properties meet the technical requirements for the location of highway pavement work. The stabilization methods that are widely used are mechanical stabilization and chemical stabilization. Mechanical stabilization is to increase the strength of the soil's bearing capacity by improving the structure and mechanical properties of the soil, while chemical stabilization is increasing the strength of the soil's bearing capacity by reducing or eliminating the less favorable technical properties of the soil by mixing the soil with chemicals such as cement, lime and pozzolan [9].

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2.2 Polyester Resin Solution

Resin is a chemical substance that is quite thick, tends to be transparent, does not dissolve in water, is flammable and will harden quickly and some are slow[10]. According to several sources, resin has been used since ancient times, mostly as a varnish coating or adhesive, for example resin resin, incense lump resin as a material for making statues and offerings. As time progressed and organic resins became more difficult to produce, humans began to make synthetics from chemical materials. Nowadays resins are produced in various types and methods according to their uses, such as acrylic, epoxy, melamine and others [11].

2.3 Marble Powder

Marble powder/marble stone waste is the remaining waste produced in the marble stone processing process which is not utilized [12]. Marble or marble is a rock resulting from a metamorphosis or conversion process from limestone which changes the composition and color of the mineral content in the limestone so that it looks more artistic. PT. Sucofindo Jakarta (1995) stated that the composition contained in marble factory waste is lime. The current use of marble powder is to reduce acid levels in the soil which can affect road pavement.

2.4 Peat

Peat soil is the remains of dead plants found in swamps forming black brown mud, undergoing an anaerobic process of decay (decomposition). Peat soil is a heterogeneous mixture of organic substances buried in water-saturated conditions, its color ranges from yellow to dark brown, depending on the level of decay. Peat soil is soil that has quite high organic content and generally occurs from a mixture of fragments of organic material originating from fossilized plants. According to the literature, peat soil has been accumulated cumulatively since 20,000 years ago [1][13][14].

2.5 Soil Mechanical Properties

2.5.1 Soil compaction (Standard Proctor Test)

The level of soil compaction is measured from the dry volume weight of the compacted soil. When water is added to soil that is being compacted; the water will function as a wetting agent (lubricant) for the soil particles. Because of the presence of water, the soil particles will more easily move and slide against each other and form a denser/denser position. For the same compaction effort, the dry volume weight of the soil will increase if the water content in the soil (when compacted) increases [7].

In the proctor test, the soil is compacted in a cylinder with a volume of 1/30 ft3 (9.44 cm3).The diameter of the mold is 4 in (10.16 cm). About 2500 grams of soil was mixed with water with different water contents and then compacted using a tamper with a weight of 5.5 lb (2.5 kg), a fall height of 12 in (30.48 cm). The soil compaction was carried out in 3 layers with 25 impacts per layer. The experiment can be repeated 5 times with different water contents [15].

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Table 1: Specifications for soil density tool provisions.

Description	Standard		
Pound weight	5.5 lb	=	2.5 kg
Hammer fall height	12 inch	=	30.48 cm
Mold diameter	4 inch	=	10.16 cm
Number of collisions	25		Time
Volume	1/3 ft^2	=	9.44 cm^2
Number of layers	3		Layer
Reference: [7]			

The degree of soil density is measured from its dry volume weight; the relationship between dry volume weight (γ_d), wet volume weight (γ_b) and water content (w) is expressed by Figure 1 and equations:

$$\gamma d = \frac{\gamma b}{1 + w} \quad \ldots\ldots\ldots (1)$$

For each experiment, the wet soil volume weight (γ_b) of the soil was compaction can be calculated:

$$\gamma b = \frac{W}{V} \quad \ldots\ldots\ldots (2)$$

where:

W = The weight of the soil compacted in the mold (kg)

V = Mold volume (cm^3)

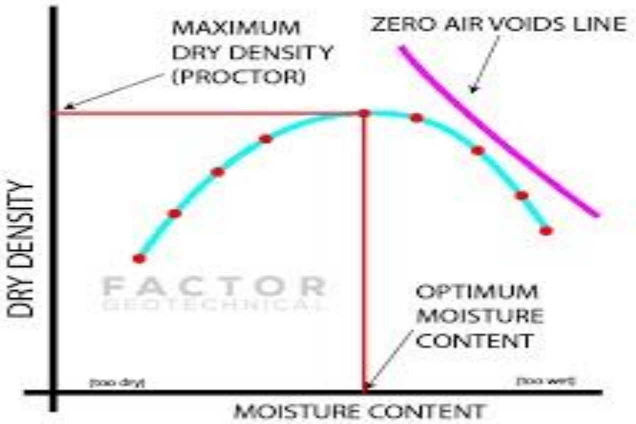

Figure 1: Relationship between water content and unit weight

Reference: [7]

Zero air void curve (zav), void number (e) can be determined using the equation:

$$\gamma dzav = \frac{Gs.\gamma w}{1 + e} \quad \ldots\ldots\ldots (3)$$

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2.5.2 California Bearing Ratio (CBR)

CBR is a soil bearing capacity experiment developed by the California State Highway Department. The principle of this test is penetration testing by inserting a piston into the test object (Figure 2). In this way the strength for making pavement can be assessed.

Figure 2: CBR testing equipment

Next, to calculate the CBR value, the following formula can be used:

$$CBR = \frac{\text{Test Load}}{\text{Standard Load}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

Standard load is the load obtained from testing crushed stone which is considered to have a CBR value of 100% as seen in Figure 3 [16].

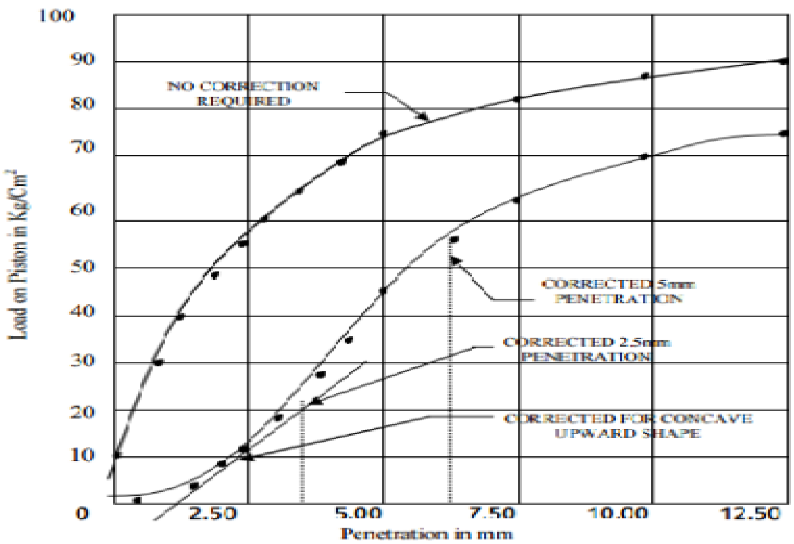

Figure 3: Relationship curve between load and penetration

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3. RESEARCH METHODOLOGY

3.1 Material Procurement

In this section, the tests carried out to measure the test parameters you want to know will be described, see Table 2, while the test materials are explained as follows.

Table 2: Test Sample Matrix (Peat Soil)

Item test	Number of samples	
Indeks properties sample	3	Set
Compactions (Standard proctor test) natural	1	Set
Compactions (Standard proctor test) additive	6	Set
CBR (Soaked)	3	Piece
CBR (Unsoaked)	3	Piece

a) Peat soil

The peat soil used is disturbed soil taken was in Tanoh Manyang village, Teunom subdistrict, Aceh Jaya district. For this test, 30 kg of material/test object is required/ test object.

b) Polyester Resin Solution

The Polyester Resin solution used is a chemical as an additional adhesive. The polyester resin solution is obtained from a building shop (*Depo Bangunan – Medan* city) in the required amount of 10% for each test object sample. The reason for using a polyester resin solution as an additional mixture is to speed up the bonding process between sample particles. The amount of solution used is 10%, which is the limit amount of added materials and reduce the cost of purchasing added materials.

c) Marble Powder

The marble powder used is taken from the remaining processing of the marble rock itself. The collection location is at the South Aceh Polytechnic laboratory, Tapaktuan sub-district, South Aceh district. The additions of marble powder to the mixture were varied as follows: 5%, 10%, 15%, 20%, 25% and 30%. Mixture variations were targeted to measure the optimal percentage for using marble powder.

Here's what happened during testing: soil that has been mixed with additional ingredients, and then left for a day before compacting, it hardens more quickly due to the increasing percentage of added ingredients [7]. When the test object was pounded, the mixed soil looked denser at a percentage of SM 10% + LR 10% and SM 15% + LR 10% up to a percentage of SM 30% + LR 10%. For submerged samples (4 days), then the test object is removed from the immersion place and left for ± 15 minutes.

Visually, it can be seen that there is a lot of water remaining around the test object. However, when testing was carried out using the CBR Test Machine. Holes caused by piston pressure remain relatively small and do not penetrate the surface. After the CBR compression test, the water content is measured.

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4. RESULTS AND DISCUSSION

4.1 Peat soil test results

The results of testing the physical and mechanical properties of the soil are shown in Table 3. Soil classification based on the unified soil classification system (USCS) method obtained soil in the peat group[17]. Original soil parameters such as original soil water content were obtained at 232.5% with a specific gravity value of 1.5 and density of 1.02 gr/cm^3. The Atterberg limit values such as the liquid limit of 266% and the plasticity index of 29.33% indicate that the soil has expansive properties. The dry soil density value was 0.68 gr/cm^3 with an optimum water content of 68%. After carrying out the CBR test, it was obtained at 1.5% for soaked conditions and 1.4 % for unsoaked conditions. The research results shown in Table 3 indicate that the relative stabilization did not meet the CBR requirement of >6%, making it unsuitable for use as embankment material. Further engineering is required, for example, by increasing the polyester resin content to >10%.

Table 3: Test Results for Physical Properties and Mechanical Properties of Peat Soil

No.	Item testing	Unit	Peat	SM 5%	SM 10%	SM 15%	SM 20%	SM 25%	SM 30%
				Resin polyester (10%)					
1	Moisture (w)	%	232.5	-	-	-	-	-	-
2	Density (γb)	gr/cm^3	1.02	1.04	1.07	1.09	1.21	1.30	1.31
3	*Specific Gravity* (Gs)		1.50	1.64	1.86	2.14	2.31	2.44	2.53
4	*Atterberg Limit* :								
	- (LL)	%	266.0	262.0	256.3	250.6	244.0	239.5	233.5
	- (*PL*)	%	236.8	234.2	229.4	225.0	221.1	216.4	213.5
	- (*PI*)	%	29.23	27.83	26.9	25.56	22.86	21.56	20.01
5	Soil clasification	Peat							
6	Proctor standard test :								
	- (W_{opt})	%	68.0	52.0	34.5	24.0	21.9	17.0	13.0
	- (γ_d)	gr/cm^3	0.68	0.70	0.73	0.87	1.03	1.10	1.18
7	CBR test :								
	CBR unsoak	%	1.5	2.3	3.6	4.5	4.7	5.0	5.4
	CBR soak	%	1.4	2.2	2.8	3.7	4.1	4.3	4.5

4.2 Analysis of the effect of added materials on peat soil in the Proctor test

The results of testing the mechanical properties of soil with variations in the mixture of added materials are shown in Table 3. There are two mechanical property tests carried out, namely the standard proctor test and the laboratory CBR test. A graphic depiction of the relationship between optimum water content and dry unit weight is shown in Figure 4.

Proctor test results from peat soil samples plus marble powder (SM) and polyster resin (LR) showed an increase in dry bulk weight of 0.68 gr/cm^3; 0.70 gr/cm^3; 0.73 gr/cm^3; 0.87 gr/cm^3; 1.03 gr/cm^3; 1.10 gr/cm^3; 1.18 gr/cm^3 from each variation of added ingredients. This means that there is a relative effect of increasing the carrying capacity due to the addition of additional materials. In direct proportion there is an increase in dry unit weight, then the optimum water content value decreases very significantly (for example, by adding 30% marble powder, 10%

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resin to peat soil, you get a $w_{optimum}$ of 13%, there is a 55% decrease from the $w_{optimum}$ of the original soil (68%)).

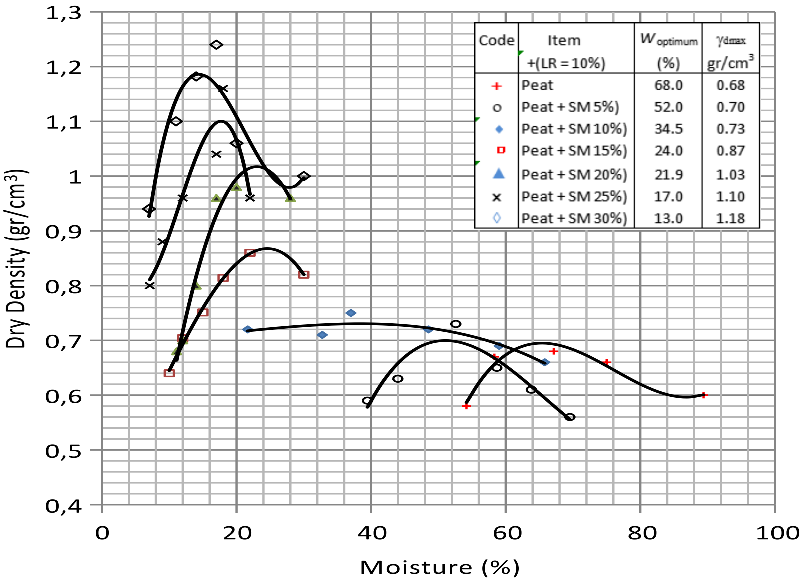

Figure 4: Relationship between moisture and dry unit weight

The decrease in the $w_{optimum}$ value is caused by the soil mixed with marble powder and polyester resin solution, the pore water is more easily squeezed out of the pore cavity during the compaction process when compared to the original soil. This is because the bond between soil particle anions and water cations is blocked by the presence of marble powder and polyester resin solution that covers the soil grains [18]. The squeezing of some of the pore water leaving the pore cavity causes the pores to become smaller because the pore cavity which was previously filled with water, is now filled with soil grains, as a result the soil becomes denser by itself.

4.3 Analysis of the effect of added materials on peat soil in the CBR test

Based on the results of the proctor test on samples with variations in mixing marble powder and polyester resin in peat soil, certain optimal results were obtained (see Table 3). $w_{optimum}$ 68%; 52%; 34.5%; 24%; 21.9%; 17% 13% is used to guide water use in laboratory CBR tests. CBR samples were made in 2 submerged and non-submerged models.

The samples were not submerged after the compaction process based on variations in added materials and the use of optimum weight followed by CBR compression testing. The test results in Table 3 sequentially obtained 1.5%; 2.3%; 3.6%; 4.5%; 4.7%; 5.0% and 5.4%. Meanwhile, for the soaking sample that was soaked for 4 days, the yield was 1.4%; 2.2%; 2.8%; 3.7%; 4.1%; 4.3% and 4.5%.

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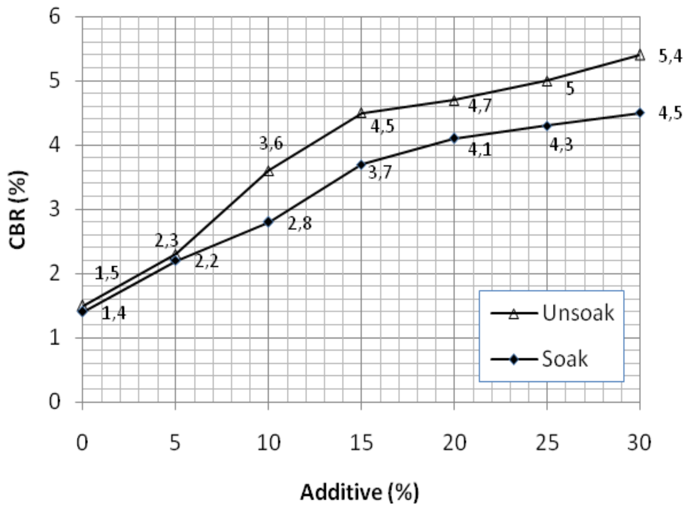

Figure 5: Relationship between added ingredients and CBR value

Figure 5 above shows that there is a change in the pattern of CBR values after mixing with marble powder and polyester resin solution. At a mixture percentage of 0% the unsoaked CBR value is greater (1.5%) than the soaked CBR value (1.4%). At a mixed percentage of SM 5% + LR 10% the unsoaked CBR value increased (2.3%) and the soaked CBR value (2.2%). The most drastic peak pattern change occurred in the mixed percentage of SM 10% + LR 10% and SM 15% + LR 10%, where there was a change in the CBRsoaked value from 2.8% to 3.7%. This change is caused by the mixture of polyester resin solution which causes the soil to harden more quickly and the influence of the reaction of the pozzolanic material which combines with the peat soil [19]. It can be concluded that the use of polyester resin (10%) mixed with a variety of marble powder in peat soil can increase the bearing capacity of the soil. However, use for road layers or embankments is not suitable because the CBR value is <6%.

5. CONCLUSION

1) The addition of marble powder and polyester resin to peat soil in certain variations resulted in an increase in physical property parameters. The bulk density value increased from 0.9% to 1.22, the Gs value from 1.5 to 2.53, the PI value from 29.23% decreased to 20.01%, the results indicate that the addition of pozzolanic additives reduced the soil's plasticity, making it stiffer.

2) The Proctor test results indicated that the addition of marble powder and polyester resin increased the maximum dry density from 0.68 g/cm³ to 1.18 g/cm³, reflecting improved soil compaction due to the filler effect of marble powder and the binding properties of polyester resin.

3) The laboratory CBR values increased under both soaked (1.4%–4.5%) and unsoaked (1.5%–5.4%) conditions. However, the addition of 30% marble powder and 10% polyester resin

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was insufficient to increase the soil bearing capacity to the minimum CBR requirement (>6%) for use as a subgrade material. Therefore, further research is required to achieve higher CBR values.

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