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THE EFFECT OF MIXING SEQUENCE ON UNCONFINED COMPRESSION STRENGTH OF CLAYSTONE-BENTONITE MIXTURES ON HIGH DENSITY

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ABSTRACT

Claystone is generally considered a material that has poor properties. This is because the shear strength is very low when interacting with water. However, it turns out that claystone can be used as a basic ingredient for making clay liners. In addition to permeability, claystone is mixed with bentonite to increase its cohesion. However, because both samples contain clay, each sample will absorb water and affect the shear strength. The purpose of this study was to analyze the effect of the steps of adding water on the shear strength of a mixture of claystone and bentonite compacted with different levels of bentonite at high density.

There are four combinations of claystone mixtures with different bentonite percentages namely 5, 10, 15 and 20% based on dry weight with a density above the Proctor standard (i.e. density of 1.8 gr/cm3). In mixing soil samples with water, the steps taken are (1) (claystone+water)+bentonite, and (2) (bentonite+water)+claystone. The mixture was compacted statically to form a test object with a diameter of 4.7 cm and a height of 9.45 cm. The sample was then tested for shear strength with the undrained compressive strength (UCT) test. The results were compared with other previously reported mixing methods (claystone+bentonite)+water.

From the analysis it was found that the shear strength of the samples prepared from all mixed methods at a density of 1.8 gr/cm3 met the requirements as a clay liner. The test results also show that the sample compacted by the (claystone+water)+bentonite method produces the highest shear strength. Considering these results, it is suggested that the sample mixing method is by stages (claystone+water)+bentonite.

Keywords: Bentonite, Claystone, Clay Liner, Compressive Strength, UCT

1. INTRODUCTION

Clay soil has a grain size of less than 0.005 mm, low permeability, high capillary water rise, highly cohesive, high shrinkage expansion, low shear strength, and slow consolidation. When this soil is sedimented and under pressure for a long time, claystone is formed. This layer is not preferred if found in construction activities because it is easy to lose strength when interacting with water. The existence of bentonite is very abundant in Indonesia, including scattered on the island of Java, Sumatra, Kalimantan, and Sulawesi (Puslitbang Tekmira, 2005).

Romadhon (2021) stated that the sample compacted by the (claystone+water)+bentonite method produced the highest shear strength value. Considering these results, it is recommended that the sample mixing method is in stages (claystone+water)+bentonite. However, the test was carried out at a density of 1.6 t/m3 (i.e. the standard density of Proctor). In some cases, higher densities are required so it is desirable to know whether the higher densities are also affected by the mixing order.

The purpose of this study was to determine and understand the effect of the order of adding water to a mixture of bentonite and claystone with a different mixing order at a density higher than the Proctor standard, to analyze the value of undrained compressive strength (qu) and cohesion for a mixture of claystone and bentonite and to determine the percentage of the mixture. Claystone and bentonite which can be qualified with different densities.

The limitation of the problem within this research is that the source of the claystone soil was taken from the Cempaka area. The test carried out is the Unconfined Compression Test (UCT) and the water used to make the sample is tap water from the laboratory. And this research was conducted at the Soil Mechanics Laboratory, Faculty of Engineering, Lambung Mangkurat University.

2. THEORITICAL STUDY

Clay Stone

Clay soils are generally poor subgrades, this is because the shear strength is very low so that the construction on this layer of soil always faces several problems such as low bearing capacity and large shrinkage properties.

Bentonite

Bentonite is a natural clay with a fine and soft powder texture. This soil will form a paste when mixed with water. Bentonite is a dioctahedral smectite clay mineral that contains about 80% montmorillonite.

Clay Liner

A good landfill usually requires a clay liner in order to reduce the mobility of leachate into the groundwater. So that usually TPA has a base coating (liner) which serves to protect groundwater from leachate contamination. The basecoat is made before the landfill is used as a landfill, generally low-permeability materials are used as the basecoat for the landfill.

Unconfined Compression Test

The testing of the sample is undrained, because the pressing is done quickly by the UCT machine, then no water comes out of the soil pores during the testing. This UCT test is a test to measure how strong the soil receives a given compressive force until the soil is separated from its grains.

Laboratory Testing

Broadly speaking, soil properties are divided into two, namely physical properties (index properties) and mechanical properties (engineering properties). Testing of the physical properties of the soil includes testing of water content, soil density, specific gravity, sieve analysis, hydrometer analysis and the limits of soil consistency. Meanwhile, the mechanical properties of the soil include the Unconfined Compression Test (UCT).

3. METHOD

The method used in this research is a laboratory testing based method. This research was conducted at the Soil Mechanics Laboratory, Faculty of Engineering, Lambung Mangkurat University. The presentation of the research results is presented descriptively and the data analysis method is carried out based on laboratory testing standards. The flow chart of this research is as follows:

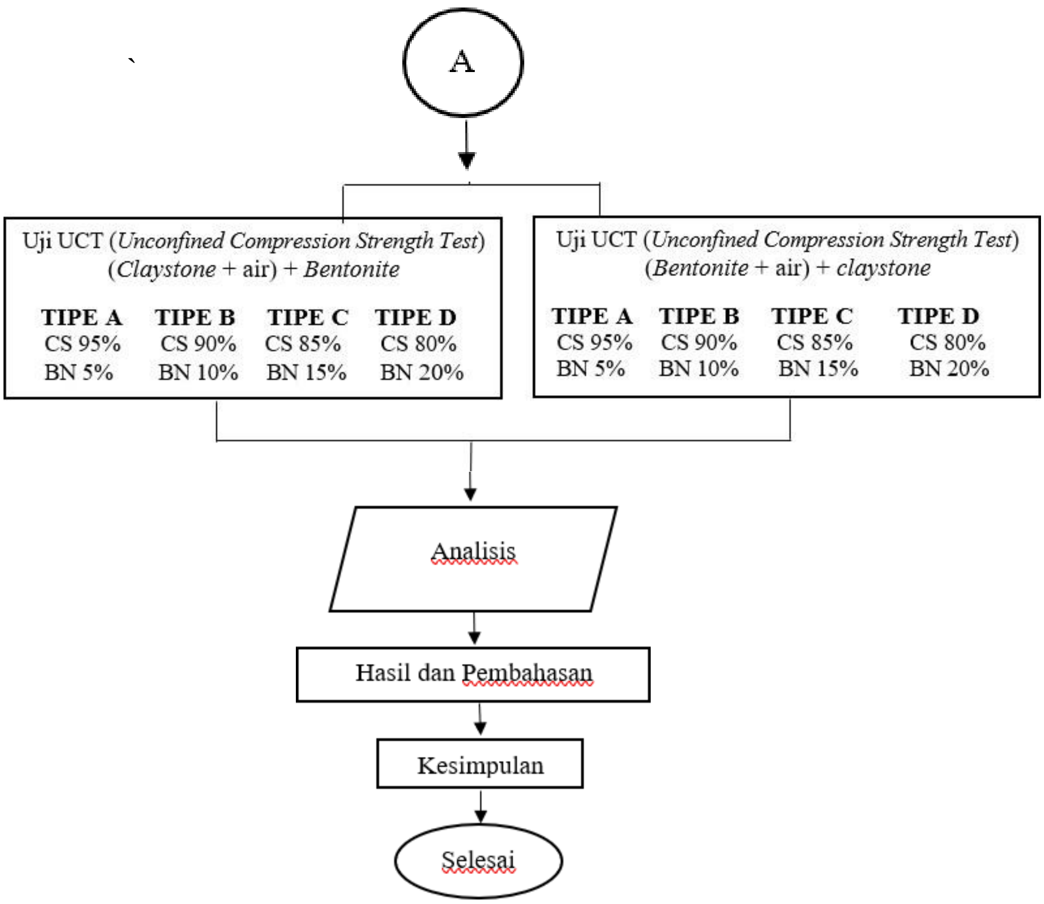

Figure 1. Research Flowchart

4. RESULT AND DISCUSSION

Physical and Mechanical Characters of Claystone and Bentonite

The tests carried out to determine the physical and mechanical characteristics of claystone and bentonite are sieve analysis, hydrometer analysis, liquid limit, plastic limit, water content, specific gravity (Gs), and Unconfined Compression Strength Test (UCT).

Table 1. Shows the results of the physical characteristics of claystone obtained from the water content test, specific gravity, sieve analysis, hydrometer analysis, and Atterberg limits. The plasticity index obtained is 33.73%, this shows that this soil is included in the medium plasticity soil group. According to the USCS classification, the results obtained from the grain gradation and plasticity analysis test, claystone can be classified as CH (clay high plasticity).

Table 1. Value of Claystone Characteristics

Sample No.				Claystone 100%
Natural State	Specific Gravity (Gs)			2,66
	Water content (W)		%	2,39
Grain Distribution	Gravel (> 2 mm)		%	0.00
	Course sand (0.6-2.0 mm)		%	0.02
	Medium sand (0.2-0.6 mm)		%	0.18
	Fine sand (0.05-0.2 mm)		%	10,13
	Silt and Clay (0.002-0.05)		%	40,20
	Clay (<0.002mm)		%	49,47
	Classified Grading Pass	No. 10 (2.00 mm)	%	100
		No. 40 (0.425 mm)	%	99.97
		No. 200 (0.075 mm)	%	96,86
Atterberg Limits	Liquid limit		%	54,59
	Plastic limit		%	20,86
	Plasticity Index		%	33.73
	Classification			CH

The values obtained from the UCT claystone+water test at a density of 1.8 g/cm3 with a moisture content of 10%, 15%, and 20% respectively can be seen in table 2. cu is 12 qu while strain (%) is the sample value. test when maximum stress is reached.

Table 2. UCT Results of sample 100% Claystone

Unconfined Compression Test				
No.	Sampel Cs 100% Bn 0%	q_u (kg/cm²)	c_u (kg/cm²)	Strain (%)
1	γ_d 1,8 gr/cm³ & Kadar Air 10%	7,994	3,997	8,681
2	γ_d 1,8 gr/cm³ & Kadar Air 15%	7,749	3,875	8,681
3	γ_d 1,8 gr/cm³ & Kadar Air 20%	6,995	3,497	7,813

Figure 2. shows the results of 100% claystone UCT at a density of 1.8 g/cm3 with a moisture content of 10%, 15%, and 20%, respectively. The value of qu obtained continues to decrease with increasing water content. This is because the resulting sample is getting softer and wetter according to the increase in water content.

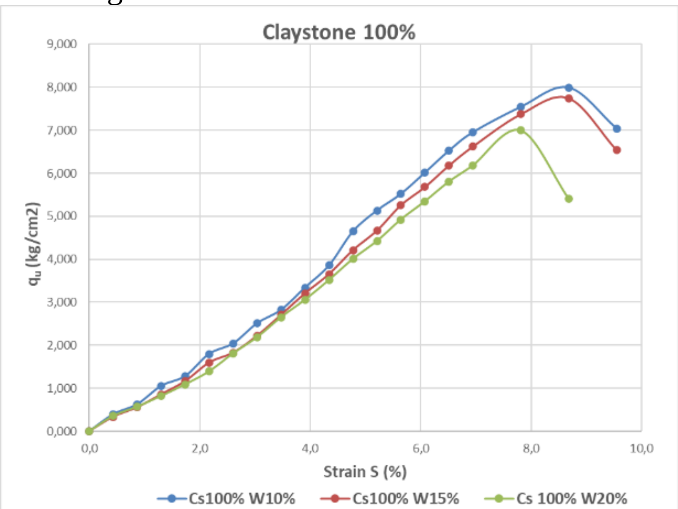

Figure 2. Graph of UCT (Cs+water) density 1.8 gr/cm3

Table 3. Shows the results of the characteristic values of bentonite obtained from the water content test, specific gravity, sieve analysis, hydrometer analysis, and Atterberg limits. The plasticity index value obtained is 380.65%, which shows that bentonite is classified as a very high plasticity soil. Based on the results of the analysis of the grain gradation test, bentonite is classified as CH (clay high plasticity) or inorganic clay with high plasticity.

Table 3. Characteristic Value of Bentonite

Sample No.				Bentonite 100%
Natural State	Specific Gravity (Gs)			2.73
	Water content (W)		%	13.89
Grain Distribution	Gravel (> 2 mm)		%	0.00
	Course sand (0.6-2.0 mm)		%	0.00
	Medium sand (0.2-0.6 mm)		%	0.00
	Fine sand (0.05-0.2 mm)		%	2.88
	Silt and Clay (0.002-0.05)		%	13.46
	Clay (<0.002mm)		%	83.65
	Classified Grading Pass	No. 10 (2.00 mm)	%	100.00
		No. 40 (0.425 mm)	%	100.00
		No. 200 (0.075 mm)	%	100.00
Atterberg Limits	Liquid limit		%	475.34
	Plastic limit		%	94.69
	Plasticity Index		%	380.65

The Effect of Mixed Difference Orders on Unconfined Compression Test Values

Type A mixtures consist of 95% claystone and 5% bentonite. In Figure 3. It can be seen that the value of the shear strength of the sample with a moisture content of 10% 15% has increased, but at a moisture content of 20% it has decreased. This is caused by the addition of repulsive forces that occur on the clay surface and produce a smaller shear strength.

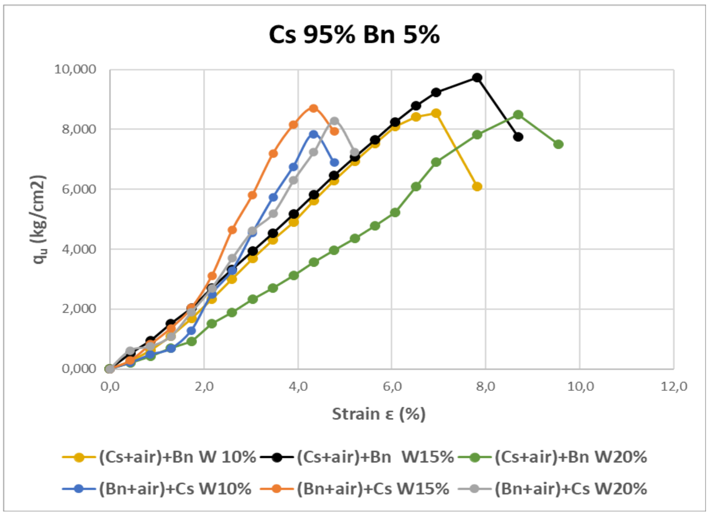

Figure 3. Graph of mixed UCT Type A (Cs 95% and Bn 5%)

Type B mixtures consist of 90% claystone and 10% bentonite. In Figure 4, it can be seen that the shear strength with a moisture content of 10%–15% has increased, but at a water content of 20% it has decreased. In soil compaction, water is needed as a lubricant so that the soil becomes easily compacted and produces higher density and strength. However, when excess water is added, compaction is difficult due to the large repulsion force against the clay surface which results in lower strength.

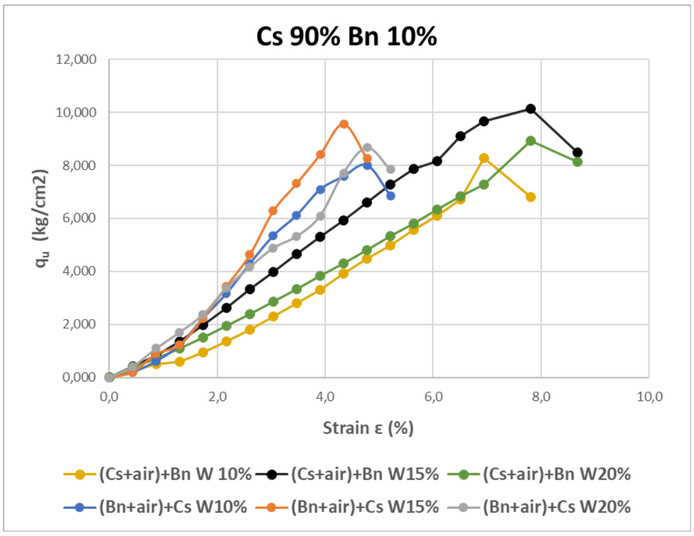

Figure 4. Graph of mixed Type B UCT (Cs 90% and Bn 10%)

The Type C mixture consists of 85% claystone and 15% bentonite. In Figure 5, it can be seen that the value of shear strength with a moisture content of 10%–15% has increased, but at a water content of 20% it has decreased. This result is the same as for other types of samples, which is caused by a decrease in the shear strength of the soil due to an increase in the water content of the sample.

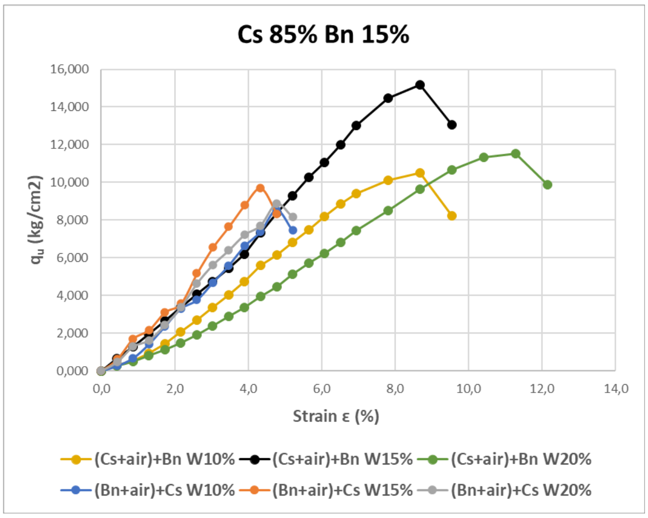

Figure 5. Graph of Type C mixed UCT (Cs 85% and Bn 15%)

The Type D mix consists of 80% claystone and 20% bentonite. In Figure 6, it can be seen that the value of shear strength with a moisture content of 10%–15% has increased, but at a water content of 20% it has decreased. As previously explained, the decrease in the shear strength of the soil due to the increase in water content is due to the increase in the repulsion force against the clay surface. While the moisture content of 15%, is the optimum moisture content of claystone.

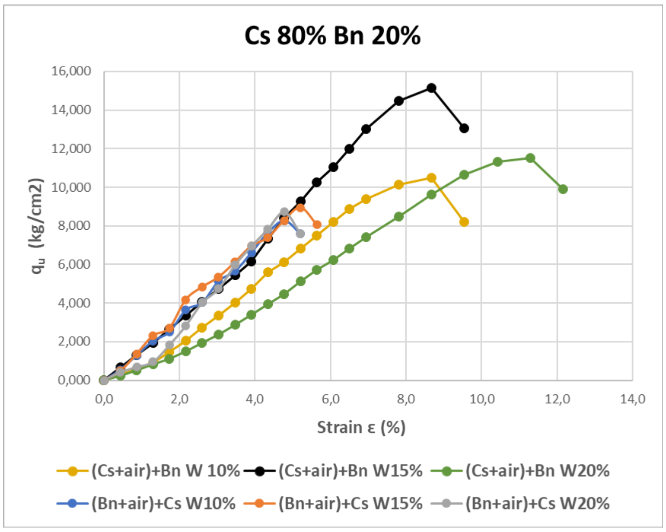

Figure 6. Graph of mixed Type D UCT (Cs 80% and Bn 20%)

Comparison of q_u and c_u values at different moisture content

In this case there are 2 mixing methods with different densities. The first is mixing claystone and bentonite at a density of 1.6 gr/cm3 reported by Romadhon (2021) in a previous study and the second is mixing claystone and bentonite at a density of 1.8 gr/cm3. The implementation of each density is carried out by 2 different methods, namely the method of mixing claystone, which is added with water first and then mixed and added bentonite ((Cs+Air)+Bn) and the second method of mixing bentonite is added with water first then mixed and added claystone ((Bn+Air)+Cs). Below is a comparison of the value of Cu with bentonite content and moisture content of 10%, 15% and 20%.

Table 4. Value of Unconfined Compression Strength

No.	Sampel	Undrained Compressive Strength (C_u) (kPa)			
		Tipe A	Tipe B	Tipe C	Tipe D
		Cs 95%	Cs 90%	Cs 85%	Cs 80%
		Bn 5%	Bn 10%	Bn 15%	Bn 20%
Romadhon, 2021 (*Claystone*+Air)+*bentonite*					
1	γ_d 1,6 gr/cm³ & Kadar Air 10%	50,959	90,190	109,956	154,765
2	γ_d 1,6 gr/cm³ & Kadar Air 15%	78,675	111,355	179,573	167,415
3	γ_d 1,6 gr/cm³ & Kadar Air 20%	65,469	80,434	110,859	113,591
Romadhon, 2021 (*bentonite*+Air)+*Claystone*					
4	γ_d 1,6 gr/cm³ & Kadar Air 10%	43,797	61,613	103,806	94,369
5	γ_d 1,6 gr/cm³ & Kadar Air 15%	59,717	77,382	115,130	105,693
6	γ_d 1,6 gr/cm³ & Kadar Air 20%	47,184	65,764	106,622	96,334
(*Claystone*+Air)+*bentonite*					
7	γ_d 1,8 gr/cm³ & Kadar Air 10%	418,358	405,735	514,960	680,086
8	γ_d 1,8 gr/cm³ & Kadar Air 15%	476,980	496,631	743,241	704,625
9	γ_d 1,8 gr/cm³ & Kadar Air 20%	415,861	437,679	565,602	565,928
(*bentonite*+Air)+*Claystone*					
10	γ_d 1,8 gr/cm³ & Kadar Air 10%	384,814	392,725	418,478	405,602
11	γ_d 1,8 gr/cm³ & Kadar Air 15%	426,853	468,891	475,369	439,001
12	γ_d 1,8 gr/cm³ & Kadar Air 20%	405,602	424,916	434,573	428,135

5. CONCLUSION

From the results and discussion, the following conclusions can be drawn:

1. The results of the effect of the order of differences in the addition of water to claystone and Bentonite samples at a density greater than the standard proctor (density 1.8 gr/cm3) for the value of Undrained Compressive Strength (UCT) with 5% to 15% Bentonite content and 10% moisture content. , 15% and 20%, the results obtained increased, and at 20% Bentonite content the value of Undrained Compressive Strength (UCT) was constant or decreased in strength, except for samples with 20% Bentonite content and 10% moisture content, which increased significantly. These results strengthen the statement of research that has been done previously (density 1.6 g/cm3).
2. The results of the Undrained Compressive Strength (UCT) (cu) at a density of 1.6 gr/cm3 (Romadhon, 2021) with the mixed method (Cs+Water)+Bn, the optimum value obtained at 15% water content with 15% Bentonite content of 179 ,53 kPa. And the mixed method (Bn+Water)+Cs the optimum value obtained at and a moisture content of 15% with a 15% bentonite content of 115.30 kPa. Meanwhile, at a density of 1.8 g/cm3 with the mixed method (Cs+Water)+Bn, the optimum value obtained at 15% water content with 15% Bentonite content was 743,241 kPa. And the mixed method (Bn+Water)+Cs the optimum value obtained at 15% water content with 15% Bentonite content of 475.369 kPa. So that the maximum Cu obtained is the mixing method (Cs+Water)+Bn at a density of 1.8 g/cm with a moisture content of 15% and a Bentonite content of 15%.
3. In this case, the percentage of bentonite addition in all mixed methods at a density higher than the Proctor standard (density 1.8 gr/cm3) has fulfilled the requirements as a landfill clayliner layer.

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