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Unconfined Compressive Strength Of Sedimentary Soil Stabilized With Portland Cement With Varying Curing Time

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Abstract: Soil improvement is commonly carried out in construction work with the aim of increasing the bearing capacity / strength of the soil so that it can carry the construction load that will stand on it. The method that is often used is soil stabilization with the addition of stabilization materials. In this study, soil stabilization was carried out with the addition of Portland Cement. Initially, the process involved gathering soil samples and conducting laboratory tests to assess the soil's physical and mechanical characteristics. Subsequently, the soil samples were prepared to undergo Unconfined Compressive Strength (UCS) testing, employing three different proportions of cement: 5%, 10%, and 20%. The findings indicated that the soil specimen possessed a moisture content of 97.13%, a specific gravity of 2.51, a liquid limit of 33.80%, and a plasticity limit of 22.52%, resulting in a plastic index value of 11.28%. According to the USCS (Unified Soil Classification System) method, the sedimentary soil was classified as CL (Clay-Low), representing clay soils with low plasticity values. Unconfined compressive strength testing on sedimentary soil samples without portland cement obtained a compressive strength. Unconfined compressive strength testing was conducted on sedimentary soil samples in the absence of Portland cement, yielding a compressive strength value of 0.352 kg/cm2. Conversely, when the soil was stabilized with varying proportions of Portland cement, the highest compressive strength value of 14.45 kg/cm2 was observed in the soil sample mixed with 20% cement and subjected to a 28-day curing period. The outcomes demonstrate that the Unconfined compressive strength of sedimentary soil dredged from Bili-Bili Dam, when stabilized with Portland cement, exhibits an inclination towards increased load-bearing capacity and strength as the percentage of cement and curing time are augmented. With this enhanced strength, the soil can be categorized as having a firm consistency suitable for constructing structures and road base soils.

Keywords; **Unconfined stress, sedimentary soil, portland cement**

I. Introduction

The soil as the foundation of a construction must be able to withstand the loads that work on it because the soil is the foundation that receives and holds the loads above it. As a foundation, the soil must have good compressive strength or bearing capacity to support the construction load. Therefore, before construction work is carried out, the bearing capacity/strength must be known in advance. Inadequate soil strength is a problem that is often encountered in the implementation of construction, especially road construction and is the cause of economic losses or can also cause accidents. One of the best ways to solve the problem is to replace the subgrade with a good enough soil. Geotechnical experts try to overcome by changing its physical properties. The improvement of physical properties from poor soil to good soil in the field of civil engineering is called soil stabilization. Soil stabilization can be done by adding certain additives to soil that does not meet the requirements for its use. Some of the mixtures that have been widely used include lime, Portland cement, asphalt, and sand. This research describes the increase in soil strength from the effect of mixing on sedimentary soil from the dredging of Bili-bili Dam.

One of the reasons for the utilization of dredged soil from Bili-bili Dam is considering the occurrence of sediment deposits around the reservoir sluice gate, which

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currently amounts to 40 million cubic meters of mud material deposited in the Bili-bili Dam, while the sediment capacity of this dam is only 29 million cubic meters [1-3]. This can hamper the function of the reservoir itself. The results of dredging in the form of soil material, generally in the form of soft soil, then when disposed of to other locations in large enough quantities and ongoing can result in an impact on the environment without thinking about how to overcome these impacts.

This study aimed to explore an alternative approach to utilize the dredged material from the Bili-bili Dam, not only as a waste management strategy but also as a means to enhance soil stability. The method employed in this research involved incorporating Portland cement into the sedimentary soil, followed by conducting Unconfined compressive strength testing in the laboratory. Through this comprehensive investigation into the potential of the dredged sediment, valuable outcomes were obtained, which can be harnessed to address various economic needs and promote sustainable development. Soil stabilization serves as a precise technique to enhance soil strength, utilizing laboratory testing as a basis [4]. Chemical stabilization, on the other hand, involves the addition of a specialized stabilizing agent (chemical) capable of improving soil mass stability [5].

The existence of soft soil is one of the problems in the field of construction. Soft soil is soil that has a high moisture content and low bearing capacity. Sedimentation is a process of deposition of material transported by water, wind, ice, or glaciers in a basin. Another definition says that sedimentation is the carrying of material resulting from erosion and weathering by water, wind or glaciers to an area which is then deposited. Sedimentary soils have unfavorable characteristics for construction, because the bearing capacity of the soil is low and the decline that can occur is very large due to the load it carries, as well as the relatively high consistency. The unfavorable properties of sedimentary soils are heavily influenced by water. The higher the water content, the lower the soil bearing capacity. Thus, one way to stabilize sedimentary soil is by adding Portland cement to increase its strength so as to reduce the amount of settlement that occurs due to loading.

Soil classification systems are used to classify soils according to the general behavior of the soil under specific physical conditions. Most soil classifications use very simple test indices to derive soil characteristics. These characteristics are used to determine the classification group. Generally, classification is based on particle size obtained from sieve analysis (sedimentation experiments) and plasticity [6].

Unconfined Compressive Strength Testing is a compressive strength test conducted in the Soil Mechanics laboratory. The Unconfined compressive strength test method uses the Indonesian National Standard (SNI). The cohesive soil Unconfined compressive strength test method is a revision of SNI 03-3638-1994. This standard is the result of the adoption of ASTM Designation: D 2166-00, Standard Test Methods for Unconfined Compressive Strength of Cohesive Soil.

The Unconfined compressive strength test apparatus may be a plate-like apparatus with a weighing scale (a platform weighing scale) equipped with a screw-jack-activated load yoke, hydraulic jacking device, or other loading system with a capacity suitable for its purpose, among others, to regulate the loading speed. For soils with a Unconfined compressive strength of less than 100 kN/m2 (100 kPa), the Unconfined compressive strength test apparatus shall be capable of measuring the pressure for every 1 kN/m2 (1 kPa) increase. For soils with a Unconfined compressive strength of 100 kN/m2 (100 kPa) or more, the Unconfined compressive strength tester shall be capable of measuring the pressure for every 5 kN/m2 (5 kPa) increase. The extruder shall have the ability to extrude the soil sample from the tube without causing significant disturbance, i.e. the speed is fixed and the direction is adjusted to the direction in which the soil sample enters the tube at the time of collection in the field. The deformation measuring instrument shall be a measuring watch with a reading scale of 0.03 mm (0.001 inch) or smaller, and has a measuring capacity of at least 20% of the height of the test specimen, or other measuring instruments that meet the requirements, such as electric measuring instruments. A dimensional measuring device in the form of a vernier caliper (sigmat), or other suitable device, to measure the physical dimensions of the test specimen with a reading accuracy of 0.1%. A second-scale measuring device for the duration of the test must be used to adjust the specified strain rate. The scales used to weigh the test specimens should be able to determine the mass of the test specimens with a reading accuracy of 0.1% of their total mass [7].

Calculate the axial strain (ε_1), to the nearest 0.1%, corresponding to the applied load, as follows:

$$\varepsilon_1 = \frac{\Delta h}{H_0} x\, 100 \quad \text{.......... (1)}$$

Description:

ε_1 = is the axial strain, expressed in %
ΔH = is the change in the height of the test object according to the reading on the deformation measuring watch, expressed in mm.
H_0 = is the original test specimen height, expressed in mm

Calculate the compressive stress (σc), to the nearest 1 kN/m^2 (1 kPa), according to the applied load, as follows:

$$\sigma_c = \frac{P}{A_c} \quad \text{.......... (2)}$$

Description:

σ_c = Compressive stress, expressed in kN/m^2
P = The applied load, expressed in kN
A_c = Average cross-sectional area or corrected area according to the applied load, expressed in m^2

II. Research Methodology

This research was conducted in the Soil Mechanics Laboratory and carried out within 2 months. The first stage, sediment sampling / soft soil dredging around the Bili-bili Dam Intake. In the second stage, testing the basic characteristics of soft soil; Moisture Content Testing; Specific gravity (Gs); Weight Content; Atterberg limits (liquid limit and plastic limit); and Sieve Analysis.

Atterberg limit testing consists of two tests, namely liquid limit and plastic limit. Liquid limit was conducted to determine the moisture content of soil in the liquid limit state using a device consisting of a brass bowl resting on a hard rubber base. The liquid limit is the moisture content of the soil required to close the slit along the bottom of the soil sample in the bowl on the 25th stroke. Since it is difficult to control the moisture content at the time the slit closes on the 25th stroke, the liquid limit test is carried out at least four times on the same soil with different moisture contents. Plastic limit was conducted to determine the moisture content of the soil at the limit of plastic state and semi-solid state. Plastic limit is the moisture content at which the soil when rolled to a diameter of 3 mm becomes cracked.

Sieve analysis is one way to determine the size variation of particles in soil. These variations are expressed as a percentage of the total dry weight. To distinguish and pinpoint each of these soil properties, a systematic method was used so that certain soils can be selected appropriately.

The purpose of this examination is to classify and classify the types of soil that pass the sieve in order to easily analyze the general properties of the soil. The tools used include: one unit of ASTM standard sieves, namely sieves No. 4, 8, 16, 30, 40, 100, 200 and pan, oven with temperature control, sieve cutting machine and scales with an accuracy of 0.01 grams. There were two methods used to obtain the size distribution of soil particles, namely sieve analysis (grain sizeanalysis coarser part) and hydrometer analysis (size analysis finerpart),

III. Results and Discussion

A. Research Result

Basic characteristics testing using several sediment soil samples. The results of these laboratory tests for basic characteristics such as specific gravity, moisture content, volume weight, liquid limit, plastic limit, plasticity index, soil gradation, are listed in ranges and can be seen in Table 1.

Testing the mechanical properties of dredged soil, in this case the Unconfined compressive strength test. Unconfined compressive strength testing was carried out in two stages, namely, testing the Unconfined

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compressive strength of the original dredged soil and testing the Unconfined compressive strength with stabilization, namely by adding a percentage of 5%, 10%, and 20% portland cement to the weight of the sediment soil sample. This test uses a curing time of 3 days, 7 days, 14 days, and 28 days.

Table 1. Index of Sedimentary Soil Properties

No.	Indeks Properties	Unit	Result
1.	Water Content	%	97,13
2.	Specific gravity (GS)	-	2,51
3.	Wet Content Weight (${}^{\gamma}$wet)	gr/cm^3	1,61
4.	Dry Content Weight (${}^{\gamma}$dry)	gr/cm^3	0,82
5.	Liquid Limits (LL)	%	33,80
6.	Plastic Limits (PL)	%	22,52
7.	Plasticity Index (PI)	%	11,28
8.	Sand	%	2,08
9.	Silt + Clay	%	97,92

The summary of the test results and analysis of the Unconfined compressive strength of native soil can be seen in the stress-strain relationship graph in Figure 1.

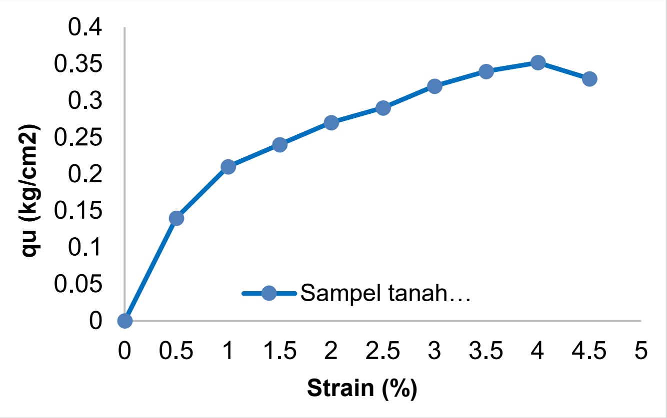

Figure 1. Unconfined Compressive Strength of Soil Sediment

Sedimentary soil samples in this study were stabilized with the addition of Portland cement (PCC Cement). Each treatment was added with cement at 5%, 10%, and 20% of the weight of oven-dried sediment soil samples, respectively. The type of Unconfined compressive strength test with cement mixture with curing time of 3, 7, 14, and 28 days can be seen in the following Figure 2, 3 and 4.

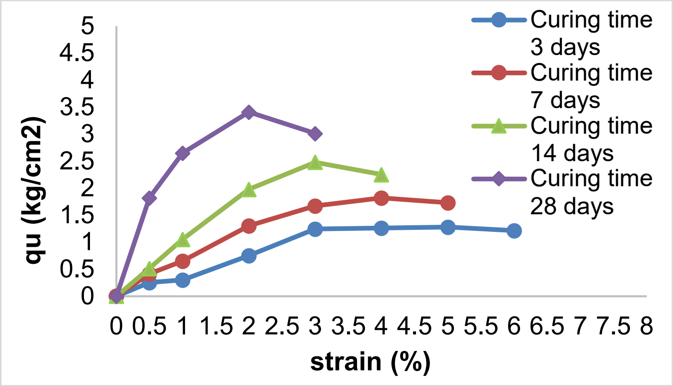

Figure 2. Summary of Unconfined Compressive Strength of soil Sediment with 5% Cement Stabilization with Curing Time 3,7,14, and 28 days

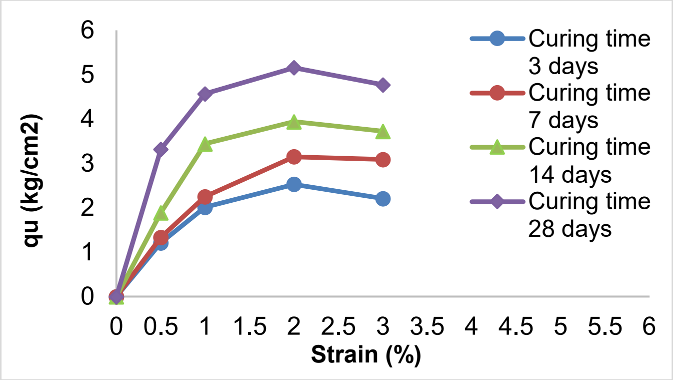

Figure 3. Summary of Unconfined Compressive Strength of soil Sediment with 10% Cement Stabilization with Curing Time 3,7,14, and 28 days

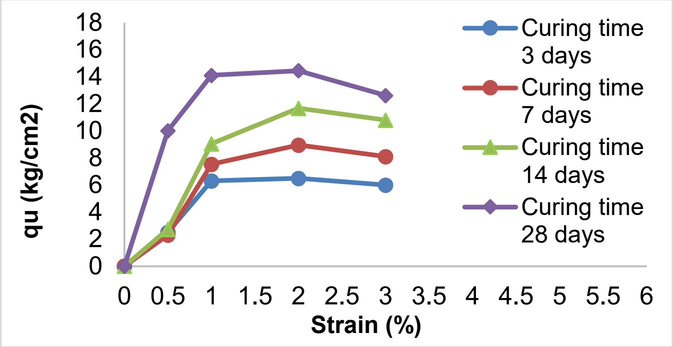

Figure 4. Summary of Unconfined Compressive Strength of soil Sediment with 20% Cement Stabilization with Curing Time 3,7,14, and 28 days

Table 2. Stress and Strain values with the addition of cement and Curing Time

% Portland cement	Laboratory testing	Unit	Curing Time (days)			
			3	7	14	28
5	Stress (qu)	Kg/cm²	1,28	1,82	2,48	3,41
	Strain (Ɛ)	%	5,00	4,00	3,00	2,00
10	Stress (qu)	Kg/cm²	2,53	3,15	3,94	5,16
	Strain (Ɛ)	%	2,00	2,00	2,00	2,00
20	Stress (qu)	Kg/cm²	6,50	8,96	11,68	14,45
	Strain (Ɛ)	%	2,00	2,00	2,00	2,00

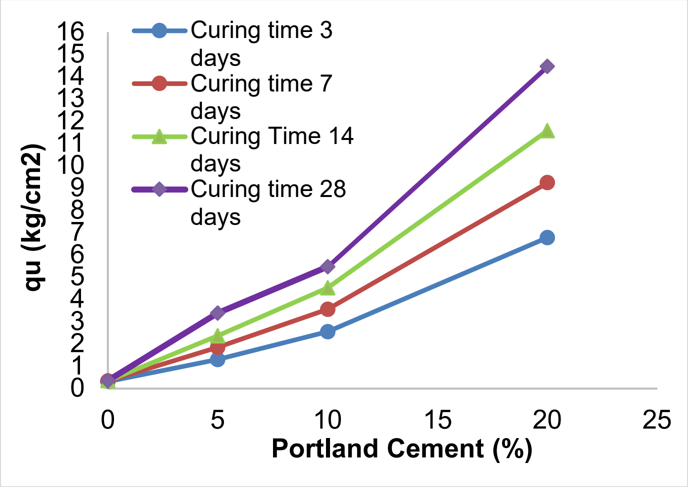

Figure 5. Relationship graph of qu with Portland cement with Curing Time 3,7,14, and 28 days

DISCUSSION

From the results of the free compressive strength test, the behaviors obtained in the form of changes regarding the mechanical properties of the soil after stabilization with variations in cement content against the curing time as shown in the table and graph above.

The test results of sedimentary soil characteristics provide values as shown in Table 2 above, based on these values can be analyzed through the following discussion: From the sieve analysis test / grain size distribution using several samples shows results that are not different from each other for each sample point, the results obtained with a percentage value are: sand = 2.08%, silt / clay = 97.02%. From the consistency limit test, the liquid limit = 33.80%, plastic limit = 22.52%, and plasticity index = 11.28% were obtained,

The results of testing the mechanical properties of sedimentary soil obtained a value for free compressive strength (qu) = 0.352 kg / cm², this means that the ability of this type of soil to withstand pressure from above of 0.352 kg / cm², from the value of free compressive strength of this type of sedimentary soil including soft soil types.

The outcomes of the unconfined compressive strength test revealed a trend of increased strength in sedimentary soil when stabilized with Portland Cement. This relationship between the cement mixture and curing time is visually represented in the graphical image, indicating that the strength of the soil improves with higher percentages of cement and longer curing durations.

The purpose of conducting the compressive strength analysis with cement stabilization in this study was to determine the value of free compressive strength (qu) in the sedimentary soil under investigation. Upon testing and analyzing the free compressive strength of the sedimentary soil stabilized with 5% cement, it was found that after 3 days of curing, the strength value (qu) ranged at 1.28 kg/cm². After 7 days of curing, the strength value increased to 1.82 kg/cm², indicating that the soil falls into the category of stiff consistency. Furthermore, after 14 days of curing, the qu value reached 2.48 kg/cm², and after 28 days of curing, the qu value further improved to 3.41 kg/cm², indicating that the soil can be classified as having a very stiff consistency.

When 10% cement was added to the soil with a curing time of 3 days, a value of qu = 2.53 kg/cm² was obtained, classifying the soil as very stiff. After 7 days of curing, the value of qu increased to 3.15 kg/cm², indicating that the soil remained in the very stiff category. After 14 days of curing, the qu value further increased to 3.94 kg/cm², and after 28 days of curing, the qu value reached 5.16 kg/cm², indicating that the soil can be classified as hard.

In the case of adding 20% cement, after 3 days of curing, the qu value was 6.50 kg/cm². After 28 days of curing, the qu value increased significantly to 14.45 kg/cm², indicating that the soil can be classified as having a hard consistency.

These values exhibit a linear growth pattern when the percentage of cement and curing time were increased, indicating that the free compressive strength of cement-stabilized soil from the dredged sediment of Bili-bili Dam displayed an enhanced load-bearing capacity. These findings establish that the soil achieved a hard consistency category, rendering it suitable for subgrade applications in the construction of buildings and roads. The research focused on examining the characteristics of stabilized dredged sediment soil through a series of laboratory tests, aiming to assess the index and mechanical properties of the soil to facilitate soil improvement techniques. This investigation specifically targeted the dredged sediment soil obtained from Bili-bili Dam.

IV. Conclusion

Based on the results of testing and discussion in this study, the following conclusions can be given:

1. The fundamental characteristics of the sedimentary soil from Bili-bili Dam indicate that it predominantly consists of fine-grained soil (silt-clay) with a soft consistency. This places it in the category of moderate to poor soil, rendering it unsuitable for use as a construction material or subgrade material.
2. Utilizing the USCS (Unified Soil Classification System) method, the sedimentary soil can be classified as CL (Clay-Low) soil type, characterized by clay with low plasticity values.
3. Stabilizing the sedimentary soil with Portland Cement leads to a significant improvement in free compressive strength, with the strength values increasing with higher percentages of cement content (5%, 10%, and 20%) and longer curing durations. The optimal cement content can be chosen based on specific requirements, be it for subgrade applications in building structures or road base soils.

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