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Reaction Modulus Capacity Of The Dredging Sediment Stabilized By Cement As A Road Pavement Sub Grade

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Abstract

This study aims to define the reaction modulus bearing capacity of the dredging sediment of Bili-Bili dam as a pavement sub grade, which is stabilized by cement. This research was conducted under laboratory and field-based using dredging sediment samples around the intake of the dam that located in the regency of Gowa, South Sulawesi province. Several steps of testing procedure were done that started with defining the soil characteristics of the sample, obtaining the *CBR* values of the samples that have been stabilized with cement, and then defining the reaction modulus capacity of the sediment using loading test. The results of characteristic analysis and the *CBR* values of the research show that the bearing capacity of the dredging sediment that has been stabilized with cement met the requirement as a pavement sub grade. The reaction modulus capacity of the soil was then tested using loading test and, it was shown that the reaction modulus of the sub-grade (k) increased along with the percentage addition of cement. This can be seen through the graph of relationship of sub grade modulus reaction and *CBR* variation. This graph was then compared with the standard graph of PU Bina Marga for any kind of soil types.

Key words: Soil bearing capacity, Soil reaction modulus, stabilization, sediment.

1. Introduction

The amount of sediment at the dam of Bili-Bili shows a significant increase every year. This means the sediment of the dam is accumulated, which is very disturbing and may interfere the function of the dam itself. Therefore routine dredging is urgently required. However, the constraint faced is the limited capacity of the dumping area and the lack of permanent landfill available.

Generally, the original existing lands are rarely found directly capable to support the repetitive traffic load without undergoing large deformation. This is because the good soil has been diminished, expensive, or difficult to be obtained economically. Thus, soil stabilization is required for the existing poor soil to meet the quality standard of a pavement subgrade [7]. This study aims to determine the reaction modulus capacity of the soil as pavement sub grade by utilizing the dredging sediment material of Bili-Bili dam that stabilized with cement.

This study was conducted based on several previous studies, such as [10] have examined the use of lime and cement as soil stabilization material which increases the *CBR* values. The combination of cement stabilized material with the sludge waste also showed an increase of free pressure strength around 3 to 7 times after stabilized [2]. The dredging study of Ariake clay in Japan that stabilized with cement and lime may increase the bearing capacity of the clay [6].

Soil stabilization has been widely used to improve the performance of the base soil layer in the pavement structure. In this case, there was an increase in strength, stiffness, and bearing capacity with variations of stabilizing [8]; [3]; [5]; [4].

Silting and sedimentation have been resulting in the malfunction of the reservoir/dam. It can be anticipated by dredging procedures. Dredging sediment materials are generally discharged into the sea, but some studies have shown that dredging sediment materials that has been processed and analyzed may be beneficial from the aspect of sustainable economic and environment as the alternative besides disposing to the sea [9].

Sediment Characteristics

Sediment characteristics in this case are the physical properties/index properties and mechanical properties of the soil. Soil mechanical properties are the ability/potential of the soil to be able to withstand the forces or stress due to the work load.

The bearing capacity of the road base material measurement was originally developed by the California Division of Highways around the 1930s, called the California Bearing Ratio (*CBR*), which is expressed in the following equation:

There are two kinds of *CBR* measurements as follow:

The value of *CBR* for penetration pressure of 0.254 cm (0.1”) respecting to the standard penetration of 70.37 kg/cm^2 (1000 psi).

$$\text{CBR value} = \frac{PI}{70{,}37} \text{ x } 100\% \text{ (PI } \textit{in kg/ cm}^2\text{)} \quad (1)$$

The value of *CBR* for penetration pressure of 0.508 cm (0.2”) respecting to the standard penetration of 105.56 kg/cm^2 (1500 psi).

$$\text{CBR value} = \frac{PI}{105{,}56} \text{ x } 100\% \text{ (PI } \textit{in kg/ cm}^2\text{)} \quad (2)$$

The sub grade strength is expressed by the modulus of soil reaction (k) as measured by the plate bearing test. Modulus of soil reaction is the relationship between the pressure of the soil (Q) and the deflection (y). Medium pressure of the soil is the relationship between the load (*P*) and the area of the plates (*A*). The relationship between variables is shown as follows:

$$Q = \frac{P}{A} \tag{3}$$

$$k = \frac{Q}{y} \tag{4}$$

2. Methodology

The sedimentary material was collected by dredging procedures. The dredging of sediment was carried out as many as 12 different points around the vicinity of the Bili-Bili dam's intake.

The research method was experimental laboratory. Initially, the test was conducted for the characteristics of dredging sediment soil of Bili-Bili Dam using the standard method [1]. The test was performed to determine the sediment characteristics and material properties of the dredging soil sediment. The next stage was to mix the dredging sediment with cement under some portions (i.e., 5%, 10%, and 20%) or the so-called soil-cement stabilization. The test was performed to determine the value of *CBR* for both the laboratory and the field. This analysis used Equation (1) and (2). Then, the next stage was testing the capacity of the modulus of soil reaction. This phase of testing used the method of modelling, i.e., *CBR* values of sediment with certain portion of cement addition (soil-cement stabilization) were made in the form of sediment sub grade stabilized by cement model. Furthermore, the loading processes were conducted by loading test. The test results were then analyzed by using Equation (3) and (4) which gives the modulus of elasticity (*k*) of dredging sediment of Bili-Bili dam that stabilized with cement.

3. Analysis Results

The results of material characteristic test for dredging sediment of Bili-Bili Dam that conducted in soil mechanics laboratory were analyzed using ASTM and ASHTO standards. The results of the analysis are then summarized in Table 1 below:

Table 1 Results of material characteristic test for dredging sediment of Bili-Bili Dam

Parameter description	Unit	Test results
Specific gravity (Gs)	-	2.435-2.520
Water content (w)	%	71.476-88.679
Wet bulk density (□ wet)	gr/cm³	1.443-1.529
Dry bulk density (□ dry)	gr/cm³	0.771-0.890
Liquid limit (LL)	%	47.19-48.40
Plastic limit (PL)	%	30.13-30.62
Plasticity index (PI)	%	17.06-17.78
Shrinkage limit (SL)	%	15.089-15.972
Grain size distribution		
a) Sand	%	2.56 – 3.69
b) Silt	%	95.93 – 96.47
c) Clay	%	0.97 – 1.31
Compaction		
a) Max. dry bulk density	gram/cm³	1.35
b) Optimum water content	%	29.6

CBR Laboratory Test

Results of *CBR* laboratory test for dredging sediment of Bili-Bili Dam namely for original soil (0% cement) and for the soil with certain portion of cement addition (5%, 10%, and 20%).

Based on the **results** of *CBR* laboratory test, then analysis was continued using Equation (1) and (2). The results of this analysis are summarized in Table 2 below:

Table 2. Summary of *CBR* laboratory test results

	CBR values (%)	
Cement	deformation (inch)	
(%)	0.1	0.2
0	2.21	2.64
5	21.07	25.67
10	40.74	52.82
20	88.93	101.47

In Situ CBR Test

In situ CBR test was performed for comparison with the CBR laboratory test. The in situ CBR test used the dredging sediment material of Bili-Bili Dam with cement percentage addition of 5%, 10%, and 20% and are made in such a way to fit the common soil suitable for sub grade.

Based on the results of in situ *CBR* test, then analysis was continued using Equation (1) and (2). The results of this analysis are summarized in Table 3 below:
Table 3. Summary of in situ *CBR* test results

Cement	*CBR* values (%) deformation (inch)	
(%)	0.1	0.2
5	8.80	9.95
10	11.27	12.23
20	18.73	22.12

The subgrade reaction modulus capacity of sediment stabilized by cement

This test used plate bearing loading test. The results of these tests were in the form of deformation model of sub grade / base soil for dredging sediment stabilized by cement. This deformation model test was used to determine the deformation pattern that occurs in the sub grade for each *CBR* values. Deformation model data were then analyzed to obtain the value of reaction modulus capacity of the soil (*k*) as the sub grade soil after.stabilized by cement

The results of sub grade deformation model test for dredging sediment that stabilized by cement and by using Equation 3, we obtained the load values (Q) on each additional load, then graphed in the relationship between deformation and any additionalload on each of *CBR* values.

Deformation value (*y*) of 0.64 cm and the load (*Q*) of 5.6 kg/cm² was obtained. Using Equation (4), the reaction modulus capacity values (k) as k1 (*CBR*1) as follows were obtained:

$$k = Q/y = 5.6/0.64$$
$$k1 = 8.75 \text{ kg/cm}^2/\text{cm}$$

The analysis results of the soil reaction modulus capacity (*k*) for *CBR*2 (*k2*) and *CBR*3 (*k3*) were obtained using the same method, as in Table 4 below:

Table 4 Results summary of *k* value analysis with cement variation

Cement variation (%)	load (kg/cm²)	deformation (cm)	*k* values (kg/cm³/cm)
5	5.6	0.64	8.750
10	5.3	0.56	9.464
20	5.6	0.46	12.174

Table 5 shows the value of soil reaction modulus capacity (*k*) with in situ *CBR*

Table 5 Results of soil reaction modulus capacity analysis with in situ *CBR*

CBR (%)	*CBR* values (%)		*k* values (kg/cm³)
	0.1"	0.2"	
*CBR*1	8.80	9.95	8.750
*CBR*2	11.27	12.23	9.464
*CBR*3	18.73	22.12	12.174

Based on the testing results, the graph of relationship between *CBR* values with soil reaction modulus capacity (*k*) for the dredging sediment stabilized by cement was made as follows:

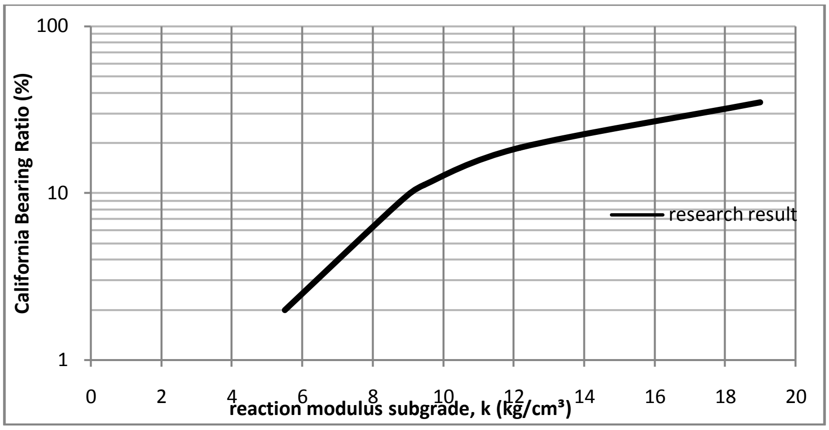

Figure 1 Relation between *k* values with *CBR*

The graph is in general similar to the graph of PU and can be compared. The results of this comparison can be seen in Figure 2 below:

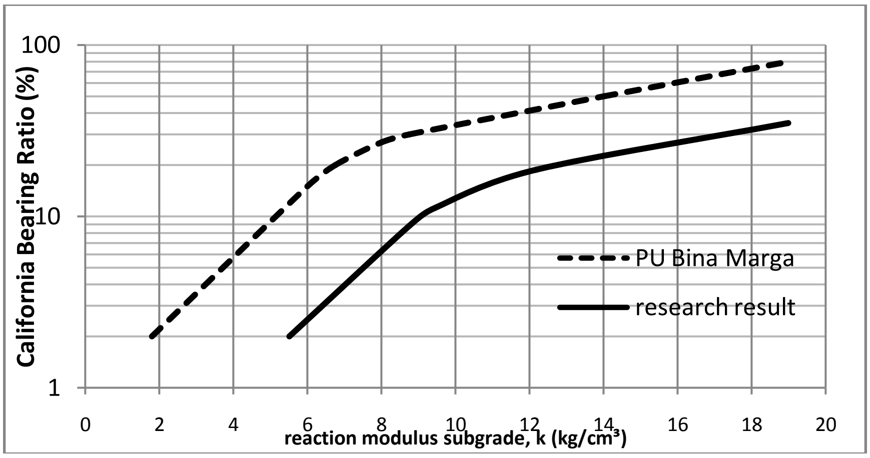

Figure 2 Relation between *CBR* and sub grade reaction modulus capacity based on the current research and PU Bina Marga.

Figure 2 shows that the pattern is almost the same for both observation data, where the graph for cement stabilization of sediment dredging on the right chart for gthe common soil or specifically, an increase in the value of *k* for the soil sediment stabilized by cement for the same values of *CBR* or the *CBR* values of PU are larger than the test results for the same value of k.

Based on the analysis and description above, a graph showed the relationship between the portion of cement with *CBR* average values and the value of soil reaction modulus capacity (k) can be made as follows:

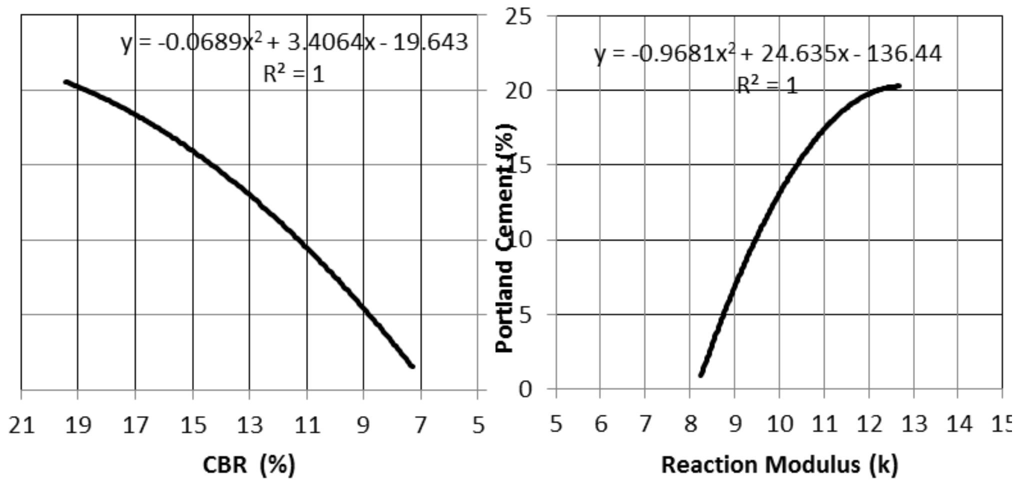

Figure 3 Relationship of *CBR* average values, soil reaction modulus capacity (k) with the portion of cement in the dredging sediment material.

From Figure 3, an empirical equation for the relationship between portland cement portion with soil reaction modulus capacity values (k) can be derived as:

$$sp = -0{,}9681(k)^2 + 24{,}635(k) - 136{,}44 \quad (5)$$

While the empirical equation for the relationship between Portland cement portion with *CBR* values is

$$sp = -0{,}0592(CBR)^2 + 3{,}1219(CBR) - 19{,}064 \quad (6)$$

These equations can be used to determine the value of Portland cement portion based on the value of soil reaction modulus capacity (k) or in the other way around.

4. Conclusion

Based on the testing and analysis of the soil characteristics of dredging soil sediment of Bili-Bili Dam, show that the index properties of soil sediments are in the category of fine-grained soil silt-loam and are at moderate to poor sub grade.

The soil bearing capacity test of dredging sediment stabilized by cement shows an increase of the bearing capacity along with the increase of cement portion.

The soil reaction modulus capacity test of dredging sediment stabilized by cement shows that with the addition of cement may increase the soil reaction modlulus capacity (k) and the value of *CBR*. These results can be used as references in designing the quality of the sub grade of road pavement particularly for the sediment that has similar characteristics with the dredging sediment of Bili-Bili dam.

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