A Study on Utilization of Jeneberang River's Soil Sediment as the Sub-grade Course Material of Flexible Pavement

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Abstract: The dredging Jeneberang's sediment can be utilized as a construction material for road and building. This research aims to study the feasibility of material on the characteristics of the material as a flexible pavement subgrade material. The study conducts a stabilization method using Portland cement in order to increase the strength of the soil sediment. The result of study showed that the dredging sediment soil stabilized with cement tends to increase its strength with the addition of the cement content and the curing time. The relationship between CBR values and modulus resilient (k) follows the similar pattern of curve that published by the Indonesia Public Highways Department. The numerical models between the Portland cement contents (sp), modulus resilient (k), and CBR are defined and useful in determining the cement content when the values of the modulus resilient (k) and the CBR of the subgrade course are acknowledged or the contrary.

Key Words: Soil Cement, Sediment, Subgrade, Flexible Pavement, Jeneberang River.

1. INTRODUCTION

Within last 10 years, the issue of sedimentation in Jenebrang River, South Sulawesi, Indonesia is exacerbated with the occurrence of ruins in Bawakaraeng Mountain, one of the highest mountains in South Sulawesi located in upstream of Jeneberang River. Last time on July 2005, hillside of Bawakaraeng's caldera had ruined and created huge landslide disaster which produced tremendous amount of sediment in upstream area of Jeneberang River. This landslide has produced approximately ± 300 million m3 of soil and sand through upper region of Jeneberang River – Bili-Bili Dam – bottom region of Jeneberang River. The process of sedimentation which disembogues in Makassar will create critical changes on the morphology of its surrounding environment and also endanger the important infrastructure in the downstream of the river.

It is forecasted that the high possibility of sedimentation will occur in that area. If it is not anticipated with the system of dredging, it will be possible to disable the function of Bili-Bili Dam (Samang, 2007). The dredging sediment materials can be utilized as a construction material for road and building. As a matter of consideration, it can be used for construction material of subgrade especially for flexible pavement. This research aims to analyze the feasibility of material through laboratory testing on the characteristics of the material as a flexible pavement subgrade material with method of stabilization. It is expected to enhance the quality of soil which is stabilized.

Stabilization of Jeneberang River's material as subgrade of flexible pavement is conducted in order to form bearing capacity of subgrade soil as well as to prevent settlement due to the process of consolidation. The durability and strength of road construction is heavily influenced by the behavior of soil's bearing capacity. The most common problem occurred is related to the permanent deformation of certain types of soil due to traffic load.

Soil Stabilization is one of effective methods to improve soil's strength, where the field experiment is expected to be based on several results in laboratory. The method of stabilization commonly used is mechanical stabilization and chemical stabilization. Mechanical stabilization (compaction), while chemical stabilization is an amalgamation of soil with chemical substance such as cement, lime or pozzolan and the other substance used for soil stabilization. In this research, cement is used as additional material. It is expected that it can be effective to stabilize the dredging sediment material of Jeneberang River and can react chemically and physically in order to increase the bearing capacity of sediment. Thus, the dredging sediment material stabilized with cement can be utilized as a material for subgrade of flexible pavement.

Several researches in past regarding soil stabilization which used several kinds of substance such as lime, fly ash, cement had been conducted by several researchers. Specifically for soft soil stabilization using Natrium Silicate and UCS, Moayedi, et al (2011) found that the addition of 5 mol/L Natrium Silicate indicated the increase of compressive strength of UCS but the chemical molarity of ucs plummeted along with the length of curing time. Beeghly and Shrock (2010) in their research concluded that the proportional addition for variety of stabilization material provide an advantage to pozzolan and sulfo-pozzolan, reaction of cement. The value of pH above 11 for 28 days is required in order to maintain lime solution and mineral alumina.

The result of soil stabilization for peat soil showed that the engineering properties of it can be improved with the addition of Portland cement and sand which contain silicate. It functions as padding (Islam and Hashim, 2008). Furthermore, Kalantari and Huat (2009) has tried to stabilize peat soil with Portland cement and stone ashes, where it can be seen that there are variety of mixture with same volume in peat soil. With optimum water content and curing time of 90 days, it resulted into CBR immersion of 15% and without immersion of 28%.

The use of stone ashes and soil cement to improve resilient modulus and compressive strength of certain frozen and liquid material has shown that there is rise of resilient modulus in specimen until cycles of 12 with curing time of 28 days. After cycles of 12, shrinkage began occurring. On the curing time of 3 days, there is increase of cycles until 30 for both frozen and liquid specimen. The same tendency occurred in the value of compressive strength (Naji, et al, 2010). On the other hand, Joel and Abgede (2010) researched about the use of lime and cement as material of soil stabilization which amounted in to the CBR value of 170% and UCS for 7 days is 2350 kN/m2. Mixture combination between 6% lime and 8% cement and also 8% lime and 12% cement can be recommended for sub base or base. The research from Jauberthie, et al (2010) in their research stated that the addition of lime and curing of specimens could increase the value of CBR, resilient modulus and could decrease plastic stress.

In addition, Solanki, et al (2009) in their research conducted the soil stabilization with cement which is compared with the use of lime and fly ash as stabilization material. It showed that there is increase of resilient modulus, elasticity modulus and higher value of compressive strength if using cement instead of lime or stone ash. The combination of cement's stabilization material with sewage sludge also indicated that the value of compressive strength increase 3-7 times after it is stabilized, the expansion decreased 10-60%, the values of CBR increased 30 times (Chen and Lin, 2009). In order to model the value of compressive strength of stabilized soil, Anagnostopoulos and Chatziangelou (2008) found that regression model showed better result to be developed compared to the laboratory test for compressive strength without curing session.

Within the context of stabilized dredging soil, the research conducted by Grubb, et al (2010) indicated that there is possibility to conduct stabilization of dredging soil in large scale, with effective cost and environmentally compatible. And then, Grubb, et al (2010) stated that the research of stabilized dredging soil showed the indicators such as compressive strength, compaction made this stabilization is more fastidious than the application of sub grade soil's improvement.

The results from former researchers have given underline base and theoretical support upon the hypothesis and planning for this research in order to conduct soil stabilization of dredging soil by using stabilization material of cement. This is expected to be utilized as material of subgrade for flexible pavement (pavement which used mixture of asphalt layer on its surface). Because of that, this research aims to analyze the basic characteristic of dredging sediment material of Jebeberang River which has potential to be utilized as subgrade material for flexible pavement. Furthermore, this research analyzed the potential of compressive strength using dredging material which has been stabilized by Portland cement with the variety on cement content and curing time. Lastly, the research models the relationship between CBR and modulus resilient of sub grade soil from a layer of subgrade soil from flexible pavement which uses dredging sediment material stabilized with cement.

2. METHOD AND MATERIAL

2.1. Method of Research

Method of research is shown in the flowchart of (Figure 1)

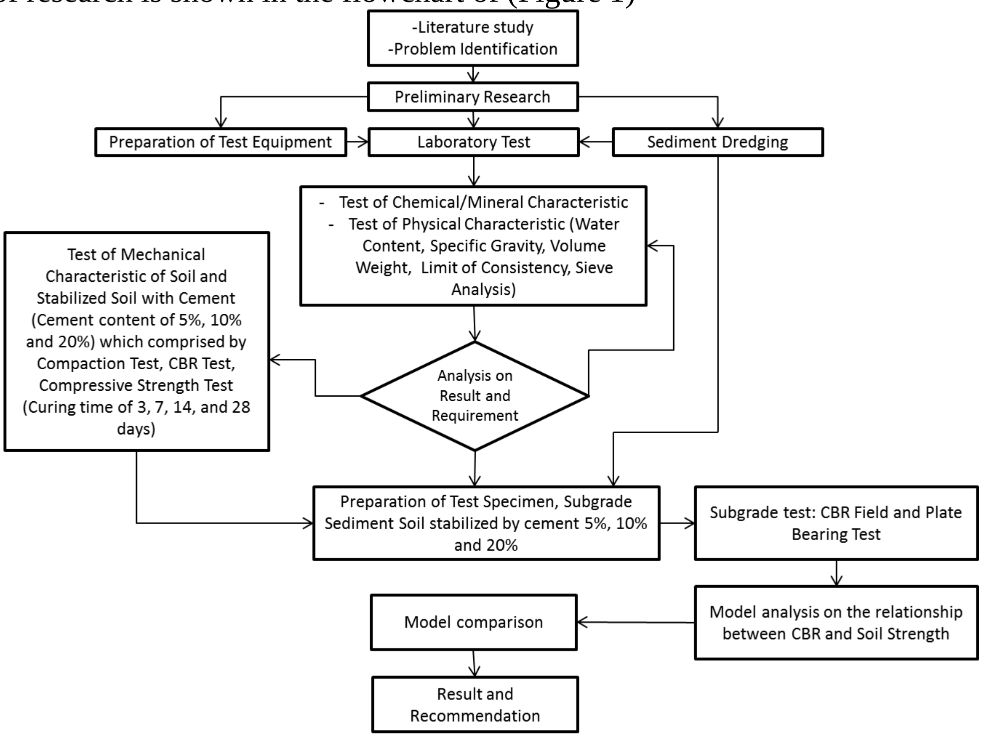


Figure 1. Method of Research

Chart in Figure 1 briefly explained in several explanations below:

- In the phase of literature study upon past study showed that the research on soil stabilization has been conducted with using several types of soil and stabilization material. Generally, it has similar goals which are soil strength, soil characteristic, bearing capacity of soil, soil settlement and etc. On the other hand, the use of soil stabilization method as subgrade of flexible pavement experiences difficulty, because it is hard to be conducted directly and in full at the field. Thus, Laboratory-based approach is expected to deal with the problem.
- In this laboratory-based study, soil stabilization method is conducted upon dredging soil. By observing the results from laboratory test upon the characteristic of sediment soil, the stabilization is executed wish using cement. There are varieties on the content of cement and curing time. Afterwards, the stabilized soil will be used as basic material for flexible pavement. Because of that, the value of parameter design from certain layer of sub grade soil from flexible pavement is examined through test of Laboratory-based CBR and Field-based CBR as well as an examination for compressive strength of stabilized soil. This test is conducted to analyze the performance of sub grade soil from dredging sediment soil stabilized by Portland cement of 5%, 10% and 20%. It is examined by locating the layer of flexible pavement on it and loaded with traffic load to analyze deformation model which is occurred.
- Afterwards, based on the results of experiments in the laboratory, where the dredging sediment soil is stabilized by cement in order to increase its bearing capacity and strength, the phase of modeling is executed to obtain model of relationship between the value of CBR of subgrade which uses sediment soil stabilized by cement with its value compressive strength and elastic modulus.

2.2. Material of Sediment

Material of dredging soil sediment which is used in this research is taken from the Jeneberang River. Specifically from the area where the sediment material is deposited around the Intake of Bili-Bili Dam which is located in Gowa regency, South Sulawesi. It is located from radius of 100-200 m from intake gate of Dam with the depth of +30 m below water level.

2.3. Method of Testing

A. Test of Properties Index

Procedure of soil's basic characteristic examination is based on the standard of procedures such as AASHTO, ASTM and SNI. The kinds of testing are the data of sieve analysis, hydrometer analysis, atterberg limit test (liquid limit, plastic limit, shrinkage limit and plasticity index), specific gravity (Gs), water content (w), weight of soil (γ), porosity (n), cohesion (c), saturation degree (S_r), shear angle (φ), compressive strength (q_u), Standard compaction maximum dry weight and optimum water content), and value of bearing capacity (CBR), both CBR immersion and without immersion

B. Testing with Cement Stabilization

The method of testing for dredging sediment with cement stabilization using the standard from AASHTO T144-74, whereas ASTM 558-82 (1990) and SNI 03 3438-1994 are used in the formation of Portland cement for road and SNI 03 3440-1994 for the examination with Portland cement for road.

C. Standard Proctor Test

Standard Proctor test is conducted in pure soil (0% cement) and cement stabilized soil (with the variety of cement's content addition from 5%, 10% and 20%). The method of testing is executed basing on the Standard of AASHTO T-99 and ASTM D-698. In order to obtain normal compaction curve line, there are 5 samples prepared with weight of 2.0 kg each, both for pure soil and stabilized soil. Following this, the water is added to the samples proportionally with the amount of 22% (440 ml), 24% (480 ml), 26% (520 ml), 28% (560 ml), and 30% (600 ml). Afterwards, the samples are kept in sealed plastic for ± 24 hours in order to make water mixes well with soil. Compaction test is executed after that. Each sample is examined with crushing it 25 times in each layer (3 layers). The data from the experiments in laboratory are analyzed to obtain the graph on the relationship between water content and dry weight of soil (ɣdry) in each specimen. The results which are obtained are maximum water content and optimum dry weight of soil.

D. Compressive Strength Test

Before the compressive strength test is conducted, the molding materials should be prepared. The mold is made of PVC pipe with the diameter of 5.5 cm and height of 10 cm. The specimens which are used are pure/original soil and soil-cement (with the variation of 5%, 10% and 20%). The numbers of samples used are 32; each sample has its variety (0%, 5%, 10%, and 20%) with curing time of 3 days, 7 days, 14 days and 28 days. After this, the compressive strength test is conducted in the laboratory. The result of it will be analyzed to gain the graph on the relationship between stress-strain for each of sample with different curing time.

E. Test of California Bearing Ratio (CBR)

Test of CBR which is conducted consists by laboratory-based and field-based CBR test. On the laboratory-based CBR test, it is divided into two types of tests which are CBR with and without immersion. The laboratory-based CBR test uses CBR equipments which are available in the laboratory, whereas the field-base test uses the equipments based on the standard used in the field. The laboratory-based CBR test which has been conducted used the equipments available in Soil Mechanics Laboratory.

The samples which are used are pure/original soil and cement stabilized soil (5%, 10%, and 20%), the weight of each sample is 5 Kg with the addition of water as much as optimum water content (compaction test). Four of the samples (pure/original soil and soil with the addition of cement) are compacted in the standard mold. Following this, the examination using the equipment of laboratory-based CBR test is done for each of sample + mold which have been compacted. The result of this is analyzed based on the Standard. It is obtained the graph on the relationship between load (lb) and settlement (inc). The value of field-based CBR is gotten from graph which is on the settlement/penetration of 0,1" and 0,2". This value gives an indication on the value of bearing capacity of cement stabilized dredging sediment material as subgrade of pavement for each of the cement's percentage.

F. Test of Physical Model of Cement Stabilized Soil Layer's Prototype

This test is conducted by forming container from steel plate with size of 100x50x40 cm which will be functioned as a place of compaction of cement stabilized soil (5%, 10%, and 20%).

This will mentioned as physical model of subgrade of cement stabilization. This physical model will be used for field-based CBR test and loading test (plate bearing test). Those methods of testing are: cement stabilized dredging sediment material soil in mold is compacted with standard compaction with variety of cement's addition in each sample. After curing time of 28 days, the field-based CBR test is conducted. This test is done by using Standard equipments which are commonly used. The purpose of this test is to obtain the value of field-based CBR from the variety of cement's addition which will be expressed as CBR1, CBR2, and CBR3. Those values will be used as data to conduct loading test. This test is executed in Laboratory of Structure.

The results from the loading test are the value of soil's modulus resilient (k) for each CBR's value which is expressed as k_1, k_2 and k_3. Furthermore, the value of CBR and k will be used to create a curve on the relationship between soil's modulus resilient (k) and the value of CBR. That curve is perceived as a new finding for cement stabilized sediment soil. This result can be compacted with the same graphic for general soil that can be found in PU Bina Marga.

3. RESULT AND DISCUSSION

3.1 Mineral Characteristic of Dredging Sediment Material

The result of examination mineral characteristic of dredging sediment material indicated that the dredging sediment material contained several kinds of mineral such as SiO_2, AL_2O_3, H_2O, Fe, CaO, Na_2O, K_2O, and MgO. In addition, Table discloses that the mineral element Silicone-Oxide (SiO2) occupies the dominant portion with the percentage of 75,42%-77,31%, followed by Aluminium Oxide (Al_2O_3) with approximately 6,76%-6,81%, then H_2O (6,20%-7,21%), and Fe total (4,12% - 4,21%). The other substances are available with relatively small amount. Clay minerals in this sediment soil can be represented as illite clay minerals with type of silt-clay.

3.2. Physical Characteristic of Dredging Sediment Material

The results of laboratory test upon variety of index characteristic of dredging sediment material are enclosed in the Table 1.

Table 1. Property Index of Sediment Material

Property Index	Unit	Result
Specific Gravity (Gs)	-	2,435 - 2,520
Water Content (w)	%	71,476 - 88,679
Wet Weight (γ wet)	gr/cm³	1,443 - 1,529
Dry Weight (γ 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
The value of pores (e)	%	1,828 – 2,248
Porosity (n)	%	64,640 – 69,210
Saturation degree (Sr)	%	94,867 – 99,026
Shear angle (Ø)	degree	18º23' - 20º56'
Cohesion (c)	kg/cm²	0,061 - 0,077
Permeability Coefficient (k)	cm/det	$4,6203.10^{-6}$ - $2,1475.10^{-6}$

Sieve Analysis		
a) Sand	%	2,56 – 3,69
b) Silt	%	95,93 – 96,47
c) Clay	%	0,97 – 1,31

Table 1 shows that the value of specific gravity is ranging from 2,435 to 2,520. Based on that, it can be classified that this type of sediment soil as silt-clay soil which lies under the type of inorganic soil. This type of soil consists by fine-grained soil which possess high characteristic of shrinkage. With this characteristic, if this dredging sediment is used directly as subgrade of pavement, it will trigger destruction on the surface of road pavement. Within the context of advancing the utilization of Jeneberang River's sediment material, the material is still required to be stabilized in order to improve the physical characteristic of it.

The results of sieve analysis in the laboratory upon several spots from Jeneberang River's dredging sediment material give several characteristics on size, grain, soil of dredging sediment as what are enclosed in below curve (Figure 2)

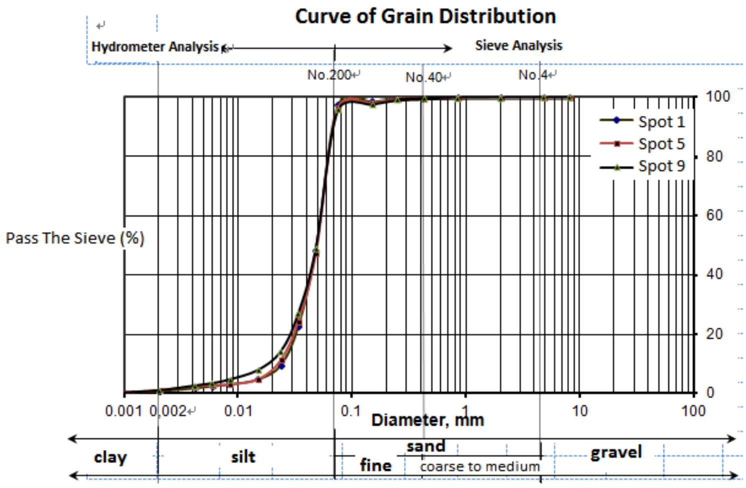
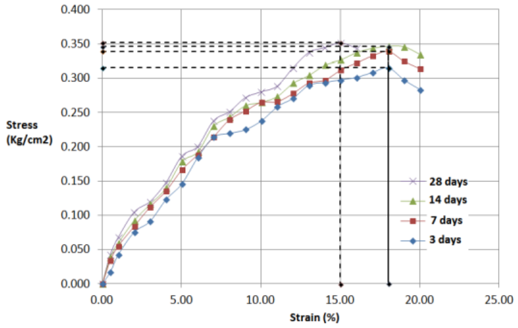


Figure 2 Curve of sediment material's grain size distribution

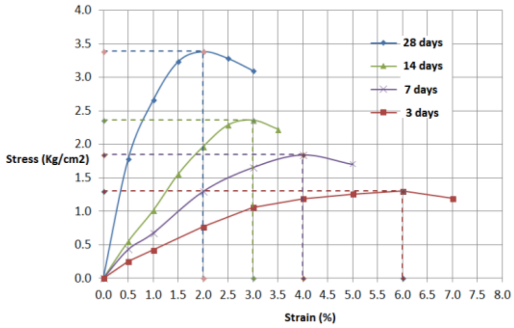
Figure 2 indicates that the percentage of size gradation of sand is ranging from 2,56 – 3,69%, silt is from 95,93–96,47%, and clay is around 0,97–1,31%. These results cite that fine-grained soil dominates with the percentage of 96.5% and the rest are coarse-grained soil, 3.5%. Based on this result, dredging sediment can be classified as a construction material with gradation-class A75 (AASHTO). This soil has physical and mechanical characteristics which are not suitable to be used directly as subgrade of road pavement, because it will induce deformation on the subgrade or create damage on the road construction.

3.3 The Result of Compressive Strength Test

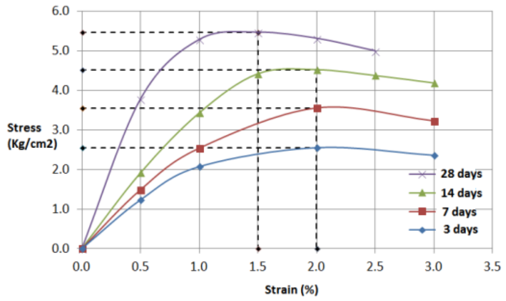
The results of laboratory test upon the index physical characteristics of dredging sediment material are show below (Figure 3)



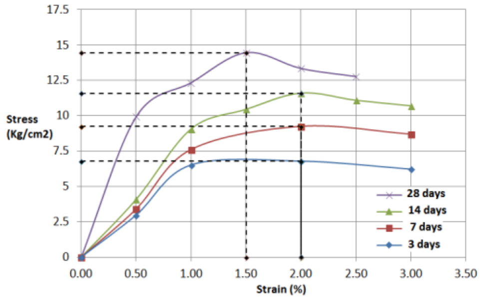
a. Cement Stabilization 0%



b. Cement Stabilization 5%



c. Cement Stabilization 10%



d. Cement Stabilization 20%

Figure 3. Stress-Strain Curve of Cement Stabilized Dredging Sediment

The analysis on the relationship between compressive strength (*qu*) with cement content and curing time are shown below (Figure 4 and 5)

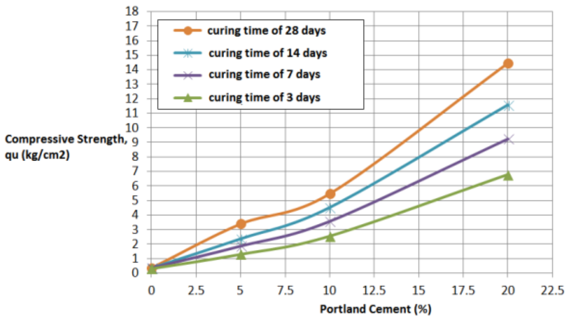


Figure 4 *qu* and cement content

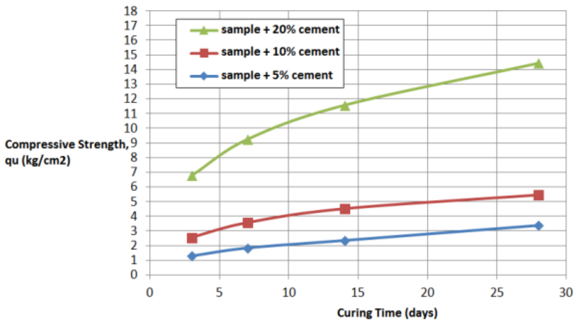
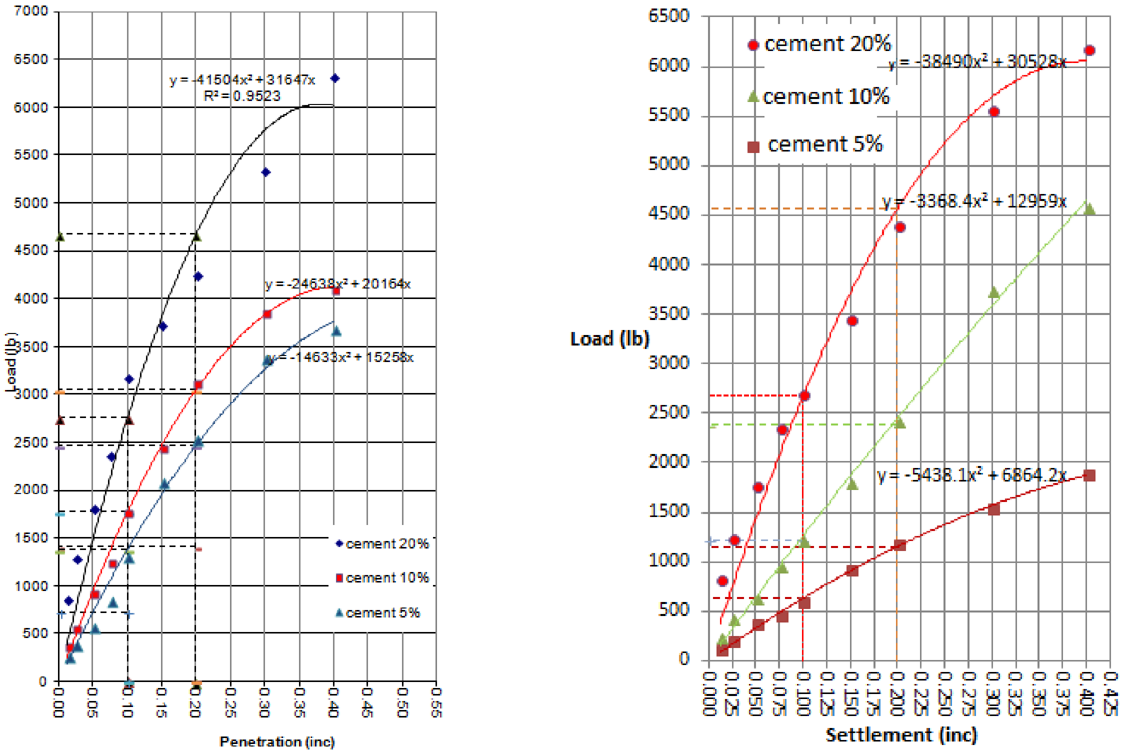


Figure 5 *qu* and curing time

Based on the results above which indicate the value of compressive strength of cement stabilized soil, it can be inferred that dredging sediment soil which is stabilized by cement has tendency of increase on its value of compressive strength. The higher the percentage of cement and the length of curing time are, the greater the value of compressive strength is.

3.4 Results of CBR test

The results of laboratory-based CBR test with and without immersion which used dredging sediment material with cement stabilization with the variety of cement content (5%, 10% and 20%) are shown below (Figure 6).



a. CBR without immersion

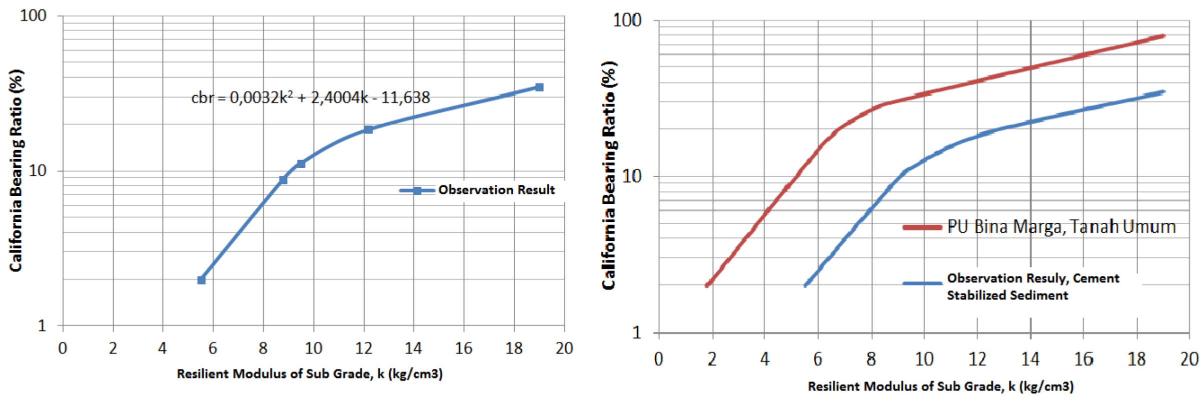
b. CBR with immersion

Figure 6. Result of Laboratory-based of CBR test

Based on the analysis of CBR test's result, both CBR test with and without immersion showed that the type of sediment from pure/original soil and cement stabilized soil experienced some changes and the rise of CBR's value. However, the value of CBR with immersion is lower than that of without immersion. This is influenced by the penetration of water through voids of mixture of soil and soil-cement.

3.5 Deformation Model of Subgrade Soil of Cement Stabilized Sediment Soil

The examination of deformation model of subgrade cement stabilized dredging sediment use plate bearing test. This test is used to observe the deformation pattern occurred on the subgrade of cement stabilized dredging sediment soil. It is conducted by adding cement in certain percentages or CBR value (5%=CBR1, 10%=CBR2, and 20%=CBR3). After that, it is analyzed to determine the value of soil's modulus resilient (k). The value of soil's modulus resilient from the result of deformation model's examination of road's sub grade for every field-based CBR test model is notated as k1, k2, and k3. The result is in form of curve which describes the relationship between field-based CBR and the soil's modulus resilient for cement stabilized dredging sediment soil. The curve of it will be compared with the same curve from PU Bina Marga for the common type of soil. The curve can be seen in Figure 7.



a. Result of *Plate Bearing Test* b. Comparison with the graph of PU Bina Marga

Figure 7 Model of Relationship between k and CBR

Figure 7a shows the pattern of relationships between the value of subgrade's elastic modulus and the value of CBR: cbr = $0,0032k^2 + 2,4004k - 11,638$. This model can be used to determine the value of field-based CBR if the value of soil's modulus resilient is acknowledged for the dredging sediment soil. Figure 7b illustrates that for the same value of CBR, the value of soil's modulus resilient for cement stabilized sediment soil is higher or better compared to that of obtained using the curve from PU.

Based on this analysis, the graphs on the relationship between the percentage of Portland cement with the value of CBR and the value of soil's modulus resilient can be made which are shown below (Figure 8)

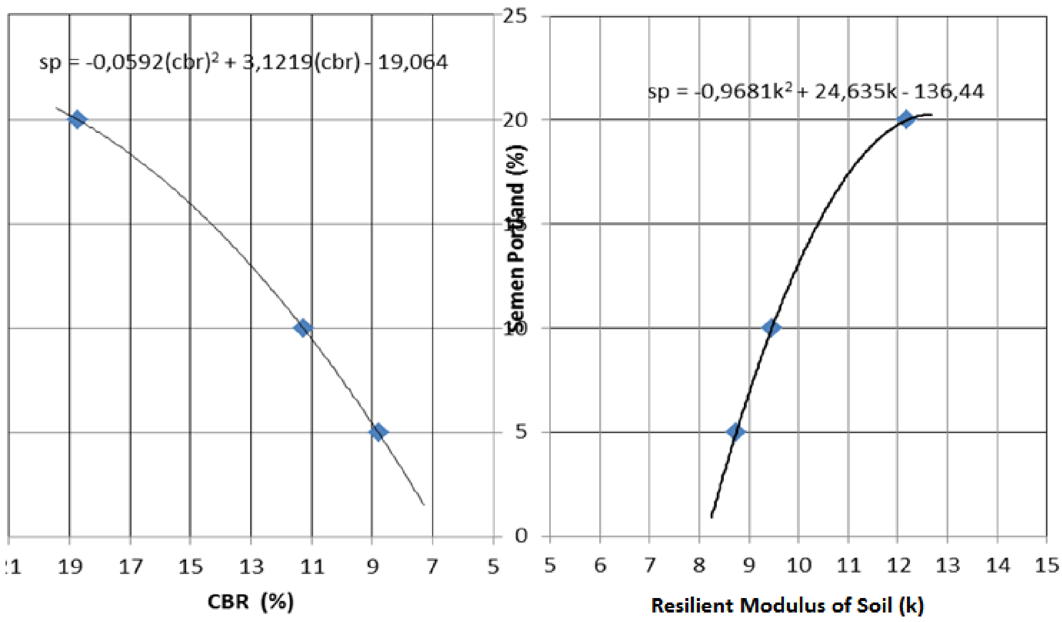


Figure 8 Cement Percentages upon The Value of CBR and Modulus Resilient of Subgrade Soil

Based on the Figure 8, it is obtained a model on the relationship between content of Portland cement with modulus resilient of soil (k): sp = $-0,9681(k)^2 + 24,635(k) - 136,44$, whereas the model on the relationship between Portland cement with CBR value is sp = $-0,0592(cbr)^2 + 3,1219(cbr) - 19,064$.

4. CONCLUSIONS

This research has assessed the feasibility of dredging sediment material from Jeneberang River through laboratory examination on the material's characteristic as subgrade of flexible pavement. The method of soil stabilization has also been conducted to improve the soil strength of sediment. Based on the assessment in laboratory and field as well as the modeling which has been conducted, there are several points that can be concluded which are related to the purposes of this research.

The result of basic characteristic examination of dredging sediment soil from Jeneberang Rivers shows that the sediment soil is classified under the category of silt-clay soil with fine grain. With this characteristic, the use of sediment material directly as subgrade on flexible pavement will able to create damages on the layer of road pavement. Because of that, the soil stabilization is required to improve the characteristic of it.

The advance result of this research indicates that the cement stabilized dredging sediment soil experiences the increase soil's strength by the addition of cement and longer curing time. It is indicated by the rise of value of subgrade's modulus resilient (k1, k2, and k3) which are k1 = 8,750 kg/cm³ for CBR1, k2 = 9,464 kg/cm³ for CBR2, and k3 = 12,174 kg/cm³ for CBR3, where the index of 1, 2, and 3 indicates the increase of cement's content which are 5%, 10%, and 20%. This phenomenon can be observed from the model on the relationship between value of k with CBR; $cbr = 0{,}0032k^2 + 2{,}4004k - 11{,}638$.

The pattern on the relationship between fielf-based CBR with soil's modulus resilient (k) for dredging sediment soil tends to reproduce the same pattern with that of given by Department of PU Bina Marga, Republic of Indonesia for the general/common soil. The result of comparing both graphs illustrates that there is increase of value of k on the cement stabilized sediment soil with the same value of CBR from PU, or the value of CBR from PU Bina Marga is higher than the result of examination for the same value of k.

Within the context of usage of cement for the purpose of stabilization, It is obtained a model on the relationship between content of Portland cement with modulus resilient of soil (k): $sp = -0{,}9681(k)^2 + 24{,}635(k) - 136{,}44$, whereas the model on the relationship between Portland cement with CBR value is sp = $= -0{,}0592(cbr)^2 + 3{,}1219(cbr) - 19{,}064$. This model can be used to measure the content of Portland cement if the value of subgrade's modulus resilient is known and to measure the content of Portland cement if the value of CBR is available, or vice versa.

The results which are obtained from this research can be used as a reference material in the design of pavement subgrade on the layer of road pavement especially on the notion of utilizing the sediment material from Jeneberang River which is stabilized with Portland cement

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