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Jurnal Gradasi Teknik Sipil diterbitkan oleh Pusat Penelitian dan Pengabdian Kepada Masyarakat Politeknik Negeri Banjarmasin. Ruang lingkup makalah meliputi Bidang Teknik dan Manajemen dengan konsentrasi Bidang Transportasi, Geoteknik, Struktur, Keairan dan Manajemen Konstruksi. Isi makalah dapat berupa penyajian isu aktual di bidang Teknik Sipil, review terhadap perkembangan penelitian, pemaparan hasil penelitian, dan pengembangan metode, aplikasi, dan prosedur di bidang Teknik Sipil. Makalah ditulis mengikuti panduan penulisan.

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ANALYSIS OF LATERITE SOIL WITH PORTLAND CEMENT MIXED VARIATIONS AND THE EFFECT ON THE CBR UNSOAKED

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Abstrak

Kabupaten Ketapang dan Kabupaten Kayong Utara memiliki konstruksi jalan yang sering mengalami kerusakan sebelum *live age* yang direncanakan. Hal ini disebabkan oleh perilaku lempung ekspansif. Tanah dasar merupakan struktur dasar dalam membangun konstruksi jalan karena tanah dasar akan menopang beban lalu lintas atau beban konstruksi. Kekuatan dan ketahanan struktur perkerasan jalan akan tergantung pada sifat dan daya dukung tanah dasar. Secara praktis stabilisasi tanah adalah suatu teknik perkuatan terhadap pondasi atau tanah dasar dengan menggunakan bahan campuran. Oleh karena itu, diperlukan variasi perbaikan tanah yang berbeda. Berdasarkan hasil pengujian, nilai CBR Sukadana awalnya mendapat poin 2,95%. Nilai CBR Sukadana untuk campuran 6% dan 10% masing-masing mendapatkan 17,14% dan 25,02%. Nilai CBR Sungai Melayu Rayak semula mendapat poin 4,65%. Kemudian untuk campuran 6% dan 10% nilai CBR mengalami kenaikan sebesar 13,78% dan 18%. Nilai daya dukung konstruksi tanah jalan raya dapat diketahui dari hasil pengujian CBR pada setiap variasi. CBR juga dapat mengukur kekuatan tanah. Penambahan semen ke dalam tanah cenderung meningkatkan daya dukung tanah. Hal ini dikarenakan semen dapat berfungsi sebagai pengikat antara partikel tanah dengan senyawa kimia yang terkandung dalam semen.

Kata kunci*—Tanah Laterit, CBR, Semen Portland*

Abstract

Ketapang and Kayong Utara Regency have road construction that often suffers damage before the planned life age caused by the behaviour of expansive clay. Subgrade is a fundamental structure in building road construction because the subgrade will support traffic loads or construction loads. The strength and durability of the pavement structure road will depend on the properties and bearing capacity of the subgrade. Practically, the soil stabilization is a reinforcement engineering on the foundation or subgrade by using mixed materials. Therefore, different soil improvement variations are needed. Based on the test result, the initial CBR value of Sukadana is 2.95% point. The CBR value for the 6% and 10 % mixture, respectively, are 17.14% and 25.02%. The original CBR value of Sungai Melayu Rayak is 4.65% point. Then, for the 6% and 10% mixture, the CBR values increased by 13.78% and 18%. The value of the bearing capacity of the highway soil construction can be found from the results of CBR testing on each variation. The CBR also can measure the strength of the soil. The addition of cement to the earth tends to increase the bearing capacity of the ground. It is because cement can function as a binder between soil particles with chemical compounds contained in the cement.

Keywords— *CBR, Laterite Soil, Portland Cement*

I. INTRODUCTION

Soil is the basis of a structure or construction, such as building construction, road construction and other construction. In the technical sense, the soil is the accumulation of mineral particles that are cemented (chemically bonded) to each other formed due to weathering of rock (Bahari, 2019). Water and carbon dioxide from the air form carbonic acids, which then react with rock minerals and form new minerals added to dissolved salts. As a result of the chemical formation of soil, the soil has different structures and properties.

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One type of soil is laterite soil. Laterite soils are also known as red soils (Umam, 2021). Laterite soil or Red Soil is soil with a red to brown color formed in a humid, cold environment and puddles (Zulkipli, 2020). This soil has a deep soil profile, readily absorbs water, has moderate organic matter content, and has high pH or neutral acidity levels.

The laterite has a brick red or slightly brownish color. It is because the iron content in this land is very much. Laterite soils have various colors from red, brown, yellow, fine-grained residual soil with a light texture having a nodular grain shape and well cemented (Bahari, 2019; Saputra & Putra, 2020). The physical properties of laterite soils vary greatly depending on the mineralogical composition and particle size distribution of the ground; granulometry can range from fine to gravel depending on the origin and formation process to affect geotechnical properties as plasticity and compressive strength (Santoso, 2020).

In Indonesia, the distribution of laterite soils is over 8,085 million hectares spread over Sumatra, Kalimantan, Sulawesi, Irian Jaya and Java. Laterite soils are commonly found in Kalimantan, especially the West Kalimantan. Often laterite soils affect road construction in West Kalimantan. It is because the subgrade will support traffic loads or construction loads.

Ketapang Regency and Kayong Utara Regency have road construction that often suffers damage before the planned life age caused by the behavior of expansive clay. The subgrade is a fundamental structure in building road construction because the subgrade will support traffic loads or construction loads (Raharmadi, 2017).

The strength and durability of the pavement structure road will depend on the properties and bearing capacity of the subgrade (Saputra & Putra, 2020). Some of the problems that often arise regarding the durability and strength of a product are that bare soil dominates road pavement.

Some unfavorable properties of the subgrade can cause damage problems to include the nature of the considerable shrinkage due to changes in water level (Saputra, et al., 2019). The improvements to soft subgrade due to changes in grade water generally by modifying or carrying out special handling make the subgrade better for road construction and materials that meet road planning standards.

One of the efforts to improve the soil properties is to have good support and maintain volume changes, namely using stabilization. Practically soil stabilization is a reinforcement engineering against foundation or subgrade by using mixed materials (Priadi, 2019). That matter can be expected to increase the load-bearing ability and bearing capacity to physical and chemical stress due to weather or environmental influences during the useful life of road construction (Saputra, et al., 2019). Subgrade properties such as strength stiffness, expansion potential, water penetration, and volume change. Therefore, different soil improvement variations are needed.

The simplest way that can be used is compression. The subgrade conditions that meet are stable with a high CBR (California Bearing Ratio) value required in road construction. California Bearing Ratio (CBR) is the ratio between the penetration of material to material with the same depth and speed of penetration (expressed in percent) (Erliawan & Firdaus, 2019; Firdaus et al., 2019). But if in field conditions with soil conditions problematic or unsupportive base for road construction, then in addition to compaction, special treatment is also required. These unique treatments include using additives to improve the subgrade.

One of the treatments is adding soil cement to the road construction. Soil cement is a mixture of soil (loose) and a certain amount of cement portland and water compacted to a maximum density (Bahari, 2019). Next, the mixture hardens with cement hydration and the surface cover with asphalt pavement. It is commonly used mainly as a foundation for roads, highways, airports, shoulders and parking lots (Karwur, et al., 2013, Kamajaya Asrul 2021). Soil-cement It is also often used as a subbase for rigid (rigid) or pavements flexible, stacking area, repair on a grained foundation (patching), safeguarding of cliffs in earthen dams and embankment works, stabilization subgrade. In the condition of the mixture that has reached the maximum density then hardens due to the cement hydration process, it will form a solid material.

The material structurally works like plate concrete and will not deform under loading. Therefore, the bearing capacity of soil-cement is much greater than that of foundation with aggregate (granular) (Marhendi & Yusup, 2017). Within the service life, the cement contained in the mixture of Soil Cement continues to experience the hydration process for a long time (Santoso, 2020). This hydration process always follows by the shrinkage of the material leading to cracks preceded by hair cracks. This crack will increase significantly over time. And it becomes a characteristic of Soil Cement construction.

Soil cement stability is obtained only from cement hydration and not due to the cohesion or internal friction of the soil particles, and almost all soil types can be hardened with cement (except humus) (Santoso, 2020).

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However, this requires the selection and grouping of materials in terms of the quantity of cement use. The finer the gradation of the material, the more surface area per unit kilogram increases. This results in the use of cement will increase big too.

AASHTO identified land and the grouping into two types of soil, coarse-grained soil and coarse-grained soil fine-grained. The cement used is portland cement which complies with ASTM, AASHTO, CSA or other specifications, namely cement type I and I.a, or standard type and waterproof type. Based on Nasional (2000), water used for mixing soil cement that is clean water and even better if water can be drunk. The amount of water used depends on the water content optimum material used. In this condition, the maximum density of soil-cement can be reached.

This research aims to determine the CBR value of soil and mixtures soil with aggregate compacted with certain moisture content. This research is a penetration experiment used to assess the strength of the subgrade or other materials for pavement materials for roads or parking lots or industrial buildings that require a solid foundation. CBR value obtained from examination used to calculate the pavement layer thickness (Subbase, Base course, and Surfacing) (Kabdiyono, 2019).

CBR testing submerged (soaked) and unsoaked (unsoaked) almost the test is same. Still, before the penetration test CBR, the difference carried out immersion for a specific time by recording the deformation or development at predetermined time intervals.

II. METHOD

The research used soil samples from the sub-district of Sukadana, North Kayong Regency and Sungai Melayu District, District Ketapang. The area's soil is lateritic, and this can be proven through direct observation in the field. Tests carried out at the stage of physical soil testing include sieve test, Atterberg limit test, specific gravity, and moisture content. After mixing soil and cement or soil cement, the preliminary examination, the CBR (California Bearing Ratio) test. The testing procedure in this study consists of the preparation material & tools, fieldwork and laboratory work. The stages of research implementation are as follows.

Figure 1. Sampling location at Sungai Melayu District

Figure 2. Sampling location at Sukadana District

A. Laboratory Testing Procedure
1. Soil Physical Properties Testing
   The physical properties of the soil are the properties of the soil in its original state used to determine the soil type. This test is carried out on soil samples that will be used, namely the soil identification test. The steps to do soil test are:
   a. Water content testing
      This step determines the soil's maximum density by collision, namely by knowing the relationship between the water content and the soil density. This test uses the standard SNI 03-1774-2012.
   b. Filter Analysis
      This sieve analysis is intended to determine the size distribution details of soil. The purpose of this test is to determine the amount of soil that is retained and passed through a predetermined sieve, as well as determine the distribution of the grain size of the soil.
   c. Testing the limits of consistency (Atterberg Limit)

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The shrinkage limit is defined as the water content at a position between semi-solid and solid, i.e., the percentage of maximum moisture content. The classification of expansive soil based on the plasticity index and the shrinkage limit is shown in table 1.

The reduction of subsequent water content does not cause a decrease in soil volume. The purpose of this test is to determine the shrinkage limit of soil. Linear shrinkage is a percentage of the original length of the sample tested soil. The equipment used is linear shrinkage, shrinkage dish, oven, water bottle, spatula, caliper, glass.

TABLE 1. The Classification of Expansive Soil

Plasticity Index (%)	The Shrinkage Limit (%)	Degree of Expansiveness
>32	>35	Very high
23 – 32	24 – 41	High
12 – 23	15 – 48	Medium
<12	<18	Low

(Source: Raman, C., 1967)

d. Soil density testing

This step determines the soil's maximum density by collision, namely by knowing the relationship between the water content and the soil density. This test uses the standard SNI 03-1774-2012.

B. Mixing soil and cement

This test used Gresik cement, Portland cement Type I, that meets the provisions of SNI 15-2049-2004. This study used laterite soil from the Sukadana sub-district and Sungai Melayu sub-district. The soil must be free of organic matter that can interfere with the hydration process of portland cement. When tested according to the procedure of SNI 19-6426-2000, the value of its pH after an hour interval must be greater than 12.2.

Meanwhile, to determine the percentage of cement to be used, the soil laterite added or mixed with cement at a percentage of 6% and 10% of the weight of the soil used. Several tests laboratory shows that the addition of cement content generally ranges between 8% to 10%. After obtaining the optimum cement content with the condition of the concentration of optimum water, then the cement-soil mixture has been compacted in CBR molds.

C. CBR Testing

The equipment used in the CBR test is as follows. The equipment shown at Fig. 3.

1. Penetration machine (loading machine) with a capacity of at least 4.45 tons (10,000lb) with a penetration speed of 1.27 mm (0.05 inches) per minute.
2. Cylindrical metal mold with an inner diameter of 152.4 ±0.66mm (6 ± 0.0026 inch) by 177.8 ± 0.46 mm (7 ± 0.005 inch). The mold must be equipped with an extension collar. With a height of 50 mm and many perforated bases, plates can be fixed precisely (not moving) on both ends of the mold. At least three prints are provided for testing.
3. Metal separation disc (spacer disk) with a diameter (150.8 ±0.80) mm and height (61.37 ± 0.25) mm.
4. The pounder is following the compaction inspection method. Swell testing tool consisting of chips perforated developers, adjustment rods, metal tripods, and pointer watch.
5. Piece weight 2.27 kg (5 lb), diameter 194.2 mm with 54.0 mm diameter hole.
6. Metal penetration piston 49.5 mm (1.95 in) in diameter, 1935 mm2 (3 inches) wide area.
7. One load watch and one penetration gauge
8. The Scale.

Figure 3. CBR Equipment Tools

The CBR test result is measuring the magnitude of load at a certain penetration. The amount of penetration as a basis for determining CBR is 0.1 inches and 0.2 inches.

History of article:
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From the two calculation values used, the value of the following equation calculates largest.

Penetration 0,1 inches (0,254 cm)

$$CBR(\%) = \frac{P1(psi)}{1000(psi)} \times 100\%$$

Penetration 0,2 inches (0,508 cm)

$$CBR(\%) = \frac{P1(psi)}{1500(psi)} \times 100\%$$

The implementation of the CBR test in the laboratory is explained by the step below.

1. Soil samples in sacks are first removed and stored in the prepared pan, then dried first in the Civil Engineering Laboratory room for 24 hours.
2. Then prepare three metal cylinders or molds along with a wedge plate for three samples under test.
3. After that, prepare the original soil of 6 kg and a mixture of 6% cement of (390 grams) and 10% (650 grams) and water that has been determined.
4. After the soil sample is mixed with cement, start doing a collision with three samples with each blow different, for the first ten strokes, the second 30 strokes, third hit 65 strokes.
5. After finishing pounding the wedge plate along with other tools, then removed.
6. Then flatten the ground sample that has been ground with using a leveling knife.
7. Weigh the mold and the soil that is still in the mold.
8. Set the watch in the penetration machine, then perform tests and record time in CBR testing.
9. After completing the CBR test, the mold is removed from the penetration machine.
10. Prepare 3 cups for the three samples in each mold. Sample 1 is at the top, sample 2 is in the middle, and sample 3 is lower than the other.
11. Previously the cup was weighed first, then weighed the soil in the cup to determine the mass of the soil wet and cup.
12. The cup's sample is weighed, then placed it in the oven for 24 hours.
13. After being in the oven, the sample is weighed again to determine the soil dry and cup mass.
14. The CBR test is done, the value of the mass of water, the mass of the cup, the mass of dry soil, moisture content, and average moisture content.

III. RESULT AND DISCUSSION

This research used soil samples to take soil samples by going directly to the field with a tool hoe and container for models in the form of sacks. The soil taken is 100 m from the highway because the soil sampled is original soil (subgrade). After it, the model will dry first about 48 hours ago. Then it will bring to the Civil Engineering laboratory Ketapang State Polytechnic.

A. Water Content Analysis and Filter Testing

The water content test is carried out to determine the natural water content present in the water in the soil in the Sukadana and Sungai Melayu Rayak areas. Water content test 3 samples of laterite soil, then take the average of the water content of the three samples. The results of water content testing at Sukadana & Sungai Melayu Rayak are shown in Table 2 and Table 3. The average water content at Sukadana District is 22,15 %, meanwhile at Sungai Melayu Rayak is 17,99 %.

TABLE 2. Water Content of Sukadana District

Water Content Testing	Sample		
	1	2	3
Weight of cup and wet soil	59,18	59,77	59,06
Weight of cup and dry soil	50,04	50,69	50,08
Weight of cup	9,51	9,28	9,25
Weight of water	9,14	9,08	8,98
Weight of dry soil	40,53	41,41	40,83
Water content	22,55	21,92	21,99
Average water content (%)	22,15		

Source: laboratory test results

TABLE 3. Water Content of Sungai Melayu Rayak District

Water Content Testing	Sample		
	1	2	3
Weight of cup and wet soil	59,03	59,61	59,21
Weight of cup and dry soil	52,28	51,64	51,07
Weight of cup	9,17	9,40	9,27
Weight of water	6,75	7,97	8,14
Weight of dry soil	43,11	42,24	41,8
Water content	15,65	18,86	19,47
Average water content (%)	22,15		

Source: laboratory test results

The sieve test is carried out by mechanical means; namely, the soil sample is shaken with a certain speed on an array of sieves, then each that is retained on the sieve is weighed, and the data entered into a logarithmic graph showing the relationship between grain diameter (mm) and the percentage of pass. The results of filter analysis

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testing at Sukadana are shown in Table 4. Also, the graph of filter analysis testing at Sukadana is shown in Fig. 4 below.

TABLE 4. Filter Analysis of Sukadana District

Filter Number	Retained Percentage (%)	Percentage of Passing filter (%)
4	3,60	96,40
10	20,97	75,43
20	28,15	47,28
40	29,58	17,70
60	10,24	7,46
140	6,17	1,29
200	1,20	0,08
Pan	0,08	0,00
	100,00	

Source: laboratory test results

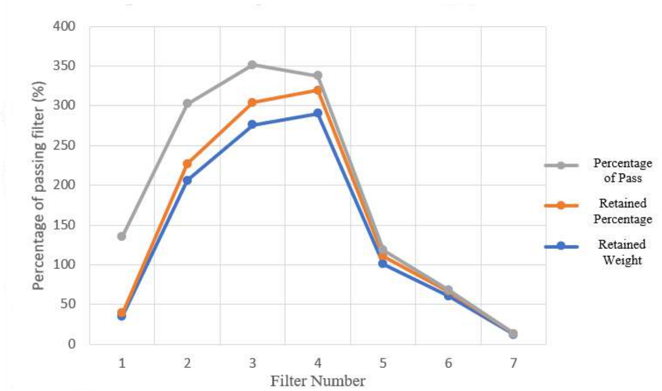

Figure 4. Graph of filter analysis testing at Sukadana

Based on Fig.4, the Percentage of Passing filter at Sukadana are 96,41%, 75,44%, 47,3%, 17,73%, 7,49%, 1,32%, and 0,08%.

Meanwhile the results of filter analysis testing at Sungai Melayu Rayak are shown in Table 5. Also, the graph of filter analysis testing at Sungai Melayu Rayak is shown in Fig. 5 below.

TABLE 5. Filter Analysis of Sungai Melayu Rayak District

Filter Number	Retained Percentage (%)	Percentage of Passing filter (%)
4	7,09	92,91
10	24,29	68,62
20	24,79	43,83
40	25,11	18,72
60	11,68	7,04
140	5,87	1,17
200	1,13	0,04
Pan	0,04	0,00
	100,00	

Source: laboratory test results

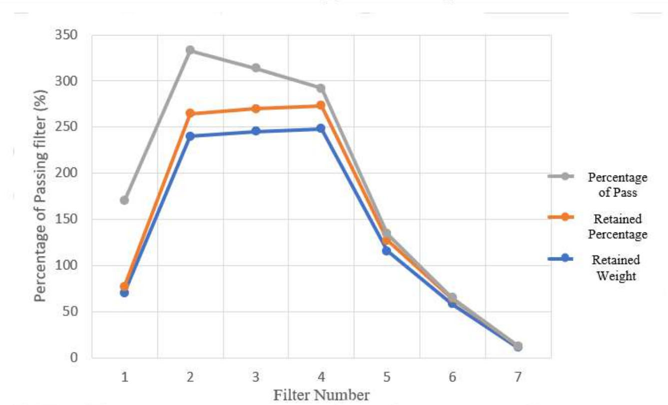

Figure 5. Graph of filter analysis testing at Sungai Melayu Rayak District

Based on Fig.5, the Percentage of Passing filter at Sungai Melayu Rayak are 92,91%, 68,63%, 43,85%, 18,7%, 7,03%, 1,16% and 0,04%.

B. Atterberg Limit and Plasticity Index

Atterberg limit testing consists of a liquid limit. The liquid limit value is the amount of water content during the transition period of the solid soil state to the liquid form, while the plastic limit is the lowest limit condition of water content when the soil is still in a plastic condition.

The Graph Atterberg limit in Sukadana District is shown at Fig. 6. Based on Fig. 6, the water content values are 31.29%, 33.22%, 34.17%, 35.94%. According to the AASHTO Classification System, from the Sukadana location, the liquid limit value (LL) : 35,65% (< 40%), Plasticity Index (PI) : 9,03% (< 10%) and the percentage of passing the No. 200 sieve: 0.08% (< 35%). Based on these results, the soil material, including group A-2-4, is a type of soil gravel and sand containing silt or clay, which are good soil types that can be used as fill material or subgrade.

History of article:
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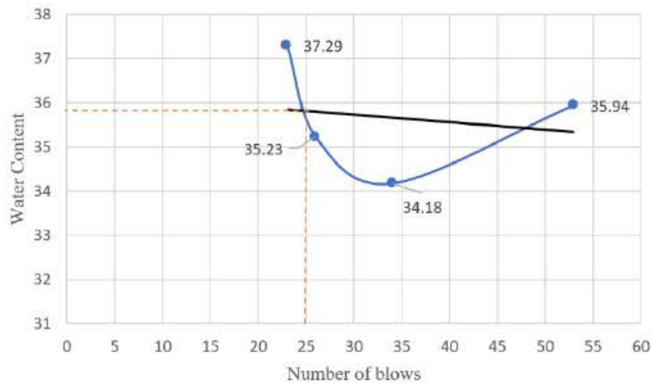

Figure 6. Graph of Atterberg Limit at Sukadana District

The Graph Atterberg limit in Sungai Melayu Rayak District is shown at Fig. 7. Based on Fig.7, the water content value is 37.72%, 33.27%, 25.89%, and 13.46%. From the location of Sungai Melayu Rayak, the liquid limit value (LL): 32.86% (<40 %), Plastic Index (PI) :5,62 % (<10 %)and the percentage passed the No.200 sieve : 0.04% (< 10 %). Based on these results, the soil material includes group A-2-4, a type of gravel and sand containing silt or clay, which is a good type of soil that can be used as fill material or subgrade.

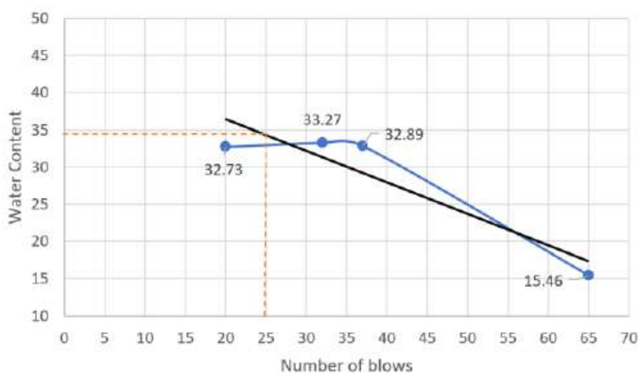

Figure 7. Graph of Atterberg Limit at Sungai Melayu Rayak District

The plasticity index value is the difference between the liquid limit of the soil and the plastic limit soil. The plasticity index value in Sukadana and Sungai Melayu Rayak is presented in Table 6 and Table 7.

TABLE 6. Plasticity Index at Sukadana District

Content	%
Liquid limit	35,65
Plastic limit	17,96
Plasticity Index	9,03

Source: laboratory test results

TABLE 7. Plasticity Index at Sungai Melayu Rayak District

Content	%
Liquid limit	28,58
Plastic limit	27,24
Plasticity Index	5,62

Source: laboratory test results

Based on Table 6 and Table 7, the test results in the liquid limit values (LL) table from Sukadana is 35.65%. The liquid limit value from the area of Sungai Melayu is 28.58%. Meanwhile, the results of the plastic limit (PL) test from the Sukadana is 17.96%. The plastic limit value from the Sungai Melayu Rayak and the plasticity index (PI) value is 27.24%.

C. Analysis of Soil Content

This soil compaction uses laterite soil samples from the Sukadana and the Sungai Melayu Rayak area with a weight of 2,500 grams. Test soil compaction carried out in the laboratory using the compaction method. The standard uses a lateritic soil sample that has previously been dried in the sun so that water content is uniform. Furthermore, the optimum water content results will be used for the addition of water in soil compaction to test the mechanical properties of the soil. Later, the optimum water content (wopt) and dry density value will be obtained optimum for each sample. The results of sample testing in the laboratory obtained optimum water content for the original and mixed soil.

Soil compaction without mixture (0%) uses the original soil sample from Sukadana and Sungai Melayu Rayak, which weighs 2.500 grams. The graph of soil compaction without mixture (0%) at Sukadana district is shown at Fig. 8.

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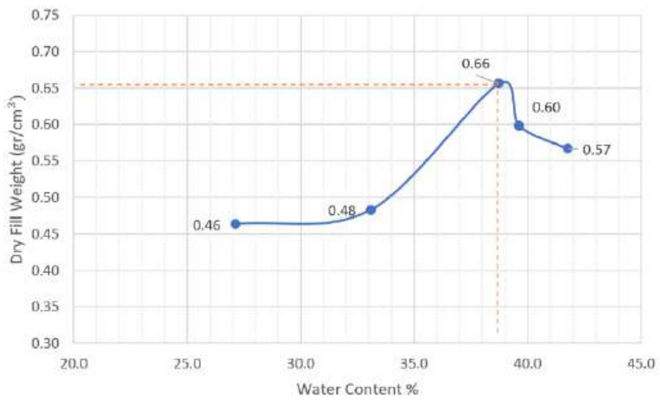

Figure 8. Graph of Soil Compaction without mixture at Sukadana

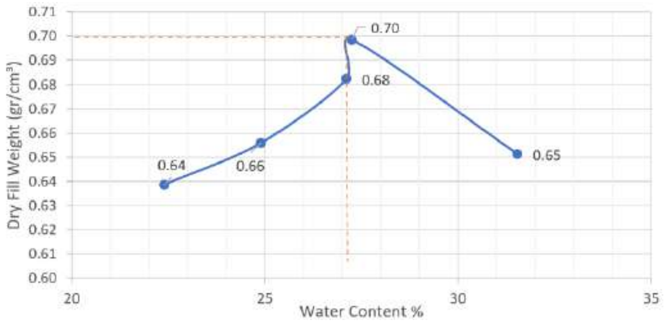

Figure 9. Graph of Soil Compaction without mixture at Sungai Melayu Rayak

Based on Fig.8, the original soil's optimum water content (wopt) value is 39%, and dry volume weight (γd max) is 0.67 gr/cm³. The graph of soil compaction without mixture (0%) at Sungai Melayu Rayak district is shown at Fig. 9. Based on Fig.9, the original soil's optimum water content (wopt) value is 27,25%, and dry volume weight (γd max) is 0.70 gr/cm³.

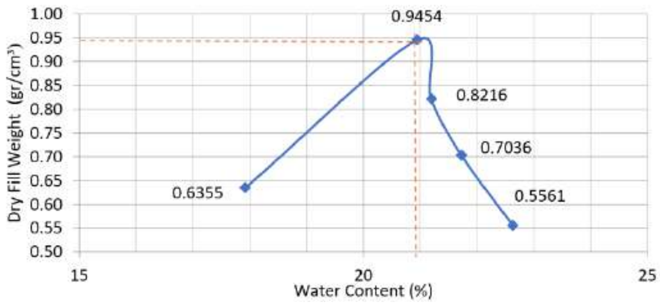

Figure 10. Graph of Soil Compaction with 6% mixture at Sukadana

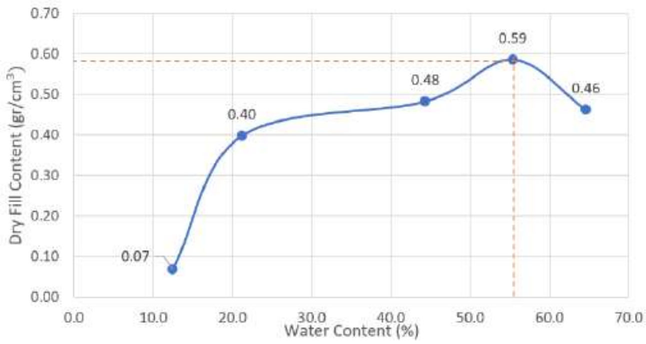

Figure 11. Graph of Soil Compaction with 6% mixture at Sungai Melayu Rayak

After that, the compaction of soil and cement mixture (6%) at Sukadana and Sungai Melayu District is conducted. The graph of soil compaction is compaction of soil and cement (6%) at Sukadana district is shown at Fig. 10. Also, the graph of soil compaction is compaction of soil and cement (6%) at Sungai Melayu Rayak district is shown at Fig. 11.

Based on Fig. 10 obtained the value of the optimum water content (wopt) with a mixture of 6% from the Sukadana is 21.20% and dry volume weight (γd max) is 0.95 gr/cm³. Based on Fig. 11 obtained the value of the optimum water content (wopt) with a mixture of 6% from the Sungai Melayu Rayak is 55,36% and dry volume weight (γd max) is 0.59 gr/cm³.

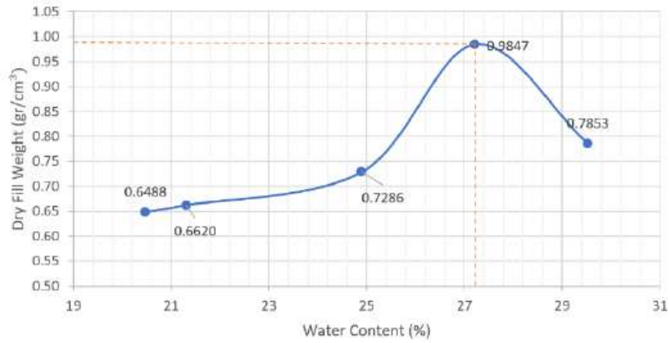

Figure 12. Graph of Soil Compaction with 10% mixture at Sukadana

History of article:
Received: 13 Agustus 2021 Revised: - , Published: Desember 2021

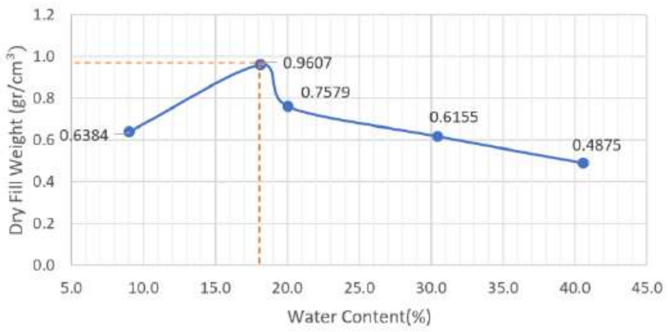

Figure 13. Graph of Soil Compaction with 10% mixture at Sungai Melayu Rayak

The compaction of soil and cement mixture (10%) at Sukadana and Sungai Melayu District is shown at Fig. 12 and Fig. 13. Based on Fig. 12 obtained the value of the optimum water content (wopt) with a mixture of 10% from the Sukadana is 27,22% and dry volume weight (γd max is 0.9847 gr/cm³. Based on Fig. 13 obtained the value of the optimum water content (wopt) with a mixture of 6% from the Sungai Melayu Rayak is 18,13% and dry volume weight (γd max) is 0.9607 gr/cm³.

D. CBR (California Bearing Ratio)

The CBR value is expressed in percentage, obtained by dividing the load value corrected for penetration of 2.54mm (0.10 in) and 5.08 mm (0.20 in) with standard loads of 13 Kn (3000 lbs) and 20 Kn (4500 lbs), respectively, and multiply by 100.

First, plan to determine the design CBR, which is the value of maximum density (ρd maximum) multiplied by 95%, we get design dry density. From the value of the dry density of the invention, the value of CBR design. Figure 14 and Figure 15 below shows a graph of the results of the CBR design without mixture (0%) from various area in Sukadana District.

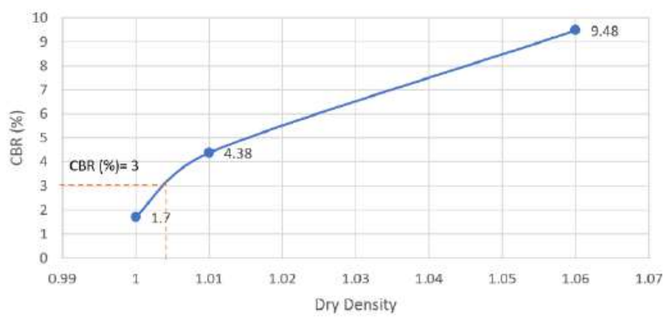

Figure 14. CBR Design of soil without mixture (0%) at 1st Area Sukadana

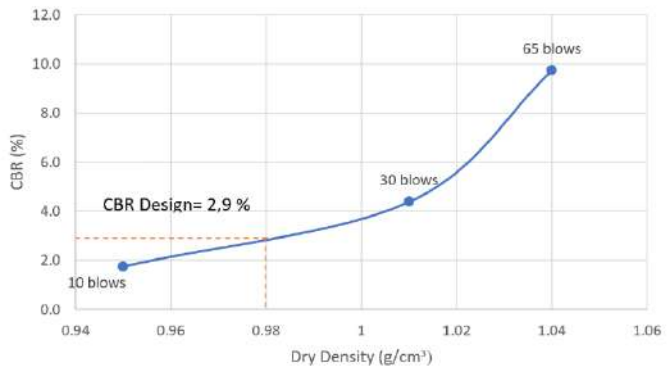

Figure 15. CBR Design of soil without mixture (0%) at 2nd Area Sukadana

TABLE 8. CBR Test Result without mixture (0%) in Sukadana

Items	1st Area	2nd Area
Compaction Method	SNI 1742: 2021	
Optimum Water Content	39 %	39 %
Maximum Dry Density	1,06 (g/cm³)	1,04 (g/cm³)
Dry Density Design	1,007 (g/cm³)	0,988 (g/cm³)
CBR Design	3%	2,9 %

Source: laboratory test results

Based Table 8 shows the results of the CBR design without mixture (0%) at 1st location Sukadana District. The CBR composition gets a 3% point with 39% optimum water content. Based Table 9 shows the results of the CBR design without mixture (0%) at 2nd location Sukadana District. The CBR composition gets a 2,9% point with 39% optimum water content.

Meanwhile, the value of CBR design without mixture (0%) at various area in Sungai Melayu Rayak is shown at Fig.16 and Fig.17.

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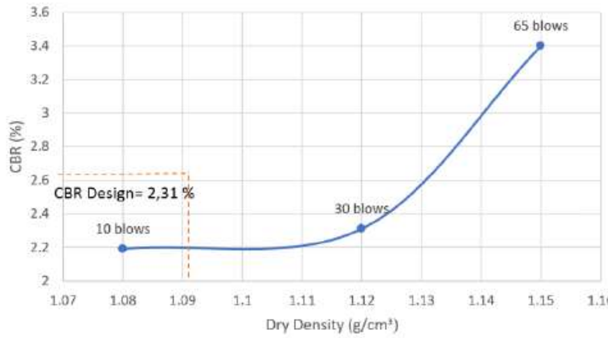

Figure 16. CBR Design of soil without mixture (0%) at 1st Area Sungai Melayu Rayak

Figure 17. CBR Design of soil withou mixture (0%) at 2nd Area Sungai Melayu Rayak

TABLE 9. CBR Test Result without mixture (0%) in Sungai Melayu Rayak

Items	1st Area	2nd Area
Compaction Method	SNI 1742: 2021	
Optimum Water Content	27,25 %	27,25 %
Maximum Dry Density	1,15 (g/cm³)	1,12 (g/cm³)
Dry Density Design	1,0925 (g/cm³)	1,064 (g/cm³)
CBR Design	2,31%	7%

Source: laboratory test results

Table 9 shows the results of the CBR design without mixture (0%) at 1st area Sungai Melayu Rayak District. The CBR composition gets a 2,31% point with 27,25% optimum water content. The 2nd area Sungai Melayu Rayak District obtained 7% points CBR composition with 27,25% optimum water content.

The CBR design of soil with 6% mixture presented by Figure 18 and Figure 19 below. The graph shows the results of the CBR design with 6% mixture from various area in Sukadana District.

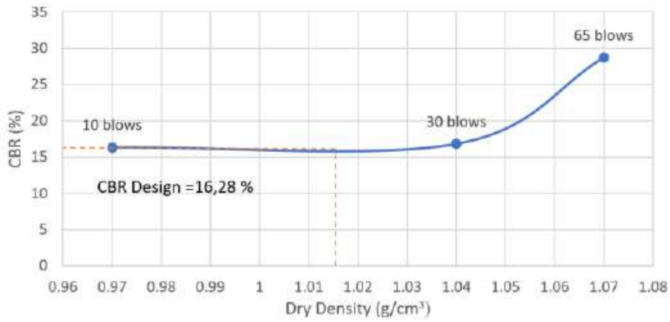

Figure 18. CBR Design of soil with 6% mixture at 1st Area Sukadana

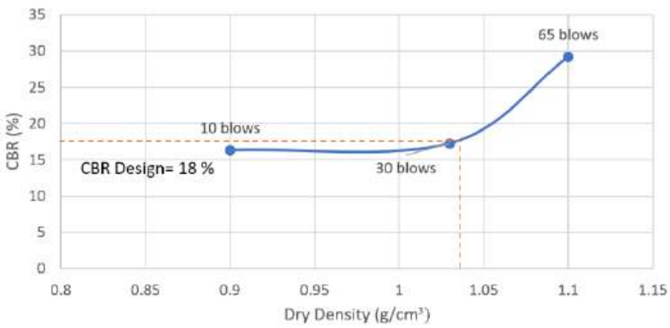

Figure 19. CBR Design of soil with 6% mixture at 2nd Area Sukadana

TABLE 10. CBR Test Result with 6% mixture in Sukadana

Items	1st Area	2nd Area
Compaction Method	SNI 1742: 2021	
Optimum Water Content	21,20 %	21,20 %
Maximum Dry Density	1,07 (g/cm³)	1,1 (g/cm³)
Dry Density Design	1,0165 (g/cm³)	1,045 (g/cm³)
CBR Design	16,28%	18%

Source: laboratory test results

Table 10 shows the results of the CBR design with 6% mixture at 1st area Sukadana District. The CBR composition gets a 16,28% point with 21,20% optimum water content. The 2nd area Sukadana District obtained 18%

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ejurnal.poliban.ac.id

points CBR composition with 21,20% optimum water content.

The CBR design of soil with 6% mixture from various area in Sungai Melayu Rayak presented by Figure 20 and Figure 21 below. The graph shows the results of the CBR design with 6% mixture from various area in Sungai Melayu District.

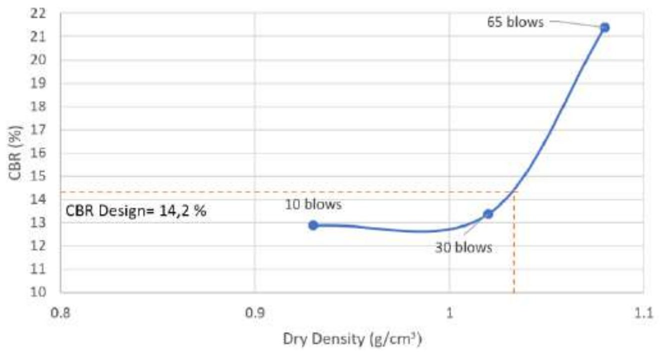

Figure 20. CBR Design of soil with 6% mixture at 1st Sungai Melayu Rayak Area

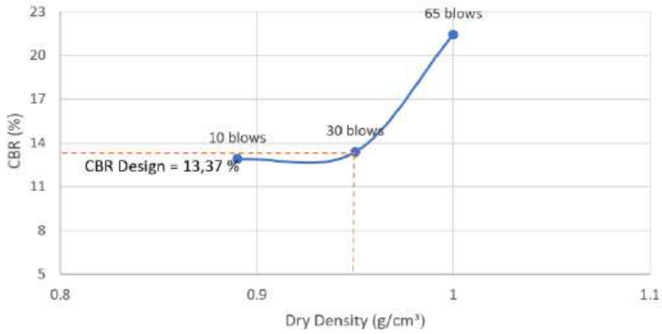

Figure 21. CBR Design of soil with 6% mixture at 2nd Area Sungai Melayu Rayak

TABLE 11. CBR Test Result with 6% mixture in Sungai Melayu Rayak

Items	1st Area	2nd Area
Compaction Method	SNI 1742: 2021	
Optimum Water Content	18,13 %	18,13 %
Maximum Dry Density	1,08 (g/cm³)	1,00 (g/cm³)
Dry Density Design	1,026 (g/cm³)	0,95 (g/cm³)
CBR Design	14,2%	13,37%

Source: laboratory test results

Table 11 shows the results of the CBR design with 6% mixture at 1st area Sungai Melayu Rayak District. The CBR composition gets a 14,2% point with 18,13% optimum water content. The 2nd area Sungai Melayu Rayak District obtained 13,37% points CBR composition with 18,13% optimum water content.

The CBR design of soil with 10% mixture from various area in Sukadana presented by Figure 22 and Figure 23 below. The graph shows the results of the CBR design with 10% mixture from various area in Sukadana District.

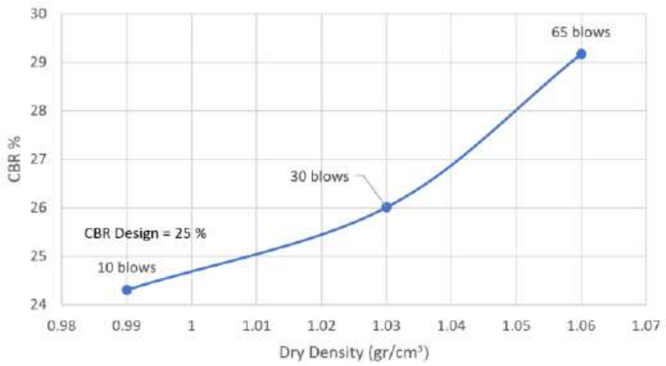

Figure 22. CBR Design of soil with 10% mixture at 1st Area Sukadana

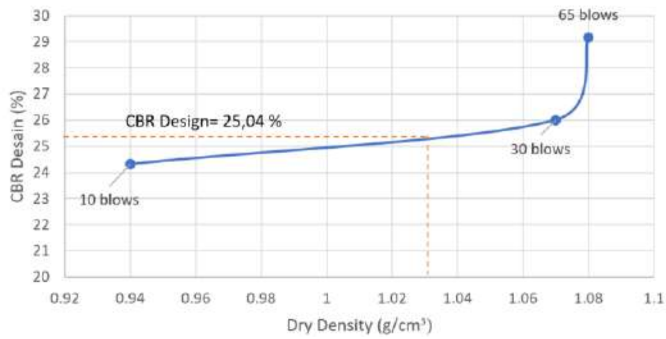

Figure 23. CBR Design of soil with 10% mixture at 1st Area Sukadana

TABLE 12. CBR Test Result with 10% mixture in Sukadana

Items	1st Area	2nd Area
Compaction Method	SNI 1742: 2021	
Optimum Water Content	27,22 %	27,22 %
Maximum Dry Density	1,006 (g/cm³)	1,08 (g/cm³)

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ejurnal.poliban.ac.id

Items	1st Area	2nd Area
Dry Density Design	1,007 (g/cm³)	1,026 (g/cm³)
CBR Design	25%	25,04%

Source: laboratory test results

Table 12 shows the results of the CBR design with 10% mixture at 1st area Sukadana District. The CBR composition gets a 25% point with 27,22% optimum water content. The 2nd area Sukadana District obtained 25,04% points CBR composition with 27,22% optimum water content.

The CBR design of soil with 10% mixture from various area in Sungai Melayu Rayak presented by Figure 24 and Figure 25 below. The graph shows the results of the CBR design with 10% mixture from various area in Sungai Melayu District.

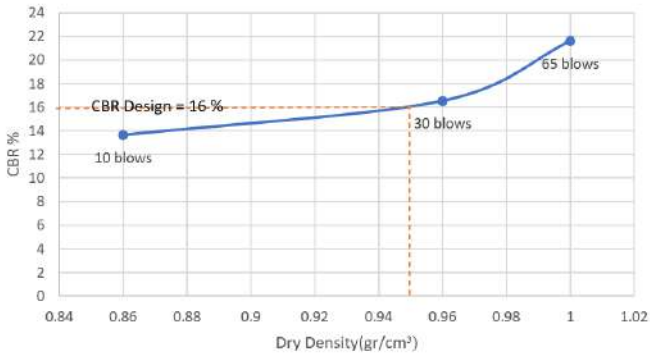

Figure 24. CBR Design of soil with 10% mixture at 1st Area Sungai Melayu Rayak

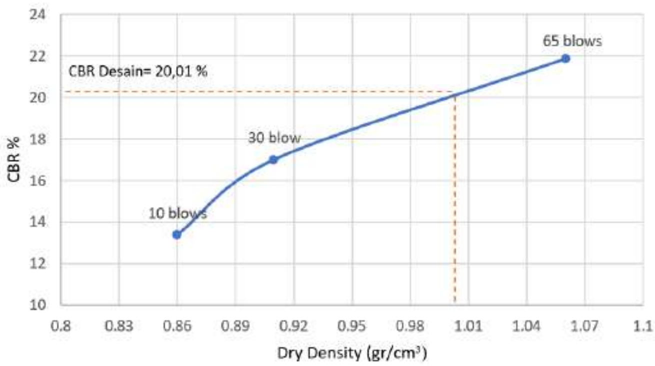

Figure 25. CBR Design of soil with 10% mixture at 2nd Area Sungai Melayu Rayak

TABLE 13. CBR Test Result with 10% mixture in Sungai Melayu Rayak

Items	1st Area	2nd Area
Compaction Method	SNI 1742: 2021	
Optimum Water Content	55,36 %	55,36 %
Maximum Dry Density	1,06 (g/cm³)	1,00 (g/cm³)
Dry Density Design	1,007 (g/cm³)	0,95 (g/cm³)
CBR Design	20,01%	16%

Source: laboratory test results

Table 12 shows the results of the CBR design with 10% mixture at 1st area Sukadana District. The CBR composition gets a 20,01% point with 55,36% optimum water content. The 2nd area Sukadana District obtained 16% points CBR composition with 55,36% optimum water content.

TABLE 13. CBR Test Result in Sukadana

Sample	Cement Content		
	0%	6%	10%
1	3%	16,28%	25%
2	2,9%	18%	25,04%
Average	2,95%	17,14%	25,02%

Source: laboratory test results

TABLE 14. CBR Test Result in Sungai Melayu Rayak

Sample	Cement Content		
	0%	6%	10%
1	2,31%	14,2%	20,01%
2	7%	13,37%	16%
Average	4,65%	13,78%	18%

Source: laboratory test results

TABLE 14. Optimum Water Content

Sukadana			Sungai Melayu Rayak		
0%	6%	10%	0%	6%	10%
29%	21,20%	27,22%	27,25%	18,13%	55,26%

Source: laboratory test results

The average CBR results from Sukadana and Sungai Melayu Rayak district shown at Table 14 and Table 15. The average CBR results from Sukadana and Sungai Melayu Rayak district shown at Table 14 and Table 15. The average CBR result in Sukadana District with 0%

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cement content was 2,95%. The Sukadana CBR result with 6% mixture was 17,14%, and the 10% mixture was 25,02%.

The average CBR result in Sungai Melayu Rayak District with 0% cement content was 4,65%. The Sungai Melayu Rayak CBR result with 6% mixture was 13,78%, and the 10% mixture was 18%. Meanwhile, the optimum water content in Sukadana District with 0%, 6%, and 10% was respectively get 29%, 21,20%, and 27,22%. Meanwhile, the optimum water content in Sukadana District with 0%, 6%, and 10% was respectively 29%, 21,20%, and 27,22%.

Based on the results of research conducted at the Civil Engineering Laboratory of the Ketapang State Polytechnic, the results of the physical properties of the soil at the Sukadana and Sungai Melayu Rayak locations included group A-2-4. This category is a type of gravel and sand that contains silt or clay.

The soil compaction test in the laboratory was carried out using the compaction method (standard proctor). It was conducted to determine the behaviour of the laterite soil, which can be used as a reference for further research. From the results of soil compaction testing, the optimum water content value (wopt) was obtained for the original and mixed soil. The compaction test was carried out to see the maximum soil density and water content used in the CBR test. The results showed that the addition of cement could affect the value of dry soil density.

The density of Sukadana dry soil has increased from the original soil compaction of 0.67 gr/cm³ with a mixture of 6% at 0.95 gr/cm³ and a mixture of 10% cement of 0.9847 gr/cm³. Meanwhile, the Sukadana optimum water content with 0% mixture has declined by 39%. Also, the 6% mixture declined by 21.20%, and the 10% mixture has increased by 27.22%.

Besides that, the soil density of Sungai Melayu Rayak has decreased from the original soil compaction was 0.70 gr/cm³. The Sukadana, 6% mixture, experiencing decreased of 0.59 gr/cm³, and the 10% mixture has an increase of 0.9607 gr/cm³. The Sungai Melayu Rayak optimum water content increased from the original soil by 27.25%. In contrast, the Sungai Melayu Rayak 6% mixture declined by 18.13%, and the 10% mixture increased again by 55.36%.

The value of the bearing capacity of the highway soil construction can be seen from the results of CBR testing on each variation. The CBR also can measure the strength of the soil (Firdaus et al., 2019). Results obtained were expressed in the form of a percentage of the comparison results between the loads required to penetrate the standard load. The value of the soil strength of a road material will be influenced by soil quality, grain bonding and density. Strong and complex material means not easily crushed and become more granular small, or deformed due to the influence of load or water (Umam, 2021; Karwur et al., 2013). The gradation good or that produces a high CBR value is tight. If this type of grain gradation is compacted, the void ratio that occurs will be tiny. A tight gradation will be more stable when it receives a load. The grain deformation that occurs is relatively tiny.

Based on the test result, the CBR value of Sukadana obtained a 2.95% point. The CBR value increased by 17.14% for the 6% mixture. Also, it has increased by 25.02% for the 10% mixture. The CBR value of Sungai Melayu Rayak originally get 4.65% point. After being mixed with cement with the 6% combination, it increased by 13.78%. Then, for the 10% mixture, it also increased by 18%. The highest CBR value has been obtained with a mixture of 10% cement variations both from Sukadana and Sungai Melayu Raya, reaching 25.02% and 18%.

The addition of cement to the soil tends to increase the bearing capacity of the soil. It is because cement can function as a binder between soil particles with chemical compounds contained in cement. Value-added bearing capacity of the soil against the addition of cement is caused by improved soil quality after mixing with cement. Until the ability of the soil to carry the load on it becomes more significant. The value of the bearing capacity of the soil can also affect the choice of material in highway construction (Erliawan & Firdaus, 2019)

IV. CONCLUSION

The value of the bearing capacity of the highway soil construction can be seen from the results of CBR testing on each variation. The CBR also can measure the strength of the soil. The value of the soil strength of a road material will be influenced by soil quality, grain bonding and density. Strong and complex material means not easily crushed and become more granular small, or deformed due to the influence of load or water. The biggest average of CBR is shown at Sukadana District with the 10% mixture, which gets 25,02% points. Also, the most prominent optimum water content is shown at Sungai Melayu Rayak District, which obtained 55,36% points.

The addition of cement to the soil tends to increase the bearing capacity of the soil. It is because cement can function as a binder between soil particles with chemical compounds contained in cement. Value-added bearing capacity of the soil against the addition of cement is

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caused by improved soil quality after mixing with cement. Until the ability of the soil to carry the load on it becomes more significant.

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