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Soil Classification and Correlation of Laboratory CBR Values with CBR Value from Subgrade DCP Test on Reconstruction Project of Mirit – Tambakmulyo Road Section, Kebumen, Central Java

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Abstract. The California Bearing Ratio (CBR) value has become the standard for determining the bearing capacity of soil, especially subgrade, in highway construction. Usually expressed as a percentage, the CBR figure can be obtained in the laboratory (CBR Lab) or the field through the Dynamic Cone Penetrometer (DCP) test. This study examines the relationship between the Laboratory CBR and the Field CBR from the results of the DCP test on 12 soil samples obtained at the research location on the Mirit - Tambakmulyo Road Section (Kebumen Regency, Central Java). The samples were then analyzed using a mathematical formula to obtain a regression equation and correlation value. Based on the AASHTO method, the soil at the research location is classified as A-6 soil type, namely clay soil, with a general assessment of moderate to poor subgrade. For the USCS method, the most dominant soil classification is CL: non-organic clay with low to moderate plasticity, gravelly clay, sandy clay, and dusty clay. The Laboratory CBR value was obtained from 5.59% to 7.90%. Two samples have a CBR Value <6.00%, namely Sample 10 and Sample 11. Meanwhile, for the CBR value from the DCP test in the field, the CBR range is 5.11% to 12.96%. There is only one sample with a CBR Value <6.00%, namely sample 5, which has a CBR figure of 5.11%. The CBR value of 6.00% is the minimum subgrade requirement in the Manual Desain Perkerasan 2024 released by the Indonesian Directorate General of Highways. From the results of the regression calculation and correlation of Field CBR to Laboratory CBR, the equation $y = -0.0614x + 7.1492$ is obtained with a correlation coefficient $(r) = -0.1862$. The correlation pattern obtained is a weak negative direct correlation. The coefficient of determination $(R^2) = 0.035$ indicates that the accuracy of the regression model is quite good. This study proves that the correlation between Field CBR value and Laboratory CBR is weak and not statistically significant.

Keywords: Laboratory CBR, DCP, Subgrade, Bearing Capacity

INTRODUCTION

The structural capability of flexible pavement combines the structural capability values of each constituent layer, which generally consists of four (4) layers, including subgrade, sub-base course, base course, and surface course. The four layers of flexible pavement construction have their respective functions (Bakri, 2020). The surface course is located at the top of the flexible pavement system, which structurally functions to receive and spread the load of passing vehicles to the layers below. The base course is located between the surface layer and the lower foundation layer, supporting the surface layer in receiving loads and transferring them to the lower foundation layer.

The sub-base course is located between the top foundation course and the subgrade. It serves to spread the wheel load to the subgrade. It also prevents groundwater from rising to the subgrade, the base surface for pavement construction. This layer can be formed from native or stabilized soil, depending on its capacity to support the load of the layers above it.

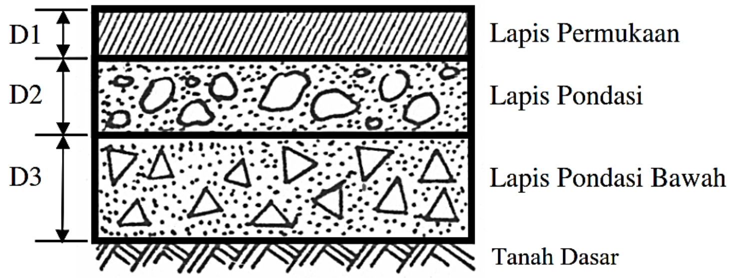

FIGURE 1. Pavement Layer Arrangement
(Public Works Department, 1987)

Judging from the function of each layer of the flexible pavement system, the bearing capacity of the subgrade has an important role in determining the thickness and type of material used in the layers above it. The strength and durability of the construction is highly dependent on the subgrade. Subgrade layers have specific requirements regarding the relationship between density and bearing capacity. Generally, issues concerning subgrade soils include deformation due to traffic loads, shrinkage-swelling properties due to changes in moisture content, bearing capacity, and the strength and durability of the construction (Nur et al., 2021).

The problem of soil deformation and capacity can be seen from the subgrade's bearing capacity, represented by the CBR (California Bearing Ratio) value, which can be obtained from laboratory tests and field tests. In contrast, soil expansion and shrinkage properties due to moisture content can be seen from the laboratory's plasticity index and physical soil test. Both support each other in assessing subgrade soils' characteristics and bearing capacity. Determination of subgrade soil type is classified by two standards, namely based on USCS (Unified Soil Classification System) and AASHTO (American Association of State Highway and Transport Officials) standards. This research aims to see the relationship or correlation between laboratory CBR data and CBR results from DCP tests in the field. In addition, this research also aims to see the type and classification of subgrade soil at the research site based on USCS and AASHTO standards.

Through their research, Darmawan et al. (2022) found an insignificant statistical relationship between Laboratory CBR and DCP Test Result CBR in the Nanga Pinoh – Ela Hilir – Central Kalimantan Border Road Construction Project 1. The subgrade soil type in the AASHTO classification system is A-2-4, namely gravel and silty or clayey sand. The correlation found in soil with an excellent classification as a subgrade has a weak positive direction. Burhanuddin & Junaidi (2018) conducted a similar study with ten samples taken on the Sp. Lamnyong – Lamreung (Aceh) road section found an insignificant relationship between the Laboratory CBR and the DCP Test Result CBR. Research on the relationship between laboratory CBR and field CBR has been widely conducted. However, the relationship pattern between laboratory CBR and field CBR cannot be generalized; the correlation at one location differs from the correlation pattern at another. This gap attracts researchers to study the correlation of Field CBR from DCP test results with Laboratory CBR. The following paragraph will discuss previous studies correlating laboratory CBR data with field CBR from DCP tests. While looking for the relationship pattern, samples are also analyzed and classified based on USCS and AASHTO. This can be seen as an added value of the writing rather than just a search for correlation.

This research was conducted on the Mirit – Tambakmulyo Road Reconstruction Project, Kebumen Regency, Central Java. The 26,9 km reconstruction road project was carried out under a multi-year contract scheme in 2023-2024 (Maharani & Alexander, 2023).

Subgrade Soil

The subgrade is the original soil surface excavation surface or compacted embankment surface and the basis for placement of the pavement structure above it (Kementerian Pekerjaan Umum dan Perumahan Rakyat Direktorat Jenderal Bina Marga, 2017). Subgrade capacity is always related to the bearing capacity of the soil to support the load above it.

A subgrade parameter often used to calculate the thickness of flexible pavement planning is the resilient modulus (M_R), which is the stiffness of the subgrade material. There is an approximation formula for the relationship between

CBR and the number M_R, namely M_R = 1500 x CBR (*psi*). For subgrade materials in the form of refined grains with CBR < 10, the AASTHO Guide proposes an approach with the formula M_R = 2555 x CBR 0,64 (*psi*) (Mantiri et al., 2019). The CBR value can be obtained by laboratory testing or field string.

CBR (California Bearing Ratio)

California Bearing Ratio (CBR) is a way of classifying the capacity of soil to be used as a foundation of a pavement structure (Bowles, 1981). The CBR value compares the test load and the standard load expressed as a percentage. The standard sample used is crushed stone in California. The comparison value or ratio is taken at penetrations of 2.5 and 5.0 mm, with the highest number used (Hatmoko & Suryadharma, 2020). The formula for determining the CBR number can be stated as follows (Darmawan et al., 2022):

$$CBR(\%) = \frac{Corrected\ load\ value}{standard\ load} x\ 100\% \qquad (1)$$

CBR testing under ideal conditions is conducted in a laboratory with specific density and moisture content conditions (Wilches et al., 2018). Several experiments were conducted using moisture content based on the field range and the optimum water content. In addition, soaking CBR testing was also carried out to obtain CBR values from soil samples that had been soaked for ± 96 hours (Badan Standarisasi Nasional, 2012). In addition to CBR testing in the laboratory, CBR values can also be obtained through field testing. One of them is DCP testing.

DCP (Dynamic Cone Penetration)

S. Wu and Sargand (2007) stated that the Dynamic Cone Penetration (DCP) test was first developed in South Africa by Dr. D. J. Van Vuuren in the 1960s to estimate the bearing capacity of subgrade materials for road pavement layers (Wilches et al., 2018). The test is carried out by recording the number of blows and penetration of the cone (metal cone) caused by the pounder. Recorded data in the form of penetration depth and the number of collisions are converted into CBR numbers using certain graphs and formulas. The DCP test provides the strength of the material layer to a depth of 90 cm below the surface without carrying out the type to the desired depth (Kementerian Pekerjaan Umum, 2010). The correlation graph of DCP and CBR numbers is shown in Figure 2.

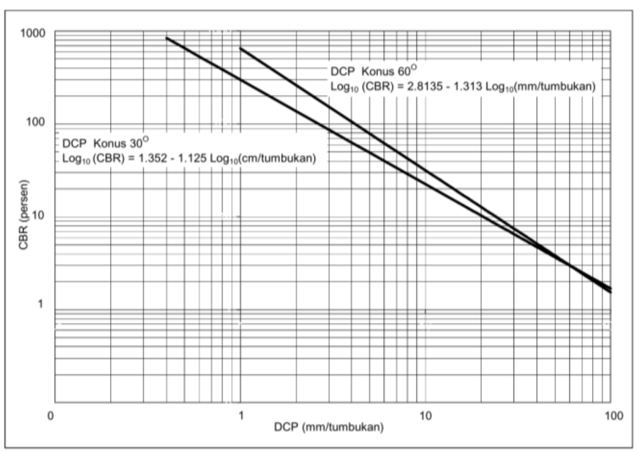

FIGURE 1. Relationship between DCP Value and CBR (Kementerian Pekerjaan Umum, 2010)

The relationship pattern between DCP and CBR is shown in the following formula:

- For a conus angle of 30°
  Log CBR = 1,352 - 1,125 (Log DCP)
- For a conus angle of 60°
  Log CBR = 2,8135 - 1,313 (Log DCP).

Regression and Correlation

Regression and correlation are statistical methods to analyze the relationship between two or more variables. The relationship is described in values between -1 and 1. The accuracy of the relationship is expressed in the coefficient of determination (R^2). Soewarno (1995) provides limitations on the value of the correlation coefficient as follows:

TABLE 1. Coefficient of Correlation and Strength of Relationship Between Variables (Darmawan et al., 2022)

Correlation Coefficient Value	Description
1	Perfect Positive Relationship
0,6 – 1	Positive Direct Relationship Good
0 – 0,6	Weak Positive Direct Relationship
0	There is no Linear Relationship
-0,6 – 0	Weak Negative Direct Relationship
-1 – -0,6	Negative Direct Relationship Good
-1	Negative Positive Relationship

Meanwhile, Marto (1996) provides the coefficient of determination (R^2), which states the accuracy of linear regression as follows:

TABLE 2. Linear Regression Accuracy Based on the Coefficient of Determination R2 (Darmawan et al., 2022)

R^2-Value	Regression Model Accuracy
< 0,25	Not Good
0,25 – 0,55	Relatively Good
0,56 – 0,75	Good
> 0,75	Very Good

METHODOLOGY

The research location is in the Mirit – Tambakmulyo Road section of STA. 0+000 to 26+900. The Mirit – Tambakmulyo section is in the administrative area of Kebumen Regency. Residents call it Deandels Road, part of the Jogja – Cilacap alternative road.

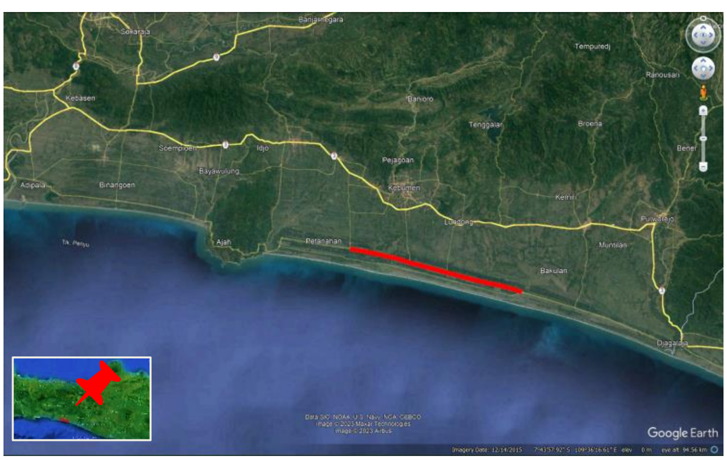

FIGURE 3. Location of Mirit - Tambakmulyo Road, Kebumen Regency, Central Java

A DCP test was conducted at the research site to determine the Field CBR Value. In addition, soil samples were taken to be tested in the laboratory to determine the classification and Laboratory CBR Value. Examination of soil properties and laboratory CBR testing was carried out at Semarang Univerity.

The research phase was divided into four stages as follows:

[1] Examination of soil physical properties:
- Water content
- Specific gravity
- Atterberg Limit

[2] Subgrade soil classification
- USCS
- AASHTO

[3] Examination of soil mechanical properties
  - Compaction Test
  - Laboratory CBR Test

[4] Analysis of field CBR data from DCP test results with laboratory CBR with linear regression and correlation models.

The data used in the study amounted to 12 sampling points. The distribution of the 12 data collection points is presented in Figure 4.

FIGURE 2. Distribution of Sample Points

The location coordinates are as follows:

TABLE 3. Sample Location Coordinates

Sample	Coordinates
1	7°48'24.54"S; 109°48'20.51"E
2	7°48'8.78"S; 109°47'16.66"E
3	7°47'55.57"S; 109°46'11.68"E
4	7°47'40.27"S; 109°45'6.74"E
5	7°47'22.21"S; 09°44'0.40"E
6	7°47'5.29"S; 109°42'56.50"E
7	7°46'38.33"S; 109°41'15.88"E
8	7°46'21.93"S; 109°40'12.51"E
9	7°46'1.52"S; 109°39'8.42"E
10	7°45'48.54"S; 109°38'4.26"E
11	7°45'33.04"S; 109°36'58.22"E
12	7°45'21.73"S; 109°35'54.05"E

RESULT AND DISCUSSION

Laboratory tests, including moisture content, specific gravity, and plasticity index, were conducted at the Soil Mechanics Laboratory of Semarang University for soil classification purposes. The test results are shown in Table 4. From Table 4, it can be seen that the 12 samples tested had specific gravity values between 2,591 and 2,696. Liquid limit values ranged from 30,38% to 38 25%. Plastic limit values were 17,09% to 20,74%, and plasticity index ranged from 12,71% to 19,26%.

TABLE 4. Soil Physical Properties
(PT. Morang Rekayasa Geoteknik, 2023)

No. Sample	w_{opt} (%)	Gs	LL (%)	PL (%)	IP (%)
1	21,39	2,620	32,18	19,09	13,09
2	20,61	2,669	35,19	20,21	14,98
3	20,47	2,637	35,70	20,74	14,96
4	18,80	2,665	33,78	18,24	15,54
5	23,92	2,637	30,38	17,09	13,29
6	24,10	2,688	35,06	20,32	14,75
7	20,35	2,651	36,05	20,20	15,85
8	20,71	2,688	31,38	18,00	13,38
9	18,28	2,696	30,53	17,81	12,71
10	22,66	2,603	37,64	20,07	17,57
11	24,63	2,591	38,25	18,99	19,26
12	19,76	2,694	35,00	20,09	14,91

TABLE 5. AASHTO Classification Results
(PT. Morang Rekayasa Geoteknik, 2023)

No. Sample	PL (%)	IP (%)	% Passed # 200	Classification
1	19,09	13,09	68,54	A-6
2	20,21	14,98	64,70	A-6
3	20,74	14,96	68,49	A-6
4	18,24	15,54	60,45	A-6
5	17,09	13,29	60,45	A-6
6	20,32	14,75	60,45	A-6
7	20,20	15,85	66,64	A-6
8	18,00	13,38	64,70	A-6
9	17,81	12,71	64,13	A-6
10	20,07	17,57	67,14	A-6
11	18,99	19,26	67,14	A-6
12	20,09	14,91	67,14	A-6

The soil type in the 12 research samples is fine-grained soil (silt and clay). AASHTO classifies fine-grained soil if the fine material (passing sieve no. 200) exceeds 35%. The silt and clay have a plastic limit of 17.09% to 20.74%. The plasticity index value ranges from 12.71% to 19.26%. This condition is by Soil A-6 in the AASHTO classification system, where the maximum plasticity limit value is 40%, and the minimum plasticity index value is 11%. Soil type A-6 generally assesses moderate to poor when used as subgrade soil. However, the performance of the subgrade in the flexible pavement system is still determined by the CBR value, which represents its bearing capacity.

TABLE 6. USCS Classification Result
(PT. Morang Rekayasa Geoteknik, 2023)

No. Sample	LL (%)	% Passed # 200	IP (%)	Classification
1	32,18	68,54	13,09	CL
2	35,19	64,70	14,98	CL
3	35,70	68,49	14,96	CL
4	33,78	60,45	15,54	CL
5	30,38	60,45	13,29	CL
6	35,06	60,45	14,75	CL
7	36,05	66,64	15,85	CL

No. Sample	LL (%)	% Passed # 200	IP (%)	Classification
8	31,38	64,70	13,38	CL
9	30,53	64,13	12,71	CL
10	37,64	67,14	17,57	CL
11	38,25	67,14	19,26	CL
12	35,00	67,14	14,91	CL

The composition of fine grains (material passing sieve no. 200) was predominantly found in 12 samples; this figure exceeds 50%, so the soil is classified as fine-grained soil. The liquid limit value of 12 samples is 30.38% to 38; 25% of this range is still below 50%. Meanwhile, the Plasticity Index ranges from 12.71% to 19.26%, above 7%. In the USCS classification system, this condition is grouped as CL (Clay Low Plasticity). This soil type is usually inorganic clay with low to moderate plasticity, gravelly clay, sandy clay, silty clay, or lean clay.

CBR Laboratory

The Immersion CBR Values from the laboratory test result are presented in Table 7.

TABLE 7. Laboratory CBR Value
(PT. Morang Rekayasa Geoteknik, 2023)

Nomor Sample	CBR Desain (%)
1	7,75
2	6,41
3	7,90
4	6,74
5	6,85
6	6,08
7	6,07
8	6,65
9	7,33
10	5,82
11	5,59
12	6,40

Based on the data from Table 6, the design CBR value obtained from the laboratory CBR test (immersion method) ranges from 5,59% to 7,90%. For all samples that the CBR lab measured, two samples had a figure <6%, namely sample 10 with a value of 5.82% and sample 11 with a value of 5.59%. The limit figure of 6% is the minimum value given by the Manual Desain Perkerasan Jalan 2024 issued by the Direktorat Jenderal Bina Marga, Kementerian Pekerjaan Umum dan Perumahan Rakyat. This manual is a reference for planning consultants for road pavement planning.

Field CBR

Dynamic Cone Pentrometer (DCP) tests were conducted in the field to obtain Field CBR figures. Field CBR results obtained from the DCP test are as follows:

TABLE 8. Field CBR from DCP Test
(PT. Morang Rekayasa Geoteknik, 2023)

Sample Number	D / n Average	Log CBR	CBR (%)
1	2,562	0,8923	7,8
2	1,632	11,127	12,96
3	1,96	10,232	10,55
4	2,791	0,8504	7,09

Sample Number	D / n Average	Log CBR	CBR (%)
5	3,734	0,7083	5,11
6	2,286	0,948	8,87
7	2,815	0,8464	7,02
8	2,832	0,8435	6,97
9	3,168	0,7887	6,15
10	2,473	0,9097	8,12
11	1,939	10,286	10,68
12	2,112	0,9867	9,7

Table 8 shows that the Field CBR values obtained from the DCP Test ranged from 5,11% to 12,96%. The CBR value from the DCP test results represents the field-bearing capacity of each test point. However, this value is very volatile considering external influences such as the accuracy of the sampling point, weather factors, and influences, calibration of test equipment, etc. The CBR value from the DCP test results can be considered for quick and urgent decision-making. However, confirmation from the laboratory CBR is required for more detailed results. This research studies the correlation of laboratory CBR with field CBR obtained from DCP Test Results.

Regression and Correlation Analysis

Based on the field CBR and laboratory CBR data obtained, a linear regression analysis was conducted to see the correlation between laboratory CBR and Field CBR. The relationship graph is presented in Figure 5.

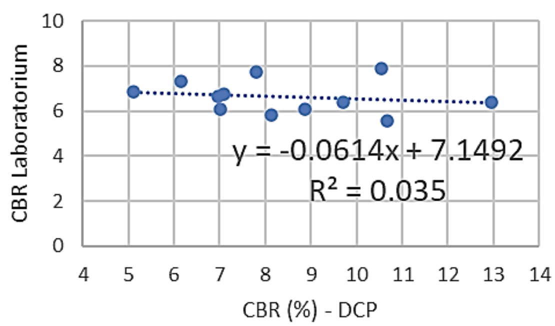

FIGURE 3. Graph of Relationship between Field CBR Value and Laboratory CBR
(Source: Analysis Result)

TABLE 9. Correlation Coefficient of Field CBR Value with Laboratory CBR
(Source: Analysis Result)

	CBR Lab	CBR DCP
CBR Lab	1	
CBR DCP	-0,18699	1

From the calculation results, the relationship between Field CBR Value and Laboratory CBR is y = -0,0614x + 7,1492 and has a correlation coefficient (*r*) -0.1862. Then, it can be concluded that the correlation between Field CBR value and Laboratory CBR is weak and not statistically significant. This condition occurs in soils classified as A-6 type soil (AASHTO) and CL soil in the USCS classification system. This study's results align with several previous studies that CBR Lab with CBR DCP results have a weak correlation and are not statistically significant. Other forms of correlation equations may be found in soils with other classifications and locations.

CONCLUSION

The conclusions that can be drawn from this research are presented in the following two points:

1. The soil classification obtained from the test results of soil physical properties is:
    a. Based on the USCS method, the most dominant soil classification is CL: non-organic clays with low to medium plasticity, gravelly, sandy, silty, and lean clays.
    b. Based on the AASHTO method, the soil at the study site is classified in soil type A-6, clayey soil, with a general assessment of moderate to poor subgrade soil.
2. The results of regression and correlation analysis calculations on Field CBR values from DCP Test and Laboratory CBR (immersion CBR) obtained the equation y = -0,0614x + 7,1492 with a correlation coefficient (r) = -0.1862. The correlation pattern obtained is weak negative direct. The coefficient of determination (R^2) = 0,035 indicates that the accuracy of the regression model is relatively good.
3. This research proves that no significant influence exists between the CBR numbers from the DCP test results and the Laboratory CBR at the research site.

Suggestions that can be given from the results of this study include

1. Based on the soil classification in the field using the AASHTO method, subgrade soil stabilization is required at the study site. Stabilization can be done with additives, replacement materials, or other supportive stabilization.
2. To obtain the soaking CBR value, it should be done carefully in the laboratory by taking soil samples from the site. Since the relationship is still negative, the Field CBR value from the DCP Test is only used as a comparison.
3. For future research, increasing the number of samples is necessary to obtain more accurate correlation coefficient (r) and determination coefficient (R^2) values.

REFERENCES

[1] Badan Standarisasi Nasional. (2012). SNI 1744:2012 Metode Uji CBR Laboratorium Badan Standardisasi Nasional. www.bsn.go.id

[2] Bakri, M. D. (2020). Analisis Tebal Perkerasan Lentur Menggunakan Metode AASHTO 1993. *Borneo Engineering : Jurnal Teknik Sipil*, *4*(1), 30–44. https://doi.org/10.35334/be.v4i1.1387

[3] Bowles, J. E. (1981). Manual de Laboratorio De Suelos en Ingenieria Civil. McGraw-Hill.

[4] Burhanuddin, & Junaidi. (2018). Hubungan Empiris Daya Dukung Tanah Dasar Menggunakan Alat Dynamic Cone Penetrometer (DCP) dan California Bearing Ratio (CBR) Rendaman untuk Desain Tebal Perkerasan Lentur Jalan Raya. *Jurnal Teknik Sipil Universitas Syah Kuala*, *1 Special Issue*(3), 553–558. https://doi.org/10.24815/jts.v1i3.9994

[5] Darmawan, T. N., Rustamaji, R. M., & Bachtiar, V. (2022). Korelasi Nilai CBR Laboratorium dan Nilai CBR Lapangan Dari Uji DCP Tanah Subgrade Pada Pembangunan Ruas Jalan Nanga Pinoh - Ela Hilir - Batas Kalimantan Tengah 1. *JeLAST: Jurnal PWK, Laut, Sipil, Tambang*, *9*(3). https://doi.org/http://dx.doi.org/10.26418/jelast.v9i3.57533

[6] Departemen Pekerjaan Umum. (1987). Petunjuk Perencanaan Tebal Perkerasan Lentur Jalan Raya Dengan Metode Analisa Komponen. Yayasan Badan Penerbit PU.

[7] Hatmoko, J. T., & Suryadharma, H. (2020). *Teknologi Perbaikan Tanah* (1st ed.). Penerbit Andi.

[8] Kementerian Pekerjaan Umum. (2010). Pedoman Cara Uji California Bearing Ratio (CBR) dengan Dynamic Cone Penetrometer (DCP).

[9] Kementerian Pekerjaan Umum dan Perumahan Rakyat Direktorat Jenderal Bina Marga. (2017). *Manual Desain Perkerasan Jalan*.

[10] Maharani, A. S. A., & Alexander, H. B. (2023, July 7). *Perbaikan Jalan Daendels Pansela Telan Rp 133,5 Miliar*. Kompas.Com. https://www.kompas.com/properti/read/2023/07/08/120000821/perbaikan-jalan-daendels-pansela-telan-rp-133-5-miliar

[11] Mantiri, C. C., Sendow, T. K., & Manopo, M. R. E. (2019). Analisa Tebal Perkerasan Lentur Jalan Baru Dengan Metode Bina Marga 2017 Dibandingkan Metode AASHTO 1993. *Jurnal Sipil Statik*, *7*(10), 1303–1316. https://ejournal.unsrat.ac.id/index.php/jss/article/view/26046/25685

[12] Nur, K., Mahyuddin, Bachtiar, E., Tumpu, M., Mukrim, M. I., Irianto, Kadir, Y., Arifin, T. S. P., Ahmad, S. N., Masdiana, Halim, H., & Syukuriah. (2021). *Perancangan Perkerasan Jalan* (A. Karim & J. Simarmata, Eds.). Yayasan Kita Menulis.

[13] Wilches, F. J., Jairo, J., Díaz, F., Rodrigo, J., & Ávila, H. (2018). Correlation Between California Bearing Ratio (CBR) and Dynamic Cone Penetrometer (DCP) for Soil from Sincelejo City in Colombia. *International Journal of Applied Engineering Research*, *13*(4), 2068–2071. http://www.ripublication.com