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Comparison Study Of Determination Of Field Cbr Values With Angkur And Dcp Equipment In Road Subgrade For Surabaya Road Development Planning

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Abstract

This study aims to evaluate the carrying capacity of the subgrade in the construction of road pavement by comparing the value of the California Bearing Ratio (CBR) of the field obtained from the CBR Angkur and Dynamic Cone Penetrometer (DCP) test. The quality of the subgrade is a crucial factor in determining stability and age of road pavement service, but often there are significant variations in the results of testing the carrying capacity of the soil between different methods. This study was conducted on Jl. Baruk Utara III, Kedung Baruk, Rungkut District, Surabaya, by collecting primary data from testing the physical and mechanical properties of the soil in the laboratory, as well as the CBR Angkur and DCP testing in the field. The results showed that the soil at the study site was classified as silt (OL) and A-4, with high water content (59.14%) and low plasticity, indicating weak carrying capacity. The CBR value of the field of the Angkur test is 2.53%, while the CBR design value of the DCP test ranges from 3.13%. Although there are numerical differences, the two methods consistently show that the subgrade has a low carrying capacity. This conclusion confirms the need for soil stabilization to ensure optimal and sustainable pavement performance.

Keywords: California Bearing Ratio, Dynamic Cone Penetrometer, Soil Carrying Capacity, Road Pavement, Soft Soil.

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INTRODUCTION

Soil is the basis of a structure or construction, both building construction or road construction, which often causes problems if it has poor properties. Poor and less favorable soil properties when used as a basis for a building or construction, including high plasticity, low shear strength, capacity or large volume changes and large potential for shrinkage flowers[1]. Road pavement is one of the key elements in modern infrastructure that sustain the wheels of the economy and facilitate human movements and goods. The quality and durability of road pavement is very dependent on subgrade or subgrade conditions that are the foundation. Unstable subgrade or low carrying capacity is a major cause of pavement structural failures, such as cracks, deformation, and surface decreases, which in turn can interfere with the smooth traffic and even endanger road users[2].

Conventionally, the method most often used to measure the carrying capacity of the subgrade is the California Bearing Ratio (CBR) test. The CBR value is an important indicator that measures the ratio of the ratio between the load needed to suppress the soil at a certain depth with the standard load needed to suppress the standard material with the same depth[3]. The high CBR value is a reflection of the carrying capacity of strong soil, while the low CBR value implies that the subgrade is not stable enough and requires special improvement efforts before the pavement construction can be continued[4]. CBR tests can be done both in the laboratory (CBR Lab) or directly in the field (CBR IN-situ). Although the Laboratory CBR test provides good conditions control, CBR tests in the field are often considered more relevant because they represent the actual soil conditions at the project site. One of the CBR testing techniques in the field is to use CBR Angkur tools. This method involves direct loading on the surface of the ground and is very suitable for testing on soils that have a variety of density levels

Nevertheless, the CBR Angkur test method does not escape the constraints. This testing process tends to take a long time, requires relatively large and heavy equipment, and becomes less practical if it must be applied to a very broad project area. These obstacles have encouraged engineers and researchers to find alternative testing methods that are more efficient, portable, and fast. One solution that has been proven effective and more used is the Dynamic Cone Penetrometer (DCP)[5]. DCP is a mild penetration test that is designed to determine the carrying capacity of the subgrade quickly. The principle of working is to drop a standard load from a predetermined height to push the konus end into the ground. The amount of collision needed to achieve a certain penetration is recorded, and this data is then used to calculate the value of empirical CBR through the correlation that has been validated by previous research[6]. The main advantage of DCP lies in its high portability, ease of operation, and its ability to provide a picture of a continuous variation of soil strength along the depth, making it an ideal choice for a fast and efficient field survey[7]. Many studies have indicated a strong correlation between the DCP value and the CBR value, which confirms the potential of DCP as a reliable tool for evaluating the carrying capacity of the soil in the field.

Various studies have been conducted to explore the use of different testing methods in evaluating the carrying capacity of subgrade. Panjaitan (2024), in his research on the Tebing Tinggi -Indrapura Toll Road project, showed that the DCP tool was very effective in identifying variations in the carrying capacity of the soil along the road corridor. Research by Winasis (2024) also emphasizes the importance of soil improvement analysis for weak subgrade, where the initial evaluation using tests such as DCP is a fundamental step. In line with that, Nababan, Akbar, and Tambun (2024) asserted that the identification of the characteristics of subgrade is essential to ensure the success of the road project. In addition, there are also studies that correlate the results of various tests, as did Alwi who discussed the correlation of the carrying capacity of the subgrade from the results of the sondir test, DCP, and Plate Bearing Test[8]. Sulistiawati, Goro, and Nurhadi (2024) also conducted an analysis of the correlation between the value of California Bearing Ratio (CBR) and the value of shear strength in soft soils [9]. With a comprehensive comparative study, it is expected to find a clear and strong correlation between the results of the two tests. If a significant correlation can be proven, this will validate the use of DCP as a more efficient and practical evaluation method in road pavement projects[10].

At the international level, several studies have validated the DCP–CBR correlation and further contextualized the limitations of each method. Chokkerd et al. (2024) [10] proposed recalibrated DCP–CBR correlations for three soil groups (clean sand, silty sand/sandy silt, and cohesive soil), reporting R^2 values of 0.89, 0.92, and 0.94, respectively, which demonstrates that the reliability of the DCP–CBR correlation is highly dependent on soil type. For cohesive and fine-grained soils such as those found at the current study site (OL/A-4 classification), the correlation coefficient is relatively high (0.94), which supports the use of DCP as a reliable surrogate for CBR Angkur in soft silt environments. Meshram (2022) [7] similarly confirmed that field CBR estimated from DCP produces results within an acceptable range of ±15% compared to static CBR Angkur measurements, provided that seasonal correction factors are applied—consistent with the approach adopted in this study. Katte et al. (2019) [5] further showed, across multiple subgrade soil types in Cameroon, that CBR values derived from both static penetration (similar to Angkur) and dynamic tests are strongly influenced by moisture content; soils with water content exceeding 55% exhibited CBR reductions of up to 40% compared to dry-side conditions, which directly explains the low CBR values observed in this study given the 59.14% water content. In terms of limitations, the CBR Angkur method's primary weakness lies in its inability to capture stratigraphic variation along the depth, as it records a single representative value from the surface zone. This can lead to overestimation or underestimation of subgrade strength in layered soil profiles. The DCP, while advantageous for depth profiling, is limited by its sensitivity to gravel or rock fragments that can cause erratic penetration readings, and its empirical conversion formulas carry inherent uncertainty when applied to soils outside the database used for calibration. In the context of this study, conducted on homogeneous soft silt, these limitations are relatively minor, but should be acknowledged when extrapolating the results to other site conditions.

Soil classification is the process of grouping soil based on its physical and mechanical properties. This classification system helps engineers to predict soil behavior and determine the right treatment[11]. For example, in the AASHTO (American Association of State Highway and Transportation Official) and USCS (Unified Soil Classification System)[12]. Each group has different characteristics, for example, clay or silt has plasticity and carrying capacity that is different from sandy soil [13]. By knowing the land classification, we can make a more appropriate decision regarding the foundation design and road pavement needed [14].

The research location located on Jl. Baruk Utara III, Kedung Baruk, Rungkut District, Surabaya, was chosen because the condition of the soil was indicated as soft soil. Soft soils are known to have low carrying capacity and are vulnerable to decline, making it an ideal subject for this research. Therefore, this study aims to evaluate the carrying capacity of the subgrade at the location using two test methods, namely the California Bearing Ratio (CBR) with an April in the field and Dynamic Cone Penetrometer (DCP). By comparing the results of these two methods, it is hoped that a comprehensive understanding of the soil conditions and its implications can be obtained on road pavement planning, as well as providing recommendations for improvement needed to ensure the stability and security of infrastructure in the future.

METHOD

So that the objectives of this study can be achieved effectively, a structured and comprehensive research method is used. This methodology includes systematic steps in examining the problem, starting from the initial preparation, the implementation of testing in the field, sampling, testing in the laboratory, data processing, to data analysis to get valid and accountable answers. In this study, the approach used was a comparative descriptive method, which focused on the comparison of test results carried out in the field and in the laboratory. The data used is primary data collected directly from the study site. This study lasted for three months, namely from November to January. Soil sampling and testing in the field was carried out on Jl. Baruk Utara III, Kedung Baruk, Rungkut District, Surabaya. Meanwhile, laboratory testing and the entire data analysis process was carried out at the Widyagama University Laboratory Building Malang, which is located on Jl. Borobudur Indah Park No. 1, Mojolangu, Lowokwaru District, Malang City, East Java.

Before testing in the field and the laboratory is carried out, the pre-research stage is carried out to take samples and plan the process. This stage includes observations of the California Bearing Ratio (CBR) test, the Dynamic Cone Penetrometer (DCP), and the soil physical properties in the laboratory. This pre-research is crucial to ensure that research is structured and on target, and accelerate the process of collecting primary data.

The tools and materials used in this study were also prepared carefully. The tools needed for the CBR test include CBR Jack, Swivel Head, Pipe Set, Loads, Aid Bridge, Proving Ring, Penetration Dial, Magting Dial Holder, and Stopwatch. For the DCP test, the tools used are set with dynamic cone penetrometers, pockets of tools, and conus. Soft soils are chosen because they tend to decrease easily when receiving loads due to low carrying capacity, and water is used as a mixture to facilitate soil management.

The testing procedure is carried out in several stages after getting a soil sample in the field. First, the physical properties of the soil are tested in the laboratory for classification. Second, the mechanical properties are tested both in the laboratory and in the field to get the CBR value from both tools. The tests carried out include testing water content to determine the water content in the soil[15], Content weight test to determine the weight per unit volume [16], Test the specific gravity for the ratio of the weight of solid grains with water weight, liquid and plastic limits to determine the plastic properties of the soil [17], California Bearing Ratio (CBR) test to measure the carrying capacity of the subgrade, the Dynamic Cone Penetrometer (DCP) test to determine the CBR subgrade and sub-base values.

The water content test procedure includes weighing empty cups, weighing cups with wet soil samples, drying it in the oven at 110 ° C for 16-24 hours, and weighing it back. The content test procedure includes measuring and weighing the ring, filling with soil samples, weighing again, drying in the oven, and weighing it again after cold. The specific gravity test involves the use of measuring flask, soil samples, and distilled water to determine the ratio of the weight of solid grains. The liquid boundary test is carried out with a liquid boundary to determine the water content when the soil starts to flow. The plastic limit test is carried out by rolling the ground to a diameter of 3 mm to determine the water content when the soil starts to crack. The CBR test procedure in the field involves the use of CBR Angkur tools to press the soil and record the necessary loads. The DCP test was carried out by colliding the hammer in the conus and recording the penetration that occurred. After all tests are complete, data are analyzed with literature studies, primary data collection, and average test comparison method to determine the difference in CBR value. This analysis will be the basis for drawing conclusions and provide advice.

RESULT AND DISCUSSION

This section presents integrated research results obtained from a series of tests, both in the laboratory and in the field, as well as discussing the interpretation and implications. This study focuses on evaluating the carrying capacity of the subgrade using two main methods: California Bearing Ratio (CBR) test with an Angkur and Dynamic Cone Penetrometer (DCP) test. The study location, which is located on Jl. Baruk Utara III, Kedung Baruk, Rungkut District, Surabaya, has unique soil characteristics, where all physical and mechanical test data will be the basis of this discussion.

1. Laboratory test

Testing in the laboratory is carried out to determine the basic characteristics of the soil, which includes physical and mechanical properties. These results become the foundation to understand the behavior of land in the field and interpret data from the field test. Can be seen data from the results of testing the physical properties of soft sauce soil as in Table 1.

Table 1 Test of Soil Physical Properties

<table>
<tr><th>No</th><th colspan="2">Properties</th><th>Land Gedung Baruk Surabaya</th></tr>
<tr><td>1</td><td colspan="2">Water Content</td><td>59.14</td></tr>
<tr><td>2</td><td colspan="2">Specific Gravity</td><td>2.17</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">Soil Volume Weight</td><td>γb (gr/cm³)</td><td>1.44</td></tr>
<tr><td>γd (gr/cm³)</td><td>1.19</td></tr>
<tr><td rowspan="3">4</td><td rowspan="3">Atterberg Limits</td><td>Liquid Limit (%)</td><td>55.82</td></tr>
<tr><td>Plastic Limit (%)</td><td>50.00</td></tr>
<tr><td>Plasticity Index (%)</td><td>5.82</td></tr>
<tr><td rowspan="2">5</td><td rowspan="2">Classification</td><td>Unified System</td><td>LO</td></tr>
<tr><td>AASHTO System</td><td>A-4</td></tr>
</table>

Based on the data listed in Table 1, the results of testing the physical properties of the soil at the study site showed several important parameters. The water content of the soil is recorded at 59.14%, a very high value and indicates that the soil is in a water saturated condition. This condition directly affects the strength and stability of the soil, because excess water can reduce the bond between soil particles, so that the carrying capacity decreases.

Wet Contents Weight (γB) measured soil of 1.44 gr/cm^3, while dry contents weight (γd) is only 1.19 gr/cm^3. This significant difference between the weight of wet and dry content confirms that most of the soil volume consists of water. The specific gravity value of soil particles (specific gravity) of 2.17 is still within the normal range for mineral soil, which confirms that soil solid particles have no composition that is too dense or too light.

The characteristics of soil consistency are also evaluated through Atterberg limits. Liquid Limit (LL) This soil is 55.82%, while the plastic limit (plastic limit/PL) is 50.00%. From these two values, the plasticity index (plasticity index/pi) is obtained by 5.82%. Low PI values indicate that this soil has a low plasticity. Based on soil classification, this result places soil at the study site in the category of silt and organic-based clay with low plasticity (OL) according to the unified system. Meanwhile, based on the AASHTO system, this land is classified as A-4. This classification is consistent with the characteristics of fine grained soils that tend to have low carrying capacity, especially in water saturated conditions[18].

2. Field Test

Field testing is carried out to evaluate the carrying capacity of the soil in its original condition, which is more representative for road pavement planning. The two main tests in the field are CBR Field, and Dynamic Cone Penetrometer (DCP).

a. California Bearing Ratio (CBR) Field

Table 2. Field CBR Test Results Using Angkur Equipment on Soft Silt Soil at Jl. Baruk Utara III, Surabaya (0% Lime Mixture) — showing penetration time, piston decrease (inch), dial reading (DIV), and applied load (lbs) at each penetration interval, measured in accordance with SNI 1738:2011

PENETRATION			
Time (Minutes)	**Penetration (inch)**	**Dial Reading (DIV)**	**Load (LBS)**
0.25	0.0125	3	32.48
0.5	0.0250	4	43.31
1	0.0500	6	64.97
1.5	0.0750	6	64.97
2	0.1000	7	75.79
3	0.1500	9	97.45
4	0.2000	10	108.28
6	0.3000	12	129.93

CBR Field is a testing method to determine the carrying capacity and strength of the land in the fiel [19]. Field CBR is defined as the ratio between the stress of penetration of a pavement of pavement and stress in penetration of standard materials at the same depth and penetration speed, expressed in the form of percent[20]. Calculation using standard SNI 1738:2011 [21]. For CBR test data displayed in Table 2, as well as the following calculations:

$$0,1 = \frac{p(lb)}{3x1000}\, x\ 100\% \quad (1)$$

$$0{,}2 = \frac{p(lb)}{3\ x\ 1500}\ x\ 100\% \quad (2)$$

Dimana:

P = Beban pada piston penetrasi 0,1 inch dan 0,2 inch.

$$0{,}1 = \frac{75.79}{3\ x\ 1000}\ x\ 100\% = 2.53\%$$

$$0{,}1 = \frac{108.28}{3\ x\ 1500}\ x\ 100\% = 2.41\%$$

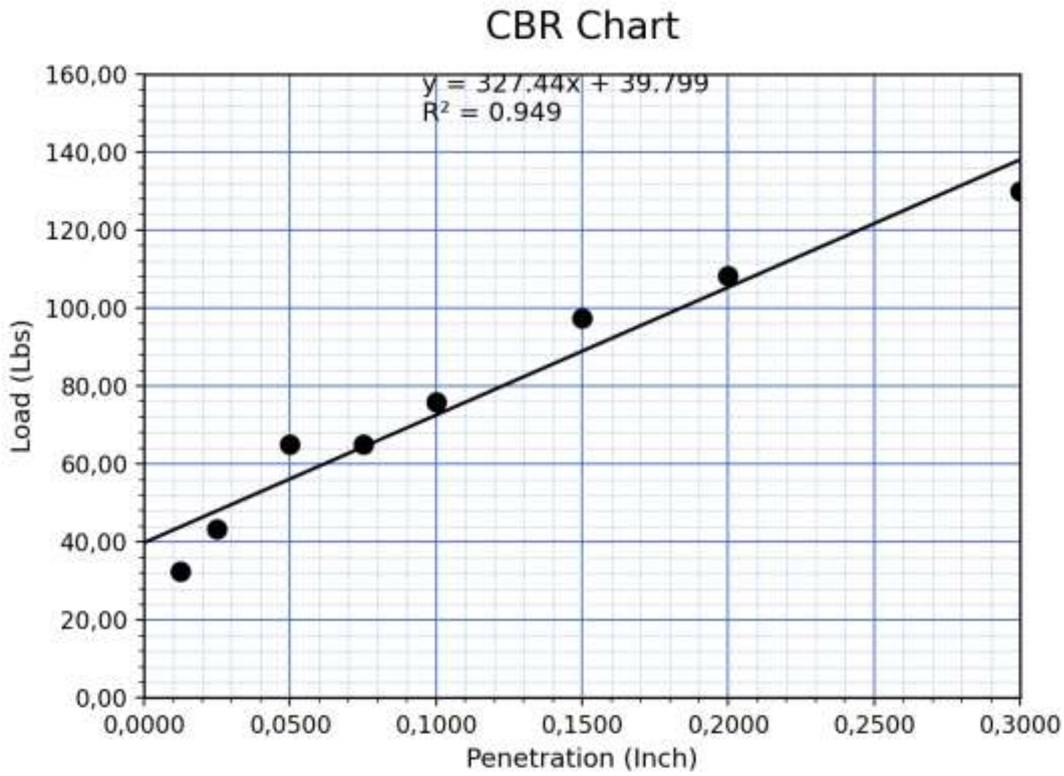

Figure 1. CBR Testing Graph

Based on Table 2 and Graph 1, the Field CBR value obtained is 2.53%. This value, according to AASHTO standards, places land in the study site in the "Weak Subgrade" category or weak subgrade, because the CBR value is less than 6%. Soil with this lowest carrying capacity is not recommended to be used as a basic layer of road pavement without any improvement or stabilization.

Graph 1 shows the relationship between the load given and the decrease (penetration). The curve in this graph tends to increase slowly, which reflects the low carrying capacity of the soil. This curve provides visual evidence that the soil is unable to withstand significant loads without experiencing a large deformation. Various factors, such as high water content, density that is not optimal, and fine - grained soil type, contribute to the low CBR value.

b. DCP (Dynamic Cone Peneumeter)

The carrying capacity of the subgrade is calculated based on the processing of the test results carried out by measuring how deep (mm) the end of the conus enters the subgrade. Correlation between the number of collisions and penetration of the conus end of the dynamic cone penetrometer (DCP) tool into the soil will give a picture of the strength of the subgrade at certain points, this test is carried out covering 4 test points.

Table 3. DCP Test Results at Point 1: Number of Blows, Cumulative Penetration (mm), DCP Index (mm/blow), Estimated CBR (%), and Subgrade Layer Thickness Classification — used to evaluate the bearing capacity profile of the subgrade at successive depth intervals in accordance with Manual Desain Perkerasan Jalan No. 02/M/BM/2024

Many Collisions	Cumulative collision	Penetration (mm)	Cumulative penetration (mm)	DCP (mm / tumbuk)	CBR (%)	Subgrade layer (mm)
0	0	40	0	0.00	0.00	h1 = 250
1	1	90	50	50.00	3.83	
1	2	140	100	50.00	3.83	
1	3	190	150	50.00	3.83	
1	4	230	190	47.50	4.09	
1	5	290	250	50.00	3.83	
1	6	340	300	50.00	3.83	h2 = 380
1	7	390	350	50.00	3.83	
1	8	420	380	47.50	4.09	
1	9	460	420	46.67	4.19	
1	10	520	480	48.00	4.04	
1	11	560	520	47.27	4.12	
1	12	610	570	47.50	4.09	
1	13	670	630	48.46	3.99	
1	14	710	670	47.86	4.05	h3 = 80
1	15	730	690	46.00	4.27	
1	16	740	700	43.75	4.56	
1	17	750	710	41.76	4.85	
Sum of Penetration		**7880**				

The Dynamic Cone Penetrometer (DCP) test is a fast and efficient method for measuring the carrying capacity of the soil in the field. This test measures the depth of conus penetration per collision, which is then converted into CBR value using empirical correlation. Based on table 3 the data shows the variation of soil strength along the depth.

DCP test results must also be adjusted to the condition of the season during testing. Based on the road pavement design manual No. 02/M/BM/2024 [20], DCP testing conducted in the dry season must be multiplied by a minimum adjustment factor of 0.7 (Table 4).

Table 4 Factors of Adjusting the Modulus of the Subgrade to Season Conditions

Season	The minimum adjustment factor for the CBR value based on DCP testing
Rainy season and saturated land	0,9
Transition period	0,8
Dry season	0,7

Table 5 CBR Value DCP results on season conditions

Point	CBR Represents (%)	The minimum adjustment factor for the CBR value based on DCP testing	CBR (%)
1	2,42	0,7	1,69
2	6,37	0,7	4,46
3	5,98	0,7	4,18
4	3,10	0,7	2,17
Average CBR value			3,13

By using the formulas given, the CBR value of each layer is calculated. Based on Table 5, the representative CBR value is 2.42%. After being adjusted to the seasonal factor, the CBR value of the design is to 1.70%. The average CBR design value of the four DCP test points is 3.13%.

This DCP result shows that the resulting CBR value, although it has a different average, remains in a low range. These values confirm the findings of the CBR Angkur test that the subgrade at the study site has a weak carrying capacity. The DCP test provides more detailed data on variations of soil strength in each layer, which is very useful for more appropriate pavement planning. This data shows that although there are variations in the CBR value between the test points, overall, the land in this location has a low carrying capacity characteristics.

c. Comparison and discussion of test results

After the analysis process, the results of the two test methods, namely CBR Angkur and DCP, are consistent in showing that the land on Jl. Baruk Utara III, Kedung Baruk, Rungkut District, Surabaya, has a low carrying capacity. The Field CBR value of CBR Angkur is 2.53% in line with the average CBR design value of DCP which ranges from 3.13%. Although there is a slight numerical difference, both of these values lead to the same conclusion: the subgrade in this location is included in the weak category and requires improvement.

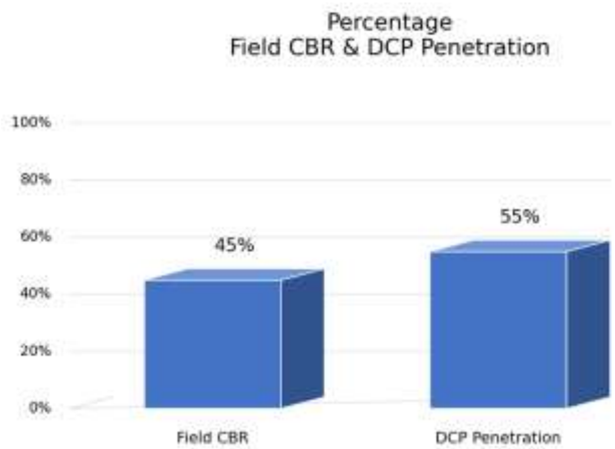

Figure 2. Comparison of CBR Values (%) Between CBR Angkur Field Test (2.53%) and Average DCP Design CBR (3.13%) at Jl. Baruk Utara III, Surabaya — both methods indicate weak subgrade classification (CBR < 6% per AASHTO M145). The DCP value is the seasonal-corrected average of four test points; the CBR Angkur value represents the governing penetration at 0.1 inch.

The difference in value between CBR Angkur and DCP can be explained by several factors. The CBR Angkur test measures the strength of the soil below the static load, while the DCP measures the soil response to the dynamic load. This difference in principle can produce variations in data. In addition, the DCP test provides a more detailed picture of the variation of soil strength along the depth, which may not be recorded by the CBR Angkur test which is more focused on one point. However, the most important thing is that these two methods, although different in technical details, provide convergent results. Figure 2 illustrates three key observations that warrant detailed discussion: (1) The CBR Angkur value (2.53%) is slightly lower than the average DCP design CBR (3.13%), with a difference of approximately 0.60 percentage points (23.7% relative gap). This divergence is consistent with the findings of Meshram (2022) who reported that static CBR tests on saturated cohesive soils tend to produce slightly lower values than dynamic penetration-based estimates, owing to the pore water pressure build-up during static loading that reduces effective stress and hence apparent soil stiffness. (2) The DCP test results show spatial variation between the four test points (Point 1: 1.69%, Point 2: 4.46%, Point 3: 4.18%, Point 4: 2.17% after seasonal correction), with a coefficient of variation suggesting moderate heterogeneity in the subgrade. This spatial variation is not captured by the single-point CBR Angkur test, which represents only one location. For design purposes, using the single Angkur value may be conservative at the specific test location but could be non-representative for the full road corridor. (3) Both the CBR Angkur value (2.53%) and the average DCP design CBR (3.13%) fall well below the minimum recommended CBR for subgrade without improvement (CBR ≥ 6% per Pt T-14-2003 and Manual Desain Perkerasan No. 02/M/BM/2024), confirming that soil stabilization or other reinforcement measures are necessary before pavement construction can proceed. The converging classification of the subgrade as “Weak” or “Poor” by both independent methods substantially increases the reliability of this conclusion.

The results of laboratory testing also support this finding. Soil classification as A-4 and OL indicates fine grained soils with low plasticity which inherent have limited carrying capacity. The results of this study provide a comprehensive understanding of the characteristics of the soil at the study site. Both laboratory and field data, both from the CBR Angkur and DCP tests, all show that the subgrade at this location has a low carrying capacity. Therefore, in the planning of road pavement construction in this area, it is highly recommended to carry out land stabilization or other improvements to increase its carrying capacity. The use of DCP, with its ability to provide rapid and detailed data on variations of soil strength, can be a very useful tool in the initial planning stage.

CONCLUSION

Based on the analysis of laboratory and field testing conducted on Jl. North Baruk III, Kedung Baruk, Rungkut District, Surabaya, it can be concluded that the soil at the study site is classified as a fine grained soil with the classification of sof-organic and a low-clasic-covered clay (OL according to Unified and A-4 according to Aashto), and has very high water content (59.14%) which shows the condition of water saturated and negative impact on the strength of the soil. The results of the Field CBR testing using an Angkur device showed a value of 2.53%, which indicated a very weak subgrade, and was strengthened by the results of the Dynamic Cone Penetrometer (DCP) test which produced the CBR design value between 3.13%. Although using a different approach (static vs. dynamic), both methods show consistent results that the carrying capacity of the soil is very low. Therefore, it is highly recommended to stabilize soil using additional materials such as lime, cement, or other chemical materials so that the CBR value meets the requirements of road construction design, as well as ensuring subgrade compaction reaches a minimum of 95% of the maximum dry density to avoid future decline and deformation. In addition, the use of sondir tests and advanced laboratory testing in the planning stage will help obtain a deeper understanding of the soil characteristics, and the use of DCP tools is recommended for initial surveys in a large area due to its speed and effectiveness in identifying areas with the weakest carrying capacity.

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