

Research Article

Comparison of Field and Laboratory Soil Stability Values on the Soko - Tuban Road

Mohammad Zainul Ikhwan*, Toni Budi Santoso

Faculty of Civil Engineering, Universitas Bojonegoro, Bojonegoro, Indonesia, 71088

*Corresponding Author: zaeny.ikhwan@gmail.com | Phone: +628113631160

ABSTRACT

The good Soko-Tuban road experienced damage that disrupted comfort. The results showed that the test soil included organic clay with an average density of 2.33 gr/cm³ and a water content of 43.19%. The liquid limit value was 77.33%, the plastic limit was 32.7%, and the plasticity index was 44.63%. DCP testing was carried out on two samples with different road conditions, namely at STA 7+100 and 7+200 (good road) and STA 7+800 and 7+900 (damaged road). The CBR value at STA 7+100 on the east side was 12.09% and 7+200 on the west side was 9.87%. At STA 7+800, the CBR value on the east side was 5.23% and STA 7+900 on the west side was 10.59%. The laboratory CBR value was taken from two samples with three variations of impacts 10x, 30x, and 65x. In good road conditions at STA 7+100 the highest average CBR value is 17.12%. In damaged road conditions at STA 7+800 the average CBR value is 11.52%. The significant difference in laboratory and field CBR values is influenced by road conditions and soil characteristics.

Keywords: Soil Condition; DCP; CBR; Laboratory Soil; Tuban Road; Soko

1. INTRODUCTION

Roads are vital infrastructure that play a fundamental role in supporting community mobility and driving economic activity across various sectors (Winardi et al., 2019). These linear transport systems are not only essential for connecting people and places, but also serve as the backbone of regional and national development. Their existence ensures accessibility between regions, facilitates the efficient distribution of goods and services, stimulates local economies, and enables individuals to perform daily activities such as commuting, trade, education, and healthcare. In essence, roads function as physical enablers of social and economic interaction. One of the critical components of effective road infrastructure is its quality. High-quality road construction promotes smooth traffic flow, minimizes vehicle operating costs, and ensures both comfort and safety for all road users. Conversely, roads that are poorly built or inadequately maintained can lead to disruptions in transportation, increased accident rates, damage to vehicles, and broader economic inefficiencies.

Unfortunately, in many regions particularly in rural and developing areas poor road conditions remain a persistent problem. Roads with uneven, bumpy, or damaged surfaces are a common sight, creating discomfort for drivers and passengers alike. More importantly, such conditions can present serious hazards, including loss of vehicle control, increased braking distances, and heightened risk of accidents (Angelia Safitra et al., 2019). One notable case of recurring road deterioration is found on a road segment along Jalan Raya in Simo Village, located in the Soko Subdistrict (Ikhwan, 2019), Tuban Regency (Sumarsono & Fauziah, 2022). This segment has become well-known among local residents and road users for its frequent damage, especially in the form of wave-like surface deformations that compromise driving comfort and vehicle stability (Harahap, 2022). Despite repeated repair efforts by local authorities, the same issues continue to emerge over time. Community reports indicate that repairs tend to offer only temporary relief and fail to address the underlying causes of failure (Sugiarto, 2016).

The persistence of road damage in this area suggests deeper, systemic issues that go beyond superficial wear and tear. Several contributing factors can be identified, including unstable subgrade soil conditions, suboptimal design and construction practices, lack of proper compaction techniques, and the impact of increasing traffic volumes—particularly heavy vehicles that exceed load capacity limits (Binamarga, 2017). Inadequate drainage and environmental conditions such as excessive rainfall or erosion may further exacerbate the deterioration process. These multidimensional factors underscore the necessity of a more comprehensive and scientific approach in addressing road failures. Without identifying and correcting the root causes, repair efforts are likely to be inefficient, repetitive, and financially wasteful.

One of the most effective ways to diagnose subgrade problems and assess the suitability of the existing soil for road construction is through geotechnical evaluation. In this regard, the California Bearing Ratio (CBR) test is widely recognized as a standard method for evaluating the strength and load-bearing capacity of subgrade materials (Darwis & Mulya, 2021). The CBR value obtained from testing provides crucial data that guides the design thickness of pavement layers. CBR testing can be conducted in controlled laboratory settings or directly in the field using the Dynamic Cone

Penetrometer (DCP), a practical and efficient tool for obtaining real-time soil strength profiles at various depths. These results help engineers understand whether the subgrade is capable of supporting the expected loads or if further stabilization, such as soil improvement or reinforcement, is required.

As highlighted by Thamrin (2018), incorporating CBR analysis into the early stages of road planning and rehabilitation is not only technically sound but also economically prudent. It allows for more targeted interventions that address the actual needs of the subgrade, thereby reducing the likelihood of repeated damage and extending the service life of the pavement structure. In conclusion, the integration of scientific testing and engineering analysis—such as CBR evaluation is essential in crafting long-term, sustainable road improvement strategies, especially in areas where chronic road damage has become a norm.

2. RESEARCH METHOD

This research adopts a quantitative analysis approach as the primary method to evaluate the level of soil stability on the Soko Tuban road segment. The main objective of this analysis is to determine the bearing capacity and structural reliability of the subgrade soil, which is a crucial factor in ensuring long-term road performance. The research methodology involves conducting both laboratory-based California Bearing Ratio (CBR) tests and field-based Dynamic Cone Penetrometer (DCP) tests at selected points along the study site. These two methods are employed to obtain comprehensive and comparative data on soil strength both under controlled laboratory conditions and in the actual field environment. At this stage, the data analysis process is designed to systematically address the core research questions posed in the formulation of the problem. The analysis is focused on two primary aspects:

1. Analyzing the CBR values obtained through laboratory testing to assess the soil's load-bearing capacity, and comparing these results with DCP test values taken directly from the field at the Soko Tuban road section.
2. Identifying and interpreting the physical properties and engineering characteristics of the soil at the site under investigation, including parameters that may influence soil strength and behavior under load.

In alignment with the descriptive-comparative nature of the study, the data analysis method involves comparing the stability values of the soil derived from both the CBR and DCP tests conducted specifically at the Soko–Tuban road located in Simo Village (Permatasari, 2021). Through this comparative analysis, the study aims to reveal the consistency and correlation between laboratory and field data, which is essential for validating test results and improving the accuracy of engineering assessments.

The entire testing process was conducted at the Civil Engineering Laboratory of Bojonegoro University, where standard procedures were followed to ensure the reliability and validity of the results. Laboratory testing of the soil's physical properties included the measurement of natural water content, determination of specific gravity, and the assessment of the Atterberg limits—namely, the plastic limit and liquid limit. These parameters play a significant role in classifying the soil type and understanding its plasticity and moisture-related behavior, which are critical for roadbed construction. The combined results of these tests offer a comprehensive overview of the soil's performance characteristics and serve as a basis for future recommendations regarding road improvement or reconstruction.

3. RESULTS AND DISCUSSION

1. Soil Moisture Content Testing (ASTM D854-71)

Table 1. Soil Moisture Content Testing

Samples	Units	1	2	3
Weight of cup (w1)	gr	14,99	14,43	15,00
Weight of cup + soil (w2)	gr	45,69	50,96	39,69
Weight of cup + dry soil (w3)	gr	35,44	40,62	32,64
Dry soil weight (Ws)	gr	20,45	26,19	17,64
Water weight (Ww)	gr	10,25	10,34	7,05
Moisture content (W)	%	50,12	39,48	39,97
Average moisture content	%		43,19	

Sources: Test Results 2025.

Based on the results of testing the soil moisture content of soil samples taken directly from the field obtained an average moisture content of 43.19%.

2. Soil Specific Weigh Testing (ASTM D854-91)

Table 2. Soil Specific Weight Testing

No	Description	Units	Sample		
			1	2	3
1	Weight of Pycnometer (W1)	gr	55,38	53,24	56,36
2	Weight of Pycnometer + Sample (W2)	gr	80,38	81,15	81,36
3	Weight of Pycnometer + Sample + Water (W3)	gr	169,10	169,27	168,89
4	Weight of Pycnometer + Water (W4)	gr	153,89	154,49	154,75
5	Temperature (t)	C°	20,00	20,00	20,00
6	A = W2 - W1	gr	25,00	27,91	25,00
7	B = W3 - W4	gr	15,21	14,78	14,14
8	C = A - B	gr	9,79	13,13	10,86
9	Specific gravity (Gs = A/C)	gr	2,55	2,13	2,30
10	Average Specific gravity	gr		2,33	

Sources: Test Results 2025

Based on **Table 2**, the conclusion can be drawn that the average specific gravity of the test soil is 2.33 gr/cm³. Based on the classification of soil by specific gravity, the soil is categorized as organic clay because it has a specific gravity of 2.33 gr/cm³, which is close to 2.58 gr/cm³.

3. Plastic Limit Test (ASTM C-4318)

Table 3. Plastic Limit Test

Sampel	Units	1	2
Weight of Wet Soil + Container (W1)	gr	30,00	30,00
Weight of Dry Soil + Container (W2)	gr	26,23	26,35
Container Weight (W3)	gr	14,44	15,14
Water Weight (Ww=W1 - W2)	gr	3,77	3,65
Dry Soil Weight (Wd = W2 - W3)	gr	11,79	11,21
Moisture Content (Ww/Wd x 100%)	%	31,98	32,56
Average Moisture Content	%		32,27

Sources: Test Results 2025

Based on the **Table 3**, it can be concluded that the two samples taken have reached a twist diameter of about ± 3 mm. The average moisture content of the two samples was 32.7%.

4. Plastic Limit Test (ASTM D-4318)

Table 4. Liquid Limit Test Results

Sample	Units	1	2	3	4
Number of Blows	-	19	23	32	43
Weight of Wet Soil + Container (W1)	gr	35,4	36,02	37,02	38,24
Weight of Dry Soil + Container (W2)	gr	25,2	26,22	28,02	29,84
Weight of Container (W3)	gr	14,19	14,12	14,45	15,15
Water Weight (Ww=W1-w2))	gr	10,2	9,8	9	8,4
Dry Soil Weight (Wd=W2-W3)	gr	11,01	12,1	13,57	14,69
Moisture Content (Ww/Wd x 100%)	%	92,64	80,99	66,32	57,18
Average	%		74,28		

Sources: Test Results 2025

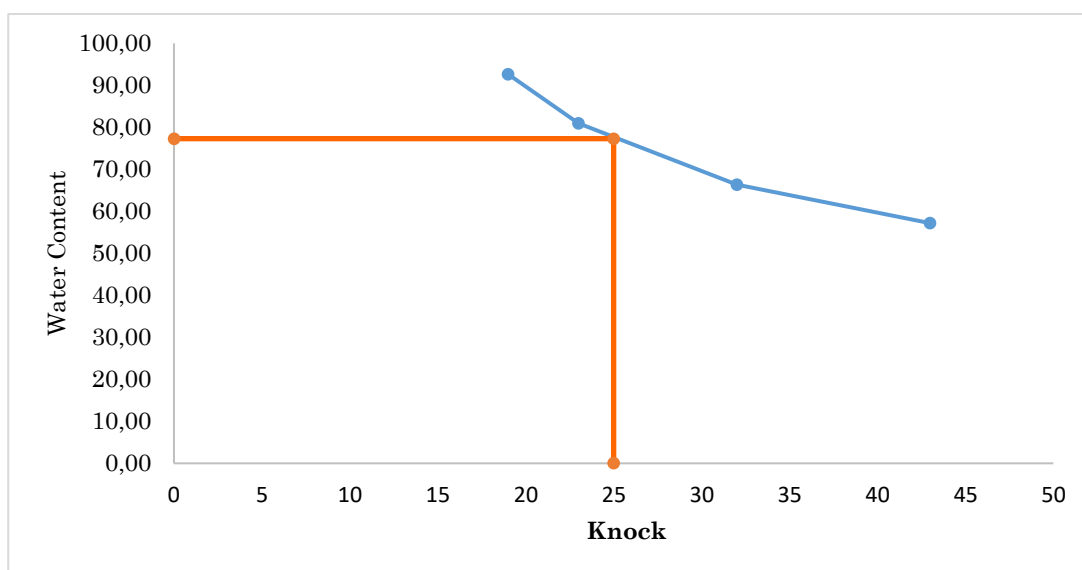


Figure 1. Liquid Limit Graphics

Based on the Liquid Limit test results shown in Figure 1, after conducting four soil tests using the Cassagrande tool, a liquid limit of 77.33% was obtained. The moisture content when the groove closes after 25 taps is the moisture content determined as the liquid limit of the soil.

5. Plasticity Index

Plasticity Index is an important parameter in describing the range of water content in which soil remains plastic. This index provides information about soil properties and its ability to deform without cracking. PI is calculated as the difference between the liquid limit and the plastic limit of the soil:

$$\begin{aligned}
 \text{Plasticity Index} &= \text{Liquid Limit} - \text{Plastic Limit} \\
 &= 77,33 \% - 32,7 \% \\
 &= 44,63 \%
 \end{aligned}$$

Based on the Plasticity Index is obtained at 44.63%. This plasticity provides an overview of the soil properties, particularly in terms of plasticity and potential volume change. According to Table 2.2, a Plasticity Index value of >17 indicates that the soil on the Soko – Tuban Highway has high plasticity and is classified as clay soil.

6. Compaction Test (ASTM D-698)

Table 5. Wet Density

No. Mould	-	1	2	3	4	5
Mould Mass	Gram	3471	3471	3471	3471	3471
Mass of Wet Soil + Mould	Gram	4703	4900	5040	5050	4890
Mass of Wet Soil, Wwet	Gram	1232	1429	1569	1579	1419
Mould Volume	cm ³	939,493	939,493	939,493	939,493	939,493
Wet Density ywet = Wwet / Vmould	gr/cm ³	1,311	1,521	1,670	1,681	1,510

Sources: Test Results 2025

Based on the Table 5, in the fifth trial with a water mixture of 1000 ml, the measured mass of the wet soil and mould showed a decrease compared to the mixture with 800 ml of water. By using five samples with different moisture contents to calculate their respective values, the results are then plotted on a graph or curve to determine the maximum dry density (γdry) and the optimum moisture content of the soil. The following is the graph.

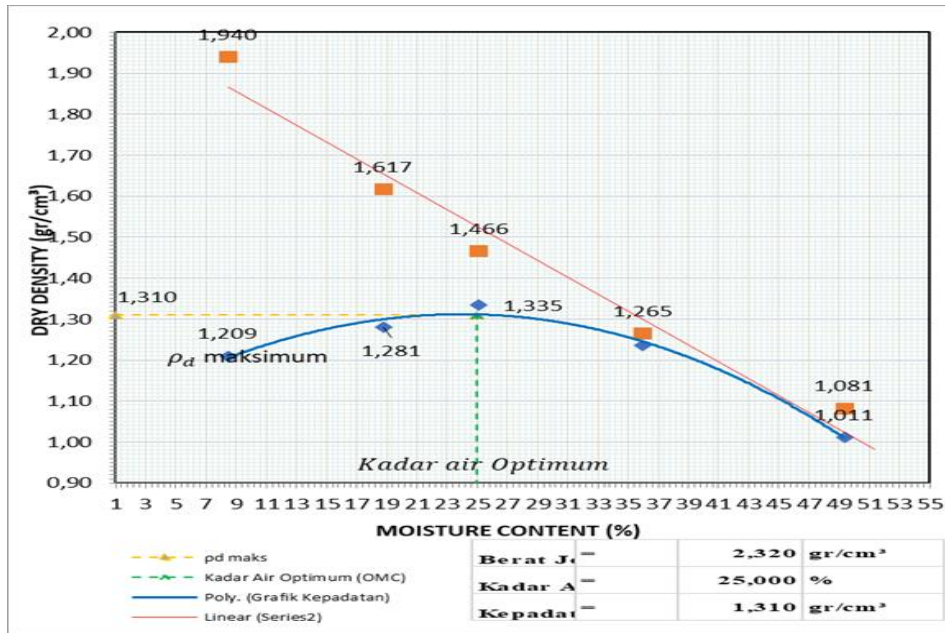


Figure 2. Compaction Test ASTM D-698

Based on the results of the compaction test (ASTM D-698) in Figure 3, the soil on the Soko - Tuban Road has a maximum dry density (ρ_d max) of 1.310 g/cm³ and an optimum moisture content (wopt) of 25.00%. These values can serve as a reference for sustainable road construction in the area.

7. Dynamic Cone Penetrometer (DCP)

Based on the road inventory results, it is known that the existing road conditions on the Soko – Tuban section fall into the category of a provincial road. This road has a width of 7 meters and is frequently traversed by heavy vehicles. The pavement type used is flexible pavement. Below are the calculation results from the dynamic analysis.

Table 6. Overall CBR Value - DCP (Dynamic Cone Penetrometer)

No	Point	CBR - DCP %
1	7 + 100 East	12,09
2	7 + 200 West	9,87
3	7 + 200 West	5,53
4	7 + 200 West	10,59

Sources: Test Results 2025

8. California Bearing Ratio (CBR)

The laboratory CBR test was conducted using two soil samples: one from a section with good road conditions and another from a damaged road section. The values obtained are load values (lbs) corresponding to penetrations of 0.1 inch and 0.2 inch for each compaction effort, namely 10, 30, and 65 blows. These values are then used in the CBR calculation.

Table 7. Overall Laboratory CBR Testing

No	Point	Number of Blows			Average
		10	30	65	
1	7 + 100	9,34	16,81	22,42	17,12
2	7 + 800	7,47	10,27	16,81	11,52

Sources: Test Results 2025

The average CBR value is determined by taking the highest value between the 2.54 mm and 5.08 mm penetrations, then calculating the average, which results in 17.59%.

4. CONCLUSION

The conclusions derived from the research conducted on the Soko, Tuban road segment reveal several critical findings regarding the soil conditions and their implications for road stability. Firstly, the soil tested along Jalan Raya Soko–Tuban is classified as organic clay. This classification is supported by the soil's average specific gravity of 2.33 gr/cm³ and a relatively high moisture content of 43.19%. Further analysis of its physical properties indicates a liquid limit of 77.33%, a plastic limit of 32.7%, and a plasticity index of 44.63%. These values reflect the soil's high plasticity and broad plasticity range, characteristics typical of clay that is highly sensitive to changes in moisture content. Such conditions imply that the soil has a strong tendency to experience significant volume and shape changes, which may compromise the structural stability and performance of road pavements built upon it. Secondly, the research also conducted field and laboratory evaluations of soil bearing capacity using the Dynamic Cone Penetrometer (DCP) method, which was then correlated with California Bearing Ratio (CBR) values. DCP testing was performed at two strategic locations: STA 7+100 and STA 7+800. At STA 7+100, which represents road segments in relatively good condition, the CBR values were found to be 12.09% on the east side and 25.51% on the west side. In contrast, at STA 7+800 representing segments in poor condition—the CBR values were significantly lower, measured at 5.23% on the east side and 10.59% on the west side. Complementary laboratory-based CBR tests were conducted on soil samples taken from both locations, using three levels of compaction impact: 10x, 30x, and 65x. The sample from the undamaged section at STA 7+100 produced the highest average CBR value of 17.12%, while the sample from the damaged section at STA 7+800 yielded a lower average CBR value of 11.52%. These findings demonstrate a clear relationship between soil conditions, CBR values, and the visible quality of the road surface, indicating that lower subgrade strength contributes to more severe pavement deterioration.

REFERENCES

- Angelia Safitri, P., K Sendow, Theo, D., & V Pandey, S. (2019). Analisa pengaruh beban berlebih terhadap umur rencana jalan (studi kasus: ruas jalan Manado - Bitung). *Jurnal Sipil Statik*, 7(3), 319–328.
- Binamarga. (2017). *Manual perkerasan jalan, kementerian pekerjaan umum dan perumahan rakyat direktorat jendral bina marga*. 1–235. <https://binamarga.pu.go.id/v3/uploads/files/112/manual-desain-perkerasan-jalan.pdf>
- Darwis, F., & Mulya, E. R. (2021). Analisis Daya Dukung Tanah Dasar Cbr Lapangan Pada Ruas Jalan Kampus Unipas Morotai. *Journal of Science and Engineering*, 4(2), 97–105. <http://ejournal.unkhair.ac.id>
- Harahap, F. (2022). *Analisa Pemilihan Jenis Perkerasan Ruas*. 5(1), 127–131.
- Ikhwan, M. Z. (2019). *Studi Preloading Dengan Kolom Pasir Sebagai Drainase Tanah Lunak (Studi Kasus Tanah Bojonegoro) Universitas Bojonegoro*.
- Permatasari, S. (2021). Hubungan Nilai Cbr Laboratorium Dan Dcp Pada Tanah Yang Dipadatkan Pada Ruas Jalan Desa Semisir Kabupaten Kotabaru. *TAPAK (Teknologi Aplikasi Konstruksi): Jurnal Program Studi Teknik Sipil*, 10(2), 133. <https://doi.org/10.24127/tp.v10i2.1582>
- Sugiarto. (2016). Mekanika Tanah I. *Gadjah Mada Unuversity Press*, 4(1), 1–23.
- Sumarsono, A., & Fauziah, M. (2022). Evaluasi Kondisi Perkerasan, Penanganan Dan Nilai Sisaperkerasan Lentur Jalan Dengan Metode Binamarga 2013 dan Metode Mekanistik Empirik (Studi Kasus: Jalan Jogja-Solo Km 14+800-16+800). *Jurnal Teknik*, 9(1), 10–27. www.teknika-ftiba.info
- Thamrin, A. H. (2018). Langkah Mengatasi Konstruksi Perkerasan Jalan yang Kuat dan Awet dengan Memanfaatkan Sumber Material Lokal. *Jurnal Infrastruktur*, 4(01), 61–72. http://103.12.84.208/personal/img-post/superman/post/20181130145128_F_KMS_JURNAL_20180726082930.pdf
- Winardi, W. A., Mulyono, A. T., & Utomo, S. H. T. (2019). Penilaian Kondisi Perkerasan Jalan Berbasis Perangkat Lunak Pada Ruas Jalan Yogyakarta–Magelang. *Jurnal HPJI*, 5(2), 109–118. <https://doi.org/10.26593/jh.v5i2.3371.109-118>