JIPE Journal of Infrastructure Planning and Engineering

Journal of Infrastructure Planning and Engineering (JIPE)

Journal homepage: https://ejournal.warmadewa.ac.id/index.php/jipe

The behavior of the Perbaungan railway subgrade

Aazokhi Waruwu[1]*, Muhammad Arfan[2], Tubel Oktor Waruwu[3]

[1]Civil Engineering Study Program, Universitas Pelita Harapan, Tangerang, Indonesia
[2]Civil Engineering Study Program, Universitas Muhammadiyah Palembang, Indonesia
[3]Civil Engineering Study Program, Institut Teknologi Medan, Indonesia
*azokhiw@gmail.com

Received on 19 March 2022, accepted on 13 April 2022, published on 18 April 2022

ABSTRACT

Railway subgrade is a layer consisting of soil material which can be in the form of natural soil, repaired material, and in the form of embankment of selected soil material that meets the specifications. The subgrade that meets the requirements is soil with a minimum CBR value of 8% with a minimum thickness of 30 cm. This study aims to analyze and evaluate the CBR value of the railway subgrade. Subgrade analysis was carried out on the improvement of the railway - replacement of concrete pads and rails R.25/33/42 to R.54 concrete pads from km 39 + 100 to km 40 + 200 along 1100 m in Perbaungan North Sumatra. The structure of the soil layer that is analyzed is the structure of the subsoil in the form of subgrade. The CBR value of the subgrade in the form of soil is determined based on the results of the analysis of the DCP data. The CBR value is evaluated based on the provisions that apply to the railway subgrade. The behavior of the railway subgrade can be seen from the CBR value of the original subgrade. Based on the results of the analysis, it was found that the behavior of the railway subgrade was quite diverse and it was found that only 39% met the requirements for the rail subgrade. Handling carried out in the field to improve the behavior of the subgrade is by using a backfill system made of good material with a density and CBR value that meets the requirements for railways.

Keywords: Dynamic Cone Penetrometer; subgrade; railway; CBR

1 Introduction

Railway is one type of land transportation infrastructure, in addition to highway and freeway. The development of rail transportation using railway began with the development of efforts to improve transportation services, both in terms of quality of transportation, speed of travel, as well as in terms of the durability of facilities and infrastructure.

Rails on railway must be designed and installed so that they remain in position, usually the rails are anchored using rail fasteners on bearings. The arrangement and structure of the rails, bearings, and rail fastenings into a single unit that cannot be separated from each other, is sturdy, and is placed on top of the ballast and then under the ballast there is a subgrade layer. Railway structural components consist of the upper and lower parts [1]. The upper structure is a track consisting of rails, bearings, and rail fasteners, while the lower structure is a foundation part consisting of ballast and subgrade.

The railway will carry a fairly heavy load, both due to the weight of the train and due to other loads, for this reason it is necessary to design a bearing construction that is safe, durable, and economical. Railway construction must be able to be traversed by rail vehicles safely within a certain level of comfort during the life of construction with the lowest possible construction and maintenance costs [2]. This construction can last a long time if it is supported by a strong subgrade and is able to withstand the loads above it.

The foundation soil that directly supports the load due to traffic loads from a pavement system is called the subgrade. Subgrade is a layer of compacted soil that serves as the foundation of the pavement system [3]. The subgrade can be in the form of compacted, repaired or reinforced embankment.

The subgrade of the embankment material needs to be compacted to meet the required density. Several studies on heaps such as [4-10]. This research discusses settlement, the use of soil reinforcement, and methods of subsidence analysis. The railway subgrade can be repaired with PVD prior to backfill.

The rail subgrade is a layer made of geotechnical materials, which can be in the form of original soil, repaired material, and in the form of an embankment of selected soil material that meets the specifications. As in the railway upgrade-the replacement of concrete pads and rails R.25/33/42 to R.54 concrete pads from km 39 + 000 to km 52 + 500 along 13,500 m in Perbaungan North Sumatra. The subgrade consists of compacted soil pile every 20 cm thick until it reaches the desired thickness.

In accordance with the function of the subgrade and seeing the location and position and distribution of the load by the top layer (ballast), the subgrade must have sufficient bearing strength. According to the provisions that apply to PT. Kereta Api (Persero), the bearing strength of the subgrade is determined to have a minimum California Bearing Ratio (CBR) value of 8%. The subgrade that must meet the minimum requirement of CBR 8% is subgrade with a minimum thickness of 30 cm [1].

Subgrade that does not meet the requirements of the CBR value can be given soil reinforcement. The nailed slab system can be used as soft soil reinforcement [11-14]. This system can be carried out using a mini pile combined with a slab. Another alternative that can be used is the reinforcement of bamboo material in the form of grids or piles, such as the results of research [15-19]. This reinforcement system is reported to be able to reduce settlement and increase the bearing capacity of the soil.

The railway subgrade needs to be investigated to ensure that the bearing strength meets the minimum requirements. If the bearing strength is not sufficient, the performance of the railway may be disrupted and it will not function properly. Therefore, through this research, we will get a way to analyze the CBR value of the subgrade, determine the CBR value of the subgrade, and evaluate the results according to the minimum CBR standard for railway subgrade CBR.

2 Data and Methods

The location of data collection for the improvement of the Aras Kabu – Siantar crossing railway which is located in Perbaungan, North Sumatra Province at km 39 + 100 to 40 + 200.

Dynamic Cone Penetrometer (DCP) testing in the field was carried out on the original soil prior to stockpiling. The test is every 50 m interval starting from km 39 + 100 to 40 + 200. The data presentation includes the number of blow and penetration in each test. DCP test data, each from km 39 + 100 to km 40 + 200.

The penetration depth in the DCP test is carried out up to a maximum of 1000 mm. The number of blows is affected by the density of the soil, soil that has a good density generally shows the number of blows increasing. As shown in the DCP data from km 39 + 100 to km 39 + 250, the number of blows to achieve penetration close to 1000 mm varies quite a bit from 17-50 blows. These data provide initial clues in analyzing the CBR value of the subgrade. Generally good soil has a large number of blows to achieve a penetration close to 1000 mm.

Testing with the DCP tool is basically the same as the Cone Penetrometer (CP), which is both looking for the CBR value of a soil layer directly in the field. It's just that the CP tool is equipped with a proving ring and a reading watch, while on the DCP it is through measurement (units). This tool is used in earthworks because it is easy to move to all the required points but the position of the layer that is checked is only up to 1000 mm.

The test is carried out by recording the number of blowsand the penetration of the cones embedded in the soil or foundation layer due to the impact of the impactor, then using graphs and formulas, the penetrometer readings are converted into readings equivalent to the CBR value.

The formula used for cone 30° is the equation Log CBR = 2.503 – 1.15 (Log DCP) and for cone 60° with the equation Log CBR = 2.48 – 1.057 (Log DCP). The CBR value equivalent to normal subgrade is determined as in Equation 1. If the pavement foundation consists of several layers or if the original subgrade consists of several layers with the highest strength located at the top layer, the CBR of the subgrade is determined according to the formula.

$$CBR = \left(\frac{\sum_i h_i CBR^{0,33}}{\sum_i h}\right)^3 \quad (1)$$

These data were used to analyze the CBR value of the subgrade under embankment. Based on the results of the CBR analysis of the subgrade, an evaluation was carried out to determine the feasibility of the original soil as a railway subgrade.

The CBR values along the track can be used as a consideration for planning the use of reinforcement and embankment on it. The stability of the embankment is influenced by the CBR value of the subgrade below it. Backfill is required to increase the CBR value of the subgrade and to reach the planned rail height.

3 Results and Discussion

Based on the DCP test data at each point in the field, a graph of the relationship between blow and penetration is made. The test results are divided into several segments, each between 3-5 test points. Each point was analyzed to get the CBR value of the subgrade using Equation 1.

3.1 Subgrade CBR Analysis Results

Subgrade DCP test results at km 39 + 100 to 39 + 250 shown in the relationship between blow and penetration (mm) as in Figure 1. The results of the analysis of the CBR value of the subgrade at km 39 + 100 obtained 2.51%, for km 39 + 150 with a CBR of 5.71%, for km 39 + 200 with a CBR of 3.40%, and for km 39 + 250 with a CBR of 9.89%. The CBR value in this segment is quite varied, this shows that the subgrade behavior is not uniform. Most of the subgrade CBR values are still less than 8% as a minimum requirement for railway subgrade CBR values.

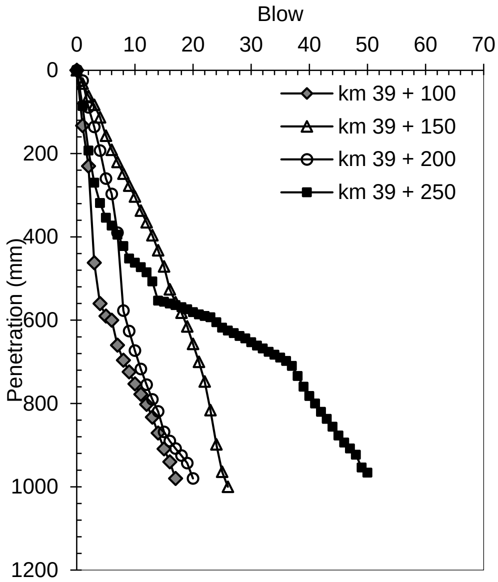

Figure 1. DCP test results at km 39 + 100 to 39 + 250

The results of the subgrade DCP test at km 39 + 300 to 39 + 450 are shown in the relationship between blow and penetration as in Figure 2. The result of calculating the CBR value at km 39 + 300 is 3.88%, CBR at km 39 + 350 is 4.07%, CBR at km 39 + 400 is 2.67%, and CBR at km 39 + 450 is 2.10%. The behavior of these four subgrades shows a fairly low CBR value and all of them do not qualify as railway subgrades.

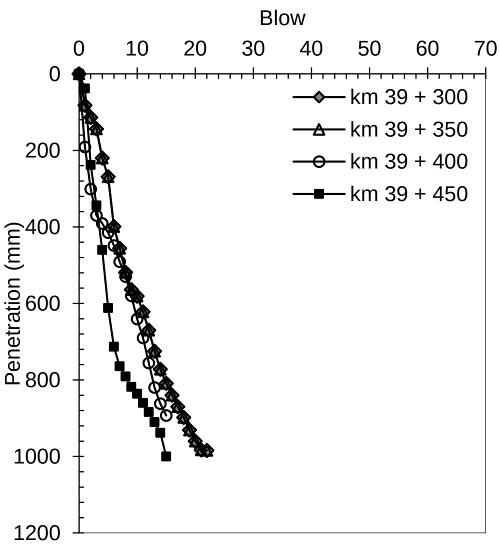

Figure 2. DCP test results at km 39 + 300 to 39 + 450

The results of the subgrade DCP test at km 39 + 500 to 39 + 650 are shown in the relationship between the number of blows and penetration (mm) as shown in Figure 3.

The analysis results for the point of km 39 + 500, the CBR value is 2.68%, for km 39 + 550 is 9.70%, the CBR value for km 39 + 600 is 18.72%, and for km 39 + 650 is 18.63 %. The subgrade at this location mostly qualifies as a railway subgrade.

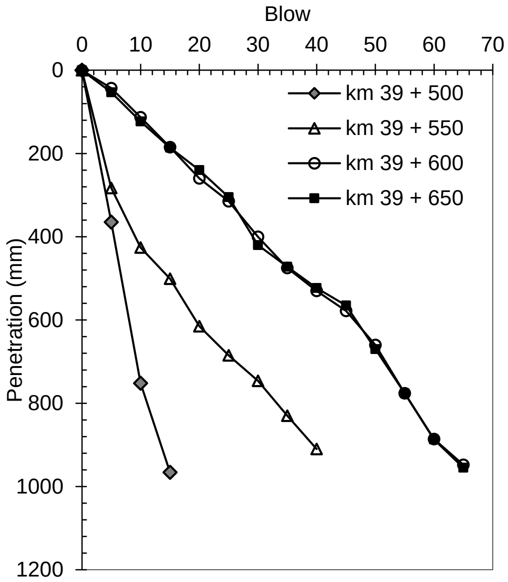

Figure 3. DCP test results at km 39 + 500 to 39 + 650

The results of the subgrade DCP test carried out at km 39 + 700 to km 39 + 850 are shown in the relationship between the number of blows and penetration (mm) as shown in Figure 4.

The results of the analysis of the CBR value at km 39 + 700 obtained 7.08%. The same thing was done at other points and the CBR value obtained at km 39 + 750 is 12.64%, for km 39 + 800 is 17.29%, and for km 39 + 850 is 2.04%. Based on the CBR value, the behavior of the railway subgrade shows non-uniformity between one point and another. Some meet the requirements for railway subgrade and some do not, because the CBR is less than 8%.

Figure 5 shows the results of the subgrade DCP test conducted at km 39 + 900 to 40 + 050. This data shows the relationship between the number of blows and penetration (mm).

The CBR result at km 39 + 900 is 2.14%, at km 39 + 950 is 1.52%, for km 40 + 000 is 0.62%, and km 40 + 050 is 9.57%. Most of the subgrade at these test points shows behavior as soft subgrade, because it has a fairly low CBR value.

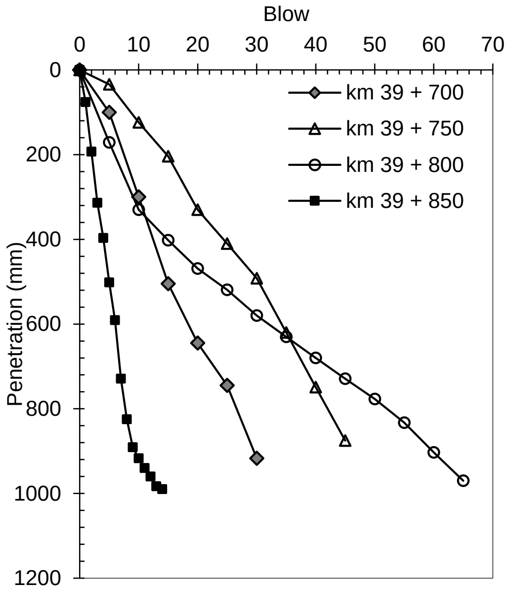

Figure 4. DCP test results at km 39 + 700 to 39 + 850

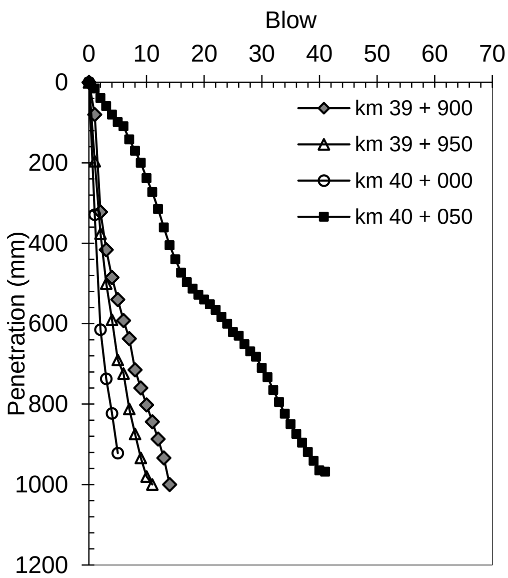

Figure 5. DCP test results at km 39 + 900 to 400 + 050

The results of the subgrade DCP test at km 40 + 100 to 40 + 200 consist of three points including the DCP test points at km 40 + 100, km 40 + 150, and km 40 + 200. The graph of the relationship between the number of blow and penetration is shown in Figure 6.

The CBR value at km 40 + 100 is 18.92%, CBR at km 40 + 150 is 3.48% and the CBR value at km 40 + 200 is 6.26%. The CBR values at the test points are quite varied, and only one point is eligible as a railway subgrade.

3.2 Evaluation and Discussion of Subgrade CBR Level

The results of the analysis of the original soil CBR value at the data collection location are shown in Figure 7. The CBR value of the subgrade at the point one with other points looking very diverse, this shows that the behavior of the subgrade has different properties from one another. The subgrade CBR at km 39 + 100 to km 39 + 500 and km 39 + 850 to km 40 + 000 looks relatively small. The relatively smaller CBR value is one of the basic considerations for using embankment soil.

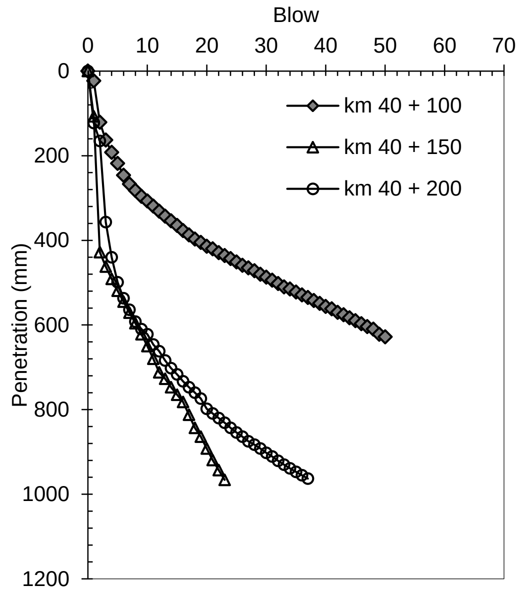

Figure 6. DCP test results at km 40 + 100 to 40 + 200

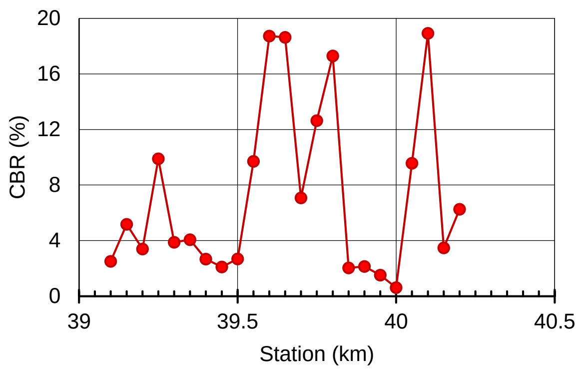

Figure 7. Results of CBR analysis of subgrade km 39 + 100 to 40 + 200

Evaluation of the results of the analysis of the CBR value of the subgrade for each test point at 50 m intervals is shown in Table 1. The subgrade CBR value for each point is described and compared with the minimum CBR value requirements for rail subgrades. If the CBR value of the subgrade is less than 8%, then it is assessed as subgrade that does not meet the requirements and meets the requirements as a railway subgrade and vice versa if the CBR value is greater than 8%, then it is assessed as a subgrade that qualifies as a railway subgrade.

Based on the results of the calculation of the subgrade CBR at km 39 + 100 to 40 + 200 it was found that the percentage that met the railway subgrade was 39%, while those that did not meet were 61%. These results show that most of the original land does not meet the requirements when viewed from the adequacy of the CBR value. When compared with observations in the field, it can be seen that most of the original soil surface is submerged in water, so the soil becomes soft and has a low bearing capacity.

Table 1. Evaluation of CBR calculation results

No.	Station	CBR (%)	Evaluation
1	Sta. 39 + 100	2.51	< 8%
2	Sta. 39 + 150	5.17	< 8%
3	Sta. 39 + 200	3.4	< 8%
4	Sta. 39 + 250	9.89	> 8%
5	Sta. 39 + 300	3.88	< 8%
6	Sta. 39 + 350	4.07	< 8%
7	Sta. 39 + 400	2.67	< 8%
8	Sta. 39 + 450	2.1	< 8%
9	Sta. 39 + 500	2.68	< 8%
10	Sta. 39 + 550	9.7	> 8%
11	Sta. 39 + 600	18.72	> 8%
12	Sta. 39 + 650	18.63	> 8%
13	Sta. 39 + 700	7.08	< 8%
14	Sta. 39 + 750	12.64	> 8%
15	Sta. 39 + 800	17.29	> 8%
16	Sta. 39 + 850	2.04	< 8%
17	Sta. 39 + 900	2.14	< 8%
18	Sta. 39 + 950	1.52	< 8%
19	Sta. 40 + 000	0.62	< 8%
20	Sta. 40 + 050	9.57	> 8%
21	Sta. 40 + 100	18.92	> 8%
22	Sta. 40 + 150	3.48	< 8%
23	Sta. 40 + 200	6.26	< 8%

4 Conclusion

Based on from the results and discussion, several conclusions were obtained, including from the results of data analysis, the CBR value of the subgrade was obtained at 0.62-18.92%. The results of the evaluation of the subgrade CBR value at km 39 + 100 to 40 + 200 found that only 39% met the railway subgrade while 61% did not meet the applicable requirements, namely 8%. Recommendations for solutions to problems in the field need to be filled with good materials along the planned rail replacement work. The embankment material is compacted every 20 cm and tested for density and the CBR value of the embankment soil.

Acknowledgement

Herewith, the author team would like to express their deepest gratitude to PT. Bajatra Pandapotan KSO, for their willingness to allow the location of research and data collection in the field.

References

[1] S. H. T. Utomo, *Jalan Rel*. Yogyakarta: Beta Offset, 2009.
[2] G. Rusbintardjo, *Konstruksi Jalan Rel*. Semarang: Unissula Press, 2012.
[3] H. C. Hardiyatmo, *Pemeliharaan Jalan Raya*. Yogyakarta: Gadjah Mada University Press, 2015.
[4] A. S. Balasubramaniam, H. Cai, D. Zhu, C. Surarak, and E. Y. N. Oh, "Settlements of Embankments in Soft Soils," *Geotech. Eng.*, vol. 41, no. 2, pp. 1–19, 2010.
[5] A. Marto and B. A. Othman, "The Potential Use of Bamboo as Green Material for Soft Clay Reinforcement System," in *Proceedings of the International Conference on Environmental Science and Engineering*, 2011, vol. 8, pp. 129–133.
[6] M. N. Islam, C. T. Gnanendran, and S. T. Sivakumar, "Effectiveness of Preloading on the Time Dependent Settlement Behaviour of an Embankment," *GeoCongress @ ASCE*, pp. 2253–2262, 2012, doi: 10.1061/9780784412121.231.
[7] W. Al-Ani, D. Wanatowski, and S. H. Chan, "Numerical Analysis of Piled Embankments on Soft Soils," in *Ground Improvement and Geosynthetics*, 2014, pp. 30–39.
[8] C. Li, "A simplified method for prediction of embankment settlement in clays," *J. Rock Mech. Geotech. Eng.*, vol. 6, no. 1, pp. 61–66, 2014, doi: 10.1016/j.jrmge.2013.12.002.
[9] R. D. Susanti, Maulana, and A. Waruwu, "Bearing Capacity Improvement of Peat Soil by Preloading," *ARPN J. Eng. Appl. Sci.*, vol. 12, no. 1, pp. 121–124, 2017.
[10] J. J. Muhammed, P. W. Jayawickrama, A. Teferra, and M. A. Özer, "Settlement of a Railway Embankment on PVD-Improved Karakore soft Alluvial Soil," *Eng. Sci. Technol. an Int. J.*, vol. 23, no. 5, pp. 1015–1027, 2020, doi: 10.1016/j.jestch.2020.03.004.
[11] A. Waruwu, H. C. Hardiyatmo, and A. Rifa'i, "Deflection Behavior of The Nailed Slab System-Supported Embankment on Peat Soil," *J. Appl. Eng. Sci.*, vol. 15, no. 4, pp. 556–563, 2017, doi: 10.5937/jaes15-15113.
[12] A. Waruwu, H. C. Hardiyatmo, and A. Rifa'i, "Behavior of Nailed-Slab System on Peat Soil Under Loading," in *The 1st Warmadewa University International Conference on Architecture and Civil Engineering*, 2017, pp. 91–97.
[13] A. Waruwu, H. C. Hardiyatmo, and A. Rifa'i, "The Performance of The Nailed Slab System-Supported Embankment on Peat Soil," *Int. Rev. Civ. Eng.*, vol. 10, no. 5, pp. 243–248, 2019, doi: 10.15866/irece.v10i5.15757.
[14] A. Waruwu, H. C. Hardiyatmo, and A. Rifa'i, "Uji Beban Timbunan yang Diperkuat dengan Sistem Pelat Terpaku pada Tanah Gambut," *Media Komun. Tek. Sipil*, vol. 25, no. 2, pp. 152–159, 2019, doi: 10.14710/mkts.v25i2.21018.
[15] A. Waruwu, "Bamboo Reinforcement in Shallow Foundation on the Peat Soil," *J. Civ. Eng. Res.*, vol. 2014, no. 3A, pp. 96–102, 2014, doi: 10.5923/c.jce.201402.16.
[16] A. Waruwu and R. D. Susanti, "Behavior of Soil Peat with Reinforcement of Bamboo Grid," *IOSR J. Eng. www.iosrjen.org ISSN*, vol. 5, no. 11, pp. 29–36, 2015, [Online]. Available: www.iosrjen.org.
[17] Maulana, Azwar, R. D. Susanti, and A. Waruwu, "Potential of Bamboo Pile as Reinforcement of Peat Soil under Embankment," *ARPN J. Eng. Appl. Sci.*, vol. 13, no. 1, pp. 52–56, 2018.
[18] A. Waruwu, H. Halim, T. Nasution, and Y. Hanova, "Bamboo Grid Reinforcement on Peat Soil under Repeated Loading," *J. Eng. Appl. Sci.*, vol. 13, no. 8, pp. 2190–2196, 2018, doi: 10.3923/jeasci.2018.2190.2196.
[19] M. Maulana, Y. Hanova, A. Waruwu, and E. R. Putra, "Simplified Method for Prediction of Settlement in Bamboo Piles-Reinforced Peat under Embankment," *J. Appl. Eng. Sci.*, vol. 17, no. 1, pp. 35–42, 2019, doi: 10.5937/jaes17-18793.