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Original Article

An Approach for Determining the Accuracy of the Field CBR Value of Road Pavement Due to Ineffective Compaction

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Abstract *- This paper aims to provide the simplest and most applicable method as an approach for determining the field CBR value of road pavement. Soil compaction in road foundation construction is performed differently than soil compaction in the laboratory. As a result, there were various non-uniformities in soil density and CBR values that were planned with soil density and CBR values acquired in the field after compaction. Field CBR testing is often performed at a specific range to identify the difference between soil density and CBR value. However, due to the enormous number of test points, the test would take a very long time and will be quite expensive. As a result, multiple approach methods were adopted to provide a margin of error in the disparity between the CBR value and the density of the soil in the field. The defined boundaries could be used as a guide to determine the accuracy of the compaction performed. The approach method used in this study is by comparing the results of soil investigation in the laboratory to those taken in the field at various certain points. The results of the soil investigation are then utilized to assess the performance of the compaction performed in the field. When defining the targeted CBR value, the margin specified in the comparison results could be utilized as a minimum limit value.*

Keywords — *CBR, Field CBR, Road Pavement, Soil Density.*

I. INTRODUCTION

Compaction has been widely used in the execution of numerous building projects. However, a variety of impediments allow compaction to occur inefficiently at times. As a result, different field settings are no longer acceptable as originally planned. A road pavement is a combination of aggregate and binder that is used to withstand traffic loads. Crushed stone, split stone, and river stone are common aggregates used in road paving. Cement, asphalt, and clay are among the binding materials employed. Compaction tests are commonly used to identify the correlation between moisture content and specific gravity, as well as to assess the soil's compliance with density criteria. According to ASTM D698, there is a direct correlation between moisture content and the dry density of solid soil. In general, there is an optimum water content value for various types of soil to achieve maximum dry density. The dry density after compaction is determined by the type of soil, moisture content, and Pulverizer effort. The Proctor test, a basic laboratory test, may be used to evaluate soil density parameters. The CBR test has the capability of determining the general thickness of the pavement; typically, the strength of the subgrade is indicated in the CBR value, where the CBR value is the ratio of the strength of the subgrade or other materials used for pavement construction.

This study is designated as a Fundamental Study, which means that it will evaluate and apply basic theories to assess current variables and changes. The Empirical Approach Method was employed in this study, which is a study that observes changes in various dependent variables and other variables whose values are defined to build a correlation to changes in the reference value in this study. Density and CBR values are the final values that form the correlative reference. The correlation is represented graphically by a correlation curve formed by comparing density changes and CBR values obtained for each soil type.

II. LITERATURE STUDY

Civil engineering construction work is always dependent on data from field studies addressing the physical and mechanical properties of the soil where the construction will stand independently, such as road construction, where the design significantly depends on soil CBR data [1,2,3]. This demonstrates that, in addition to data on the bearing capacity of the soil, the CBR value of the soil plays a critical role in civil engineering construction planning [7,21]. CBR testing is the most commonly employed type of testing in underdeveloped nations such as Indonesia. The conventional method of determining in-situ CBR values takes a long time and expensive equipment [14,15]. There are several techniques for estimating the CBR value, such as using soil grading or soil plasticity data. The Cone Penetrometer Test, on the other hand, is the most precise method [8]. This instrument may be used to do quick in-situ soil measurements for road pavements and subgrade layers. Furthermore, this strategy has been quite successful in being used in a variety of regions, including Africa and Southeast Asia [18,19,20].

Several earlier research has discovered a link between the CBR and CPT values based on the water content and then supplied in a logarithmic equation based on a linear regression test to then build an equation [11,12,13,16,17].

Because the equations employed are not the result of soils in that location, but soils from other areas, the use of equations like this, in general, may be able to disregard the physical qualities of the soil to be analyzed [9,10]. As a result, it is preferable to calculate the connection between CPT and CBR values for soils in a given location to the equations obtained from the soil's physical parameters. Because the simplest equations get good results in the study of statistics [6].

The adoption of a conservative, generally used number, namely the average value, poses a severe challenge in calculating the value of soil density in a specific location. Meanwhile, it is known that the existence of spatial non-uniformity influences the subgrade density value in a particular area [4,5].

Because CBR values and shear characteristics are important in road design, it is required to research the site of the proposed road to avoid or reduce losses caused by errors in calculating the values of soil parameters in the road project. The formula for predicting the lab CBR value based on field testing data (CPT carrying capacity) may be found by searching for the correlation between the CBR value and the CPT value; the CBR value and the soil bearing capacity; and the CPT value and the soil bearing capacity [2,4,9,11].

III. METHODOLOGY

This study was carried out on a road foundation work project on Java Island's southern coast, Indonesia. The investigation was carried out by collecting soil samples from the work site in the form of clay and gravel from a 10 km long worksite that was divided into 5 stations, which were then examined in the laboratory. Basic characteristics, compaction, and laboratory CBR testing were performed on the two types of soil. Following the collection of all data, the CBR and density data were connected to determine the connection between the two.

Furthermore, field CBR testing was performed at work areas that had been assessed for moisture content and compacted using a Vibro compactor in two, four, and eight passes. After obtaining field CBR data with density and moisture content, all data were connected to determine the influence of one variable on another. This test is performed under three conditions: optimum water content, suboptimal water content, and excess water content. As a result, the water content variable can have a more contrasted impact and offer hints to the data projection at the test point with moisture content in that range.

IV. RESULTS AND DISCUSSION

The materials studied in this investigation were divided into two categories: gravel and soft soil (clay). As previously stated, testing of material qualities covers both physical properties (index properties) and mechanical properties.

Table 1. Gravel properties test recapitulation

Test	Result	
	Value	Unit
Basic Properties:		
Initial water content (w)	3,25	%
Specific Gravity (Gs)	2,70	-
Sieve Analysis:		
a Gravel	82,48	%
b Sand	15,00	%
c Silt and Clay	2,52	%
Standard Proctor :		
a Maximum Dry Density, (γd)	1,51	gr/cm^3
b Optimum Moisture Content (OMC)	5,07	%
Classification According to USCS: GW/GP		
Mechanical Properties:		
California Bearing Ratio	33.87	%

According to laboratory investigation, the gravel material is dominated by a gravel component of 82.48 percent. Due to the CU value of 5.16 and CC of 1.29 with little/no fine-grained soil, the gravel used in this study is classified as GW, namely Sandy Gravel with good gradation, according to the Unified Soil Classification System.

Table 2. Clay properties test recapitulation

Test	Result	
	Value	Unit
Basic Properties:		
Initial water content (w)	35,71	%
Specific gravity (Gs)	2,65	-
Sieve Analysis and Hydrometer:		
a Sand	35,20	%
b Silt	34,55	%
c Clay	30,25	%
Atterberg Limits:		
a Liquid Limit (LL)	60,76	%

b	Plastic Limit (PL)	46,35	%
c	Plasticity Index (PI)	14,42	%
d	Shrinkage Limit (SL)	26,51	%
Standard Proctor:			
a	Maximum dry Density, (γd)	1,41	gr/cm^3
b	Optimum Moisture Content (OMC)	23,94	%
Classification according to USCS: MH			
Mechanical Properties:			
California Bearing Ratio – Unsoaked (CBR)		7,79	%

On the Atterberg limits test, the plastic limit value was 46.35 percent and the plasticity index was 14.40 percent based on laboratory analysis. It is discovered that the soil type belongs to the MH group (silt with high plasticity) by linking the plastic limit value with the plasticity index on the plasticity diagram.

The maximum dry density was attained in the laboratory compaction test at a specific moisture content. This value was utilized as a reference throughout the field compaction procedure. The results of the compaction test are greatly dependent on the type of soil, moisture content, and compaction effort. There are two sorts of compaction methods: Standard Proctor and Modified Proctor. The following are the results of a laboratory compaction test on the soil type and compaction procedure variables.

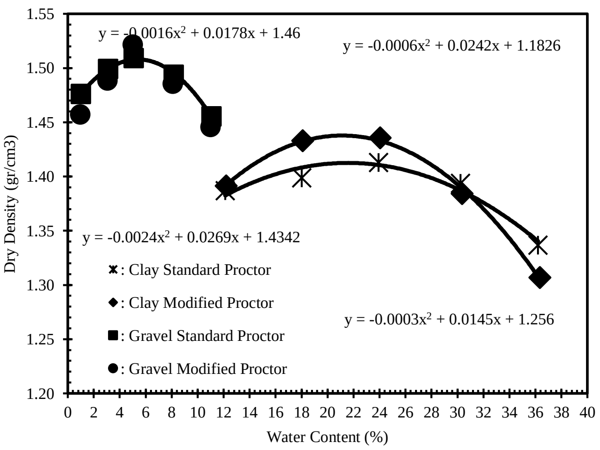

Fig. 1 Correlation between Moisture Content and Dry Density of Various Soil Types and Compaction Methods

The behavior depicted in Figure 1 is compatible with the outcomes of the compaction test of gravel and soft soil using the modified Proctor method, which relates to ASTM D-1557, and Standard Proctor, which refers to ASTM D-698. The Modified Proctor method has been shown to enhance soil density, particularly in gravelly soils. Cohesiveness can considerably improve. The gravel, on the other hand, did not exhibit a significant change in density. This is owing to the granular material's cohesive and loose character, therefore the soil structure will remain unchanged. Compaction can occasionally impair the gradation and produce a loss in mechanical value. Because of the granular structure of gravel, the water content does not fluctuate considerably. The water content does not change much in the gravel due to the nature of the granular material which tends to have very low absorption.

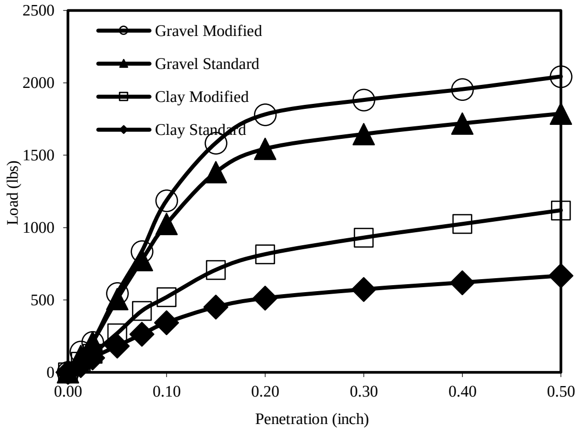

Fig. 2 Load-Penetration Behaviour on Optimum Moisture Content

The soft soil compacted using the Standard Proctor method had a CBR value of 11.47 percent at the optimum moisture content. The Modified Proctor method achieved a CBR value of 18.13 percent for soft soil. Meanwhile, gravel using the Standard Proctor method delivers a CBR value of 34.32 percent, and the Modified Proctor method reached a CBR value of 39.60 percent.

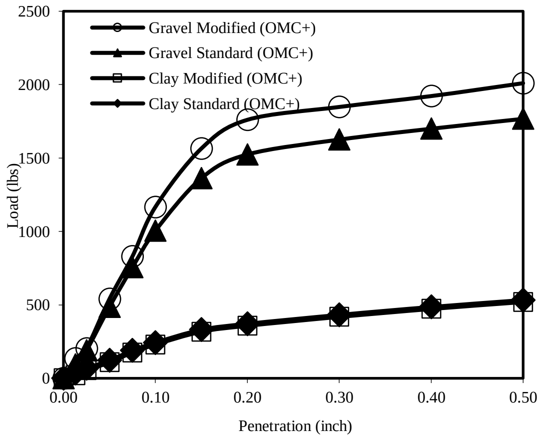

Fig. 3 Load-Penetration Behaviour on Excess Moisture Content

Based on Figure 3, at excess moisture content, the soft soil compacted using the Standard Proctor method reached a CBR value of 8.24%. Soft soil using the Modified Proctor method reached a CBR value of 7.94%. Meanwhile, gravel with the Standard

Proctor method reached a CBR value of 33.87%, and with the Modified Proctor method, it reached a CBR value of 39.12%.

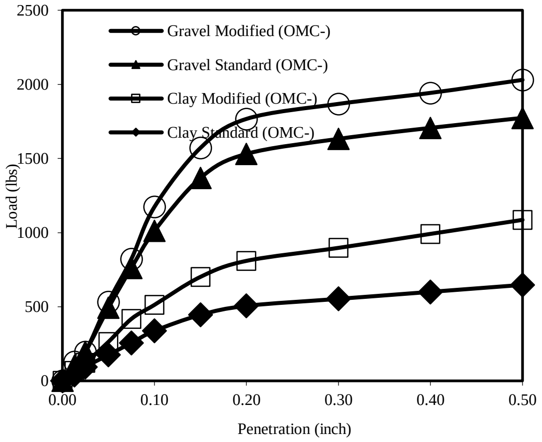

Fig. 4 Load-Penetration Behaviour on Moisture Content Below Optimum

At below optimum moisture content, the soft soil compacted using the Standard Proctor method reached a CBR value of 11.24%. Soft soil using the Modified Proctor method reached a CBR value of 17.98%. Meanwhile, the gravel using the Standard Proctor method reached a CBR value of 34.02%, and with the Modified Proctor method, it reached a CBR value of 39.27%.

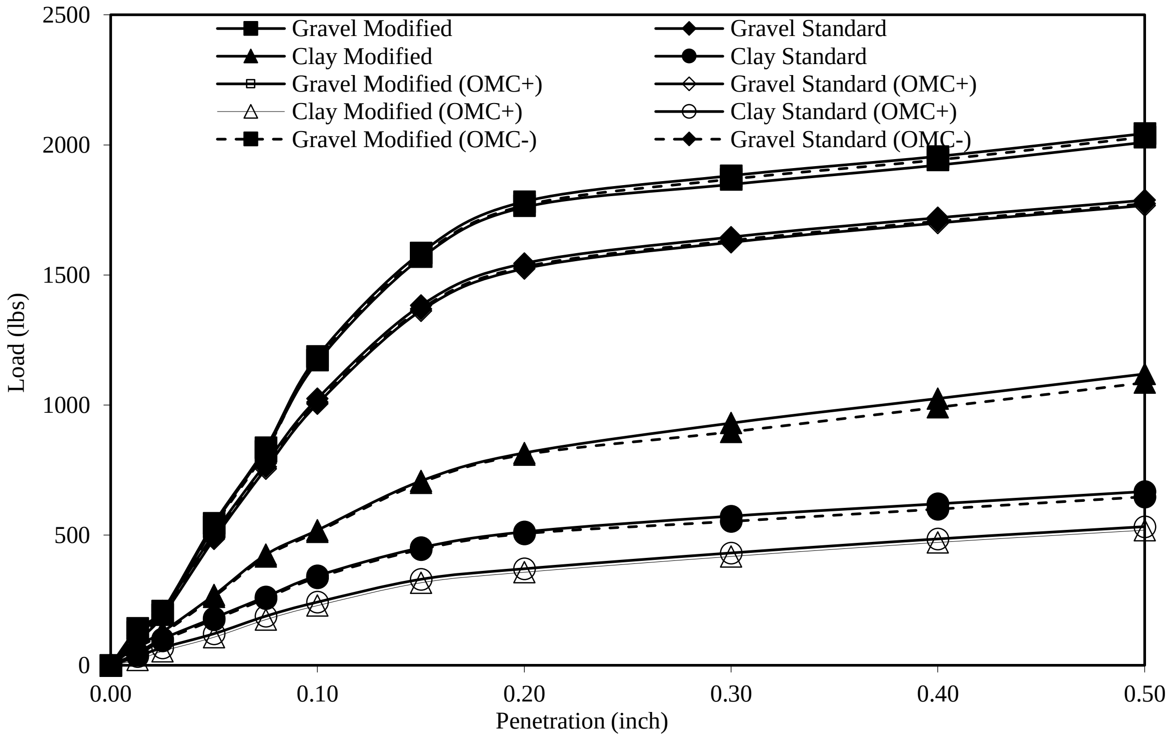

Fig. 5 Summary of Load-Penetration Behaviour on Various Moisture Content

On soft soil, the difference between the Standard and Modified compaction methods indicates a reduction. This is because excessive compaction at a cohesive soil moisture level over the optimum causes the soil to have clayey characteristics and hence cannot be loaded. Meanwhile, if soft soil is compacted with a water content lower than the optimum, the CBR value does not fall as far as the excess moisture condition. This demonstrates the importance of keeping the water content in the correct range and avoiding saturated soil conditions in soft soil buildings. Meanwhile, granular soil has no discernible response to changes in water content. The Modified compaction method, on the other hand, has the potential to raise the CBR value. This shows that water content is not a significant influence on non-cohesive soil types. The thing that needs to be considered is the implementation of compaction to achieve the desired dry density and mechanical value.

To determine the empirical approach based on graphs, a graph showing the relation between correlated parameters must first be created. Because the scale is the same in every scenario, density may be utilized as a parameter in choosing the line to be created by the correlation graph. As a result, the first step is to create a graph illustrating the relationship between density and CBR value.

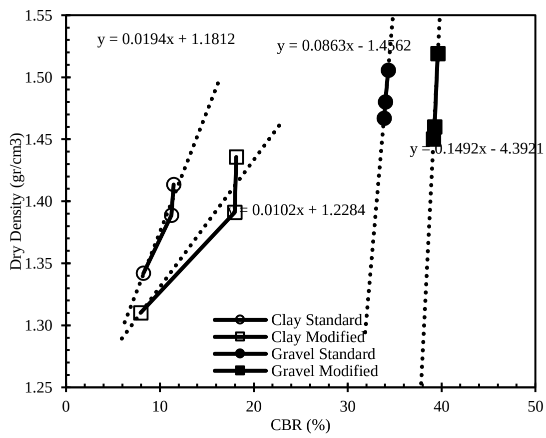

Fig. 6 Correlation between CBR value and dry density of clay and gravel using various compaction methods

The line formed between the density coordinates and the CBR value of each variation exhibits a linear behavior, which is particularly noticeable in gravel. As a result, the equations used in this approach are linear, and each alteration has its empirical equation. After the graph is formed, the next step is to correlate the compaction graph to the CBR correlation graph with the same Y-axis scale.

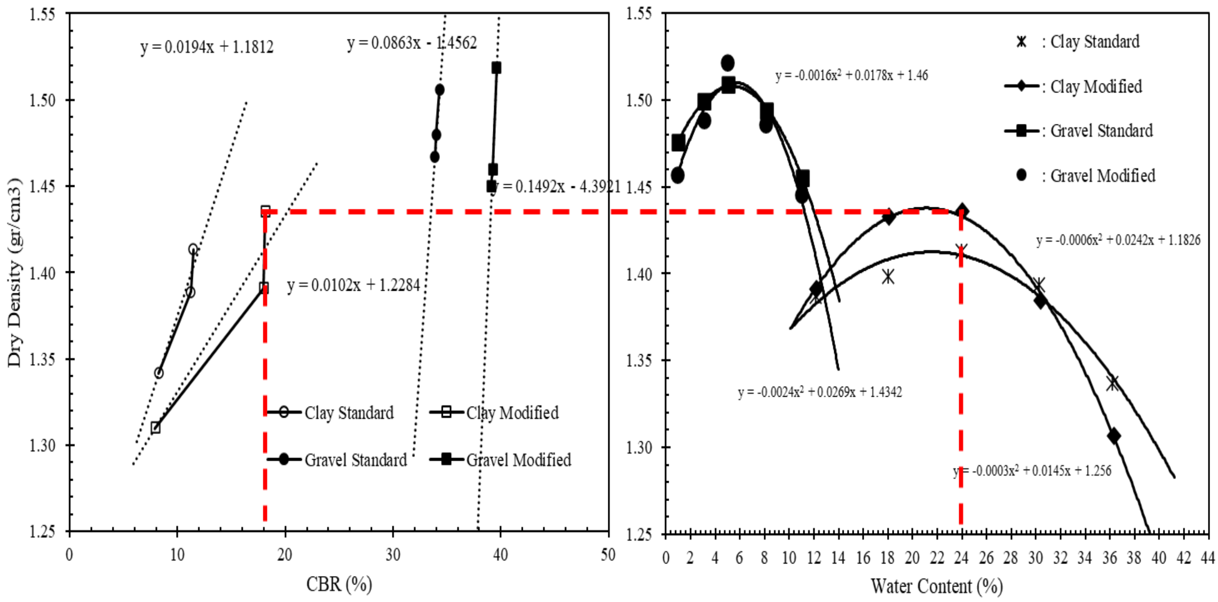

Fig. 7 Empirical Correlation Between Water Content-Density-CBR Value With Various Soil Type and Density

In the figure above, it can be seen that by connecting the graph of the relationship between density and water content with the relationship between density and CBR, one of the values of the three variables can be determined. By knowing one of the variables on one of the axes, the value of the other 2 variables can be obtained through an empirical line whose equations are known. This method can also be used to determine or validate field CBR data based on the density data that has been obtained, or the value of water content, considering that by using 1 variable, the correlation of 2 variables can be obtained.

To evaluate the level of accuracy or the probable margin of error, trial testing at various sites in the field is required to determine the method's validity. The test was conducted on the Kutawaru-Jeruklegi road segment, with 5 test stations. The test was performed per compaction, in this case utilizing a Vibro-compactor with two, four, and eight passes. The purpose of this is to determine the degree of density that may be achieved by utilizing a compactor roller. When testing in the field, a ring sample was used to determine the characteristics of wet density, dry density, and moisture content.

Table 3. Recapitulation and comparison of field CBR to laboratory CBR

Sample	CBR (%)	Dry Density	Empirical CBR (%)	Accuracy (%)
STA 0-2 N2	12.07	1.36	12.90	6.89
STA 0-2 N4	18.32	1.41	17.80	-2.82
STA 0-2 N8	22.27	1.46	22.71	1.94
STA 2-4 N2	12.50	1.36	12.90	3.20
STA 2-4 N4	18.54	1.41	17.80	-3.95
STA 2-4 N8	22.42	1.46	22.71	1.29

STA 4-6 N2	12.50	1.36	12.90	3.20
STA 4-6 N4	19.18	1.42	18.78	-2.08
STA 4-6 N8	22.70	1.46	22.71	0.01
STA 6-8 N2	12.36	1.36	12.90	4.40
STA 6-8 N4	18.75	1.41	17.80	-5.06
STA 6-8 N8	23.14	1.47	23.69	2.38
STA 8-10 N2	12.72	1.36	12.90	1.45
STA 8-10 N4	19.40	1.42	18.78	-3.17
STA 8-10 N8	22.70	1.47	23.69	4.33

The CBR values acquired successfully in the field CBR testing indicated slightly varying values, although not by much. The Practical CBR value ranges from -5.06 percent to 6.89 percent based on the Empirical CBR value derived by the formula established through graph correlation. This suggests that the method's accuracy is roughly 10% or one-tenth of the empirical CBR value. As a result, for subsequent road segments that will be compacted, it is advised that the target CBR value be increased by 10% over the initial target CBR value.

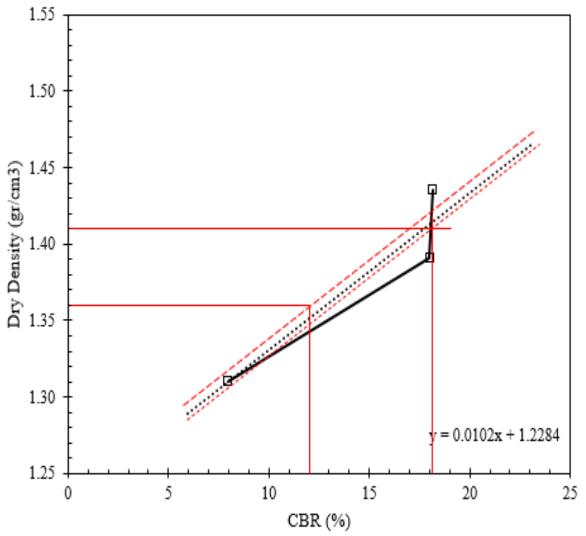

Fig. 8 Margin of Error Visualization Based on Comparison of Empirical and Practical CBR

The top and lower bounds are approximately 10% of the Empirical CBR value. As a result, to determine the margin, the formula must be adjusted to the derived linear equation. The formula Y= 1.05 (0.0102X+1.2284) is used to get the top limit. Meanwhile, the formula Y= 0.95 (0.0102X+1.2284) is employed to find the lower limit.

V. CONCLUSION

Reduction parameters must be calculated by collecting a specimen and determining the compaction and mechanical variables to use as a reference in creating the empirical equation that will emerge. A correlation graph combining density, moisture content, and CBR values is also required as a foundation for deriving the correlation line and its equation. If the material utilized is soft soil with a moisture content that exceeds the recommended moisture level, the strength loss might be severe. The mechanical value can be greatly reduced under saturated situations. The biggest drop in strength that happened in this research was 2.2 times, or by 220 percent.

REFERENCES

[1] Arbianto R, Yuono T, & Gunarso G, Comparison of California Bearing Ratio (CBR) Value-Based on Cone Penetration Test (CPT) and Dynamic Cone Penetrometer (DCP). JACEE (Journal of Advanced Civil and Environmental Engineering). 4(2) (2021) 70-78.

[2] Miller K. S, Simple Field Tests for Economic Working Platform Design. In Piling 2020: Proceedings of the Piling 2020 Conference, ICE Publishing. (2021) 323-328.

[3] Abdulnabi T. Y, & Abdulrazzaq Z. G, An Estimated Correlation Between California Bearing Ratio (CBR) with Some Soil Parameters of Gypseous Silty Sandy Soils, Tikrit J. Eng. Sci. 27 (2020) 58-64.

[4] Harimei B, Analysis of Soil Bearing Capacity in Planning for Public Facilities and Infrastructure, Journal of Geocelebes. 2(1) (2018) 42-46.

[5] Darwis F, & Mulya E.R, Analysis of Basic Soil Bearing Capacity Based on the Laboratory CBR Test and Field CBR Test on the Road Segment of the Unipas Morotai Campus, Journal of Science and Engineering. 4(2) (2021) 97-105.

[6] Mueller R. O, & Hancock G. R, Structural Equation Modeling. Routledge. (2018) 445-456.

[7] Noor Dhani, L. Samang, T Harianto and A. R Djamaluddin, Characteristics Study of Over Boulder Asbuton as Pozzolanic Material for Soft Soil Stabilization. IOP Conf. Series: Earth and Environmental Science. 419 (2020) 012043.

[8] Kodikara J, Islam T, & Sounthararajah A, Review of Soil Compaction: History and Recent Developments. Transportation Geotechnics. 17 (2018) 24-34.

[9] Meehan C. L, Cacciola D. V, Tehrani F. S, & Baker III W. J, Assessing Soil Compaction Using Continuous Compaction Control and Location-Specific in Situ Tests, Automation in Construction. 73 (2017) 31-44.

[10] Rehman Z. U, Khalid U, Farooq K, & Mujtaba H, Prediction of CBR Value from Index Properties of Different Soils. Technol. J. Univ. Eng. Technol. (UET). 22 (2017) 17-26.

[11] Katte V. Y, Mfoyet S. M, Manefouet B, Wouatong A. S. L, & Bezeng L. A, Correlation of California Bearing Ratio (CBR) Value with Soil Properties of Road Subgrade Soil, Geotechnical and Geological Engineering. 37(1) (2019) 217-234.

[12] Liu Y, & Wassgren C, Modifications to Johanson's Role Compaction Model for Improved Relative Density Predictions, Powder Technology. 297 (2016) 294-302.

[13] Srihandayani S, Soehardi F, & Putri L.D, CBR Laboratory Analysis for Determining the Number of Compaction Tracks to Achieve Field CBR. In IOP Conference Series: Earth and Environmental Science, IOP Publishing. 469(1) (2020) 012012.

[14] Gindorfer A, & Cornielje H, Essential Standards for CBR Field Workers. Disability, CBR & Inclusive Development. 31(2) (2020).

[15] Kurnaz T. F, & Kaya Y, Prediction of the California Bearing Ratio (CBR) of Compacted Soils by Using a GMDH-Type Neural Network, The European Physical Journal Plus. 134(7) (2019) 326.

[16] Gül Y, & Çayir H. M, Prediction of the California Bearing Ratio from Some Field Measurements of Soils, in Proceedings of the Institution of Civil Engineers-Municipal Engineer, Thomas Telford Ltd. 174(4) (2021) 241-250.

[17] Kuttah D, The Strong Correlation Between the Laboratory Dynamic CBR and the Compaction Characteristics of Sandy Soil, International Journal of Geo-Engineering. 10(1) (2019) 1-13.
[18] Nugroh S. A, Value Estimation of California Bearing Ratio from Hand Cone Penetrometer Test for Pekanbaru Soils, Civil Engineering Department, University of Riau, Indonesia. (2019).
[19] Reddy C. S, & Rao E. R, A Study on Impact of Variables on Precision of Correlation Equations of CBR of Sandy Soils, International Journal of Earth Sciences and Engineering. 9(3) (2016) 1029-1032.
[20] Hussein A. A, & Alshkane Y. M, Prediction of CBR and MR of Fine-Grained Soil Using DCPI. In Proceedings of the International Engineering Conference on Developments in Civil & Computer Engineering, Erbil, Iraq. (2018) 26-27.
[21] Marthen M. Tangkeallo, Lawalenna Samang, Achmad Bakri Muhiddin and A.R. Djamaluddin,Experimental Study on Bearing Capacity of Laterite Soil Stabilization using Zeolite Activated by Waterglass and Geogrid Reinforcement as Base Layer. Journal of Engineering and Applied Sciences. 15 (2020) 1496-1501.