The Correlation Between Cone End Resistance (qc) And California Bearing Ratio (CBR) Of Land In Banjarbaru

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Abstract: All this time, the score of CBR is calculated according to qc score. Generally, planner usually refers to graph / nomogram which published on literature book, but the graph / nomogram on the book may not probably able to apply in all areas, including Banjarbaru. In this particular research, it aimed to make the graph or equation between CBR and Cone test in the cone area of 0.5 in 2. The both tests used the same sample of water contents and density. The samples were taken in four areas in Banjarbaru; Balitra, Jalan Semeru (Semeru Street), Mandiangin Circuit, and Banjarbaru Asri Housing. There took soil samples in three points of every areas. By the test, obtained the correlation between CBR and Cone End Resistance (qc) on Banjarbaru area: CBR = 0.0545 qc + 2.618 and the qc score is between 50 kg/cm2 to 300 kg/cm2.

Keywords: CBR, qc, compaction, water content.

1. Introduction

The checking of CBR score is usually taking too long time if through the laboratory test. To make the shorten time, the planner usually conducts the CBR test in the field directly. The standard of CBR test type is, by using pistons. Because the large of pistons body, it need a heavy weight to push the piston into the certain depth of soil. Another test of CBR is using Cone Penetrometer. The Cone Penetrometer is easier than pistons test. The pointed of cone end makes the tool easy to push into the ground, so the loading weight is smaller than using a piston. In this checking, it requires the data of cone end resistance and the correlation between cone end resistance and CBR.

Actually, there is an available graph on correlation between cone end resistance and CBR which is produced by the research result of Bakrie Oemar dan Nurly Gofar on 1995. But, the graph was research on unknown area, and the structure and characteristic of soil might certainly different. The graph of the correlation between Cone End Resistance (qc) and California Bearing Ratio (CBR) of land in Banjarbaru is not available yet. This factor makes the planner usually conducting a CBR test in laboratory or tends to enlarge the safety factor in the design, as the impact, the project cost also increase. Based on the background, the researcher conducted the research on the correlation between Cone End Resistance (qc) and California Bearing Ratio (CBR) of land in Banjarbaru.

1.1 California Bearing Ratio

CBR test was issued by California Transportation Department on 1992. The test aims to determine the feasibility of subsoil which will use as base course in a highway construction. Since the World War II, U.S Army Corps of Engineers adapts this test in the construction of airfield. The score of CBR is a comparison between the penetration load of a material and the standard material on the same depth and penetration speed. In a formula;

\[ \text{CBR} = \left( \frac{\text{tension test}}{\text{tension standard}} \right) \times 100\% \] eq. 1

Table of tension standard scores is presented in Table 1.
Table 1. The scores of tension standard on each penetration

| Penetration | Unit of tension standard |
|-------------|--------------------------|
| mm          | Inch | Mpa | Psi |
| 2.5         | 0.10 | 6.9 | 100 |
| 5.0         | 0.20 | 10.3| 1500|
| 7.5         | 0.30 | 13.0| 1900|
| 10.0        | 0.40 | 16.0| 2300|
| 12.7        | 0.50 | 18.0| 2600|

Source: Bowles (1992)

The CBR score is used to assess the soil, especially as base course on highway pavement or airfield. The typical rating of CBR score is presented in Table 2.

Table 2. Soil Classification according to CBR score

| CBR No | Common Levels | Function       | Classification |
|--------|---------------|----------------|----------------|
| 0-3    | Very poor     | Sub grade      | OH,CH,MH,OL    | A5,A6,A7       |
| 3-7    | Poor to fair  | Sub grade      | OH,CH,MH,OL    | A4,A5,A6,A7    |
| 7-20   | Fair          | Sub base       | OL,CL,ML,SC,SM,SP | A2,A4,A6,A7 |
| 20-50  | Good          | Base or sub base | GM,GC,SW,SM,SP,GP | Ab,A2-5,A3,A2-6 |
| >50    | Excellent     | Base           |                | A1a,A2-4,A3    |

Source: Bowles (1992)

1.2 Laboratory CBR Test

This test use Penetrometer tools with minimum capacity of 4.45 ton and the speed of penetration of 1.25 mm per minutes. Laboratory CBR test requires compaction test. The common sample on Laboratory CBR test is soil in optimum water contents. But, the checking of CBR can be conducted to varieties of water contents and dry content weights. The disadvantages of this test are:

- Taking too long time compare to direct field test, because it through testing procedures, such as filtering, Atterberg limit test, and compaction.
- Taking more cost on taking the samples and carrying the samples to laboratory.

1.3 Field CBR Test

If compare to laboratory test, Field CBR test has advantages on time (data may take at that time) and no need to take the soil sample. The first common of field CBR test is pistons test. The pistons test use a mechanical CBR jack with a capacity of 10 tons, and requires a truck or other heavy vehicle loaded, then under the vehicle is set a mechanical jack. The disadvantage of this test is the use of trucks or heavy vehicles that make this test not efficient.

The second of field CBR test is cone test or Cone Penetrometer. Cone Penetrometer is developed by U.S Army Corps of Engineers to test the cohesive soil capacity which will be passed the combat vehicle. The cone penetrometer has two models; military and commercial, consisting of handle, proving ring, and dial gauge. The cone is made by material of stainless steel with height of 1.5 inch and width of 0.5 inch².

The advantages of the Cone Penetrometer are:

- Very fast, especially by electronic device supporting to record the end resistance.
- Possibility to record continuity on the soil resistance on the layers that will be tested.
- No requires any loading due to the pointed of cone end makes the tool easy to penetrate into the ground.
2. Methodology

The research procedures is presented in Figure 1:

![Flow Chart of the Research](image)

**2.1 Field Work**

The samples were taken in; Balitra, Jalan Semeru (Semeru Street), Mandiangin Circuit, and Banjarbaru Asri Housing. There took soil samples in three points of every areas.

**2.2 Laboratory Work: Soil Physical Characteristic Test**

In the test, it aims to know the liquid limit (LL), plastic limit (PL), and specific gravity (Gs). The standard of ASTM D-4318 is used to measure the plastic limit and liquid limit, and the standard of ASTM D-854 is used to measure the specific gravity.

**2.3 Compaction Test**

The steps of compaction are:

1) Checking the initial water content before the compaction test
2) Obtained the score of optimum water content based on the test of plastic limit and liquid limit.
3) The test subjects is divided into five; one subject on optimum water contents, two subjects on lower than optimum water contents, and two subjects on higher than optimum water contents. Adding water aiming to reach the standard water content, must consider the score of natural water contents.
4) The score of zero air voids is based on the score of soil specific gravity (Gs).
5) Mixing time. The longer of soil mixing time, it will obtain higher the maximum density, because by the longer of mixing time, the clay structure will be more dispersed.

The compaction procedures are according to standard of ASTM D 698-78.
2.3 CBR Test and Cone Penetration Test

The soil sample with the same soil density will be tested through 2 kinds of tests, which are CBR test and penetration test. On CBR test, the soil samples will be checked on a penetration where the penetration speed standard is 1.25 mm/det. The CBR score is based on the penetration score of 2.5 mm. If the score of 5 mm penetration is higher, then the test must retake. And, if the CBR score of 5 mm penetration in the retake test is higher than the penetration score of 2.5 mm, then the CBR score of 5 mm penetration will be used. The CBR test procedures are based on the standard of ASTM 1883-87. Moreover, on penetration test, the cone will be put on penetrometer tools to replace the pistons. Then, the cone is pushed into the soil where the depth of penetration and density is same with the CBR test.

The factors must consider in CBR test and Cone test are:
1) Reach the touch field perfectly between the pistons and cone and the soil surface. The soil surface must be flat.
2) Give the same treatment to soil sample through the CBR test and cone penetration test, such as colliding energy, adding water, mixing time, and others. This is to ensure the same density on the soil samples and the correlation between the CBR score and the result of cone end resistance is accountable.

3. Findings

3.1 Soil Attribute

The result of soil physical characteristic test is presented in table 3:

| Location                  | Point/Location | Symbol of Soil Classification | Gs  |
|----------------------------|----------------|-------------------------------|-----|
| Balitra                    | 1              | CL                            | 2.73|
| Balitra                    | 2              | CL                            | 2.70|
| Balitra                    | 3              | CL                            | 2.77|
| Sirkuit Mandiangin         | 1              | ML                            | 2.68|
| Sirkuit Mandiangin         | 2              | ML                            | 2.67|
| Sirkuit Mandiangin         | 3              | ML                            | 2.70|
| Jalan Semeru               | 1              | CL                            | 2.78|
| Jalan Semeru               | 2              | CL                            | 2.72|
| Jalan Semeru               | 3              | CL                            | 2.70|
| Komp. Banjarbaru Asri      | 1              | CL                            | 2.73|
| Komp. Banjarbaru Asri      | 2              | CL                            | 2.77|
| Komp. Banjarbaru Asri      | 3              | CL                            | 2.71|

3.2 CBR Test and Cone Test

Based on the laboratory test, the CBR score in Balitra is 5.2% - 15.9% and the cone end resistance is 49.947 kg/cm2 – 215.813 kg/cm2. The graph on the correlation between the CBR score and cone end resistance in Balitra is presented in Figure 2.
Figure 2. The Graph On The Correlation Between The CBR Score And Cone End Resistance

Figure 2 show the inclination the higher of $q_c$ score, then the CBR score is also high. The dispersed points make positive line with the equation of $\text{CBR} = 0.0565 \times q_c + 2.289$ and the linear correlation between the score of CBR and $q_c$ is very good and high. By the score of $R^2 = 0.9323$, 93.23% the variety of CBR score can be explained by the linear correlation with score of $q_c$.

On Mandiangin circuit, the CBR score is 11.6% - 17.2%, and the cone score is 109.905 kg/cm$^2$ – 299.740 kg/cm$^2$. The graph on correlation between CBR and cone end resistance in Mandiangin circuit is presented in Figure 3.

Figure 3. The Graph On The Correlation Between The CBR Score And Cone End Resistance

Figure 3 show the inclination the higher of $q_c$ score, then the CBR score is also high. The dispersed points make positive line with the equation of $\text{CBR} = 0.0427 \times q_c + 5.1809$ and the linear correlation between the score of CBR and $q_c$ is very good and high. By the score of $R^2 = 0.8825$, 88.25% the variety of CBR score can be explained by the linear correlation with score of $q_c$.

On Semeru Street, the CBR score is 6.1% - 17.9% and the cone score is 88.923 kg/cm$^2$ – 270.765 kg/cm$^2$. The graph on correlation between CBR and cone end resistance in Semeru Street is presented in Figure 4.
Figure 4. The Graph On The Correlation Between The CBR Score And Cone End Resistance

Figure 4 show the inclination the higher of $q_c$ score, then the CBR score is also high. The dispersed points make positive linear line with the equation of $\text{CBR} = 0.0584 \times q_c + 1.8747$ and the linear correlation between the score of CBR and $q_c$ is very good and high. By the score of $R^2 = 0.9642$, 96.42% the variety of CBR score can be explained by the linear correlation with score of $q_c$.

The last on Banjarbaru Asri housing, the CBR score is 12.5% - 16.3% and the cone score is $173.849 \text{ kg/cm}^2 - 268.767 \text{ kg/cm}^2$. The graph on correlation between CBR and cone end resistance in Banjarbaru Asri housing is presented in Figure 5.

Figure 5. The Graph On The Correlation Between The CBR Score And Cone End Resistance

Figure 5 show the inclination the higher of $q_c$ score, then the CBR score is also high. The dispersed points make positive linear line with the equation of $\text{CBR} = 0.0344 \times q_c + 7.2514$ and the linear correlation between the score of CBR and $q_c$ is very good and high. By the score of $R^2 = 0.5331$, 53.31% the variety of CBR score can be explained by the linear correlation with score of $q_c$.

4. Discussion: The Correlation Between CBR and $q_c$ in Banjarbaru

After obtained the correlation between CBR and Cone End Resistance on each area, the next step is making graph which explain on correlation between CBR and Cone End Resistance in Banjarbaru. Figure 6 show the inclination the higher of $q_c$ score, then the CBR score is also high. The dispersed points make positive linear line with the equation of $\text{CBR} = 0.0545 \times q_c + 2.618$ and the linear correlation between the score of CBR and $q_c$ is very good and high. By the score of $R^2 = 0.9325$, 93.25% the variety of CBR score can be explained by the linear correlation with score of $q_c$. 
5. Conclusion

The calculation of CBR score using cone Penetrometer is the easier ways.

1) There are some researches on the correlation between CBR and qc, such Bakrie Oemar and Nurly Gofar (1995), but the research result may not probably able to apply in all areas.

2) In Banjarbaru, the correlation between CBR and qc is formulated by the formula of \( CBR = 0.0545 \times qc + 2.618 \)

References

[1] T. D. Arief and S. H. Markopolos, Krislinawati, 2002. “Model Korelasi Antara Cc Dengan L1 Untuk Tanah Lempung Di Surabaya,” Dimens. Tek. Sipil, vol. 4, no. 1, pp. 9–14.

[2] O. Bakrie and N. Gofar, 1995. Sifat-Sifat Tanah Dan Metoda Pengukurannya. Palembang: Universitas Sriwijaya.

[3] J. Bowles, 1992. Engineering Properties of Soil and Their Measurement, 4th Edito. New York: Megrow-Hill.

[4] H. Budhiaty, R. Sylviana, D. Damayanti, S. Al Ansari, and A. Santoso, 2013. “Pengukuran Nilai California Bearing Ratio (CBR) Lapis Perkerasan Aspal Dengan Alat Dynamic Cone Penetrometer (DCP),” J. Bentang, vol. 1, no. 2, pp. 35–43.

[5] N. A. Budiman, 2013. “Pengaruh Penambahan Abu Ampas Tebu Terhadap Sifat Fisik Dan Sifat Mekanik Tanah Lempung Ekspansif,” J. Ilm. Tek. Sipil, vol. 17, no. 1, pp. 84–96.

[6] A. G.M and A. O.A, 2013. “Influence of Inorganic Salts on Soils Liquid and Plastic Limits,” Civ. Eng. Dimens., vol. 15, no. 1, pp. 51–60.

[7] H. Hardiyatmo, 2006. Mekanika Tanah I, Edisi Keem. Yogyakarta: Gajah Mada University Press.

[8] P. I. L. Lengkong, 2013. “Hubungan Nilai CBR Laboratorium Dan DCP Pada Tanah Yang Dipadatkan Pada Ruas Jalan Wori–Likupang Kabupaten Minahasa Utara,” J. Sipil Statik, vol. 1, no. 5, pp. 368–376.

[9] B. Lumikis, S. Monintja, S. Balamba, and A. 2013. Sarajar, “Korelasi Antara Tegangan Geser Dan Nilai CBR Pada Tanah Lempung Ekspansif Dengan Bahan Campuran Semen,” J. Sipil Statik, vol. 1, no. 6, pp. 400–407.

[10] Marwan and D. Sundary, 2012., “Hubungan Nilai California Bearing Ratio Dengan Indeks Plastisitas Tanah Desa Neuheun Aceh Besar,” J. Tek. Sipil Univ. Syiah Kuala, vol. 2, no. September 2012, pp. 97–104.
[11] O. Nasrullah, 2010. “Pengaruh Sodium Hidroksida (NaOH) Sebagai Bahan Stabilisasi Terhadap CBR rendaman dan Batas-batas Konsistensi Tanah Lempung Bukit Rawi,” Universitas Muhammadiyah Palangkaraya.

[12] M. Purnomo, 2011. “Korelasi Antara CBR, PI Dan Kuat Geser Tanah Lempung,” *J. Tek. Sipil dan Perenc.*, vol. 13, no. 1, pp. 81–90.

[13] A. Rostikasari, N. S. Surjandari, and N. Djarwanti, 2016. “Korelasi Indeks Kompresi (CC) Dengan Parameter Kadar Air Alamiah (wn) Dan Indeks Plastisitas ( IP ),” *e-Jurnal MATRIKS Tek. SIPIL*, vol. 55, pp. 570–575.

[14] M. Shalahuddin, 2012. “Varian CBR Yang Mewakili Terhadap Kedalaman Uji DCP,” *J. Aptek*, vol. 4, no. 2, pp. 65–70.

[15] L. A. Widari, 2015. “Pengaruh Penambahan Pasir Pada Tanah Lempung Terhadap Kuat Geser Tanah,” *Teras J.*, vol. 5, no. 2, pp. 144–152.

[16] K. Zaro, S. Nugroho, and F. Fatnanta, 2014. “Pengaruh Kadar Lempung Dengan Kadar Air Diatas OMC Terhadap Nilai CBR Dengan Dan Tanpa Rendaman Pada Tanah Lempung Organik,” *Jom F Tek.*, vol. 1, no. 2, pp. 1–5.