The Correlation Between CBR (California Bearing Ratio) and UCS (Unconfined Compression Strength) Laterite Soils in Palangka Raya as Heap Material

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Abstract: In road construction activities, the use of soil as heap material is commonly practiced. Soils are heaping above soft soils aiming to increase the carrying capacity of the soft soils layer. The parameters for reference are the CBR (California Bearing Ratio) and UCS (Unconfined Compression Strength) scores. But, the test of CBR and UCS takes a long time in the process. Therefore, an approach is needed to obtain the score of CBR and UCS. Then by find out one of the parameters score, will also find out the others parameter scores. Aim to obtain the correlation between CBR and UCS scores, firstly, need to perform test in laboratory. The test conducted to soil samples from Tangkiling village, Bukit Batu district, Palangka Raya City, Central Kalimantan Province. The results showed that the correlation between UCS and CBR scores were, UCS = 0.2416, CBR = 1.2389, with R score was 0.9193. This data showed a very high correlation between UCS and CBR.

Keyword: correlation, CBR, UCS, laterite, silt, clay, heap

1. Introduction

The activity of soils heaping for construction is common matter, especially on soft soils characteristics. The soils heaping above the soft soils have high risks of sliding failure and over-degradation, where it will affect to score of CBR (California Bearing Ratio) and UCS (Unconfined Compression Strength). Aiming to produce a planning of good and strong construction, it needs complete and accurate data. The data must be collected through tests in laboratory. By the laboratory test, it will obtain the soils properties and mechanism. The soil physical properties will provide an overview of the classification, seen from grain size and soil plasticity, and mechanical properties such as soil carrying capacity to withstand the dynamic loads and unconfined compression strength of soil to withstand the static loads.

In common principle, the process of heaping soil is carried out by heaping the soil. Then, based on the aim and purpose of using the soils, heaping soils are divided into 2 types. They are:

1) Common heaping is heaping soils for surface final elevation or base as required in the plan or the target of the work without any other special purposes.
2) Optional heaping is heaping soils to improve the carrying capacity of the subgrade as required in a work.

The laterite soils are formed because of the cold humid environment and the puddles. This soils are red, and the others variant is brown. The type of soils are very widespread in Indonesia, and estimated of 8.085 million hectares of red soil spreading among Papua, Kalimantan, Sumatra, Java, and Sulawesi. The common soil mechanical properties uses as parameters for heaping options are CBR and UCS scores. In practical planning, it sometimes does not need to perform an overall soil experiment - it only requires an approach of CBR score to UCS. But, to obtain the approach, it needs to test in laboratory.

1.1 Heaping Soils

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1.2 Laterite Soils

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1.3 California Bearing Ratio (CBR)

CBR test aims to know the comparison between trial loading and standard loading, and it states in percentage (Soedarmo, 1993 in Predrikson, 2015). The price of CBR is carrying capacity of compacted soil through compaction at a certain moisture content compared to standard materials in the form of crushed stone with having 100% CBR score in withstand the traffic load. Therefore, the CBR score is the percentage or comparison of soils carrying capacity compared to carrying capacity of standard crushed stone at the same penetration score (0.1 inches and 0.2 inches). According to Directorate General of Highways, 1976 (in Predrikson 2015) soils can be classified on its use for subgrade based on CBR score of the soil type. And the CBR score of subgrade presented in Table 1:

| CBR Score | CBR of subgrade |
|-----------|-----------------|
| > 24%     | Very Good       |
| 8 – 24%    | Good            |
| 5 – 8%     | Medium          |
| 3 – 5%     | Poor            |
| 2 – 3%     | Very Poor       |

Source: Directorate General of Highways (1976) in Predrikson (2015)

1.4 UCS (Unconfined Compression Strength)

Aiming to test the Unconfined Compression strength of soil, it performs the test of the land ability toward static tension which is given periodically. The maximum capability score of the soil can be interpreted as the compression strength score of soil (qu). The UCS test can be used in soil samples of disturbed or undisturbed conditions, and remolded or compacted soil samples.

In this experiment, the soil samples are remolded. The soil samples will be pressed in unconfined state until broken on one axis. Because unconfined prism experiments are carried out in the air, then the factor of soil water content are essential (Albajili, 2014).

Then, by test results of unconfined compression strength (qu) will be found out the consistency of clay soil (Hardiyatmo, 2010 in Muda 2016) as presented in Table 2:

| Consistency   | qu(kN/m²) |
|---------------|-----------|
| Hard Clay     | > 400     |
| Very Stiff Clay | 200 - 400 |
| Stiff Clay    | 100 - 200 |
| Medium Clay   | 50 - 100  |
| Soft Clay     | 25 – 50   |
| Very Soft Clay | < 25      |

Source: Hardiyatmo(2006 in Muda 2016)

1.5 Previous Related Research

Muda (2016) in a study on stabilization of clay in Bukit Rawi using Sand and cement, obtained the correlation score of CBR and UCS, were: CBR = 0.1325 UCS, with price of CBR ranged between 50-150% and UCS between 7-14 kg / cm2.

Predikson (2015) in a research entitled “The correlation between CBR and UCS score of clay in Palangka Raya with Sand and Cement stabilization”, obtained correlation between CBR and UCS is CBR = 4.14 UCS + 28.15.
2. Methodology

2.1 Research Stages

The research stages are:
1. Preparation of tools and equipment in laboratory
2. Taking laterite soil samples in Tangkiling village, Bukit Batu district
3. Testing the physical of laterite soil properties
4. Making soil samples for CBR and UCS test of laterite soils, including the sample variations based on addition and reduction of optimum moisture content based on previous compaction test result.
5. Test of CBR and UCS score on all samples variation.
6. Analysis of testing result

Briefly, the research stages are explained in Figure 1:

![Flow Chart of the Research](image)

Figure 1. Flow Chart of the Research

2.2 Location of Taking Sample

The samples were taken in:
1) Sample A is taken from Jl. Tjilik Riwut KM. 36 (Trans Kalimantan to Jl. A. Yani, Sampit) with height of 30 meters above the sea level and position (S 01°58'27.1" E 113°44'45.9").
2) Sample B is taken from Jl. Tjilik Riwut KM. 33.5 (Trans Kalimantan to Jl. A. Yani, Sampit) with height of 37 meters above the sea level and position (S 01°58'33.5" 113°45'15.1").
3) Sample C is taken from Jl. Tjilik Riwut KM. 35 (Trans Kalimantan to Jl. A. Yani, Sampit) with height of 29 meters above the sea level and position (S 01°58'32.9" E 113°44'56.5").

Location of taking sample are explained in Figure 2:

3. Findings

After conducted test at Geotechnical Laboratory of Faculty of Engineering UM Palangkaraya, obtained the soil properties of Laterite in Tangkiling village, Palangka Raya, is presented in Table 3:
Table 3. Testing Result and Soil Properties of Laterite

| Test Types                          | Sat. | Sample A | Sample B | Sample C |
|-------------------------------------|------|----------|----------|----------|
| Soil Moisture Content               | %    | 2.18     | 1.56     | 2.29     |
| Average of specific gravity         |      | 2.64     | 2.66     | 2.63     |
| Liquid Limit (LL)                   | %    | 29.60    | 33.35    | 40.50    |
| Plastic Limit (PL)                  | %    | 19.49    | 25.54    | 29.77    |
| Plasticity Index (PI)               | %    | 10.11    | 7.96     | 10.73    |
| Weight of Maximum Dried Content     | gr/cm$^3$ | 1.84    | 1.81     | 1.73     |
| Optimum Moisture content            | %    | 15.75    | 16.00    | 15.95    |
| Swelling                            | %    | 0.04     | 0.03     | 0.01     |
| CBR                                 | %    | 9.50     | 10.90    | 20.50    |
| UCS                                 | kg/cm$^3$ | 1.25    | 1.75     | 2.95     |

Based on the result of its gravity as presented in table 1, the soil includes into type of non-organic lanau with the specific gravity score is around 2.62-2.68.

3.1 Test Result of California Bearing Ratio (CBR).

Laboratory CBR test here is an immersion of CBR test. The samples test should be immersed for 1 day and soaked for 5 days. This CBR testing conducted based on $w_{\text{opt}}$ score from the result of soil compaction, and continues to make soil samples based on 10% addition and reduction of $w_{\text{opt}}$ score. The results are presented in Table 4 and Figure 3.

Table 4. CBR Test Result of Soils

| Types     | Score of CBR (%) |
|-----------|------------------|
|           | -10% $w_{\text{opt}}$ | $w_{\text{opt}}$ | +10% $w_{\text{opt}}$ |
| Sample A  | 11.40            | 9.50            | 7.40            |
| Sample B  | 13.00            | 10.70           | 9.20            |
| Sample C  | 24.30            | 18.00           | 14.20           |

In order to have easier understanding toward the comparison of CBR test result, then it displays into block diagram and presented in Figure 3.
In general, the obtained CBR score from test results, according to the Directorate General of Highways (1976) in Muda (2016) states that laterite soils with CBR score between 8-24% for subgrade is good category. Meanwhile, according to Bowles (1993), classification based on the price of CBR 7-20%, then, in general level, includes in medium category, and use for subbase.

3.2 Test Result of Unconfined Compression Strength (UCS).

In UCS test, the each sample was immersed for 7 days. This test is conducted in two times of experiments. And, the taken score is the average score of the result. The test results of each sample are presented in Table 5 and Figure 4.

| Type          | Score of UCS (kg/cm²) |
|---------------|-----------------------|
|               | -10% \( w_{opt} \) | \( w_{opt} \) | +10% \( w_{opt} \) |
| Sample A      |                       |
| Variation 1   | 1.28                  | 1.15              | 1.05              |
| Variation 2   | 1.35                  | 1.25              | 1.12              |
| Average       | 1.32                  | 1.20              | 1.09              |
| Sample B      |                       |
| Variation 1   | 1.98                  | 1.75              | 1.04              |
| Variation 2   | 1.00                  | 1.01              | 1.11              |
| Average       | 1.49                  | 1.38              | 1.08              |
| Sample C      |                       |
| Variation 1   | 5.22                  | 2.95              | 1.92              |
| Variation 2   | 5.15                  | 2.35              | 1.89              |
| Average       | 5.19                  | 2.65              | 1.91              |

Based on the average score of UCS, each point has experiences variations results. As in soils consistency based on the score of \( qu \), then the condition of laterite soils at point 1, the correlation between Unconfined Compression Strength (\( qu \)) and consistency is 105.46 kN / m², including in rigid clay. Meanwhile, at point 2, the result of correlation between unconfined compression strength (\( qu \)) and consistency is 259.97 kN/m², including in rigid clay. And at point 3, the result of correlation between unconfined compression strength (\( qu \)) and consistency is 508.65 kN / m², including in hard clay.
3.3 **Comparation of CBR and UCS scores**

The comparison of CBR (California Bearing Ratio) and UCS (Unconfined Compression Strength) scores are presented in Table 6 and Figure 5.

### Table 6. Test Result of Scores variation on samples of CBR and UCS

| Type  | Condition of \( w_{opt} \)       | \(-10\% w_{opt}\) | \( w_{opt} \) | \(+10\% w_{opt}\) |
|-------|----------------------------------|-------------------|---------------|-------------------|
|       | CBR (%)                          |                   |               |                   |
| Sample A | 11,40 | 9,50 | 7,40 |
| Sample B | 13,00 | 10,70 | 9,20 |
| Sample C | 24,30 | 18,00 | 14,20 |
|       | UCS (gr/cm\(^2\))                |                   |               |                   |
| Sample A | 1,32 | 1,20 | 1,09 |
| Sample B | 1,49 | 1,38 | 1,08 |
| Sample C | 5,19 | 2,65 | 1,91 |

**Figure 5. Chart of Test Result of CBR and UCS**

Based on figure 4, in general, it shows almost the same trend. Where, the highest score in parameters of CBR and UCS is on the test results with 10% addition of optimum moisture content and vice versa. Meanwhile, based on the taken samples point, Point A is the highest score in parameters of CBR and UCS scores, and followed by point B and point C. However, the overall of soil samples can be used as a heap material, as regulated by Bina Marga and Bowless.

**4. Discussion**

When discuss about the correlation, it will try the correlation between the two parameters; the score of CBR and UCS based on test results. Graphics and analytic are used to make easier in obtaining the result. For graphical methods, will make graphical on correlation between the score of CBR and UCS and continue to make a linear line as correlation line between the two parameters. The result of graphical correlation is presented in Figure 6.
Based on figure 5, the correlation score of CBR and UCS shows that if the soils CBR score is high, so there increase of UCS soil score and vice versa. In this test, it obtains the final result of score $R = 0.9193$. Meanwhile, the obtained linear equation is $y = 0.2416 x - 1.2389$. In accordance with the graphic in figure 5, the CBR score is depicted as axis X, and UCS score is depicted as axis Y. Then, the correlation equation is $UCS = 0.2416 CBR - 1.2389$.

5. Conclusion

1) Basically, soils in Tangkiling Village, Bukit Batu district, Palangka Raya City, Central Kalimantan Province, have physical properties according to USCS which belong to ML category and CL category with types, crushed stone, non-organic clay lanau with low to medium plasticity, clay-mixed lanau and fine sand. Manwhile, according to AASHTO, it includes into group A-2-4 and A-2-6 which have fine pebble and lanau-sand or clay.

2) Sample C is the highest on CBR test and in condition of OMC -10% with score of 24.30%. According to the Director General of Highways (1976), soils with CBR score > 24% for subgrade is very good category. Meanwhile, according to Bowles (1993), classification based on the price of CBR 20-50%, then, in general level, includes in good category, and use for subbase.

3) Sample C is the highest on CBR test and in condition of OMC -10% is 5.19 kg/cm². For the correlation results of unconfined compression strong (qu) with the consistency is 508.65 kN/m², include in hard clay.

4) The correlation of CBR (California Bearing Ratio) and UCS (Unconfined Compressive Strength) is: $UCS = 0.2416 CBR - 1$, with $R = 0.9193$.

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