Analysis of soil subgrade bearing capacity for clay using laboratory testing data

L D Putri1,2,*, A Hakam1, R Thamrin1 and Y Yossyafra1

1 Civil Engineering of Universitas Andalas, Padang, Sumatera Barat, Indonesia
2 Civil Engineering of Universitas Lancang Kuning, Pekanbaru, Riau, Indonesia

*lusidwiputri@unilak.ac.id

Abstract. Road construction failures are often caused by unsupported subgrade classification. The purpose of this study was to determine the bearing capacity of subgrade on clay using test data in the laboratory. The contribution of this study can later be a recommendation in the use of subgrade types of clay and alternative uses. One of the properties of land strength associated with roads in the California Bearing Ratio (CBR). The method used is soil physical testing and CBR testing. The soil sample used was undisturbed soil in the subgrade in Minas District, Siak Regency, Riau Province. The result showed that the clay studied was non-organic Sandy Lean Clay CL) with low plasticity based on the USCS classification table. 2.681 specific gravity, water content 29.94%, liquid limit 33.64%, plastic limit 23.67% and plasticity index 9.97%. Soaked CBR test results obtained 4.21% and included in the medium classification. The use of this type of clay soil for subgrade with the bearing capacity of CBR classification needs to be pursued with alternative improvements and soil reinforcement that can increase the CBR value to a minimum of 6%.

1. Introduction

The problem of bearing capacity of the subgrade is a problem that is often encountered in the implementation of road construction activities [1]. The poor condition of subgrade can cause construction failure due to reduced bearing capacity as a result of contamination of aggregate material by subgrade or loss of sub-base aggregate into the subgrade. Vertical deformation as a result of the application of the load is related to the distribution of the vertical stress transferred to the soil sample [2]. Roads on this type of soil mostly fail before the planned age and even require routine maintenance that requires special attention [3]. Most of the factors to predict hardened road life are subgrade bearing capacity, loading effect, type of test, compaction method, variables related to the environment (especially humidity, temperature, aging), and pavement design parameters [1]. Subgrade affects the cost of road construction because the bearing capacity of the subgrade determines the thickness of the pavement layers [4].

Most of the land in Riau Province is clay type soil, so special attention is needed if roads are to be built. The development of clay soils is a challenge because of its low shear strength and high compressibility [5]. The low shear strength of clay soils significantly limits the amount of load that can be borne by clay soils with an adequate level of security in the short term [6]. Subgrade conditions that have many different layers of soil then the spread of the charge will be different from unstable soils [7]. For this reason, it is necessary to examine the physical and mechanical properties of the soil to determine
the bearing capacity of this clay. One of the properties of soil strength associated with roads is the California Bearing Ratio (CBR) [1,3,4,8].

The purpose of this study was to determine the bearing capacity of the subgrade on clay using test data in the laboratory. The contribution of this study can be a recommendation in the use of subgrade types of clay and alternative uses. This soil data can also be used as numerical modeling material by finite elements to predict potential failures [9]. The two numerical models, 2D and 3D used to depend on the characteristics of the soil layer [10]. To measure lateral displacement and estimated shear strain, image processing analysis based on optical flow can also be performed [11]. Numerical finite element analysis using the application is used to solve problems in clay [12]. Rapid maintenance of clay subgrade is one of the main ways to solve problems related to road construction [13]. In addition to quick maintenance, embankments are also an alternative, but adding new embankments that are close to the old one can also lead to a series of geotechnical problems including excessive differential resolution which causes cracks in the longitudinal pavement especially those on clay [14].

1.1. Clay
Clay is a soil that has micronic to the submicronic size which is derived from weathering rock constituent chemical elements. Clay is very hard in a dry state. The permeability of clay is very low so the clay is plastic [15]. Clay has poor mechanical properties. Besides, clay has high water content, high compressibility, low bearing capacity, low stability and a small coefficient of permeability that will result in the process of consolidation will take place in a long time. Soil classification based on the Unified Soil Classification System (USCS).

1.2. Atterberg limit
The liquid limit is the groundwater content at the boundary between the liquid limit and the plastic limit. How to determine it can use the Casagrande tool. Usually, the experiment is carried out on several soil samples with different water contents and the number of blows is calculated for each water content. Thus it can be graphed the water content of the number of blows. From this graph, it can be read the water content at a particular blow.

The plastic limit is the water level at the lower limit of the plastic area or the minimum water content where the soil can be rolled up to a diameter of 3.1 mm (1/8 inch). This water content is determined by grinding the ground on a glass plate until the diameter of the stem is formed to reach 1/8 inch. When the soil starts to break when the diameter is 1/8 inch, the soil water content is the plastic limit.

Shrinkage limit shows the water content or the limit where the soil is saturated, which is already dry, will not shrink anymore, even if it is dried continuously or the limit where after losing the next water content does not cause a decrease in soil volume.

The plasticity index is the difference between the liquid limit and the plastic limit (the interval of water content in soil conditions is still plastic) because it shows the plasticity of the soil. If the soil has a high PI, then the soil contains a lot of clay granules. If the PI is low, like silt, a slight reduction in water content results in the soil becoming dry [15].

1.3. California Bearing Ratio (CBR)
CBR is defined as a comparison between the load on an experiment (test load) with a standard load at the same penetration and expressed in percent. The test results can be obtained by measuring the amount of load at a particular penetration [15]. The Department of Public Works has limited the CBR strength value for a subgrade of at least 6% [4]. The establishes a subgrade for roads into several groups as listed in Table 1.
Based on the Regulation of The Implementation of Highway Development Department of Public Works (1972) in Chairullah [4], various types of local soil can be used for road material with the provisions as in Table 2 below.

| Classification | Type of Soil    | CBR (%) |
|----------------|----------------|---------|
| Very Good      | a. Sirtu       | 25 - 60 |
|                | b. Gravel/Sand | 20 - 60 |
| Good           | a. Rough sand  | 10 - 30 |
|                | b. Fine sand   | 6 - 25  |
| Middle         | Silt or/and clay| 4 - 15 |
| Ugly           | Organic clays | 3 - 8   |
| Very ugly      | Humus/ Organic soil | -     |

Table 1. Basic subgrade classification for roads.

Table 2. CBR and PI value requirements for road construction.

| Material      | CBR (%) | PI (%) |
|---------------|---------|--------|
| Subgrade      | \( \geq 6\% \) | \( \leq 15\% \) |
| Subbase       | \( \geq 20\% \) | \( \leq 10\% \) |
| Base course   | \( \geq 50\% \) | \( \leq 4\% \) |

2. Methods

The method used is the physical testing of clay soil and CBR testing in the laboratory. The soil sample used was undisturbed clay soil at the subgrade in Minas District, Siak Regency, Riau Province. The measurements made are divided into two kinds, namely the measurement of physical properties (index properties) and mechanical properties of the soil (engineering properties). Measurement of physical properties includes measurement of specific gravity, grain distribution, and limits of soil consistency, namely liquid limit, plastic limit, and plastic index, while the mechanical properties measured are CBR values using SNI 03-1744-2008. The test is carried out on native soil. Clay samples used were taken directly using hand bore.

3. Results and discussion

3.1. Soil properties and CBR values

The results of the tests obtained are specific gravity, grain distribution, and soil consistency limits, namely the liquid limit value (LL), plastic limit (PL) and plastic index (PI), soil type and CBR value are as follows; 2,681 specific gravity, water content 29.94\%, liquid limit 33.64\%, plastic limit 23.67\% and plasticity index 9.97\% with CBR value in the laboratory of 4.21\% as shown in Figure 1, Figure 2 and Table 3.
Subgrade classification based on USCS for soils with LL values less than 50 and is non-organic and aggregate soils that pass the filter plus 200 is greater than 30% with a sand percentage greater than gravel and percentage of gravel is smaller than 15%, so soil classification based on USCS is CL type Sandy Lean Clay like the graph in Figure 2.

In Figures 1 and 2, it was found that the results of the study showed the properties of the clay that were studied were the specific gravity values 2.681, the water content 29.94%, the liquid limit 33.64%, the plastic limit 23.67% and the plasticity index 9.97%. The clay soils included non-organic Sandy Lean Clay (CL) soils with low plasticity based on the USCS classification table.

The CBR value of native soil obtained from laboratory testing was 4.21%. The value obtained does not meet the requirements of the General Specifications of Bina Marga is ≥ 6%. The categories of native soils acquired are included in the medium classification.

Analysis of laboratory data for subgrade soils that are of clay type according to the summary contained in Table 3.
Table 3. Original soil property values.

| Mechanical properties of soil |          |
|------------------------------|----------|
| Liquid Limit (LL)            | 33.64%   |
| Plastic Limit (PL)           | 23.67%   |
| Plastic Index (PI)           | 9.97%    |
| Soil Type                    | CL (Sandy Lean Clay) |
| CBR                          | 4.21%    |

4. Conclusion
The CBR value of native soil obtained from laboratory testing was 4.21%. The value obtained does not meet the requirements of the General Specifications of Bina Marga is ≥ 6%. The categories of native soil acquired are included in the medium classification. The use of this type of clay for subgrade with the bearing capacity of CBR classification needs to be pursued with alternative improvements and soil reinforcement that can increase the CBR value to a minimum of 6%.

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