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# Effects of Physical and Mechanical Properties of Soft Soil on Subgrades Performances in Lubuk Bayas Village, Serdang Bedagai Regency

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# Effects of Physical and Mechanical Properties of Soft Soil on Subgrades Performances in Lubuk Bayas Village, Serdang Bedagai Regency

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**Abstract.** Generally, the existence of soft soil in Indonesia will be a problem in the construction of highway construction. One factor that influences and needs to be known in road construction is the characteristics of the subgrade where the pavement construction will be placed on it. Poor soil characteristics can cause bumpy road surfaces, cracks, or other road damage. Therefore, before carrying out a soil improvement, it is necessary to know its characteristics through the physical and mechanical properties of the subgrade. This research was conducted in Lubuk Bayas Village, Serdang Bedagai Regency, North Sumatra Province. Tests of physical properties in this study include sieve analysis, water content, specific gravity, plasticity limit test, and liquid limit test. The soil shear strength test and California Bearing Ratio (CBR) test were carried out to test the mechanical properties using a Dynamic Cone Penetrometer (DCP). From the results of testing the physical properties of the soil, it was found that Samples 1, 2, and 3 were fine-grained soils with the percentage of soil passing the No.200 sieve greater than 50%. The USCS classification system shows that samples 1 and 2 of the soil are in the Lean Clay (CL) group, while sample 3 is in the Fat Clay (CH) group. Samples 1, 2, and 3 include soils with high plasticity because the PI value is >17. The results of testing the mechanical properties of the soil Sample 1 obtained the value of c = 0.1299 kg/cm² and Ø = 13.2º, in Sample 2 obtained the value of c = 0.1075 kg/cm² and the value of Ø = 11.2º and in Sample 3 obtained the value of c = 0.1275 kg /cm² and the value of Ø = 11.9º. DCP testing on samples 1, 2 and 3 obtained CBR values of 5.35%, 4.73% and 3.15%. From the CBR results, it can be seen that the soil in this location has a low soil bearing capacity, so if it is to be used as a subgrade layer, it will be necessary to repair the soil first so that structural damage does not occur in the future. Soil improvement can be made by stabilizing the soil using natural materials to maintain environmental sustainability. Natural materials that can be used include sand with certain gradations, stone ash, palm shell ash, and various other natural materials.

## 1. Introduction

Indonesia is currently incessantly carrying out infrastructure development such as roads to facilitate the flow of transportation and advance the community's economy [1]. Therefore, it is hoped that the construction of the road will function as expected. For this to be carried out properly, it is necessary to pay attention to and consider the factors that will affect the function of the road construction service.

One of the most important factors to know in building road construction is the characteristics of the subgrade on which the pavement will be built [2]. In some areas, primarily rural areas, there are still many roads that only use local soil as a road subgrade. This condition is not a problem if the subgrade condition has a reasonably good soil composition. However, if the subgrade consists of a soft soil layer, it will cause problems in the future [3].

Where in the area during the summer, the road conditions are solid, but when it comes to the rainy season, at some point locations in the area, the soil becomes muddy, which often causes vehicles to experience problems when crossing it. Soil that has poor characteristics can cause damage to the road surface, such as cracks and the appearance of waves on the road. This possibility occurs due to subgrade damage due to the low value of the bearing capacity and shear strength of the soil. Therefore, it is necessary to conduct further studies on soil characteristics, such as the physical and mechanical properties of the subgrade in the area. This research was conducted in Lubuk Bayas Village, Serdang Bedagai Regency.

## 2. Theoretical of Soft Soils

Soft soil is fine-grained soil with low bearing capacity, high compressibility and low shear force [4], [5]. As a result of the low bearing capacity of soft soil, construction costs will be more expensive, and the safety rate will be lower so that construction becomes unsafe [6]. Soft soils include clay and silt types. In clay, soil characteristics can be observed directly in the field, which will crack when dry (shrink) and expand in wet conditions [7]. The grain size of silt soil is more significant than clay soil.

Determining soil's physical properties required a series of tests in the soil test laboratory. The physical properties test includes sieve analysis, specific gravity, liquid limit, plastic limit, and plasticity index [5]. Sieve analysis was conducted to classify the soil based on the percentage of soil passing in each sieve number. Soil classification based on grain size was grouped using the Unified Soil Classification System (USCS) method. The liquid limit is the percentage of the minimum water content of the soil from a liquid state to a plastic state. This test uses the Cassagrande tool with the ASTM method. The plastic limit is the change in the water content of the soil in a plastic state to semi-solid, which is calculated based on the percentage of water to the dry weight of the soil. The plasticity index (PI) shows the plasticity of the soil. If the soil has a high PI value, then the soil is indicated to contain many clay grains. If the soil has a low PI value, such as silt, then a slight reduction in the moisture content of the soil can cause the soil to dry out.

It is essential to know the mechanical properties of the soil in order to take into account the strength or bearing capacity of the soil to the structure above it. Soil mechanical properties can be determined by conducting a series of initial tests such as a direct shear test and a Field CBR test using a Dynamic Cone Penetrometer (DCP). Direct shear testing will produce soil parameters such as shear angle and cohesive values. While the test using the Dynamic Cone Penetrometer (DCP) will produce the value or percentage of CBR from an original ground surface. The soil testing results will help determine the bearing capacity of the soil where a structure will be built. The bearing capacity of the soil is associated with the CBR value obtained from AASHTO [8], as shown in Table 1.

**Table 1**. The Bearing Capacity of The Soil Related to The CBR Value

| CBR | Bearing Capacity |
|---|---|
| 2% – 5% | Poor |
| 6% – 9% | Medium |
| > 9% | Good |

## 3. Research Methodology

Soil sampling in this study came from Lubuk Bayas Village, Perbaungan District, Serdang Bedagai Regency. This research was conducted by taking both disturbed and undisturbed soil samples. This research activity includes a literature study, soil sampling on-site, direct field testing, and laboratory testing. The test samples were taken in the field where the road is bumpy or cracked and carried out 3 points with a distance of each point of approximately 200 meters. Laboratory tests include testing the soil's physical properties and direct shear tests. Physical properties testing includes sieve analysis, specific gravity test, moisture content, liquid limit, and plastic limit. Meanwhile, testing of mechanical properties includes direct shear test and field CBR test using a Dynamic Cone Penetrometer (DCP).

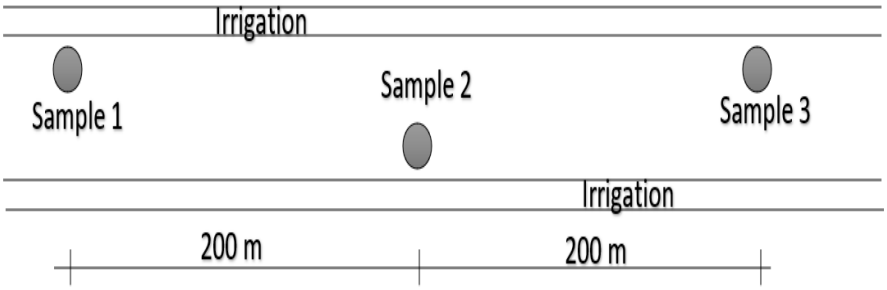


**Figure 1**. Soil Sampling Point

## 4. Result Analysis & Discussion

### *4.1 Physical Properties*

Soil physical testing consists of sieve analysis, grain density, moisture content, liquid limit and plastic limit. This test was carried out at the Civil Engineering Laboratory of Jaya Corindo Design Medan has shown in Table 2.

**Table 2**. Results of Physical Properties

| Type of Test | Results | | |
|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 |
| Specific Gravity | 2.59 | 2.58 | 2.60 |
| Water Content (%) | 22.28 | 23.78 | 24.34 |
| Liquid Limit (%) | 45.17 | 43.87 | 67.07 |
| Plastic Limit (%) | 19.67 | 24.66 | 32.20 |
| Plasticity Index (%) | 25.49 | 19.21 | 34.87 |
| Sieve Analysis (%) (Passing No.200) | 52.60 | 53.70 | 56.25 |

From the results of soil sample testing carried out in the laboratory, samples 1, 2, and 3 are fine-grained soils, where the percentage of soil that passes the No.200 sieve is greater than 50%. According to the soil, classification using the Unified Soil Classification System (USCS), samples 1 and 2 belong to the Lean Clay (CL) group, where the percentage of Liquid Limit is less than 50% and PI is greater than 0.73% (LL-20%). Meanwhile, sample 3 is included in the Fat Clay (CH) group, where the percentage

of Liquid Limit is greater than 50% and PI greater than 0.73(LL-20)%. For plasticity, samples 1,2 and 3 include soils with high plasticity because the PI value is greater than 19 which potential for the soil to swell.

*4.2 Mechanical Properties*

Soil mechanical testing consists of field testing using a Dynamic Cone Penetrometer (DCP) and laboratory testing, namely direct shear testing as shown in Table 3 and Table 4, respectively.

**Table 3**. Results of CBR Value based on Dynamic Cone Penetrometer (DCP) testing

| No. of Sample | CBR Value (%) |
|---|---|
| 1 | 5.35 |
| 2 | 4.73 |
| 3 | 3.15 |

Based on the results obtained in the Table 3, the range of CBR value that study in this research in between 3.15% until 5.35%. So that, based on this value, by referring manual standard that stated in AASHTO, the soil under this CBR value is poor in bearing capacity. This CBR value affected by the physical properties of the soils that obtained in Table 2.

**Table 4**. Results of Direct Shear Test

| Load (kg) | No. of Sample | Normal stress, σ (kg/cm²) | Shear stress, τ (kg/cm²) | Cohesion, c (kg/cm²) | Friction Angle, φ (º) |
|---|---|---|---|---|---|
| 4.25 | 1 | 0.15 | 0.16 | 0.130 | 13.2 |
| | 2 | | 0.134 | | |
| | 3 | | 0.159 | | |
| 8.5 | 1 | 0.3 | 0.198 | 0.108 | 11.2 |
| | 2 | | 0.173 | | |
| | 3 | | 0.191 | | |
| 12.8 | 1 | 0.45 | 0.237 | 0.128 | 11.0 |
| | 2 | | 0.194 | | |
| | 3 | | 0.223 | | |

The shear strength of the soil (Table 4) is described as the function of normal stress on the cohesion and friction angle. The friction angle and cohesion value of clay soils are less than 17 º and 1kg/cm$^2$ dominated as high potential failure. Friction angle and cohesion are the two important physical properties of the soil which determines angle of failure, shear strength, safety factor as well as stability of soils. The cohesion of the clay soil from place to place due to variation in the presence of cementing materials which helps to combine soil particles tightly. This is the bonding of the particles with each other.

## 5. Conclusions and Suggestions

Based on the results obtained in this study shows that the soil at the location of Lubuk Bayas Village, Serdang Bedagai Regency, North Sumatra Province has a low soil bearing capacity, so if it is to be used as a subgrade layer, it is necessary to repair the soil first so that there is no structural damage in the area in future. So that, researcher suggested that the soil need to be improved by stabilizing the soil using natural materials to maintain the environmental sustainability which is the natural materials such as sand with specific gradations, stone ash, palm shell ash, and various other natural materials are recommended.

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