Determination of Types and Characteristics of Laterite Soil as Basic Land for Building Construction

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Abstract. Laterite soil is red soil because it contains iron and aluminum. It is an old type of soil, so it is suitable for all plants. Laterite soils are located in the reservoir area of the Wonogiri Dam - Central Java. The nature of laterite soil that quickly absorbs water and the soil texture is strong and dense indicates the type of soil used for a mixture to make roads. This study aims to identify and characterize the lateritic soils to support the construction of roads that will be used. It is needed to test the soil's property index, including moisture content test, density test, Atterberg limit, and grain sieve analysis. At the same time, it tested the classification of laterite soil characteristics using standards of USCS and AASHTO. To test the shear strength of the laterite soil is using Direct Shear. Based on the analysis, the laterite soil from sedimentation in Wonogiri dam is classified as poor and does not meet the requirements to be used as a subgrade in building construction. It can be considered include need to improve to carried out first.

Keywords: laterite soil, property index test, soil characteristics.

1. Introduction

The mineral oxide content of iron causes the laterite soils, even though the concentration is only small [8]. Relatively high clay minerals are mainly illite and montmorillonite contained in laterite soils [6]. Clay minerals and high metal elements can be used in construction, industry, and other works. [12] Recommends adding a little lime 2% and cement 3% will be very efficient in improving the ability of laterite soils. Research on lateritic soils has been very much done, especially in Asia and Africa, which have a lot of this type of soil. [10] showed that the higher the clay and mineral content in the lateritic soil, the lower the soil strength. [5] concluded that stabilization of laterite soil with lime will increase soil strength by 2-3 times. [11] explained the effect of adding a lime mixture of red soil to the soil's carrying capacity, such as CBR value, moisture content (W), and dry content weight (Yd). The land can be utilized in various constructions. It is supported by the development of research on laterite soil utilization [12].

The strength of building construction and road pavement is highly dependent on the stability of the subgrade of the building and the road itself. While the subgrade conditions in the field are varied, one of which is used in this study is lateritic soil (red soil). The subgrade is usually under the pavement layer, which supports the pavement layer, as shown in Figure 1 below.
For unfavorable soil conditions as the basis for buildings and roads, it is necessary to improve soil stability to support the construction. For this reason, it is necessary to identify and characterize the lateritic soil, whether it is good enough or it is necessary to first stabilize the lateritic soil to support the construction of buildings and roads that will be used.

Determination of particle size variations in the soil or called soil mechanical analysis. For the percentage of the total dry weight expressed as a variation. There are two standard methods used for the distribution of soil particle size, namely:

- **a) Sieve analysis**
  - It is for sieve and vibrates on soil sample through a set of sieve where the sieve hole is getting smaller, for particles larger than 0.075 mm diameter

- **b) Hydrometer analysis**
  - It is made based on the principle of sedimentation (deposition) of soil grains in water for particle sizes smaller than 0.075 mm in diameter

Laboratory tests are used to identify and classify the characteristics of lateritic soils. Some soil parameters include:

- Water content
- Specific gravity
- Atterberg limit include liquid limit, plastic limit
- Direct shear testing.

2. **Materials and Method**

2.1 **Study Location**

The study location is the Wonogiri Dam, in Sendang Village, Wonogiri District, Wonogiri Regency, Central Java. The position of the dam is approximately 7 km to the south of Wonogiri City. The Wonogiri dam is the largest dam ever built in the Bengawan Solo watershed, with a catchment area of 1,350 km². Wonogiri Reservoir is located 3 km south of Wonogiri Regency City. The construction of the Wonogiri Dam began in 1976 and was completed around 1981.

The topography of the Wonogiri Regency is mostly hilly, with ± 20% of the area being limestone hills, especially those in the southern region of Wonogiri. Most of the topography is uneven, with an average slope of 300, so there are differences between one area and another that make the conditions of natural resources different. Only a small area has fertility and potential for agriculture.

Areas with wavy topography (land slope 2 – 15%) have an area of 7,865 hectares. This area with wavy topography occupies almost all of the Wonogiri Regency [7].
2.2 Stages-Completion-Study
In working on this study, it takes several stages of systematic work-up. Following the stages of study completion are as follows:

a) Fieldwork
Fieldwork includes site surveys and the preparation of tools and materials. The survey location is in the Wonogiri reservoir area, Central Java, which currently has much sedimentation at the bottom of the dam. In this study, soil samples were taken at a depth of 0 – 0.50 m around the reservoir area.

b) Soil sample test
Testing of property index, classification of laterite soil and testing of mechanical properties namely Direct Shear using disturbed soil samples at 2 (two) locations each taken 6 kg of lateritic soil samples. The test was tested at the Soil Mechanics Laboratory, Civil Engineering Department and Soil and Groundwater Laboratory, Water Engineering Department, Faculty of Engineering, Universitas Brawijaya.

2.3 Soil Classification System
Due to the grain size distribution of the soil only, the soil classification system on texture is relatively simple, so it is considered inadequate for most engineering purposes. Therefore, according to the Atterberg limit, a soil classification system is also essential. For example, the state of the soil will go through a specific process, namely liquid boundary, plastic limit, and shrinkage limit. The two systems that take into account the distribution of grain sizes and Atterberg limits are: (M.Das, 1995)

a) System Classification AASHTO (American Association of State Highway and Transportation Officials)
Soil is classified into seven major groups, namely A-1 to A-7. Granular soils with 35% or less of the number of soil grains passing sieve number 200 are classified into A-1, A-2, and A-3. While soils with grains passing sieve no. 200, more than 35% are classified in groups A-4, A-5, A-6, and A-7. Most of the silt and clay fall into groups A-4 and A-7. The criteria in the soil classification system are grain size. The graveyard is a part of the soil that passes through a sieve of 75 mm (3
in) and is maintained at no.200 (2 mm). Sand is part of the soil that passes through sieve no. 200 (0.075 mm). Mud and clay are the part of the soil that passes through the sieve no. 200.

- Plasticity. When the finer parts of the soil have a plasticity index (PI) of 10 or less use the name muddy while the finer parts of the soil have a plasticity index of 11 or more use clay.
- If rocks (larger than 75 mm) are found in soil samples whose soil classification will be determined, the rocks must be removed first. However, the percentage of rocks removed should be noted.

| Group classification | A-1 | A-3 | A-2 |
|----------------------|-----|-----|-----|
| A-1-a                |     |     |     |
| A-1-b                |     |     |     |
| A-2-4                |     |     |     |
| A-2-5                |     |     |     |
| A-2-6                |     |     |     |
| A-2-7                |     |     |     |
| Sieve Analysis (% get away) |
| No. 10               | Max 50 |     |     |
| No. 40               | Max 30 | Max 50 | Min 51 |
| No. 200              | Max 15 | Max 10 | Max 26 |
| The nature of the faction that passes the filter no. 40 |
| Liquid Limit (LL)    | Max 40 | Max 41 | Max 40 | Min 41 |
| Plasticity Index (PI)| Max 6  | NP   | Max 10 | Max 10 |
| The most dominant type of materials |
| Appraisal as subgrade material |
| General classification | silt-clay soil |
| Group classification | A-4 | A-5 | A-6 | A-7 | A-7-5* | A-7-6** |
| Sieve analysis (% get away) |
| No. 10               | Min 36 |     |     |     |     |     |
| No. 40               | Min 36 |     |     |     |     |     |
| No. 200              | Min 36 |     |     |     |     |     |
| The nature of the faction that passes the filter No.40 |
| Liquid limit (LL)    | Max 40 | Max 41 | Max 40 | Min 41 |
| Plasticity index (PI)| Max 10 | Max 10 | Min 11 | Min 11 |
| The most dominant type of material |
| Appraisal as subgrade material |

*for A-7-5, PI <= LL - 30
**for A-7-6, PI > LL - 30

### Table 1. Soil Classification for Highway Subgrade (AASHTO System)

| General classification | Grained soil (35% or less of all soil samples passed the No. 200 sieve) |
|------------------------|-------------------------------------------------------------------------|
| Group classification   | A-1 | A-3 | A-2 |
| A-1-a                  |     |     |     |
| A-1-b                  |     |     |     |
| A-2-4                  |     |     |     |
| A-2-5                  |     |     |     |
| A-2-6                  |     |     |     |
| A-2-7                  |     |     |     |
| Sieve Analysis (% get away) |
| No. 10                 | Max 50 |     |     |
| No. 40                 | Max 30 | Max 50 | Min 51 |
| No. 200                | Max 15 | Max 10 | Max 26 |
| The nature of the faction that passes the filter no. 40 |
| Liquid Limit (LL)      | Max 40 | Max 41 | Max 40 | Min 41 |
| Plasticity Index (PI)  | Max 6  | NP   | Max 10 | Max 10 |
| The most dominant type of materials |
| Appraisal as subgrade material |

The most dominant type of materials:
- Crushed stone, gravel, and sand
- Fine sand
- gravel and sand that is silty or silty

Appraisal as subgrade material:
- Very good to good
b) Standard of USCS (Unified Soil Classification System) classification system that categorizes soils into two major groups, namely:
- Coarse-grained soils, such as pebbles and sand, are less than half percent of the total weight of the soil sample that passes filter no. 200. This group starts with the initial letter G or S. G for pebbles or pebbles soil and S for sandy or sandy soil.
- Fine-grained soil is a soil that is more than half percent of the total weight of the soil sample that passes the No. 200 sieve. The symbol for this group begins with the initial letter M for inorganic silt. C for inorganic clay, and O for silt - organic. The PT symbol is used for peat, manure, and other soils with a high organic content.

3. Results And Discussion

3.1 Research on Sieve Analysis and Hydrometer
The data obtained from this study are:

| Table 2. Specific Gravity |
|--------------------------|
| Wt. of dry soil (Ws)     | 145.72 | 145.91 | 146.25 | 146.42 | 146.61 |
| Wt. of picno + water + soil (W1) | 134.359 | 134.605 | 134.749 | 134.913 | 135.097 |
| Temperature (°C)         | 62     | 50     | 43     | 35     | 26     |
| Wt. of picno + water (W2) | 2.315  | 2.300  | 2.353  | 2.355  | 2.357  |
| Gs =(Ws)/(Ws-(W1-W2))    | 2.336  |

The average specific gravity of soils Gs 2.336

From this study, the composition of the soil grains was obtained as follows:

| Table 3. Granular Composition |
|-------------------------------|
| Composition  | Weight(%) |
| Gravel        | 0.00       |
| Sand          | 11.43      |
| Silt          | 72.73      |
| Clay          | 15.84      |

For the percentage of gravel weight obtained from the results of the sieve analysis as shown in the table below:

| Table 4. Sieve Analysis Results |
|--------------------------------|
| Filter | Filter Stuck (gr) | Retained Amount (gr) | % Retained Amount | % Pass The filter |
|--------|-------------------|----------------------|-------------------|-------------------|
| 1/2    | 0                 | 0                    | 0                 | 100               |
| 3/8    | 0                 | 0                    | 0                 | 100               |
| 1/4    | 0                 | 0                    | 0                 | 100               |
| 4      | 0                 | 0                    | 0                 | 100               |
| 10     | 0                 | 0                    | 0                 | 100               |
| 20     | 0                 | 0                    | 0                 | 100               |
| 30     | 0                 | 0                    | 0                 | 100               |
| 40     | 0                 | 0                    | 0                 | 100               |
| 60     | 0.222             | 0.222                | 0.44              | 99.56             |
| 100    | 1.350             | 1.572                | 3.14              | 96.86             |
| 200    | 4.142             | 5.714                | 11.43             | 88.57             |
| pan    | 44.3              | 50                   | 100               | 0.00              |
While the percentage weight of silt and clay is obtained from the results of the hydrometer analysis in the table below:

| Diameter (mm) | Weight (%) |
|---------------|------------|
| 0.0782        | 82.38      |
| 0.0445        | 60.20      |
| 0.0323        | 57.03      |
| 0.0246        | 47.53      |
| 0.0099        | 31.68      |
| 0.0076        | 15.84      |

From this study, the limits for Atterberg's consistency can be seen in the table below:

| Consistency Limit | (%) |
|-------------------|-----|
| Liquid limit      | 49.77|
| Plastic limit     | 33.58|
| Plasticity index  | 16.20|

USCS (Unified Soil Classification System) and AASHTO (American Association of State Highway and Transporting Official) standards are used to test the classification of laterite soil characteristics. Based on these standards, the results of the distribution analysis test on red soil (laterite), as below:

1. Grains percentage that pass the filter No. 10 = 100%
2. Grains percentage that pass the filter No. 40 = 100%
3. Grains percentage that pass the filter No. 200 = 88.57% (F)

Data No. 40 obtained the plasticity index (PI) = 33.58%, and the liquid limit (LL) was 49.77%. In that data, the condition of the granules passed in the sieving process. Based on the soil classification table on the Highway Subgrade (System AASHTO) it is known that the data no. 20 passed the sieve with an F of 88.57% so that the soil could be categorized as silt-clay. These types fall into categories A-4, A-5, A-6, A-7.

In the column on the left to the column on the right, it is found that the soil that has been tested falls into categories A-7-5 and A-7-6. In category A-7-6, it is known that PI > LL – 30 with the type of material being the most dominant. The most dominant type is the loamy soil type and obtained an assessment on most of the ordinary soil to the soil classified as poor.

To determine the quality of the soil as the basis of the road, in addition to the class and subgroup of the soil in question, a number called the group index (GI) is also needed. The calculation for the group index can be done with the equation below:

\[
GI = \left( F - 35 \right) \left[ 0.2 + 0.005 \left( LL - 40 \right) \right] + 0.01 \left( F - 15 \right) \left( PI - 10 \right) \\
= \left( 88.57 - 35 \right) \left[ 0.2 + 0.005 \left( 49.77 - 40 \right) \right] + 0.01 \left( 88.57 - 15 \right) \left( 33.58 - 10 \right) \\
= 30.68 \approx 31
\]

Thus, lateritic soils are classified as A-7-6 (31).

The Unified Classification System Table (According to ASTM 1982) (M.Das, 1995) for laterite soils that pass the No. sieve. 200 = 88.57% including fine-grained soil and liquid limit (LL) = 49.77% including silt and clay whose LL is less than 50% included in the group symbols ML, CL, OL. The
Plasticity Graph for the classification of fine-grained soils with plasticity index (PI) = 33.58 % and liquid limit (LL) = 49.77%. The symbol CL (low to moderate plasticity inorganic clay, sandy, silty, gravel, and lean clays) can classify laterite soils. (See Fig 3 below)

![Plasticity Graph](image)

**Figure 3. Plasticity Graph [9]**

The direct shear test of the soil is defined has a soft consistency (12.5-25 kPa) and very soft < 12.5 kPa (Bowles, 1989). In general, shear stress can be formulated by:

\[ \tau = c + \sigma \tan \phi \] (1)

Which are \( \tau \) is the parameter of the direct shear test (kg/cm\(^2\)), \( c \) is the cohesion parameter (kg/cm\(^2\)), \( \phi \) is the parameter of shear angle (°), and \( \sigma \) is the stress normal parameter (kg/cm\(^2\)).

Several things that related to the direct shear test of the soil, namely: [2]

a) The direct shear test of the soil, which is fine-grained with related to the parameter \( c \) (cohesion),

b) The direct shear test of the soil which is coarse-grained with related to the parameter \( \Phi \) (shear angle), and

c) The direct shear test of the soil from a mixture of fine and coarse soil is related to the parameters \( c \) (cohesion) and \( \Phi \) (shear angle).

Direct shear testing was carried out in disturbed (remolded) sample conditions with a soil density of 1800 gr/cm\(^3\) and average soil content of different samples. For direct shear test carried out with soaked soil samples and the results are shown in the table below:

| Information          | Sample 1 | Sample 2 | Sample 3 |
|----------------------|----------|----------|----------|
| Average soil content (%) | 39.43    | 26.61    | 27.03    |
| Shear angle (\( \phi ^\circ \)) | 21.94    | 33.88    | 31.14    |
| Cohesion (kg/cm\(^2\))    | 0.174    | 0.162    | 0.373    |

**4. Conclusions**

Based on all the test results, the red soil (laterite) from the sedimentation of the Wonogiri dam and has been tested does not meet the requirements to be used as a subgrade in building construction. Based on the determination of types and characteristics of laterite soil as basic land for building construction, this research suggests that improvement/stability is carried out first.
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