The soil characteristics mapping of Pagar Alam City (A case study of North Pagar Alam District)

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Abstract. Pagar Alam city is one of districts in South Sumatera province that has an area of ± 63,366 hectares (Monograph of the city of Pagaralam, 2013). So far, the people of Pagar Alam city, especially the north Pagar Alam district, have no reference to determine the soil type of its area; therefore this study carried out an analysis of the soil characteristics and conducted a mapping of its types of characteristics and the soil water content in the north Pagar Alam district. A geomap is a map that depicts existing image of the earth’s surface which is represented on a flat surface in a certain projection. Geomapping is a process of measuring, calculating and depicting the earth’s surface using certain methods. Soil is the surface layer of the earth that comes from parent material that has undergone an advanced process, due to natural changes under the influence of water, air, and various kinds of organisms, both living and dead (Dokuchaev 1870). After conducting 20 soil sample tests, it can be seen from the interpolated and overlayed sub-district map that the land in North Pagar Alam district has sandy silt soil where 19.69 km² of the area has good grades of the soil and the other 23.90 km² of the area consists of poorly graded sand.

1. Introduction
Pagar Alam city is a developed area that already has a lot of settlements which one day will definitely experience population density, especially the north Pagar Alam. Along with the population growth, there will also be more developments such as houses, shophouses, markets and also many settlements. So far, the people of Pagar Alam City, especially North Pagar Alam, do not have any reference yet to determine the state of the soil type. Concerning that fact, this study focused on an analysis of the soil characteristics and mapping the type of soil in the North Pagar Alam district.

2. Theoretical framework

2.1. Definition of Soil
Soil is the surface layer of the earth that comes from parent material which has undergone an advanced process, due to natural changes under the influence of water, air, and various organisms, both living and dead. The degree of change is seen in the composition, structure and color of the weathering results (Dokuchaev 1870).
2.2. Mapping

Map is a description of the earth's surface which is depicted on a flat surface and then reduced to a certain scale. The use of map is very diverse, one of them is as a portrait of the earth’s surface which helps people easier to study about it. Mapping is a process of measuring, calculating and depicting the earth's surface using certain methods that obtain both softcopy and hardcopy result.

2.3. Classification and Characteristics of Soil

In general, soil classification is the grouping of various types of soil into groups based on their physical properties and characteristics. The classification and characteristics of the soil are as follows:

a. Clay

Clay soil is a multi-component soil consisting of three phases, namely solid, liquid, and air. The solid part is polymorphous consisting of organic and inorganic minerals. Characteristics of the clay soil are:
1. Fine-grained size, 0.01 – 0.09 mm.
2. Low permeability
3. High capillary water rise
4. Very cohesive
5. High swelling shrinkage level
6. Slow consolidation process
7. Swelling-shrinkage nature

![Clay Soil](Source: [1])

b. Silt Soil

Silt is soil or grains composing soil/rock which size is between sand and clay. Most of the silt is composed of very fine-grained quartz and numbers of particles in the form of flattened plates which are fragments of mica minerals.

The characteristics of silt soil are as follows:
1. Fine-grained size, between 0.1 – 0.9 mm.
2. Cohesive
3. Quite high capillary water rise
4. Low permeability
5. High swelling shrinkage level
6. Slow dropping process
c. Sand
Sand is soil with large particles. This kind of soil is formed from igneous and sedimentary rocks that have large and coarse grains or what is often called gravel.

The characteristics of sand are as follows:
1. The grain size is between 1 - 10 mm
2. Non-cohesive
3. Low capillary water rise
4. Medium to fast dropping process

Figure 3. Sand
Source: Sanggapraman, 2010

d. Gravel
Gravel is basically a large rock and actually shows the amount of grains of sand. It can be also categorized as sandstone which contains a lot of silica. Generally, it has smooth texture and rounded shame as a result of mountain rock fragments

The characteristics of gravel are as follows:
1. Rounded or nearly spherical shape
2. Rough surface texture
3. Maximum grain size
2.4. Specific Gravity ($G_s$)

Specific gravity ($G_s$) is the ratio between the volume weights of solid grains ($\gamma_s$) to the volume weight of water ($\gamma_w$) at $4^\circ$ C. $G_s$ is dimensionless. Typically, the specific gravity of sand, gravel, coarse-grained materials, and cohesive soils as a soil mixture ranges from 2.65 to 2.75. Specific gravity $G_s = 2.67$ is usually used for non-cohesive soils or granular soils, while for cohesive soils that do not contain $G_s$ organic matter ranges from 2.68 to 2.72. Typical values of minerals specific gravity for various soils can be seen in Table 1.

| Mineral           | Specific Gravity | Mineral           | Specific Gravity |
|-------------------|------------------|-------------------|------------------|
| Bentonite         | 2.13 – 2.18      | Muscovite (mica)  | 2.80 – 2.90      |
| Gypsum            | 2.19 – 2.30      | Dolomite          | 2.87             |
| Gibbsite          | 2.30 – 2.40      | Aragonite         | 2.94             |
| Montmorillonite   | 2.40             | Anhydrite         | 3.00             |
| Orthoclase feldspar| 2.50 – 2.56    | Biotite (mica)    | 3.00 – 3.10      |
| Illite            | 2.00 – 2.10      | Hornblende        | 3.00 – 3.47      |
| Quartz            | 2.60             | Augite            | 3.20 – 3.40      |
| Kaolinite         | 2.60 – 2.63      | Olivine           | 3.27 – 3.37      |
| Chlorite          | 2.60 – 3.00      | Lismonite         | 3.8              |
| Plagioclase feldspar| 2.62 – 2.76   | Siderite          | 3.83 – 3.88      |
| Talc              | 2.70 – 2.80      | Hermatite         | 4.90 – 5.30      |
| Calcite           | 2.80 – 2.90      | Magnetite         | 5.17 – 5.18      |

Source: Soil Mechanics 1989
2.5. **Soil characteristics testing**

Soil characteristics testing is the activity of analyzing soil samples to determine the soil conditions and characteristics. Below are three soil characteristics tests:

2.5.1. **Sieve analysis testing** Aggregate sieve analysis is weight percentage determination of the aggregate that passes from a set of filters and then obtains the percentage values. This test aims to find out the gradation or classification of the soil grain size and also to obtain the distribution of the amount or percentage of fine aggregate and coarse aggregate. By knowing the grain size classification of certain soil, the soil classification and description can be determined as well. The amount of soil grains is usually described in a graph called the gradation curve graph or grain size distribution curve graph.

   a. **Uniformity Coefficient**

   \[
   C_u = \frac{D_{60}}{D_{10}}
   \]

   \(C_u\) = Uniformity Coefficient  
   \(D_{60}\) = the diameter corresponding to 60% finer  
   \(D_{10}\) = the diameter corresponding to 10% finer

   b. **Coefficient of Gradation**

   \[
   C_c = \frac{D_{30}^2}{D_{60} \times D_{10}}
   \]

   \(C_c\) = Coefficient of Gradation  
   \(D_{30}\) = the diameter corresponding to 10% finer

   Soils that are well graded will have \(C_u > 4\) and \(C_c\) between 1 and 3 for gravel soils while sandy soils will have \(C_u > 6\) and \(C_c\) between 1 and 3.

2.5.2. **Determination of Water Content** To decide the water content, an amount of soil was placed in a crucible or small can which weight (W1) had been determined. Crucible containing the soil was weighed (W2) and then put in an oven at 105°C temperature for 24 hours. Then the crucible and the soil were weighed again (W3). Therefore, it was found that:

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![Laboratory Sieve Shaker](source: [4])
Water weight = $W_2 - W_3$
Dry soil weight = $W_3 - W_1$
Water content = \( \frac{(W_2 - W_3)}{(W_3 - W_1)} \times 100\% \)

2.5.3. Specific Gravity ($Gs$) Soil specific gravity is the ratio between the grain weight of the soil and the weight of the contents of distilled water with the same content at 40°C. This test aims to determine and be able to determine the amount of weight and type of soil correctly by using the soil content weight determination technique.

Soil unit weight = $W_2 - W_1$
Water weight of fully filled pycnometer = $W_4 - W_1$
Water weight of pycnometer containing water and soil = $W_3 - W_2$
Water weight without soil = $(W_4 - W_1) - (W_3 - W_2)$
Determined specific gravity = $G_s = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$

![Figure 6. How to Measure Soil Specific Gravity](Sumber: [5])

2.6. Geographic Information System (GIS) Application
Geographic Information System (GIS) is an application used to manage (input, management and output) spatial data or geographically referenced data. Any data that refers to a location on the earth's surface can be referred to as geographic spatial data.

3. Research methodology

3.1. Research Location
This research was conducted in the area of Pagar Alam city, North Pagar Alam district, South Sumatra Province. Based on the regional profile, North Pagar Alam district has an area of 55.47 km² and is located at an altitude of 705-870 masl. This area is located in the middle of the urban of Pagar Alam city.

3.2. Literature Review
Some various reading sources such as books and journals that have been conducted by previous researchers were used as supporting information. The sources that were read and quoted are as follow:
1. Soil mechanics book 1, sixth edition, 2012 (Hary Christady Hardiyatmo).
2. Soil mechanics book 1, fifth edition, 2010 (Hary Christady Hardiyatmo).
3. Soil mechanics book 1, second edition, 1989 (Joseph E. Bowles).
4. Mechanics book volume 1, 1993 (Braja M. Das, Noor Endah and Indrasurya B. Mochtar).
5. The new 2017 edition of soil mechanics (L.D. Wesley).
6. Concepts and Applications of Soil Mechanics 2013 (E. Sutarman).
7. The 2013 monograph book of Pagar Alam city.
8. Research journal of Sub-Surface Soil Conditions on Jalan Raya Babat - Bojonegoro - Padangan (Mohammad Muntaha), 2011
9. Journal of Clay Soil Improvement from Grobogan Purwodadi with a mixture of cement and rice husk ash (Ninik Ariyani, Prilani Dwi Wahyuni), 2007.

3.3. Data Collection

3.3.1. Primary Data Primary data is the data that is taken directly through direct observations at the research location or the field. The primary data obtained in this study are:
1. 20 samples of the soil taken at a depth of 0.5-1 m for the laboratory used
2. The soil samples result test conducted in the laboratory to find out:
   a. Water content
   b. Soil specific gravity (GS)
   c. Filter analysis

3.4. Soil Sampling
Soil samples weighing ± 5 kg were taken as deep as 0.5 - 1 m. The samples taken were disturbed soil and the process used manual tools such as crowbars, cement spoons, meters and containers.

3.5. Laboratorium Testing
a. Water content
   Soil water content is the ratio of the weight of water contained in the soil to the dry weight of the soil. Soil water content can be determined from the ratio between the weights of water contained in the pores of the soil grains with the grain weight of the soil itself after drying under standard conditions (SNI 03-1965-1990).

b. Soil Specific Gravity (GS)
   Soil specific gravity is the ratio between the grain weight of the soil and the weight of the contents of distilled water with the same content at 40C (SNI 03-1964-1990).

c. Sieve Analysis
   This method was used to determine the particle size distribution (gradation) of fine and coarse aggregates by using a sieve that aimed to obtain the grain size distribution or the grains percentage. Aggregate analysis is the determination of the percentage of the aggregate’s weight passed from a set of filters which was then depicted on a grain distribution chart.
   The equipment used in this test included scales, a filter set, an oven, a separator, a filter shake machine, trays and other tools (SNI 03-1968-1990).
3.6. Flow Chart

4. Result and discussion

4.1. Determining the Sampling Location
The location for taking the soil samples was decided by using the arcGIS application. The soil samples were taken from 20 different locations within the area of 1800 m².

Figure 7. Twenty Sampling Location

4.2. Determining the Coordinate of Points of Each Location Using GPS.
The sub-districts locations that are showed by each numbered point on the satellite image map and their coordinates of point are as follow:
4.3. Soil Sample Testing
Soil sample testing was carried out at the STTP Laboratory of Pagar Alam. The soil that had been taken was put into a plastic bag and then being tested using a test object in the laboratory. Several tests conducted are as follow:
1. Water content testing (SNI 03-1965-1990)
2. Soil specific gravity (SNI 03-1964-1990)
3. Filter analysis (SNI 03-1968-1990)

4.4. Water Content Testing
All samples were subjected to water content testing which was carried out in the civil engineering laboratory of Pagar Alam STTP. The process of the water content testing of sample 1 at Dempo Makmur sub-district can be seen in Table 4.2. and 4.3. The tests of other samples can be seen in Appendices 1 – 20.

Table 2. Water Content Testing

| Location          | Tested by          | Date of Test         |
|-------------------|--------------------|----------------------|
| Dempo Makmur Sub-District | Hery Permana Sati | April 24, 2018 |

| Property | Sample 1 | Sample 2 |
|----------|----------|----------|
| Weight of empty crucible | 12.00 kg | 12.00 kg |
| Weight of crucible + wet soil | 24.00 kg | 24.00 kg |
| Weight of crucible + dry soil | 18.00 kg | 19.00 kg |
| Weight of water | 6.00 kg | 5.00 kg |
| Weight of dry soil | 6.00 kg | 7.00 kg |
| Water content (%) | 71.43 | 85.71 |

| Means of water content (%) | 85.71 |
4.5. **Soil Specific Gravity Testing (Gs)**

Soil specific gravity testing was conducted to all samples at the civil engineering laboratory of Pagar Alam STTP. Table 4.5 shows the soil specific test of sample 1 taken from Dempo Makmur sub-district. The rest of the sample test can be seen in Appendices 1 - 20.

**Table 3. Soil Specific Gravity Testing**

| Location          | Tested by                     | Date of Test | Depth |
|-------------------|-------------------------------|--------------|-------|
| Dempo Makmur Sub-District | Hery Permuna Sati | April 10, 2018 | 1 meter |

| Parameter                                      | Value 1   | Value 2   |
|------------------------------------------------|-----------|-----------|
| Pycnometer’s number                           | 1         | 2         |
| Pycnometer’s weight (gram)                     | 65.00     | 68.00     |
| Pycnometer’s weight + soil (gram)              | 81.00     | 83.00     |
| Pycnometer’s weight + soil + water (gram)      | 177.00    | 179.00    |
| Specific Gravity                               | 1.78      | 3.00      |
| Mean of soil specific gravity                  | 2.39      |           |

(Source: Soil Specific Gravity Testing, 2018)

4.6. **Sieve Analysis Testing**

After the water content and soil specific gravity tests were carried out, sieve analysis testing was also done on all samples. The sieve analysis test on sample 1 that was soil taken from the Dempo Makmur sub-district can be seen in Table 4.8 while sieve analysis testing on other samples can be seen in appendix 1-20.

**Table 4. Sieve Analysis Testing**

| Location          | Tested by                     | Date of Test | Depth |
|-------------------|-------------------------------|--------------|-------|
| Dempo Makmur      | Hery Permuna Sati             | April 10, 2018 | 1 meter |

| Parameter                                      | Value 1   | Value 2   | Value 3   | Value 4   | Value 5   | Value 6   | Value 7   | Value 8   | Value 9   | Value 10  | Value 11  | Value 12  | Value 13  | Value 14  | Value 15  | Value 16  | Value 17  | Value 18  | Value 19  | Value 20  |
|------------------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Size               | 100       | 100       | 100       | 100       | 100       | 100       | 100       | 100       | 100       | 100       | 100       | 100       | 100       | 100       | 100       | 100       | 100       | 100       | 100       |
| Sieve (mm)         | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      | 4.75      |
| Mass (gram)        | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    | 411.00    |
| Mass (gram)        | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     | 68.00     |
| Mass (gram)        | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     | 81.00     |
| Mass (gram)        | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    | 177.00    |
| Mass (gram)        | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    | 179.00    |
| Mass (gram)        | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    | 170.00    |

(Source: Soil Specific Gravity Testing, 2018)
4.7. Data Analysis

After all tests were carried out and the raw data were obtained from the test results, data analysis was conducted using arcGIS. The steps of the data analysis are as follows:

1. The first step in data processing is by opening the *arcGIS* application and then entering the satellite image map into the *arcGIS* page.
2. After the satellite image map appears, each test data that has been tested in the laboratory was entered into the application as shown in Figure 8.

![Figure 8. Data Analysis of Soil Types Map](image)

3. After each test data had been input, interpolation could be carried out to form a land distribution map in the North Pagar Alam sub-district. The interpolated map is shown in Figure 9 along with the map image of the interpolated map.

![Figure 9. Interpolation Result Map](image)

4. To see the interpolation result map distribution of each sub-district more clearly, it is necessary to combine or overlay the map of the sub-districts and the interpolation result map. The map of sub-districts can be seen in Figure 10.

![Figure 10. Sub-district Map](image)
5. The well-graded sandy silt soils that can be seen on the overlay map (Figure 11) are colored red, while the poorly graded sandy silt soils are shown in green. Based on the twenty soil sample points, there were ten sub-districts that had well-graded and poorly graded silt sandy soil. The well-graded silt sandy soil was found in sample 7 at sub-district, sample 11 at Kuripan Babas sub-district, sample 12, 13, 14 at Curup Jare sub-district, sample 16, 17 at Selibar sub-district. In addition, there was also a poorly graded sandy silt soil in sample 1, 2, 3, 4, 5, 6, 8, 9, 10, 15, 18, 19 and 20 as seen in Figure 12 below.

4.8. Result
The following figure is a map of the soil types distribution in North Pagar Alam district that had been processed using the arcGIS application.

5. Conclusions and suggestions
5.1. Conclusion
Based on the research result and discussion, it can be concluded that:
1. After conducting 20 soil sample tests, it can be seen from the interpolated and overlayed sub-district map that the land in North Pagar Alam District has sandy silt soil consisting of 19.69 km² area of well-graded silt sandy soil which was found in sample 7 of Sukorejo sub-district, sample 11 of Kuripan Babas sub-district, sample 12, 13 and 14 of Curup Jare sub-district and sample 16 and 17 of Selibar sub-district. Meanwhile, it was also founded that 23.90 km² of the area has poorly graded sandy silt soil.
2. In testing the water content, there were several samples or sub-districts that had 100% water content,
namely: sample 5 of Dempo Makmur sub-district, sample 6 and 7 of Sukorejo sub-district, sample 11 of Kuripan Babas sub-district, sample 12, 14, 15 of Curup Jare sub-district and sample 18 of Selibar sub-district.

5.2. Suggestions
Some suggestions offered from this research are:
1. This research can be developed on a larger scale, for example having bigger sampling area used in study.
2. In determining the type of soil, in addition to testing the sieve analysis and specific gravity (Gs), other test can be also carried such as sondir test and atterberg limits.

References
[1] Kidhot Kasjuaji. 2018, Clay Clay. accessed on Wednesday 23/07/2018 (In Bahasa)
[2] Deddy Wihanda. 2013, Tanah Lanau. accessed on 23/07/2018 (In Bahasa)
[3] Casey. 2016. Pebbles. accessed on Wednesday, 23/07/2018 (In Bahasa)
[4] HaryChristady Hardiyatmo, 2012. Soil Mechanics 1 6th Edition. Yogyakarta: Gadjah Mada University Press. (In Bahasa)
[5] LD Wesley, 2017. Soil Mechanics New Edition. Yogyakarta: Andi (In Bahasa)