Soil characteristics analysis based on the unified soil classification system

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Abstract. The purpose of this research is to determine soil classification and identify the swelling potential of soil clay in the Jababeka I (sample 1) and the Lippo Cikarang (sample 2), Indonesia. The research was carried out by the experimental method. Soil classification based on the Unified Soil Classification Systems (USCS) determined by No.200 sieve analysis and A-chart (LL vs PI chart), while based on the American Association of State Highway and Transportation Officials Soil Classification System (AASTHO), classification determined by No.200 sieve analysis, liquid limit (LL) and plasticity index (PI). The results show the soils are clay of high plasticity (CH) in determining of the USCS, whereas in AASTHO, the soils are A7-6, which means clay of high plasticity. Furthermore, the swelling potential or expansion potential of clay is determined by indirect methods namely by the results of LL, PI, SL, and percentage of the passing of sieve No.200. Moreover, consolidation test is also carried out to obtain compression coefficient (Cv) and coefficient of consolidation (Cc) to determine the mineral content. The results of this experimental research that soils contain kaolinite minerals, a very high swelling potential with the possible change in volume of 10-30 %.

1. Introduction
The soil has certain characteristics so it needs to be analyzed to obtain data as a basis for determining the type of building construction. Gambill said that soil classification systems are widely used for quickly and easily summarizing soil properties and provide a shorthand method of communication between scientists, engineers, and end-users [1]. The Unified Soil Classification System (USCS) was chosen because this classification system is suitable for the soil to be used for buildings. On USCS, soil classified into two categories: 1) Coarse-grained soil, which is sand and gravel were less than 50% of the total weight of the soil sample that passing N0.200 sieve. 2) Fine-grained soil, which is soil with 50% or more of the total weight of soil passing the No. 200 sieve [2].

In civil engineering, the soil has an important role because it supports the basic construction strength of buildings. To minimize the potential building failure, it is necessary to have data on the results of adequate and meticulous investigation of soil during the planning and implementation of building construction. One of the determinants of the success of implementing a civil project is data input (soil investigation data) with high accuracy [3]. Therefore, it needs to be carefully analyzed about the physical and mechanical properties of the soil so that it can know the behavior of the soil and the type of soil.
Some areas in Indonesia have clay subsoils, such as in West Java (including Cikampek, Cikarang, Bandung, and Serang). Expansive soils, which are considered as problematic soils, have a worldwide distribution and hence, their proper identification and characterization become an absolute necessity in the perspective of the present day geotechnical engineering practice [4]. Expansive soils are generally characterized by the presence of clay minerals of the montmorillonite (smectite) group [5]. Such soils give rise to problems in civil engineering works because of their capacity to undergo large volume changes with changes in moisture content, which expand and shrink when the moisture in the soil changes. In this research, an analysis of soil classification was carried out according to the USCS system and further investigation into the swelling potential of soil samples taken from Jababeka I and Lippo Cikarang, Indonesia.

2. Research methods
The method used is testing soil samples. This research was conducted at the Soil Mechanics Laboratory of the Faculty of Engineering, Jakarta State University with soil sampling in two places, namely in the area of UNJ soil located in the Jababeka I (sample 1) and the Lippo Cikarang (sample 2), Cikarang area of Bekasi Regency which represents soil in the Cikarang area of Bekasi district.

As explained earlier that for fine-grained soil types with high plasticity it is very important to know. Soil plasticity is caused by the presence of clay mineral particles in the soil. Soil plasticity describes the ability of the soil to adjust shape change at a constant volume without cracks in the soil. The properties and characteristics of the soil are strongly influenced by the composition and size of the grain. Therefore, the classification of soil is always based on the size of the grain, so that soil investigations always begin with granular analysis.

Sampling is done by drilling to a depth of 6.00 meters and at the same time testing the SPT Standard Penetration Test. From drilling, a number of samples will be tested in the laboratory. Soil testing aims to determine the physical and mechanical properties of the soil such as soil water content and soil specific gravity. Furthermore, the determination of consistency limits to determine the liquid limit and plastic limit and shrinkage limit. Then a soil gradation test was conducted which consisted of sieve analysis for coarse-grained soil content and a hydrometer analysis for fine-grained soil content passed no. 200. The Group of soil on the American Association of State Highway and Transportation Officials (AASHTO) soil classification system determined by grain size distribution, Liquid Limit (LL) and Plasticity Index (PI), while on the Unified Soil Classification Systems (USCS) determined by No.200 sieve analysis, and A-chart (LL vs PI chart). Furthermore, the swelling potential or expansion potential of clay is determined by indirect methods. Moreover, consolidation test is also carried out to obtain compression coefficient (Cv) and coefficient of consolidation (Cc) to determine the mineral content.

3. Results and discussion
The results of testing the physical properties of soil samples 1 and 2 respectively are that the soil has a water content of 31.479 % and 61.467 %, while the specific gravity is 2.58 gr/cm³ and 2.667 gr/cm³. Based on Atterberg limit testing, Cikarang soil respectively has a liquid limit (LL) of 76.53% and 89.50%, plastic limit (PL) of 25.99 % and 46.79 %, while the shrinkage limit (SL) is 8.56 % and 9.83 %. The sieve analysis test results obtained sand content of 1.7 % and 5.0 %, silt of 43.34 % and 59.09 %, while clay of 54.75 % and 36.00 %. From the sieve analysis test that passed the No.200 as many as 98.30 % and 95.09 %. The results of soil mechanical test which is a consolidation test obtained that Cc amounted to 0.175 and 0.420 and Cv respectively 0.0185 and 0.00834 cm²/sec. From the atterberg limit test, soil consisting of the liquid limit, plastic limit and shrinkage limit can be estimated. Liquid limits greater than 50 % are one of the common characteristics possessed by expansive clay. The high value of Plasticity Index (PI), which is above 17 %, also indicates that the soil is categorized as clay with high plasticity and is cohesive.

In classifying soil, there are two ways, namely the method of USCS (Unified Soil Classification System) and the method of American Association of State Highway and Transportation Officials (AASHTO). Soil classification describes the mechanical characteristics of the soil, also determines the
quality of the soil for planning purposes as well as in carrying out construction. Based on the results of testing the grain size distribution, Jababeka 1 sample with 98.30 % passed No.200 sieve and liquid limit of 76.53 %, as well as samples from Lippo with 99.04 % passing the No.200 sieve and the liquid limit, is 89.50 %. The results show the soil is clay of high plasticity (CH) in the USCS whereas in AASTHO classification, the soil is A7-6 which means clay of high plasticity.

After knowing from the test results that the soil type is expansive clay, then clay is identified further to predict the swelling potential or expansion potential. The estimated expansion potential serves as a guide for analysis and design of structures that are safe in expansive soils.

Identification of swelling potential is done by means indirect method. This method uses soil properties such as plastic limit, liquid limit, shrinkage limit and the percentage of passing the no.200 sieve to estimate swelling potential rate.

Table 1. Clay mineral content [6].

| Mineral       | Cc     | Cv                  |
|---------------|--------|---------------------|
| Montmorillonite | 1.00 – 2.60 | 0.000006- 0.00003 |
| Illite         | 0.50 – 1.00 | 0.00003 - 0.00024 |
| Kaolinite      | 0.19 – 0.28 | 0.0012 - 0.009     |

Minerals found in expansive soils, in general, are montmorillonite, kaolinite, and illite. Table 1 taken from the results of the mineralogical test by Cornell University shows correlation Cc and Cv with mineral content in the soil [6]. Based on table 1, it can be concluded that the soil of Cikarang contains mineral kaolinite. Expansive clay containing kaolinite minerals is usually not very high (low) if compared to the montmorillonite clay minerals which have high liquid content, high IP and low shrinkage limits.

Swelling in clays can be sub-categorized into two distinctive types, namely: a) Elastic rebound in the compressed soil mass due to a reduction in compressive force. b) Imbibing of water resulting in expansion of water-sensitive clays [7]. Most often, this phenomenon is wrongly attributed to settlement and the remedial or response measures are directed to correct the perceived “settlement” do not solve the problem and sometimes even aggravate or accentuate the problem by causing more damage [8]. To determine the level of expansion of expansive clay was carried out in two ways, namely the by Holtz and Gibb [9] and by Chen [10] method.

Table 2. Correlation of test indices with swelling rates [9].

| Data from the Test Index | Possible Swelling (% change in volume) | Swelling rate |
|--------------------------|---------------------------------------|---------------|
| Colloid Content (%)      | Plasticity Index (%)                  | Shrinkage Limit (%) |
| >28                      | >35                                  | <11           | >30          | Very high |
| 20-31                    | 25-40                                | 7-12          | 20-30        | High      |
| 13-23                    | 15-28                                | 10-16         | 10-20        | Medium    |
| <15                      | <18                                  | >15           | <10          | Low       |

Table 2 taken from Holtz and Gibb shows the correlation of PI and SL with swelling rates and possible % change in volume [9]. From the analysis of the samples, and by means plastic index (PI) is the difference between LL and PL, Jababeka I has a plastic limit (PI) of 50.54 %, whereas Lippo Cikarang has a plastic limit (PI) of 42.71 %. Based on table 2, it can be concluded that the soil in the Jababeka I and the Lippo Cikarang respectively are clay which has the potential to swell very high with the possibility of a volume change of more than 30%.
Table 3. Correlation of field and laboratory data with swelling rates [11].

| % Pass sieve No.200 | Liquid Limits % | N (blow/ft) | Possible Swelling (% change in volume) | Swelling potential |
|---------------------|-----------------|-------------|----------------------------------------|-------------------|
| > 95                | > 60            | > 30        | > 10                                   | Very high         |
| 60-95               | 40-60           | 20-30       | 3-10                                   | High              |
| 30-60               | 30-40           | 10-20       | 1-5                                    | Medium            |
| < 30                | < 30            | < 10        | 1                                      | Low               |

Based on table 3, swelling potential and its possibility of change in volume (%) are correlated with the value of LL and percentage of the passing of sieve no.200. Based on the resulting of testing, Jababeka 1 samples have 98.30% passed No.200 sieve and a liquid limit of 76.53%, as well as samples from Lippo, which have 99.04% passing the No.200 sieve and the liquid limit of 89.50%. It can be concluded Jababeka 1 and Lippo Cikarang soil is known to have a very high swelling potential with the possibility of swelling more than 10% of the total volume.

The results of the identification of expansive soil swelling rates in this study in the following table.

Table 4. The results of the identification of expansive soil swelling rates.

| No | Theory  | Category       | Experiment Result | Conclusion          |
|----|---------|----------------|-------------------|---------------------|
| 1. | Cornell | Cc = 0.19 – 0.28, Cv = 0.0012-0.009 | Jababeka 1: Cc = 0.175, CV= 0.00185 Lippo Cikarang: Cc = 0.242, CV= 0.00834 | Mineral Kaolinite |
| 2. | Holtz and Gibbs | PI > 35 %, Shrinkage < 11 | Jababeka 1: PI =50.54 %, Shrinkage = 8.56 % Lippo Cikarang: PI = 42.71 %, Shrinkage =9.83 % | The potential for swelling is very high and the possibility of changes in volume > 30% |
| 3. | Chen | % Pass # 200 > 95%, LL > 60% | Jababeka 1: % Pass # 200 = 98.30%, LL = 76.53% Lippo Cikarang: % Pass # 200 = 99.04%, LL = 89.50% | The potential for swelling is very high and the possibility of changes in volume > 10% |

4. Conclusions
Based on the results of the analysis conducted in this study, it can be concluded that the type of expansive clay minerals found in the Cikarang region is kaolinite with the swelling potential is very high, and the possibility of change in volume is 10-30%. To improve the condition of expansive clay soils can be done by doing soil stability.

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