Mechanical Review of Fine Sand-Clay Variants

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ABSTRACT

Clay in nature consist of a mixture of grains and minerals with or without the content of organic matter. The variation in the size of clay grains and the proportion of their distribution is a very useful indicator for knowing soil behavior. Testing the combination of fine sand - clay (FSC) using clay from Kulim Pekanbaru and fine sand from Teratak Buluh Riau. Variants of the percentage of FSC are carried out with the types of tests carried out are Standard Proctor Test, Unconfined Compressive strength test, Direct Shear Test and sieve analysis test and hydrometer. Increasing the percentage of clay in the FSC variant, increases the liquid limit, increases the plastic limit and increases the plasticity index. Increases optimum moisture content, decreases maximum dry density and increases soil friction angle and decreases compressive strength

I. Introduction

Soil has the property of increasing its density and shear strength. Plastic equilibrium conditions only occur in some soils, in soils with high compressibility which is indicated by a decrease in the limit bearing capacity (qu) which is difficult to analyze, the decrease can only be observed.

Terms such as gravel, sand, silt and clay are used in civil engineering to differentiate between types of soil. Soil can consist of two or more mixtures of soil and sand. And sometimes there is also organic content. The mixed material is then used as an additional name to differentiate the main element material. For example, silty clay is clay soil that contains silt [1].

Variations in soil grain size and distribution proportions are very useful indicators for understanding soil behavior. For example, if soil consists of various sized grains, the soil will be denser and more stable than soil consisting of uniform grains. Because soil containing various grain sizes has good properties, this soil is called well graded. On the other hand, soil that consists of slight variations in grain size is less able to support loads well, so this soil is called poorly graded soil, which is generally very difficult to compact, especially when dry. Sand is generally uniformly graded and cannot be compacted well, so it cannot support large loads.

Soil shear strength can be expressed by Coulomb with the equation $\tau = C + \tan\emptyset$. Coarse-grained soil with cohesion, $c = 0$, then its shear strength depends only on the friction between the grains. This type of soil is called granular soil or non-cohesive soil. On the other hand, soil that contains many fine grains, such as clay, silt and colloids, is called fine-grained soil or cohesive soil. Granular soil has shear resistance in the form of friction which is a function of normal stress. If the normal stress is large, the shear resistance is also large, which immediately increases with an increase in the normal stress [2].

If a load is applied to saturated cohesive soil, then the load will first be supported by water pressure in the soil pore cavities. In this condition, the clay grains cannot approach each other to develop shear resistance as long as the water in the pore cavity does not leave the cavity. Because the pore cavity of clay soil is very small, the release of water from the pore cavity takes a long time. If after a long time the water in the pore cavity decreases, the clay grains approach each other, so that their frictional resistance increases. Loading tests on cohesive soil are generally carried out in undrained conditions. This problem is not found in granular soils where the pore cavities are relatively large, because when a load is applied, water immediately leaves the pore cavities and the grains can approach each other, causing their frictional resistance to immediately increase. Loading tests on granular soil are generally carried out in drained conditions.

There are several types of methods for testing soil shear strength, including direct shear test, triaxial test, unconfined compressive test, and vane shear test. Direct shear tests and unfined compressive strength tests can be carried out by means of stress control or strain control. Stress control is more applicable in the field, while strain control is easier to test in the laboratory.

The plasticity index is the water content interval in which the soil remains in a plastic condition, it also states the relative amount of clay particles in the soil, if the PI is high then the soil contains a lot of clay grains [3]. The relationship between water content and LL and PL values affects the PI value. Generally, fine-grained soil in the field with a water content close to the LL value will be softer than soil with a water content close to the PL value. Soil with high plasticity always indicates poor soil characteristics

II. Method

The test materials were clay material from Kulim and sand from Teratak Buluh with a variant ratio of 100% clay: 0% sand, 75% clay: 25% sand, 50% clay: 50% sand and 25% clay: 75% sand.

The tests carried out are the Standard Proctor Test, Sifter Analysis Test, Hydrometer Test and consistency test (LL, PL and PI), and Unconfine Compressive Strength test and Direct Shear Test under undrained strain control conditions.

III. Results and Discussion

The results of the clay sieve analysis test used are as shown in Figure 1.

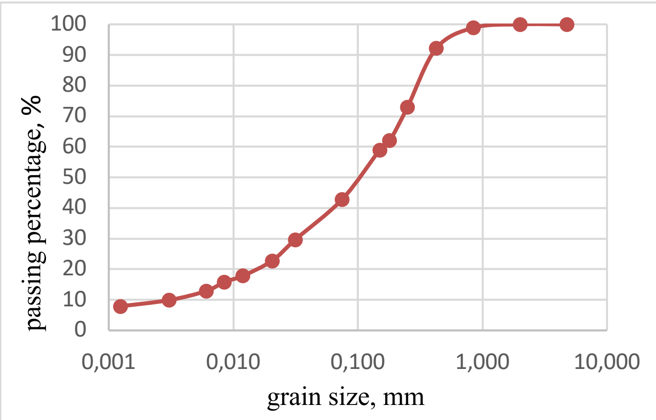

Fig. 1. Clay grain size gradation

From Figure 1 it can be seen that the clay used passes the 2.00 mm sieve (# no. 10), the gradation is continuous (continuous graded) and passes the 0.425 mm sieve (# no. 40) is 92% and passes the 0.075 mm sieve (# no. . 200) is 42%. With a liquid limit value of 69.80%, a plastic limit of 32.46% and a plasticity index of 37.34%, this clay is included in the SM type of USCS calcification. The behavior of the clay-sand mixture should be governed by large size particles at a clay content smaller than 23.5%, which is consistent with visual inspection of the mixture [4]

The results of the grain size gradation of the clay (L) – sand (P) combination variants can be seen in Figure 2 below.

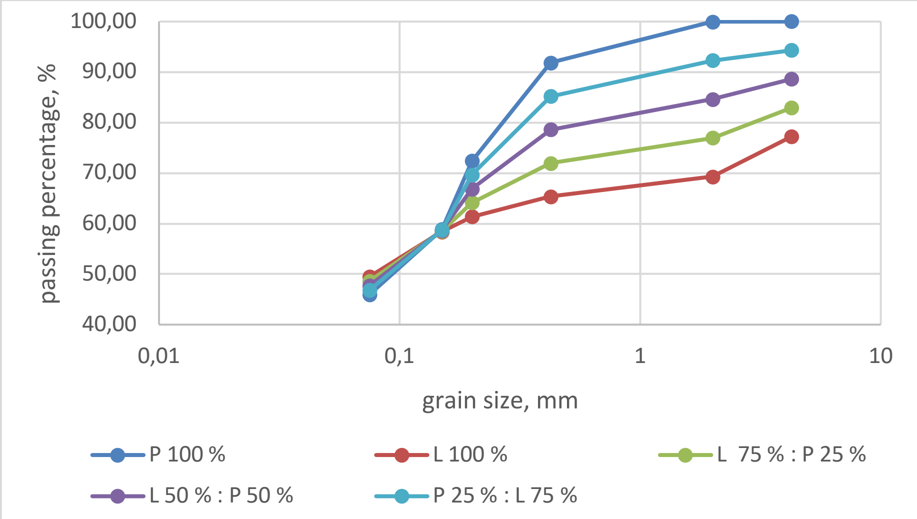

Fig. 2. Grain size gradation of clay-sand variants.

From Figure 2 it can be seen that with a filter size larger than 0.15 mm (# no. 100) adding a percentage of sand will make the gradation look coarser. From Figure 1 it can also be seen that with a filter size larger than 0.15 mm, adding the percentage of sand will make the gradation look a little finer, this happens because the percentage of sand and clay in # no. 100 and # no. 200 is almost the same value. Variants of 50% clay and 50% sand, you can see the gradation is continuous.

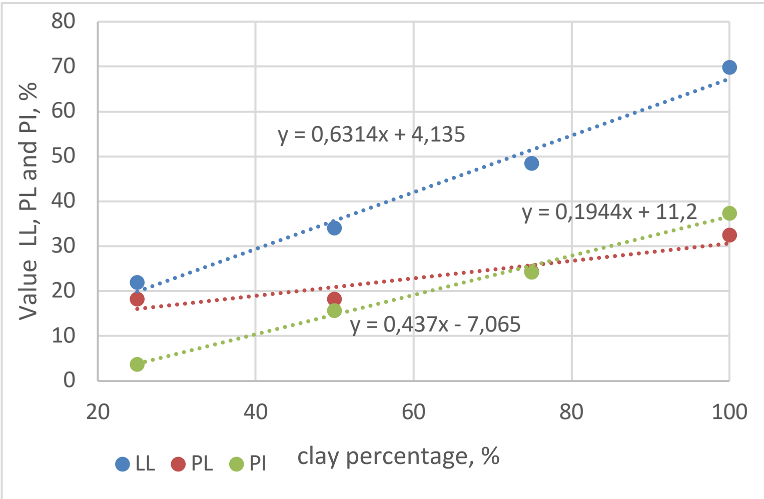

Fig. 3. Consistency test results

The results of the consistency test with the clay-sand variant are shown in Figure 3. From Figure 3 it can be seen that increasing the percentage of clay will increase the liquid limit value with the equation y = 0.6314 x + 4.135, increasing the plastic limit value with the equation y = 0.1944 x + 11.2 and increase the plasticity index value with the equation y = 0.437 x + 7.065. The dispersion percentage increases with the Atterberg limit and the dispersion ratio and plasticity index relationship are related by a direct relationship [5].

Clay consists of granules and plates formed from tetrahedral / silica crystals and octahedral / alumina crystals. The series of tetrahedra crystals or plates consists of 1 Si ++++ and 4 O- - , the excess negative charge (-) is reduced by sharing oxygen atoms with adjacent tetrahedra crystals to form a plate structure. Likewise, a series of octahedra crystals consisting of 1 Al+++ and 6 OH–, the excess negative charge forms plates as in Figure 4.

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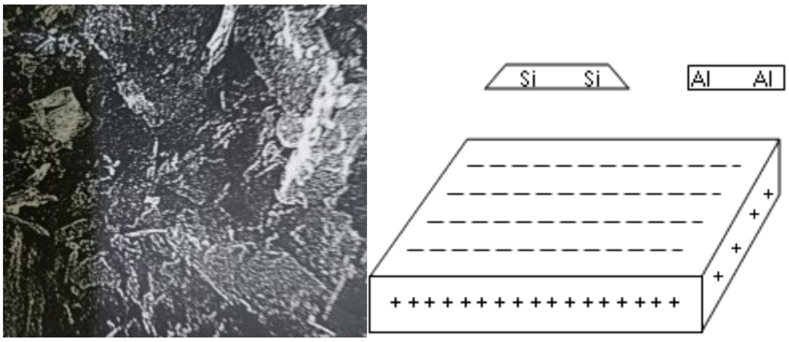

(a) (b)

Fig. 4. Clay plate with electron microscope (a), illustration of tetrahedra and octahedra (b)

Clay minerals are a complex aluminum silica composition consisting of 2 units, namely Silica tetrahedron and Alumina octahedron as in Figure 5 and Figure 6. Each tetrahedron contains 4 oxygen atoms surrounding one silica atom. The combination of tetrahedral silica groups forms a silica sheet. The octahedral unit contains 6 hydroxyls surrounding one aluminum atom. The octahedral combination of aluminum hydroxyl forms one octahedral sheet (also called gibbsite sheet). Sometimes magnesium replaces aluminum atoms, this is called sheet brucite.

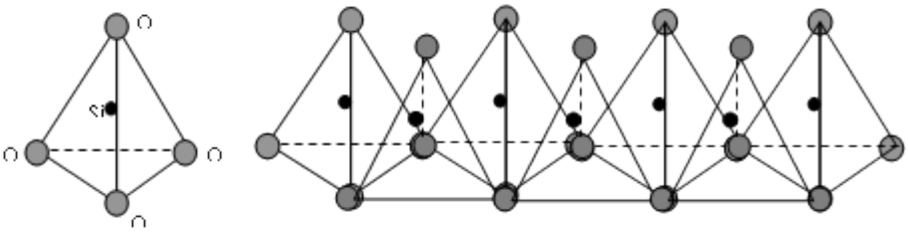

Fig. 5. Tetrahedra/Silica, a fundamental crystal type of clay

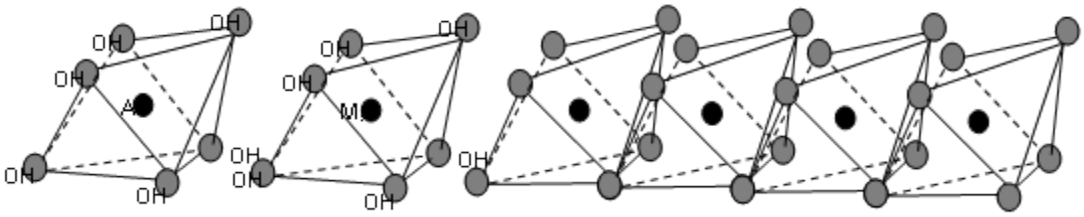

Fig. 6. Octahedra / Alumina and Magnesium, Octahedral (gibbsite) sheet.

Clay minerals are a complex aluminum silica composition consisting of 2 units, namely Silica tetrahedron and Alumina octahedron. Each tetrahedron contains 4 oxygen atoms surrounding one silica atom. The combination of tetrahedral silica groups forms a silica sheet. The octahedral unit contains 6 hydroxyls surrounding one aluminum atom. The octahedral combination of aluminum hydroxyl forms one octahedral sheet (also called gibbsite sheet). Sometimes magnesium replaces aluminum atoms, this is called sheet brucite.

These tetrahedra plates and octahedra plates are bonded and stacked together as in Figure 7. The stacking between clay crystal plates which both have a negative charge is a weak van der Waal bond. This weak bond is what causes the soil to not be very solid.

Clay is a collection of crystalline mineral grains that are microscopic and in the form of flakes or plates. Soil consistency characteristics are more influenced by microscopic clay crystals which are plastic. This plate forms plastic, cohesive properties and has the ability to absorb ions. These properties are greatly influenced by the water content in the soil. Plasticity becomes small if there is fine grain content.

This plasticity index value is applied to highway construction layers. The plasticity index increases successively to the layers below, such as PI 0 – 2% in class A base aggregates, PI 2 - 4% in class B base aggregates, PI 4 – 6% in class C/S base aggregates and PI < 12 % in the subsoil layer. The plasticity index value influences the adhesion value between materials, elasticity value and gives rise to spring properties. We can feel the spring effect when we are on the side of a road passed by a heavy truck. In road construction layers, the plasticity index increases gradually to prevent gaps between layers.

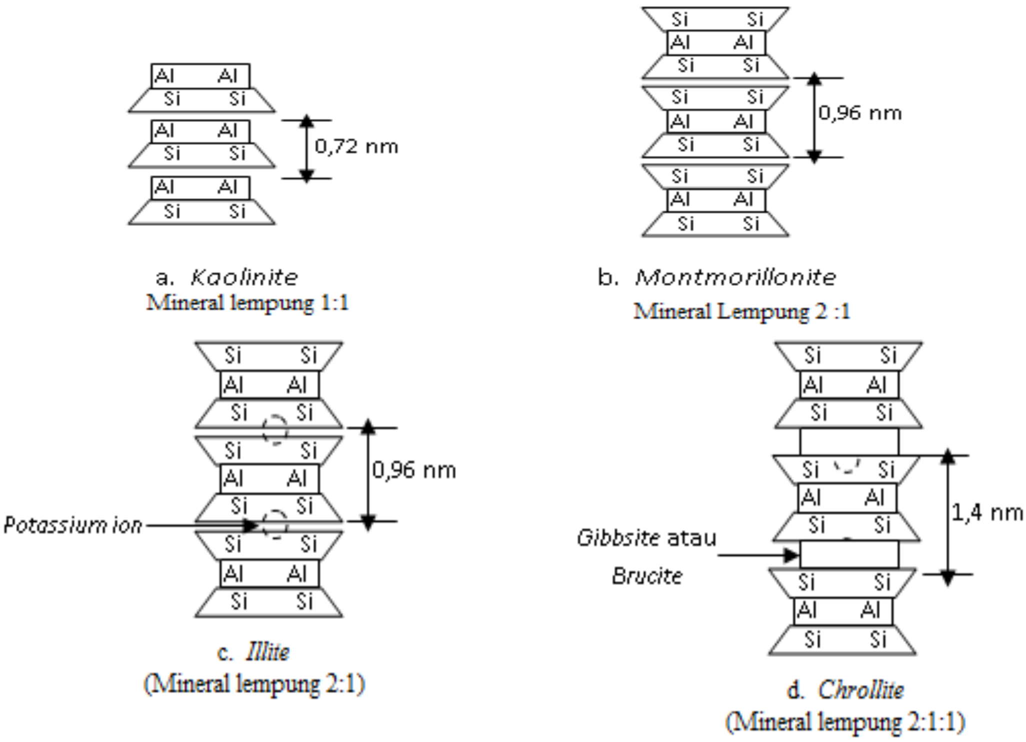

Fig. 7. Stacking of tetrahedra and octahedra plates.

Evaluation of the hydraulic conductivity of bentonite-sand mixtures with known amounts of expected alteration products from montmorillonite [6]. Accurate predictions for sand-clay samples containing 20% clay volume and above [7-8]. Lime Consumption Curves show that the lime reaction kinetics are also slower at these low bentonite contents. Finally, the Electrical Resistivity curve shows the same pattern for all mixtures and is closely related to Lime Consumption [9].

Fig. 8. Graph of the relationship between clay-sand variants with OMC and MDD

The optimum water content (OMC) and maximum dry density (MDD) values with the clay-sand variant are in Figure 8. From Figure 8 it can be seen that, as the clay content increases, the optimum water content value increases with the equation y = 0.0784 x + 13.55, this is caused by the increase in the value of the surface area of the granules per unit weight. It can also be seen that the maximum dry density value decreases with the equation y = -0.004 x + 1.885 which is caused by the increasing fineness of the grain gradation. Soil that consists of various grain sizes will be denser and more stable. The results of the direct shear strength test can be seen in Figure 9.

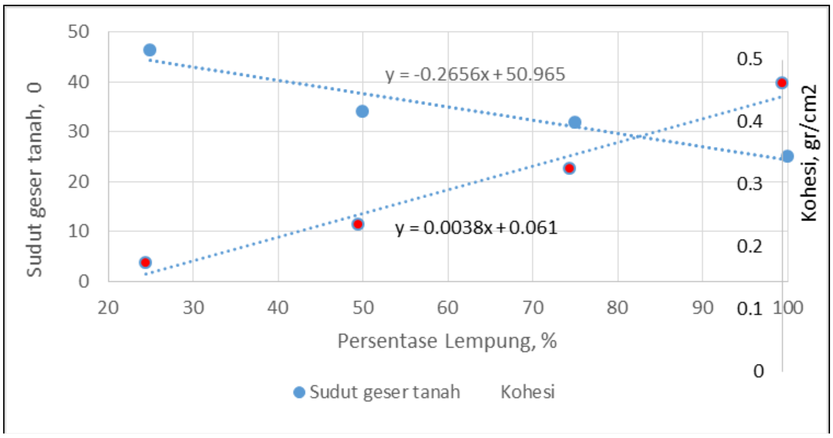

Fig. 9. Comparison of direct shear strength test results

In this research, undrained direct shear was carried out on clay-sand with optimum water content, pore water had no effect on shear resistance because the shear resistance was direct due to friction between close grains. In Figure 9 it can be seen that as the percentage of clay increases, the soil friction angle will decrease with the relationship y = - 0.2656 x + 50.965. The load on saturated clay is initially supported by pore water pressure. The pore cavities of clay soil are very small, so the release of water from the pore cavities takes time because as long as the pore water does not leave the pore cavities, the clay grains cannot approach to develop shear resistance. The load on sand with relatively large pore cavities means that water immediately leaves the pore cavities and the grains can approach each other, resulting in their frictional resistance immediately increasing.

Further studies should be carried out to investigate interfaces in dissolved sand-clay mixtures and structures with interface direct shear tests, to highlight the influence of clay fraction on the interface response, under various loading variations [10-12]. Undrained shear strength is inversely proportional to increasing sand percentage. The results of this work provide a useful addition to the literature regarding the behavior of low plasticity clay-sand mixtures [13-16].

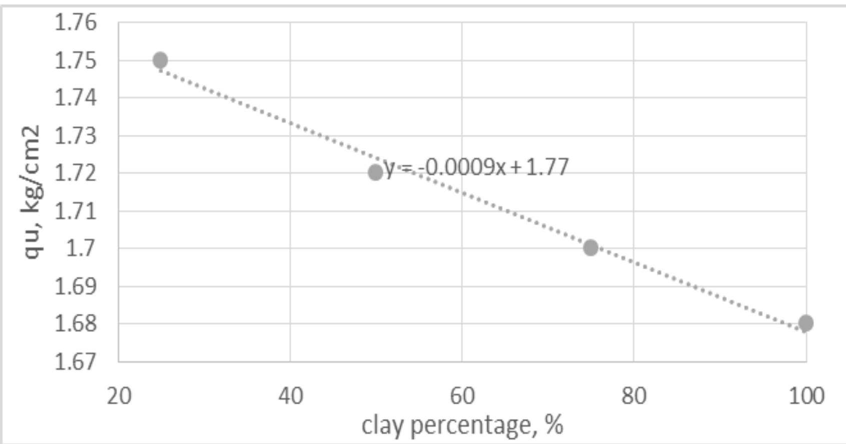

Fig. 10. Graph of the relationship between the addition of clay percentage and unconfined compressive strength

The results of the unconfined compressive strength test can be seen in Figure 10. From Figure 10 it can be seen that increasing the clay content will reduce the unconfined compressive strength value with the equation y = -0.00009 + 1.77. Clay has a wider contact area compared to sand. Compressive strength is the ratio of load to surface area, so the greater the surface area, the smaller the compressive strength value.

From Figure 10 it can be seen that the unconfined compressive strength value decreases with increasing clay percentage values. The UCS value increases with the length of curing time. Meanwhile, immersion treatment of the samples resulted in the UCS value decreasing [17-18].

IV. Conclusion

Several conclusions can be drawn from the results of this research regarding the characteristics of the clay-sand variant as follows:

(1) Variants of 50% clay and 50% sand, the gradation is continuous.
(2) Increasing the percentage of clay will increase the liquid limit value with the equation y = 0.6314x + 4.135, increase the plastic limit value with the equation y = 0.1944x + 11.2 and increase the plasticity index value with the equation y = 0.437x + 7.065 . Clay is a collection of crystalline mineral grains that are microscopic and in the form of flakes or plates, affecting their consistency value. This plate forms plastic, cohesive properties and has the ability to absorb ions. These properties are greatly influenced by the water content in the soil. Plasticity becomes small if there is fine grain content. The plasticity index value influences the adhesion value between materials, elasticity value and gives rise to spring properties. We can feel the spring effect when we are on the side of a road passed by a heavy truck. Gradually increasing the plasticity index will prevent excessive gaps due to spring effects which result in damage to road construction.
(3) As the clay content increases, the optimum water content value increases with the equation y = 0.0784x + 13.55, this is caused by the increase in the value of the surface area of the granules per unit weight. It can also be seen that the maximum dry density value decreases with the equation y = -0.004x + 1.885 which is caused by the increasing fineness of the grain gradation.
(4) Under loading, increasing the percentage of clay means the soil friction angle will decrease with the relationship y = - 0.2656x + 50.965 because the pore cavities of the clay are very small, so the water leaving the pore cavities takes a long time so that the grains cannot approach to develop shear resistance. Sand with relatively large pore cavities means that water immediately leaves the pore cavities and the grains can approach each other, causing frictional resistance to develop immediately.
(5) Increasing the clay content will reduce the unconfined compressive strength value according to the equation y = - 0.0009x + 1.77 because clay particles have a wider contact area than sand.

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