

## II. LITERATURE REVIEW

According to Yusof et al., 2006, describe that soft clays were a type of fine-grained soils which change volume when different from elastic deformation, consolidation and secondary compression. Soft clays defined as a disturbed cohesive soil whose water content is higher than its liquid limit; such materials display extremely low yield stresses and represent difficult construction conditions (p. 152). The lower strength of soft clays causes severe damage to pavements, runways, and building foundations, which are founded on these soils (e.g., Horpibulsuk et al., 2006; Kempfert and Gebreselassie, 2006). In order to improve the index properties and increasing the strength of soil related with the material properties, soil stabilization is required.

Soil modification is the addition of a modifier (cement, lime, cement kiln dust, bagasse ash, rice husk ash, cattle bone ash,... etc) to a problem soil in order to improve its index properties for better workability and usefulness, while soil stabilization is the treatment of problem soils to improve their index properties and strength characteristics such that they permanently become suitable for construction and meet engineering design standards (Salahudeen and Akijje, 2014).

According to Musa, 2008, “soil modification is the addition of a modifier (cement, lime, etc) to a soil to change its index properties, while soil stabilization is the treatment of soils to enable their strength and durability to be improved such that they become totally suitable for construction beyond their original classification”.

In addition, Horpibulsuk et al. (2013) stated, “to improve economic and environmental impacts, some waste  $\text{Ca}(\text{OH})_2$ -rich materials can be utilized together with waste pozzolanic materials, such as fly ash, biomass ash and rice husk ash to develop a cementitious material”. Economic and effective use of locally available materials for improving the soil properties by soil stabilizer additive are the important challenge being faced by the engineers.

Press mud is the residue from of the purification of sap before proceeded to the concoction and crystallization. Leovisi (2012) stated, “Among the other sugarcane waste, press mud is the highest pollution level and become a problem for sugarcane factory and community”. The input of press mud (as a pozzolanic material) may improve the strength of clays, where the lime act as a binder.

Since lime stabilizes soil by pozzolanic reaction, external additives can enhance this property in the lime soil mix which results in improved stabilization of soil. Several industrial by-products have been studied as additives to lime (Guleria and Dutta, 2011, Ramirez et al. 2012, Okonkwo et al. 2012). Furthermore, Thompson (1966) mentioned that “most of the soils decreases the plasticity index by addition of lime and thereby increasing the workability”.

In Cut Nuri Badariah, Nasrul, Yudha Hanova research entitle “*Perbaikan Tanah Dasar Jalan Raya Dengan Penambahan Kapur*”, used 2%, 4%, 6%, 8% and 10% lime content. The result shows the addition of lime reduce 39.15% plasticity index. In direct shear test, cohesion value increase from 0.16  $\text{kg}/\text{cm}^2$  become 0.59%, and the friction angle also increase about  $4.20^\circ$  with 4% and 6% addition of lime content.

## III. BASIC THEORY

### 3.1. Clay

Guggenheim and Martin (1995) defined the term "clay" refers to a naturally occurring material composed primarily of fine-grained minerals, which is generally plastic at appropriate water contents and will harden with dried or fired. Although clay usually contains phyllosilicates, it may contain other materials that impart plasticity and harden when dried or fired. Associated phases in clay may include materials that do not impart plasticity and organic matter (p. 225).

In soil definition, clay is a physical sense as any mineral particles that has effective diameter less than  $2\ \mu\text{m}$  ( $8 \times 10^{-5}$  in). Clay also used to refer to a particle size in a soil and in practice used to refer to the fine-grained, mineral fraction of earth material, and can include clay silicates. Typically, clay minerals formed over time in long periods by the gradual chemical weathering of rocks.

Clays form from aluminum oxide in the shape of an octahedron and silicon oxide in the shape of a tetrahedron that is weathering. Clay minerals are formed by the bonding of tetrahedral and octahedral, by way of ionic bonds that together form a single layer of clay. Clay characteristics is depending on the natural water content, because its sensitivity to water content alteration. Actually, water content affecting the strength of the clay. In dry condition the clays are hard enough, but when the clays in saturated condition the strength will decrease significantly.

### 3.2. Classification of Soil

This practice describes a system for classifying different soils with similar properties. Basically, this practice may be classified the different soils into groups and sub-groups according the engineering purposes. In general, this classification system based on laboratory determination of grain-size distribution characteristics, liquid limit, and plasticity index.

Several classification systems are now in use, Unified Soil Classification System (USCS) is one of the system. According to Das, 2009, “The original form of this system was proposed by Casagrande in 1942 for use in the airfield construction works undertaken by the Army Corps of Engineers during World War II. In cooperation with the U.S. Bureau of Reclamation, this system was revised in 1952. At present, it is used widely by engineers (ASTM Test Designation D-2487).”

This system classifies soils into two broad categories:

1. Coarse-grained soils that are gravelly and sandy in nature with less than 50% passing through the No. 200 sieve. The group symbols start with a prefix of G (gravel or gravelly soil) or S (sand or sandy soil).
2. Fine-grained soils are with 50% or more passing through the No. 200 sieve. The group symbols start with prefixes of M, which stands for inorganic silt, C for inorganic clay, or O for organic silts and clays. The symbol Pt is used for peat, muck, and other highly organic soils.

Other symbols used for the classification are:

W : well graded

P : poorly graded

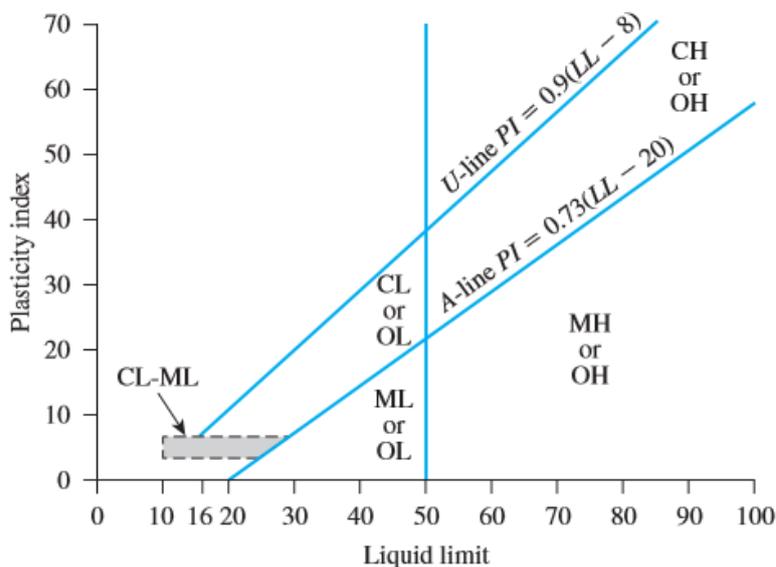
L : low plasticity (liquid limit < 50)

H : high plasticity (liquid limit >50)

There is some figure used in order classifying soil using USCS, as shown on the following figure.

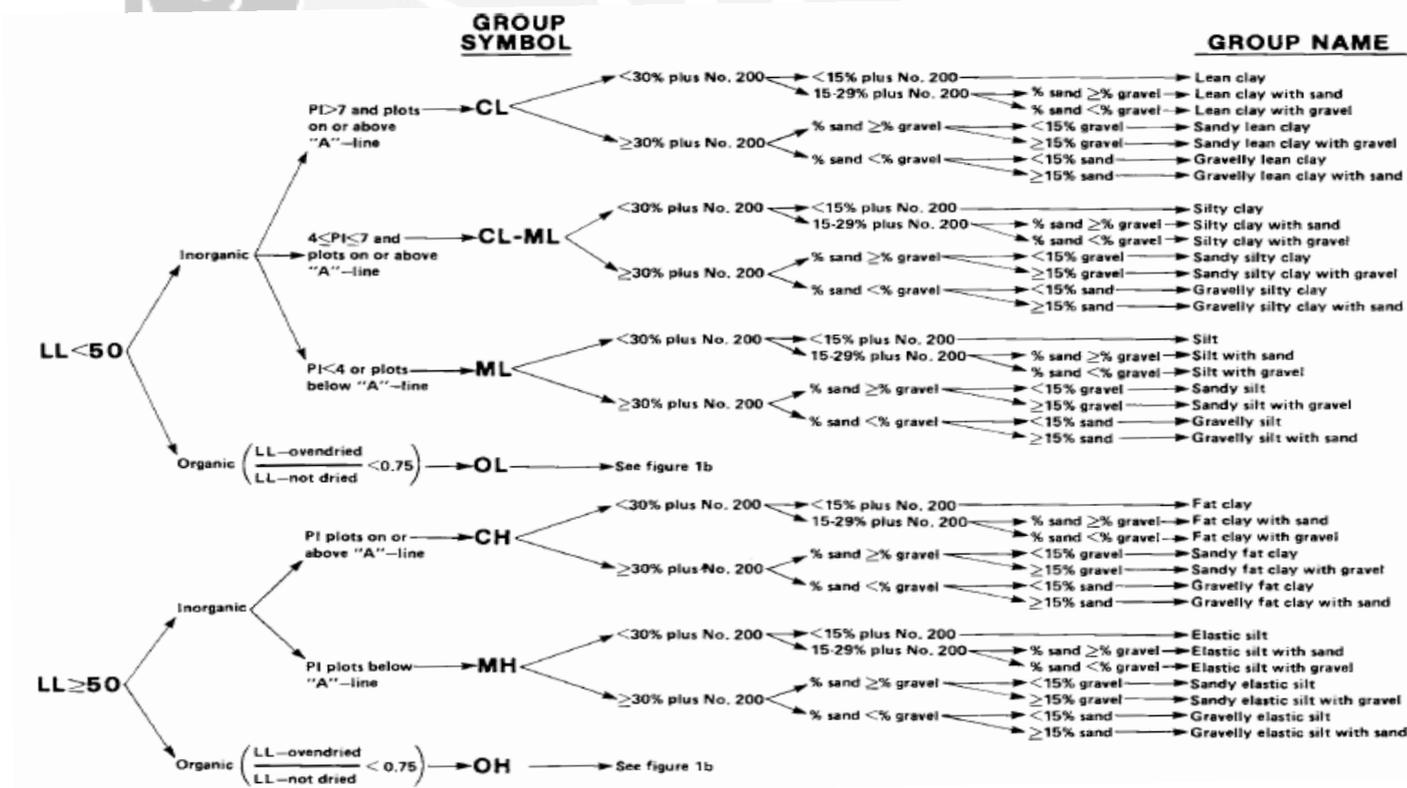
UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART		
<b>COARSE-GRAINED SOILS</b> (more than 50% of material is larger than No. 200 sieve size.)		
Clean Gravels (Less than 5% fines)		
<b>GRAVELS</b> More than 50% of coarse fraction larger than No. 4 sieve size	 GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	 GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	 GM	Silty gravels, gravel-sand-silt mixtures
	 GC	Clayey gravels, gravel-sand-clay mixtures
Clean Sands (Less than 5% fines)		
<b>SANDS</b> 50% or more of coarse fraction smaller than No. 4 sieve size	 SW	Well-graded sands, gravelly sands, little or no fines
	 SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	 SM	Silty sands, sand-silt mixtures
	 SC	Clayey sands, sand-clay mixtures
<b>FINE-GRAINED SOILS</b> (50% or more of material is smaller than No. 200 sieve size.)		
<b>SILTS AND CLAYS</b> Liquid limit less than 50%	 ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	 CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	 OL	Organic silts and organic silty clays of low plasticity
<b>SILTS AND CLAYS</b> Liquid limit 50% or greater	 MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	 CH	Inorganic clays of high plasticity, fat clays
	 OH	Organic clays of medium to high plasticity, organic silts
<b>HIGHLY ORGANIC SOILS</b>	 PT	Peat and other highly organic soils

Figure 3.1. Unified Soil Classification System



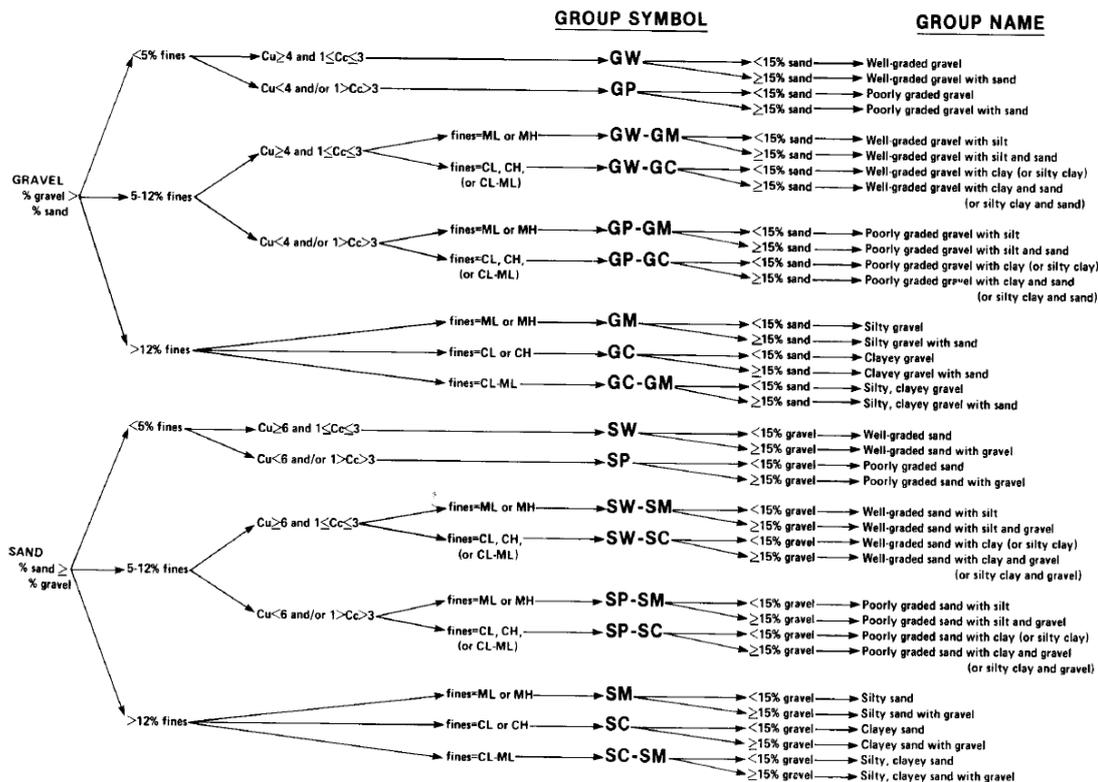
Source: Principles of Geotechnical Engineering 7th Edition by Braja M. Das

Figure 3.2. Plasticity Chart



Source: ASTM D 2487-06

Figure 3.3. Flow Chart for Classifying Fine-Grained Soil (50 % or More Passes No. 200 Sieve) as per ASTM



Source: ASTM D 2487-06

Figure 3.4. Flow Chart for Classifying Coarse-Grained Soil (More Than 50 % Retained on No. 200 Sieve) as per ASTM

For proper classification according to this system, some or all of the following information must be known:

1. Percent of gravel : the fraction passing the 76.2 mm sieve and retained on the No. 4 sieve (4.75 mm opening)
2. Percent of sand : the fraction passing the No. 4 sieve (4.75 mm opening) and retained on the No. 200 sieve (0.075 mm opening)
3. Percent of silt and clay : that is, the fraction finer than the No. 200 sieve (0.075 mm opening)
4. Uniformity coefficient (Cu) and the coefficient of gradation (Cc)
5. Liquid limit and plasticity index of the portion of soil passing the No. 40 sieve

The group symbols for coarse-grained gravelly soils are GW, GP, GM, GC, GC-GM, GW-GM, GW-GC, GP-GM, and GP-GC. Similarly, the group symbols for fine-grained soils are CL, ML, OL, CH, MH, OH, CL-ML, and Pt.

### 3.3. Press Mud

Press mud is the residue from of the purification of sap before proceeded to the concoction and crystallization. The form of press mud is soil-like waste and has high temperature during process. Composition of degraded press mud consist of: potassium oxide ( $K_2O$ ) 0.00116%, calcium oxide ( $CaO$ ) 0.01938%, magnesium oxide ( $MgO$ ) 0.00221%, sodium oxide ( $Na_2O$ ) 0.00126%, iron(III) oxide ( $Fe_2O_3$ ) 0.00459%, sulfur trioxide ( $SO_3$ ) 0.00256%, aluminium oxide ( $Al_2O_3$ ) 0.00357%, and silicon dioxide ( $SiO_2$ ) 60.18%.

Fadjari, (2009), also stated that “the composition of press mud also different one sugar cane factory with another and some studies stated that Silica include in composition of press mud. It depends on the origin of the cane”.

### 3.4. Lime

There are some types of lime, in order to treat soils. Lime in the form of quicklime (calcium oxide –  $CaO$ ), hydrated lime (calcium hydroxide –  $Ca(OH)_2$ ), or lime slurry. Chemically, quicklime is transforming calcium carbonate (limestone –  $CaCO_3$ ) into calcium oxide. When quicklime chemically reacts with water the hydrated lime is created.

Lime, or  $\text{CaO}$  or  $\text{Ca(OH)}_2$ , the burned byproduct of lime stone ( $\text{CaCO}_3$ ), is one of the oldest developed construction materials, and humans have been using it for more than 2,000 years, when the Romans used soil-lime mixtures to construct roads (Dash et al., 2012). The use of lime is primarily because of its overall economy and ease of construction, coupled with simplicity of this technology that provides an added attraction for engineers.

The addition of lime to a fine-grained soil in the presence of water initiates several reactions. The two primary reactions, cation exchange and flocculation–agglomeration, take place rapidly and produce immediate improvements in soil plasticity, workability, uncured strength, and load-deformation properties. (Mallela et al., 2004).

### **3.5. Soil Stabilization**

Soil stabilization can be defined as the treatment for problematic soil to improve their index properties and strength characteristics. Stabilization is by soil stabilizer additive. Stabilization can be achieved stabilizer additive, such as fly ash, rice husk ash, bagasse ash and biomass ash. Nevertheless, the utilization of press mud from sugarcane waste as a stabilizer is limited studied.

The major strength gains of lime treated clay is mainly derived from three reactions, those are: hydration of soil, flocculation/ion exchange, and pozzolanic reaction. Other mechanism is carbonation, this reaction causes minor strength increase and can be neglected. Short term reaction includes hydration (for

quicklime) and flocculation (cation exchange). Longer term reactions are cementation/pozzolanic reaction and carbonation.

Pozzolanic reactions occurred when pozzolanic clays and lime mixed in the presence of water. When  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$ , of soil react with calcium that contain in lime, it will produce a stable calcium silicates and aluminates. Pozzolanic reaction is slow reaction because it depends on time and temperature.

Pozzolanic reaction is the slow chemical reaction between a pozzolan (siliceous or silicaaluminous materials) and calcium hydroxide (lime) (Mehta & Monteiro, 1993). The pozzolanic reaction can be describe as:

- Silicates:



- Aluminates:

