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 μm (8×10^{-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:

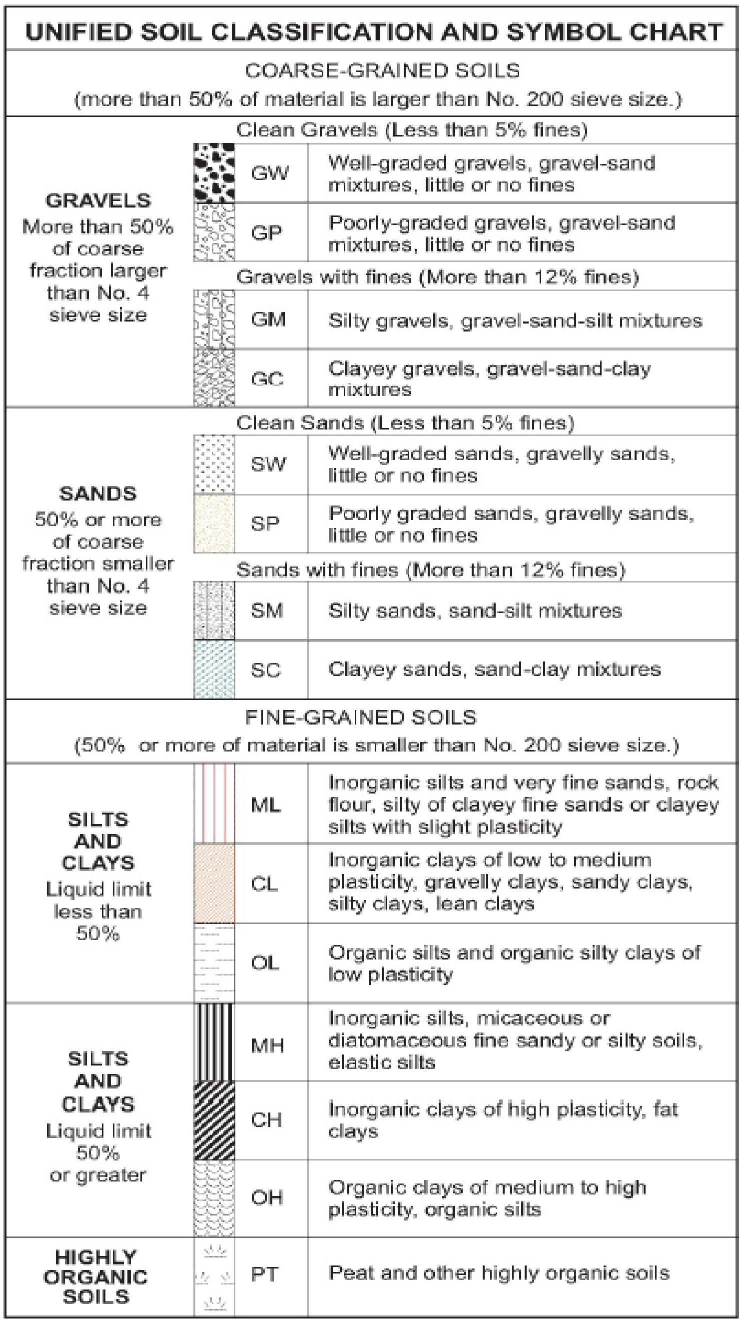
W : well graded

P : poorly graded

L : low plasticity (liquid limit < 50)

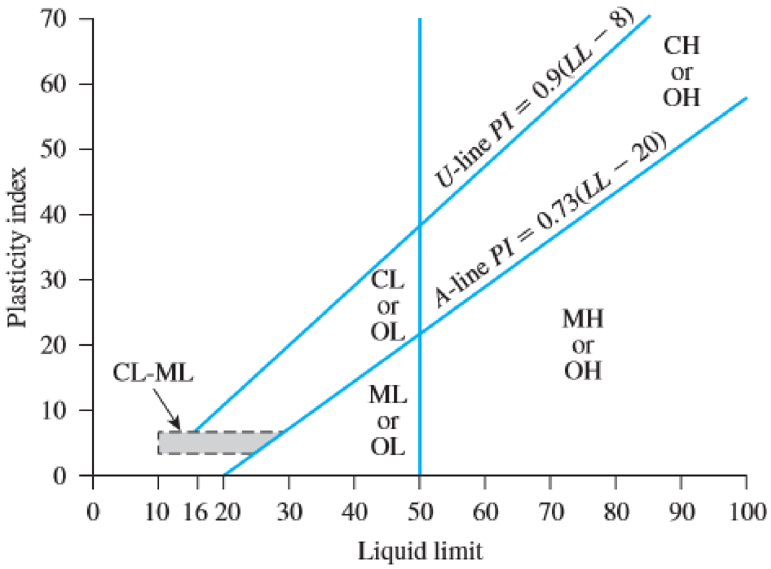
H : high plasticity (liquid limit >50)

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



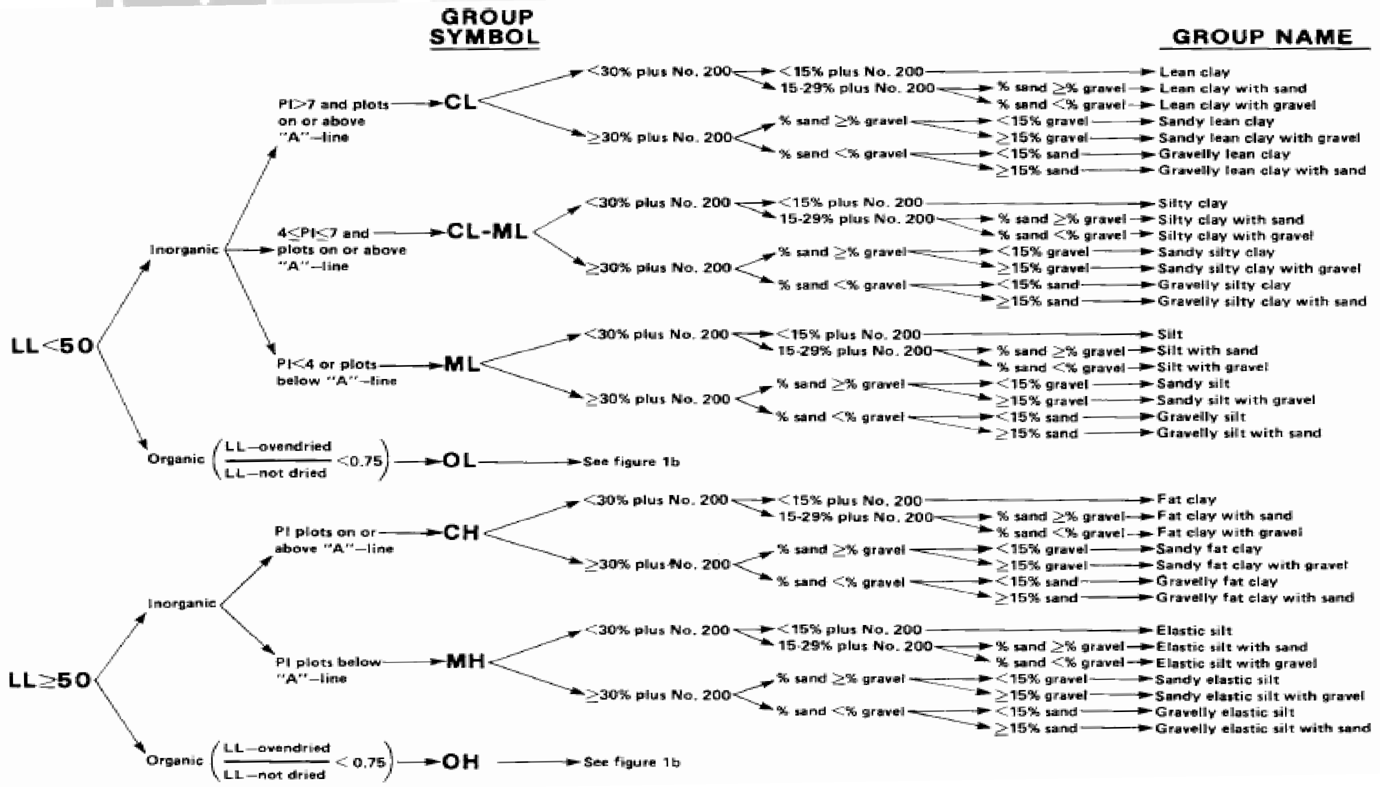
UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART		
COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	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
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	
	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
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS 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
SILTS AND CLAYS 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
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

Figure 3.1. Unified Soil Classification System



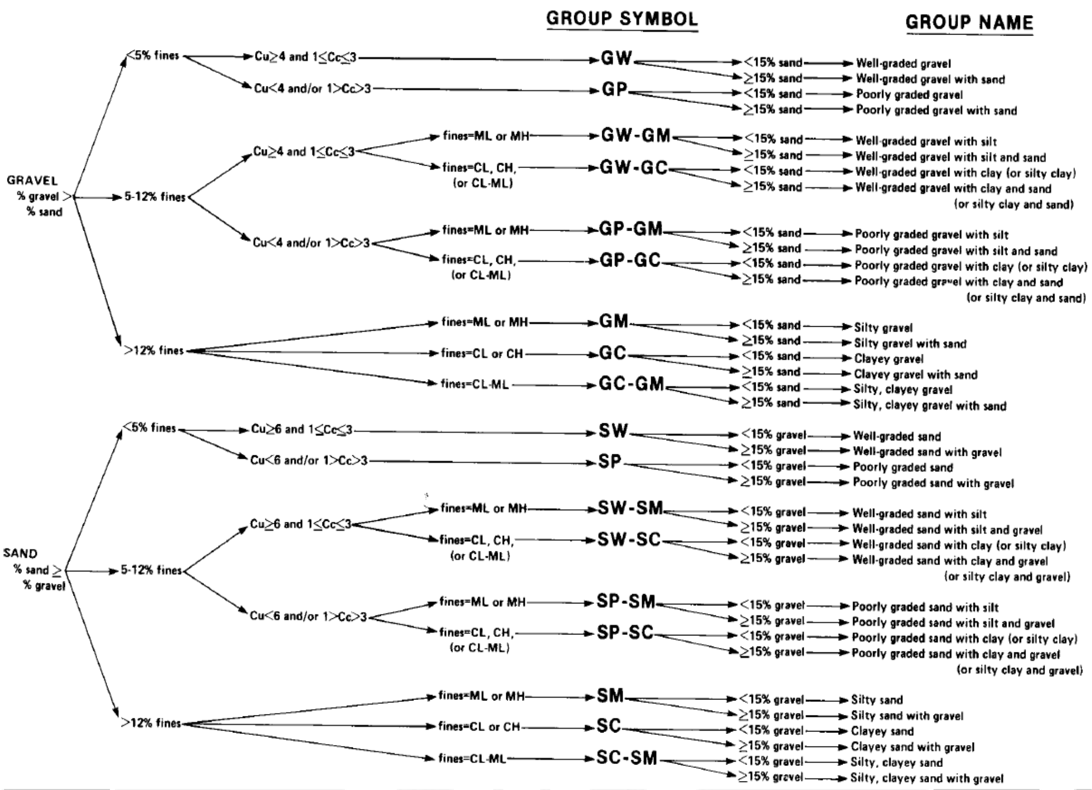
Source: Principles of Geotechnical Engineering 7th Edition by Braja M. Das

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 CaO or $Ca(OH)_2$, the burned byproduct of lime stone ($CaCO_3$), 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 SiO_2 and Al_2O_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:

  $SiO_2 + Ca(OH)_2 + H_2O \rightarrow CaO\text{-}SiO_2\text{-}H_2O$ (calcium silicate)

- Aluminates:

  $Al_2O_3 + Ca(OH)_2 + H_2O \rightarrow CaO\text{-} Al_2O_3\text{-} H_2O$ (calcium aluminate)