1.8 CLAY MINERALOGY

Clay mineralogy is the science dealing with the structure of clay minerals on microscopic, molecular, and atomic scale. It also includes the study of the mineralogical composition and electrical properties of the clay particles. The behavior of fine grained soils, on the other hand, depends to a large extent on the nature and characteristics of the minerals present. The most significant properties of clay depend upon the type of mineral.

1.8.1CLAY MINERALS

To understand the various unique engineering behavior of clay, it is most beneficial to study microstructures of clay particles first.

There are three types of clay minerals:

- ✤ Kaolinite clay
- Montomorillonite clay
- ✤ Illite clay

All of these clay minerals have two basic atomic sheet

1. Silica tetrahedral sheet

2. Aluminum octahedron sheet

1.Silica tetrahedral sheet

In <u>silica tetrahedral sheet</u>, silica (Si) occupies the center positions and oxygen ions (O) are strongly bonded to the core atoms. Silica tetrahedral sheet is symbolized with a trapezoid, of which the shorter face holds electrically unsatisfied oxygen atoms and the longer face holds electrically satisfied oxygen atoms.

2.Aluminum octahedron sheet

In aluminum octahedron sheet, aluminum (Al) ion positioned at the center and hydroxyl ion (OH⁻) bonded to the core atoms. Aluminum octahedron sheet is symbolized with a rectangle with top and bottom faces having the same

characteristics of exposed hydroxyl ions. Figure 1.16 gives the atomic structure of the above two basic sheets.



Figure 1.16 Silica tetrahedral and aluminum octahedron

1.8.1.1KAOLINITE CLAY

The basic unit of this type of clay is formed by atomic bond of the unsatisfied face of silica sheet and either face of aluminum sheet as seen in Figure 1.17. The bond between two sheets is strong and is primary bond. However, the stack of two sheets is not a form of clay yet. Many layers of basic kaolinite unit make a kaolinite clay. The thickness of one unit is about 7.2 angstrom. SEM (Scanning Electron Microscope) image of kaolinite clay is illustrated in Figure 1.18.



Figure 1.17 Kaolinite clay



Figure 1.18 SEM image of Kaolinite clay

1.8.1.2 MONTMORILLONITE CLAY

The unused OH⁻ face of aluminum sheet of the silica and aluminum sheet unit in the Kaolinite clay structure may attract the unsatisfied face of another silica sheet to make a three layer stack and shown in Figure 1.19 and SEM image is illustrated in Figure

. This makes the basic unit of Montmorillonite clay structure with the thickness of about 10 angstrom. The link is due to natural attraction for the cations in the intervening space and due to Vander Waal forces. The negatively charged surfaces of the silica sheet attract water in the space between two structural units. This results in an expansion of the mineral. The soil containing a large amount of the mineral montmorillonite exhibits high shrinkage and swelling characteristics.



Figure 1.19 Montmorillonite clay



Figure 1.20 SEM image of Montmorillonite clay

1.8.1.3 ILLITE CLAY

Basic structure of this clay is the same as the one of montmorillonite. However, potassium ion (K^+) are filled in between facing O²⁻ and O²⁻surfaces of silica sheets as seen in Figure 1.21. The characteristics of this clay are classified as in between those of kaolinite and montmorillonite. SEM image is shown in Figure 1.22.

Figure 1.21 Illite clay

Figure 1.22: SEM image of Illite clay

1.8.2CLAY SHAPES AND SURFACE AREAS

Clays are formed in stack of several layers of basic sheet units. These are generally flat and smaller in size, and thus, their surface areas per weight are very large. Table 1.6 compares the types of clay with their general shapes, general dimensions, and surface areas. The specific surface is defined as the surface area of clay per 1 gm of dry clay particles.

Clay type	Typical length (µm)	Typical thickness (µm)	Typical dimensional ratio (L x L x T)	Specific surface (m ² /g)
Kaolinite	0.3-3	0.05-1	10 x 10 x 1	10-20
Montmorilloni	-0.1-	0.001-	100 x 100 x	800
te	1.0	0.01	1	
Illite	0.1-2	0.01-0.2	20 x 20 x 1	80-
	*		\rightarrow	100

Table 1.6: Comparison of shape and surface areas of clay particles

1.8.3 CLAY WATER SYSTEM

In the natural environment, clays are often formed under water. In water, positively charged ions (cations) and positive edges of dipoles (water molecules) are attracted to the clay surface. Several layers of water molecules are attracted on the clay surface in a very ordinary way. The water layer with thickness of 10 angstrom is called adsorbed water layer. The layer is very rigidly, electrically attracted to the clay surface and behaves as if a part of the particle itself.

In the outer part of water, there are distributions of mobile cations and anions. Those cations and anions are from resolved minerals and other matters in natural water. Cations further attract dipoles around them. This type of water is called electrostricted water, and they move together when a cation moves. The rest of the space is filled with regular water, which is called free water. There is a boundary within which a clay particle has influence electricity. The layer extending from the clay particle surface to the limit of attraction is known as Diffuse Double Layer. The above description is outlined in Figure 1.23.

1.8.4 SOIL STRUCTURE

The geometrical arrangement of soil particles with respect to one another is known as soil structure. The soils in nature have different structures depending upon the particle size and the mode of formation.

1.8.4.1Soil Structure for Coarse Grained Soil

1)Single grained structure:

Cohesion less soils, such as gravel and sand, are composed of bulky grains in which the gravitational forces are more predominant than surface forces. When deposition of these soil occurs, the particles settle under gravitational forces and take an equilibrium position as shown in Figure1.24. Each particle is in contact with those surrounding it. The arrangement is somewhat similar to the stacking of oranges on a grocer's counter. Depending upon the relative position of soil particles, the soil may be a loose structure or dense structure.

Figure 1.24 Single grained structure

2)Honey comb structure

It is possible for fine sands or silts to be deposited such that the particles when setting develop a particle-to-particle contact that bridges over large voids in the soil mass (Figure 1.25). The honeycomb structure usually develops when the particle size is between 0.002 mm and 0.02 mm.

Figure1.25 Honey comb structure

1.8.4.2.Soil Structure for 1<u>Clav Dispersed clav</u>

The final structures of clay are established from the balance of interactive forces and external forces applied to the clay assemblage. If the final inter particle forces are repulsive, the particles want to separate from each other when the boundary confinements are removed. This is a situation of dispersed clay. The soils in dispersed structure generally have a low shear strength, high compressibility, and low permeability.

Figure 1.26 Dispersed clay

2)Flocculated structures

If the inter particle force are attractive, then particles want to come together, making flocculated clay. If the edge charges are positive, most likely, the edges are attracted to the flat surface of other clay particles. This makes a card house structure of flocculated clay, most commonly in salt water environment. In freshwater environments, more face-to-face flocculated structures are formed due to negative charges at the edges.

Figure 1.27:Flocculated clay

1.8.4.3 QUICK CLAY

Quick clay is also known as Leda clay and Champlain sea clay, is a unique form of highly sensitive marine clay, with the tendency to change from a relatively stiff condition to a liquid mass when it is disturbed. Undisturbed quick clay resembles a water saturated gel. When a mass of quick clay undergoes sufficient stress, however, it instantly turns into flowing ooze.

1.8.5 CLAY VERSUS SAND

Clays are quite different from sand in their characteristics and behaviors. Those are summarized in Table 1.7.

Properties and behavior	Clay	Sand
Particle size	Small (< 0.005 or 0.002 mm)	Large (>0.075 mm)
Structure	Clay structures	Crystal formations
Shape	Flat	Angular to round

Table 1.7: Comparison between clay and sand

Surface charge	Negative and sometimes	Negligible
	positive at edge	
Specific charge	Large	Small
Interactive forces	Strong	Negligible
Plasticity	Plastic	Non plastic
Shear resistance	By cohesion	By friction
Volume change	Large, time dependent	Small, instantaneous

