INS 3121
SOIL MECHANICS

Origin of Soil & Grain Size Distribution

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Reference

Das, B. M. (2010), ‘‘Principles of Geotechnical Engineering’’ Seventh Edition, CENGAGE Learning.

The purpose of today's class is to introduce you the orign of soils and particle sizes of soils.

- When you complete today's class, you should be able to:
- Understand the formation and composition of soils.
- Know the main minerals in soils.
- Determine particle size distribution of a soil mass.
- Interpret grading curves.
- Understand the differences between coarse-grained and fine-grained soils.

Chapter Outline

ROCK CYCLE

ORİGİN OF SOİL

GRAİN-SİZE DİSTRİBUTİON OF SOİL

2.1 Rock Cycle and the Origin of Soil

- Mineral grains: the product of rock weathering.
- Rocks: Igneous, sedimentary and metamorphic.

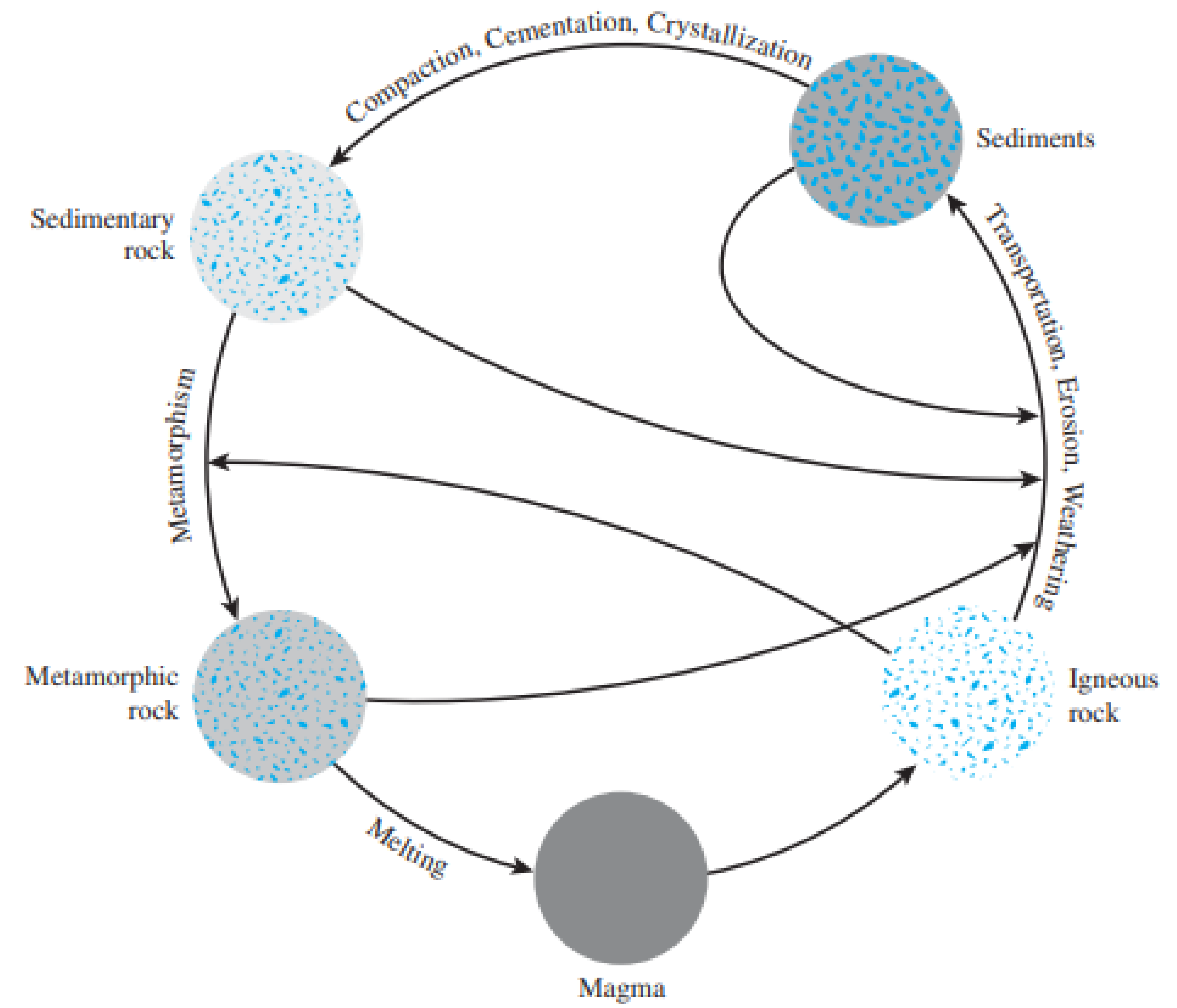


Figure 2.1 Rock cycle

Igneous Rock

- Igneous rocks are formed by the solidification of molten magma ejected from deep within the earth’s mantle.
- Fissure eruption or volcanic eruption
- Plutons: magma ceases its mobility below the earth’s surface and cools to form intrusive igneous rocks.
- The types of igneous: depend on factors such as the composition of the magma and the rate of cooling associated with it.

Igneous Rock

- Bowen's reaction principle: describes the sequence by which new minerals are formed as magma cools.

  1. discontinuous ferromagnesian reaction series, in which the minerals formed are different in their chemical composition and crystalline structure
  2. continuous plagioclase feldspar reaction series, in which the minerals formed have different chemical compositions with similar crystalline structures

Igneous Rock

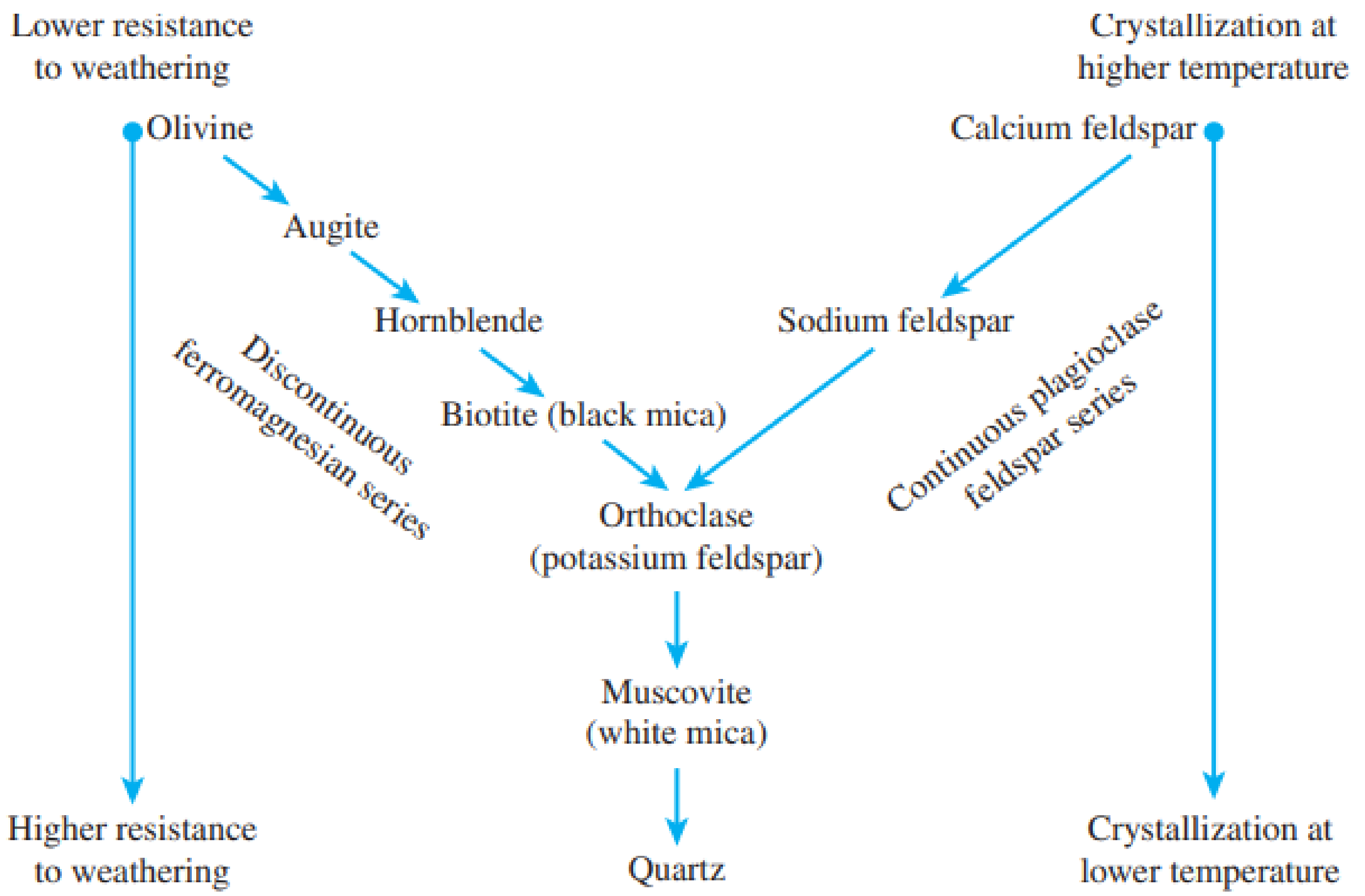


Figure 2.2 Bowen's reaction series

Igneous Rock

Table 2.1 Composition of Minerals Shown in Bowen's Reaction Series

Mineral		Composition
Olivine		$(Mg, Fe)_2SiO_4$
Augite		$Ca, Na(Mg, Fe, Al)(Al, Si_2O_6)$
Hornblende		Complex ferromagnesian silicate of Ca, Na, Mg, Ti, and Al
Biotite (black mica)		$K(Mg, Fe)_3AlSi_3O_{10}(OH)_2$
Plagioclase	calcium feldspar	$Ca(Al_2Si_2O_8)$
	sodium feldspar	$Na(AlSi_3O_8)$
Orthoclase (potassium feldspar)		$K(AlSi_3O_8)$
Muscovite (white mica)		$KAl_3Si_3O_{10}(OH)_2$
Quartz		SiO_2

Igneous Rock

- Types of igneous rock: depend on the proportions of minerals available.
- Granite, gabbro, and basalt are some of the common types of igneous rock generally encountered in the field

Table 2.2 Composition of Some Igneous Rocks

Name of rock	Mode of occurrence	Texture	Abundant minerals	Less abundant minerals
Granite	Intrusive	Coarse	Quartz, sodium feldspar, potassium feldspar	Biotite, muscovite, hornblende
Rhyolite	Extrusive	Fine		
Gabbro	Intrusive	Coarse	Plagioclase, pyroxines, olivine	Hornblende, biotite, magnetite
Basalt	Extrusive	Fine		
Diorite	Intrusive	Coarse	Plagioclase, hornblende	Biotite, pyroxenes (quartz usually absent)
Andesite	Extrusive	Fine		
Syenite	Intrusive	Coarse	Potassium feldspar	Sodium feldspar, biotite, hornblende
Trachyte	Extrusive	Fine		
Peridotite	Intrusive	Coarse	Olivine, pyroxenes	Oxides of iron

Igneous Rock

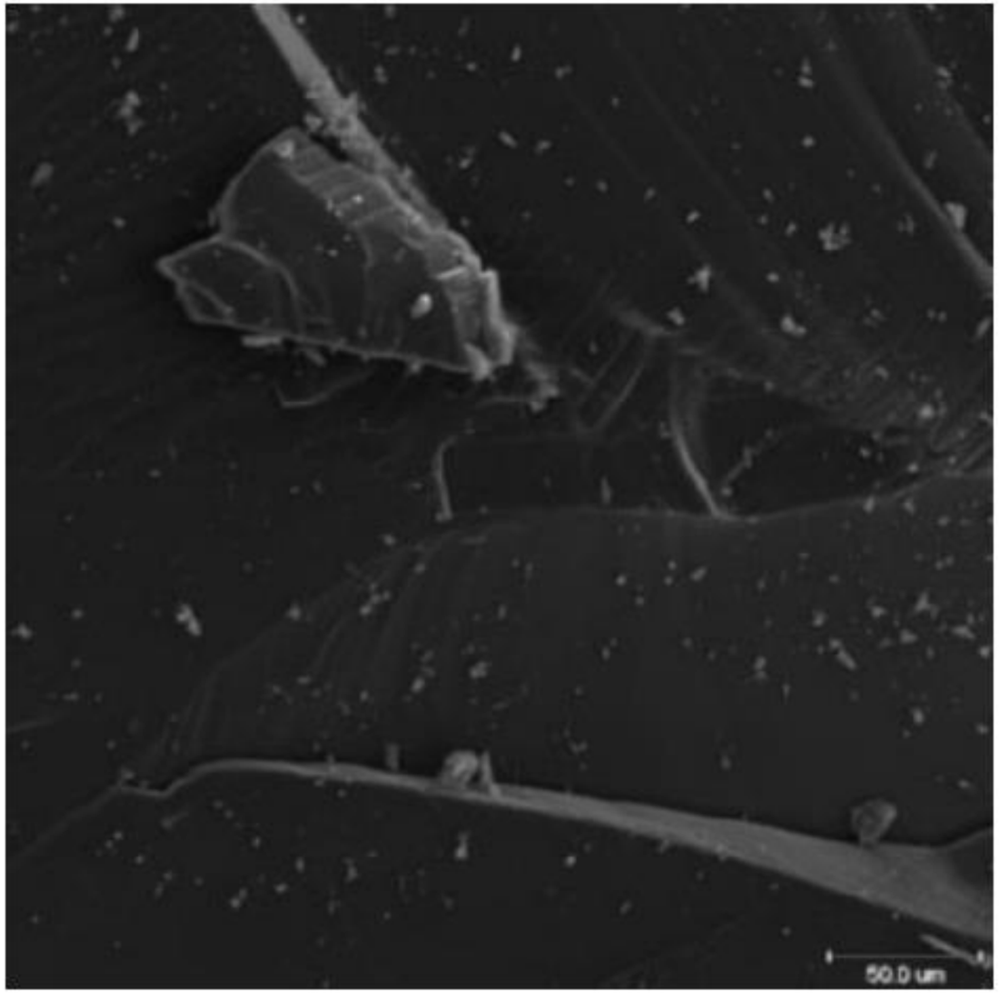


Figure 2.3
Scanning electron micrograph of fractured surface of quartz showing glass-like fractures with no discrete planar surface (*Courtesy of David J. White, Iowa State University, Ames, Iowa*)

Igneous Rock

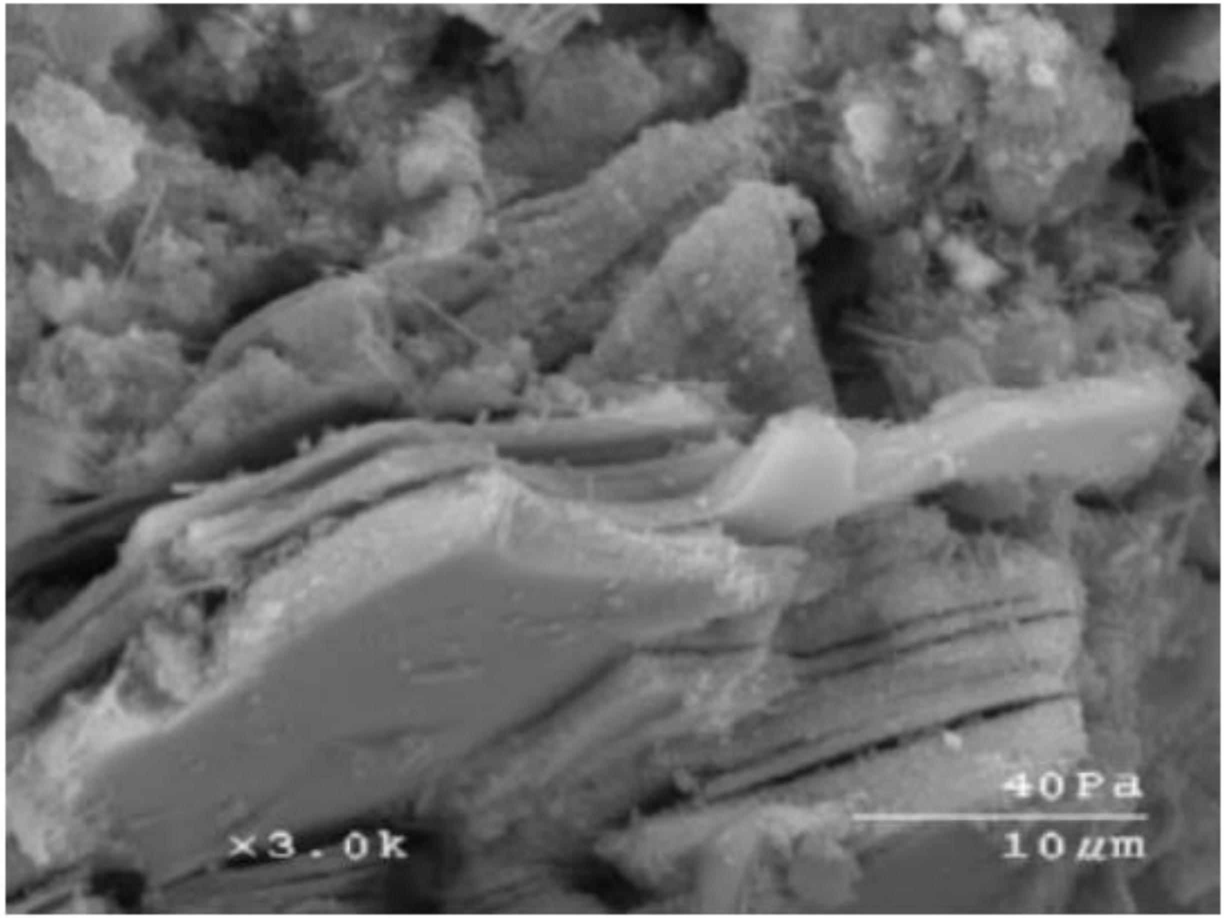


Figure 2.4
Scanning electron micrograph showing basal cleavage of individual mica grains (*Courtesy of David J. White, Iowa State University, Ames, Iowa*)

Formation of soils

- Soils are formed from the physical and chemical weathering of rocks. Physical weathering involves reduction of size without any change in the original composition of the parent rock. The main agents responsible for this process are exfoliation, unloading, erosion, freezing, and thawing.
- Chemical weathering causes both reductions in size and chemical alteration of the original parent rock.
- The main agents responsible for chemical weathering are hydration, carbonation, and oxidation.
- Often, chemical and physical weathering take place in concert.

Weathering

- Weathering: the process of breaking down rocks by mechanical and chemical processes into smaller pieces.
- Mechanical weathering : caused by the expansion and contraction of rocks from the continuous gain and loss of heat, resulting in ultimate disintegration.
- Physical agents that help disintegrate rocks:
    - ice, glacier ice, wind, running water of streams and rivers, ocean waves.
- In mechanical weathering, large rocks are broken down into smaller pieces without any change in the chemical composition.

Weathering

Figure 2.5 Mechanical erosion due to ocean waves and wind at Yehliu, Taiwan (*Courtesy of Braja M. Das, Henderson, Nevada*)

Figure 2.5 (Continued)

Weathering

- Chemical weathering : the original rock minerals are transformed into new minerals by chemical reaction.
- Water and carbondioxide from the atmosphere form carbonic acid, which reacts with the existing rock minerals to form new minerals and soluble salts.
- Soluble salts present in the ground water and organic acids formed from decayed organic matter also cause chemical weathering.
- Sedimentary and metamorphic rocks also weather in a similar manner.

$$H_2O + CO_2 \rightarrow \underset{\text{Carbonic acid}}{H_2CO_3} \rightarrow H^+ + (HCO_3)^-$$

$$\underset{\text{Orthoclase}}{2K(AlSi_3O_8)} + 2H^+ + H_2O \rightarrow 2K^+ + \underset{\text{Silica}}{4SiO_2} + \underset{\text{Kaolinite (clay mineral)}}{Al_2Si_2O_5(OH)_4}$$

Weathering

- Clay minerals : product of chemical weathering of feldspars, ferromagnesians, and micas.
- Three important clay minerals:
  1. Kaolinite
  2. Illite
  3. Montmorillonite

Transportation of Weathering Products

- The products of weathering may stay in the same place or may be moved to other places by ice, water, wind, and gravity.

- Residual soils:. Soils that remain at the site of weathering are called residual soils (i.e. the weathered products at their place of origin) These soils retain many of the elements that comprise the parent rock.

- Transported soils

  1. Glacial soils
  2. Alluvial soils
  3. Lacustrine soils
  4. Marine soils
  5. Aeolian soils
  6. Colluvial soils

SOIL TYPES BASED ON WAETHERING AGENTS

- *Alluvial soils (Fluvial soils)* are fine sediments that have been eroded from rock and transported by water, and have settled on river and stream beds.
- *Collovial soils* (collovium) are soils found at the base of mountains that have been eroded by the combination of water and gravity.
- *Eolian* soils are sand-sized particles deposited by wind.
- *Glacial soils* are soils that were transported and deposited by glaciers. They are mixed soils consisting of rock debris, sand, silt, clays, and boulders.
- *Glacial clays* are soils that were deposited in ancient lakes and subsequently frozen. The thawing of these lakes revealed soil profiles of neatly stratified silt and clay, sometimes called varved clay.

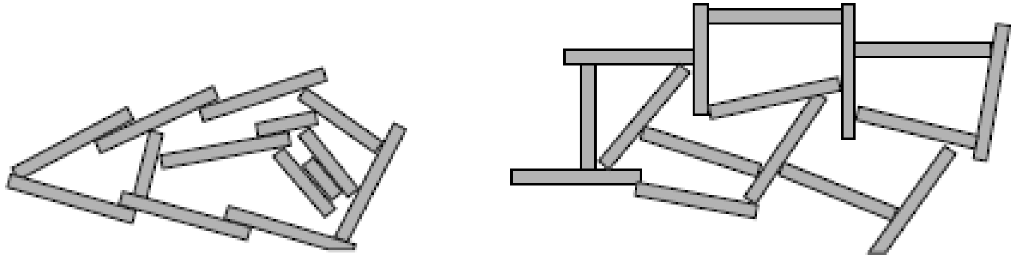
The silt layer is light in color and was deposited during summer periods, while the thinner, dark clay layer was deposited during winter periods.

- *Lacustrine* soils are mostly silts and clays deposited in glacial lake waters.
- *Loess* is a wind-blown, uniform, fi ne-grained soil.
- *Marine soils* are sand, silts, and clays deposited in salt or brackish water(marine environment).

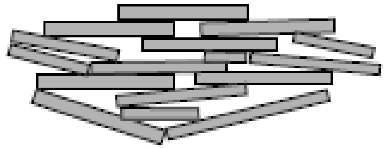
SOIL FABRIC

Two common types of soil fabric—flocculated and dispersed—are formed during soil deposition of fine-grained soils, as shown schematically in the Figure .

- A flocculated structure, formed in a saltwater environment, results when many particles tend to orient parallel to one another. A flocculated structure, formed in a freshwater environment, results when many particles tend to orient perpendicular to one another.
- A dispersed structure occurs when a majority of the particles orient parallel to one another.



(*a*) Flocculated structure—saltwater environment (*b*) Flocculated structure—freshwater environment



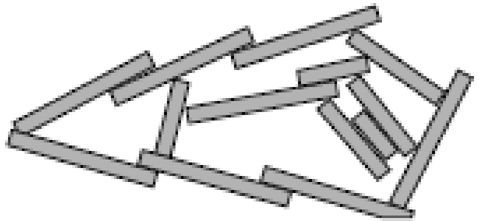
(*c*) Dispersed structure

SOIL FABRIC

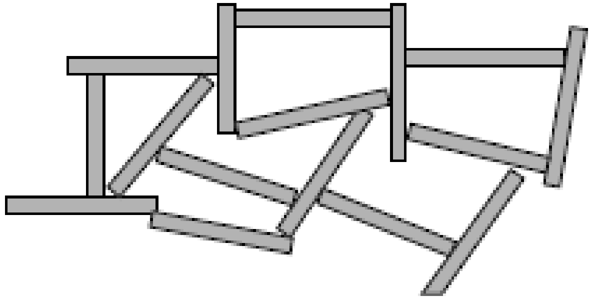
- Any loading (tectonic or otherwise) during or after deposition permanently alters the soil fabric or structural arrangement in a way that is unique to that particular loading condition.

- The history of loading and changes in the environment is imprinted in the soil fabric.

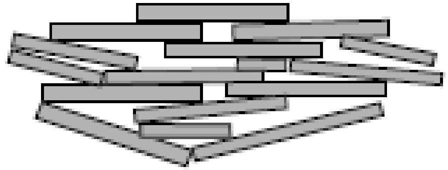
- The soil fabric is the brain; it retains the <u>memory of the birth of the soil and subsequent changes that occur</u>.



(*a*) Flocculated structure—saltwater environment



(*b*) Flocculated structure—freshwater environment



(*c*) Dispersed structure

2.7 Particle Shape

- Significant influence on the physical properties of a given soil.
- The particle shape generally can be divided into three major categories :
  1. Bulky: formed mostly by mechanical weathering of rock and minerals. Geologists use such terms as angular, subangular, subrounded, and rounded to describe the shapes of bulky particles.
  2. Flaky: very low sphericity—usually 0.01 or less. These particles are predominantly clay minerals.
  3. Needle shaped: much less common than the other two particle types. Examples of soils containing needle-shaped particles are some coral deposits and attapulgite clays.

Particle Shape

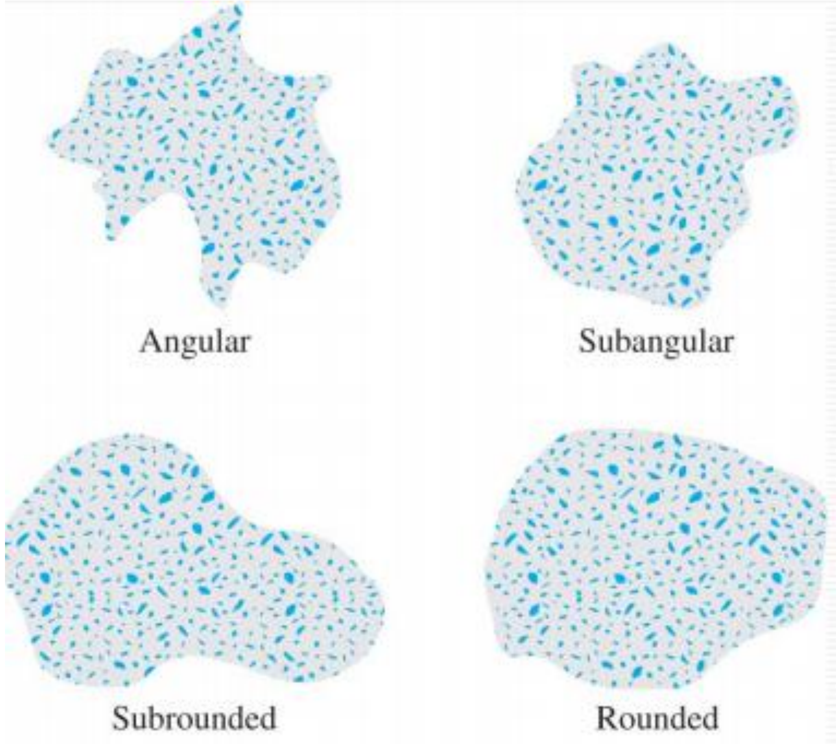


Figure 2.29 Shape of bulky particles

2.2 Soil-Particle Size

- Gravels: pieces of rocks with occasional particles of quartz, feldspar, and other minerals
- Sand particles: made of mostly quartz and feldspar
- Silts: microscopic soil fractions that consist of very fine quartz grains and some flake-shaped particles that are fragments of micaceous minerals
- Clays: mostly flake-shaped microscopic and submicroscopic particles of mica, clay minerals, and other minerals

2.2 Soil-Particle Size

Table 2.3 Particle-Size Classifications

Name of organization	Grain size (mm)			
	Gravel	Sand	Silt	Clay
Massachusetts Institute of Technology (MIT)	>2	2 to 0.06	0.06 to 0.002	<0.002
U.S. Department of Agriculture (USDA)	>2	2 to 0.05	0.05 to 0.002	<0.002
American Association of State Highway and Transportation Officials (AASHTO)	76.2 to 2	2 to 0.075	0.075 to 0.002	<0.002
Unified Soil Classification System (U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and American Society for Testing and Materials)	76.2 to 4.75	4.75 to 0.075	Fines (i.e., silts and clays) <0.075	

Note: Sieve openings of 4.75 mm are found on a U.S. No. 4 sieve; 2-mm openings on a U.S. No. 10 sieve; 0.075-mm openings on a U.S. No. 200 sieve. See Table 2.5.

2.2 Soil-Particle Size

- The boundary values separating groups are different for various classification systems.

Type	Particle Size (mm)		
	AASHTO	USCS	TS-1500
Gravel	2-76.2	4.75-76.2	2-76.2
Sand	0.075-2	0.075-4.75	0.075-2
Silt	0.002-0.075	<0.075	0.002-0.075
Clay	<0.002		<0.002

TABLE 2.1 Soil Types, Descriptions, and Average Grain Sizes According to ASTM D 2487

Soil type	Description	Average grain size
Gravel	Rounded and/or angular bulky hard rock, coarsely divided	Coarse: 75 mm to 19 mm Fine: 19 mm to 4.75 mm
Sand	Rounded and/or angular hard rock, finely divided	Coarse: 4.75 mm to 2.0 mm (No. 10) Medium: 2.0 mm to 0.425 mm (No. 40) Fine: 0.425 mm to 0.075 mm (No. 200)
Silt	Particle size between clay and sand. Exhibit little or no strength when dried.	0.075 mm to 0.002 mm
Clay	Particles are smooth and mostly clay minerals. Exhibit significant strength when dried; water reduces strength.	<0.002 mm

2.2 Soil-Particle Size

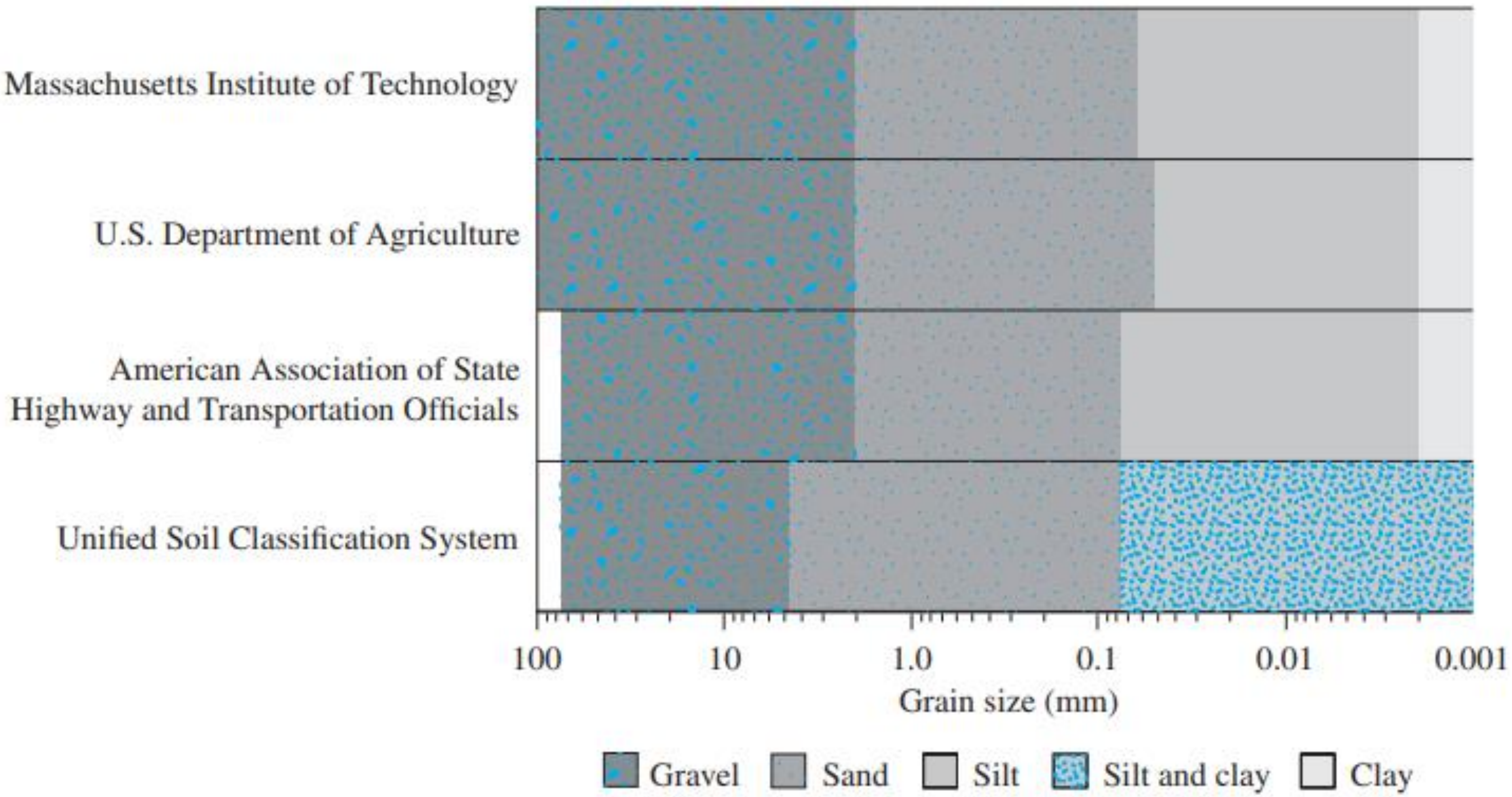


Figure 2.7 Soil-separate-size limits by various systems

2.2 Soil-Particle Size

- Clays: particles smaller than 0.002 mm

  - develop plasticity when mixed with a limited amount of water

  - in some cases, particles between 0.002 mm and 0.005 mm in size are also referred to as clay

  - Particles are classified as clay on the basis of their size; they do not necessarily contain clay minerals

- Clay particles: Clay particles are mostly in the colloidal size range (<1 μm), and 2 μm appears to be the upper limit.

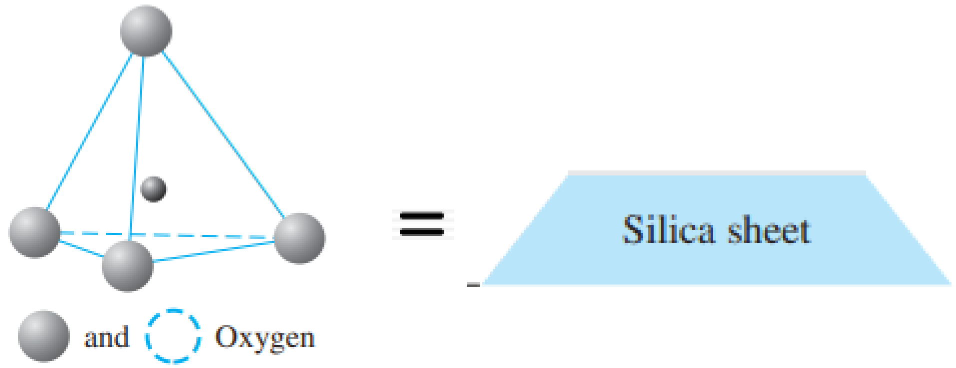
2.3 Clay Minerals

➢ Three important clay minerals:

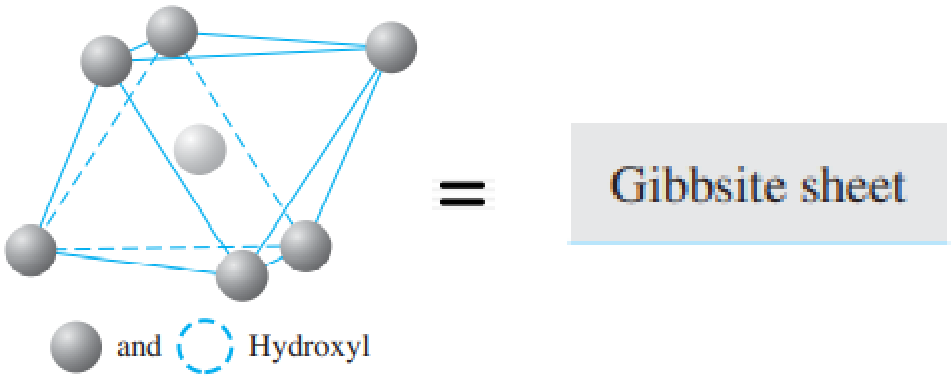
1. Kaolinite
2. Illite
3. Montmorillonite

➢ Two basic units: Tetrahedron, Octahedron

- Silica tetrahedron
- Alumina octahedron



(a)



(c)

2.3 Clay Minerals

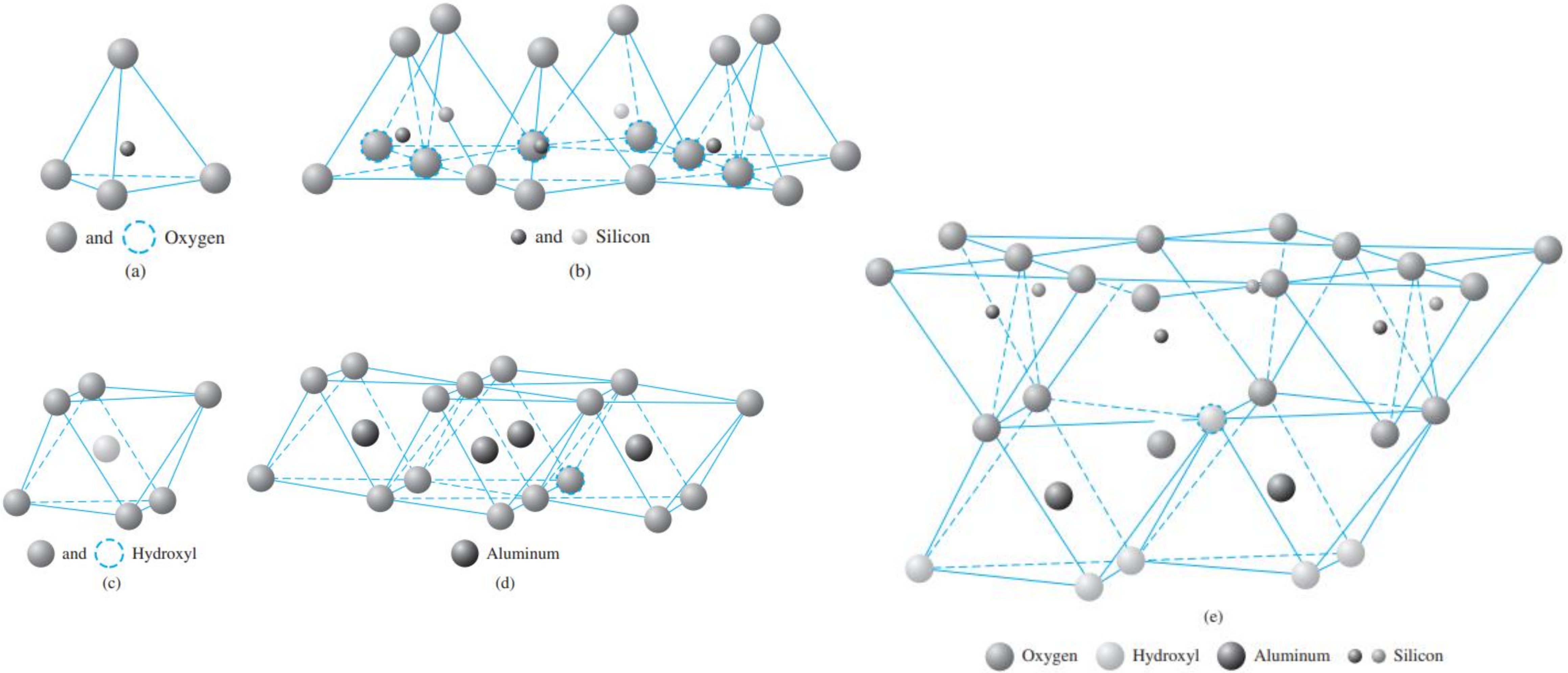


Figure 2.10 (a) Silica tetrahedron; (b) silica sheet; (c) alumina octahedron; (d) octahedral (gibbsite) sheet; (e) elemental silica-gibbsite sheet (*After Grim, 1959. With permission from ASCE.*)

Kaolinite

- Consists of repeating layer of silica-gibbsite sheets in a 1:1 lattice
- Hydrogen bonding
- Lateral dimension = 1000 – 20000Å, - thickness =100 –1000Å
- specific surface = 15 m^2/g (the surface area per unit mass)

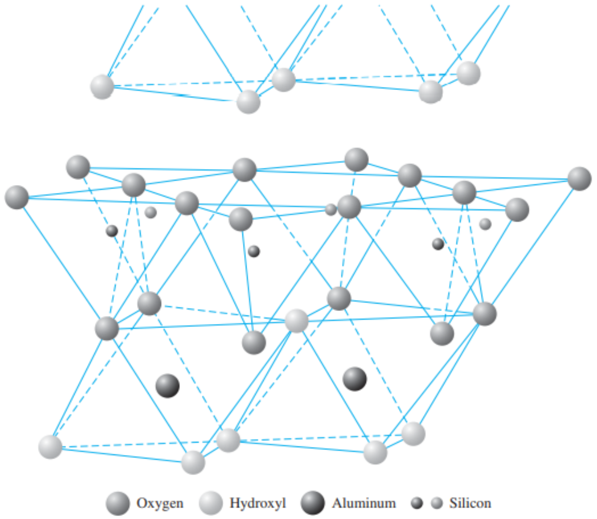


Figure 2.11 Atomic structure of montmorillonite (*After Grim, 1959. With permission from ASCE.*)

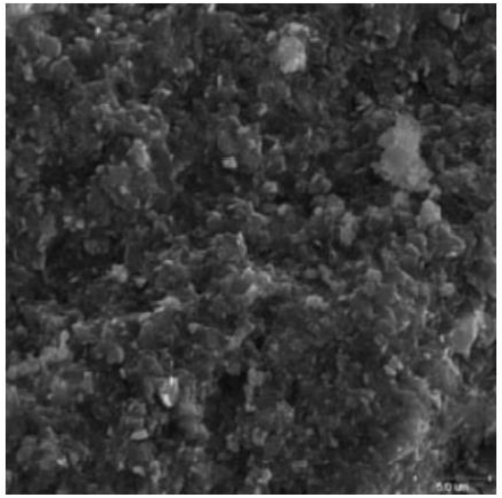


Figure 2.13 Scanning electron micrograph of a kaolinite specimen (*Courtesy of David J. White, Iowa State University, Ames, Iowa*)

Kaolinite

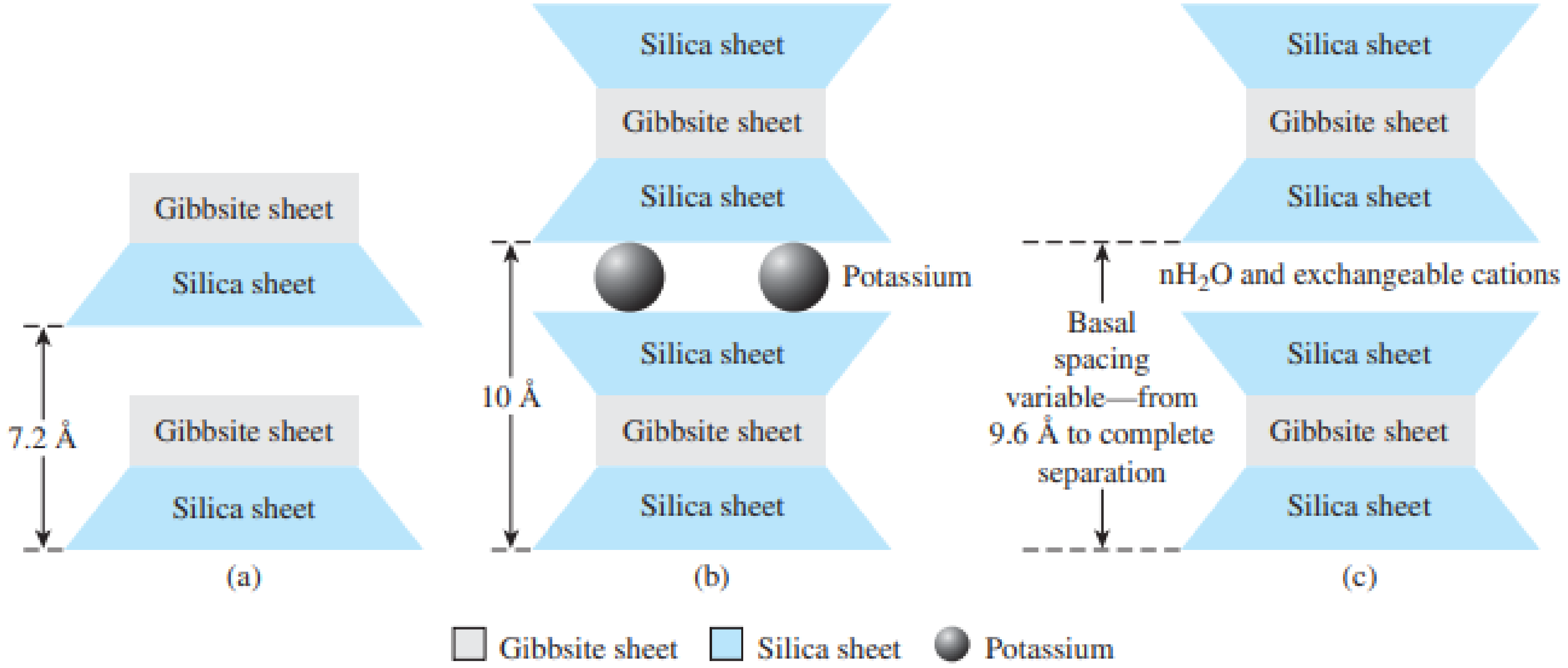


Figure 2.12 Diagram of the structures of (a) kaolinite; (b) illite; (c) montmorillonite

Illite

- consists of a gibbsite sheet bonded to two silica sheets—one at the top and another at the bottom.
- called clay mica
- bonded by potassium ions (K^+)
- lateral dimension = 1000 - 5000Å, - thickness = 50 - 500Å
- specific surface = 80 m^2/g
- Isomorphous substitution: substitution of one element for another with no change in the crystalline form

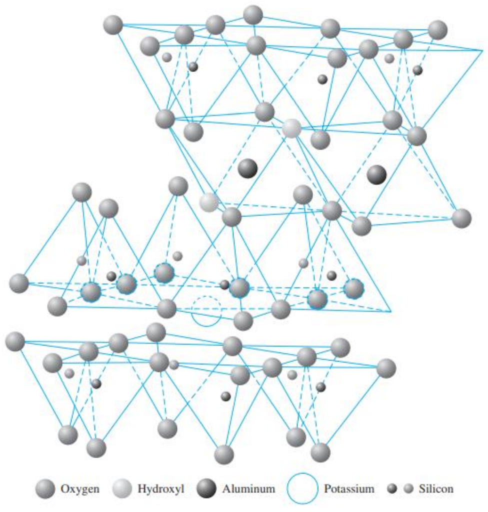


Figure 2.14 Atomic structure of illite

Montmorillonite

- Structure similar to that of illite—that is, one gibbsite sheet sandwiched between two silica sheets.
- Water layer bonding
- Isomorphous substitution : aluminum → magnesium and iron
- lateral dimension = 1000 - 5000Å, - thickness = 10 - 50Å
- Specific surface = 800 m^2/g

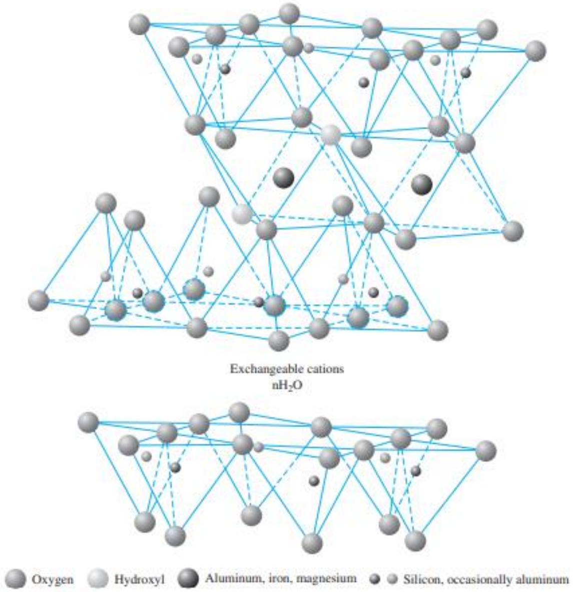


Figure 2.15 Atomic structure of montmorillonite (After Grim, 1959. With permission from ASCE.)

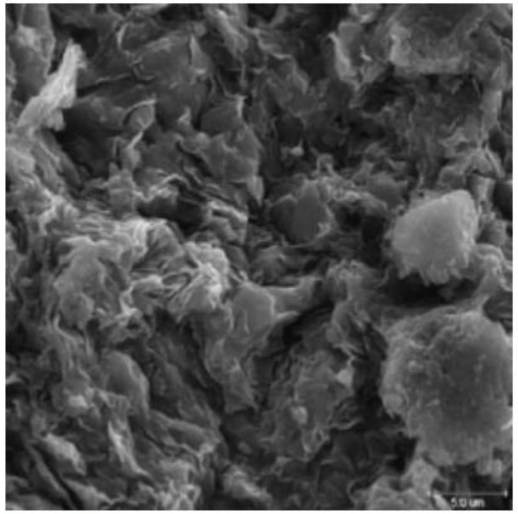
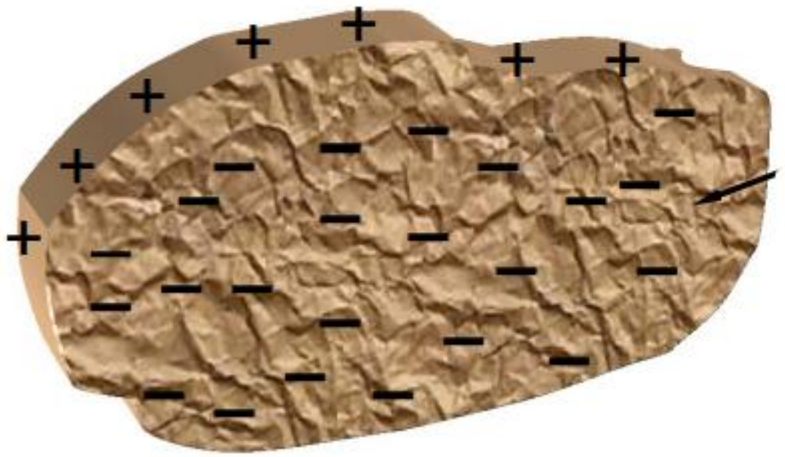


Figure 2.16 Scanning electron micrograph showing the fabric of montmorillonite (Courtesy of David J. White, Iowa State University, Ames, Iowa)

Clay particles



- Carry a net negative charge on their surfaces.
- Positive charge at the edges.
- Diffuse Double Layer:
  - In dry clay, the negative charge is balanced by exchangeable cations like Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} surrounding the particles being held by electrostatic attraction.
  - When water is added to clay, these cations and a few anions float around the clay particles.
  - The cation concentration decreases with the distance from the surface of the particle.

Clay particles

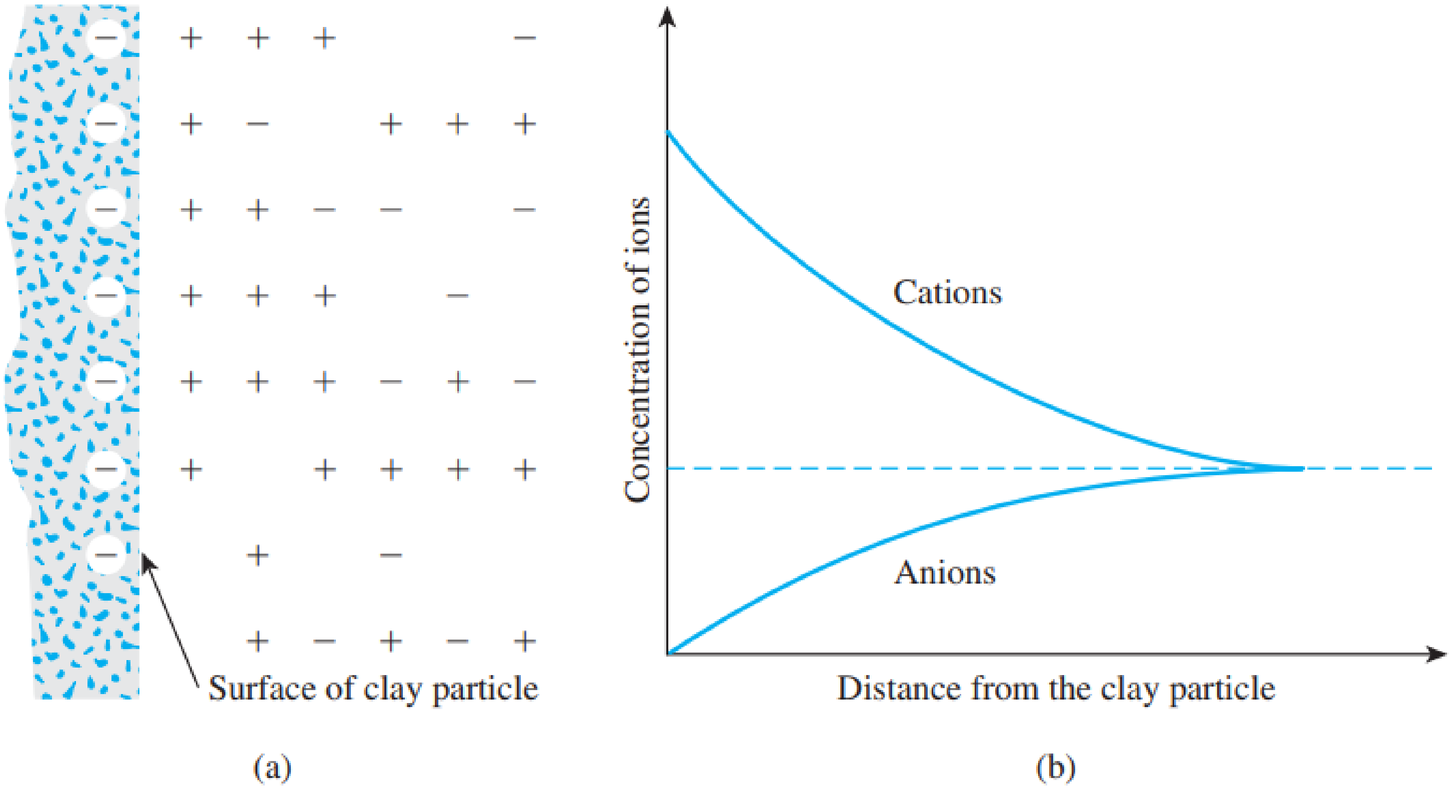


Figure 2.17 Diffuse double layer

Dipole character

- Water molecules are polar. Hydrogen atoms are not axisymmetric around an oxygen atom; instead, they occur at a bonded angle of 105°.
- A water molecule has a positive charge at one side and a negative charge at the other side

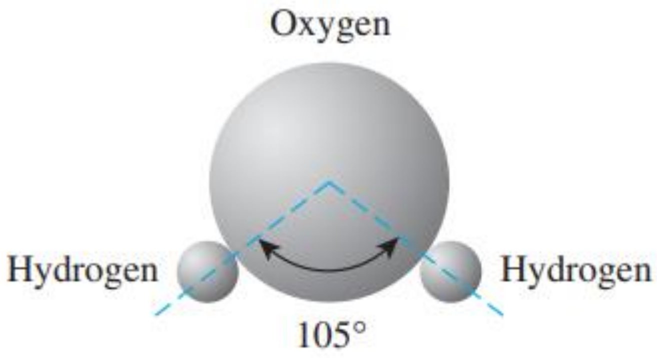


Figure 2.18 Dipolar character of water

Clay particle-water molecule attraction

- Dipolar water is attracted both by the negatively charged surface of the clay particles and by the cations in the double layer.
- The cations, in turn, are attracted to the soil particles.
- A third mechanism by which water is attracted to clay particles is hydrogen bonding, where hydrogen atoms in the water molecules are shared with oxygen atoms on the surface of the clay.

Clay particle-water molecule attraction

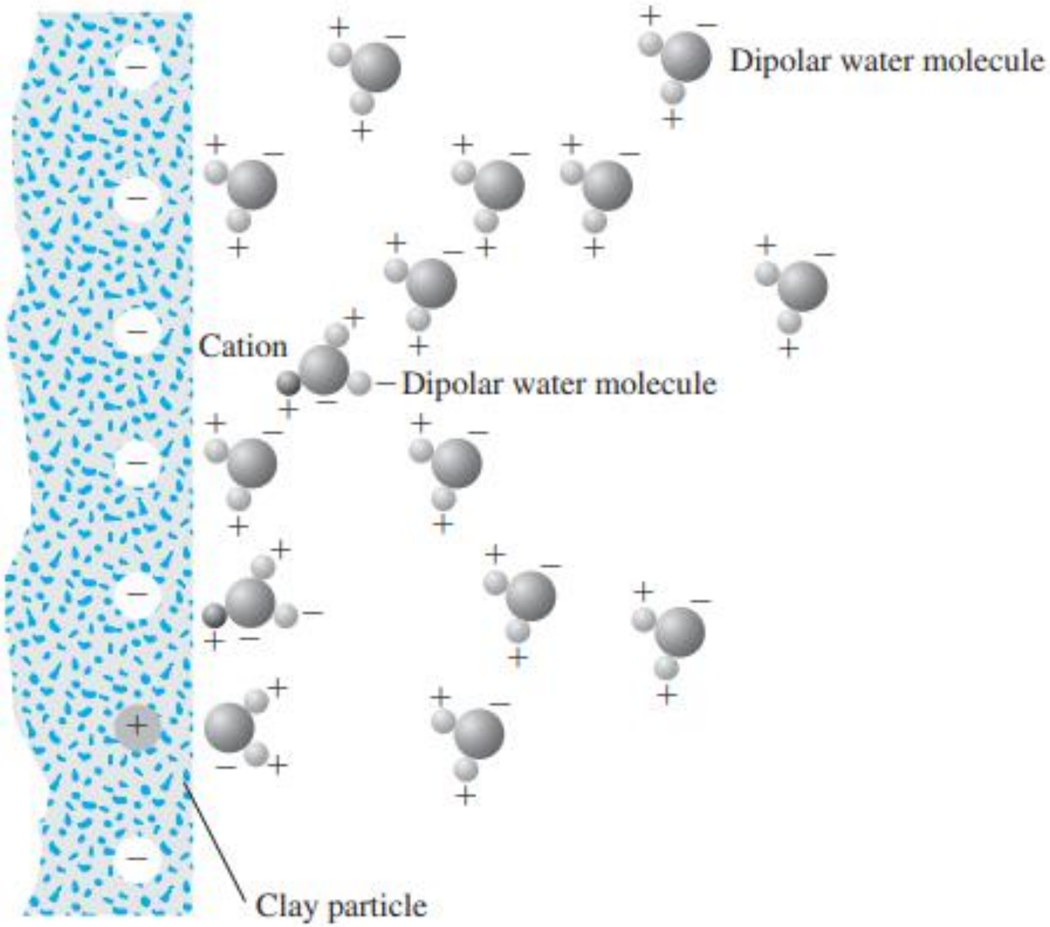
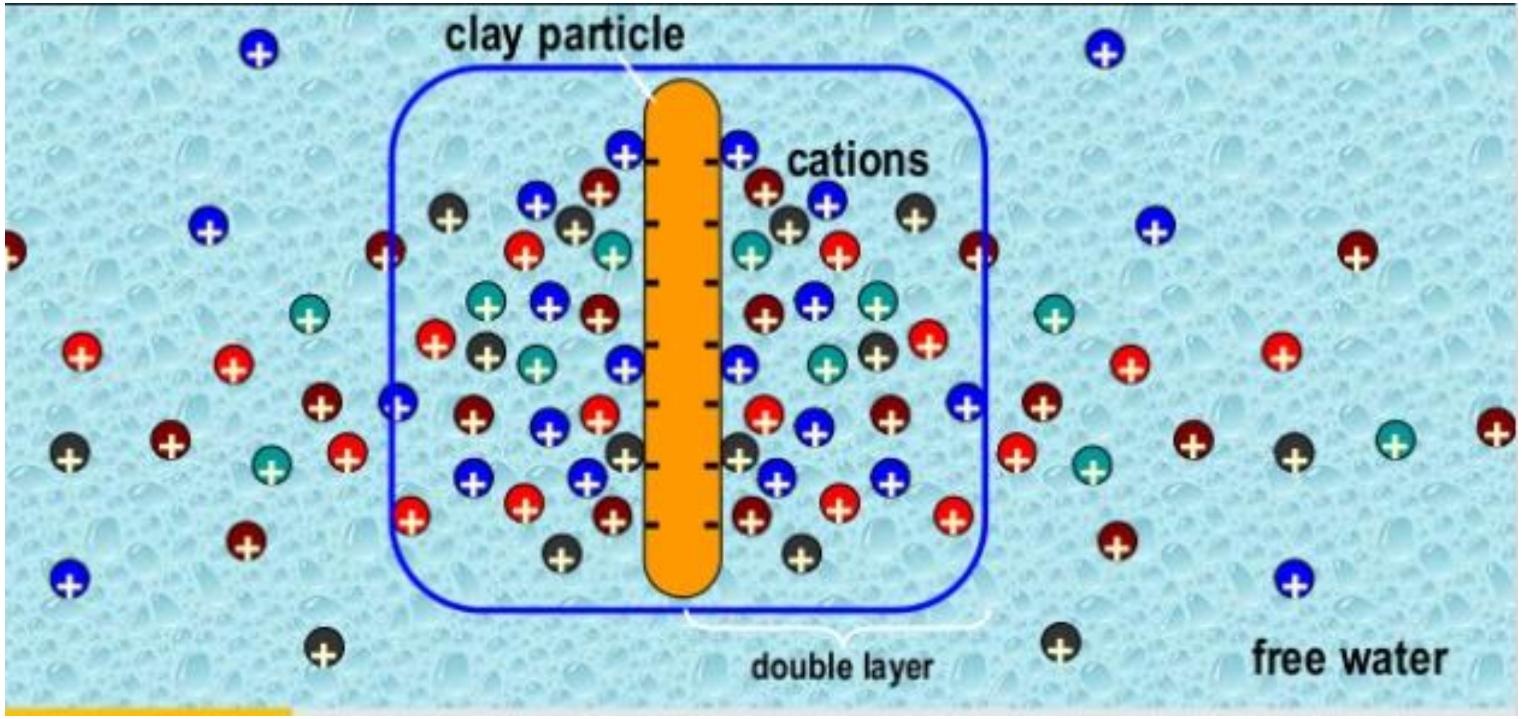


Figure 2.19 Attraction of dipolar molecules in diffuse double layer

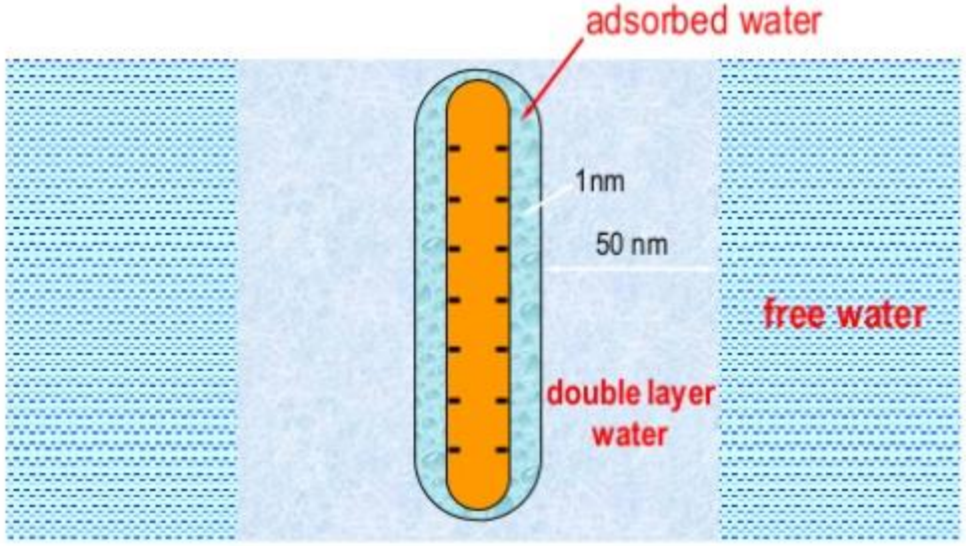
Double-layer water

➢ All the water held to clay particles by force of attraction.



Adsorbed water

- The innermost layer of double-layer water, which is held very strongly by clay.
- The thickness of the adsorbed water film determine the engineering behavior of clays.



Clay-water attraction

- Orientation of water around the clay particles gives clay soils their plastic properties.

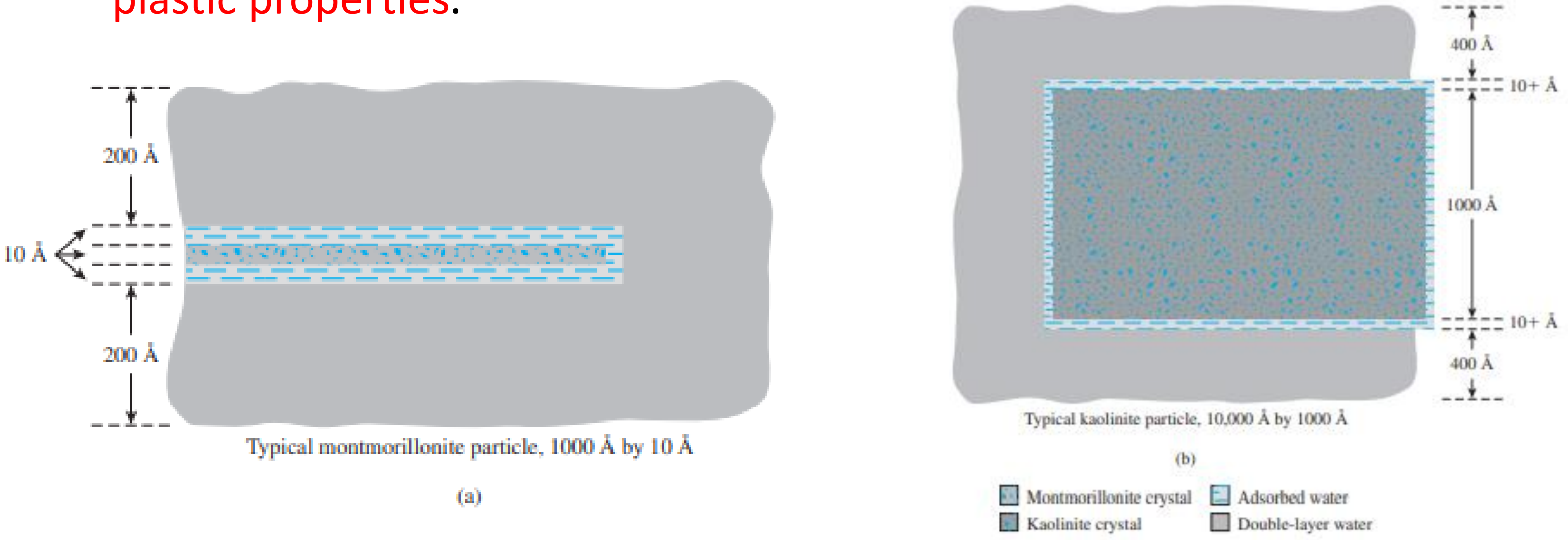


Figure 2.20 Clay water (*Redrawn after Lambe, 1958. With permission from ASCE.*)

2.4 Specific Gravity (G_S)

Specific gravity: the ratio of the unit weight of a given material to the unit weight of water.

- The specific gravity of soil solids is often needed for various calculations in soil mechanics.
- It can be determined accurately in the laboratory
- Mostly G_S = 2.60 to 2.9
- Typical Value of Sand : 2.65

2.4 Specific Gravity (G_S)

Table 2.4 Specific Gravity of Common Minerals

Mineral	Specific gravity, G_s
Quartz	2.65
Kaolinite	2.6
Illite	2.8
Montmorillonite	2.65–2.80
Halloysite	2.0–2.55
Potassium feldspar	2.57
Sodium and calcium feldspar	2.62–2.76
Chlorite	2.6–2.9
Biotite	2.8–3.2
Muscovite	2.76–3.1
Hornblende	3.0–3.47
Limonite	3.6–4.0
Olivine	3.27–3.7

2.5 Mechanical Analysis of Soil

Mechanical analysis: the determination of the size range of particles, expressed as a percentage of the total dry weight.

- Two methods:

  1. Sieve Analysis—for particle sizes larger than 0.075 mm in diameter
  2. Hydrometer Analysis—for particle sizes smaller than 0.075 mm in diameter.

Sieve analysis

Table 2.5 U.S. Standard Sieve Sizes

Sieve no.	Opening (mm)	Sieve no.	Opening (mm)
4	4.75	35	0.500
5	4.00	40	0.425
6	3.35	50	0.355
7	2.80	60	0.250
8	2.36	70	0.212
10	2.00	80	0.180
12	1.70	100	0.150
14	1.40	120	0.125
16	1.18	140	0.106
18	1.00	170	0.090
20	0.850	200	0.075
25	0.710	270	0.053
30	0.600		

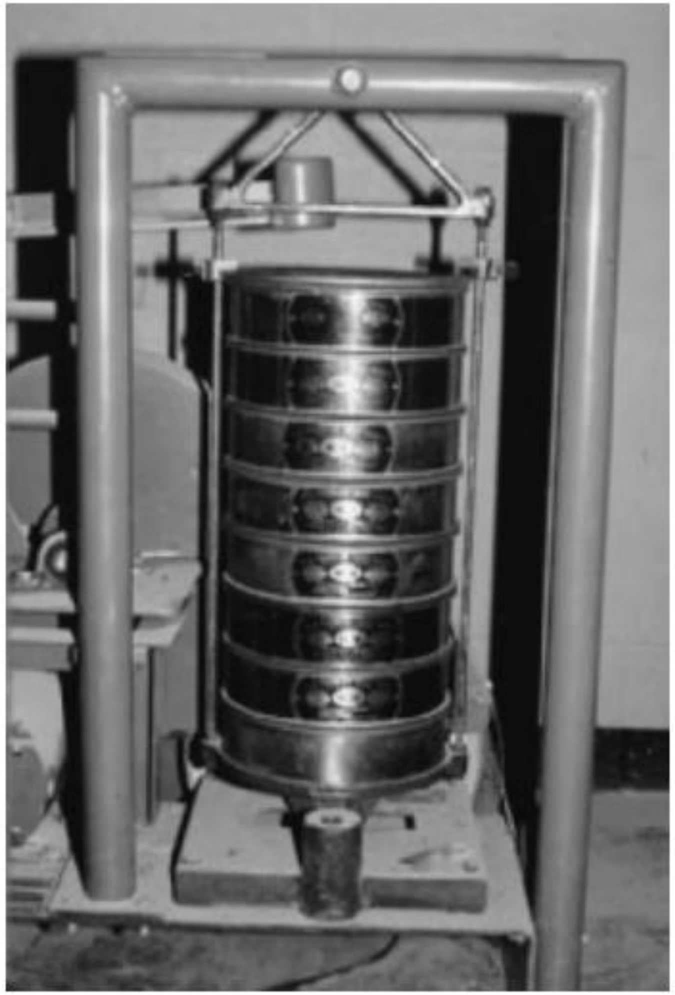


Figure 2.21 A set of sieves for a test in the laboratory (*Courtesy of Braja M. Das, Henderson, Nevada*)

Evaluation of Sieve analysis Results

1. Determine the mass of soil retained on each sieve (i.e., $M_1, M_2, \cdots M_n$) and in the pan (i.e., M_p)
2. Determine the total mass of the soil: $M_1 + M_2 + \cdots + M_i + \cdots + M_n + M_p = \sum M$
3. Determine the cumulative mass of soil retained above each sieve. For the ith sieve, it is $M_1 + M_2 + \cdots + M_i$
4. The mass of soil passing the ith sieve is $\sum M - (M_1 + M_2 + \ldots + M_i)$
5. The percent of soil passing the ith sieve (or percent finer) is:

$$F = \frac{\sum M - (M_1 + M_2 + \ldots + M_i)}{\sum M} \times 100$$

2.5 Mechanical Analysis of Soil

- The calculations are plotted on semilogarithmic graph paper.

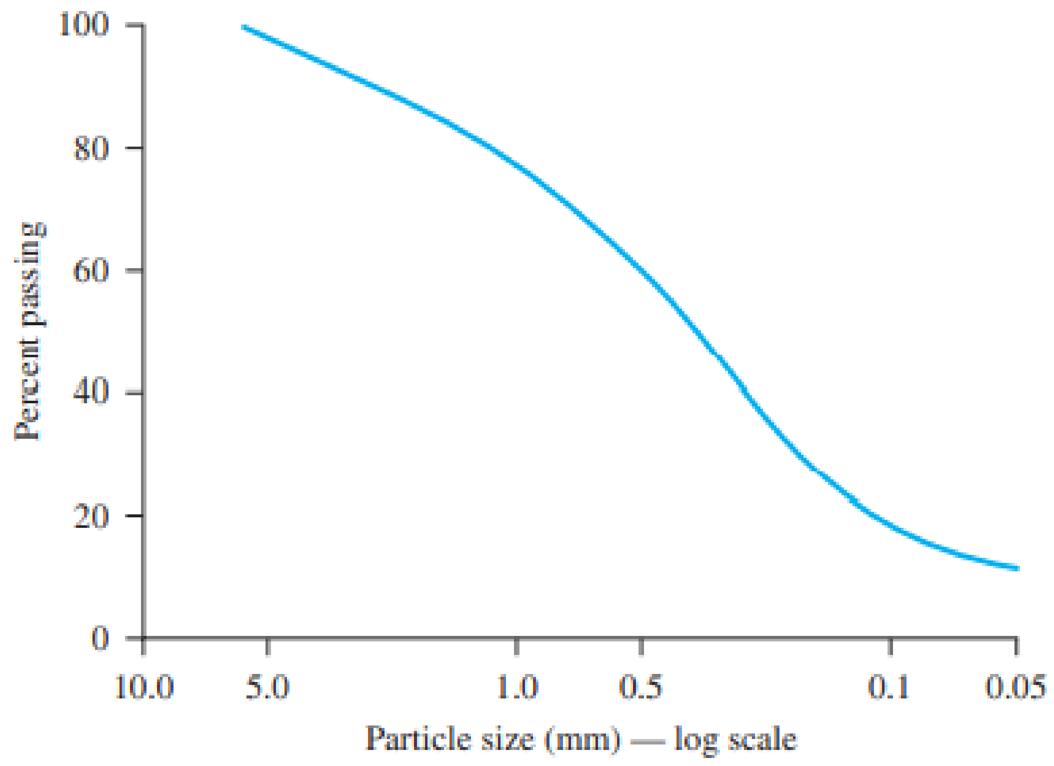


Figure 2.22 Particle-size distribution curve

Hydrometer Analysis

- Based on the principle of sedimentation of soil grains in water.
- Stokes' Law
- For simplicity, it is assumed that all the soil particles are spheres;

$$v = \frac{\rho_s - \rho_w}{18\eta} D^2 \tag{2.1}$$

where v = velocity
ρ_s = density of soil particles
ρ_w = density of water
η = viscosity of water
D = diameter of soil particles

Hydrometer Analysis

Thus, from Eq. (2.1),

$$D = \sqrt{\frac{18\eta v}{\rho_s - \rho_w}} = \sqrt{\frac{18\eta}{\rho_s - \rho_w}}\sqrt{\frac{L}{t}} \tag{2.2}$$

$$\rho_s = G_s \rho_w \tag{2.3}$$

$$D = \sqrt{\frac{18\eta}{(G_s - 1)\rho_w}}\sqrt{\frac{L}{t}} \tag{2.4}$$

If the units of η are (g · sec)/cm^2, ρ_w is in g/cm^3, L is in cm, t is in min, and D is in mm, then

$$\frac{D(\text{mm})}{10} = \sqrt{\frac{18\eta\,[(\text{g}\cdot\text{sec})/\text{cm}^2]}{(G_s - 1)\rho_w\,(\text{g/cm}^3)}}\sqrt{\frac{L\,(\text{cm})}{t\,(\text{min}) \times 60}}$$

or

$$D = \sqrt{\frac{30\eta}{(G_s - 1)\rho_w}}\sqrt{\frac{L}{t}}$$

Hydrometer Analysis

- K is a function of G_s and η, which are dependent on the temperature of the test.

Assume ρ_w to be approximately equal to 1 g/cm^3, so that

$$D\ (\text{mm}) = K\sqrt{\frac{L\ (\text{cm})}{t\ (\text{min})}} \tag{2.5}$$

where

$$K = \sqrt{\frac{30\eta}{(G_s - 1)}} \tag{2.6}$$

Hydrometer test

- Conducted in a sedimentation cylinder usually with 50 g of oven-dried sample. Sometimes 100-g samples also can be used.
- Sedimentation cylinder: 457 mm high, and 63.5 mm in diameter.
- Dispersing agent: Sodium hexametaphosphate.
- Hydrometers are calibrated for soils that have a specific gravity, G_s of 2.65; for soils of other specific gravity, it is necessary to make a correction.
- Hydrometer analysis is effective for separating soil fractions down to a size of about 0.5 μ.

Hydrometer

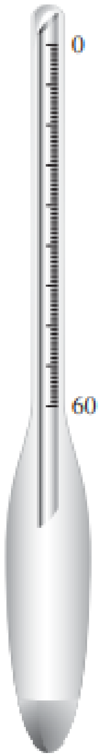


Figure 2.23
ASTM 152H hydrometer
(Courtesy of ELE International)

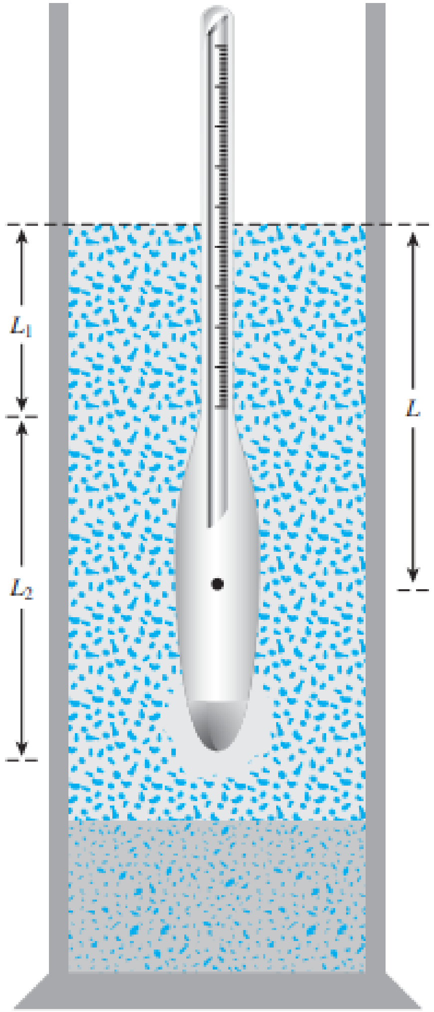


Figure 2.24 Definition of L in hydrometer test

Sieve analysis and hydrometer analysis

- The results of sieve analysis and hydrometer analysis for finer fractions for a given soil are combined on one graph.

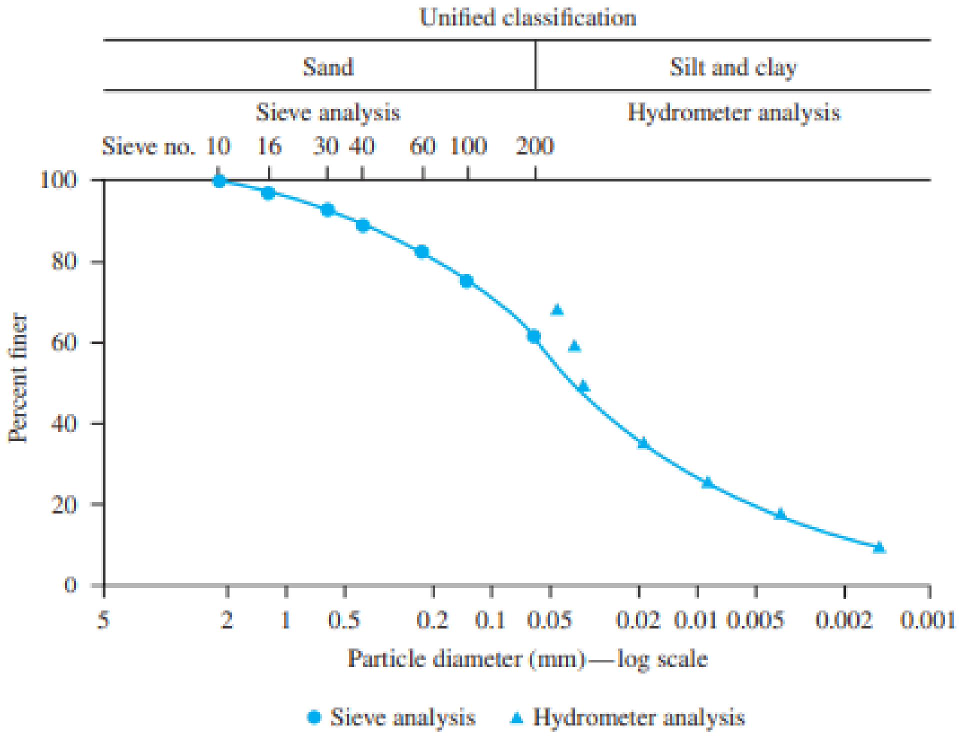


Figure 2.25 Particle-size distribution curve—sieve analysis and hydrometer analysis

2.6 Particle-Size Distribution Curve

- Four parameters for a given soil:

1. Effective size (D_{10}): This parameter is the diameter in the particle-size distribution curve corresponding to 10% finer. The effective size of a granular soil is a good measure to estimate the hydraulic conductivity and drainage through soil.

2. Uniformity coefficient (C_u): This parameter is defined as

$$C_u = \frac{D_{60}}{D_{10}}$$

where D_{60} = diameter corresponding to 60% finer.

2.6 Particle-Size Distribution Curve

3. Coefficient of gradation (Cc): This parameter is defined as

$$C_C = \frac{D_{30}^2}{D_{60} \times D_{10}}$$

- The percentages of gravel, sand, silt, and clay-size particles present in a soil can be obtained from the particle-size distribution curve.

- The particle-size distribution curve shows not only the range of particle sizes present in a soil, but also the type of distribution of various-size particles.

2.6 Particle-Size Distribution Curve

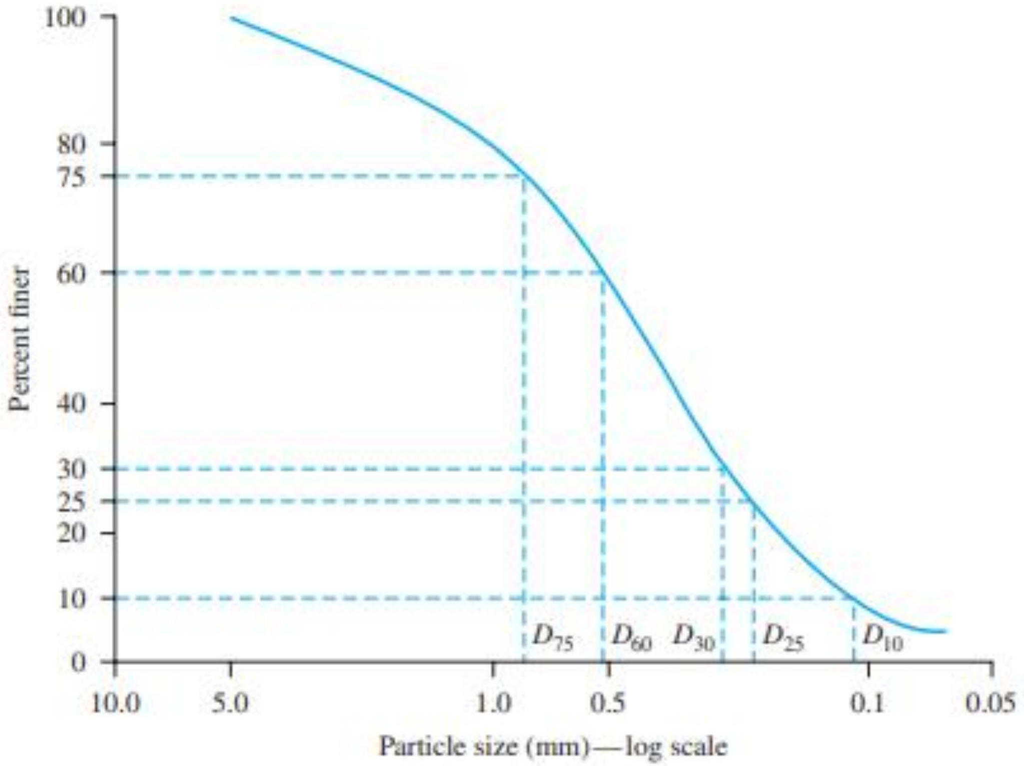


Figure 2.26 Definition of D_{75}, D_{60}, D_{30}, D_{25}, and D_{10}

2.6 Particle-Size Distribution Curve

- Curve I: represents a type of soil in which most of the soil grains are the same size. This is called poorly graded soil

- Curve II: represents a soil in which the particle sizes are distributed over a wide range, termed well graded.

  - For sands, $C_c = 1-3$ and $C_u \geq 6$

  - For gravels, $C_c = 1-3$ and $C_u \geq 4$

- Curve III: combination of two or more uniformly graded fractions.

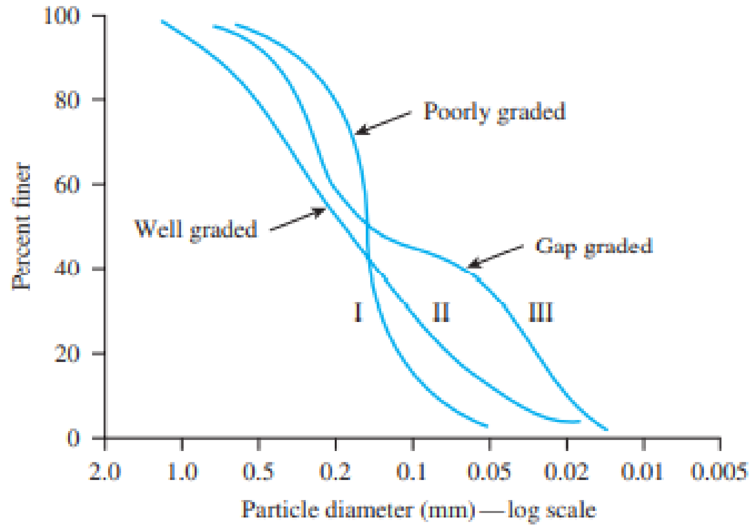


Figure 2.27 Different types of particle-size distribution curves

IMPORTANCE OF GRAIN SIZE DISTRIBUTION

- Particle size analyses have many uses in engineering. They are used to select aggregates for concrete, soils for the construction of dams and highways, soils as fi lters, and material for grouting and chemical injection.
- In next class, you will learn about how the particle size distribution is used with other physical properties of soils in a classification system designed to help you select soils for particular applications.

Coarse-grained and fine -grained soils have different characteristics:

- **Fine-grained soils have much larger surface areas than coarse-grained soils and are responsible for the major physical and mechanical differences between coarse-grained and fine-grained soils.**
- **The engineering properties of fine-grained soils depend mainly on mineralogical factors.**
- **Coarse-grained soils have good load-bearing capacities and good drainage qualities, and their strength and volume-change characteristics are not significantly affected by changes in moisture conditions.**
- **Fine-grained soils have poor load-bearing capacities and poor drainage qualities, and their strength and volume-change characteristics are significantly affected by changes in moisture conditions.**

Summary&Essential Points

1. Rocks can be classified into three basic categories: (a) igneous, (b) sedimentary, and (c) metamorphic.
2. Soils are formed by chemical and mechanical weathering of rocks.
3. Based on the size of the soil particles, soil can be classified as gravel, sand, silt, or clay.
4. Clays are mostly flake-shaped microscopic and submicroscopic particles of mica, clay minerals, and other minerals.
5. Clay minerals are complex aluminum silicates that develop plasticity when mixed with a limited amount of water.
6. Mechanical analysis is a process for determining the size range of particles present in a soil mass. Sieve analysis and hydrometer analysis are two tests used in the mechanical analysis of soil.

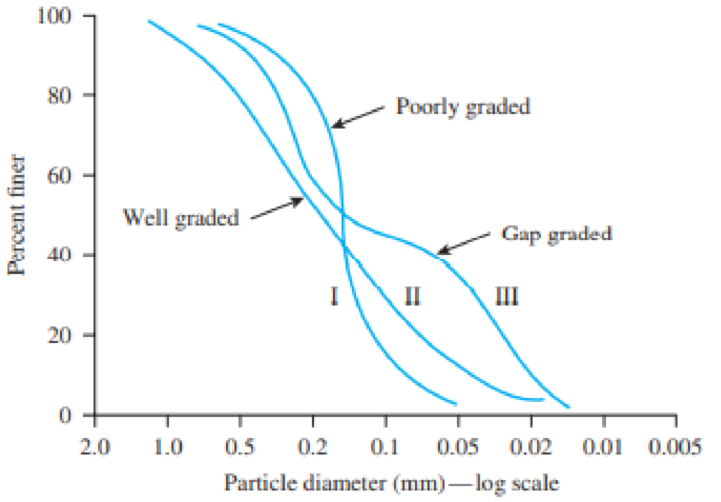
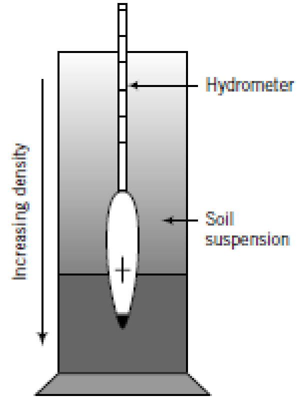


Figure 2.27 Different types of particle-size distribution curves



Essential Points (Cont'd)

7. A sieve analysis is used to determine the grain size distribution of coarse-grained soils.
8. For fine-grained soils, a hydrometer analysis is used to fi nd the particle size distribution.
9. Particle size distribution is represented on a semilogarithmic plot of % fi ner (ordinate, arithmeticscale) versus particle size (abscissa, logarithmic scale).
10. The particle size distribution plot is used to delineate the different soil textures (percentages of gravel, sand, silt, and clay) in a soil.
11. The effective size, D_{10}, is the diameter of the particles of which 10% of the soil is finer. D_{10} is an important value in regulating flow through soils and can significantly influence the mechanical behavior of soils.
12. D_{50} is the average grain size diameter of the soil.

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12. important value in regulating flow through soils and can significantly influence the mechanical
13. behavior of soils.
14. D_{50} is the average grain size diameter of the soil.
15. Two coefficients—the uniformity coefficient and the coefficient of curvature—are used to characterize the particle size distribution.
16. Poorly graded soils have uniformity coefficients ,4 and steep gradation curves. Well-graded soils have uniformity coefficients .4, coefficients of curvature between 1 and 3, and flat gradation curves. Gap-graded soils have coeffi cients of curvature ,1 or .3, and one or more humps on the gradation curves.