Geotechnical Engineering I
CE 341

What do we learn in this course?

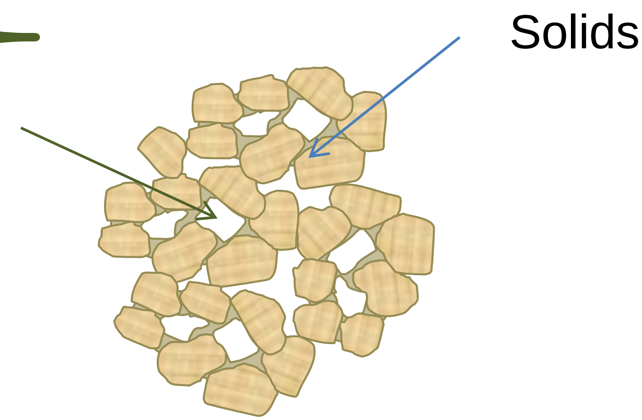
- Introduction to Geotechnical Engineering (1)
- Formation, Soil Composition, Type and Identification of Soils (2)
- Soil Structure and Fabric (1)
- Index (1)
- Properties of Soil (1)
- Engineering Classification of Soils (2)
- Compaction (3)
- Principles of Total and Effective Stresses (1)

What do we learn in this course?

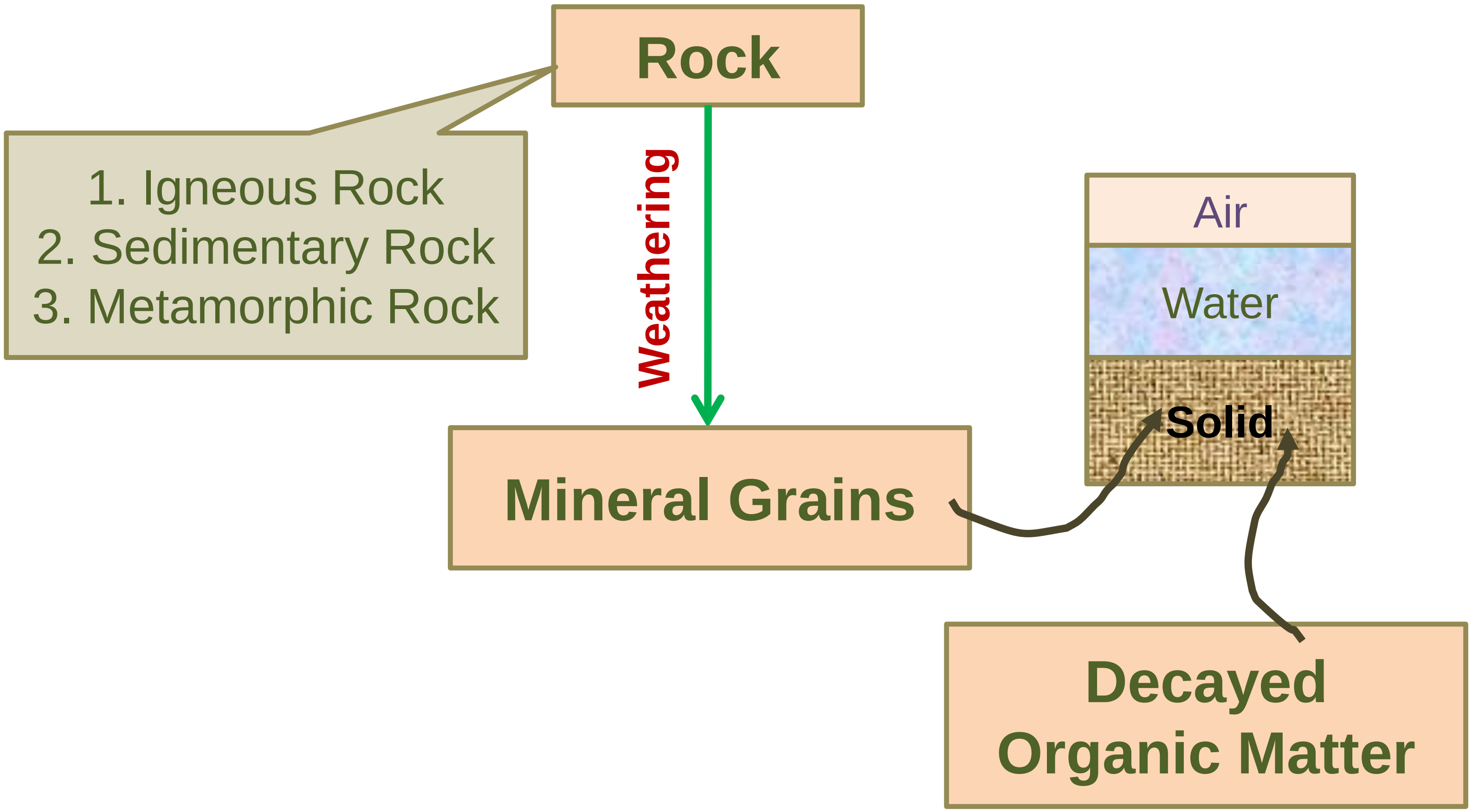
- Permeability and Seepage (4)
- Stress-Strain-strength Characteristics of Soils (4)
- Compressibility and Settlement Behaviour of Soils (4)
- Lateral Earth Pressure (3)
- Stress Distribution (2)

Soils

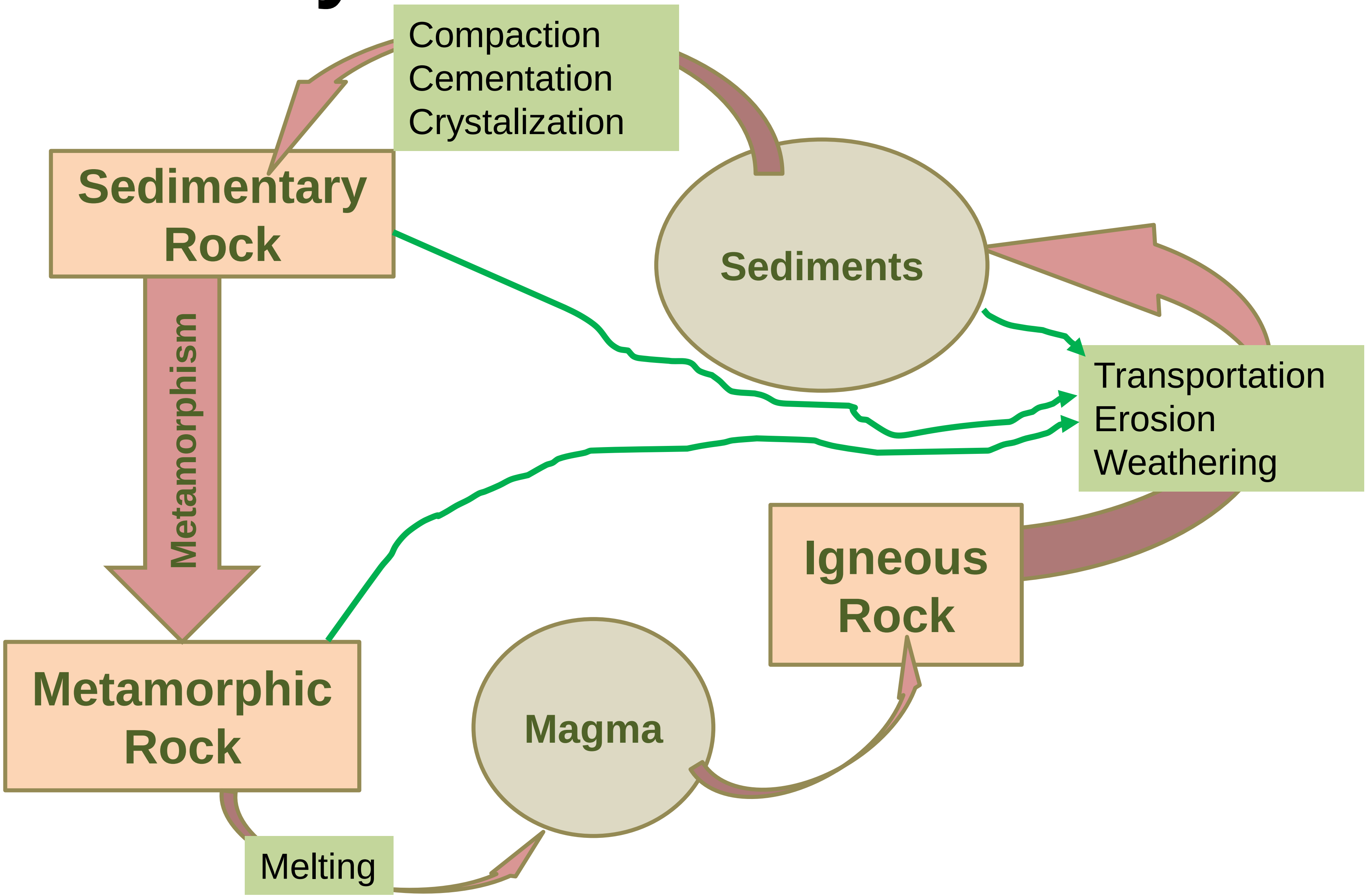
- Three phase system
- Solid Phase
- Liquid Phase: Water
- Gas Phase: Air



Soil Formation



Rock Cycle



Compaction
Cementation
Crystalization
Sedimentary Rock
Sediments
Metamorphism
Transportation
Erosion
Weathering
Igneous Rock
Metamorphic Rock
Magma
Melting

Soil Composition

- Infinite variety of substances may be found in soils
- Four basic components:
  - minerals (45 %),
  - organic matter (5 %),
  - air (25 %) and
  - water (25 %).
- In reality, these percentages of the four components vary tremendously.

Ideal soil (ideal for the growth of most plants)

Soil Composition

- Soil air and water are found in the pore spaces between the solid soil particles.
- The ratio of air-filled pore space to water-filled pore space often changes depending on water additions through precipitation, groundwater discharge, and flooding.
- The volume of the pore space: can be altered, one way or the other, by several processes.

Organic matter content

- <5% (in South Carolina, typically 1% or less)→ Inorganic soil
- > 50% of the solid portion of the soil in some cases (e.g., in wetland soils).

OC	Effects on Properties	Soil Class
<5 %	little	Inorganic soil
6 – 20 %	Affects properties but still behaves like mineral soil	Organic silts and clays
21 – 74 %	OC governs; traditional Soil Mechanics may be applicable	Silty or Clayey Organic soil
> 75 %	Behaviour distinct from traditional soil mechanics	Peat

Types of Soils

- Gravel
- Sand
- Silt
- Clay

Coarse-grained soils (mineral fragments) (Gravel, Sand) → Identified according to particle size

Fine-grained soils (Silt, Clay) → Physical properties other than particle size for identification, microscopic

Two or more of these constituents → Natural Soil (A mixture) ← Organic material (partly or fully decomposed)

Soils are generally called gravel, sand, silt or clay, depending on their predominant size of particles within the soil.

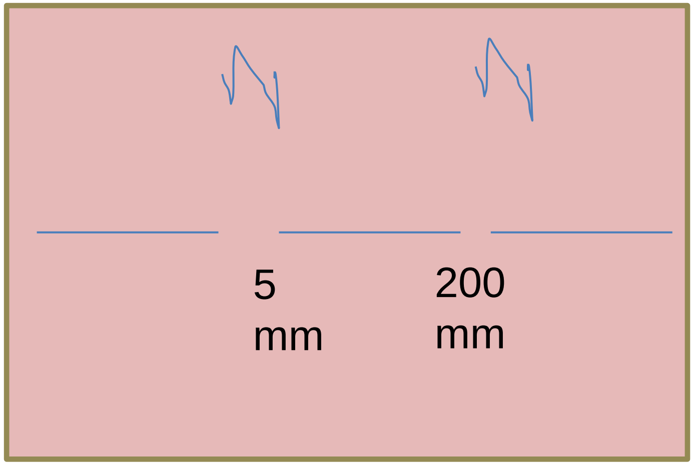
Gravel and Sand

Coarse Grained Soil Material

↓

Mineral Fragments

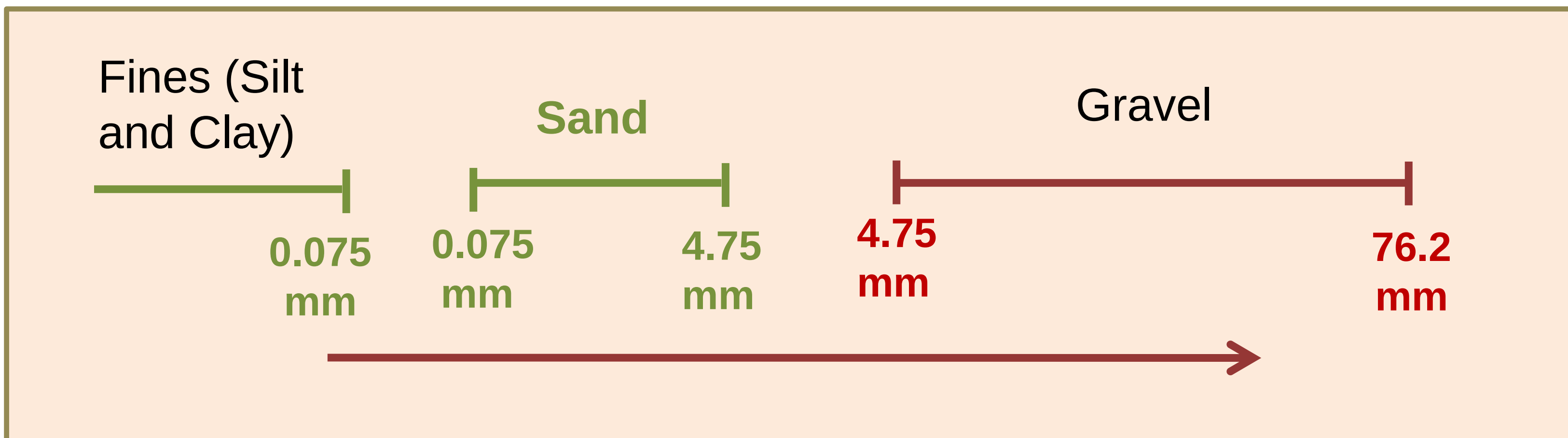
Identified primarily on the basis of particle size (diameter)



Gravel and Sand

Particle Size Classification by ASTM

Particle Size Limits of Soil Constituents



Particle Diameter

Particle size Classification (Grain size in mm)

Name of Organization	Gravel	Sand	Silt	Clay
Massachusetts Institute of Technology (MIT)	>2	2 to 0.06	0.06 to 0.002	<0.002
US 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 (silts and Clays) <0.075	

Sand

Particle Size Limits of Soil Constituents (ASTM Classification)

Particle Diameter

Questions

- If particle size diameter > 4.75 mm?
- If particle size diameter < 0.075 mm?
- If particle size diameter = 78 mm?

According to which classification?
Follow ASTM→ Unified Soil Classification

U.S. standard Sieve Sizes

Sieve No.	Opening (mm)
4	4.75
5	
6	
7	
8	
10	2
12	
14	
16	
18	
20	0.85
25	

Sieve No.	Opening (mm)
30	
35	
40	0.425
50	
60	0.25
70	
80	0.18
100	0.15
120	
140	
170	
200	0.075
270	

Gravel and Sand

- **A complete description of a coarse grained soil**

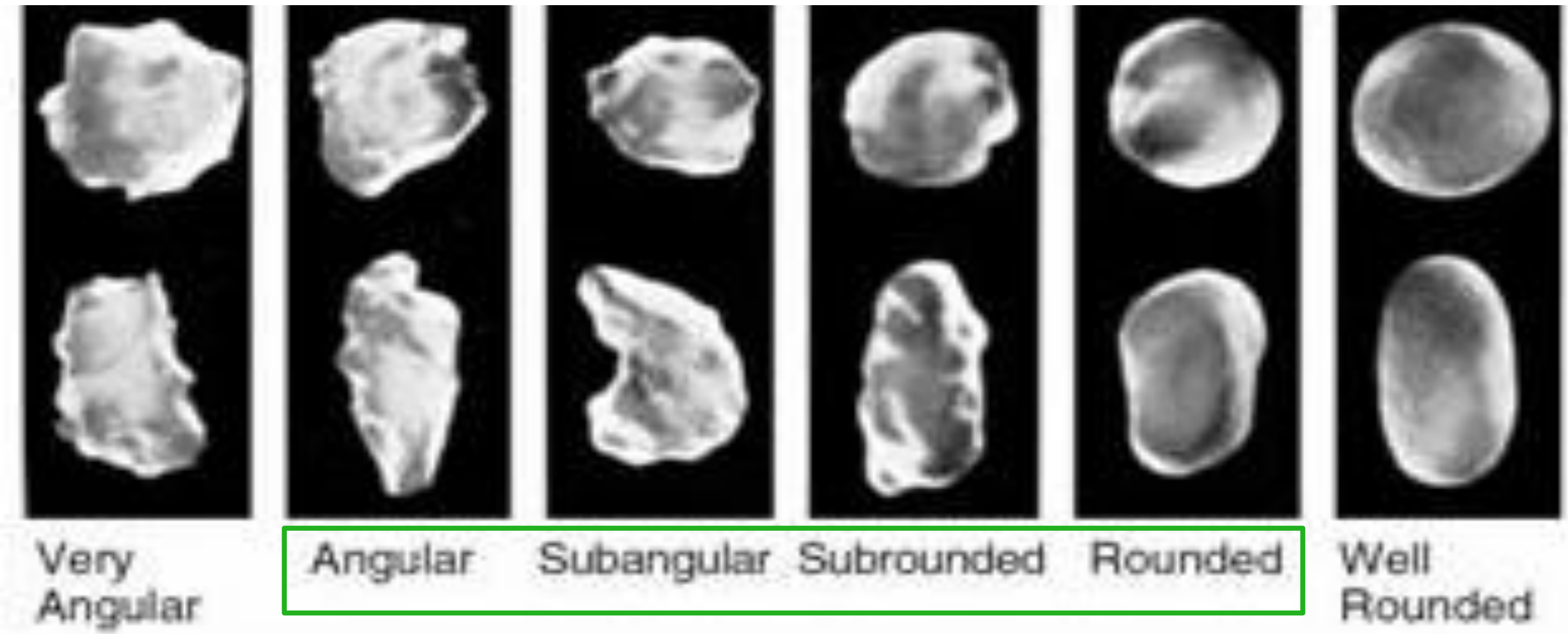
1. An estimate of the quantity of material in each size range
2. Gradation
3. Particle shape
    - Has an influence on the density and stability of the soil deposit
4. Mineralogical composition

Gradation: Coarse Grained Soil

- Gradation may be described as
  - Well-graded: soil contains a good representation of all particle sizes ranging from coarse to fine
  - Fairly well-graded
  - Fairly uniform
  - Uniform: all particles are of same size approximately
  - Gap-graded:
    - Mixtures of uniform coarse-sized paricles + uniform fine size particles
    - There is a break in gradation between two sizes
  - Poorly graded: Any soil that is not well-graded

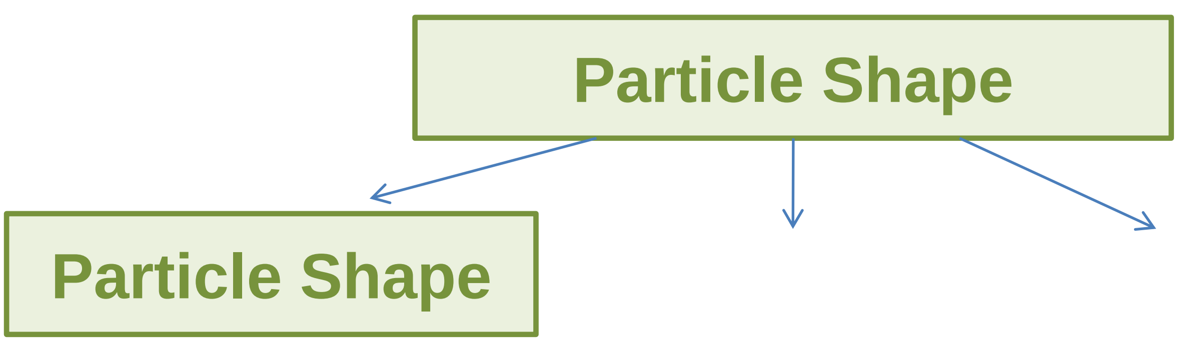
Grain (Particle) Shape

- Typical shapes of particles



Particle Shape

- As important as the particle size distribution
- Has significant influence on the physical properties of a given soil
- Difficult to measure



Coarse Particle of Soil Inspection

- By naked eye or with a small hand lens
- Estimate the degree of weathering
- Note that the prevalence of weak rock materials (such as shale and mica), if any
  - May influence the durability or compressibility of the deposit

Fine grained soil materials

Particle Size Diameter < 0.075 mm

Silt

-Coarser portion of the microscopic soil fraction

- possesses little or no plasticity or cohesion

Clay

- Predominently an aggregate of microscopic and sub-microscopic flake-shaped crystalline minerals

Physical properties other than particle size → for field identtification

Silt

Rock Flour
(The least Plastic)

Primarily very fine
rounded quartz grains

Plastic Silt
(The Most Plastic)

An appreciable quantity of
flake-shaped particles

Distinction between Silt and Clay

Why are they not distinguished based on particle size?

1. Both are microscopic

2. Significant physical properties of the two materials are related only indirectly to the size of the particles

What are the criteria for field identification?

Physical properties other than particle size

Silt and Clay

Table : Distinction between Silt and Clay based on Manual Tests

Basis/criteria	Silt	Clay
1. Dry Strength (described as very low, low, medium, high or very high)	Very low to low (A silt fragment crushes easily)	High to Very high (A clay fragment can be broken with great effort)
2. Dilatancy Reaction (Dilatancy or Shaking Test: described by rapid, slow or none)	Rapid (More permeable)	None (Less permeable)

Silt and Clay

Table : Distinction between Silt and Clay based on Manual Tests

Basis/criteria	Silt	Clay
3. Toughness of Plastic Thread (Weak to friable, Medium, or Tough)	Weak to friable	Tough
4. Time to Settle in Dispersion Test	15 – 60 min	Several hours to days

Procedure to test Dry Strength

small briquet of soil

→ Molded and allowed to dry in the air

→ Then it is broken

→ A fragment (1/8 inch) is pressed between thumb and forefinger

→ Effort required to break the fragment provides the basis for describing the strength

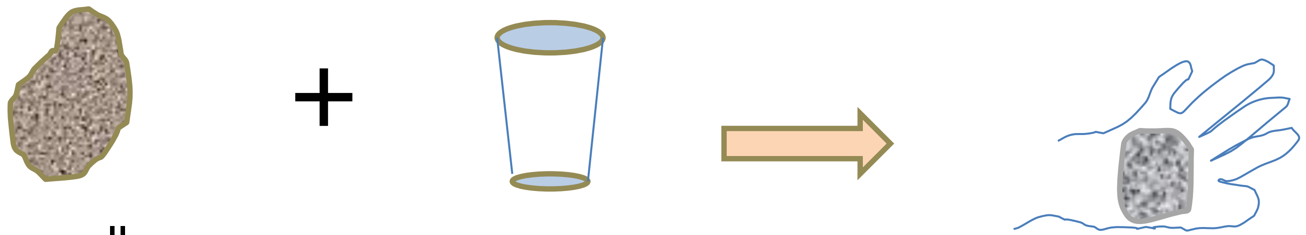
Result: Very low, low, medium, high or very high

Result of Dry Strength Test

Type of Soil	Dry Strength
Sandy silt	None to very low
Silt	Very low to low
Clayey silt	Low to medium
Sandy clay	Low to high
Silty clay	Medium to high
Clay	High to very high
Organic silt	Low to medium
Organic clay	Medium to very high

Dilatancy or Shaking Test

1.

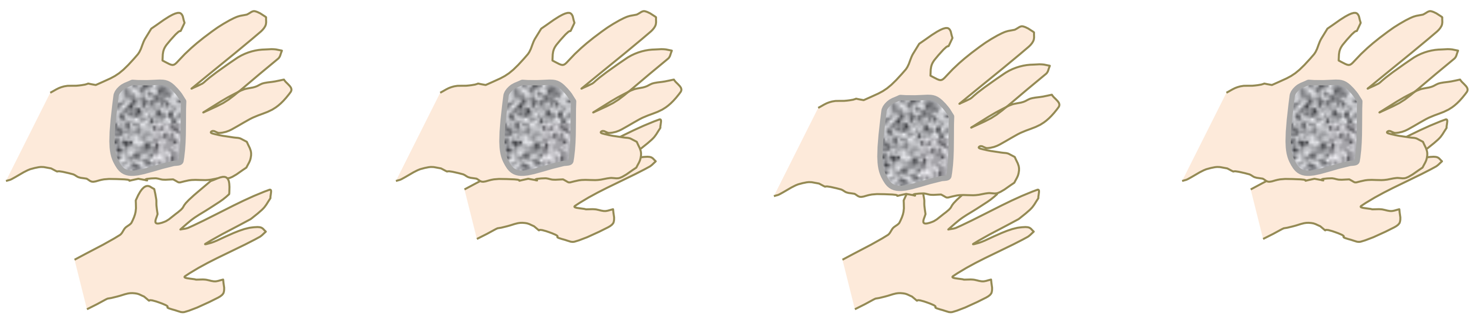


A small amount of soil

Water

A small amount of soil is mixed with water to a soft consistency in the palm of the hand.

2.



The back of the hand is lightly tapped

Result of Shaking Test

Water rises **quickly** to its surface and gives it a shiny or glistering appearance → Silty Soil

Then if soil pat is deformed, due to squeezing and stretching, the water flows back into it and leaves the surface with dull appearance.

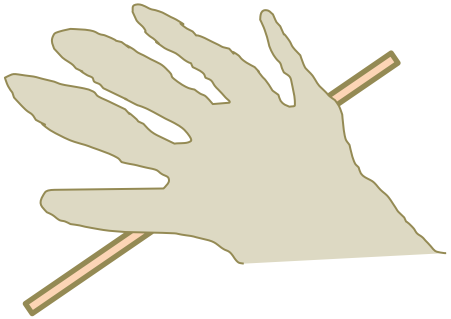
The greater proportion of clay, the slower the reaction to the test → Clay → slower reaction

Result: Rapid, slow, or none

Result of Shaking Test

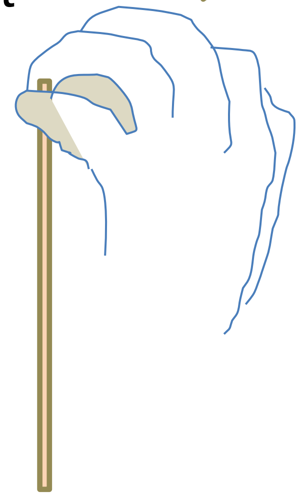
Type of Soil	Shaking
Sandy silt	Rapid
Silt	Rapid
Clayey silt	Rapid to slow
Sandy clay	Slow to none
Silty clay	Slow to none
Clay	None
Organic silt	Slow
Organic clay	None

Plasticity/Toughness Test



1. Roll the soil into a long thread (1/8 inch diameter) **without severe cracking**, **just near the crumbly stage**

2. Test whether it can support its own weight



Remember: Plasticity is characteristic property of clays. At certain moisture content, a soil containing appreciable quantity of clay → can be deformed and remolded in the hand without disintegration.

Crumbly Stage: A soil approaches a nonplastic condition and crumbly stage, during continued manipulation as moisture is lost.

Result of Plasticity/Toughness Test

Plasticity Test indicates:

1. Whether a plastic thread can be formed
2. Regarding the toughness of the thread near the crumbling state

Type of soil	Observations
Highly plastic clay	Long thread (1/8 inch diameter), sufficient strength to support its own weight
Silt	Can seldom be rolled into a thread with a diameter as small as 1/8 inch without severe cracking, completely lacking in tensile strength unless small amounts of clay are present.

Result of Plasticity/Toughness Test

Result of Toughness of the thread: **Weak to friable**, medium, or tough.

Type of Soil	Toughness of Plastic Thread
Sandy Silt	**Weak to friable**
Silt	**Weak to friable**
Organic Silt	**Weak to friable**
Clayey silt	**Medium**

Type of Soil	Toughness of Plastic Thread
Sandy Clay	**Medium**
Silty Clay	**Medium**
Clay	**Tough**
Organic clay	**Tough**

Dispersion Test

Useful test not only to distinguish between silt and clay, but also for making a rough estimate of the relative amounts of sand, silt and clay in a material

Coarser particles → Fall out fast
Finest particle → remain in suspension the longest

Result of Dispersion Test

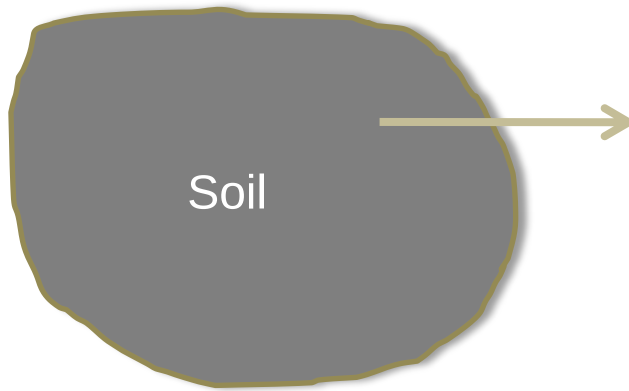
Type of Soil	Time to settle in Dispersion Test
Sand	30 – 60 sec
Silt	15 – 60 sec
Clay	At least several hours - several days

Less time required, if the particles of clay combine in groups or floccules

Result of Dispersion Test

Type of Soil	Time to settle in Dispersion Test
Sandy silt	30 sec – 60 min
Silt	15 min – 60 min
Clayey silt	15 min – several hours
Sandy clay	30 sec - several hours
Silty clay	15 min – several hours
Clay	Several hours to days
Organic silt	15 min – several hours
Organic clay	Several hours - days

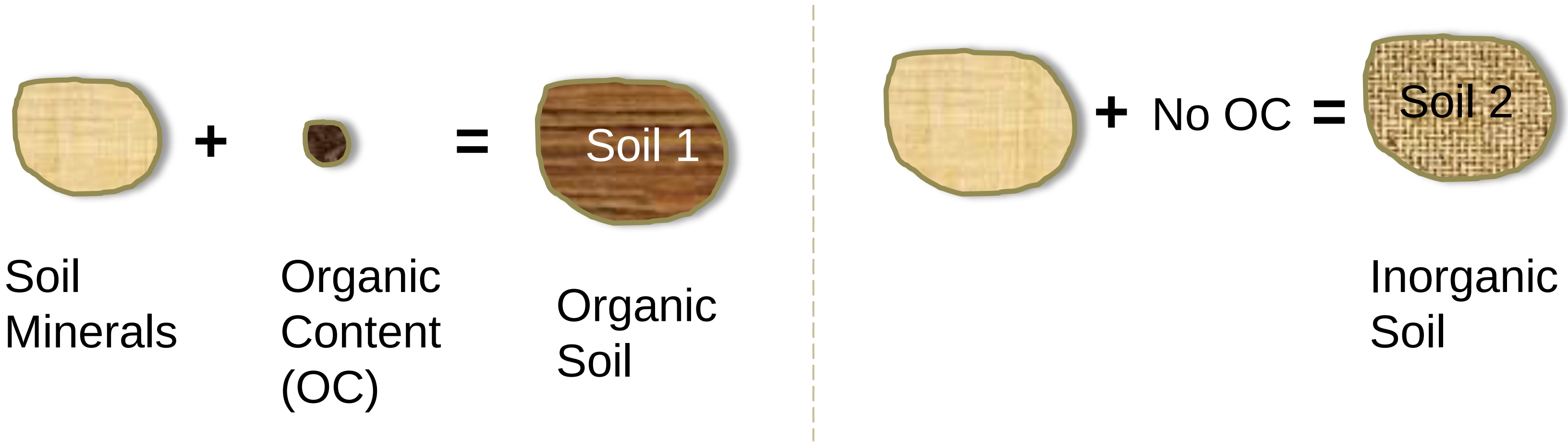
Organic Soil Materials



1. Minerals
2. **Organic Material**

Very small quantities of organic matter → have significant influence on the physical properties of soil

Organic Soil Materials

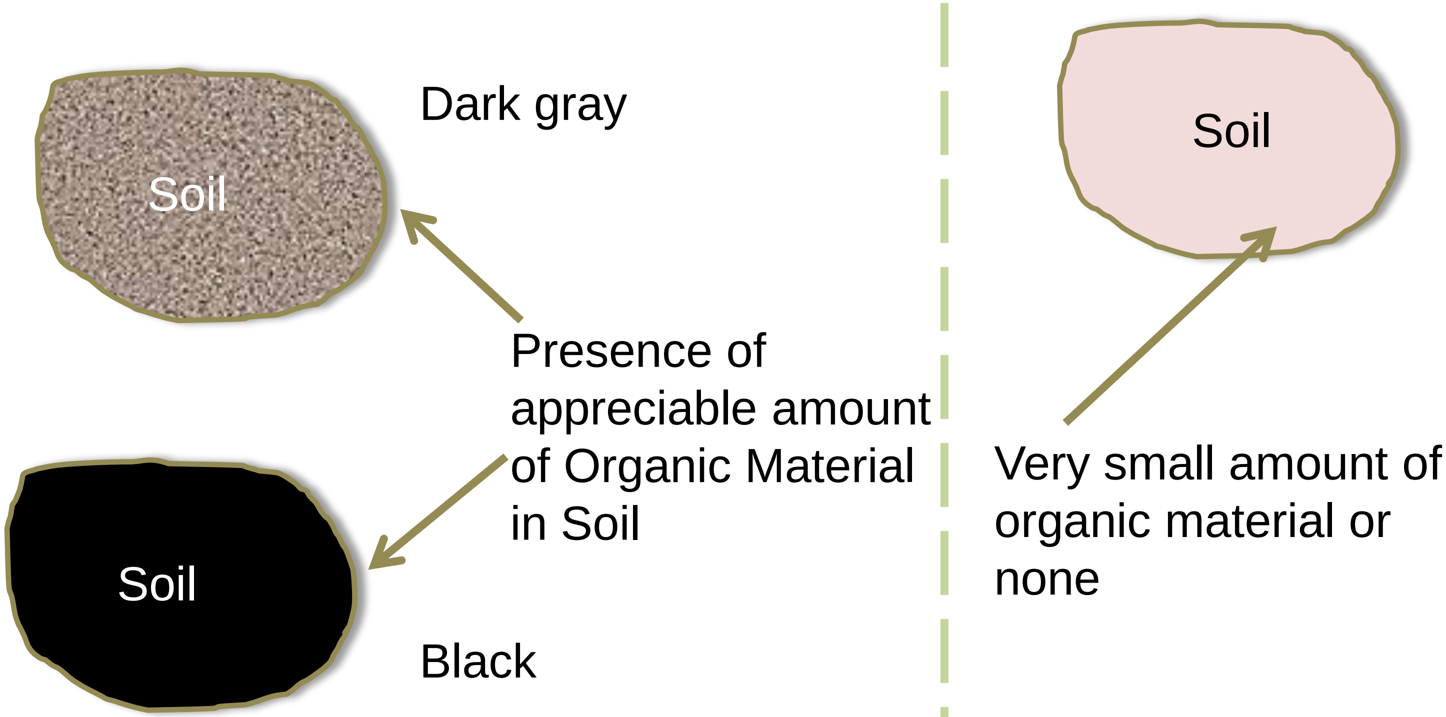


Most organic soils (Soil 1)

1. Weaker
2. More compressible than Soil 2

Eventhough both the soils (Soil 1 and Soil 2) have same mineral composition

Identify Organic Soil



- Odor of decaying vegetation
- Presence of fibrous particles of vegetable matter

Sometimes apply heat to brought out the odor if it cannot be distinguished by normal observation

Organic Soil

Organic Soil → Usually found in top soil and marshy place

Classification of organic soil, according to ASTM (Edil, 1997):

OC	Effects on Properties	Soil Class
<5 %	little	Inorganic soil
6 – 20 %	Affects properties but still behaves like mineral soil	Organic silts and clays
21 – 74 %	OC governs; traditional Soil Mechanics may be applicable	Silty or Clayey Organic soil
> 75 %	Behaviour distinct from traditional soil mechanics	Peat

Assignment-1

1. How do you identify an organic soil?
2. Differentiate between
   (a) Sandy silt and Sandy clay
   (b) Inorganic sit and Organic clay
   (c) Organic silt and Organic clay
   (d) Clayey silt and Silty clay
3. What is the basis for the identification of coarse grained soil?
4. Why are the methods of describing coarse grained soil and fine grained soil different?
5. ‘The distinction between silt and clay cannot be based on particle size.’ Explain.
6. What should you mention while describing a coarse grained soil?

Discussions

1. Visual Inspection of a soil
   - Particle shape
   - colour
   - odor

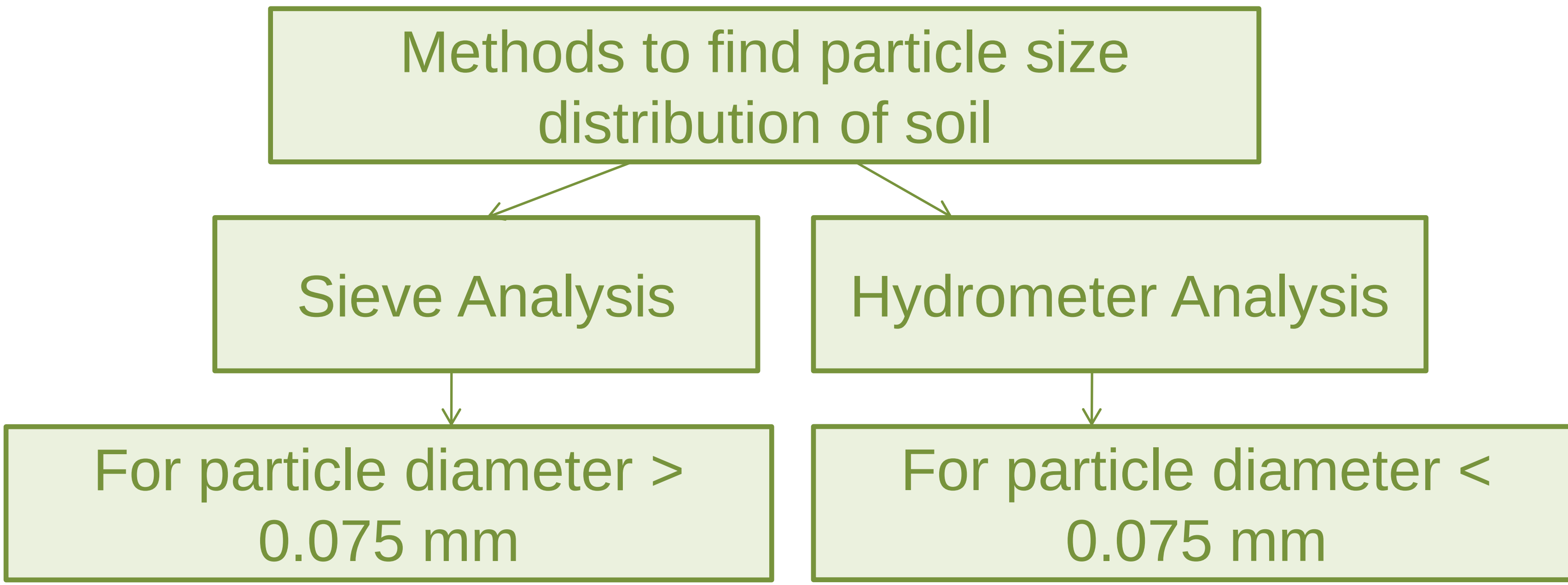
   Inorganic/ organic

2. Results of Dry strength, shaking, toughness, dispersion

3. Dispersion Test: Rough estimate of relative amounts of sand, silt and clay

Mechanical Analysis of Soil

- Determination of the size range of particles present in a soil, expressed as a percentage of the total dry weight



Sieve Analysis

Hydrometer Analysis