AGGREGATES

Section 1 – Physical Properties

Physical Properties

- Texture – appearance
- Particle Size
- Density – mass per unit volume
- Cohesion – attraction of particles
- Consistency – variability of hardness or softness

Physical Properties (continued)

- **Durability – the ability to resist abrasion or degradation**
- **Permeability – ability to conduct or discharge water**
- **Strength – ability to carry load or resist deformation**
- **Compressibility – ability to compact**

  - **We will discuss the nature of the properties now and the specific tests in Section 3**

Texture

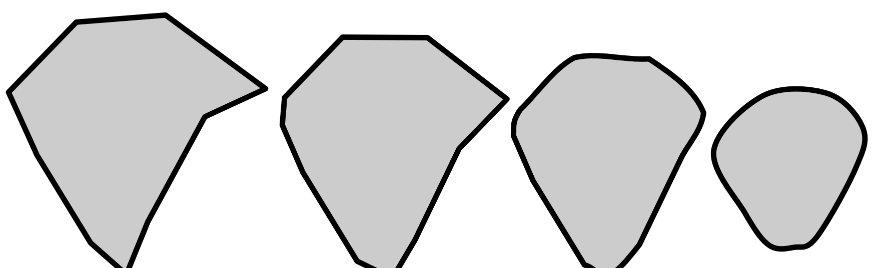
- **Function of:**
  - **Particle surface profile**
- **Color – Minerology, Wetness**
- **Surface Roughness**
- **Particle Shape – Angular, rounded, bulky, flat and elongated, etc.**
  - **Determined by:**
    - **1) Visual**
    - **2) measurement**

Coarse Aggregate Examination

¾ in.

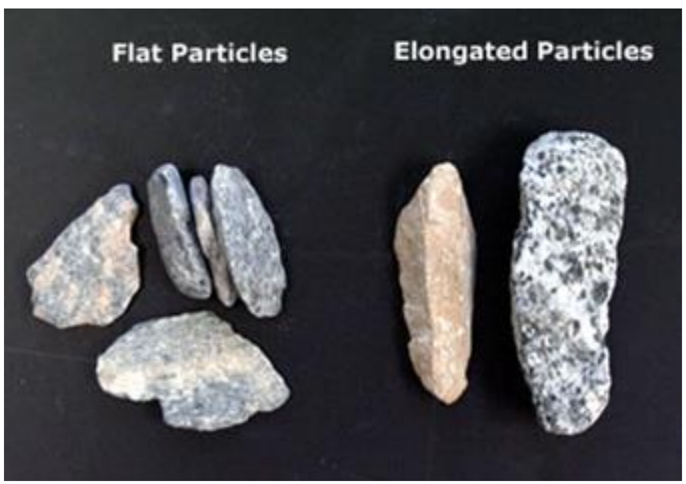
Particle Shape

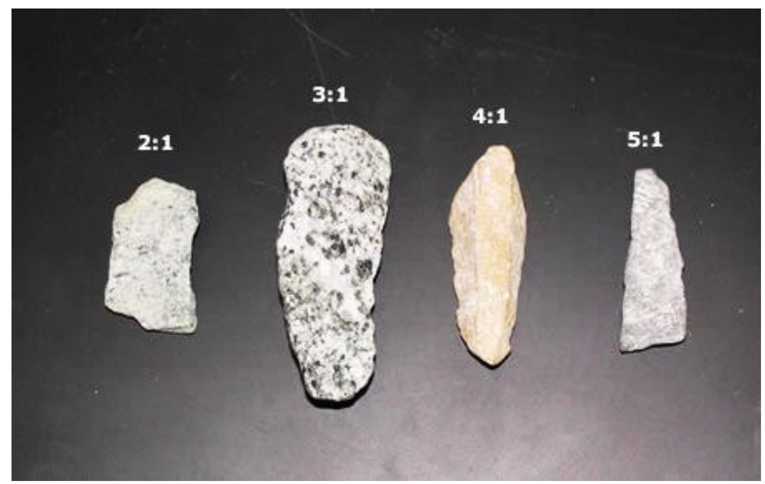
- **Angular – most edges square or sharp**
  - **Crushing and Grinding**
- **Rounded – most edges rounded, water washed**
- **Bulky – all dimensions of the same order of magnitude; generally used to describe soils**


Particle Shape (continued)

- Flat and Elongated – one dimension significantly different
  - SHRP greatest dimension at least five times the smallest dimension





Particle Size

- **Particle Size – the smallest square hole through which it will pass, i.e., a Sieve**
  - **Fine for Bulky Material**
  - **Difficult for Irregular**

  - **Determined by**
    - **1) Fractionation**
    - **2) Gradation**

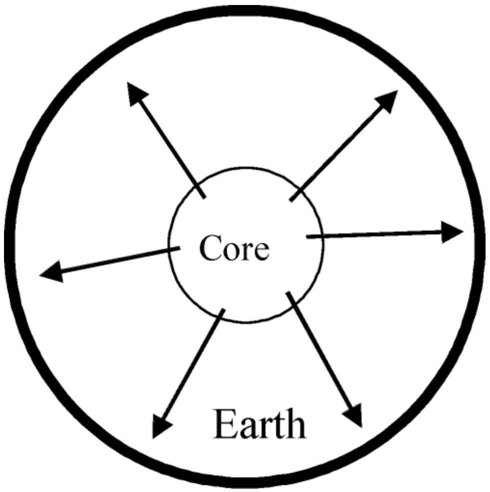
Particle Size

Particle size also defines soil types:

Size	AASHTO	ASTM
Gravel	> #10	> #4
Sand	#10 to #200	#4 to #200
Silt	0.075mm to 0.005mm	Consistency
Clay	< 0.005 mm	Consistency

Earth’s Formation

Makeup of Earth’s Crust



1> Oxygen	47%	PerCent by Weight
2> Silicon	28%	O, Si -------------->
3> Aluminum	8%	O, Si, Al ---------->
4> Iron	5%	O, Si, Al, Fe ------>
5> Calcium	4%	
6> Sodium	3%	
7> Potassium	3%	
8> Magnesium	2%	
9> Hydrogen	Trace	
10> Everything else		

Magma Under Heat and Pressure Flows to the Surface and Solidifies to make the Rocks which Break Down to form Boulders, Cobbles, Gravel, Sand and Silt (and Clay)

Physical Weathering

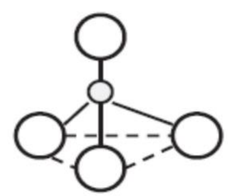
- Physical Weathering
  - Forms the coarse particles
    - Gravel
    - Sand
    - Silt
  - Change in Size but not in Form
    - Crushing, Grinding, Impact and Tumbling, Splitting (ice wedging), Temperature Gradient, etc.
    - Smaller Particles are like the parent material

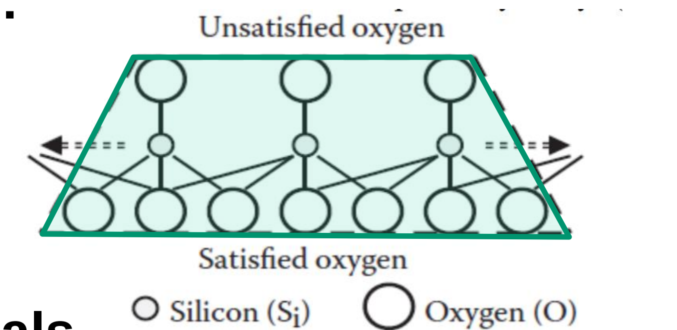
Chemical Weathering

- **Chemical Weathering**
  - **Forms Clay**
  - **Change in Form**
    - **Acid Rain (Sulfuric acid, H_2SO_4, Nitric acid HNO_3, Carbonic acid, H_2CO_3, etc.), Decomposing Organic Material and Organisms seeps through the coarse particles.**
    - **Dissolves the outer layers of the coarse particles and creates a slurry rich in free atoms which create Crystals.**
    - **Remember, the common atoms are Oxygen, Silicon and Aluminum.**

Chemical Weathering

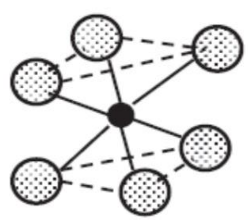
- Chemical Weathering
  - That Slurry allows those atoms to form Crystals.
    - Two Common Types
      - Silicon Tetrahedrals:

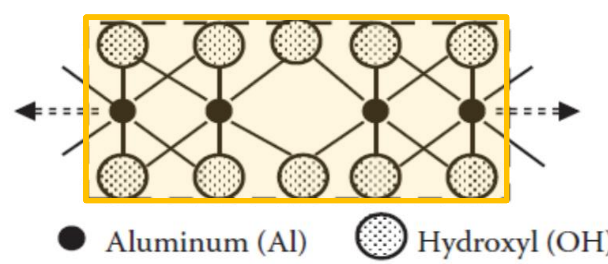




(a) Silica tetrahedral sheet

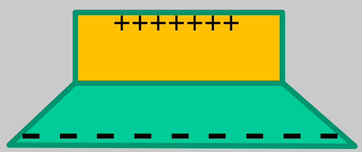
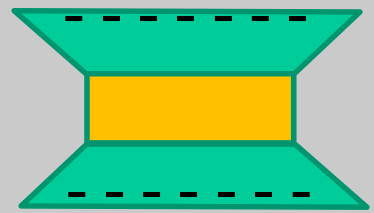
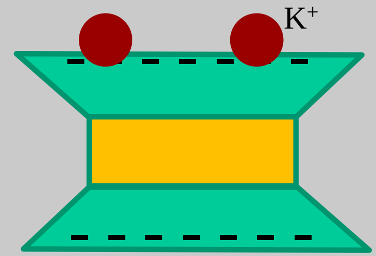
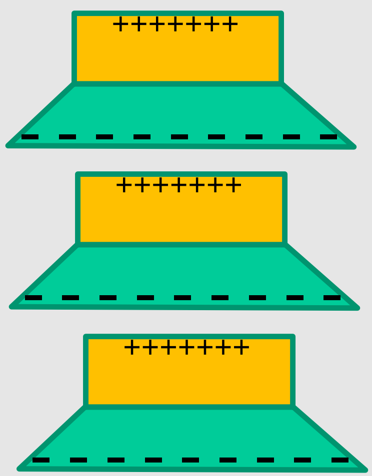
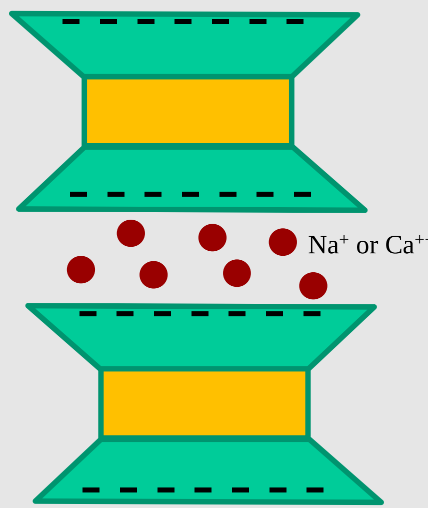
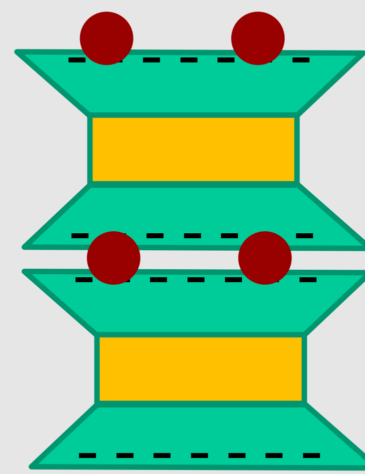
      - Aluminum Octahedrals





(b) Aluminum octahedral sheet

Three Major Clays

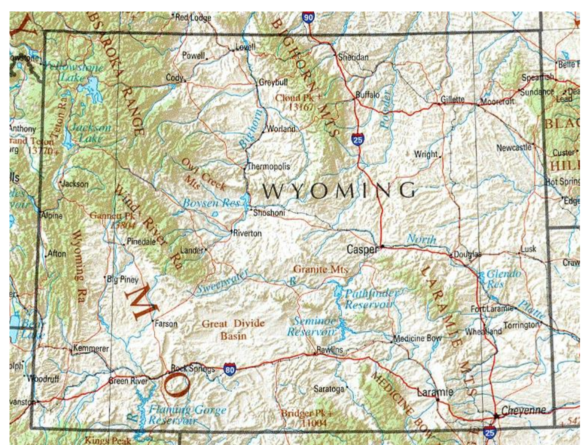
Kaolinite	Montmorrilonite (Bentonite)	Illite
		
		

Particle Size

Particle Size

-#40

x 1.3×10^6



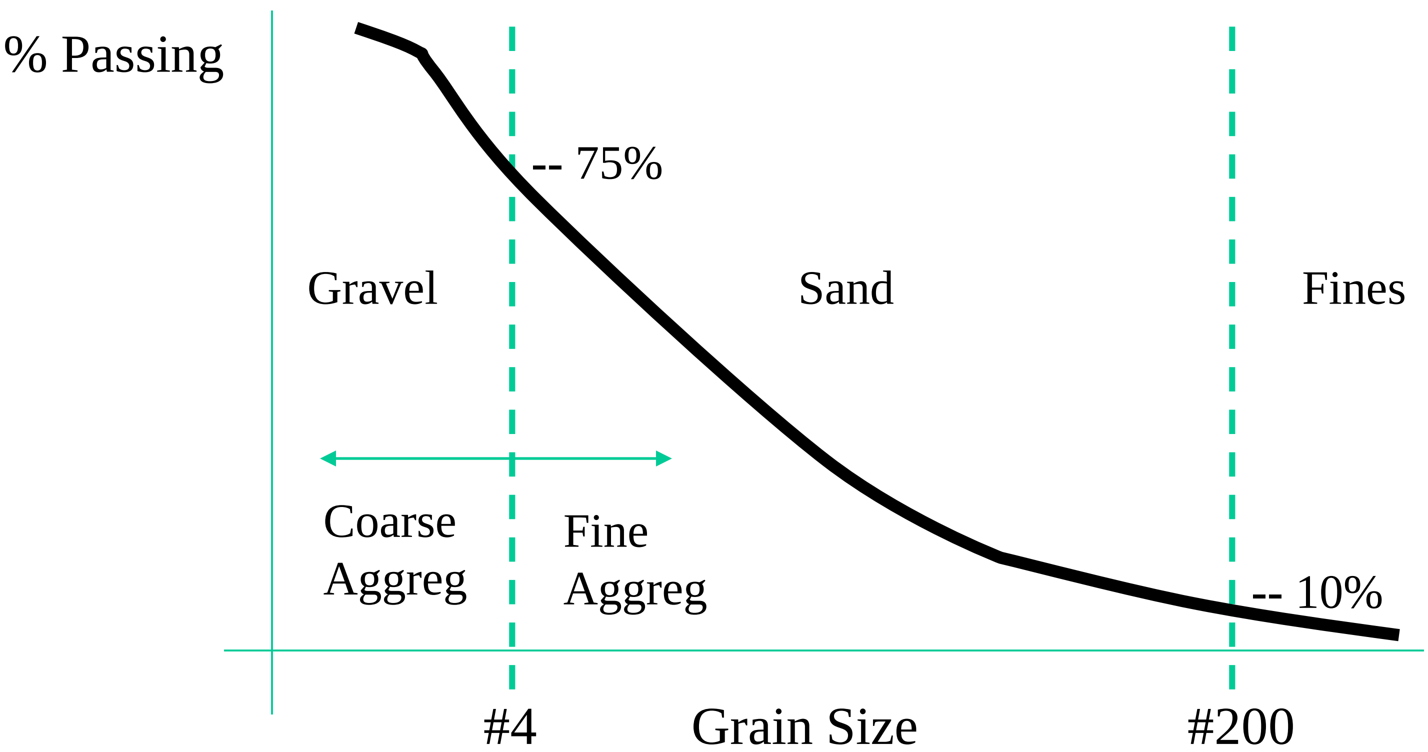
x 35 ft

Fractionation

- **Definition:**
  - **1) Physical separations of a sample into 2 or more fractions**
    - **Stockpiling**
  - **2) The determination of amounts larger or smaller than certain sizes of significance**
    - **% Retained on the #4 Sieve**
      - rock, coarse aggregate, +#4 fraction
    - **% Passing the #4 Sieve fines,**
      - fine aggregate, - #4 fraction
    - **% Passing the #200 sieve**
      - binder, - #200 fraction

Fractionation (continued)

- 3) **The determination of amounts of material within certain ranges;**
  - **%Sand = (-#4 fraction) – (-#200 fraction)**



Gradation

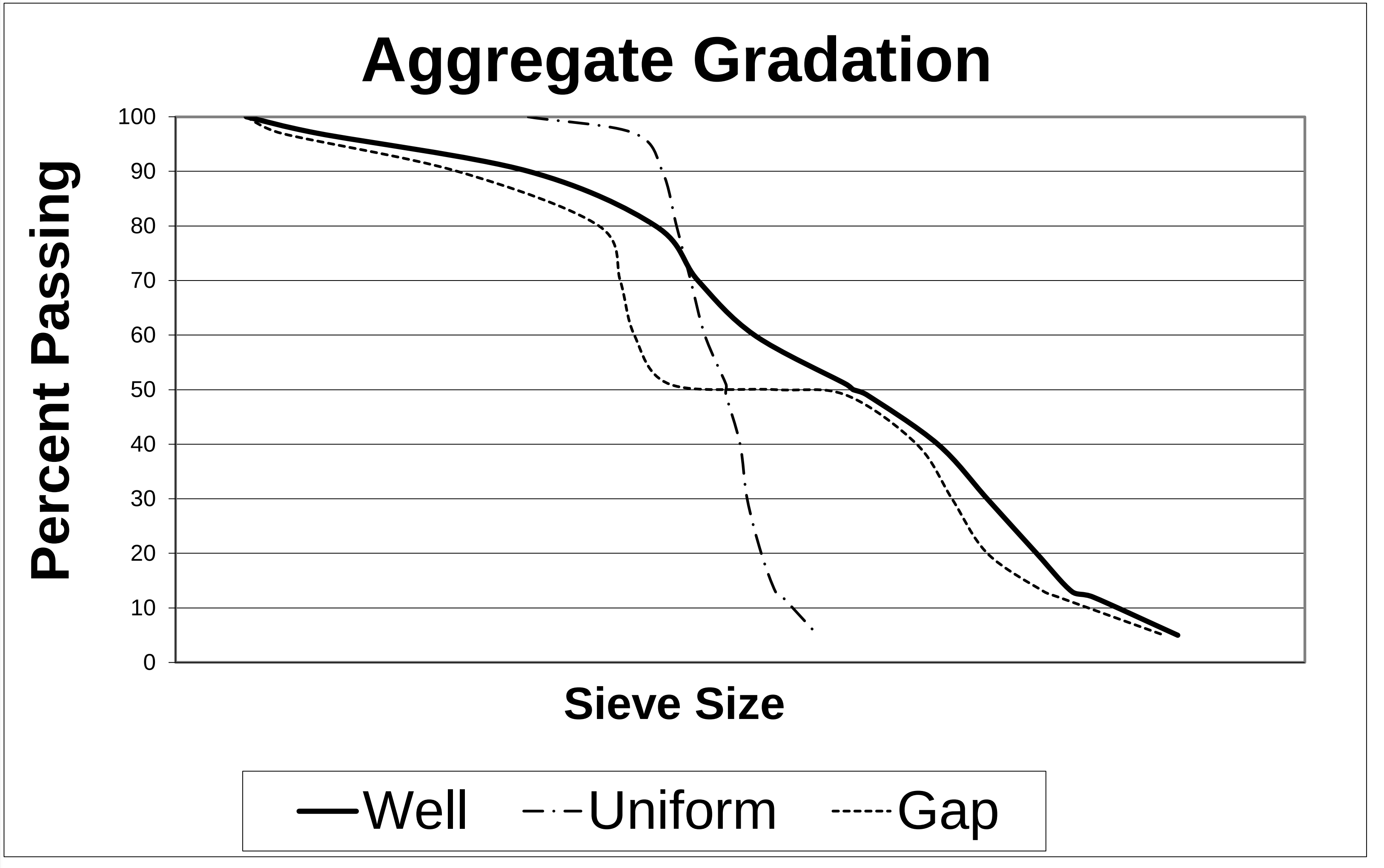
- **Definition:**
  - **Determination of manner in which size variation occurs over a full range of particle sizes**

- **Gradation vs. Fractionation**
  - **Fractionation – looks at critical sizes**
  - **Gradation – looks at many sizes**

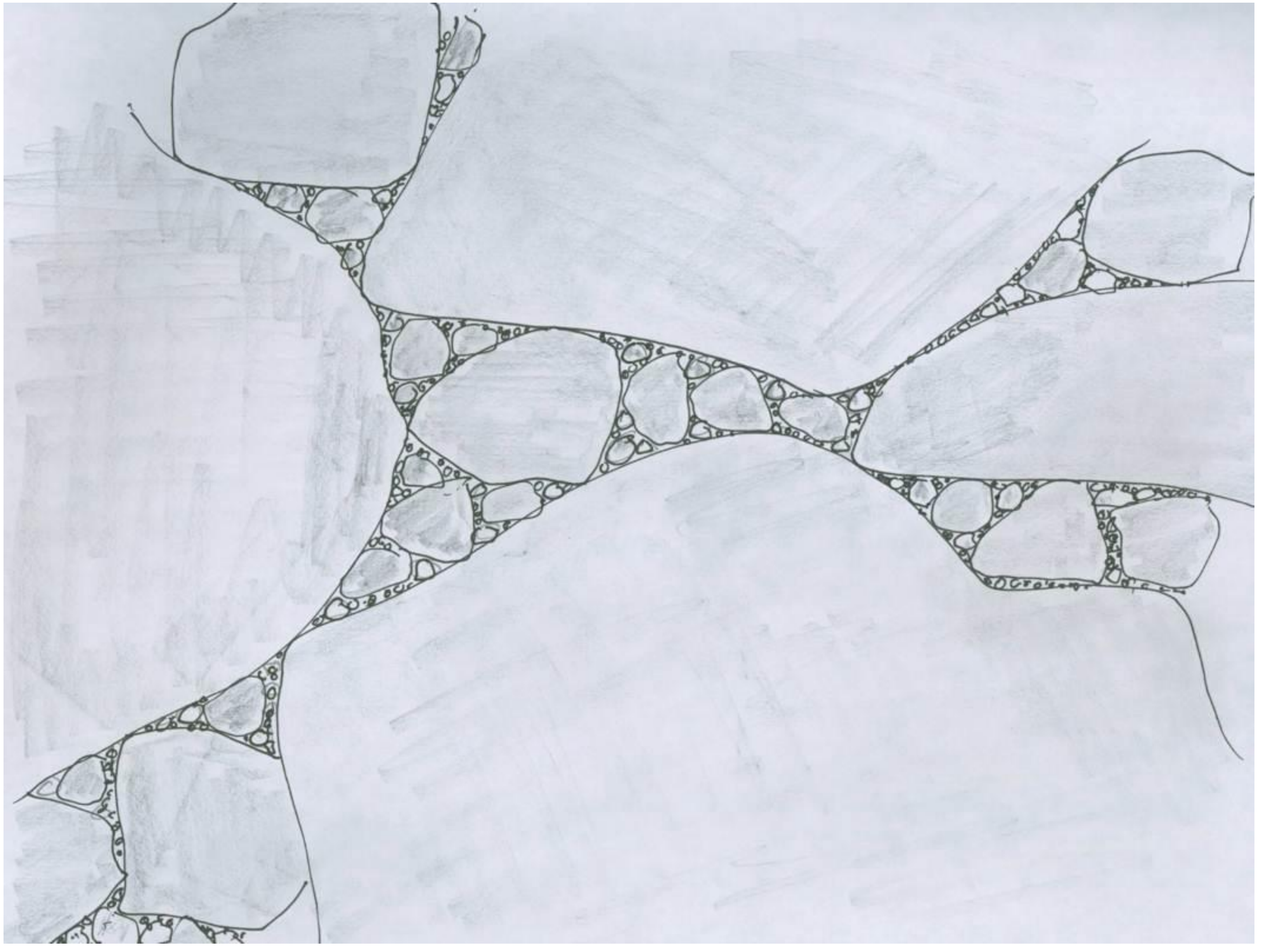
Gradation (continued)

- **Good; Bad – depends on intended engineering use**
- **Well Graded – some material in all sizes; also called dense graded**
- **Uniform or Poorly Graded – primarily composed of particles of a single size; also called one-sized material (i.e., all passing one sieve and retained on the next)**
- **Gap Graded– little or no material within a given size range (i.e., mix of two uniform soils)**
- **Open – high percentage of coarse sizes and small percentage of fines**

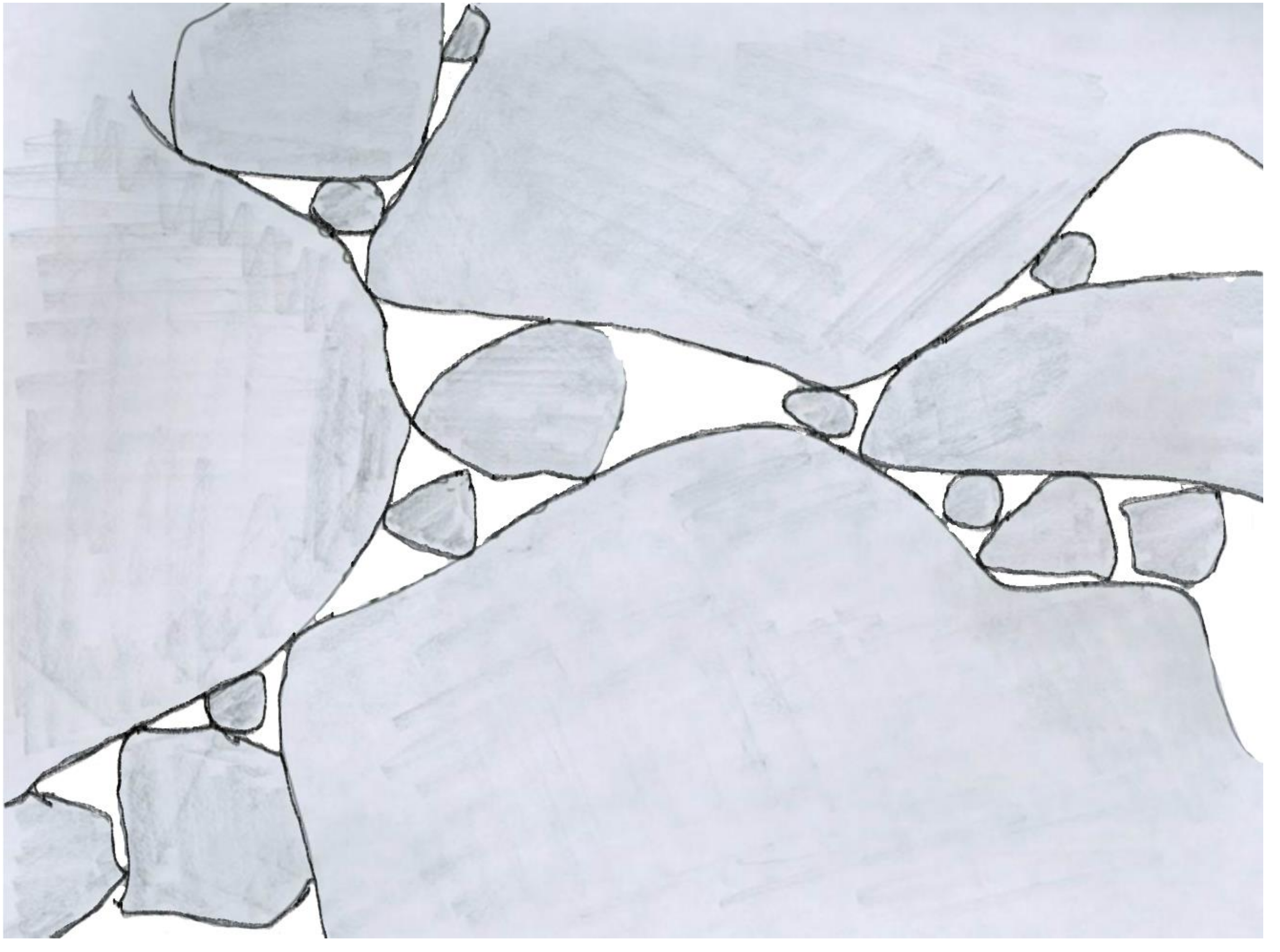
Aggregate Gradation



Well Graded Soil



Uniformly Graded Soil

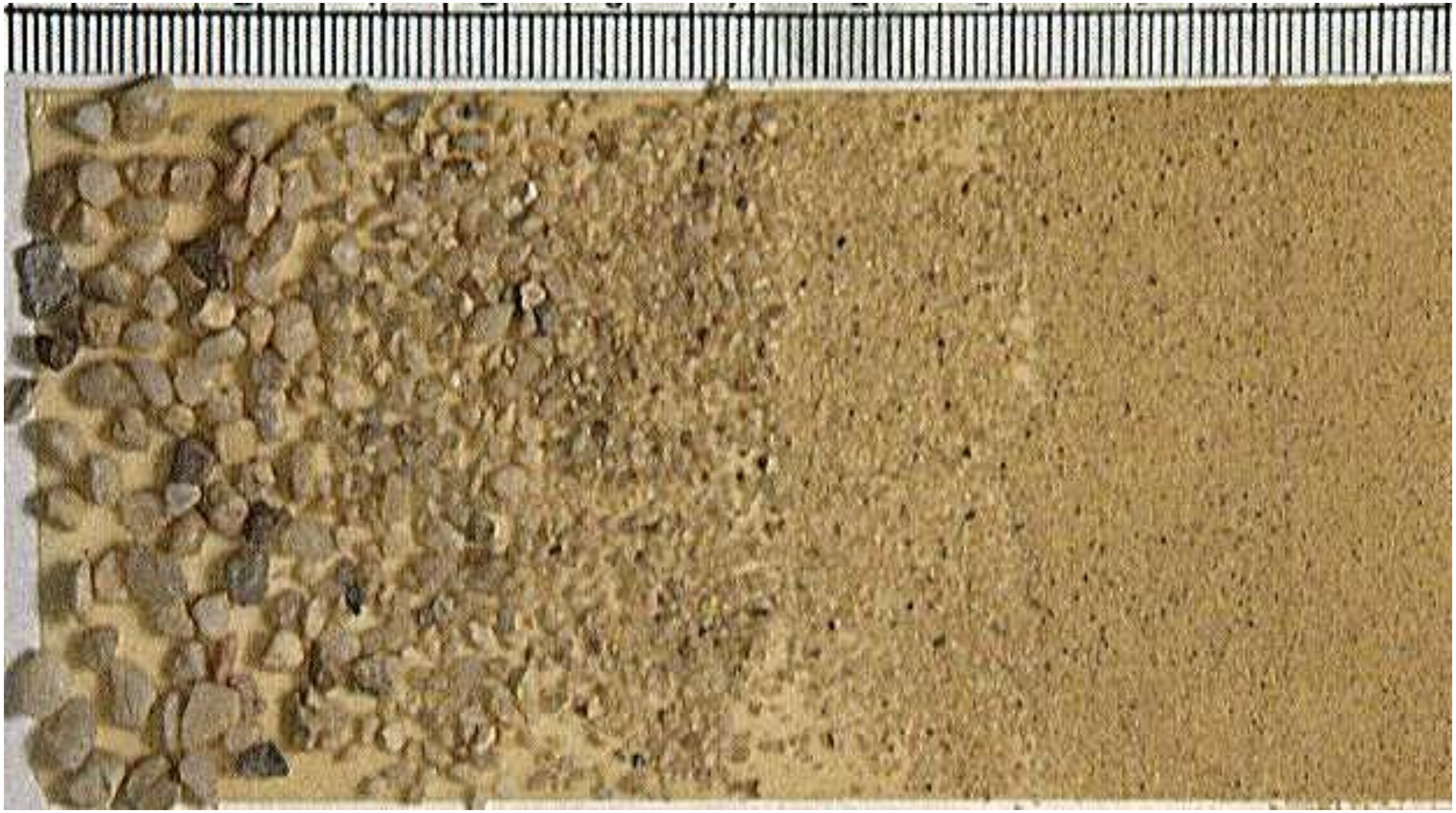


Coarse Aggregate Examination

Coarse **Fine**

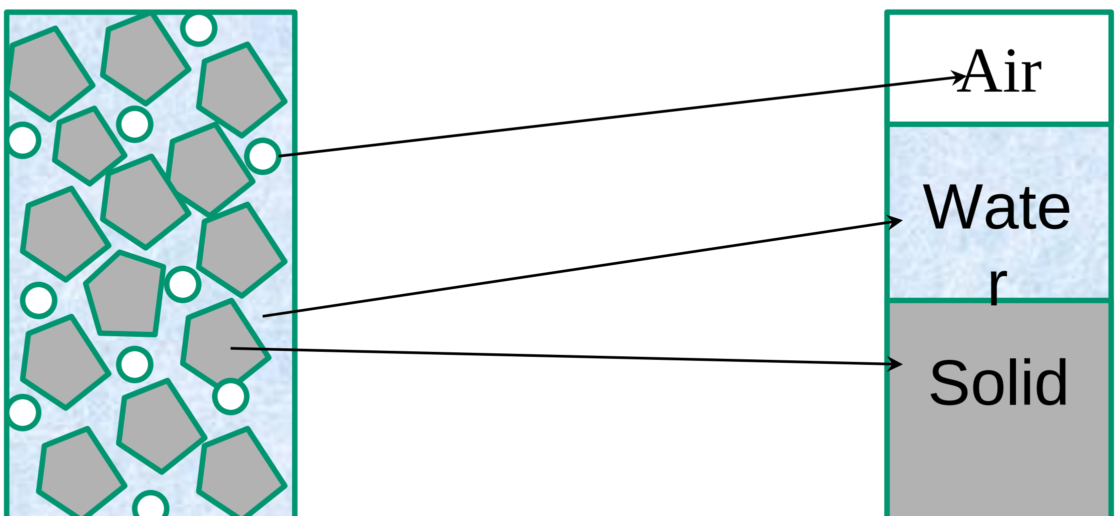
Fine Aggregate Examination

Coarse **Fine**

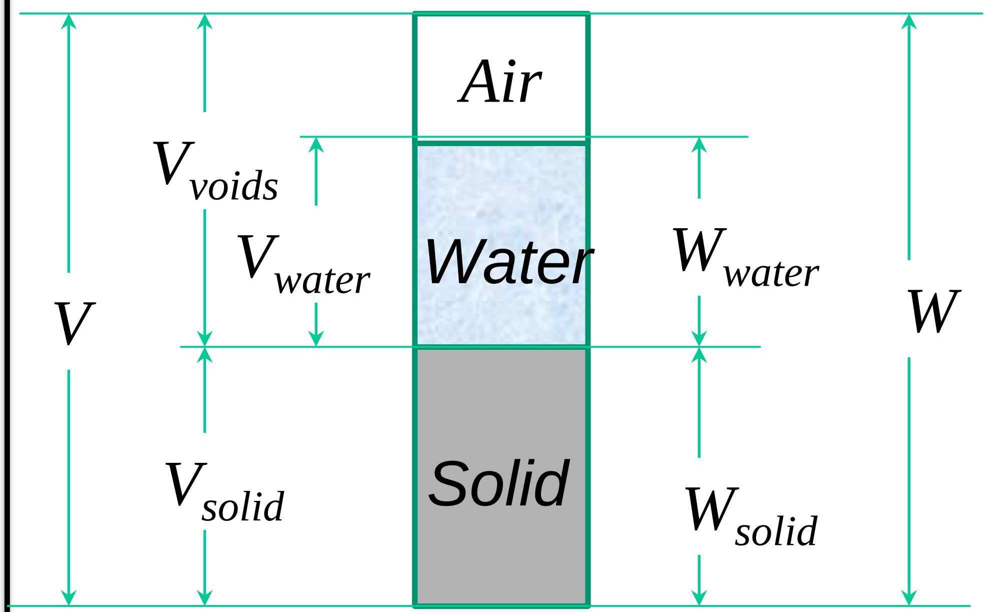


Phases of a Soil or Aggregate

- **Soil (Aggregate) is a blend of Solid, Liquid and Gas**
  - **Solid – Minerals**
  - **Liquid – Water**
  - **Gas – Air**
- **Easier to think about the Individual Phases rather than the blend**



Important Phase Relationships



Water Content

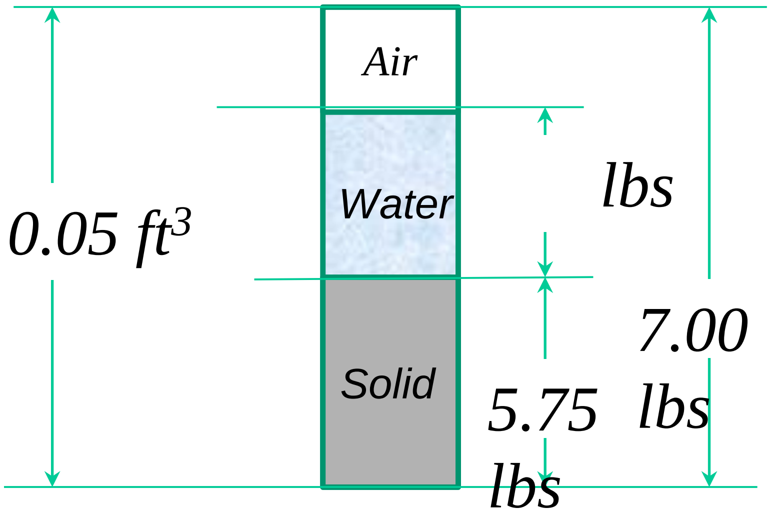
$$w = \frac{W_{water}}{W_{solid}} x100\%$$

$$\text{(Wet) Unit Weight} = \frac{W}{V} ......(pcf)$$

$$\text{Dry Unit Weight} = \frac{W_{solid}}{V} ......(pcf)$$

Example – Unit Weights and Water Content

Sand Cone Test: Removed 7.00 pounds of soil which dried to 5.75 pounds. The volume of the hole was 0.05 ft^3



Water Content

$$= \frac{W_{water}}{W_{solid}} = \frac{lbs}{5.75\ lbs} x100\%$$

$$\text{Water Content} = 21.7\%$$

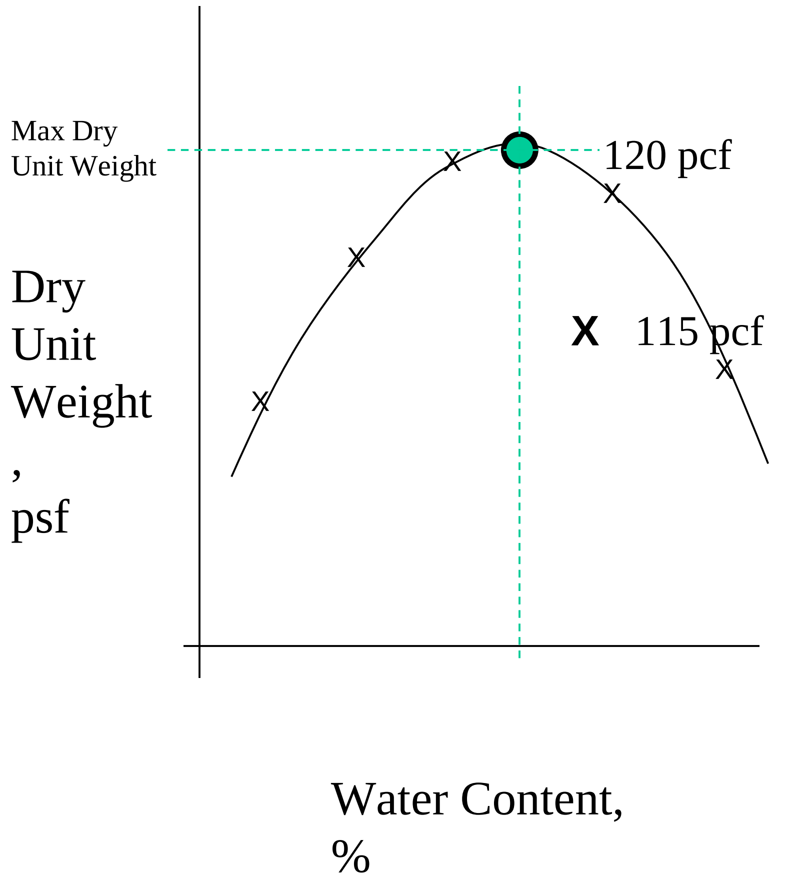
$$\text{(Wet) Unit Weight} = \frac{W}{V} = \frac{7.00\ lbs}{0.05\ ft^3} = 140\, pcf$$

$$\text{Dry Unit Weight} = \frac{W_{solid}}{V} = \frac{5.75\ lbs}{ft^3} = 115\ pcf$$

Example – Relative Density

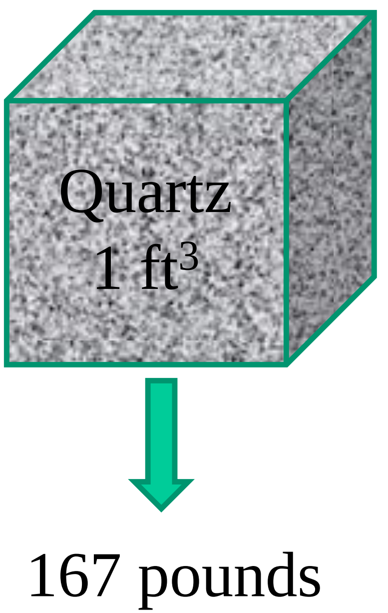
- **Relative Density – the ratio of the weight of material in the field to the maximum compacted weight of equal volume. %**
  - **Maximum Dry Unit Weight = 120 pcf (Lab Test)**
  - **Field Dry Unit Weight (previous page) = 115 pcf**
  - **Relative Density**

    = 115 pcf*100%
    120 pcf
  - **= 96% Relative Density**



Density (continued)

- **Unit Wt. of Water = 62.4 lb/ft^3 @ 77°F**
- **Specific Gravity – ratio of the weight of a given volume of material to the weight of an equal volume of water.**



$$s.g. = \frac{\text{Unit Wt. Of Material}}{\text{Unit Wt. Of Water}}$$

$$\text{Unit Wt of Quartz} = \frac{167\ lbs}{1\ ft^3} = 167\ pcf$$

$$s.g. = \frac{167\ pcf}{62.4\ pcf} = 2.67$$

Cohesion

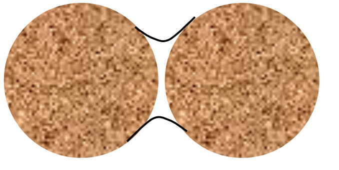
Function of:

Particle size and shape and type of material

Two Types of Cohesion:

<u>Apparent Cohesion</u> - is the attraction between sand particles caused by water

Generalities:



- **Maximum when sand is moist**
- **Does not exist when sand is dry or very wet**
- **Change causes collapse and bulking**
- **Can be very dangerous in construction**

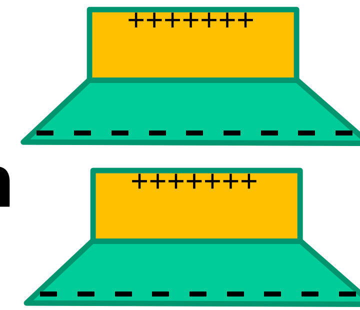
Cohesion

Function of:

Particle size and shape and type of material

Two Types of Cohesion:

<u>True Cohesion</u> - is the attraction between clay particles



Generalities:

- **Decreasing size = increased cohesion**
- **Increased clay = increased cohesion**
- **Angularity or Bulkiness = decreased cohesion**

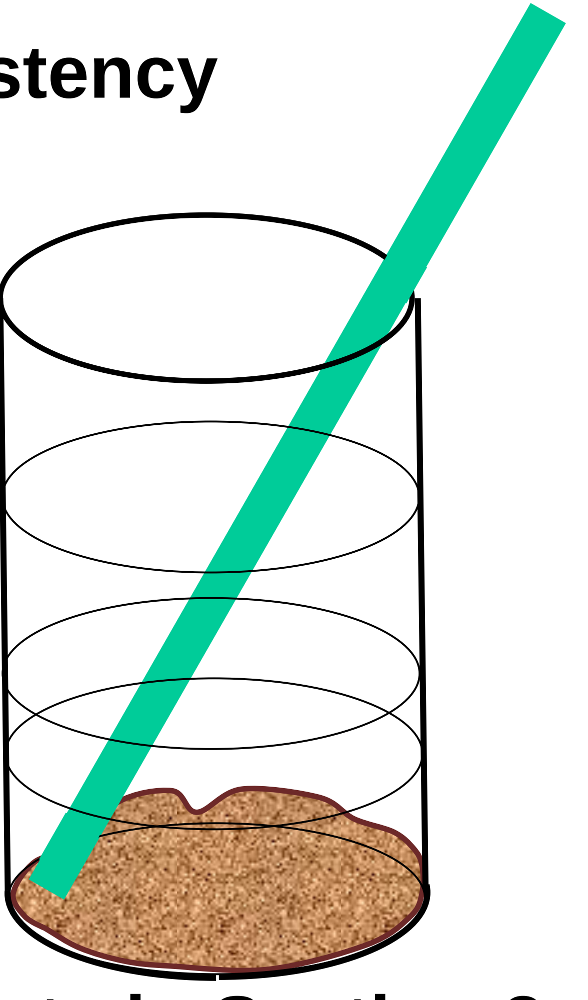
Consistency

- **Function of:**
  - **Type of material and moisture content or degree of saturation**
- **Primary use:**
  - **Fine grained soils**
- **Atterburg System:**
  - **Developed to define consistency in terms of moisture content and behavior**

Atterburg System

States of Consistency

- Liquid
- Plastic
- Semi – solid
- Solid
  - We will discuss the Tests in Section 3



Atterburg System (continued)

Atterburg Limits

- **Definition:**
  - **The moisture content at which a material changes states:**
    - **Liquid Limit – (LL) – the moisture content at the transition from liquid to plastic**
    - **Plastic Limit (PL) – the moisture content at the transition from plastic to semi-solid**
    - **Shrinkage Limit (SL) – the moisture content at the transition from semi-solid to solid**

Atterburg System (continued)

Atterburg Indexes

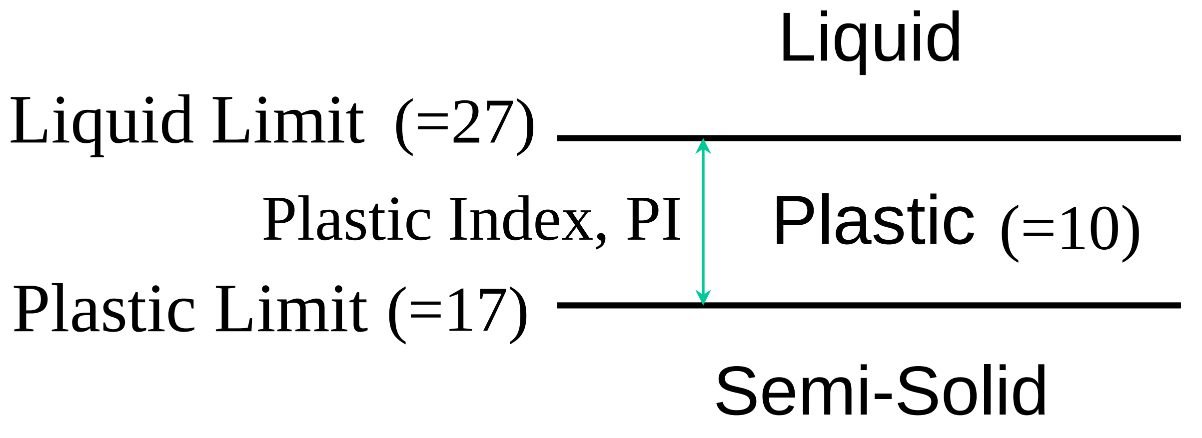
- **Definition:**
  - **The difference in moisture content at the Atterburg Limits**
  - **Plastic Index (PI) – difference in moisture contents at LL and PL**
  - **Shrinkage Index (SI) – difference in moisture contents at PL and SL**

Atterburg System

States	Limits	Indexes
Liquid		
	LL	
Plastic		PI = LL-PL
	PL	
Semi-solid		SI = PL-SL
	SL	
Solid		

Plasticity Index (PI)

➢ **Plasticity Index = Liquid Limit – Plastic Limit**



- **PI = LL – PL**
- **PI = 27 – 17 = 10 (for example)**
- **The range over which a soil is plastic**

Plasticity Index (PI)

- **It is an indicator of the ability of the soil to hold water.**
  - **Soil that has a large PI can absorb a lot of water and still remain plastic.**
- **It indicates the soil's moisture susceptibility.**
  - **Some soils can absorb a lot of water, others become easily saturated, then water flows through them.**
    - **Swelling soils…**

Atterburg System (continued)

Generalities:

- Increased clay content = increased LL and PI
- Increased clay content = less desirability
- Most important properties are LL, PL and PI in defining behavior

Atterburg System (continued)

- Decreased PI = increased permeability and reduced compressibility
- Many granular materials do not have a plastic or liquid phase and are NP, NV
- In PMP aggregates, any LL or PI is undesirable but may be tolerable in base/subbase depending upon use

Permeability

Definition:

Ease with which water will flow through the soil

Function of:

Soil type, particle size, density, cohesion, and particle shape

Permeability (continued)

Generalities:

- High clay content = low permeability
- High % coarse aggregate = high permeability
- High relative density = low permeability
- Bulky, angular aggregate = higher permeability than flat or rounded aggregate

Strength

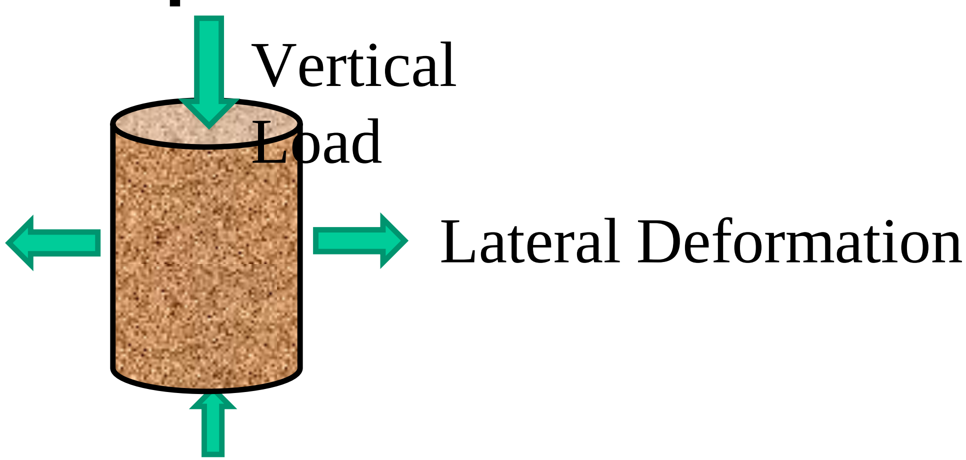
- **Function of:**
  - **Soil type, particle size and shape, density, moisture content, state of compaction and durability**

Strength (continued)

- **Measures of Strength:**
  - **Shear strength – geotechnical /foundation engineer**
  - **Bearing capacity – foundation engineer**
  - **California Bearing Ratio (CBR)**
  - **“R” Value – used by WYDOT and a few other DOTs for strength and moisture sensitivity**
  - **Unconfined compressive strength – treated material**

"R" Value

- **Definition:**
  - **A measure of the resistance of a material to lateral deformation under an applied vertical load**
- **Test – AASHTO T 190, Resistance R-value and Expansion Pressure of Compacted Soils**



"R" Value (continued)

- Theoretical Range – 0 (Water) to 100 (Steel)
- Practical Range – 5 to 80
- Aggregate Range – 40 to 80
- Minimum Values:
  - Subbase and gravel roads – 60
  - Base - 75

Durability

- **Function of:**
  - **Parent rock, degree of weathering**

- **Generalities:**
  - **The closer to the top of the surfacing layers, the more durable the aggregate required**
  - **Resistance to abrasion or degradation (Durability) is required during manufacture, placement, compaction and service**
  - **AASHTO T96 – Los Angeles Machine**
  - **AASHTO T104 - Soundness**
  - **Others**