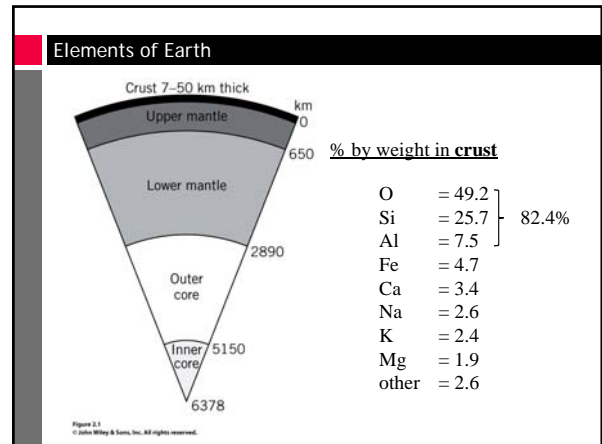


CIVE 3208/EART4107

## Geotechnical Mechanics

Lecture 2:  
**Origin and Particle Size of Soil**

2012 Fall



### Rocks

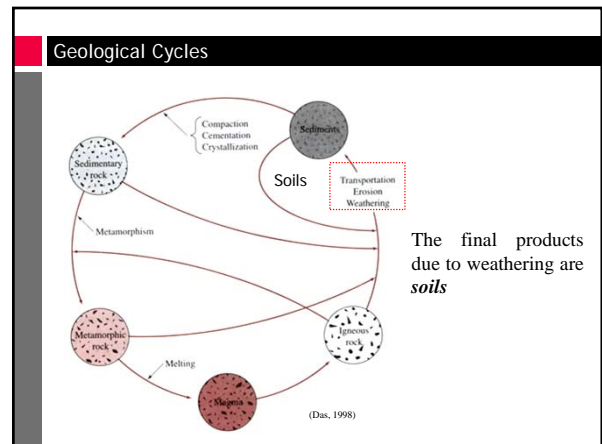
- Rock: aggregates connected with strong bonding: Igneous, Sedimentary, Metamorphic
- **Igneous Rock**
  - Formed by the solidification of molten magma ejected from deep within the earth's mantle.
  - Common types of igneous rock
    - granite - quartz, sodium and potassium feldspar
    - basalt - calcium and sodium feldspar and ferromagnesian silicates

### Rocks

- **Sedimentary Rock**
  - Formed by gradual deposition and in layers
  - The deposits of soil formed by weathering, compact as a result of overburden pressure and with the presence of cementing agents like iron oxide, calcite, dolomite and quartz, form a rock.
  - e.g. shales, sandstone, limestone, conglomerate


### Rocks

- **Metamorphic Rock**
  - Formed by alteration of igneous & sedimentary rocks by pressure/temperature
  - Metamorphism is the process of changing the composition and texture of rocks as a result of heat and pressure
  - Original rock structure and mineral composition are changed
  - granite ----> gneisses
  - shale ----> slate
  - calcite and dolomite ----> marble

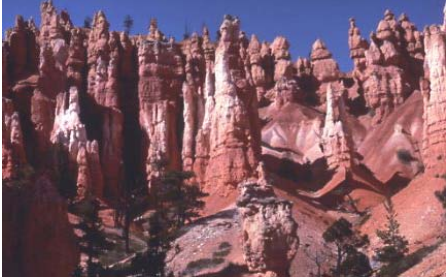


**Weathering**

➤ The weathering profile in glaciated areas north of the Ohio and Missouri Rivers.



**Weathering**



These spires at Bryce Canyon are erosional remnants caused by preferential flow paths of groundwater seepage. This view is taken from near the base of the escarpment.

**Weathering**

➤ **Physical Weathering:**

- Due to erosion (wind, water, glaciers), freezing & thawing, exfoliation (unloading)
- Breakdown the rock into smaller particles
- Angular, subangular, rounded
- No chemical change: No change in mineral composition, only a reduction in particle size

➤ **Chemical weathering**

- Due to chemical reactions, such as hydration, oxidation, carbonation
- Both a reduction in particle size, and change in mineral composition
- Generally form small particles (e.g. clay minerals): (< 0.002 mm)

**Soil Formation**

**Rock**

```

graph TD
    Rock --> ResidualSoil[Residual soil]
    Rock --> TransportedSoil[Transported soil]
    ResidualSoil --- ResidualText[formed by weathering and remain in their place of origin]
    TransportedSoil --- TransportedText[formed by weathering and transported far away]
    
```

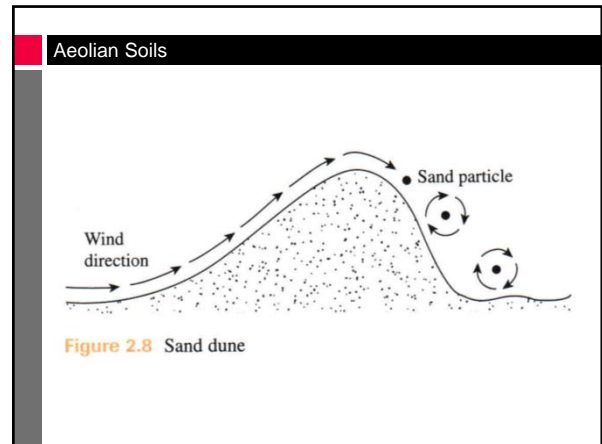
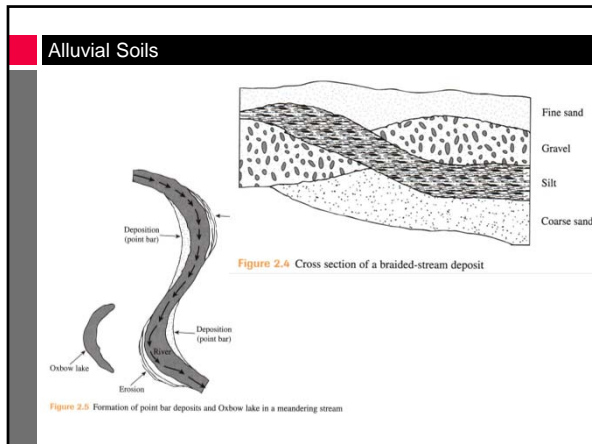
**Weathering- Residual soils**

**Residual soils** are those that weather in-place over a long period of time, typically, in semi stable and humid environs. This shows the residual soils developed over the upper Cambrian age limestone-dolostone near Johnsons Shut-In State Park



**Transported Soils**

1. **Alluvial Soils:** transported by **water** (rivers, streams etc)
2. **Marine soils:** deposited in a marine environment (salt water)
  - Lacustrine soils: formed by deposition in quiet lakes (fresh water)
3. **Glacial Soils:** transported and deposited by **glaciers**
4. **Colluvial soils:** soils accumulated at the base of slopes/hills due to **gravity** (e.g. landslides)
5. **Aeolian/Eolian soils:** transported by **wind**; e.g. sand dunes, loess



### Soil Particle Size

Two kinds of soil in this world...

- COARSE
- FINE

Basis for division is...

### Fine-Grained vs. Coarse-Grained Soils

- U.S. Standard Sieve - No. 200
  - 0.0029 inches
  - 0.075 mm
- "No. 200" means...

### Soil Particle Size

Depending on the "average" particle size, soils are generally divided into four categories.

- Gravels (several mm to cm)
- Sands (about a tenth of an mm to a few mm)
- Silts (few to several micrometers)
- Clays (smaller than about a micrometers)

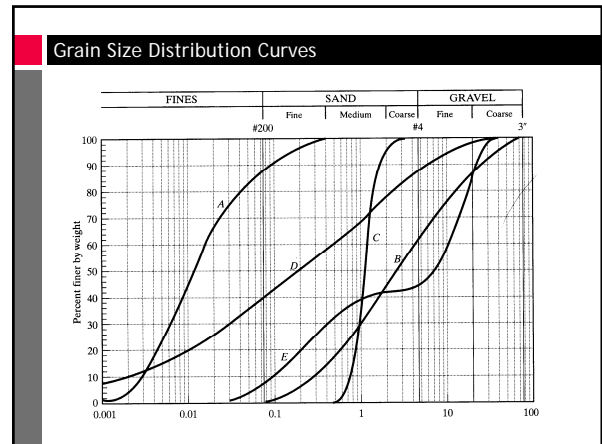
GRAVEL    SAND    SILT    CLAY

### Sieve Analysis

- Sieve analysis - used for coarse grain particles ( $> 75 \mu\text{m}$ )
- Soil passed through a series of sieves
- e.g. No.10 sieve .... has 10 apertures per linear inch

### Sieve Analysis

ASTM No.	Metric
--	19.00 mm
--	16.00 mm
--	12.70 mm
--	9.50 mm
4	6.35 mm
10	4.75 mm
20	2.00 mm
40	850 μm
60	425 μm
100	250 μm
200	150 μm
	75 μm

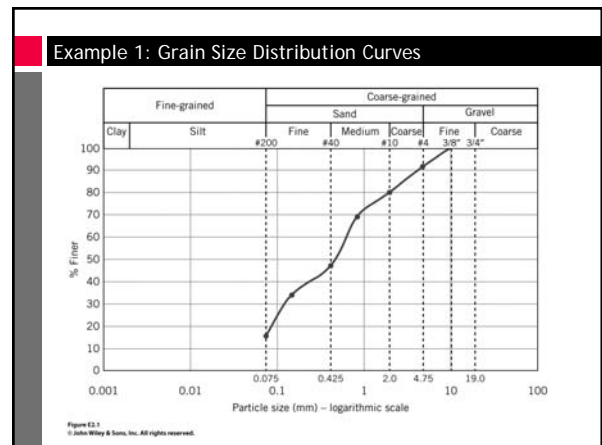


### Example 1

➤ A sieve analysis test was conducted on 650 gr of soil and the results are as follow:

Sieve #:	3/8"	4	10	20	40	100	200	pan
Mass retained (g)	0	53	76	73	142	85	120.5	99.8

➤ Plot the particle size distribution curve for this soil.



### Hydrometer Analysis

- Hydrometer test: used for smaller particles
- Analysis is based on the principle of sedimentation of soil particles in water
- The soil particles settle in water at different velocities; depending on their shape, size and weight.

### Hydrometer Analysis

- Stoke's Law: velocity proportional to diameter (assuming all particles are sphere):

$$v = \frac{D^2(\rho_s - \rho_w)}{18\eta}$$

$v$ : velocity  
 $\rho_s$ : density of soil particles  
 $\rho_w$ : density of water  
 $\eta$ : viscosity of water  
 $D$ : diameter of soil particles

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

### Hydrometer Analysis

- Assuming density of water as 1 g/cm<sup>3</sup>:

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

*K*: Function of  $G_s$  and  $\eta$  (temperature dependent)  
*L*: distance  
*t*: time  
 $\eta$ : viscosity of water  
*D*: diameter of soil particles  
 $G_s$ : specific gravity of soil

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

### Hydrometer Analysis

- Fine grained soil is mixed with water to form a uniform suspension
- Density of the soil would change as particles settle in the suspension
- Rate of settlement of soil particles in the suspension (i.e. density change with time) is measured
- Stoke's Law is used to obtain the particle size distribution

### Variation of K with $G_s$ and Temperature

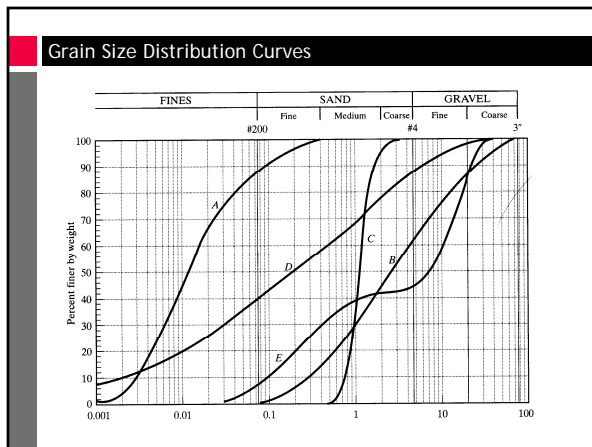
**Table 2.6** Variation of *K* with  $G_s$

Temperature (°C)	$G_s$						
	2.50	2.55	2.60	2.65	2.70	2.75	2.80
17	0.0149	0.0146	0.0144	0.0142	0.0140	0.0138	0.0136
18	0.0147	0.0144	0.0142	0.0140	0.0138	0.0136	0.0134
19	0.0145	0.0143	0.0140	0.0138	0.0136	0.0134	0.0132
20	0.0143	0.0141	0.0139	0.0137	0.0134	0.0133	0.0131
21	0.0141	0.0139	0.0137	0.0135	0.0133	0.0131	0.0129
22	0.0140	0.0137	0.0135	0.0133	0.0131	0.0129	0.0128
23	0.0138	0.0136	0.0134	0.0132	0.0130	0.0128	0.0126
24	0.0137	0.0134	0.0132	0.0130	0.0128	0.0126	0.0125
25	0.0135	0.0133	0.0131	0.0129	0.0127	0.0125	0.0123
26	0.0133	0.0131	0.0129	0.0127	0.0125	0.0124	0.0122
27	0.0132	0.0130	0.0128	0.0126	0.0124	0.0122	0.0120
28	0.0130	0.0128	0.0126	0.0124	0.0123	0.0121	0.0119
29	0.0129	0.0127	0.0125	0.0123	0.0121	0.0120	0.0118
30	0.0128	0.0126	0.0124	0.0122	0.0120	0.0118	0.0117

### Variation of L with Hydrometer Reading

**Table 2.7** Variation of *L* with hydrometer reading—ASTM 152-H hydrometer

Hydrometer reading	<i>L</i> (cm)	Hydrometer reading	<i>L</i> (cm)
0	16.3	26	12.0
1	16.1	27	11.9
2	16.0	28	11.7
3	15.8	29	11.5
4	15.6	30	11.4
5	15.5	31	11.2
6	15.3	32	11.1
7	15.2	33	10.9
8	15.0	34	10.7
9	14.8	35	10.6
10	14.7	36	10.4
11	14.5	37	10.2
12	14.3	38	10.1
13	14.2	39	9.9
14	14.0	40	9.7
15	13.8	41	9.6
16	13.7	42	9.4
17	13.5	43	9.2
18	13.3	44	9.1
19	13.2	45	8.9
20	13.0	46	8.8
21	12.9	47	8.6
22	12.7	48	8.4
23	12.5	49	8.3
24	12.4	50	8.1
25	12.2	51	7.9



### Example 2

- In a hydrometer test, the results are as follow:
  - $G_s=2.6$
  - Temperature of water=24°
  - Hydrometer reading=43 at 60 min after the start of sedimentation
- What is the diameter of the smallest-size particle that have settled beyond the zone of measurement at that time?

### Grain Size Distribution Curves

- Well graded (poorly sorted)
  
- Poorly graded (well sorted)
  
- Gap-graded

### Grain Size Distribution Parameters

- **Coefficient of uniformity,  $C_u$**

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

- $D_{60}$  = grain diameter corresponding to 60% by weight passing,
- $D_{10}$  = grain diameter corresponding to 10% by weight passing.

- **Coefficient of curvature,  $C_c$**

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

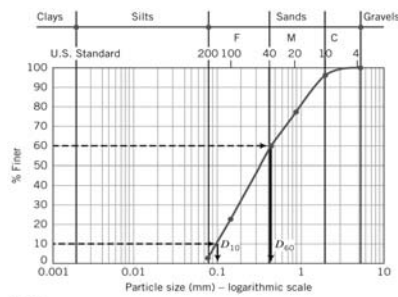
- $D_{30}$  = grain diameter corresponding to 30% by weight passing

### Grain Size Distribution Parameters

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

$$C_c = \frac{D_{30}^2}{(D_{60} \times D_{10})}$$

x% of the soil has particles smaller than  $D_x$



### Example 3

- Determine coefficient of uniformity and curvature for curve D.

