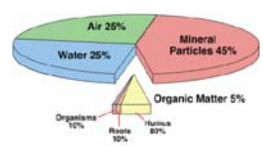
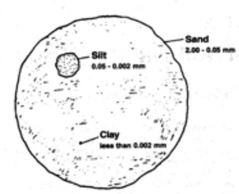
Mechanical Analysis of Soil

- Geotechnical engineering studies rock and soil supporting civil engineering systems.
- Knowledge from the field of soil science, materials science, mechanics, and hydraulics is applied to safely and economically design foundations, retaining walls, and other structures.
- Identification of soil properties presents challenges to geotechnical engineers.
- Unlike steel or concrete, the material properties and behavior of soil are difficult to predict due to its variability and limitation on investigation.

Mechanical Analysis of Soil

- As complex as it is, soil can be described simply.
- It consists of four major components: air, water, organic matter, and mineral matter.

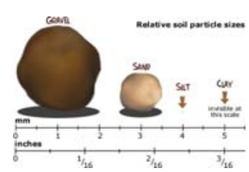




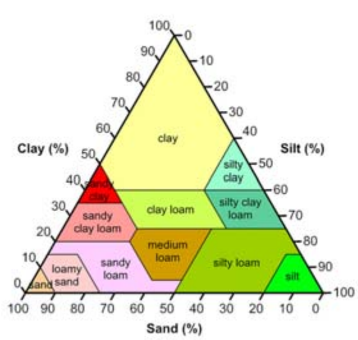
Mechanical Analysis of Soil

- The structure of soil determines its suitability for concrete, road subsurface, building foundation, or filter media.
- Soil has four constituent parts:
  - Sand is any soil particle larger than 0.06 millimeters (0.002 inches).
  - Silt is any soil particle from 0.002 - 0.06 millimeters.
  - Clay is any soil particle below 0.002 millimeters, including colloidal clay so small it does not settle out of suspension in water.

Mechanical Analysis of Soil



Mechanical Analysis of Soil



Mechanical Analysis of Soil

- The percentage distribution of those parts determines soil structure.
- Mechanical analysis is the determination of the size range of particles present in a soil, expressed as a percentage of the total dry weight.
- There are two methods generally used to find the particle-size distribution of soil:
  - (1) ***sieve analysis*** - for particle sizes larger than 0.075 mm in diameter, and
  - (2) ***hydrometer analysis*** - for particle sizes smaller than 0.075 mm in diameter.

Mechanical Analysis of Soil

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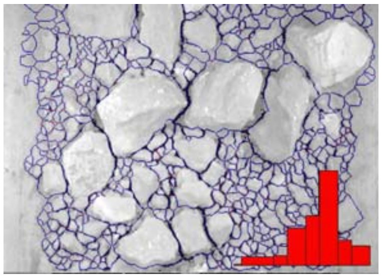
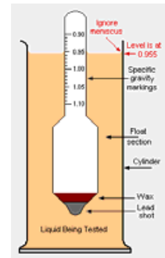


Mechanical Analysis of Soil

Sieve analysis

Hydrometer analysis



Sieve Analysis

Sieve analysis consists of shaking the soil sample through a set of sieves that have progressively smaller openings.

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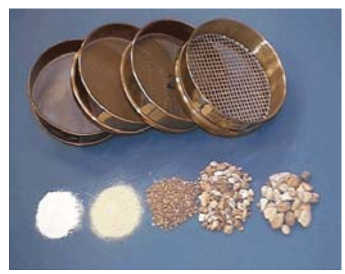


Sieve Analysis

Sieve Number	Opening (mm)
4	4.750
6	3.350
8	2.360
10	2.000
16	1.180
20	0.850
30	0.600
40	0.425
50	0.300
60	0.250
80	0.180
100	0.150
140	0.106
170	0.088
200	0.075
270	0.053

Sieve Analysis

- First the soil is oven dried and then all lumps are broken into small particle before they are passed through the sieves
- After the completion of the shaking period the mass of soil retained on each sieve is determined

Sieve Analysis

The results of sieve analysis are generally expressed in terms of the percentage of the total weight of soil that passed through different sieves

Sieve #	Diameter (mm)	Mass of soil retained on each sieve (g)	Percent retained (%)	Cumlative retained (%)	Percent finer (%)
10	2.000	0.00	0.[illegible]	0.00%	100.00%
16	1.180	9.90	2.[illegible]	2.20%	97.80%
30	0.600	24.66	5.[illegible]	7.68%	92.32%
40	0.425	17.60	3.[illegible]	11.59%	88.41%
60	0.250	23.90	5.[illegible]	16.90%	83.10%
100	0.150	35.10	7.[illegible]	24.70%	75.30%
200	0.075	59.85	13.[illegible]	38.00%	62.00%
Pan		278.99	62.[illegible]	100.00%	0.00%
	Sum =				

Sieve Analysis

The results of sieve analysis are generally expressed in terms of the percentage of the total weight of soil that passed through different sieves

Sieve #	Diameter (mm)	Mass of soil retained on each sieve (g)	Percent retained (%)	Cumlative retained (%)	Percent finer (%)
10	2.000	0.00	0.00%	0.00%	100.00%
16	1.180	9.90	2.20%	2.20%	97.80%
30	0.600	24.66	5.48%	7.68%	92.32%
40	0.425	17.60	3.91%	11.59%	88.41%
60	0.250	23.90	5.31%	16.90%	83.10%
100	0.150	35.10	7.80%	24.70%	75.30%
200	0.075	59.85	13.30%	38.00%	62.00%
Pan		278.99	62.00%	100.00%	0.00%
	Sum =	450.0			

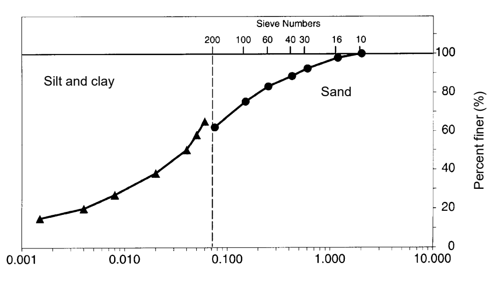
Particle-Size Distribution Curve

End of Part 1

Particle-Size Distribution Curve

- The results of mechanical analysis (sieve and hydrometer analyses) are generally presented by semi-logarithmic plots known as ***particle-size distribution curves.***
- The particle diameters are plotted in log scale, and the corresponding percent finer in arithmetic scale.

Particle-Size Distribution Curve



Recommended Procedure

1. Weigh to 0.1 g each sieve which is to be used
2. Select with care a test sample which is representative of the soil to be tested
3. Weigh to 0.1 a specimen of approximately 500 g of oven-dried soil
4. Sieve the soil through a nest of sieves by hand shaking. At least 10 minutes of hand sieving is desirable for soils with small particles.
5. Weigh to 0.1 g each sieve and the pan with the soil retained on them.
6. Subtract the weights obtained in step 1 from those of step 5 to give the weight of soil retained on each sieve.

   The sum of these retained weights should be checked against the original soil weight.

Calculations

- Percentage retained on any sieve:

$$= \frac{\text{weight of soil retained}}{\text{total soil weight}} \times 100\%$$

- Cumulative percentage retained on any sieve:

$$= \sum \text{Percentage retained}$$

- Percentage finer than an sieve size:

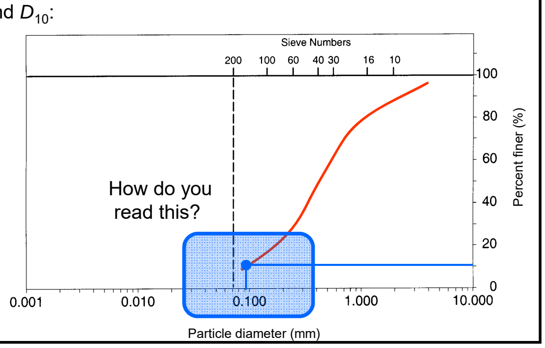
$$100\% - \sum \text{Percentage retained}$$

Effective Size, Uniformity Coefficient, and Coefficient of Gradation

- Three basic soil parameters can be determined from these grain-size distribution curves:
  - Effective size
  - Uniformity coefficient
  - Coefficient of gradation
- The diameter in the particle-size distribution curve corresponding to 10% finer is defined as the ***effective size***, or D_{10}.

Effective Size, Uniformity Coefficient, and Coefficient of Gradation

Find D_{10}:

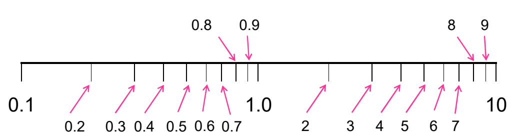


Reading Semi-Logarithmic Scales

- In science and engineering, a semi-log graph or semi-log plot is a way of visualizing data that are changing with an exponential relationship.
- One axis is plotted on a logarithmic scale.
- This kind of plot is useful when one of the variables being plotted covers a large range of values and the other has only a restricted range
- The advantage being that it can bring out features in the data that would not easily be seen if both variables had been plotted linearly.

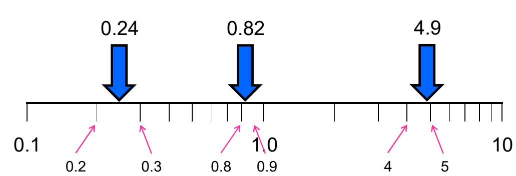
Reading Semi-Logarithmic Scales

- To facilitate use with logarithmic tables, one usually takes logs to base 10 or *e*
- Let's look at the log scale:



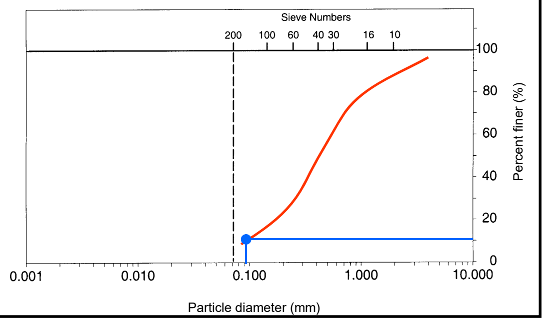
Reading Semi-Logarithmic Scales

- To facilitate use with logarithmic tables, one usually takes logs to base 10 or *e*
- Let's look at some values on a log scale and practice interpolation values:

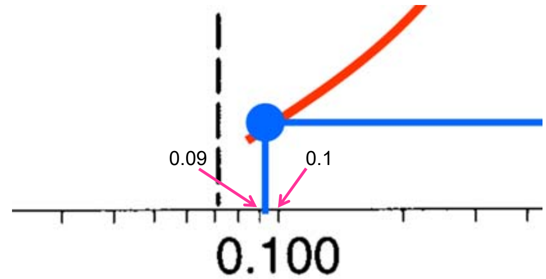


Effective Size, Uniformity Coefficient, and Coefficient of Gradation

Find D_{10}:



Effective Size, Uniformity Coefficient, and Coefficient of Gradation



D_{10} = 0.093 mm

Effective Size, Uniformity Coefficient, and Coefficient of Gradation

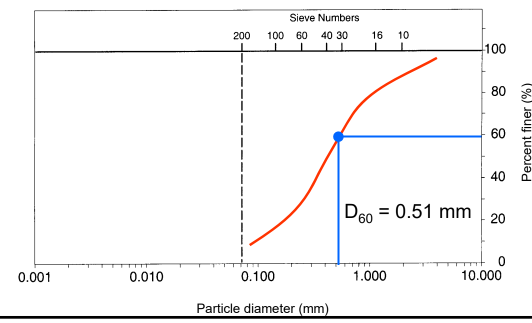
The ***uniformity coefficient*** is given by the relation

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

where D_{60} is the diameter corresponding to 60% finer in the particle-size distribution

Effective Size, Uniformity Coefficient, and Coefficient of Gradation

Find D_{60}:



Effective Size, Uniformity Coefficient, and Coefficient of Gradation

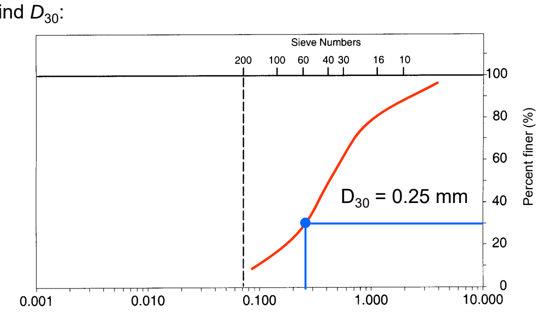
The ***coefficient of gradation*** may he expressed as

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

where D_{30} is the diameter corresponding to 30% finer in the particle-size distribution

Effective Size, Uniformity Coefficient, and Coefficient of Gradation

Find D_{30}:



Effective Size, Uniformity Coefficient, and Coefficient of Gradation

For the particle-size distribution curve we just used, the values of D_{10}, D_{30}, and D_{60} are:

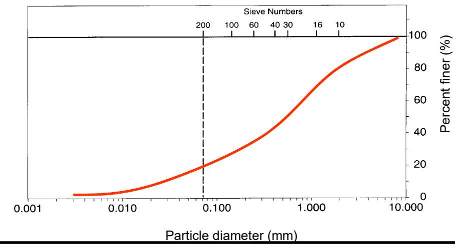
D_{10} = 0.093 mm D_{30} = 0.25 mm D_{60} = 0.51 mm

$$C_u = \frac{D_{60}}{D_{10}} = \frac{0.51\ mm}{0.093\ mm} = 5.5$$

$$C_c = \frac{D_{30}^{\ 2}}{D_{10} \times D_{60}} = \frac{(0.25\ mm)^2}{0.51\ mm \times 0.093\ mm} = 1.3$$

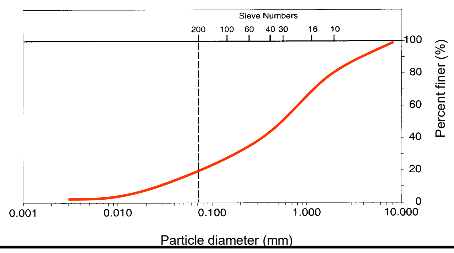
Effective Size, Uniformity Coefficient, and Coefficient of Gradation

- 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.



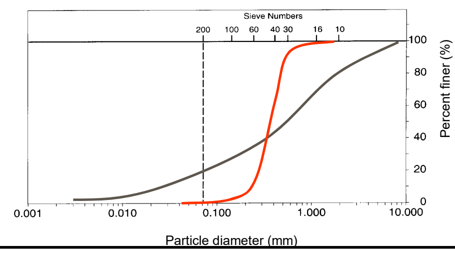
Effective Size, Uniformity Coefficient, and Coefficient of Gradation

- This particle-size distribution represents a soil in which the particles are distributed over a wide range, termed ***well graded***



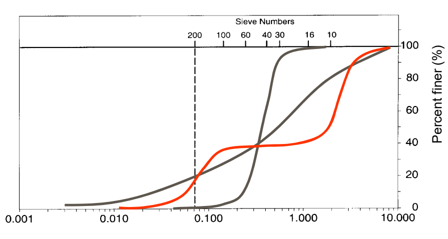
Effective Size, Uniformity Coefficient, and Coefficient of Gradation

- This particle-size distribution represents a type of soil in which most of the soil grains are the same size. This is called a ***uniformly graded*** soil.



Effective Size, Uniformity Coefficient, and Coefficient of Gradation

- This particle-size distribution represents such a soil. This type of soil is termed ***gap graded***.



Particle-Size Distribution Curve

End of Part 2

Example Sieve Analysis

- From the results of a sieve analysis, shown below, determine:
  - (a) the percent finer than each sieve and plot a grain-size distribution curve,
  - (b) D_{10}, D_{30}, D_{60} from the grain-size distribution curve,
  - (c) the uniformity coefficient, C_u, and
  - (d) the coefficient of gradation, C_c.

Sieve Number	Diameter (mm)	Mass of soil retained on each sieve (g)
4	4.750	28
10	2.000	42
20	0.850	48
40	0.425	128
60	0.250	221
100	0.150	86
200	0.075	40
Pan	—	24

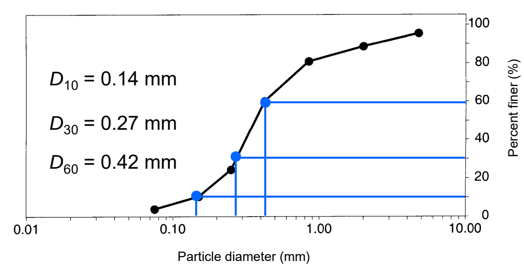
Example Sieve Analysis

Sieve Number	Diameter (mm)	Mass of soil retained on each sieve (g)
4	4.750	28
10	2.000	42
20	0.850	48
40	0.425	128
60	0.250	221
100	0.150	86
200	0.075	40
Pan	—	24

Example Sieve Analysis

Sieve Number	Mass of soil retained on each sieve (g)	Percent retained on each sieve (%)	Cumulative percent retained on each sieve (%)	Percent finer (%)
4	28	4.54	4.54	95.46
10	42	6.81	11.35	88.65
20	48	7.78	19.13	80.87
40	128	20.75	39.88	60.12
60	221	35.82	75.70	24.30
100	86	13.93	89.63	10.37
200	40	6.48	96.11	3.89
Pan	24	3.89	100.00	0

Example Sieve Analysis



Example Sieve Analysis

For the particle-size distribution curve we just used, the values of D_{10}, D_{30}, and D_{60} are:

D_{10} = 0.14 mm D_{30} = 0.27 mm D_{60} = 0.42 mm

$$C_u = \frac{D_{60}}{D_{10}} = \frac{0.42\ mm}{0.14\ mm} = 3.0$$

$$C_c = \frac{D_{30}^{\ 2}}{D_{10} \times D_{60}} = \frac{(0.27 mm)^2}{0.42\ mm \times 0.14\ mm} = 1.2$$

Mechanical Analysis of Soil

Any Questions?