MEASUREMENTS OF MATERIAL PROPERTIES

Soil Properties

1. Physical properties
2. Index Properties
3. Hydraulic Properties
4. Mechanical Properties

Index Properties

Index Properties: *Used to classify the soil or to correlate with the mechanical properties.*

1. *Moisture Content vs. Unit Weight Relationship (Compaction)*
2. *Grain Size Distribution*
3. *Atterberg Limits or Consistency Limits (LL, PL SL)*
4. *Relative Density D_r*

Californian Bearing Ratio

5. *CBR or LBR*

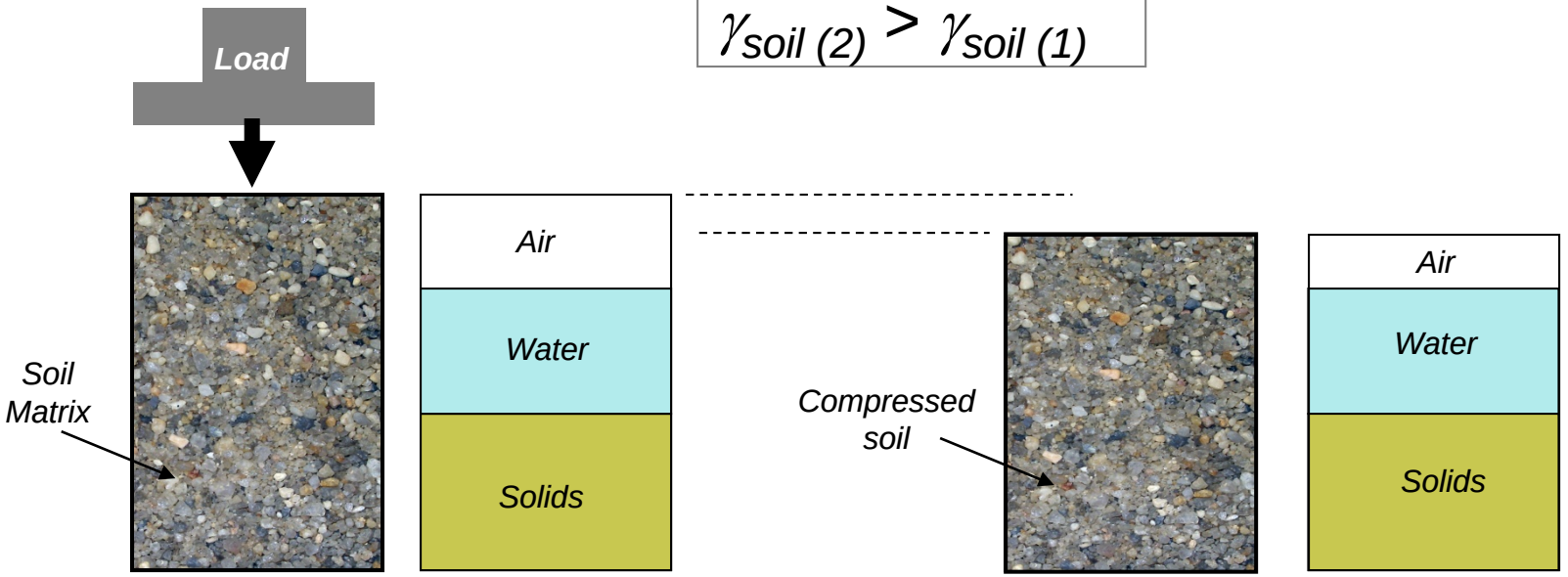
Limerock Bearing Ratio

Soil Compaction

***Definition**:*

Soil compaction is defined as the method of mechanically increasing the density of soil by reducing volume of air.

$$\gamma_{soil\ (2)} > \gamma_{soil\ (1)}$$

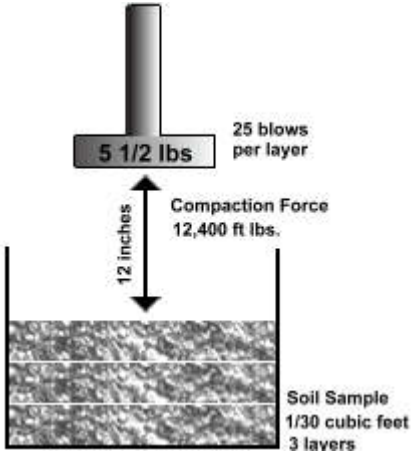


$$\gamma_{soil\ (1)} = \frac{W_{T1}}{V_{T1}}$$

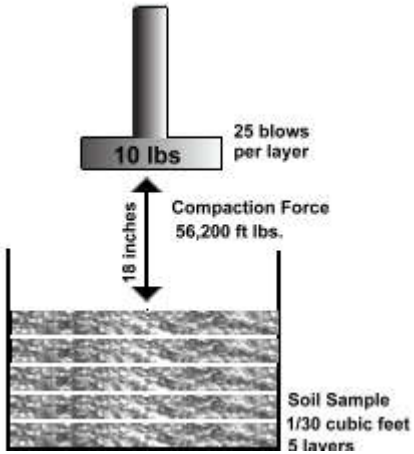
$$\gamma_{soil\ (2)} = \frac{W_{T1}}{V_{T2}}$$

Soil Compaction in the Lab:

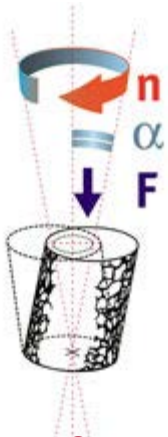
1- Standard Proctor Test
2- Modified Proctor Test
3- Gyratory Compaction



Standard Proctor Test



Modified Proctor Test



Gyratory Compaction

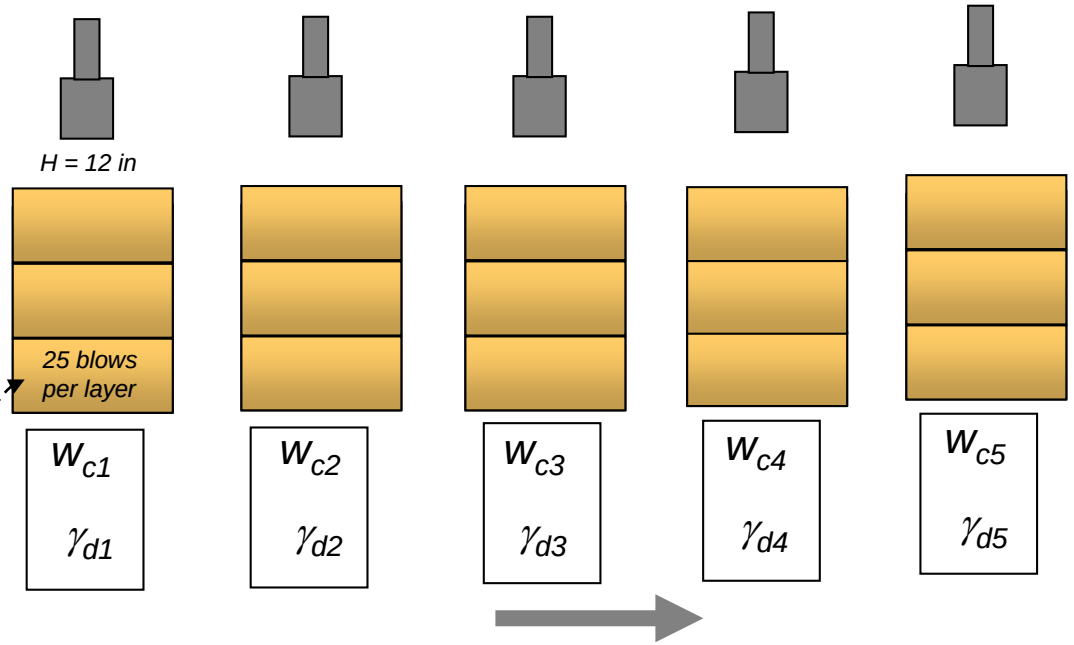
Soil Compaction in the Lab:

1- Standard Proctor Test

$$\gamma_{dry} = \frac{G_s \gamma_w}{1 + e}$$

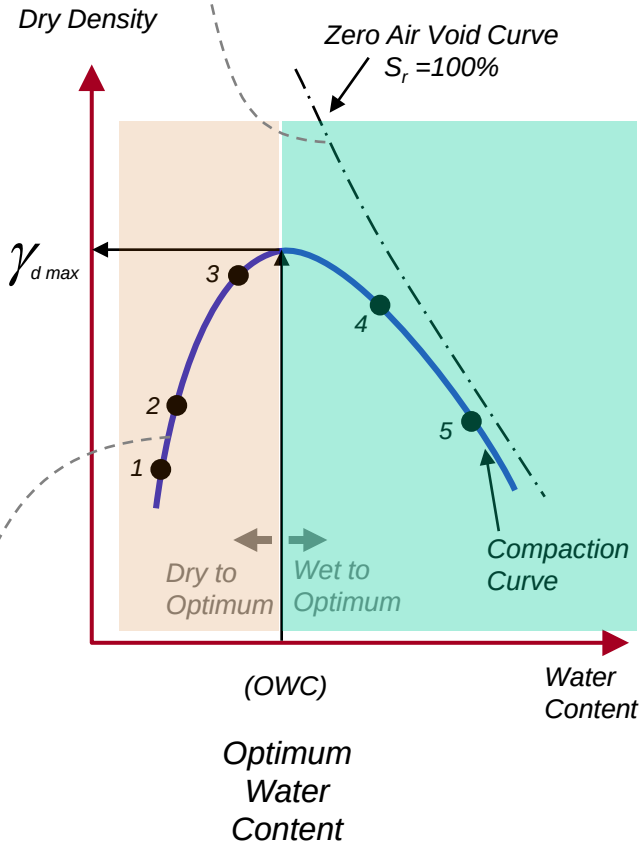
$$\gamma_{ZAV} = \frac{G_s \gamma_w}{1 + \frac{W_c G_s}{S_r}}$$

5.5 pound hammer



Increasing Water Content

4 inch diameter compaction mold.
(V = 1/30 of a cubic foot)



$$\gamma_{dry} = \frac{\gamma_{wet}}{1 + \frac{W_c\%}{100}}$$

Soil Compaction in the Lab:

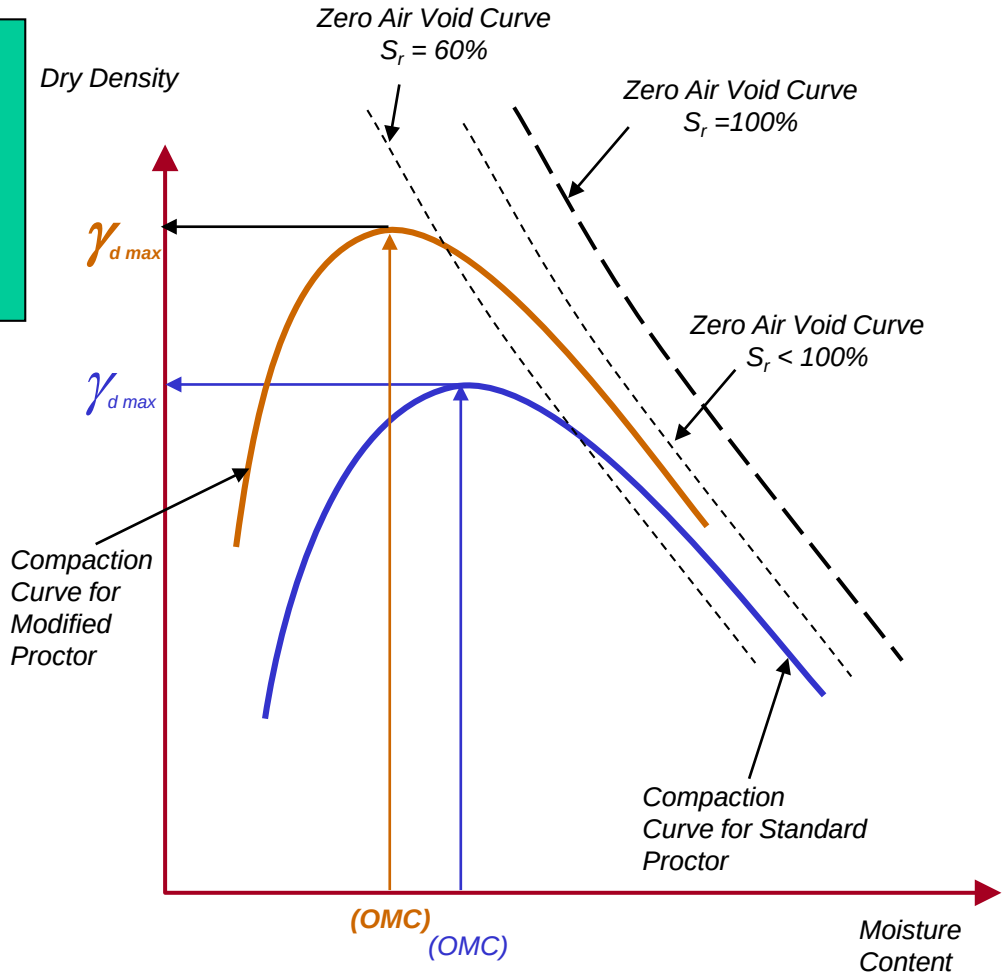
1- Standard Proctor Test

ASTM D-698 or AASHTO T-99

Energy = 12,375 foot-pounds per cubic foot

2- Modified Proctor Test ASTM D-1557 or AASHTO T-180

Energy = 56,520 foot-pounds per cubic foot



$$\text{Energy} = \frac{\text{Number of blows per layer x Number of layers x Weight of hammer x Height of drop hammer}}{\text{Volume of mold}}$$

Soil Compaction in the Field:

1- Rammers

2- Vibratory Plates

3- Smooth Rollers

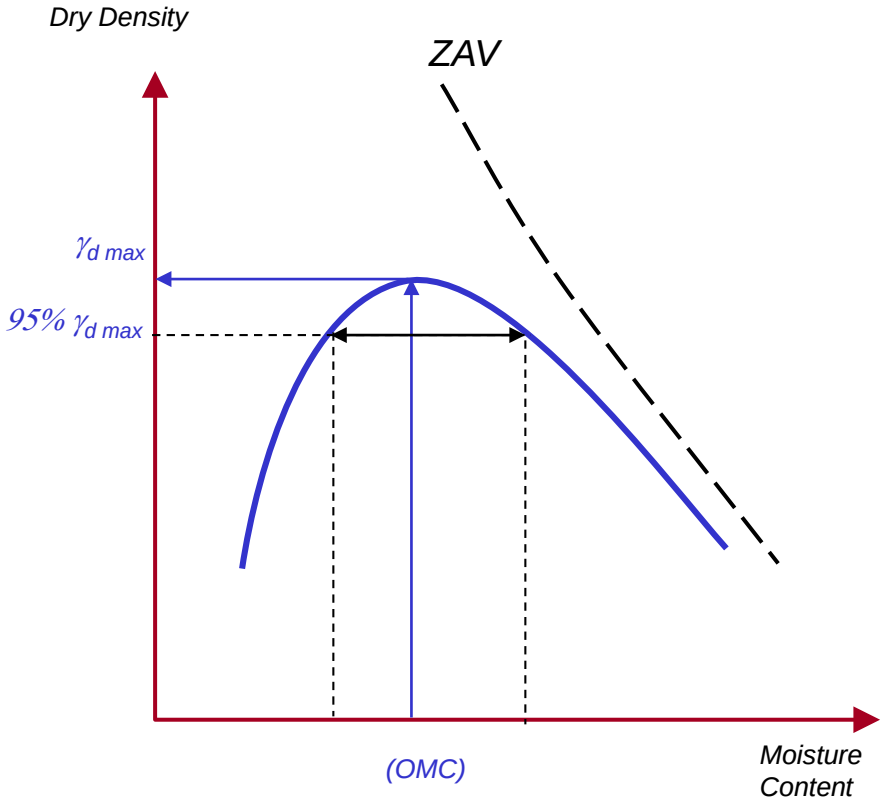
4- Rubber-Tire

5- Sheep foot Roller

6- Dynamic Compaction

Field Soil Compaction

Because of the differences between lab and field compaction methods, the maximum dry density in the field may reach 90% to 95%.



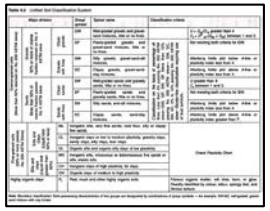
Index Properties

Grain Size Distribution
Atterberg Limits
&
Soil Classification Systems

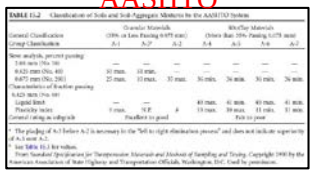
Soil Classification

The separation of soil into classes or groups each having similar characteristics and potentially similar behaviour

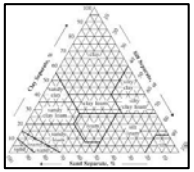
Unified Soil Classification System



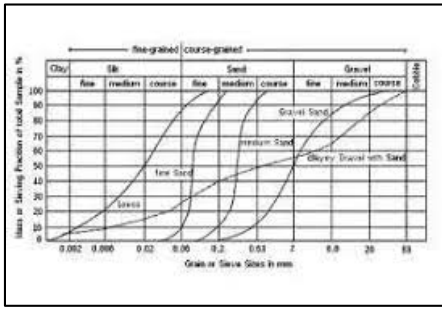
AASHTO



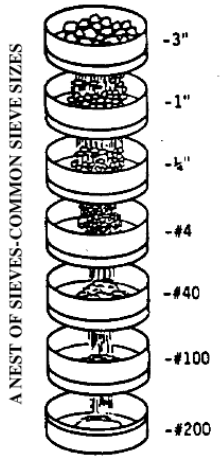
USDA Soil Textural Classification System



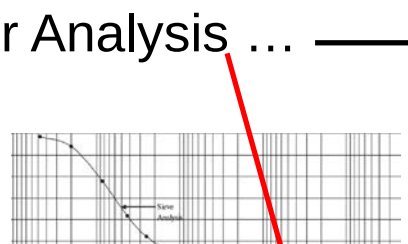
Grain Size Distribution

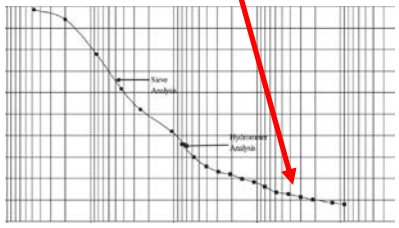


- Few simple (routine) tests are used to classify soils.
  - Gradation …… Sieve Analysis
  - Atterberg Limits ……..
  - Hydrometer Analysis …

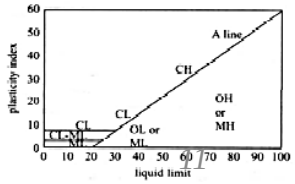


Liquid Limit
Plastic Limit
Plasticity Index





Casagrande Chart



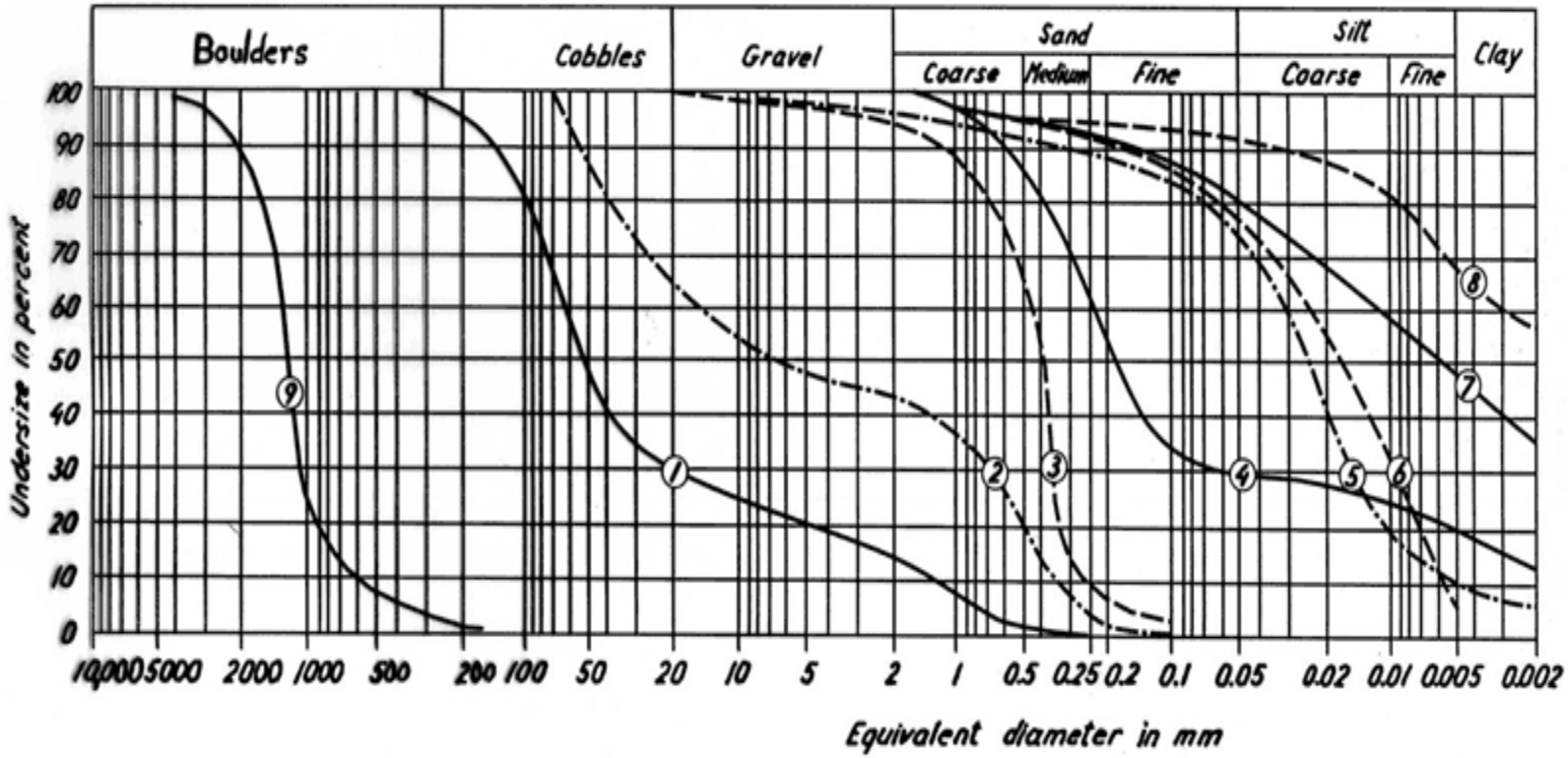


Figure 5.3. Particle-size distribution curves for sediments in Czechoslovakia (Bazant, 1979): 1. Vltava River gravel; 2. "Gap-graded" gravel; 3. Letna terrace, uniform sand; 4. Pankvac terrace, gap-graded clayey sand; 5. Micovna loess; 6. Hodonin silt; 7. Ruzyne clay; 8. Branany bentonite; 9. Quartzite talus from Boulder Mountain, Black Hills, South Dakota.

Computing CU and CC

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

Coefficient of Uniformity

High Values Indicate Well-Graded Soil

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

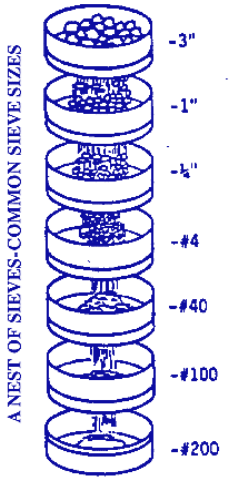
Coefficient of Curvature

Values Between 1-3 Indicate Well-Graded Soil

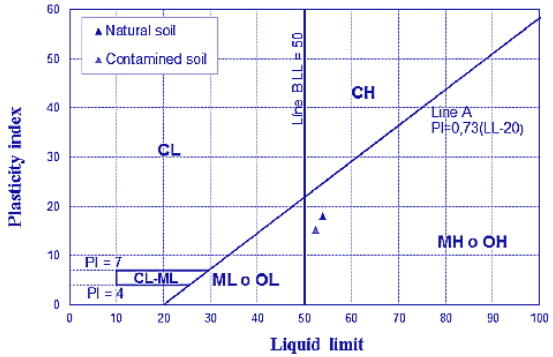
Soil Classification Systems

- USCS…….
- AASHTO……..
- USDA……..
- FAA……..
- MIT
- ASTM

Unified Soil Classification System



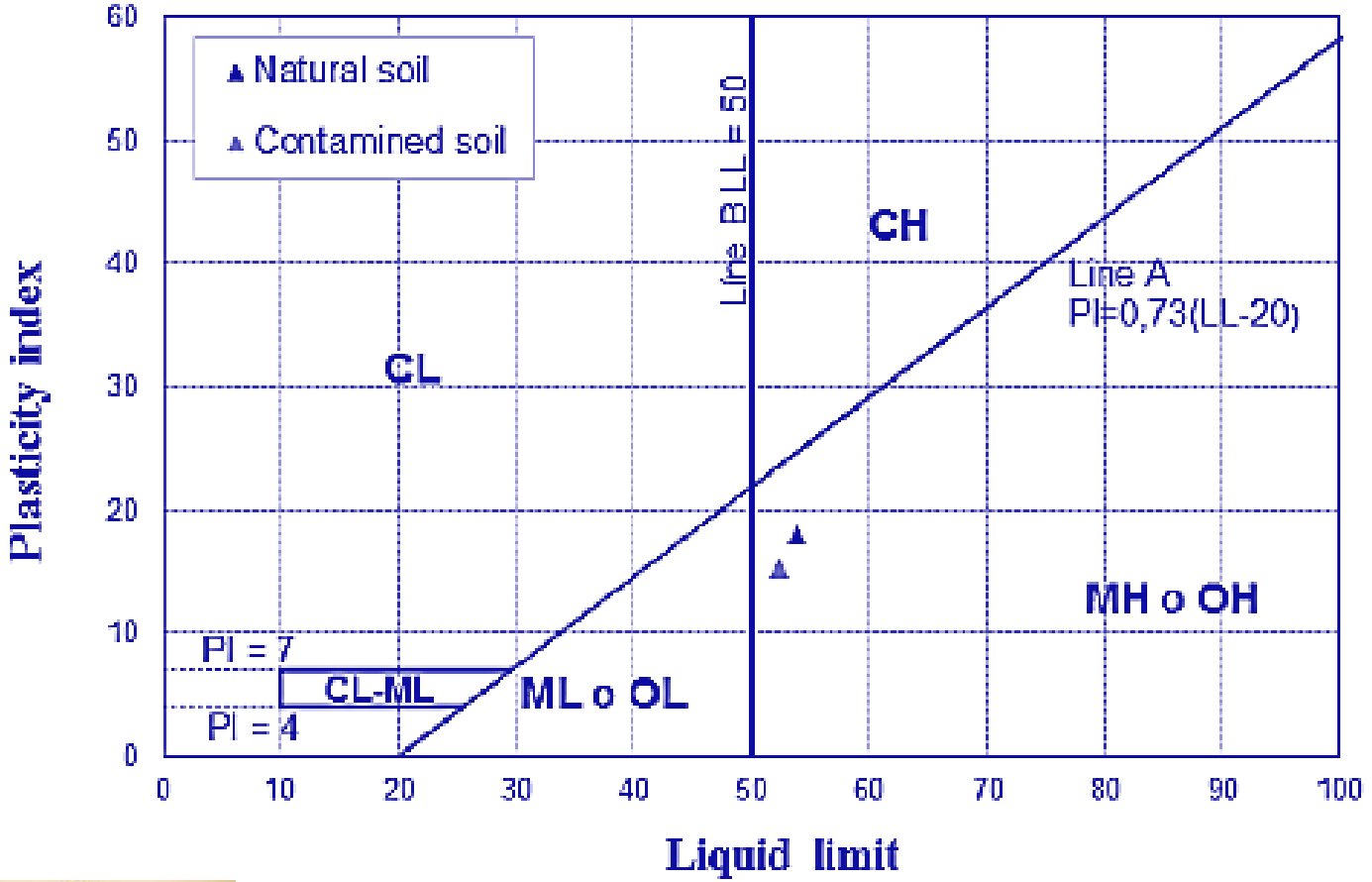
Liquid Limit
Plastic Limit
Plasticity Index



UNIFIED SOIL CLASSIFICATION
(Including Identification and Description)

Major Divisions			Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)			Information Required for Describing Soils
1	2		3	4	5			6
Coarse-grained Soils More than half of material is *larger* than No. 200 sieve size. The No. 200 sieve size is about the smallest visible to the naked eye.	Gravels More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the ¼-in. size may be used as equivalent to the No.4 sieve size)	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixture, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.			For undisturbed soils add information on stratification, degree of compactness, cementation, moisture condition, and drainage characteristics. Give typical name; indicate approximate percentages of sand and gravel, maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses. Example: Silty sand, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains, coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).
			GP	Poorly graded gravels or gravel-sand mixture, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.			
		Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-and-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).			
			GC	Clayey gravels, gravel-and-clay mixtures.	Plastic fines (for identification procedures see CL below).			
	Sands More than half of coarse fraction is smaller than No.4 sieve size.	Clean Sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.			
			SP	Poorly graded sands or gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.			
		Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).			
			SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).			
Fine-grained Soils More than half of material is *smaller* than No. 200 sieve size.					Identification Procedure on Fraction Smaller than No. 40 Sieve Size.			
					Dry Strength (Crushing Characteristics)	Dilatancy (Reaction to shaking)	Toughness (Consistency near PL)	
	Silts and Clays Liquid limit is less than 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	None to slight	Quick to slow	None	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions Give typical name; indicate degree and character of plasticity; amount and maximum size of coarse grains; color in wet condition; odor, if any; local or geologic name and other pertinent descriptive information; and symbol in parentheses. Example: Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (ML)
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	None to very slow	Medium	
	Silts and Clays Liquid limit is greater than 50		OL	Organic silts and organic silty clays of low plasticity.	Slight to medium	Slow	Slight	
			MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium	Slow to none	Slight to medium	
			CH	Inorganic clays of high plasticity, fat clays.	High to very high	None	High	
			OH	Organic clays of medium to high plasticity, organic silts.	Medium to high	None to very slow	Slight to medium	
Highly Organic Soils			Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture			

Casagrande Chart



American Association of State Highway and Transportation Officials (AASHTO) soil classification system

Table 4.1 AASHTO Soil Classification System

General classification	*Granular materials (35% or less passing US No. 200 sieve)*			*Silt-clay materials (More than 35% passing US No. 200 sieve)*							
Group classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1a	A-1b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve analysis Percent passing											
US No. 10 (2 mm)	50 max										
US No. 40 (420 μ)	30 max	50 max	51 max								
US No. 200 (75 μ)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing US No. 40 (420 μ) Liquid limit Plasticity index	6 max		Non-plastic	40 max 10 max	41 min 10 max	40 max 11 min	41 min 11 min	40 max 10 max	41 min 10 max	40 max 11 min	41 min 11 min
Group index	0		0	0		4 max		8 max	12 max	16 max	20 max
Usual types of significant constituent materials	Stone fragments gravel and sand		Fine Sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to good							Fair to poor			

Note: A-8 is identified by visual classification, and is not shown in the Table.

Classification procedure: Proceeding from left to right in the chart, the correct group will be found by the process of elimination. The first group from the left consistent with the test data is the correct classification. A-7 group is subdivided into A-7-5 or A-7-6 depending on the plastic limit. For $w_p < 30$, the classification is A-7-6; for $w_p \geq 30$, it is A-7-5.

Group Index (GI): $GI = 0.2\,a + 0.005\,a.c + 0.01\,b.d$

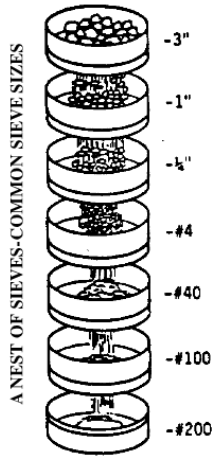
- a = %P #200 – 35
- b = %P #200 – 15
- c = LL – 40
- d = LL – 10

GI to the nearest whole number (integer)
Never negative ⟶ (0)
High GI ⟶ low quality material
EX: A-7-6(5), A-7-6(18)

USDA - Soil Texture Triangle

Grain Size Distribution

1- Sieve Analysis



2- Hydrometer Analysis

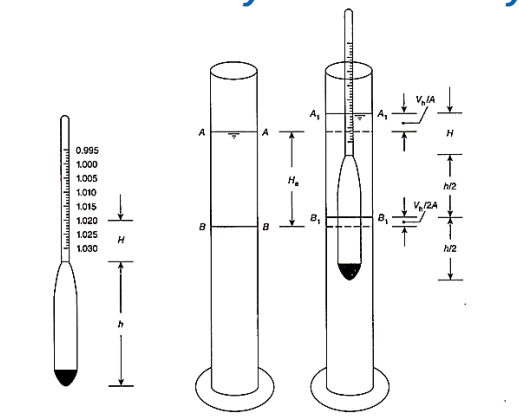
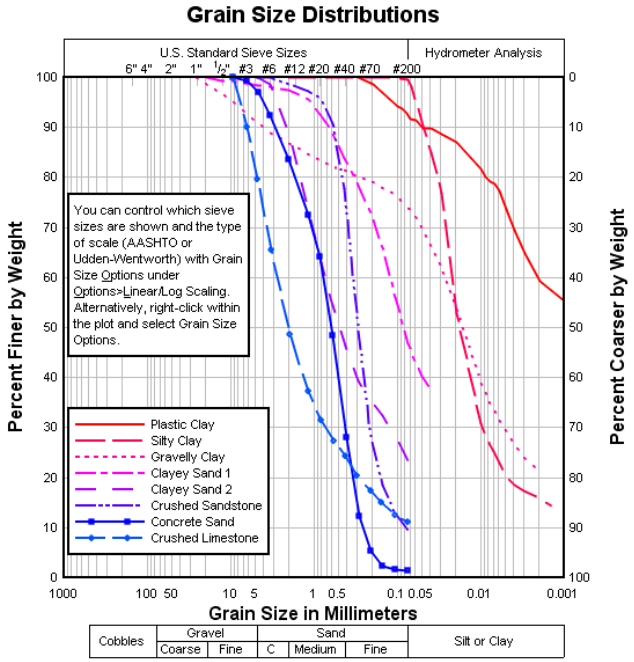
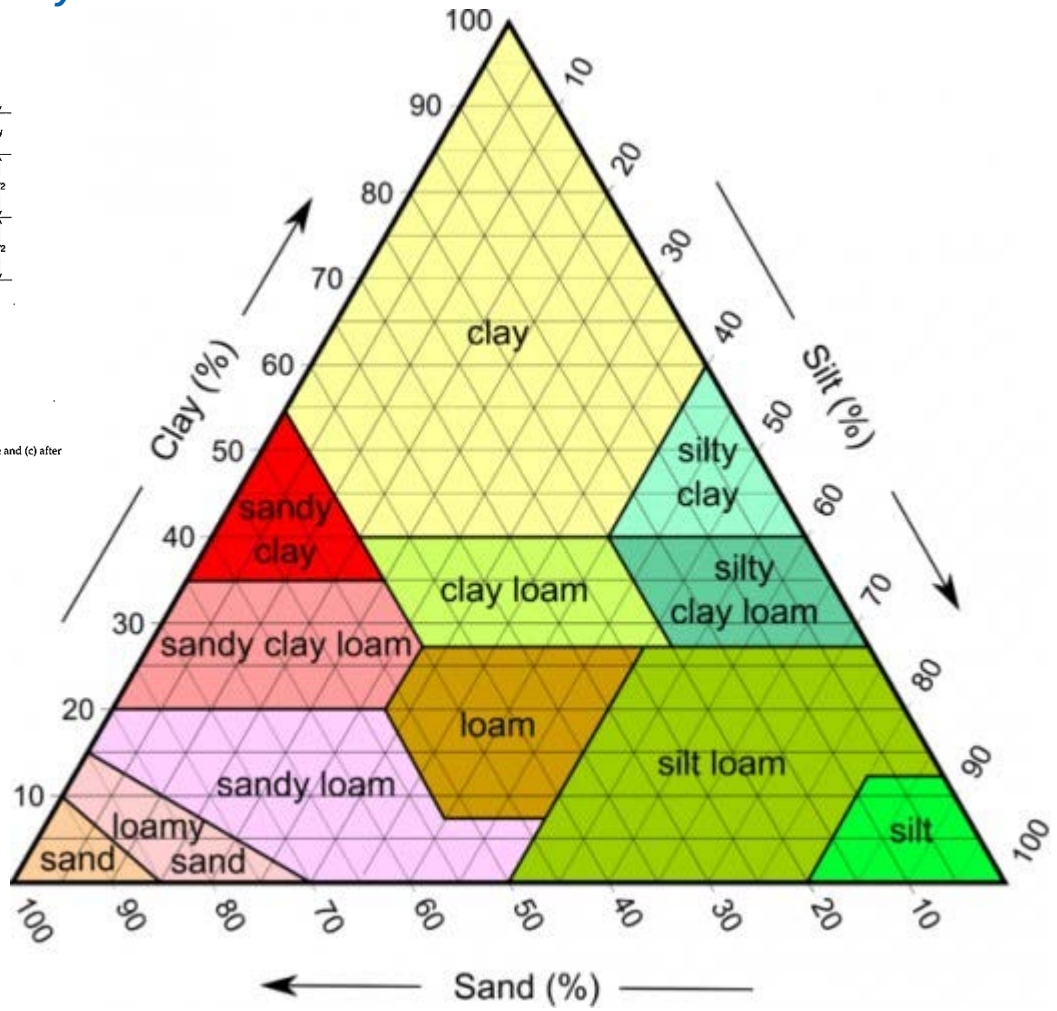


Figure 6.10 Hydrometer for sedimentation analysis: (a) Hydrometer, measuring jar (b) before and (c) after insertion of hydrometer.





USDA Soil Classification System

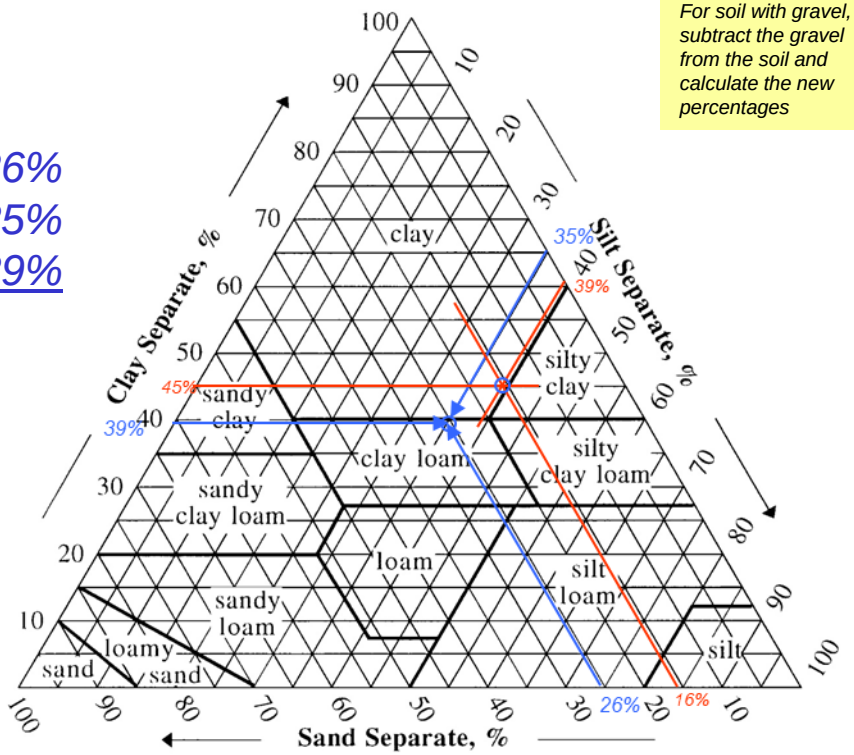
The Soil consists of Sand, Silt and Clay.

Example 1:

Given: Soil sample without gravel

Sand =	26%
Silt =	35%
Clay =	39%
Sum =	**100%**

Soil is ***Clay Loam***



For soil with gravel, subtract the gravel from the soil and calculate the new percentages

Example 2:

Given: Soil sample

Gravel =	13%
Sand =	14%
Silt =	34%
Clay =	39%
Sum =	**100%**

Drop the Gravel and recalculate the ratios.

Sand =	14%	New Soil Percentages
Silt =	34%	
Clay =	39%	
Sum	**87**	

Sand = 14/87 = 16%
Silt = 34/87 = 39%
Clay = 39/87 = 45%
Sum 100%

Soil is ***Clay***

COMPARISON OF PARTICLE SIZE SCALES