2. Soil Classification

Soil Mechanics
2015 - 2016

Soil Classification

- Is the arrangement of different soils with similar properties into groups → reflects soil's physical and mechanical properties → important for all design and construction purposes.
- Soil is classified according to characteristic properties such as:
  - Cohesion: cohesive soils (silt, clay) versus non-cohesive soils (sand, gravel, boulder).
  - Grain size: fine-grained soils (silt, clay) versus coarse-grained soils (sand, gravel, boulder).

Grain-Size Analysis

- By laboratory tests:
  1. Sieve analysis test
  2. Hydrometer test

Sieve Analysis Test

Sieve Analysis Test

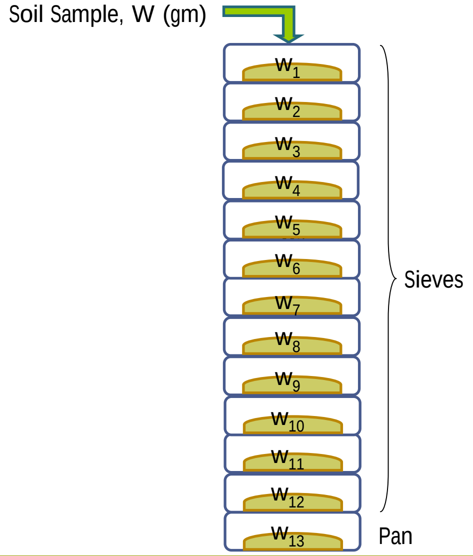
- Stack a set of sieves on top of each other with openings of decreasing sizes from top to bottom (a pan is placed below the stack).
- Sieves numbers and opening sizes:

Sieve No.	3 in	1 ½ in	¾ in	3/8 in	4	10
Opening Size (mm)	75	38	19	9.5	4.75	2

Sieve No.	20	40	60	100	140	200	PAN
Opening Size (mm)	0.85	0.425	0.25	0.15	0.106	0.075	

- Shake the sieves, manually or mechanically.
- After the soil is shaken, the mass of soil retained on each sieve is determined.

Sieve Analysis Test



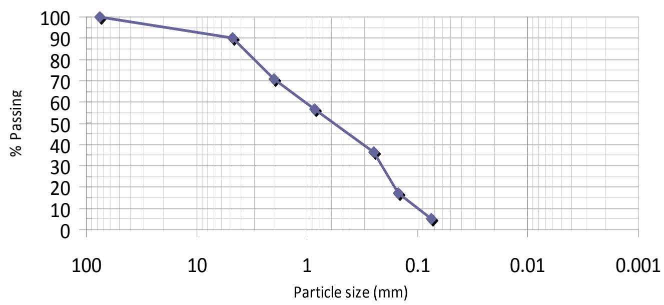
Sieve Analysis Test

Weight of sample = W gm

Sieve No.	3 in	1 ½ in		140	200
Opening size = Particle size (mm)	75	38	------------	0.106	0.075
Weight Retained on each sieve (gm)	w_1	w_2	------------	w_{11}	w_{12}
Total weight Retained (gm)	w_1	$w_1 + w_2$	------------	w_1 + ---+ w_{11}	w_1 + ---+ w_{12}
% Retained	{ }x100/W	{ }x100/W	------------	{ }x100/W	{ }x100/W
%Passing	100 -	100 -	------------	100 -	100 -

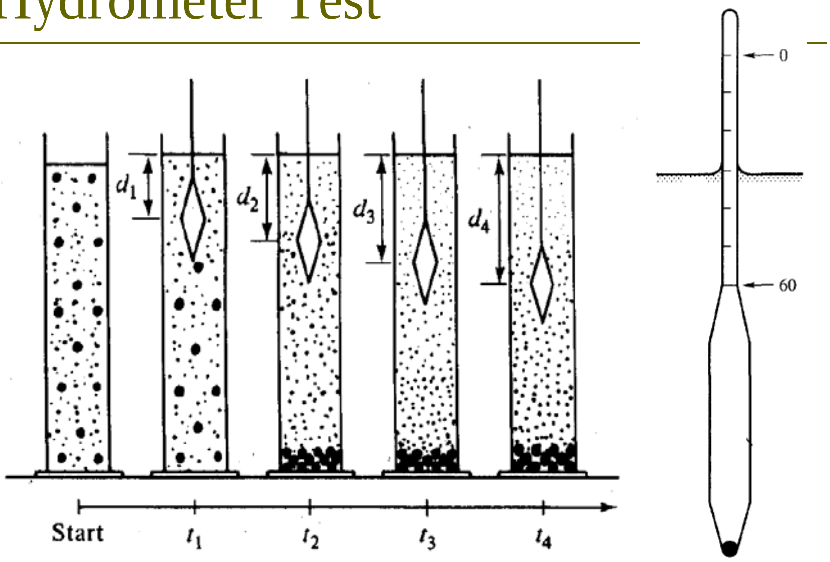
Sieve Analysis Test

- Plot % Passing versus Particle size (mm) "Grain-Size Distribution Curve, GSD"



- For coarse-grained soils, particle size > 0.075mm

Hydrometer Test



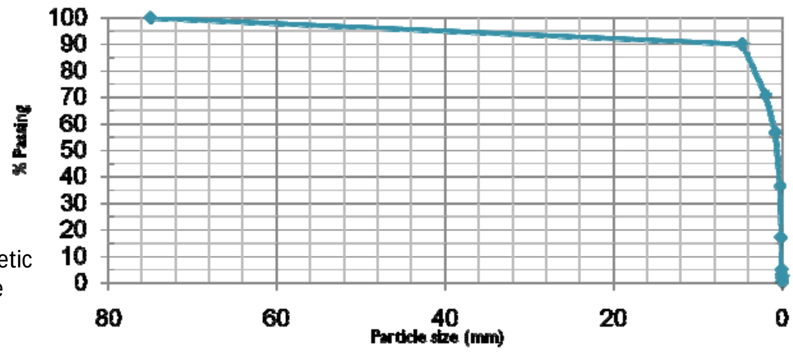
Hydrometer

Hydrometer Test

- For fine-grained soils, particle size < 0.075mm.
- Soil sample is mixed with water and additives in a graduated cylinder → soil suspension.
- Larger (heavier) particles settles faster than smaller (lighter) particles.
- The density of the suspension is indirectly measured at determined time intervals, which varies with time as particles settle.
- Computations are based on Stokes formula.
- Indirect measurement of particle size.

Grain Size Distribution Curve

	sieves							hydrometer		
Sieve No.	3 in	4	10	20	60	100	200			
Particle size (mm)	75	4.75	2.0	0.85	0.25	0.15	0.075	0.04	0.02	.01
%Passing	100.0	90.0	70.8	56.8	36.4	17.2	5.2	3.0	1.8	0.5

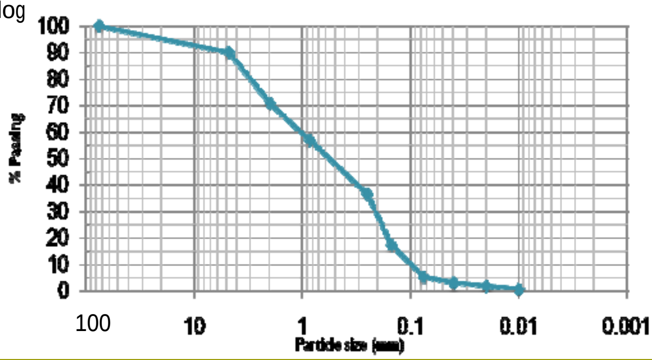


Arithmetic scale

Grain Size Distribution Curve

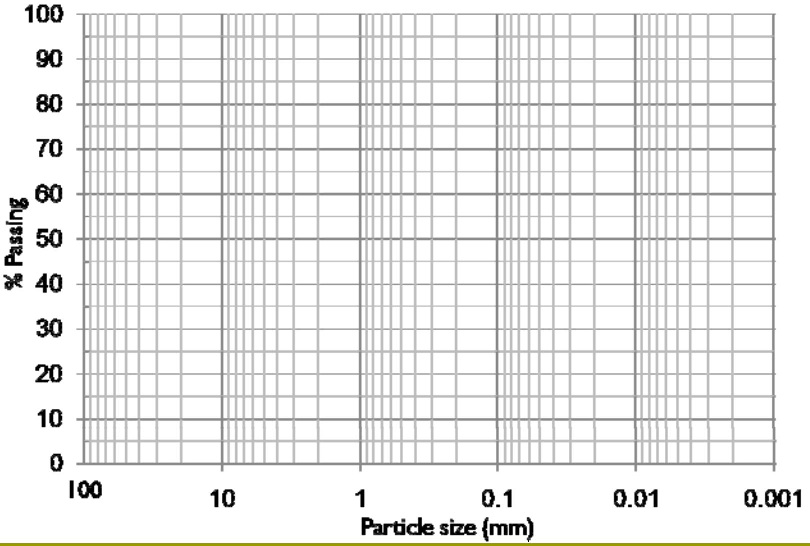
	sieves							hydrometer		
Sieve No.	3 in	4	10	20	60	100	200			
Particle size (mm)	75	4.75	2.0	0.85	0.25	0.15	0.075	0.04	0.02	.01
%Passing	100.0	90.0	70.8	56.8	36.4	17.2	5.2	3.0	1.8	0.5

GSD plotted on semi-log scale

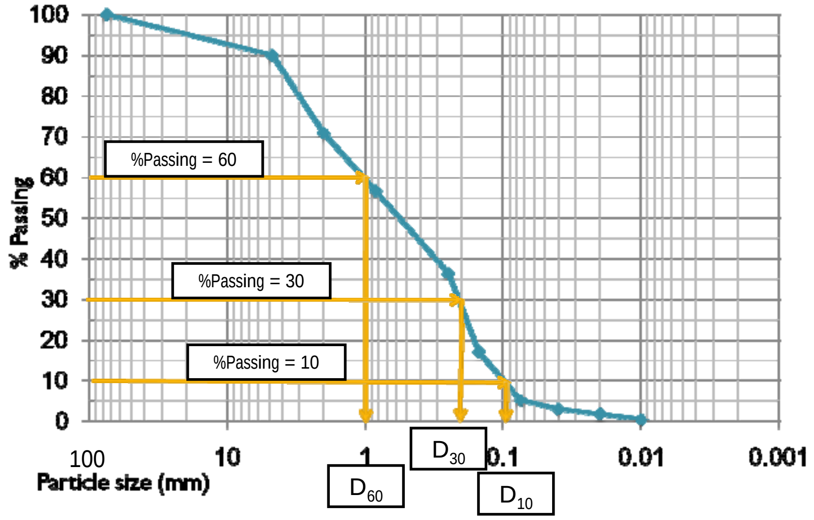


Dr. Manal A. Salem – Soil Mechanics

Semi-Log Paper



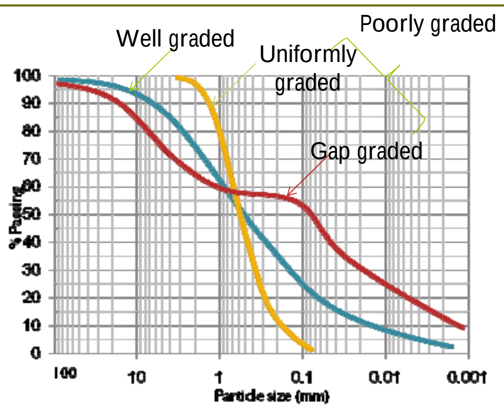
Grain Size Distribution



Grain Size Distribution

- D_{60} is the diameter in the GSD curve corresponding to 60% passing.
- D_{30} is the diameter in the GSD curve corresponding to 30% passing.
- D_{10} is the diameter in the GSD curve corresponding to 10% passing → "effective grain size".
- Uniformity coefficient (C_u) = D_{60}/D_{10}
- Curvature coefficient (C_c) = $(D_{30})^2/(D_{60}D_{10})$

Grain Size Distribution

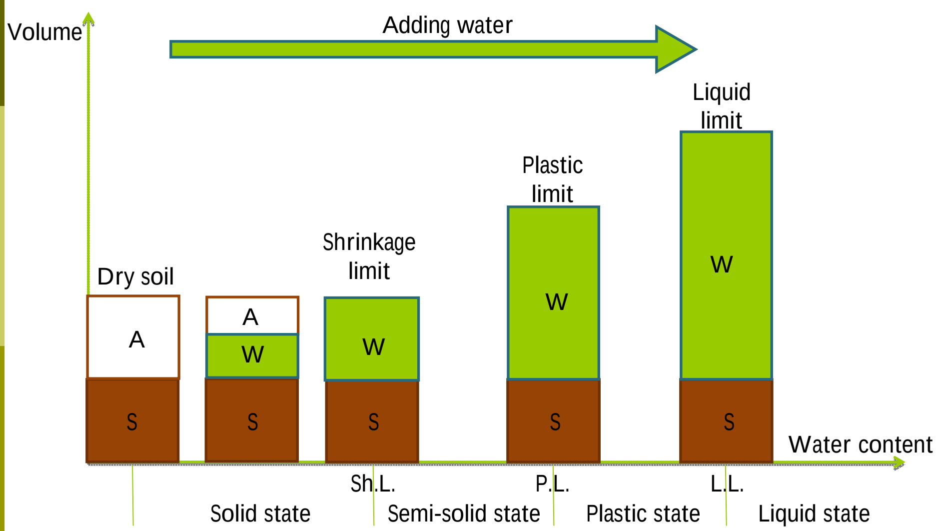


- Well graded sand, $C_u > 6$ and C_c = (1-3), otherwise, poorly graded
- Well graded gravel, $C_u > 4$ and C_c = (1-3), otherwise, poorly graded

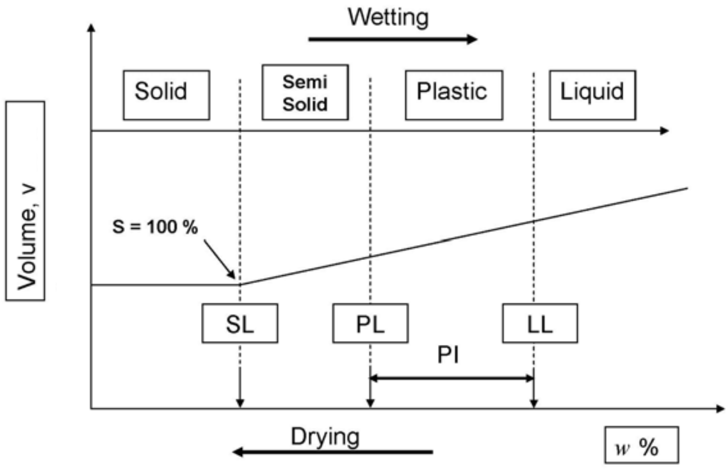
Consistency of Cohesive Soil

- Depends on the water content of the soil.
- At very low water contents, cohesive soil sample behaves more like a solid.
- At very high water contents, the same sample may flow like a liquid.
- Therefore, based on soil water content, cohesive soil may be divided into 4 basic states: solid, semi-solid, plastic, and liquid.
- The water contents separating these 4 states are named "Atterberg Limits"

Atterberg Limits



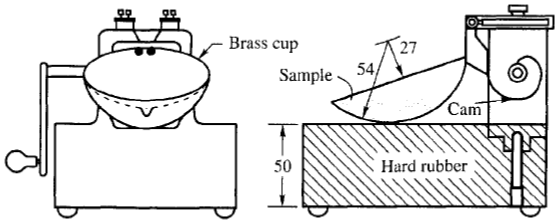
Atterberg Limits



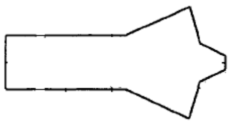
Atterberg Limits

- Shrinkage Limit (Sh.L., w_{Sh}):
  - Is the water content separating solid and semi-solid states
  - Is the maximum water content in solid sate
  - Is the minimum water content in semi-solid state
- Plastic Limit (P.L., w_P):
  - Is the water content separating semi solid and plastic states
  - Is the maximum water content in semi solid sate
  - Is the minimum water content in plastic state
- Liquid Limit (L.L., w_L):
  - Is the water content separating plastic and liquid states
  - Is the maximum water content in plastic sate
  - Is the minimum water content in liquid state
- Plasticity Index (P.I., I_P) = L.L. – P.L.
- Atterberg limits are determined through laboratory tests.

Liquid Limit Test

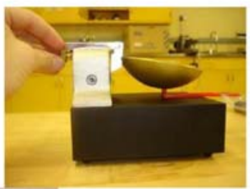


Liquid limit device



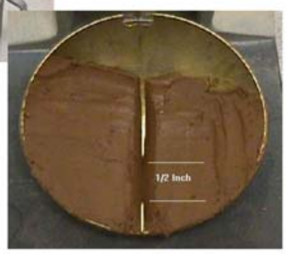
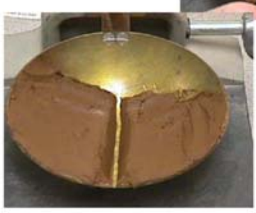
Grooving tool

Liquid Limit Test

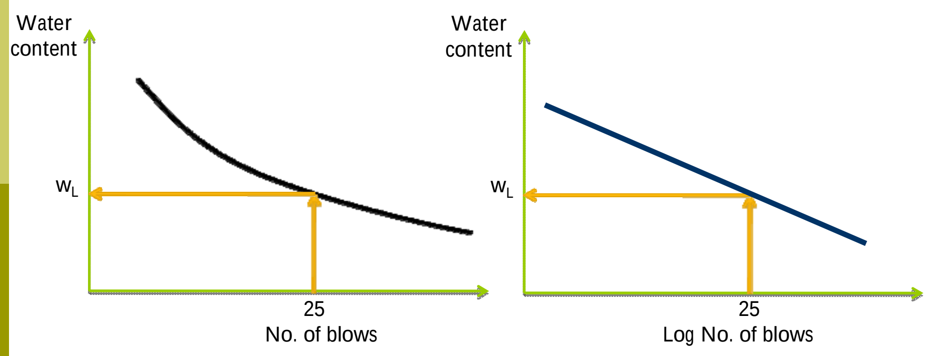
Liquid limit device

Grooving tool

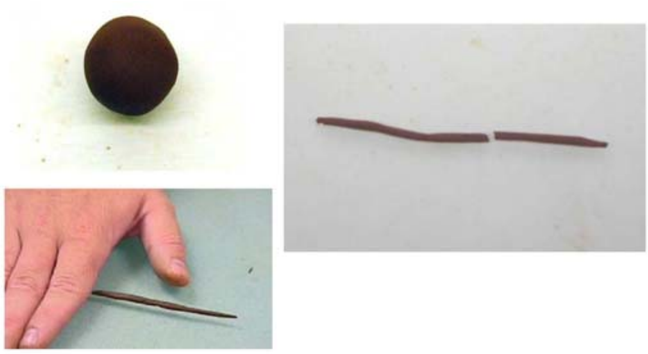
Liquid Limit Test

- The liquid limit is the water content at which a standard V-shaped groove cut in the soil will just close (0.5 inch) after 25 drops.



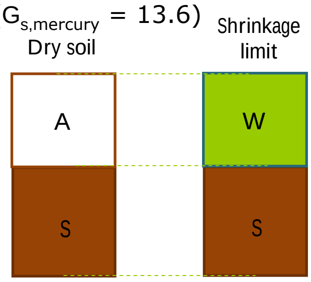
Plastic Limit Test

- The plastic limit is defined as the water content at which soil crumbles when rolled into threads 3 mm in diameter.



Shrinkage Limit Test

- Put soil sample in oven until it is completely dry, and get its weight (W_s).
- Shrinkage limit is the water content of this sample if it is saturated with water at the same volume.
- Measure the total volume of the oven-dried sample (V_T):
  - Submerging the sample in water after insulating it with paraffin wax
  - Submerging the sample in mercury ($G_{s,mercury}$ = 13.6)
- Calculations:
  - $V_s = W_s/(G_s\gamma_w)$
  - $V_v = V_T - V_s$
  - $W_w = V_v\gamma_w$
  - $Sh.L. = W_w/W_s$



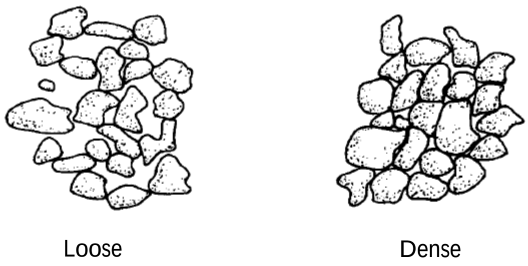
Consistency Index of Cohesive Soil

$$CI = \frac{w_L - w}{w_L - w_P}$$

CI	Soil Consistency
0 – 0.5	Very soft
0.5 – 0.625	Soft
0.625 – 0.75	Medium stiff
0.75 – 1.00	Stiff
1.00 – $w=w_{sh}$	Very stiff
$w<w_{sh}$	Hard

Egyptian Code

Relative density of coarse-grained soil



- Depends on the void ratio (e) of the soil.
- e_{max} is the maximum possible void ratio, loosest packing.
- e_{min} is the minimum possible void ratio, densest packing.

Relative density of coarse-grained soil

$$D_r(\%) = \frac{e_{\max} - e}{e_{\max} - e_{\min}} \times 100$$

D_r (%)	Soil Density
0 – 15	Very loose
15 – 35	Loose
35 - 65	Medium dense
65 – 85	Dense
85 - 100	Very dense

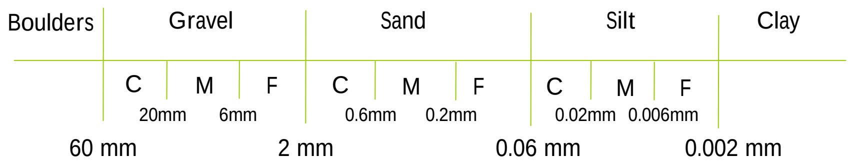
Egyptian Code

Soil Classification Systems

1. MIT Classification System
2. Unified Soil Classification System (USCS)

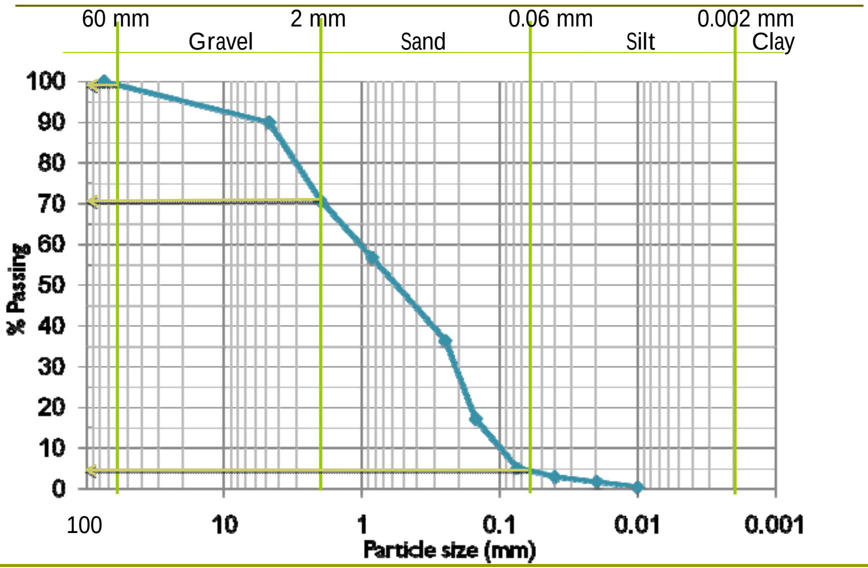
MIT Soil Classification System

- Based exclusively on grain size.
- Determined by performing sieve analysis and hydrometer tests.
- Gives each soil a "group name".



C: Coarse
M: Medium
F: Fine

MIT Soil Classification System



MIT Soil Classification System

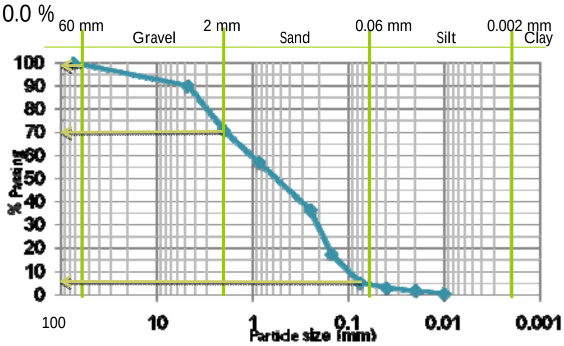
% Boulder = 100 - % Passing 60mm = 100 - 97 = 3 %

% Gravel = % Passing 60mm - % Passing 2mm = 97 – 70.8 = 26.2 %

% Sand = % Passing 2mm - % Passing 0.06mm = 70.8 – 6.0 = 64.8 %

% Silt = % Passing 0.06 mm - % Passing 0.002 mm = 6.0 – 0.0 = 6.0 %

% Clay = % Passing 0.002mm = 0.0 %



MIT Soil Classification System

- Soil Group Name:
  - 50 – 35 % : and
  - 35 – 15 % : adjective
  - 15 – 5 % : some
  - < 5 % : trace of

% Boulder = 3%

% Gravel = 27.2 %

% Sand = 65.8 %

% Silt = 5.0 %

% Clay = 0.0 %

→ Group Name: Gravelly SAND, some silt, trace boulders

Unified Soil Classification System

- Based on grain size and/or plasticity of soil.
- Need to have grain-size distribution curve and/or Atterberg limits.
- Gives each soil a "group symbol".
- Classifies soil into two main categories:
  1. Coarse-grained soil: with less than 50% passing through sieve No. 200.
  2. Fine-grained soil: with 50% or more passing through sieve No. 200.

Unified Soil Classification System

- Some or all of the following information must be known:
  1. % Fine grained soil (silt and clay) = % passing the No. 200 sieve.
  2. % Coarse grained soil (gravel and sand) = 100 - % passing the No. 200 sieve.
  3. % Gravel = 100 - % passing the No. 4 sieve.
  4. % Sand = % passing the No. 4 sieve - % passing the No. 200 sieve.
  5. Uniformity (C_u) and curvature (C_c) coefficients.
  6. Liquid and plastic limits of fine-grained soil (portion).

Unified Soil Classification System

- The following symbols are used:
  - G = Gravel
  - S = Sand
  - M = Silt
  - C = Clay
  - W = well graded
  - P = poorly graded
  - L = low plasticity (L.L. < 50%)
  - H = high plasticity (L.L. > 50%)

Unified Soil Classification System

% Passing sieve No. 200

< 50% — Coarse-grained soil

> 50% — Fine-grained soil

Use Plasticity Chart (A-line)

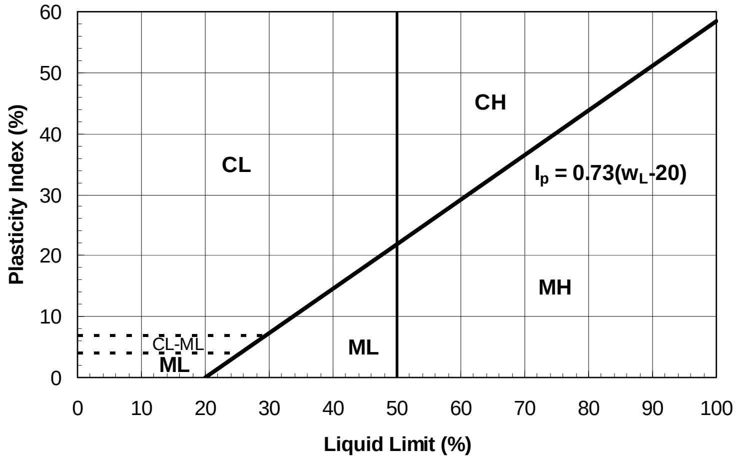
LL & PI

CH, CL

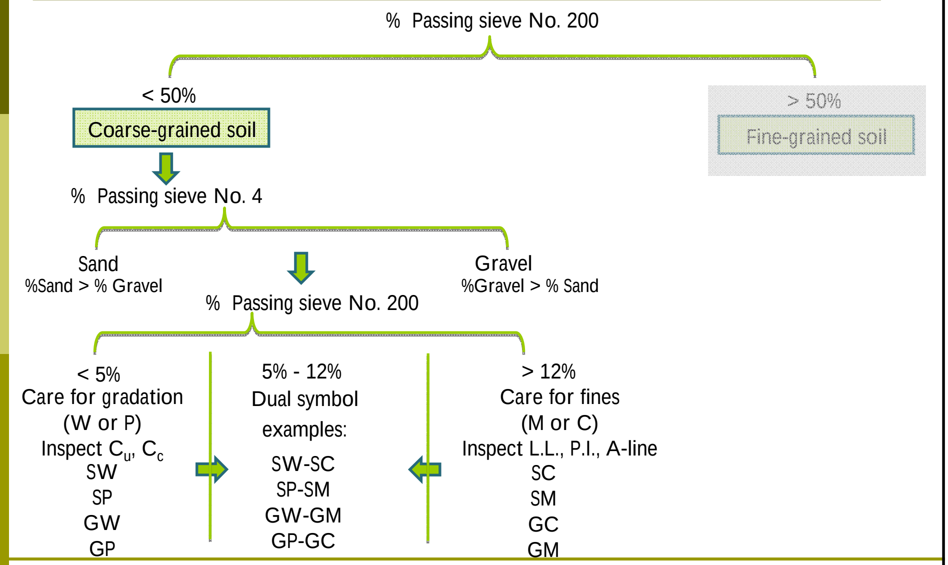
ML, MH

Unified Soil Classification System

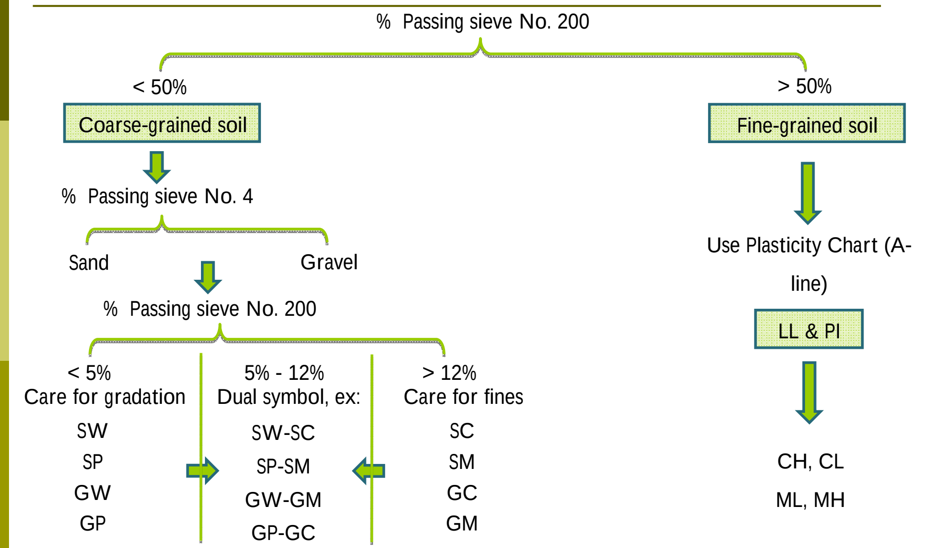
- Plasticity Chart (A-Line):



Unified Soil Classification System



USCS Summary Table



USCS Summary Table

Criteria for assigning group symbols				Group symbol
Coarse-grained soils More than 50% of retained on No. 200 sieve	**Gravels** More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[a]	$C_u \geq 4$ and $1 \leq C_c \leq 3$[c]	GW
			$C_u < 4$ and/or $1 > C_c > 3$[c]	GP
		Gravels with Fines More than 12% fines[a,d]	Use plasticity chart to determine M or C	GM GC
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[b]	$C_u \geq 6$ and $1 \leq C_c \leq 3$[c]	SW
			$C_u < 6$ and/or $1 > C_c > 3$[c]	SP
		Sands with Fines More than 12% fines[b,d]	Use plasticity chart to determine M or C	SM SC
Fine-grained soils 50% or more passes No. 200 sieve	Use Plasticity Chart			CL ML CH MH

[a]Gravels with 5 to 12% fine require dual symbols: GW-GM, GW-GC, GP-GM, GP-GC.
[b]Sands with 5 to 12% fines require dual symbols: SW-SM, SW-SC, SP-SM, SP-SC.
[c]$C_u = \frac{D_{60}}{D_{10}}$; $C_c = \frac{(D_{30})^2}{D_{60} \times D_{10}}$