

Methods of Classifying Soils

■ USDA Method

- Developed primarily for agricultural and surface soil purposes
- Not used often in soil mechanics

■ Unified Classification System

- Developed by Arthur Casagrande during World War II for the U.S. Army Corps of Engineers
- Most widely used classification system

■ AASHTO System

- Originally developed in the 1920's as the Bureau of Public Roads system
- Primarily aimed at classification for pavement purposes

- All methods similar, but differences are significant enough that they should be understood

Unified Classification System

Primary Characteristics

- G: gravels
- S: sands
- C: clays
- M: silts
- O: organic soils
- Pt: peat

SM

Gravel	- GW - Well graded - GP - Poorly graded - GM - Silty (mo) - GC - Clayey
Sand	- SW - Well graded - SP - Poorly graded - SM - Silty (mo) - SC - Clayey

Silt (mo)	- ML	} Low plasticity
Clay	- CL	
Organic	- OL	
		$w_L < 50$
Silt (mo)	- MH	} High plasticity
Clay	- CH	
Organic	- OH	
		$w_L > 50$

Peat

Secondary Characteristics

- W: well graded
- P: poorly graded
- M: silty (as opposed to a predominant silt in the left column)
- C: clayey (as opposed to a predominant clay in the left column)
- L: lean ($LL < 50$)
- H: fat ($LL > 50$)

Soil Classification Chart (Laboratory Method)

Table 4-9

Soil classification chart (laboratory method) (after ASTM D 2487)

Table 4-9 (Continued)

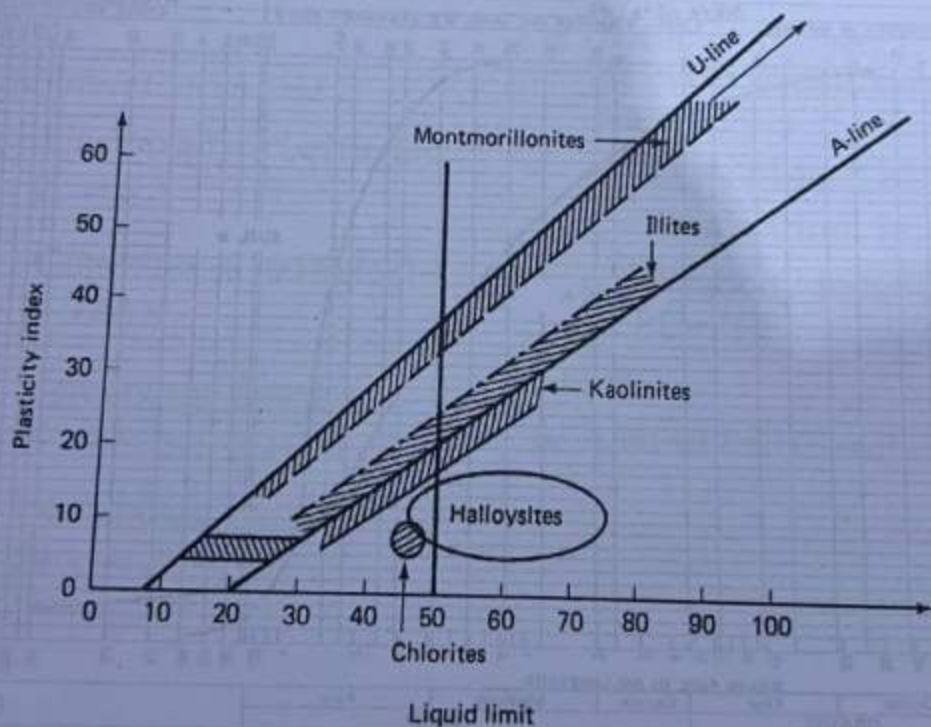
Soil classification chart (laboratory method) (after ASTM D 2487)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests ^a			Soil Classification	
			Group Symbol	Group Name
COARSE-GRAINED SOILS (Sands and Gravels) - more than 50% retained on No. 200 (0.075 mm) sieve				
FINE-GRAINED (Sils and Clays) - 50% or more passes the No. 200 (0.075 mm) sieve				
GRAVELS More than 50% of coarse fraction retained on No. 4 Sieve	CLEAN GRAVELS	$C_u \geq 6$ and $1 \leq C_c \leq 3$	GW	Well-graded gravel
		$C_u < 6$ and/or $1 > C_c > 3$	GP	Poorly-graded gravel
	GRAVELS WITH FINES	Fines classify as ML or MH	GM	Silty gravel ^{1,2,3}
		Fines classify as CL or CH	GC	Clayey gravel ^{1,2,3}
SANDS 50% or more of coarse fraction passes No. 4 Sieve	CLEAN SANDS	$C_u \geq 6$ and $1 \leq C_c \leq 3$	SW	Well-graded sand
		$C_u < 6$ and/or $1 > C_c > 3$	SP	Poorly-graded sand
	SANDS WITH FINES	Fines classify as ML or MH	SM	Silty sand ^{1,2,3}
		Fines classify as CL or CH	SC	Clayey sand ^{1,2,3}
SILTS AND CLAYS	Inorganic	PI > 7 and plots on or above "A" line ⁴	CL	Lean clay ^{1,2,3}
		PI < 4 or plots below "A" line ⁴	ML	Silt ^{1,2,3}
Liquid limit less than 50	Organic	Liquid limit - overconsolidated ⁵ < 0.75	OH	Organic clay ^{1,2,3}
		Liquid limit - not dried	OI	Organic silt ^{1,2,3}
SILTS AND CLAYS	Inorganic	PI plots on or above "A" line	CH	Fat clay ^{1,2,3}
		PI plots below "A" line	MH	Leaner silt ^{1,2,3}
Liquid limit 50 or more	Organic	Liquid limit - overconsolidated ⁵ < 0.75	OHC	Organic clay ^{1,2,3}
		Liquid limit - not dried	OIH	Organic silt ^{1,2,3}
Highly fibrous organic soils	Primary organic matter, dark in color, and organic odor		Pe	Peat

NOTES:

- Based on the material passing the 3 in. (75 mm) sieve.
- If field sample contained cobbles and/or boulders, add "with cobbles and/or boulders" to group name.
- Gravels with 5 to 12% fines require dual symbols:
GW-GM, well-graded gravel with silt;
GW-GC, well-graded gravel with clay;
GP-GM, poorly graded gravel with silt;
GP-GC, poorly graded gravel with clay.
- Sands with 5 to 12% fines require dual symbols:
SW-SM, well-graded sand with silt;
SW-SC, well-graded sand with clay;
SP-SM, poorly graded sand with silt;
SP-SC, poorly graded sand with clay.
- $C_u = \frac{D_{60}}{D_{10}}$ $C_c = \frac{(D_{30})^2}{(D_{10})(D_{60})}$
[C_u = Uniformity Coefficient; C_c = Coefficient of Curvature]
- If soil contains $\geq 15\%$ sand, add "with sand" to group name.
- If fines classify as CL-ML, use dual symbol GC-GM, SC-SM.
- If fines are organic, add "with organic fines" to group name.
- If soil contains $\geq 15\%$ gravel, add "with gravel" to group name.
- If the liquid limit and plasticity index plot in hatched area on plasticity chart, soil is a CL-ML, silty clay.
- If soil contains 15 to 29% plus No. 200 (0.075 mm), add "with sand" or "with gravel," whichever is predominant.
- If soil contains $\geq 30\%$ plus No. 200 (0.075 mm), predominantly sand, add "sandy" to group name.
- If soil contains $\geq 30\%$ plus No. 200 (0.075 mm), predominantly gravel, add "gravelly" to group name.
- PI ≥ 4 and plots on or above "A" line.
- PI < 4 or plots below "A" line.
- PI plots on or above "A" line.
- PI plots below "A" line.

Location of clay minerals on the Casagrande Plasticity Chart



Unified Classification Example

- Given

- Results of Sieve Test

- Uniformity Coefficient
 $C_u = 8.1$

- Curvature Coefficient
 $C_c = 0.9$

- Percentage Passing
#200 Sieve = 10%

- Percentage Passing #4
sieve = 89%

- Result of Atterberg Limit Tests (for portion passing #40 sieve)

- Liquid Limit $LL = 63$

- Plastic Limit $PL = 42$

- Plasticity Index = $LL - PL = 21$

- Find

- Unified Soil Classification

Unified Classification Example

● Question 3:

● How "clean" are the sands?

● Answer:

● "Clean" sands or gravels have less than 5% of the material passing the #200 sieve

● Sands (or gravels) "with fines" have more than 12% of material passing the #200 sieve

● Since $5\% < 10\% < 12\%$, no classifications are eliminated

● Remaining: "S" classification soils

● Question 4:

● How is the soil graded?

● Answer:

● Uniformity Coefficient $C_u = 8.1$, Curvature Coefficient $C_c = 0.9$.

● For SW, $C_u > 6$ and $1 < C_c < 3$, so this is eliminated

● Remaining: SP, SM and SC

AASHTO System

Table 4-13
AASHTO soil classification system based on AASHTO M 145 (or ASTM D 3282)

GENERAL CLASSIFICATION	GRANULAR MATERIALS (35 percent or less of total sample passing No. 200 sieve (0.075 mm))							SILT-CLAY MATERIALS (More than 35 percent of total sample passing No. 200 sieve (0.075 mm))			
	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5, A-7-6
Sieve analysis, percent passing:											
No. 10 (2 mm)	50 max.										
No. 40 (0.425 mm)	30 max.	50 max.	51 min.								
No. 200 (0.075 mm)	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 No. 40 (0.425 mm)											
Liquid limit				40 max.	41 min.	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		NP	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.*
Usual significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
Group Index**	0		0	0				8 max.	12 max.	16 max.	20 max.

Classification procedure:

With required test data available, proceed from left to right on chart; correct group will be found by process of elimination. The first group from left into which the test data will fit is the correct classification.

*Plasticity Index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity Index of A-7-6 subgroup is greater than LL minus 30 (see Fig 4-5).

**See group index formula (Eq. 4-3). Group index should be shown in parentheses after group symbol as: A-2-6(3), A-4(5), A-7-5(17), etc.

AASHTO System

AASHTO SYSTEM CLASSIFICATION

GROUP CLASSIFICATION	SEMI-RIGID BASES (RCP, ASPHALT CONCRETE, ETC.)							HOT MIX ASPHALT			
	A-1		A-2	A-3				A-4	A-5	A-6	A-7
	0-5	6-10		0-5	6-10	11-15	16-20				
SEMI-RIGID BASES (RCP, ASPHALT CONCRETE, ETC.)											
0-5 (w/0.075)	0-5	—	—	—	—	—	—	—	—	—	—
6-10 (w/0.075)	0-5	0-5	0-5	—	—	—	—	—	—	—	—
11-15 (w/0.075)	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
SEMI-RIGID BASES (RCP, ASPHALT CONCRETE, ETC.)											
0-5 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
6-10 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
11-15 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
16-20 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
21-25 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
26-30 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
31-35 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
36-40 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
41-45 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
46-50 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
51-55 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
56-60 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
61-65 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
66-70 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
71-75 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
76-80 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
81-85 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
86-90 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
91-95 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
96-100 (w/0.075)	—	—	—	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5

Notes: 1. The AASHTO System Classification is based on the AASHTO Test Method T-99, "Standard Method of Test for Liquid Limit, Plastic Limit, and Shrinkage Limit of Fine-grained Soils."

2. The AASHTO System Classification is based on the AASHTO Test Method T-99, "Standard Method of Test for Liquid Limit, Plastic Limit, and Shrinkage Limit of Fine-grained Soils."

3. The AASHTO System Classification is based on the AASHTO Test Method T-99, "Standard Method of Test for Liquid Limit, Plastic Limit, and Shrinkage Limit of Fine-grained Soils."

$$A-1 = (P - 10) \left[(11 - 100) \left(\frac{LL - 40}{100} \right) + (100 - 10) \right] (P - 10)$$

where: P = Percent passing No. 20 sieve, expressed as a whole number. The percentage retained only on the No. 20 sieve is 100 minus P .

LL = Liquid Limit

P_1 = Plasticity Index

The computed value of $A-1$ is then used to determine the final AASHTO System Classification.

AASHTO Classification Example

- Given (same soil as before)
- Results of Sieve Test
 - Uniformity Coefficient $C_u = 8.1$
 - Curvature Coefficient $C_c = 0.9$
 - Percentage Passing #10 Sieve: 82%
 - Percentage Passing #40 Sieve: 51%
 - Percentage Passing #200 Sieve = 10%
- Result of Atterberg Limit Tests (for portion passing #40 sieve)
 - Liquid Limit $LL = 63$
 - Plastic Limit $PL = 42$
 - Plasticity Index $= LL - PL = 21$
- Find
 - AASHTO Soil Classification

Differences between Unified and AASHTO Classification Systems

Figure 4-6. Comparison of the USCS with the AASHTO soil classification system (after Utah DOT - Pavement Design and Management Manual, 2005).

