Period #6: Soil Classification Systems and Usage

A. Fundamental Idea:

- Collect soil samples from the field.
- Perform easy and inexpensive tests on the soil samples (typically GSD tests and Atterberg Limit tests)
- Based on the results from these tests, classify the soil(s) in question
- Based on the classifications of the soil(s), determine whether or not the might be appropriate for the intended usage.
- If yes, perform more extensive lab tests on the soil(s) (shear strength, consolidation, compaction, etc.) as needed.

MAJOR SOIL CLASSIFICATION SYSTEMS USED IN THE U.S.

<u>USDA Textural Classification</u>: Used primarily in agriculture, but not much by civil or geotechnical engineers.

<u>AASHTO Classification System</u>: Used quite extensively by civil engineers in selecting soils for usage in roads and highways.

<u>Unified Classification System</u> (UCS) : Used by geotechnical engineers for selecting appropriate soils in non−highway projects.

B. USDA Textural Classification

This system is based entirely on the GSD of a given soil sample.

Soil Type	**Diameter Range**
Cobbles & Boulders	$d > 75mm$
Gravels	$2mm \leq d \leq 75mm$
Sands	$0.05mm \leq d < 2mm$
Silts	$0.002mm \leq d < 0.05mm$
Clays	$d \leq 0.002mm$

The classification in this system is based on the relative % sand, % silt, and % clay.

$$\text{relative \% sand} = \frac{\text{\% with } 0.05mm \leq d \leq 2mm}{100\% - \text{\% with } d \geq 2mm}$$

$$\text{relative \% silt} = \frac{\text{\% with } 0.002mm \leq d \leq 0.05mm}{100\% - \text{\% with } d \geq 2mm}$$

$$\text{relative \% clay} = \frac{\text{\% with } d \leq 0.002mm}{100\% - \text{\% with } d \geq 2mm}$$

Using these relative percentages, the soils are then classified according to a USDA Classification Chart.

Example #1: Classify the following soil by the USDA Textural Classification System.

Given: % gravel = 18; % sand = 51; % silt = 22; % clay = 9;

Solution:

rel. % sand = 51/82 = 62%
rel. % silt = 22/82 = 27%
rel. % clay = 9/82 = 11%

Using these values in USDA chart −−> sandy loam
However, due to the presence of 18% gravel in the soil, it is called "gravelly sandy loam."

Example #2: Classify the following soil by the USDA Textural Classification System.

Given: % gravel = 0; % sand = 30; % silt = 30; % clay = 40;

Solution:

rel. % sand = 30/100 = 30%
rel. % silt = 30/100 = 30%
rel. % clay = 40/100 = 40%

Using these values in USDA chart −−> clay loam

C. The AASHTO Classification System

- Considers both texture (GSD) and Atterberg Limits.
- Originally proposed in 1919; the system was last modified in 1945.
- This system is widely used by highway and transportation engineers.

- Performed on that part of a soil sample that falls in the gravel <−−−> clay size range.

- Using Table 5.1 of the textbook, the idea is to classify a soil as high as is possible based on the GSD and Atterberg Limits.

- Once an AASHTO Group Classification has been found, a so−called "group index" (GI) can be computed to further classify soils within a given group.

For soils in AASHTO group A−3 or lower:

$$GI = (F-35)\,[0.2 + 0.005(LL-40)] + 0.01(F-15)(PI-10)$$

For soils in A−1 or A−2:

$$GI = 0.01(F-15)(PI-10)$$

In both formulas, F is the percent of the soil sample passing the #200 sieve.

Example #3: Classify the following soil by the AASHTO System.

Given: % passing No. 10 = 100; % passing No.40 = 80;
% passing No. 200 = 58; LL = 30; PI = 10.

Solution:

From Table 5.1, the group classification is A−4.

From the given data, F=58.

$$GI = (F-35)\,[0.2 + 0.005(LL-40)] + 0.01(F-15)(PI-10)$$
$$= (23)[0.2 + 0.005(-10)] + 0.01(43)(0)$$
$$= 3.45 \text{ −−> } 3$$

Thus, the AASHTO Classification is A−4 (3).

Example #4: Classify the following soil by the AASHTO System.

Given: % passing No. 200 = 95; LL = 60; PI = 40.

Solution:

From Table 5.1, the group classification is A−7−6.

From the given data, F=95.

$$GI = (F-35)\,[0.2 + 0.005(LL-40)] + 0.01(F-15)(PI-10)$$
$$= (60)[0.2 + 0.005(20)] + 0.01(80)(30)$$
$$= 42$$

Thus, the AASHTO Classification is A−7−6 (42).

D. The Unified Classification System (UCS)

- First devised in 1942.
- Last modified in 1991.
- Like the AASHTO system, it uses both GSD and Atterberg Limit data.

Required Information:

- % of sample that is gravel : $4.75\text{mm} \le d \le 75\text{mm}$
- % of sample that is sand : $0.075\text{mm} \le d \le 4.75\text{mm}$
- % of sample that is silt & clay: $d \le 0.075\text{mm}$
- Uniformity coefficient : $C_u = D_{60}/D_{10}$
- Coefficient of gradation : $C_c = (D_{30})^2/[D_{60}*D_{10}]$

- LL and PI on portion passing #40 sieve

UCS Classification Procedure:

Step (1): Determine F_{200} (% finer than #200 sieve)

If $F_{200} <$ 50 % −−> Step (2)

If $F_{200} \ge$ 50 % −−> Step(3)

Step (2): Coarse Fraction is $R_{200} = 100 - F_{200}$

F_1 is the % passing #4, but retained on #200 (i.e. sand)

If $F_1 < (R_{200})/2$, then the coarse fraction is more gravel than sand.

Go to Table 5.2 and Figure 5.3 of the text.

If $F_1 > (R_{200})/2$, then the coarse fraction is more sand than gravel.

Go to Table 4.2 and Figure 4.2 of the text

Step (3): Fine−grained soils. Go to Table 4.2 and Figure 4.2 of the text.

Example #5: Classify the following soil using UCS

Given: gravel fraction (% retained on #4) = 30%
sand fraction (passing #4, retained on #200) = 40%
silt and clay fraction (passing #200) = 30%
LL = 30; PI = 12

Solution:

- F_{200} = 30%, therefore go to Step (2).
- F_1 = 40% and $(R_{200})/2$ = 35%
- Since $F_1 > (R_{200})/2$, coarse fraction is more sandy than gravelly −−>Table 4.3.
- From Table 4.3 and Figure 4.3:
  Group symbol is SC
  From Figure 4.4, group name is "Clayey sand with gravel"

Example #6: Classify the following soil using UCS

Given: gravel fraction (% retained on #4) = 0%
sand fraction (passing #4, retained on #200) = 14%
silt and clay fraction (passing #200) = 86%
LL = 55; PI = 28

Solution:

- F_{200} = 86%, therefore go to Step (3).
- From Table 4.4 and Figure 4.3:
  Group symbol is CH Inorganic Clay
  From Figure 4.4, group name is "Fat Clay"

E. Summary

The attractive aspect of soil classification systems is that they permit engineers to do a rapid, inexpensive preliminary assessment of a given soil's adequacy for usage in a construction project.