6. LABORATORY CLASSIFICATION OF SOIL

6.1. APPLICABLE ASTM STANDARD

- ASTM D2487: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

6.2. PURPOSE OF MEASUREMENT

Soil is classified by geotechnical engineers for engineering purposes in accordance with the Unified Soil Classification System (USCS). Soils sharing a common USCS classification possess similar engineering properties, including strength, permeability, and compressibility, so the USCS is useful for specifying soil types to achieve a desired performance.

6.3. DEFINITIONS AND THEORY

The USCS allows soil to be classified based on its engineering properties, including strength, permeability, and compressibility. To use the USCS, information regarding the liquid and plastic limits and gradation of the soil is required. Using the USCS, each soil is assigned a two-letter group symbol and a group name. The three basic soil types and the group symbols that fall under each soil type are:

- *Gravels:* *GP, GW, GM, and GC,*
- *Sands:* *SP, SW, SM, and SC, and*
- *Silts and Clays:* *ML, CL, CH, MH, OH, and OL.*

Under the USCS, there is no direct distinction between silts and clays, although clay particles are smaller than silt particles and are mineralogically different than silt particles. Silts and clays are indirectly distinguished in the USCS through the use of liquid and plastic limits as described later. Although there are six group symbols listed under silts and clays, the last three symbols (MH, OH, and OL) are relatively uncommon.

Each group symbol has two letters. The first letter describes the soil type as follows:

- *G = gravel;*
- *S = sand;*
- *M = silt (muck);*
- *C = clay; and*
- *O = organic.*

The second letter is a modifier that provides additional description of the soil:

- *P = poorly graded;*
- *W = well graded;*
- *M = silty;*
- *C = clayey;*
- *L = low-plasticity (lean); and*
- *H = high-plasticity (fat).*

In addition to the group symbol, each soil is assigned a group name, which further modifies and describes the soil.

6.4. EQUIPMENT AND MATERIALS

USCS classification can be performed using the instructions provided herein, but use of tables and charts; such as those that are published in ASTM D2487 and most undergraduate soil mechanics textbooks, may also facilitate the process.

6.5. PROCEDURE

USCS soil classification is a methodical procedure that follows these steps:

1) ***Decide if the soil is fine-grained or coarse-grained.*** If more than 50% of the soil passes the #200 sieve, it is fine-grained. Otherwise, it is coarse-grained.

2a) ***For fine-grained soils,*** plot the *LL* and *PI* on the plasticity chart (Fig. 6.1). The point will fall in the quadrant corresponding to the USCS group symbol, which will most likely be either a silt (**ML**), lean clay (**CL**), or fat clay (**CH**).

2b) ***For coarse-grained soils,*** *determine if the soil is a sand or a gravel.* The material retained by the #200 sieve is referred to as the coarse fraction. If more than 50% of the coarse fraction passes the #4 sieve, the soil is a sand. Otherwise, it is a gravel.

3a) ***For sands****, determine if it is a clean sand a dirty sand, or a dual classification.* If less than 5% of the soil passes the #200 sieve, it is a clean sand. If greater than 12% of the soil passes the #200 sieve, it is a dirty sand. If 5-12% pass the #200 sieve, it is a dual classification.

For clean sands, determine if it is well graded or poorly graded. Calculate the coefficient of uniformity, c_u, and the coefficient of curvature, c_c, on the gradation curve:

$$c_u = \frac{D_{60}}{D_{10}} \text{ and} \qquad (6.1)$$

$$c_c = \frac{(D_{30})^2}{D_{60} D_{10}}, \tag{6.2}$$

where D_{10}, D_{30}, and D_{60} are the grain sizes corresponding to 10%, 30%, and 60% passing, respectively. If $c_u > 6$ and $1 < c_c < 3$, the soil is a well-graded sand (**SW**). Otherwise, it is a poorly-graded sand (**SP**).

For dirty sand, determine if it is a silty sand or a clayey sand. Plot the *LL* and *PI* limits on the Plasticity Chart. If the point plots above the A-line, it is a clayey sand (**SC**). If it plots below the A-line, it is a silty sand (**SM**).

For dual classification: use the procedure for both clean sands and dirty sands to provide a four-letter dual classification, which may be a well-graded sand with silt (**SW-SM**), well-graded sand with clay (**SW-SC**), poorly-graded sand with silt (**SP-SM**), or poorly-graded sand with clay (**SP-SC**).

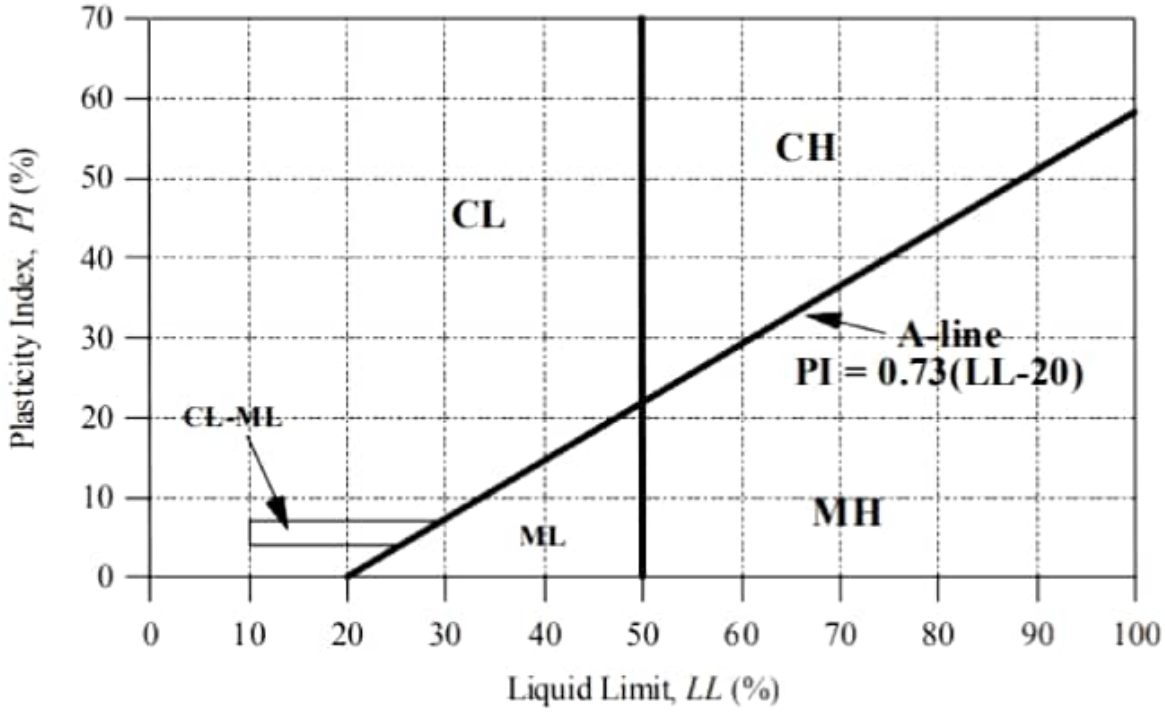

Fig. 6.1—Plasticity chart.

3b) ***For gravels, determine if it is a clean gravel, a dirty gravel, or a dual classification.*** If less than 5% of the soil passes the #200 sieve, it is a clean gravel. If greater than 12% of the soil passes the #200 sieve, it is a dirty gravel. If 5-12% pass the #200 sieve, it is a dual classification.

For clean gravel, determine if it is well graded or poorly graded. Calculate the coefficient of uniformity, c_u, and the coefficient of curvature, c_c, on the gradation curve. If $c_u > 4$ and $1 < c_c < 3$, the soil is a well-graded gravel (**GW**). Otherwise, it is a poorly-graded gravel (**GP**).

For dirty gravel, determine if it is a silty gravel or a clayey gravel. Plot the *LL* and *PI* limits on the Plasticity Chart. If the point plots above the A-line, it is a clayey gravel (**GC**). If it plots below the A-line, it is a silty gravel (**GM**).

For dual classification: use the procedure for both clean gravel and dirty gravel to provide a four-letter dual classification, which may be a well-graded gravel with silt (**GW-GM**), well-graded gravel with clay (**GW-GC**), poorly-graded gravel with silt (**GP-GM**), or poorly-graded gravel with clay (**GP-GC**).

The overall USCS procedure is represented in Fig. 6.2. To use this chart, start at the left side and work towards the right.

Coarse-Grained Soils

% passing #200	% of C.F. passing #4	% passing #200			USCS Symbol	USCS Name
<50%	>50%	0-5%	c_u>6 and 1<c_c<3?	yes	SW	Well-graded sand
				no	SP	Poorly-graded sand
		5-12%	Dual classification		SP-SM	Poorly-graded sand with silt
					SP-SC	Poorly-graded sand with clay
					SW-SM	Well-graded sand with silt
					SW-SC	Well-graded sand with clay
		12-50%	PI>0.73(LL-20)%?	yes	SC	Clayey sand
				no	SM	Silty sand
	<50%	0-5%	c_u>4 and 1<c_c<3?	yes	GW	Well-graded gravel
				no	GP	Poorly-graded gravel
		5-12%	Dual classification		GP-GM	Poorly-graded gravel with silt
					GP-GC	Poorly-graded gravel with clay
					GW-GM	Well-graded gravel with silt
					GW-GC	Well-graded gravel with clay
		12-50%	PI>0.73(LL-20)%?	yes	GC	Clayey gravel
				no	GM	Silty gravel

Fine-Grained Soils

% passing #200?	LL > 50%?	PI > 0.73(LL-20)%?	USGS Symbol	USCS Name
>50%	yes	yes	CH	Fat clay
		no	MH	Elastic silt
	no	yes	CL	Lean clay
		no	ML	Lean silt

Fig.6.2—USCS classification chart.

6.6. LIKELY SOURCES OF ERROR

Error in soil classification is a result of error in the *LL* and *PI* or gradation tests, provided that the USCS has been used properly. The most common error in *LL* and *PI* testing is allowing the plasticity index specimens to sit too long before obtaining their moist weight. This error would result in underestimating *PL* and overestimating *PI*, and may result in erroneously classifying low-plasticity soils as high-plasticity soils. The most common error in gradation testing is underestimating the percent of fines in soil by relying on mechanical sieve analysis rather than wet sieve analysis to calculate fines content. This may result in erroneously classifying silty or clayey sands and gravels as clean sands and gravels.

6.7. ADDITIONAL CONSIDERATIONS

As mentioned previously, soils sharing a common USCS group symbol possess similar engineering properties. Table 6.1 summarizes soil types that provide various performance.

Table 6.1—USCS soil types and soil performance.

To achieve:	Use	Feature
Low permeability	ML, CL, CH	Fine-grained
High permeability	GP, SP	Poorly-graded
High strength	GW, SW	Well-graded
Low compressibility	GM, GP, GW	Gravelly

The procedure for classifying soil using the USCS is described herein. However, the American Association of State Highway Transportation Officials (AASHTO) has also developed a soil classification system that is extensively used for transportation-related earthworks. The reader should be aware of the AASHTO system. Information regarding use of the AASHTO system can be found in numerous other references.

As mentioned previously, USCS classification includes a two-letter group symbol, and a more descriptive group name. Details for determining the more descriptive group name are not given herein, but can be found in the ASTM D2487 standard.