Laboratory Soil Classification

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Outline

- Introduction
- Unified Soil Classification System (USCS)
- Sieve analysis and Hydrometer test
- Atterberg limits
- Examples
Introduction

Coarse < 0.075 mm < Fine
Engineering Characterization of Soils

Soil Properties that Control its Engineering Behavior

Coarse-grained
- Particle/Grain Size Distribution
- Particle Shape

Fine-grained
- Soil Plasticity
Coarse Aggregate Application
Fine-Grained Soil Application
Problems

Frost heave

Non-uniform settlement

Sand liquefaction
Purpose

Classifying soils into groups with similar behavior

Simple indices
GSD, LL, PI

Classification system
(Language)

Communicate between engineers

Estimate engineering properties

Achieve engineering purposes

Use the accumulated experience
Classification Systems

Two commonly used systems:

- Unified Soil Classification System (USCS)
- American Association of State Highway and Transportation Officials (AASHTO) System
Unified Soil Classification System

Origin of USCS:

- Developed by Professor A. Casagrande (1948)
- Modified by Professor Casagrande, the U.S. Bureau of Reclamation, and the U.S. Army Corps of Engineers

- Four major divisions:
  - Coarse-grained
  - Fine-grained
  - Organic soils
  - Peat
Organic Soils

- Highly organic soils- Peat (Group symbol PT)
  - Composed primarily of vegetable tissue in various stages of decomposition,
  - Has a fibrous to amorphous texture, a dark-brown to black color, and an organic odor.

- Organic clay or silt (group symbol OL or OH):
  - Liquid limit (LL) after oven drying is less than 75% of its liquid limit before oven drying.
General Guidance

50%

Coarse-grained soils:            Fine-grained soils:
Gravel     Sand            Silt     Clay

50%  NO. 4  NO.200
4.75 mm  0.075 mm

• Grain size distribution

• PL, LL  
  - LL > 50

• Plasticity chart  
  - LL < 50

Required tests: Sieve analysis
Atterberg limits
Symbols

**Soil symbols:**
- G: Gravel
- S: Sand
- M: Silt
- C: Clay
- O: Organic
- Pt: Peat

**Liquid limit symbols:**
- H: High LL (LL>50)
- L: Low LL (LL<50)

**Gradation symbols:**
- W: Well-graded
- P: Poorly-graded

Examples: SW, Well-graded sand
SC, Clayey sand
SM, Silty sand
Particle Size Analysis

- **Sieve analysis** – used for particle sizes larger than 0.075 mm in diameter (larger than the No. 200 sieve), **ASTM C136**

- **Hydrometer analysis** – used for particle sizes smaller than 0.075 mm in diameter (passing the No. 200 sieve), **ASTM D422**
Sieve Analysis

- Step 1:
  a) Clean each sieve to remove any left over soil. (use **fine brush** for the sieve with smaller mesh, don’t destroy the mesh)
  b) Determine the masses of each sieve and the pan.
Sieve Analysis

- Assemble the sieves in order with the sieve with the largest size opening on top and the pan underneath.
- Place the soil sample into the top sieve.
Sieve Analysis

- Place the stack of sieves on the shaker and secure them with the screws.
- Set the shaker’s intensity level on 4 or 5 and the timer on 5 minutes.
Sieve Analysis

- Remove the sieves from the shaker. Tap each sieve over a sheet of paper to make sure all of the appropriate particles have passed through.
- Put any material that falls through into the next sieve.
## Sieve Analysis

<table>
<thead>
<tr>
<th>Sieve #</th>
<th>Diameter (mm)</th>
<th>Mass of soil retained on each sieve (g)</th>
<th>% of soil retained on each sieve</th>
<th>% passing (% finer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4.750</td>
<td>93.0</td>
<td>4.84</td>
<td>95.16</td>
</tr>
<tr>
<td>10</td>
<td>2.000</td>
<td>404.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>0.425</td>
<td>623.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>0.180</td>
<td>411.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>0.075</td>
<td>304.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pan</td>
<td>-</td>
<td>85.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total weight of soil = 1921.6
Example Calculations

For sieve #4:

\[
\% R_i = \frac{93g}{1921.66g} \times 100 = 4.84\%
\]

\[
\% P_i = 100 - 4.84 = 95.16\%
\]
Gradation Chart

<table>
<thead>
<tr>
<th>GRAVEL</th>
<th>SAND</th>
<th>SILT</th>
<th>CLAY</th>
</tr>
</thead>
</table>

- **Percent Finer by Weight (%)**
  - 100
  - 80
  - 60
  - 40
  - 20

- **Grain Size (mm)**
  - 0.001
  - 0.01
  - 0.1
  - 1.0
  - 10.0
  - 100.0

- **Types of Grading**
  - **Poorly graded**
  - **Gap graded**
  - **Well graded**
Connecting two Methods

Gradation Curve

- Sieve Analysis
- #200 sieve
- Hydrometer Analysis

- Grain Size (mm)
- Percent Passing (%)

Graph showing the gradation curve for different grain sizes and methods.
Hydrometer Analysis

- Based on the principle of spherical particle sedimentation in water.
- In order to perform this test, a small amount of soil is mixed into a suspension
- and the change in specific gravity due to the settling of the suspension is observed over time.
Hydrometer Analysis

- Using an 10-15 g of soil, determine the water content. (Microwave Oven Method)

- Obtain the equivalent of 50 g of dry soil from the material passing the #200 sieve.
Hydrometer Analysis

- Mix the soil into a thick slurry using 125 mL of the distilled water-dispersing agent solution. (The deep blue one)
- Mix the slurry in the stirring apparatus for 60 seconds.
Hydrometer Analysis

- **Transfer** to the sedimentation cylinder and fill with distilled water up to the 1000 mL mark.
- **Cover the cylinder** using a rubber glove and mix it by turning the cylinder upside down and back for 1 minute.
Hydrometer Analysis

- Place the cylinder down
- Insert the hydrometer,
- Take readings at 4, 15, 30, 60, 90, and 120 seconds.
Connecting two Methods

100% in the hydrometer results = % passing #200 sieve (scale appropriately)
Atterberg Limits

The physical and mechanical behavior of soils can be correlated to the liquid limit, plastic limit, and shrinkage limit. These form the boundaries between four states:

- Solid
- Semisolid
- Plastic
- Liquid
Liquid Limit

The moisture content (%) at which a length of 13 mm along the bottom of the groove of the liquid limit device cup closes when receiving 25 blows.
Liquid Limit

- Use portion of sample passing #40 (425mm) sieve.
- Mix soil sample with water thoroughly with a spatula.
- Using the spatula, spread the soil sample evenly over the bottom 2/3 of the cup.
- Make a groove through the soil sample.
- Crank the cam (2 blow/sec) until you see the groove in the sample close a distance along the groove of 13mm.
Liquid Limit

34 blows, 39%
23 blows, 47%
19 blows, 52%

$w_{LL} = 46.2\%$

Liquid Limit
Plastic Limit

Plastic Limit - Moisture content at which the soil crumbles when rolled into threads of 1/8 in diameter (3.175 mm).

- Select about 1.5 to 2.0 g. Roll over the plate to slowly and evenly dry the soil.
- Roll until the soil crumbles at 1/8 in.
- Collect at least 6 grams of soil, obtain a water content. This water content is the plastic limit, PL.
Plasticity Index

Plasticity Index (PI) - The difference between the Plastic Limit and the Liquid Limit is called the Plasticity Index.

$$\text{PI} = \text{LL} - \text{PL}$$

<table>
<thead>
<tr>
<th>PI (%)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Non plastic</td>
</tr>
<tr>
<td>1-5</td>
<td>Slightly plastic</td>
</tr>
<tr>
<td>5-10</td>
<td>Low plasticity</td>
</tr>
<tr>
<td>10-20</td>
<td>Medium plasticity</td>
</tr>
<tr>
<td>20-40</td>
<td>High plasticity</td>
</tr>
<tr>
<td>&gt;40</td>
<td>Very high plasticity</td>
</tr>
</tbody>
</table>
Plasticity Chart

U Line:
\[ PI = 0.9( LL - 8 ) \]

A line:
\[ PI = 0.73( LL - 22 ) \]
Example

<table>
<thead>
<tr>
<th>Passing No. 200 sieve 30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passing No. 4 sieve 70%</td>
</tr>
<tr>
<td>LL = 33</td>
</tr>
<tr>
<td>PI = 12</td>
</tr>
<tr>
<td>PI = 0.73(LL-20), A-line</td>
</tr>
<tr>
<td>PI = 0.73(33-20) = 9.49</td>
</tr>
<tr>
<td>SC</td>
</tr>
<tr>
<td>(≥15% gravel)</td>
</tr>
<tr>
<td>Clayey sand with gravel</td>
</tr>
</tbody>
</table>