FINE GRAINED SOIL PHYSICAL STATES
SOIL CLASSIFICATION

Georgia Institute of Technology

Lecture Topics

- Introduction
- Physical state of fine grained soils
- Atterberg limits
  - Casagrande Cup: Liquid Limit
  - Fall Cone: Liquid Limit
  - Plastic Limit
- Classification
- Other particle characteristics

Physical States of Fine Grained Soils

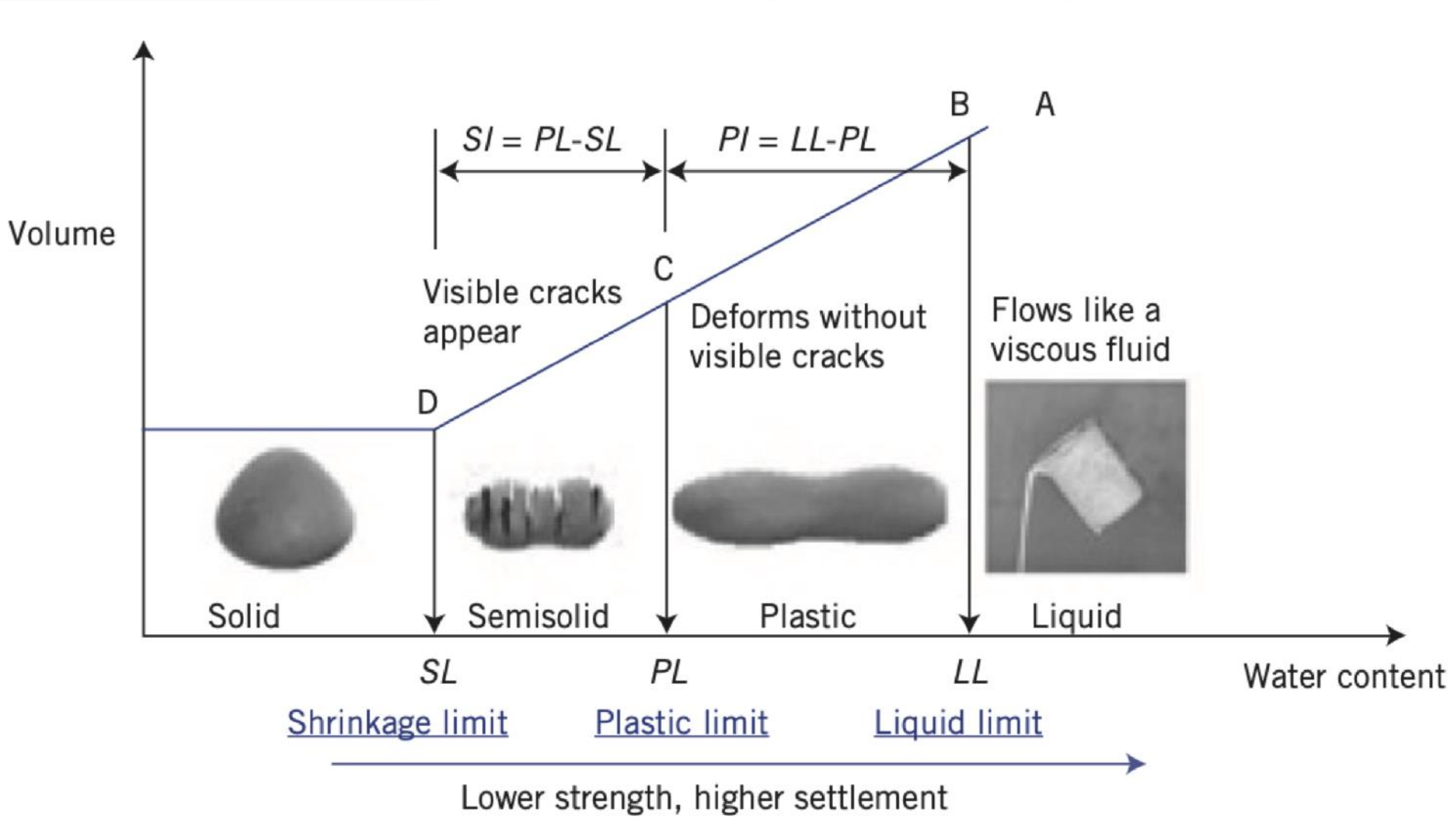
- Plasticity
  - “Ability of a soil to undergo unrecoverable deformation at constant volume without cracking or crumbling”
  - Applies to fine-grained soils
  - Clay minerals in the presence of water can be remolded without crumbling – known as plasticity
  - Consistency is a function of the amount of water, or water content, of the soil
  - Fine-grained soils can exist in four states and we use a descriptive method developed by A. Atterberg to describe these states

Atterberg Limits / Transition w%

State of Soil	Transition water content	Notes	Increasing w(%)
Solid		Note: water content = Mass water/Mass solids	
	Shrinkage limit (SL)	As water evaporates from soil, it shrinks; however, eventually equilibrium is reached -water content where no further volume change takes place, this is the shrinkage limit	
Semisolid			
	Plastic limit (PL)	– water content at transition from semi-solid to plastic (~≤40)	
Plastic			
	Liquid limit (LL)	– water content at transition from plastic to liquid (~≤100)	
Liquid			

Physical States of Fine Grained Soils

- Plot volume as a function of water content



Atterberg Limits

- Liquid limit (LL)
- Plastic Limit (PL)
- Shrinkage Limit (SL)
- All are moisture contents of the soil
- Together known as the Atterberg limits
- Determined experimentally in the laboratory
- Atterberg was a Swedish scientist working in the ceramics industry –
  - Developed the limits to help quantify how much a clay would shrink or crack when it was fired into a ceramic piece
- Every soil has unique LL, PL, and SL
- Plasticity Index (PI) = Liquid limit - plastic limit

$$PI = LL - PL$$

- Range over which a clay is plastic

Plasticity: Typical Values

- Range over which a clay is plastic

PI	Description
0	Nonplastic
1-5	Slightly Plastic
5-10	Low Plasticity
10-20	Medium Plasticity
20-40	High Plasticity
>40	Very High Plasticity

Typical Atterberg Limits for Soils

Soil type	LL (%)	PL (%)	PI (%)
Sand		Nonplastic	
Silt	30–40	20–25	10–15
Clay	40–150	25–50	15–100

Liquidity Index and Activity

- Liquidity Index – measure of soil strength

$$LI = \frac{w - PL}{PI}$$

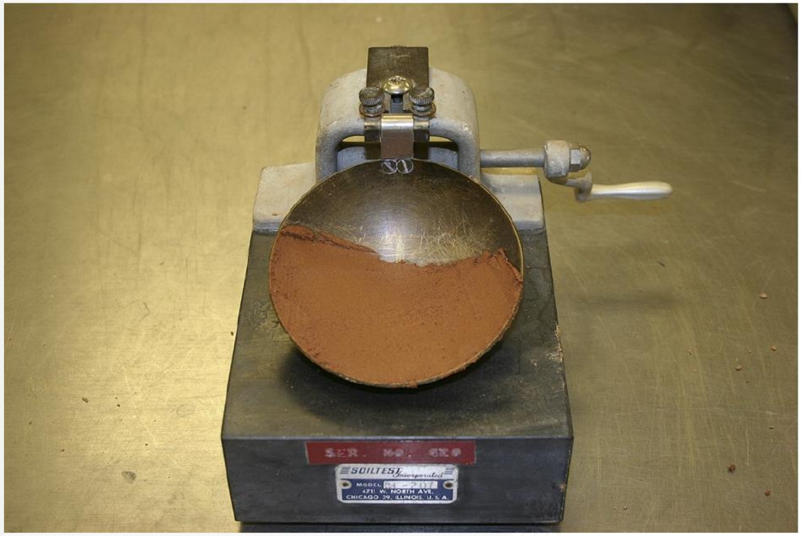
- Activity – measure of the surface area of the particles and indictor of mineralogy

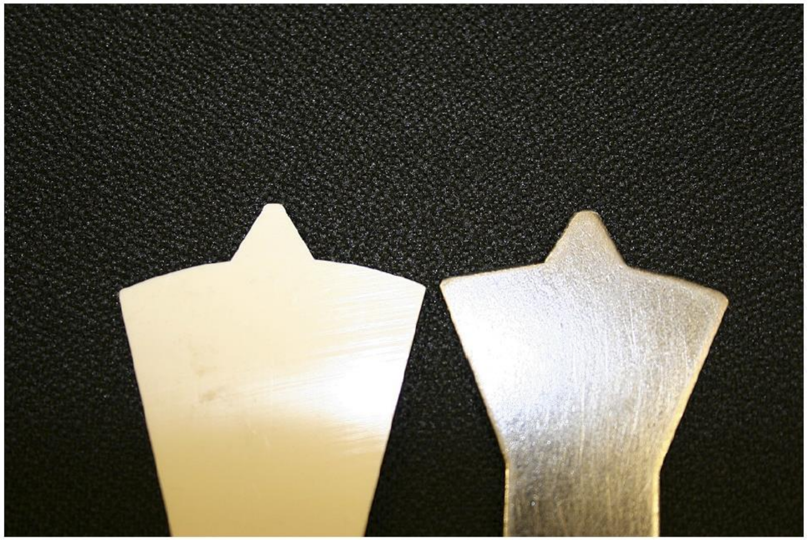
$$A = \frac{PI}{clayfraction(\%)}$$

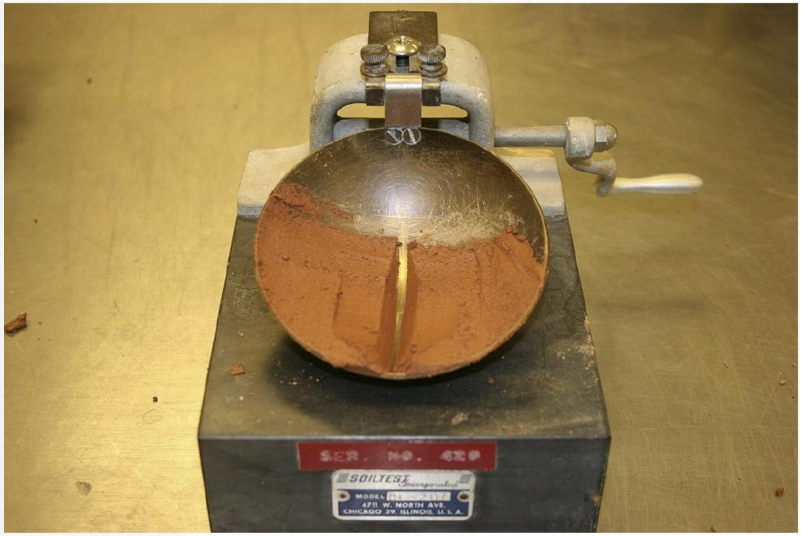
Casagrande Cup for Liquid Limit

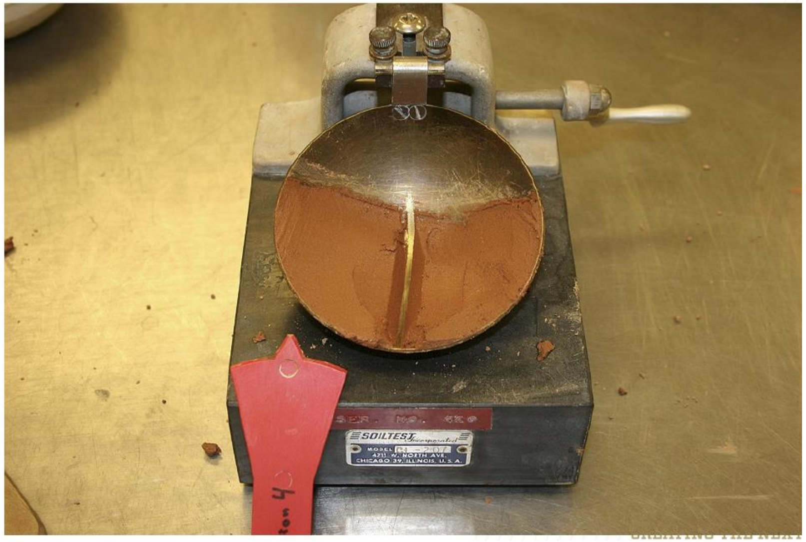
Calibration

Test Procedure 1/2

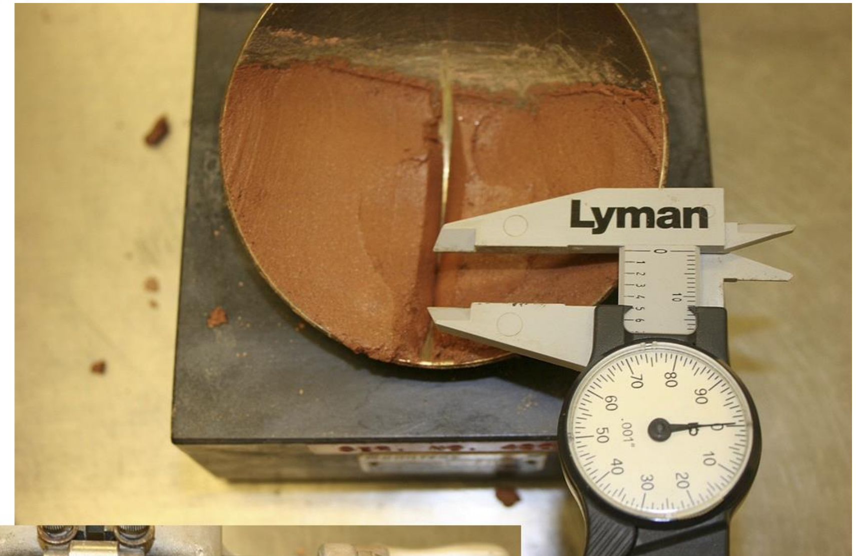




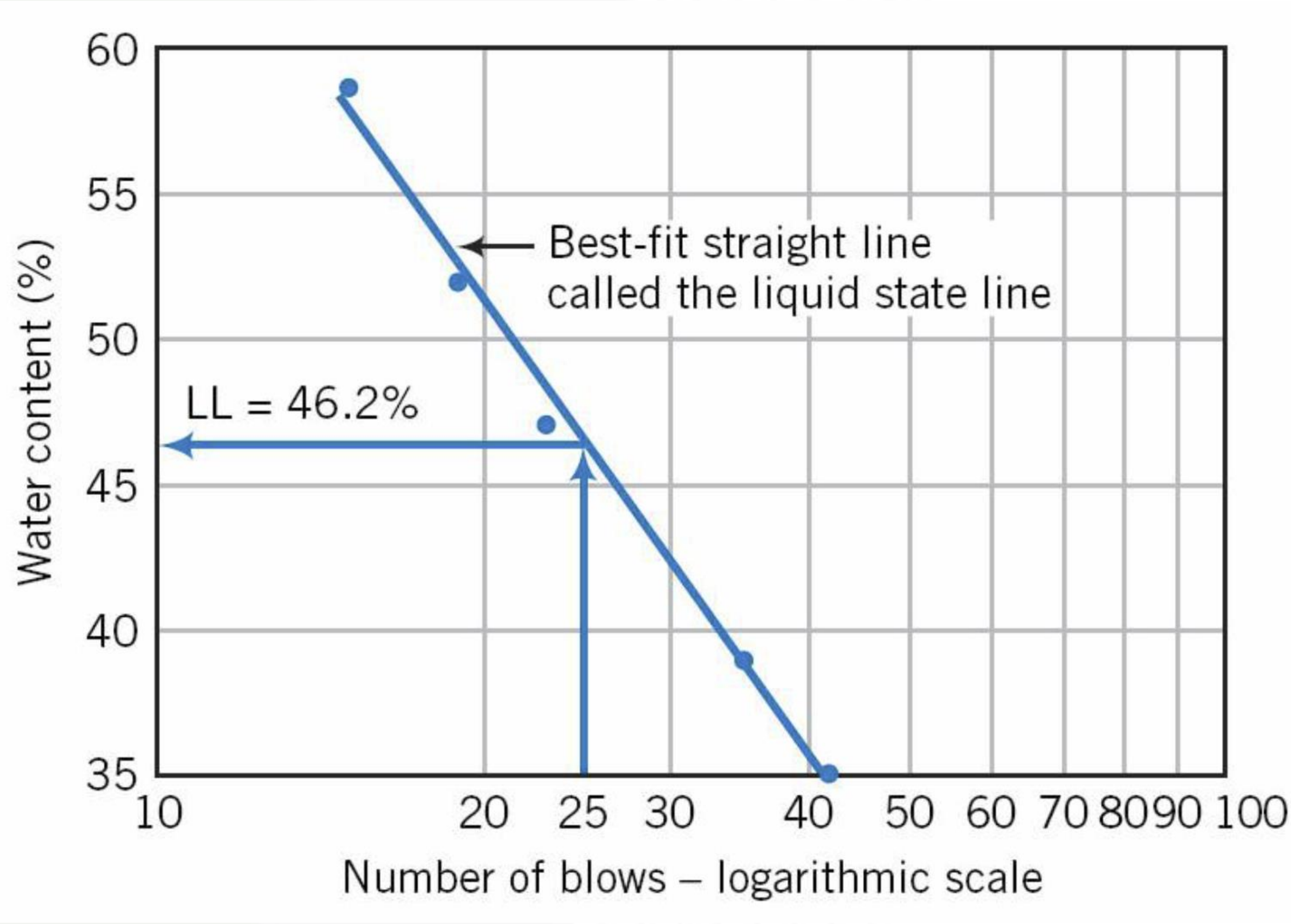




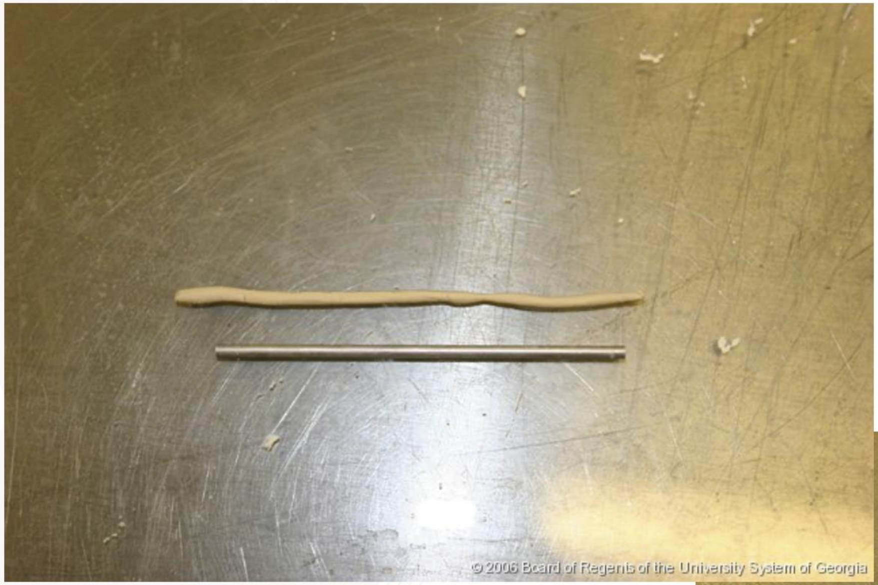
Test Procedure 2/2



Casagrande Cup Data Analysis



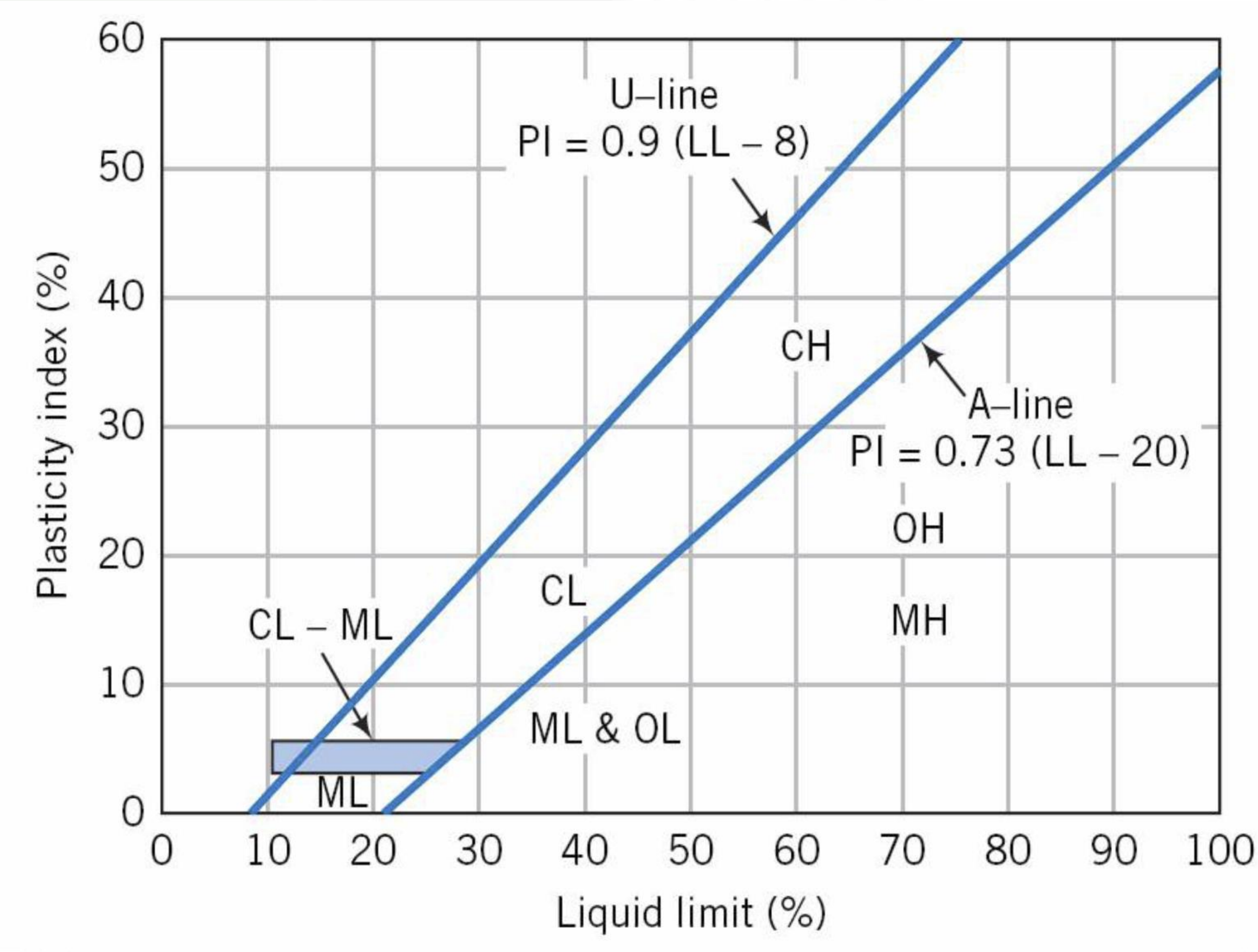
Plastic Limit



Plasticity Chart: Background

- Geotechnical engineering has existed as a discipline for ~ 90 years
  - Extensive database of plasticity characteristics
  - Use for characterization and correlation
- Arthur Casagrande organized the LL and PI data
  - Plasticity chart used for soil classification
  - Plot plasticity index versus the liquid limit
  - Have two important lines on the chart
    - A-line
      - Above the A-line are inorganic clays
      - Below the A-line are silts and organic clays
    - Also have the U-line - Upper limit of all soils ever tested

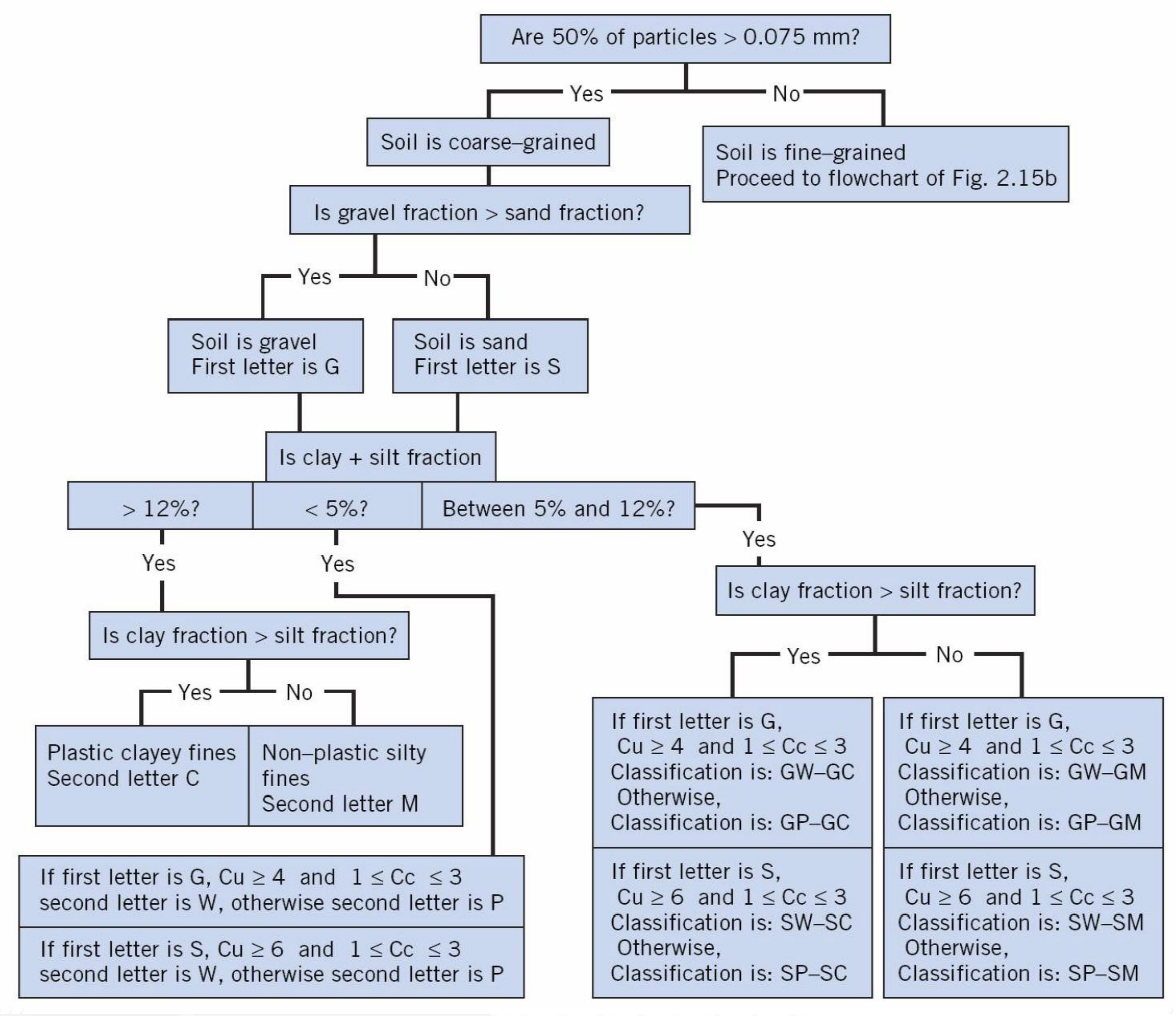
Plasticity Chart



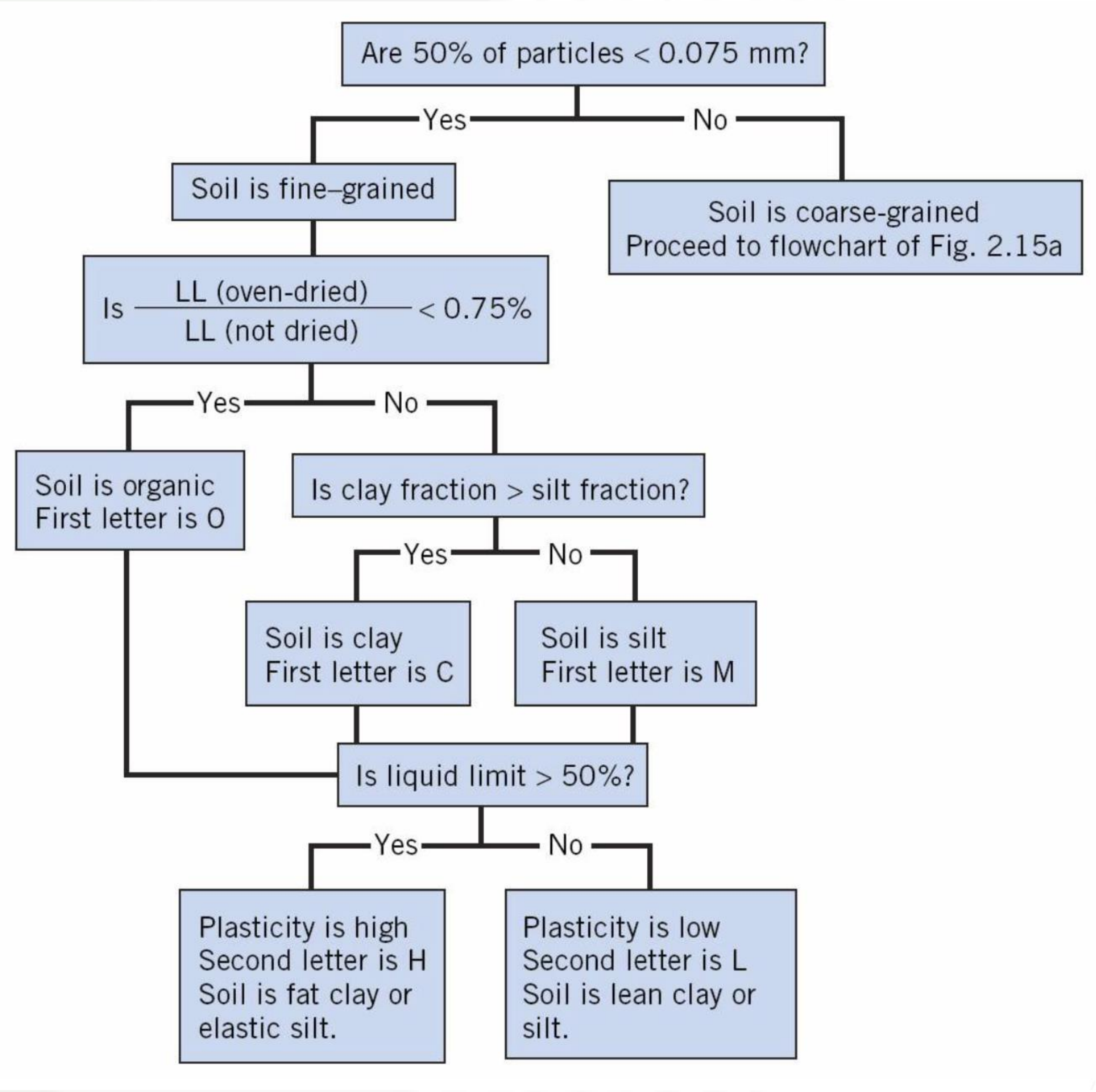
Plasticity Chart: Background

- We want a common language to describe different types of soils:
- In the U.S. we use the Unified Soil Classification System
- Give each soil a two letter designation:
  - G = gravel
  - S = sand
  - M = silt
  - C = clay
  - O = organic
  - First letter is the predominate size of the grains
  - Second letter is used to provide additional description
  - For example, we can have:
    - Silty sands : SM
    - Low plasticity clays CL

Decision Tree: Coarse Grains

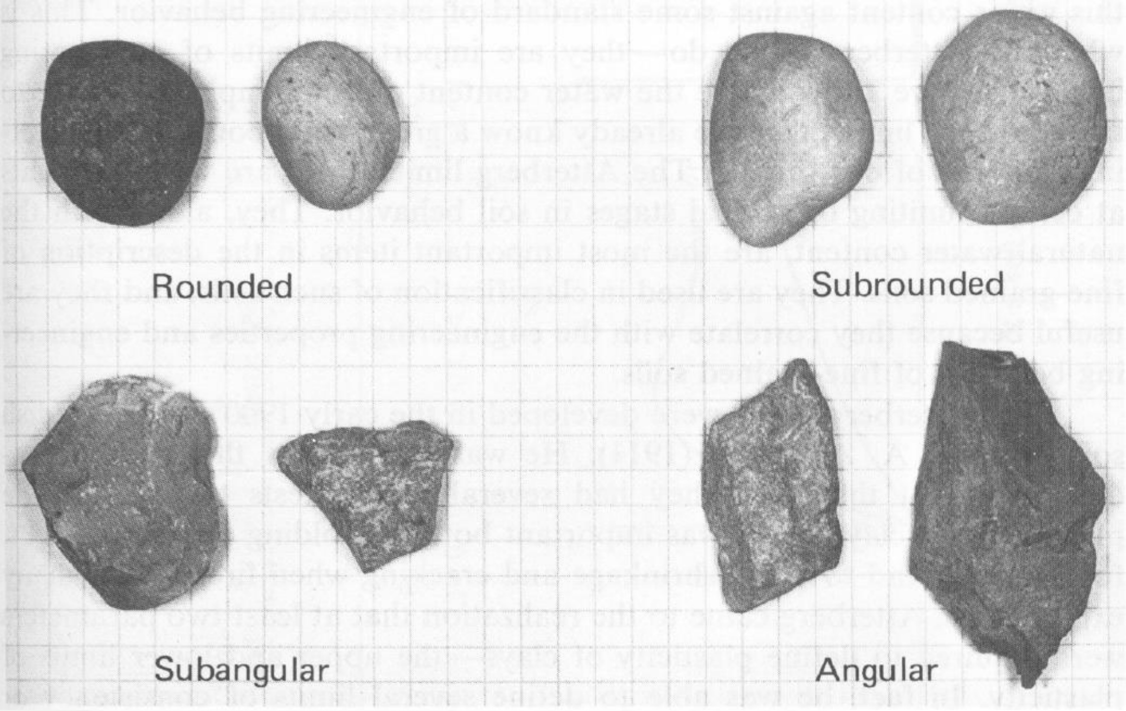


Decision Tree: Fine Grains



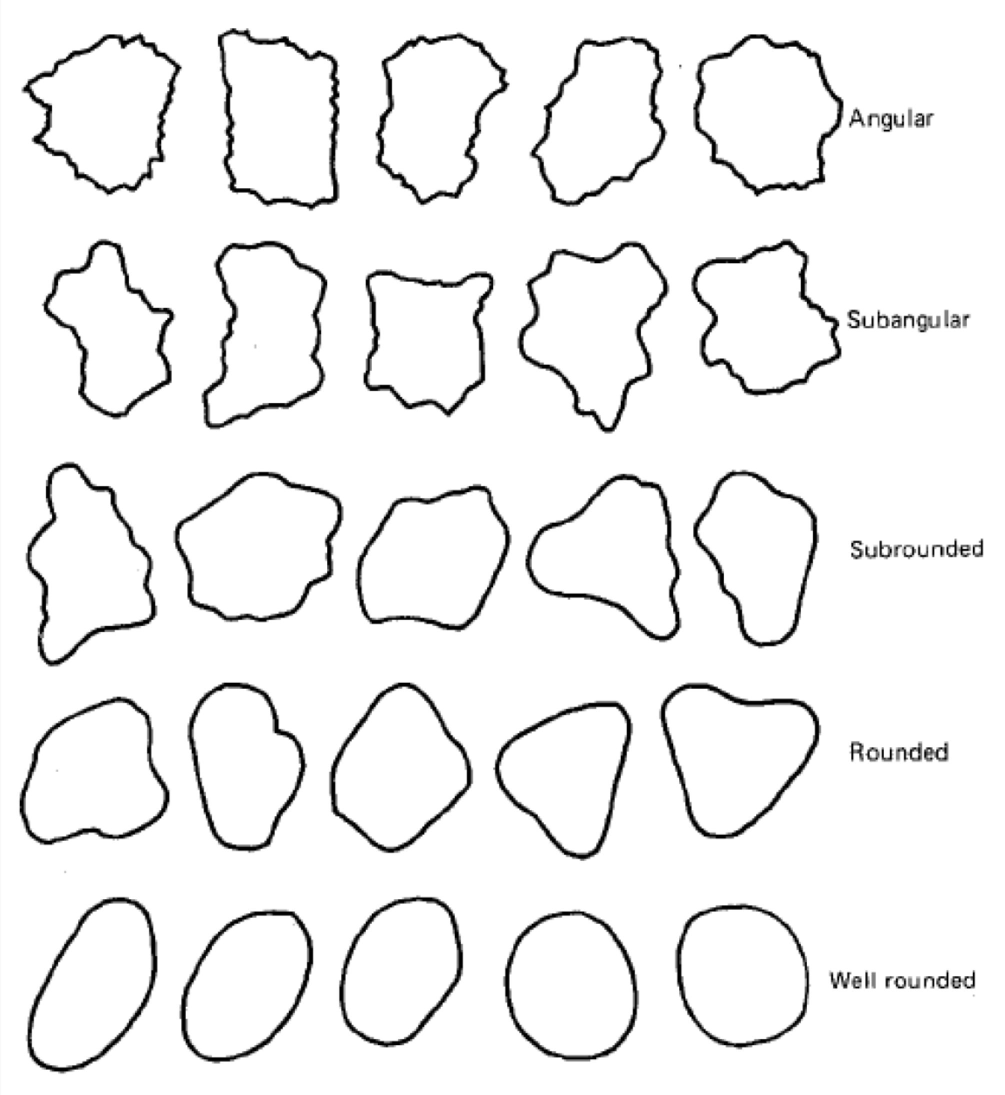
Other Characteristics

- Particle shape
  - Important in soil behavior, but difficult to measure
- Bulky - angular, subangular, subrounded, rounded



Typical shapes of coarse-grained bulky particles.
(Photograph by M. Surendra)

Range of Shapes



Sand and silt size particle shapes as seen in silhouette

Influence of Shapes

- Particle shape operates at several levels
  - Sphericity (versus eccentricity or platiness)
    - Similarity between the particles length, height, and width
  - Roundness (versus angularity) –major surface features
  - Manufactured crushed sands
    - Roundness 0.2-0.3
    - Sphericity 0.7-0.8
  - Natural sands
    - Roundness 0.3-0.9
    - Sphericity 0.5-0.9
  - Smoothness – roughness of the particle surface
  - At smaller scales, concerned about roughness