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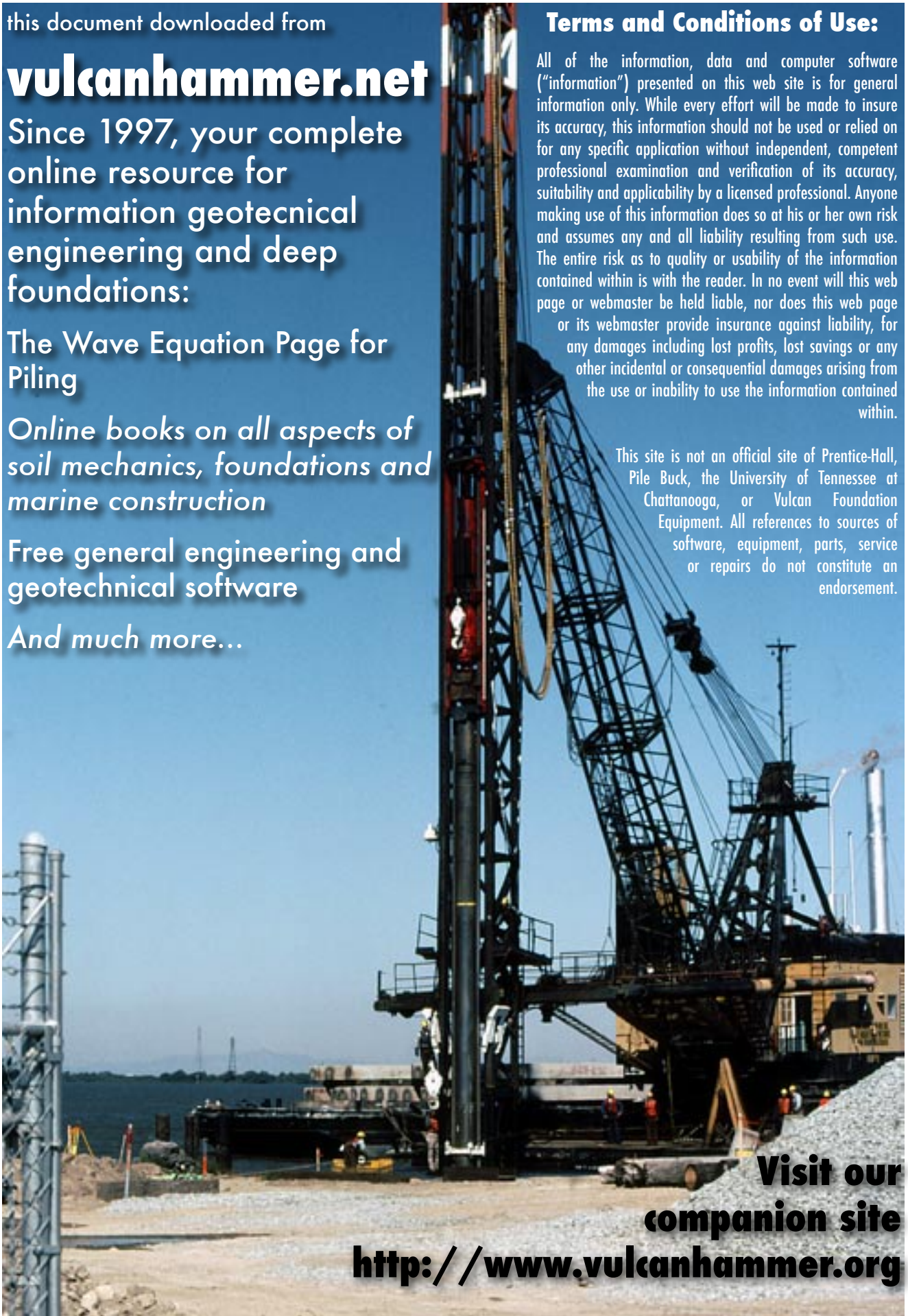
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# ENCE 361

## Soil Mechanics



Soil Composition (Continued)

# Granular or Cohesionless Soils

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- Excellent foundation material for supporting structures and roads.
- The best embankment material.
- The best backfill material for retaining walls.
- Might settle under vibratory loads or blasts.
- Dewatering can be difficult due to high permeability.
- If free draining not frost susceptible.

# Aspects of Cohesionless Soils

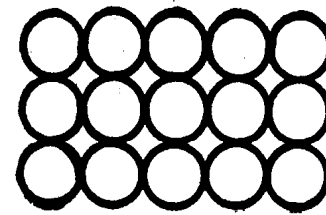
- Density
  - Both unit weight and strength of soil can vary with particle arrangement
  - Denser soils have both higher load carrying capacity and lower settlement

$$e_{\max} = 0.91$$

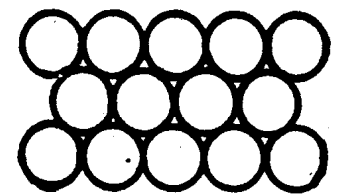
$$e_{\min} = 0.35$$

$$n_{\max} = 48\%$$

$$n_{\min} = 26\%$$



(I)



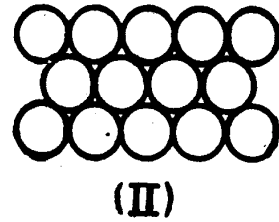
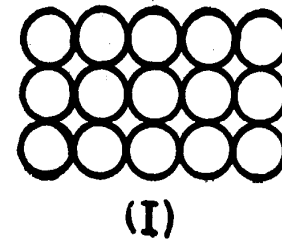
(II)

- Grain Size Distribution

# Relative Density

$$e_{\max} = 0.91$$
$$e_{\min} = 0.35$$

$$n_{\max} = 48\%$$
$$n_{\min} = 26\%$$



$$D_r = \frac{e_{\max} - e_0}{e_{\max} - e_{\min}} \times 100$$

- $e_{\max}$  = void ratio of the soil in its loosest condition
- $e_{\min}$  = void ratio of the soil in its densest condition
- $e_0$  = void ratio in the natural or condition of interest of the soil
- Convenient measure for the strength of a cohesionless soil

# Relative Density Example

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- Given

- Sand Backfill
- Unit Weight = 109 pcf
- Water Content = 8.6%
- Specific Gravity of Solids = 2.6

- Given

- $e_{\max} = 0.642$  (loosest state)
- $e_{\min} = 0.462$  (densest state)
- Find
  - Void Ratio
  - Relative Density

# Relative Density Example

- Assume  $V_t = 1 \text{ ft}^3$ ; thus,  $W_t = 109 \text{ lbs}$ .
- Weight balance:  $109 = W_s + W_w$
- Water content  $w = W_w/W_s = 0.086$
- Solving two previous equations:
  - $W_s = 100.4 \text{ lbs}$ ;  $W_w = 8.6 \text{ lbs}$ .
  - $V_s = W_s/\gamma_s = 100.4/((2.6)(62.4)) = 0.618 \text{ ft}^3$
  - $V_w = W_w/\gamma_w = 8.6/62.4 = 0.138 \text{ ft}^3$
  - $V_a = V_t - V_w - V_s = 1 - 0.138 - 0.618 = 0.243 \text{ ft}^3$

- $e = (V_a + V_w)/V_s = (0.243 + 0.138)/0.618 = 0.616$

$$D_r = \frac{e_{max} - e_0}{e_{max} - e_{min}} \times 100$$


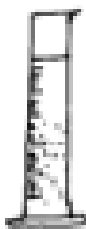


- $D_r = (.642 - .618)/(.642 - .462) = 0.142 = 14.2\%$

# Fine-Grained or Cohesive Soils

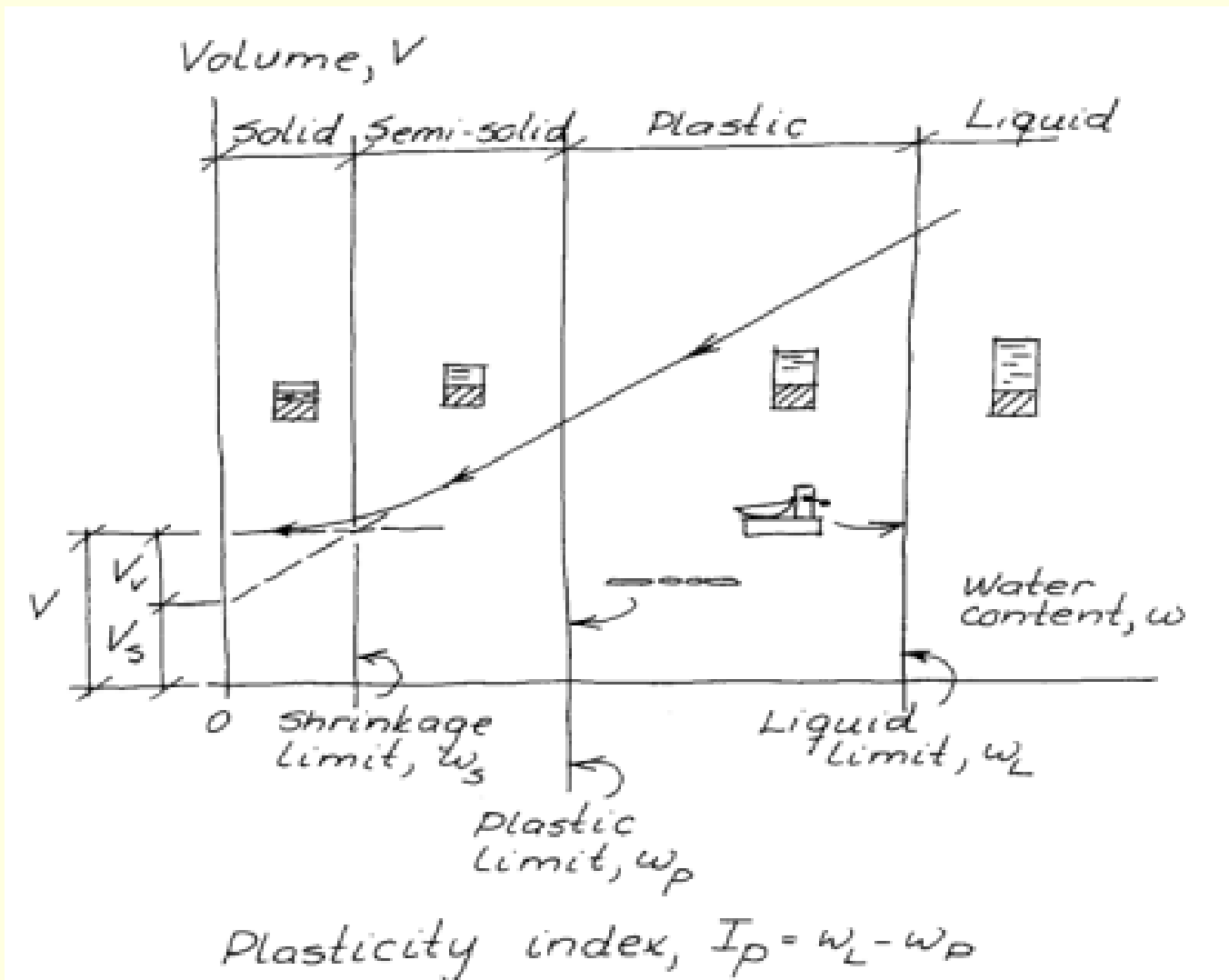
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- Clays
  - Very often, possess low shear strength.
  - Plastic and compressible.
  - Loses part of shear strength upon wetting.
  - Loses part of shear strength upon disturbance.
  - Shrinks upon drying and expands upon wetting.
  - Very poor material for backfill.
  - Poor material for embankments.
  - Practically impervious.
  - Clay slopes are prone to landslides.
- Silts
  - Characteristics
    - Relatively low shear strength
    - High Capillarity and frost susceptibility
    - Relatively low permeability
    - Difficult to compact
  - Compared to Clays
    - Better load sustaining qualities
    - Less compressible
    - More permeable
    - Exhibit less volume change

# Properties of Clay Soils

<u>Plasticity</u>	<u>Silt</u>	<u>Clay</u>
	Low	High
<u>Settlement rate</u> 	Settles within 20 min	Suspension after 24h.
<u>Dilatancy</u> 	High	Low
<u>Dry strength</u> 	Low	High

# States of Clay Soils

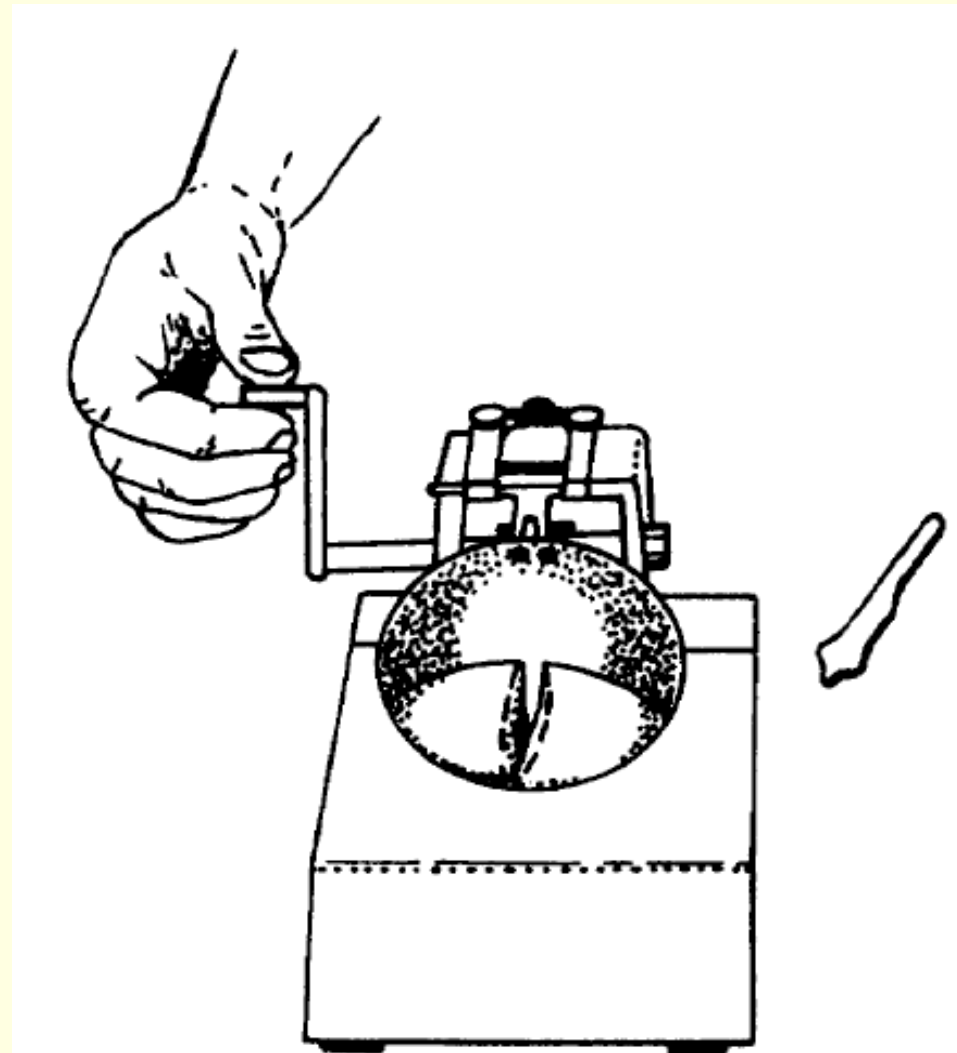


# Atterberg Limits

- Shrinkage Limit (SL)
- Plastic Limit (PL)
- Liquid Limit (LL)
- Plasticity Index  $PI = LL - PL$
- Liquidity Index  $LI = (w - PL)/PI$
- The more plastic a soil, it will:
  - Be more compressible
  - Have higher shrink-swell potential
  - Be less permeable
- Help identify and classify the soil.
- PI (plasticity index) is an indicator of soil compressibility and potential for volume change.
- PL (plastic limit) can indicate if clay has been preconsolidated. Most soils are deposited at or near their liquid limit. If the in situ natural water content ( $w$ ) is near the plastic limit (PL), then the soil is probably preconsolidated. Some stress has been applied in the past to squeeze that water out.
- PL, LL, PI and LI are always expressed as percentages

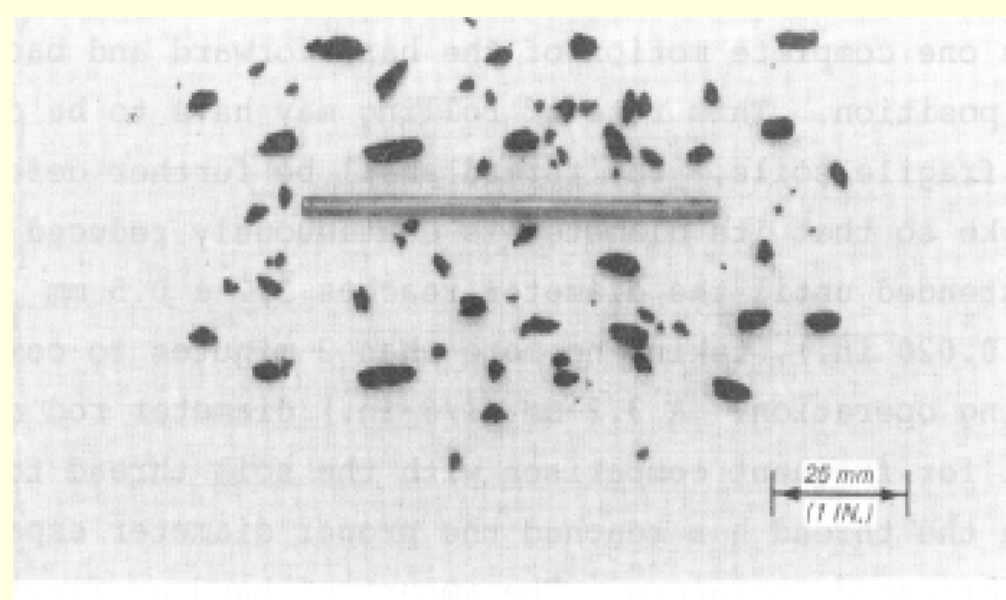
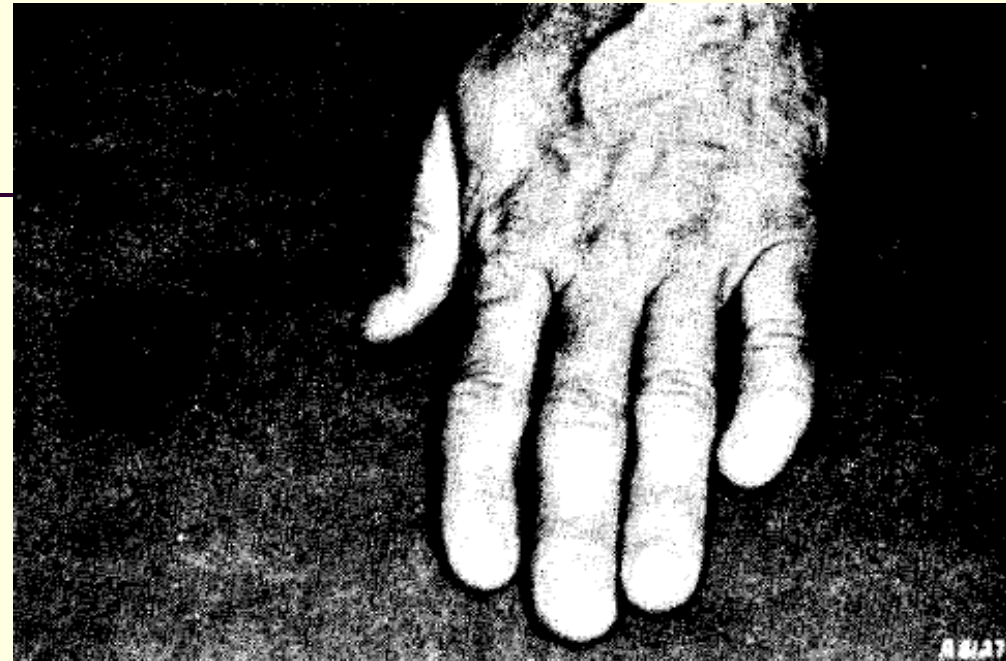
# Liquid Limit Test

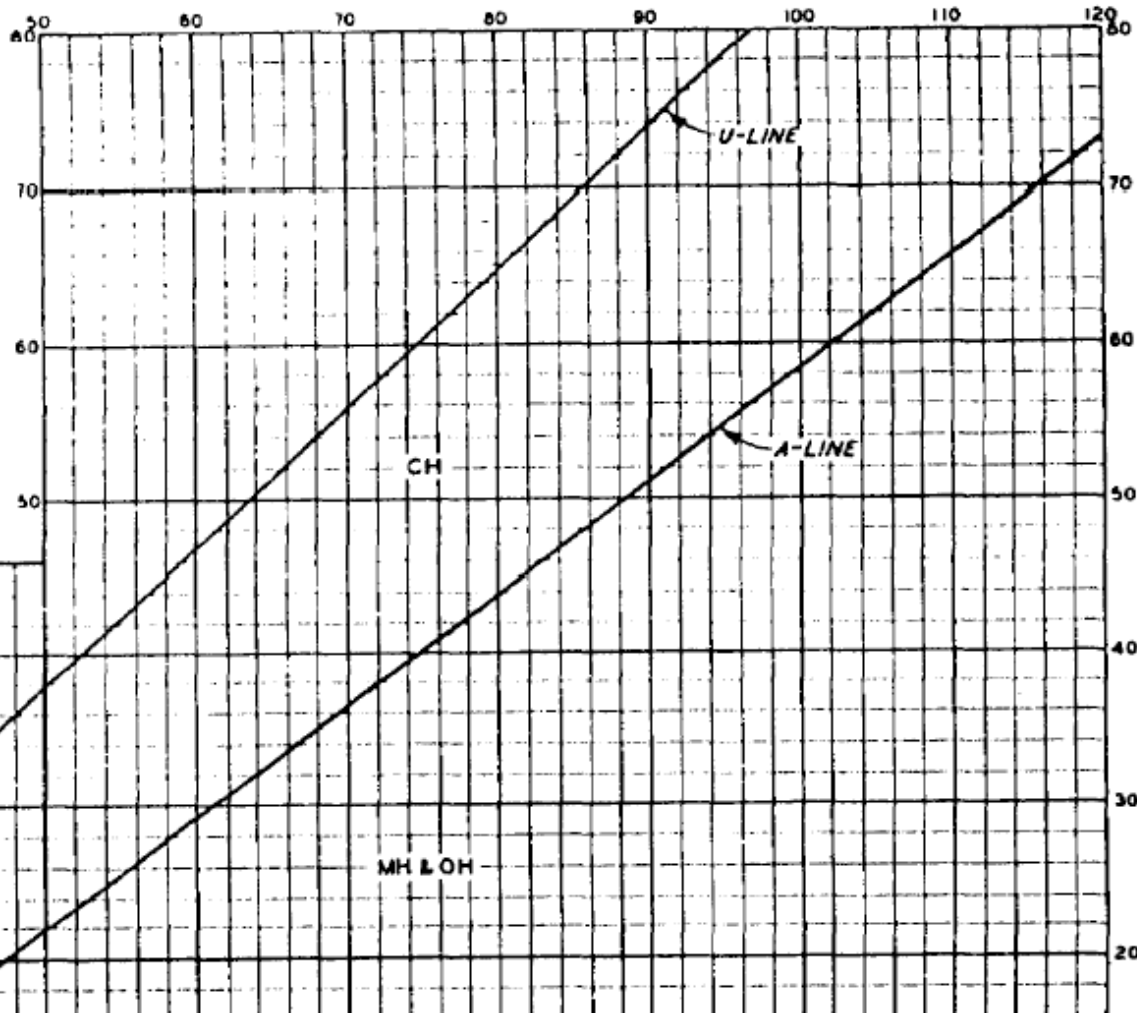
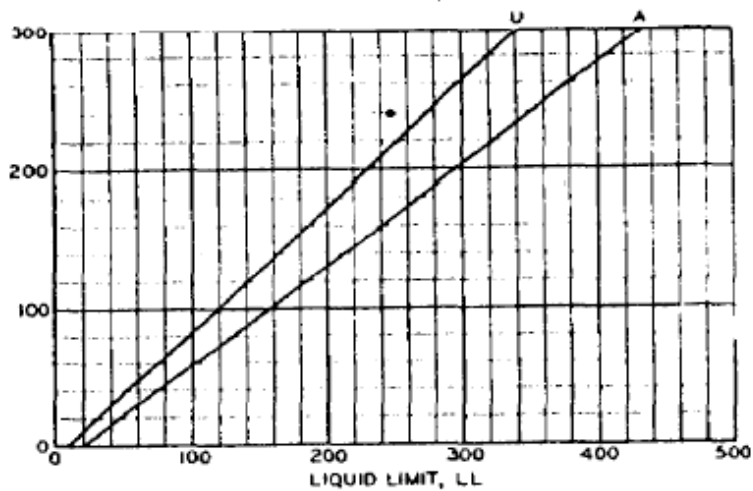
- Several samples are prepared with varying moisture contents
- Specimens placed in bottom of cup and split with grooving tool
- Crank turned and cup is impacted until groove is closed
- LL is moisture content at which groove closes with 25 blows



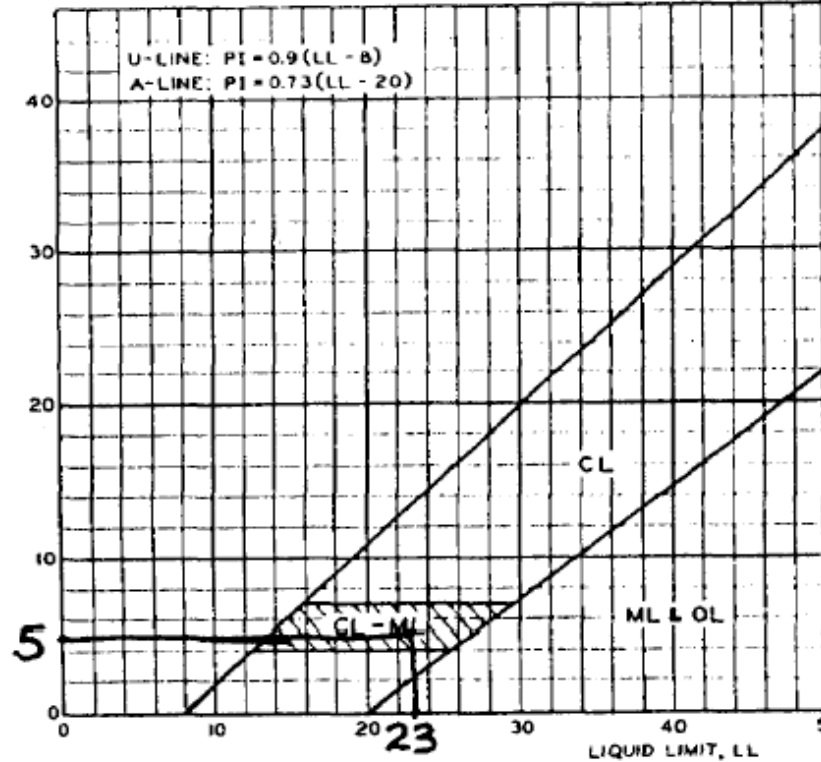
# Plastic Limit Test

- Samples prepared at varying moisture contents
- Sample rolled out on glass plate to 4.2 mm (1/8") diameter
- PL is defined as the moisture content at which rolled sample crumbles





PLASTICITY INDEX, PI



LL = 23  
 PL = 18  
 PI = 5 Cohesionless

Gravel = 53%

CL - ML USCS Classification is GM - GC

**PLASTICITY CHART**

# Atterberg Limit Example

## ■ Given

- Soil of Previous Slide
- $LL = 23$
- $PL = 18$

## ■ Find

- Plasticity Index
- Shrinkage Limit Using Holtz and Kovacs' "Quick and Dirty Method"

## ■ Solution

- $PI = LL - PL$
- $PI = 23 - 18$
- $PI = 5$
- Holtz and Kovacs Method for SL in equation form:

$$SL \cong \frac{46.4LL - 43.5PI}{PI + 46.4}$$

$$SL \cong \frac{46.4 \times 23 - 43.5 \times 5}{5 + 46.4}$$

$$SL \cong 17$$

# Consistency

- Refers to the texture and strength of a cohesive soil
- Can be measured in the field with pocket penetrometers, vane shear or torvane testers

SPT Penetration (blows/foot)	Estimated Consistency	Estimated Range of Unconfined Compressive Strength ksf
<2	Very soft (extruded between fingers when squeezed)	<0.5
2-4	Soft (moulded by light finger pressure)	0.5 - 1
4-8	Medium (moulded by strong finger pressure)	1 - 2
8-15	Stiff (readily indented by thumb but penetrated with great effort)	2 - 4
15-30	Very stiff (readily indented by thumbnail)	4 - 8
>30	Hard (indented with difficulty by thumbnail)	> 8

# Questions?

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