Soil Mechanics – Brief Review

Presented by: Gary L. Seider, P.E.

BASIC ROCK TYPES

- Igneous Rock (e.g. granite, basalt)
  - Rock formed in place by cooling from magma
  - Generally very stiff/strong and often abrasive
- Sedimentary Rock (e.g. shale, sandstone, limestone)
  - Rock formed from sediments (weathered rock) transported to position, heavily consolidated, and possibly cemented
  - Widely varying properties
- Metamorphic Rock (e.g. slate, marble)
  - Rock formed by metamorphosis (high temperature and/or pressure) of parent rock to form rock of a different type
  - Variable properties

What is a "Soil"?

- Inorganic --- Mineral
  - Gravel, Sand, Silt, Clay are Soils
  - Must be formed from weathered or disintegrated rock

- Mineral soil
  - Sediments or other accumulation of mineral particles produced by the physical or chemical weathering of rock
  - Minerals are naturally occurring.
  - Minerals have a definite chemical composition.

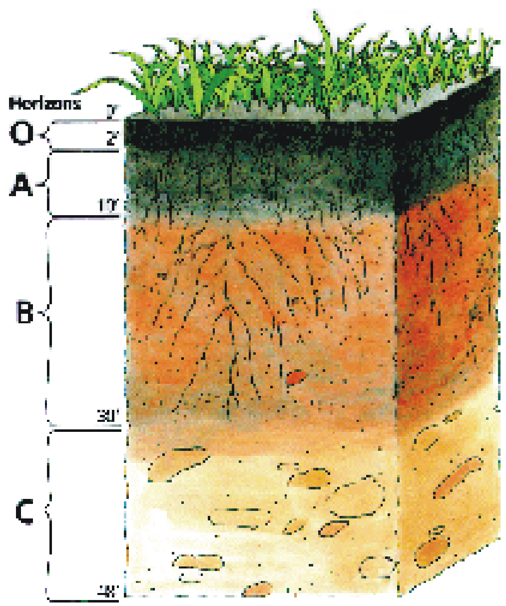
- Organic material
  - Peat, Wood, humus are NOT Soils
  - Soil containing deposits derived from plant or animal matter; typically mixed with some mineral-based soil particles.
    - "Topsoil"
    - Peat
    - Other organic soils

BASIC SOIL TYPES

- Residual Soil
  - Soil formed in place by physical/chemical weathering of parent rock
- Transported Soil
  - Soil formed by transport and placement of soil particles by natural means (water, ice, wind)
    - Aeolian – deposited by wind
    - Alluvial – deposited by running water
    - Fluvial – river/stream deposition
    - Glacial – deposited by ice flow (glaciers)
- Fill
  - Soil formed by placement of soil particles by humans
    - Engineered fill – placed and compacted to standards
    - Random (Uncontrolled) fill

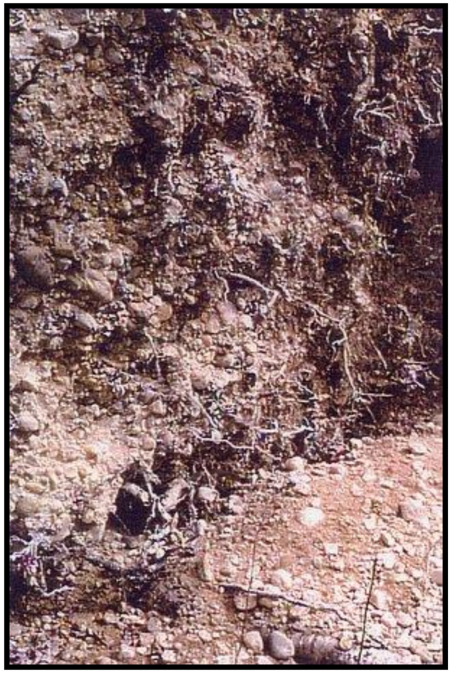
Characteristics of soil depend on how it was formed

Identification of Soil Layers



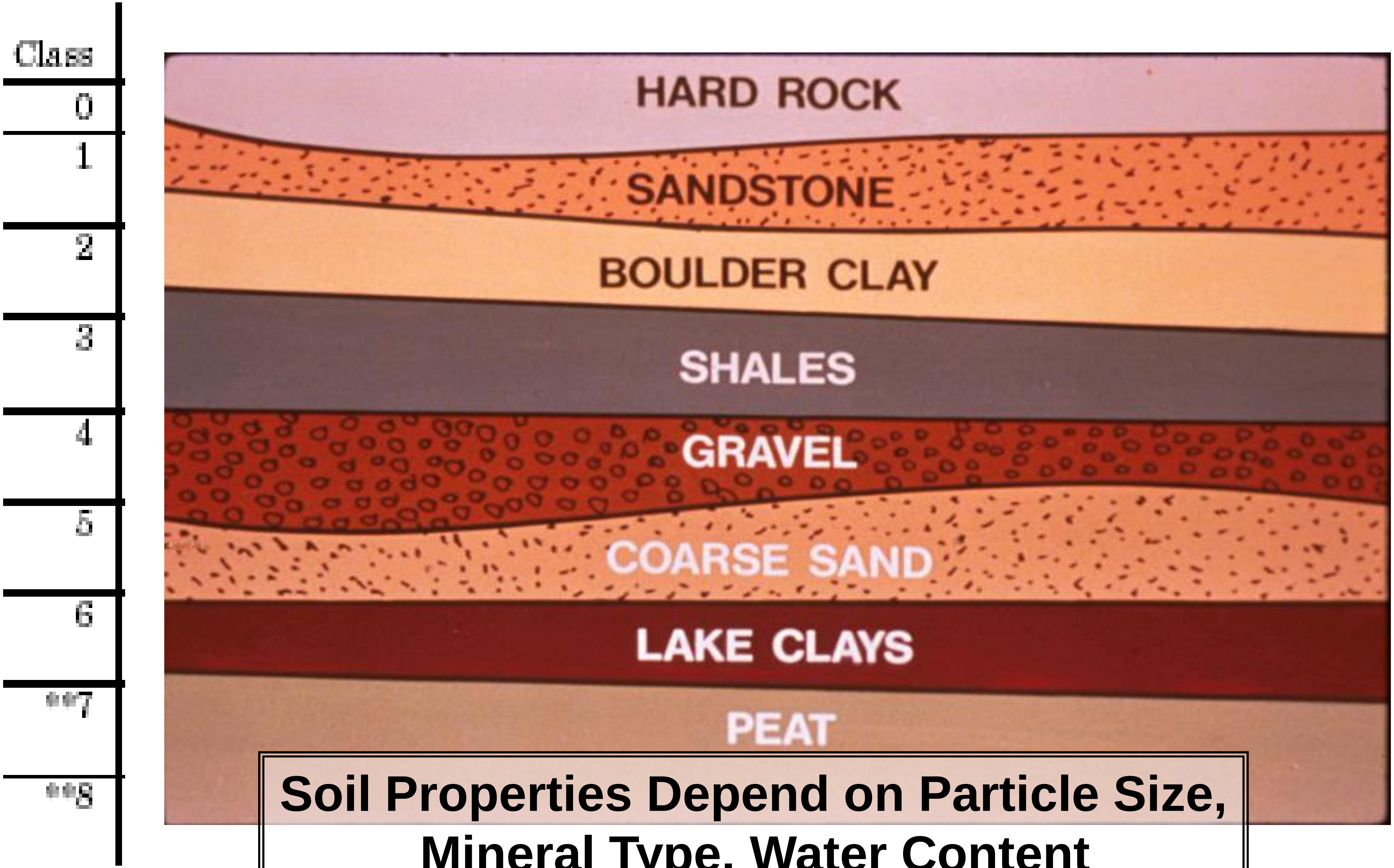
Residual Soil

Transported Soil



- **"O" horizon: both fresh and decaying plant materials**
- **"A" horizon: mix of humus & minerals, usually black**
- **"B" horizon: mineral horizon – usually red or brown**
- **"C" horizon: mineral horizon – usually gravel, silt or clay**
- **"R" horizon: underlying rock**

Soils Exist in Infinite Variety



Soil Properties Depend on Particle Size, Mineral Type, Water Content

Gravel

Rock Fragments

- 1/8” (3 mm) to 3” (76 mm) sizes
- Usually angular – large void spaces
- Granite, Limestone, trap rock, bank run, processed
- Can be loose to compact

Sand

Rock Fragments

- **Usually angular - gritty feel**
- **Typically less than 1/8" (3 mm) in size**
- **If moist will form small clumps**
- **Falls apart if touched when dry**
- **Can be loose to very dense**

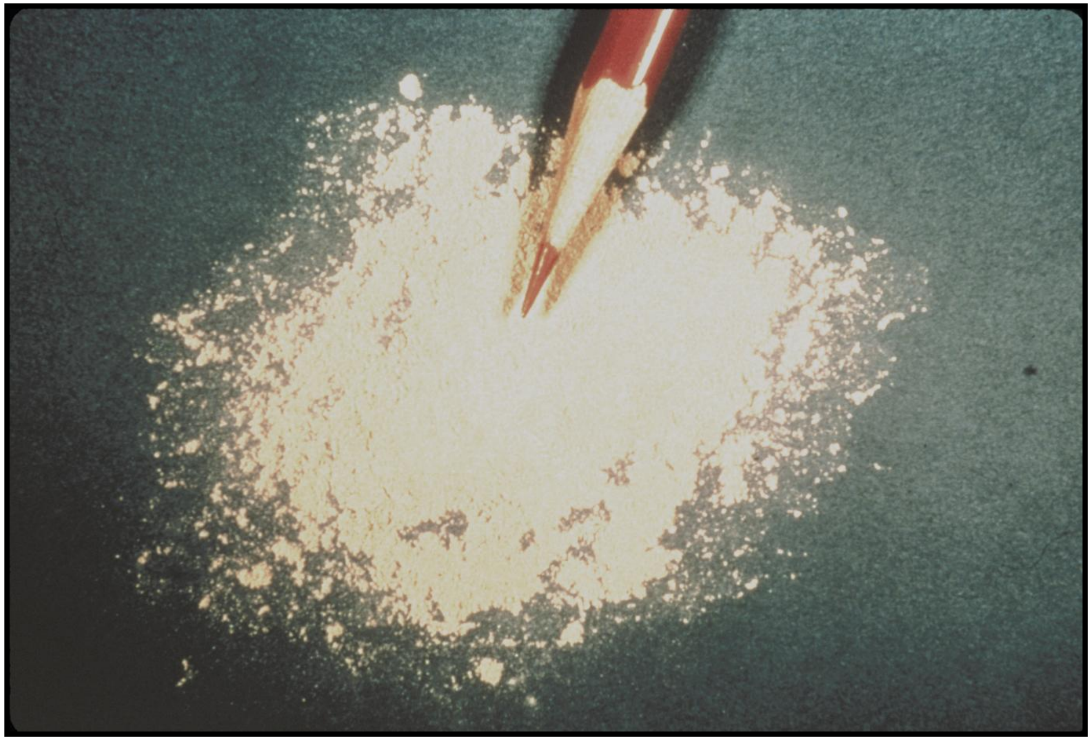
Silt

Mineral Grains

- **1/16” or smaller**
- **Smooth to the touch**
  - **Weak when dry**
  - **Easily powdered**
  - **Shows fingerprints**

- **Fine grained**
- **Typically rounded**
- **Often stains hands**
- **Can Be Very Soft to Hard**

Clays



Mineral Grains

- **Smooth to the touch**
  - **Strong when dry**
  - **Difficult to crush**
  - **Shows fingerprints**
  - **Molds easily (pottery)**

- **Extremely small particles (0.003” [0.076 mm] and less)**
- **Almost no void space**
- **Can be very soft to hard**

Organic Materials

- All decay (compress) over time – not good for anchoring or foundations.
- Most have an odor.
- Most are black in color.
- Most show roots, woody material, or bugs.

PEAT
Typically found in coastal areas
Usually thick deposits

SOIL PROPERTIES

- Classification
  - Weight-volume (density, water content, etc)
  - Gradation (particle size distribution)
  - Index Properties
    - Atterberg limits
    - Penetration resistance
  - Mineralogy
- Engineering Properties
  - Shear strength (ability to resist applied loads)
  - Hydraulic conductivity/permeability (ability to conduct water)
  - Compressibility (relates settlement to applied loads)

USCS Soil Classification

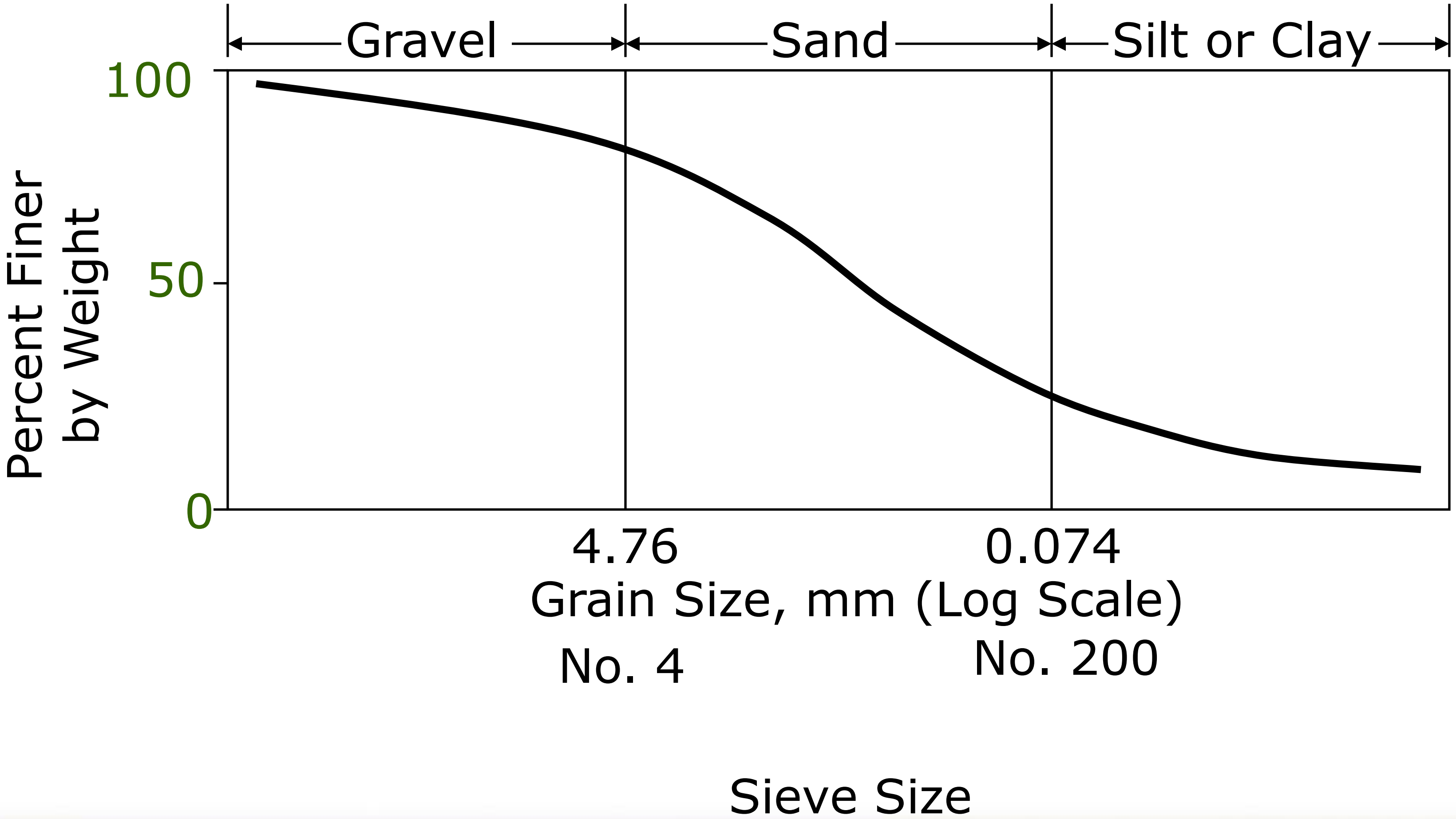
- Granular soils
  - Greater than 50% (by weight) retained by #200 Sieve
  - Classified primarily according to gradation and, to a lesser extent, on the -200 fraction
    - Sands - SP, SW, SM, SC
    - Gravels - GP, GW, GM, GC
  - Characteristics
    - Often difficult to sample
    - Behavior primarily related to density
- Fine-grained soils
  - Less than 50% (by weight) retained by #200 Sieve
  - Classified primarily according to Atterberg limits (plasticity)
    - Clays – CL, CH
    - Silts – ML, MH
  - Characteristics
    - Generally considered “cohesive” soils
    - Behavior primarily related to plasticity and drainage

Soil Particle Sizes

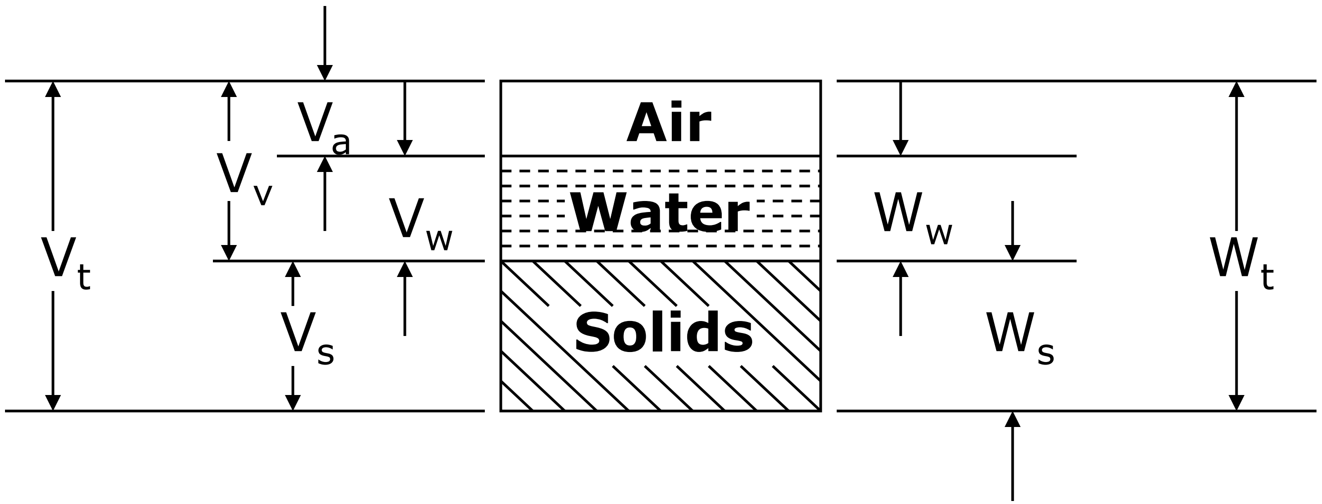
	Fraction	*Sieve Size*	*Diameter*
Boulders		**12" Plus**	**300 mm Plus**
Cobbles		**3" - 12"**	**75 - 300 mm**
Gravels	**Coarse** **Fine**	**.75" - 3"** **No. 4 - .75"**	**19 - 75 mm** **4.76 - 19 mm**
Sand	**Coarse** **Medium** **Fine**	**No. 10 - No. 4** **No. 40 - No. 10** **N0. 200 - No. 40**	**2 - 4.76 mm** **0.42 - 2 mm** **0.074 - 0.42 mm**
Fines (silts and clays)		**Passing No. 200**	**0.074 mm**

Soil Gradation

Particle Size Distribution

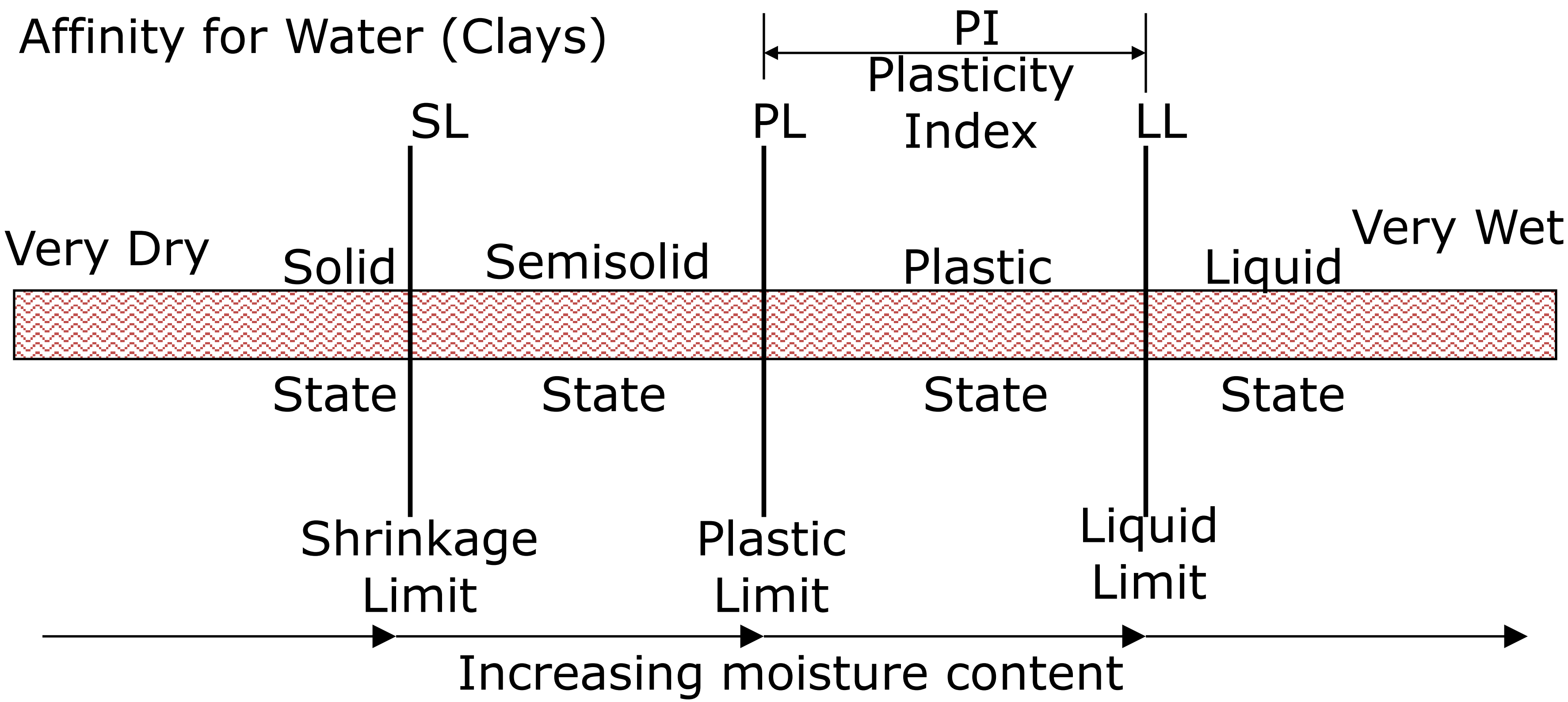


Soil Phases and Weight-Volume Relations



Moisture Content-	ω	W_w/W_s
Degree of Saturation-	S	V_w/V_v
Void Ratio-	e	V_v/V_s
Porosity-	n	V_v/V_t
Dry Unit Weight (Dry Density)-	γ_d	W_s/V_t
Total Unit Weight-	γ_t	$(W_s + W_w)/V_t$
Saturated Unit Weight-	γ_s	$(W_s + V_v\gamma_w)/V_t$

Atterberg Limits



ATTERBERG LIMITS

PL = Plastic Limit   LL = Liquid Limit   PI = LL-PL = Plasticity Index

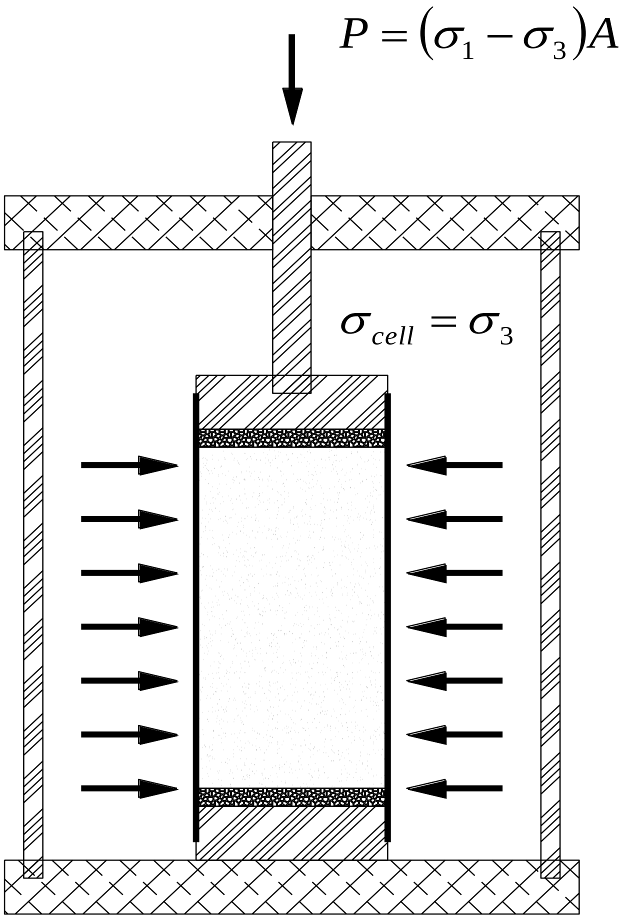
SOIL STRENGTH

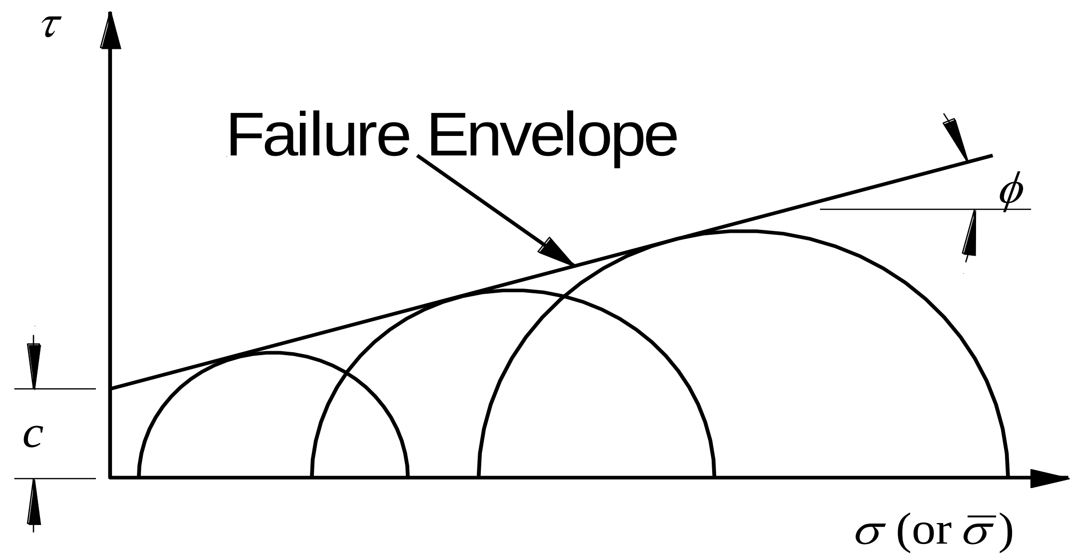
- Ability to Withstand Deformation (movement) Under Pressure or Force.

- Soil has Little or no Tensile Resistance

- Consists of Two Parts:
  - Friction Between Particles (Physical)
  - Cohesion (Chemical Bond)

Soil Shear Strength





SOIL SHEAR STRENGTH

Can Represent in Terms of Total or Effective Stresses

- In terms of total stresses (ignoring *u*)

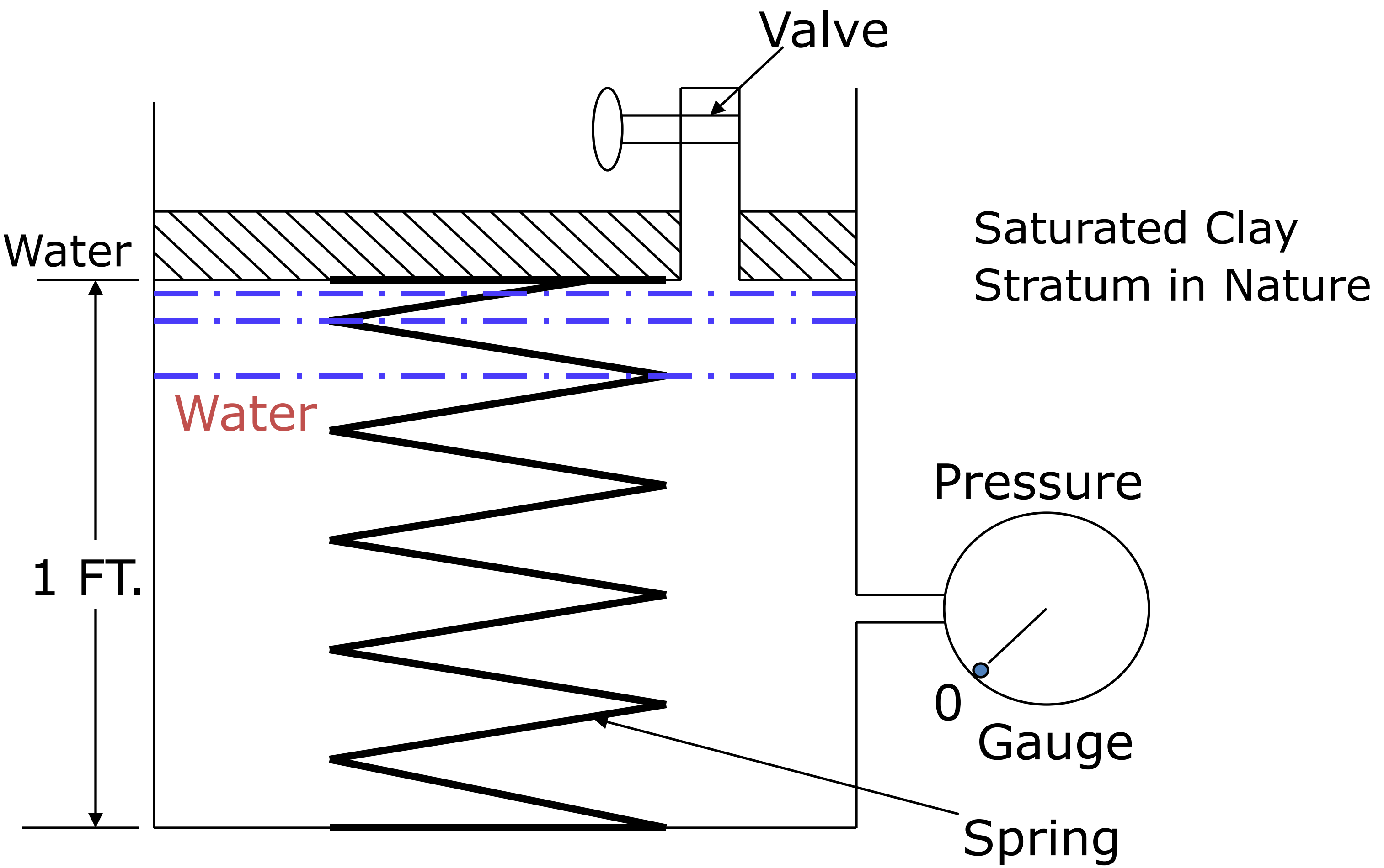
$$s = c + \sigma \tan \phi$$

- In terms of effective stresses

$$s = \overline{c} + (\sigma - u) \tan \overline{\phi}$$

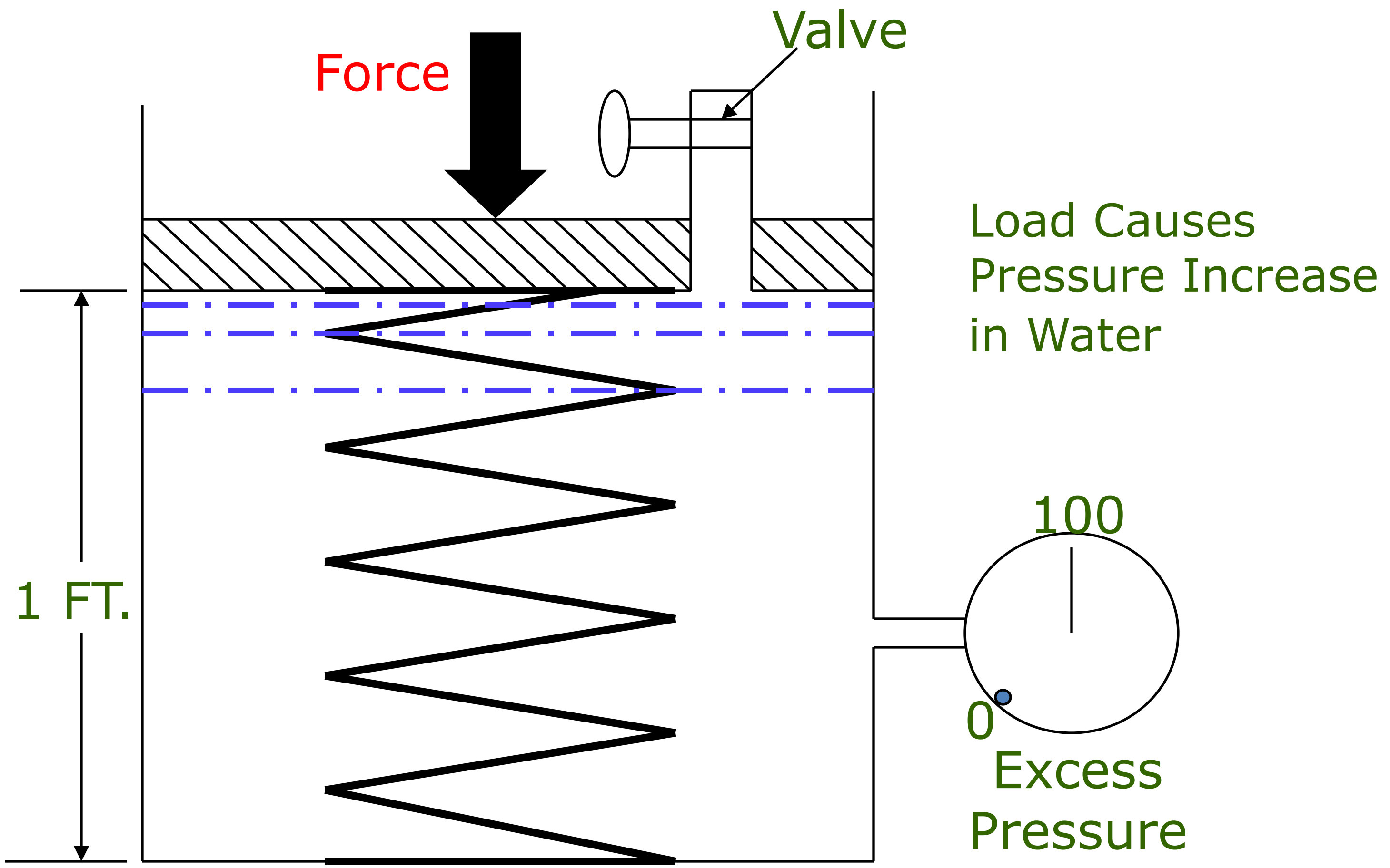
Consolidation Analogy

Spring - Soil Skeleton
Water - Pore Water in Soil



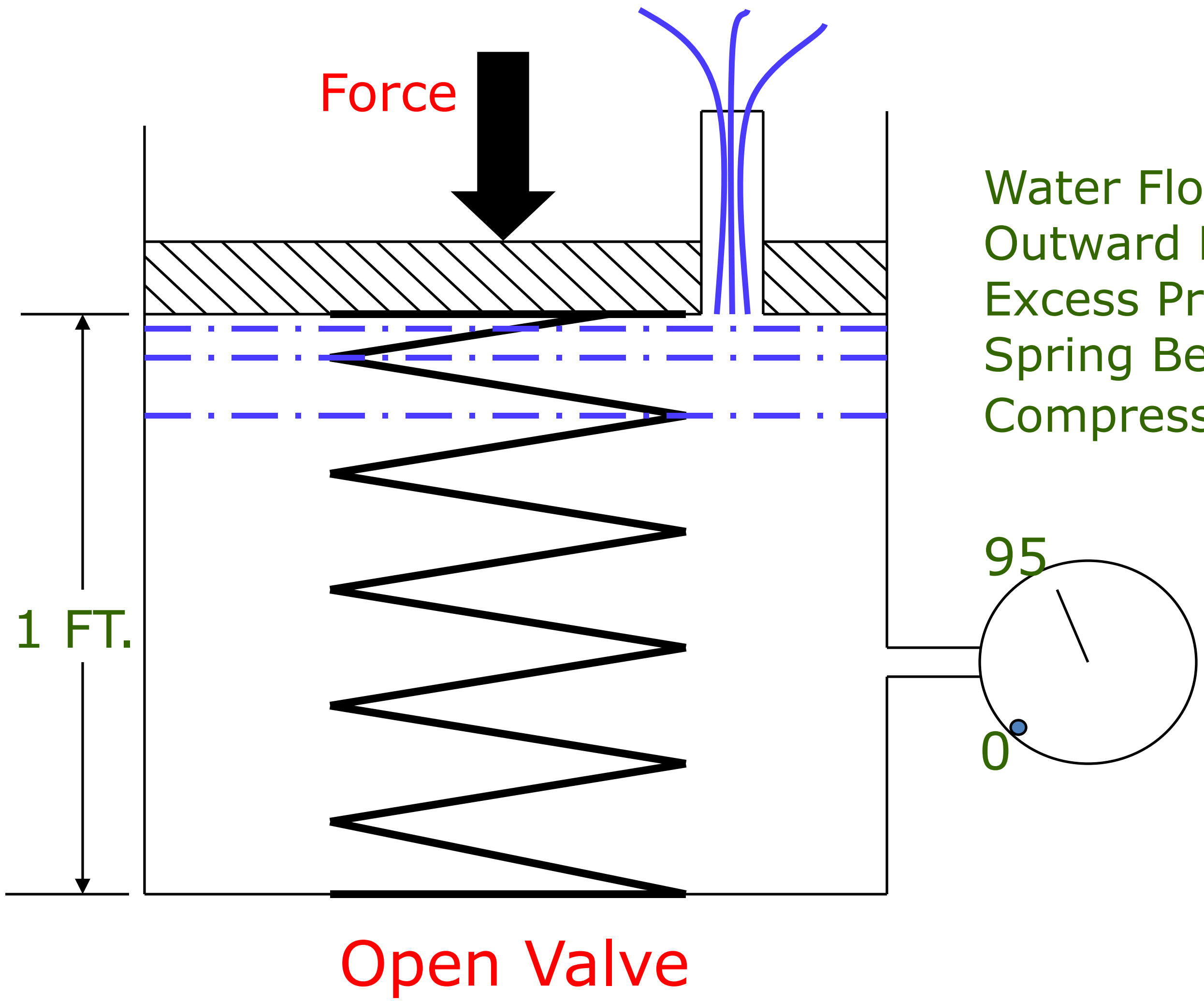
Analogy of Soil and a Spring

Consolidation Analogy



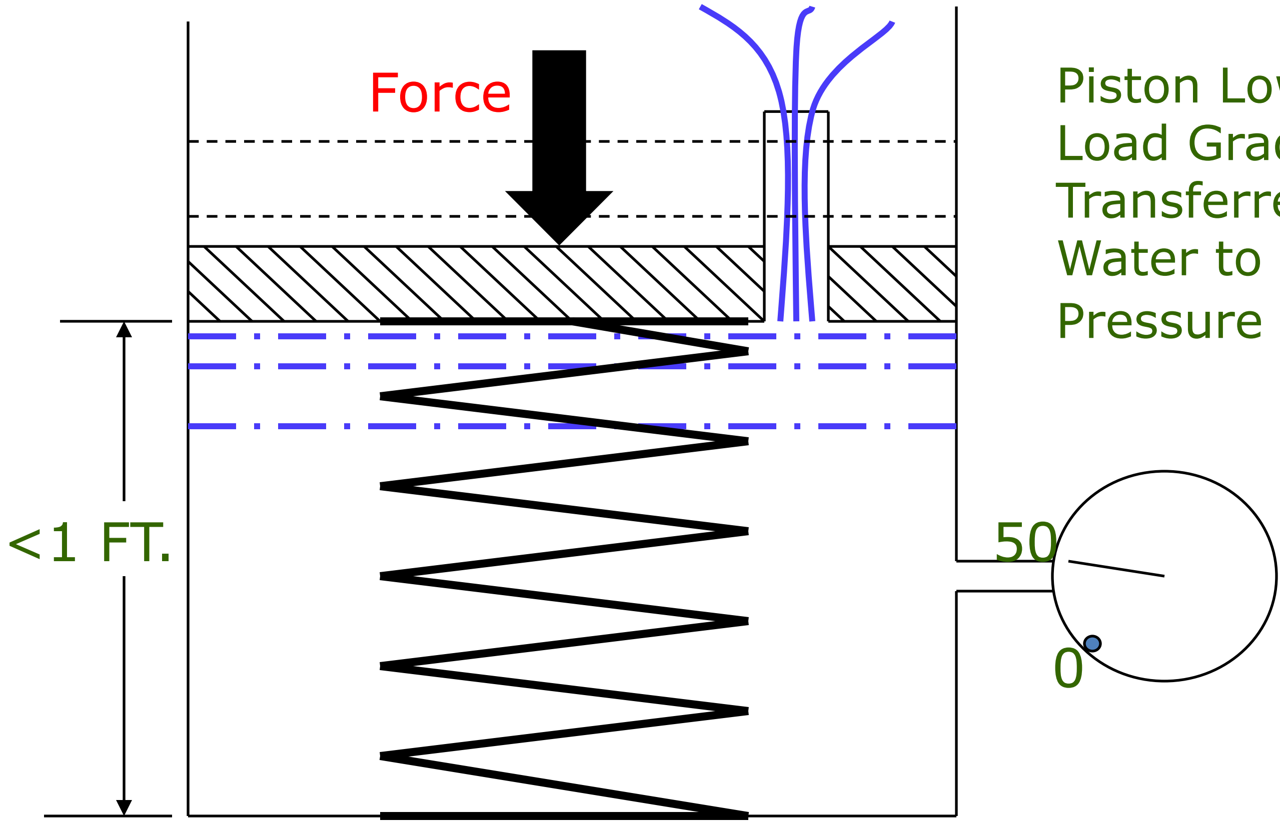
Closed Valve

Consolidation Analogy



Water Flows Outward Due to Excess Pressure - Spring Begins to Compress

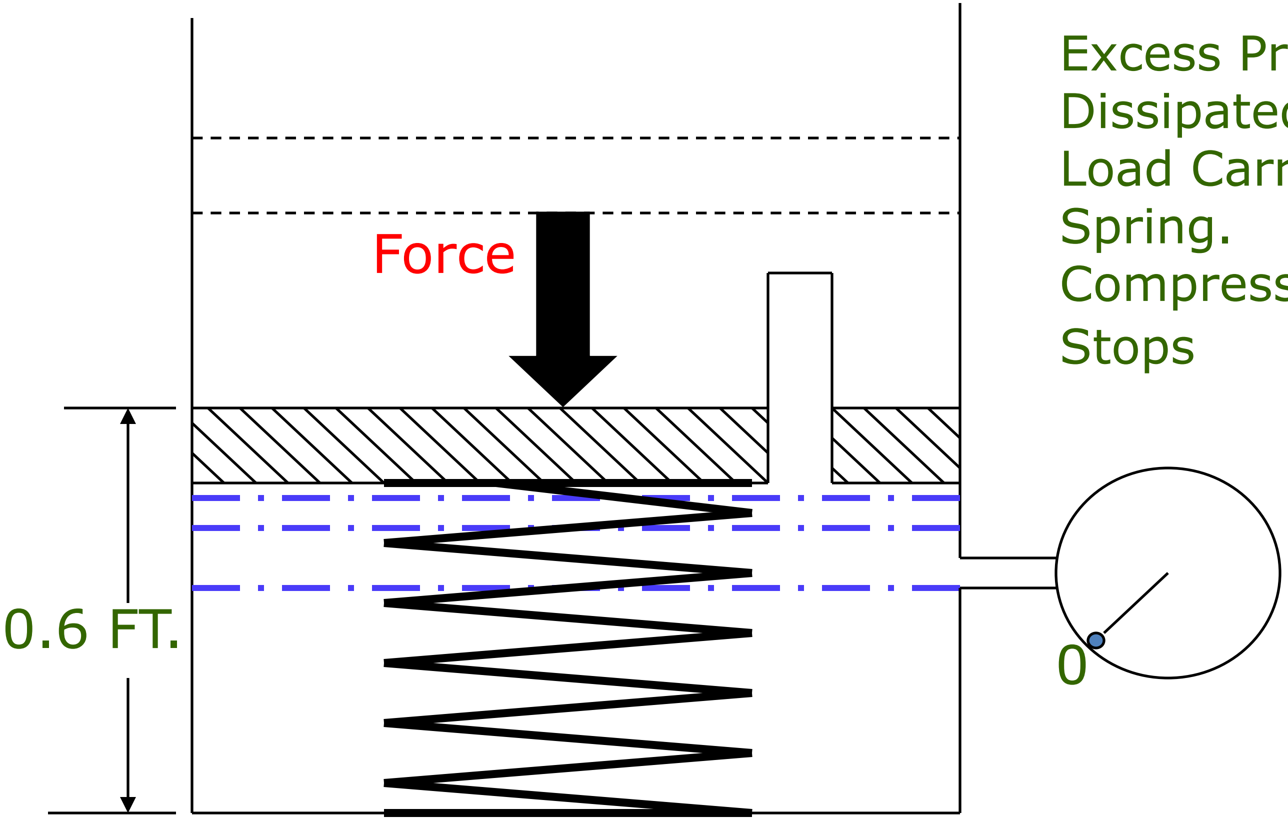
Consolidation Analogy



Open Valve

Piston Lowers -- Load Gradually Transferred From Water to Spring as Pressure Drops

Consolidation Analogy



Excess Pressure Dissipated - Full Load Carried by Spring. Compression Stops

Equilibrium - Spring Compressed

Determination of Soil Strength Parameters

- Laboratory Testing
  - Unconfined compression tests (cohesive soils)
  - Triaxial tests
  - Direct shear tests
- In-situ (in-place) Testing
  - Standard penetration test (SPT)
  - Cone penetration test (CPT)
  - Test Pit
- Correlation with index properties
  - Least reliable, but cheapest
  - Often useful for preliminary design

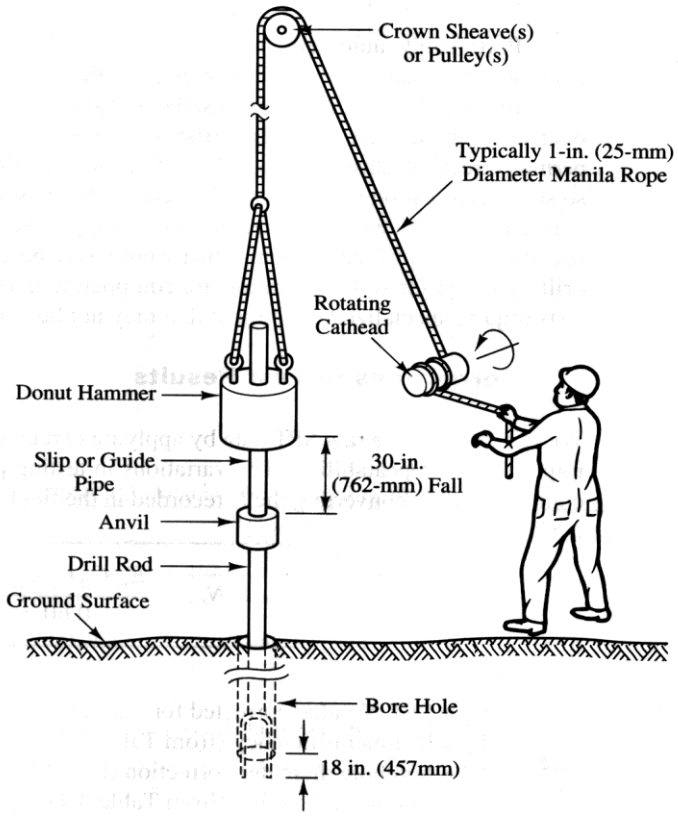
Field Testing

- Test Holes
  - Backhoe
    - inexpensive
    - common

- Borings
  - expensive
  - specialized equipment
  - specialized training

Standard Penetration Test

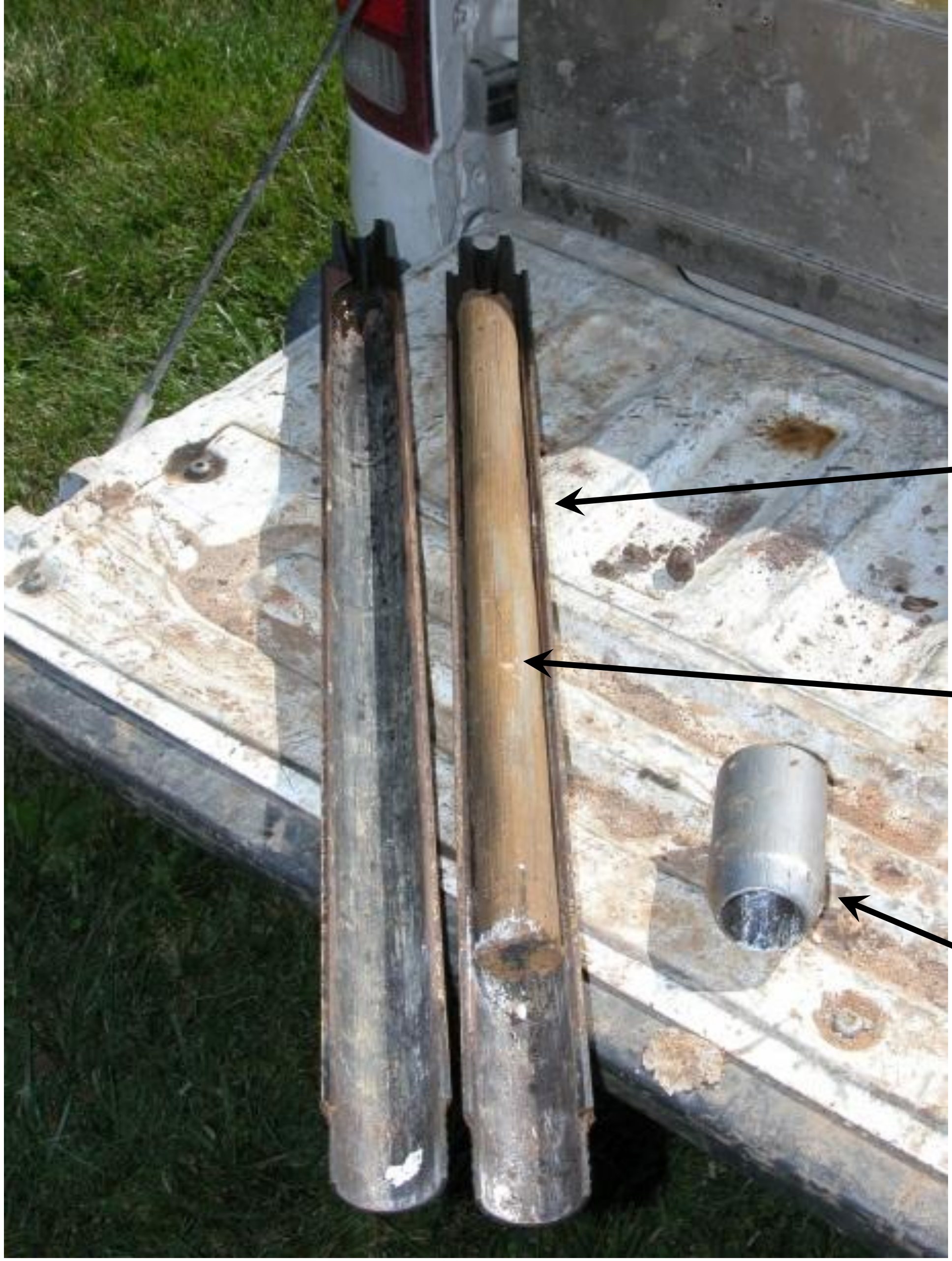
- SPT “N-value” is number of blows of special hammer required to penetrate standard sampler 12 inches
  - 140-lb hammer
  - 30-inch drop
  - Penetrate total distance of 18-inches, measure the number of blows required for each 6-inch increment
  - Compute “N-value” by summing number of blows for last 12-inches of penetration



Drill Rig


Drop Hammer
Drill Stem
Hollow
Stem
Auger
6” Increment
Marks

Split Spoon Sampler



Split Barrel Tube

Recovered Soil Sample

Open Shoe

Project No.: 04-839
Project: Centralia Site Borings

Boring Log

Rig: CME 55
Location: NE Corner Pratt & Brick Sts.
Driller: L. Gottman

Client: A.B. Chance Company
Boring No.: 1

SUBSURFACE PROFILE						SAMPLE					
Depth (ft.)	Symbol	Description	Qp, t.s.f.	Dry Density, P.C.F.	Depth/Elev.	Number	Type	Blows/ft.	Qu, T.S.F.	Standard Penetration Test blows/ft. (10 20 30 40)	Water Content % Wp — Wl (10 20 30 40)
0		Ground Surface			0.0						
		Topsoil (9")			-0.8 0.8						
		Light Gray Mottled Yellow Brown Silty Clay, (CL) Stiff, (CL)				1	SS	11		11	
5		Mottled Reddish Brown, Medium, (CL)	0.75			2	SS	6		6	
		Medium, (CL)	1.00			3	SS	6		6	
10		Mottled Yellow Brown, Grading to Clay (CH) @ 10.5 ft.	1.75		-10.5 10.5	4	SS	7		7	
		Light Gray Mottled Yellow Brown Clay, Little Sand, Stiff, (CH)	2.50			5	SS	12		12	
15		Yellow Brown Mottled Light Gray, Stiff, (CH)	3.00			6	SS	11		11	
		Light Gray Mottled Yellow Brown w/Sand, Stiff, (CH)	3.00		-19.0 19.0	7	SS	11		11	
20		Light Gray Mottled Yellow Brown Sandy Clay, Trace of Gravel, Wet, Stiff, (CL)	1.50			8	SS	8		8	
		Yellow Brown Mottled Light Gray w/Gravel, Stiff, (CL)	2.50		-24.0 24.0	9	SS	11		11	
25		Yellow Brown Mottled Light Gray Sandy Silty Clay w/Gravel, Very Stiff, (CL)	3.50			10	SS	21		21	
		Very Stiff, (CL)	3.50			11	SS	17		17	
30		Very Stiff, (CL)	3.75		-31.5 31.5	12	SS	14		14	
		Light Gray Mottled Yellow Brown Clay w/ Sand,			-32.5 32.5						

Drill Method: 3 1/4" HSA & SPT
Boring Started: 7-27-2004
Boring Completed: 7-27-2004
Tested By:
Logging By: J. Sick

HTL
Hannibal Testing Laboratories, Inc.
4510 PARIS GRAVEL ROAD · P.O. BOX 387
HANNIBAL, MISSOURI 63401 · (573) 221-7714

Groundwater Elev. During Drilling:
Groundwater Elev. @ Comp.:
Groundwater Elev. @ 5.5 Hrs.: -22.0
Boring Location:

Sheet 1 of 2

Project No.: 04-839

Project: Centralia Site Borings

Boring Log

Rig: CME 55

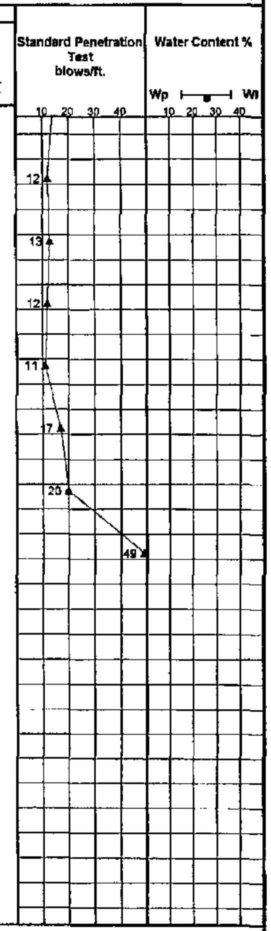
Location: NE Corner Pratt & Brick Sts.

Driller: L. Gottman

Client: A.B. Chance Company

Boring No.: 1

Depth (ft.)	Description (Subsurface Profile)	Qp, t.s.f.	Dry Density, P.C.F.	Depth/Elev.	Sample Number	Sample Type	Sample Blows/ft.	Qu, T.S.F.
	Very Stiff, (CH)	2.50		-32.3	13	SS	14	
35	Gray Mottled Yellow Brown, Very Stiff, (CH)	2.75			14	SS	12	
	Yellow Brown Mottled Light Gray, Very Stiff, (CL)	2.75			15	SS	13	
40	Light Gray, Stiff, (CH)	3.00			16	SS	12	
	Mottled Yellow Brown, Stiff, (CH)	3.50		-44.0 / 44.0	17	SS	11	
45	Yellow Brown Mottled Light Gray Silty Sandy Clay, Trace of Gravel, Very Stiff, (CL)	4.00		-46.5 / 46.5	18	SS	17	
	Very Stiff, Little Gravel Below 47 ft., (CL)	3.50			19	SS	20	
50	Some Gravel, Hard, (CL)	4.5+		-50.5 / 50.5	20	SS	49	
	End of Boring @ 50.5 ft.							
55								
60								



Drill Method: 3 1/4" HSA & SPT

Boring Started: 7-27-2004

Boring Completed: 7-27-2004

Tested By:

Logging By: J. Sick

Hannibal Testing Laboratories, Inc.
4510 PARIS GRAVEL ROAD · P.O. BOX 387
HANNIBAL, MISSOURI 63401 · (573) 221-7714

Groundwater Elev. During Drilling:

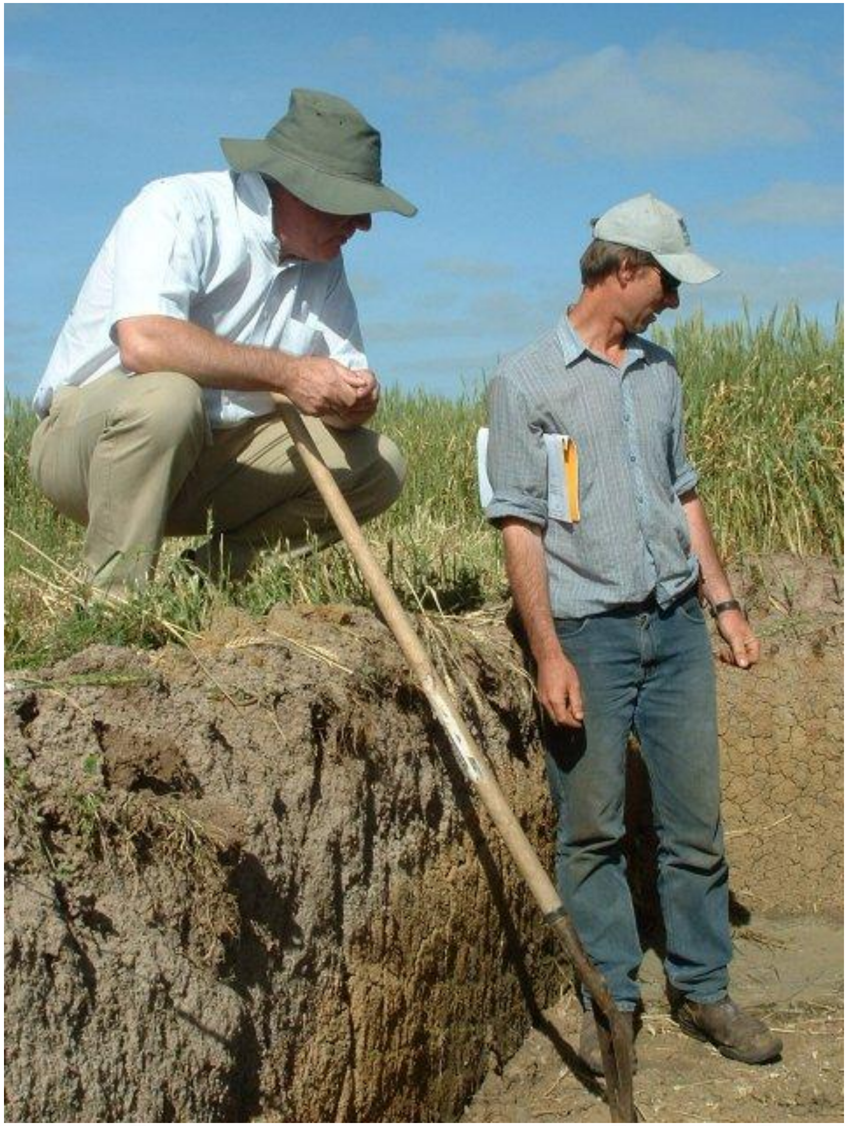
Groundwater Elev. @ Comp.:

Groundwater Elev. @ 5.5 Hrs.: -22.0

Boring Location:

Sheet 2 of 2

Test Pits



- Exposes soil layers
  - look
    - color changes
  - feel samples
    - gritty?
    - smooth?
  - Poke
    - hard?
    - easy?

Estimation of Soil Properties

The following slides, may be used to estimate soil strength parameters, but is not a substitute for actual borings and testing.

- Granular Soils
  - Most commonly related to SPT N-value
- Cohesive Soils
  - Most commonly related to Atterberg limits

Relative Density vs. N-Values

Relative Density	***N-Values***	***Friction Angle***
Very Loose	0 to 4	<28°
Loose	4 to 9	28° to 30°
Medium Dense	10 to 29	31° to 35.5°
Dense	30 to 49	36° to 41°
Very Dense	50 to 80	41° to 50°
Extremely Dense	>80	?

Consistency of Cohesive (CLAY) Soils

Consistency	Consolidation History	Blows/ft N_{70}	Comments
Very Soft	Normally Consolidated	0-2	Runs through fingers when squeezed
Soft	Normally Consolidated	3-4	Very easy to form into a ball
Medium	Normally Consolidated	5-8	Can be formed into a ball
Stiff	NC to OCR 2-3	9-15	Can make thumbprint w/ strong pressure
Very Stiff	Over Consolidated	16-30	Can scratch with thumbnail
Hard	Highly Over Consolidated	>30	Cannot be deformed by hand

Anchor Application Information

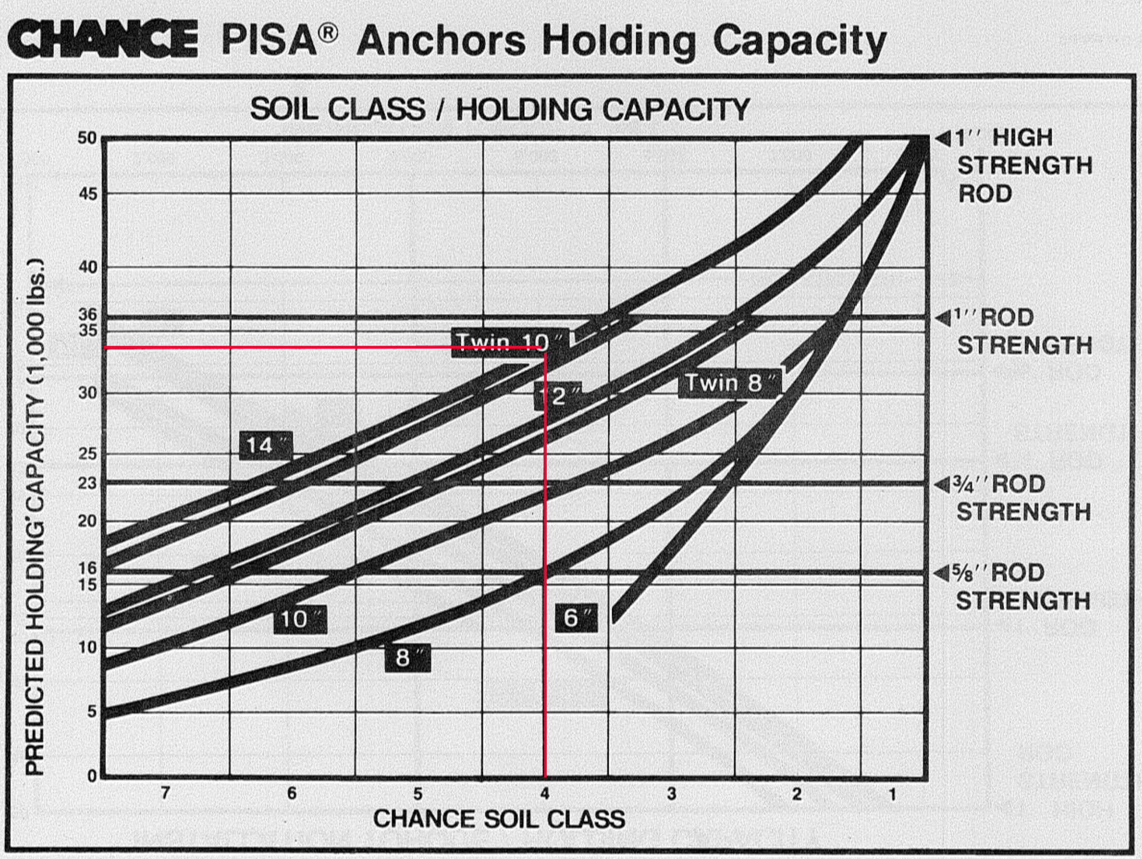
SOIL CLASSIFICATION DATA

Class	Common Soil-Type Description	Geological Soil Classification	Probe Values in.-lb. (NM)	Typical Blow Count "N" per ASTM-D1586
0	Sound hard rock, unweathered	Granite, Basalt, Massive Limestone	N.A.	N.A.
1	Very dense and/or cemented sands; coarse gravel and cobbles	Caliche, (Nitrate-bearing gravel/rock),	750 - 1600 (85 - 181)	60-100+
2	Dense fine sands; very hard silts and clays (may be preloaded)	Basal till; boulder clay; caliche; weathered laminated rock	600-750 (68 - 85)	45-60
3	Dense sands and gravel; hard silts and clays	Glacial till; weathered shales, schist, gneiss and siltstone	500 - 600 56 - 68	35-50
4	Medium dense sand and gravel; very stiff to hard silts and clays	Glacial till; hardpan; marls	400 - 500 (45 - 56)	24-40
5	Medium dense coarse sands and sandy gravels; stiff to very stiff silts and clays	Saprolites, residual soils	300 - 400 (34 - 45)	14-25
6	Loose to medium dense fine to coarse sands to stiff clays and silts	Dense hydraulic fill; compacted fill; residual soils	200 - 300 (23 - 34)	7-14
**7	Loose fine sands; Alluvium; loess; medium - stiff and varied clays; fill	Flood plain soils; lake clays; adobe; gumbo, fill	100 - 200 (11 - 23)	4-8
**8	Peat, organic silts; inundated silts, fly ash very loose sands, very soft to soft clays	Miscellaneous fill, swamp marsh	less than 100 (0 - 11)	0-5

Class 1 soils are difficult to probe consistently and the ASTM blow count may be of questionable value.
**It is advisable to install anchors deep enough, by the use of extensions, to penetrate a Class 5 ot 6, underlying the Class 7 or 8 Soils.

A-4, B-6

PISA® & Tough One® Holding Capacity



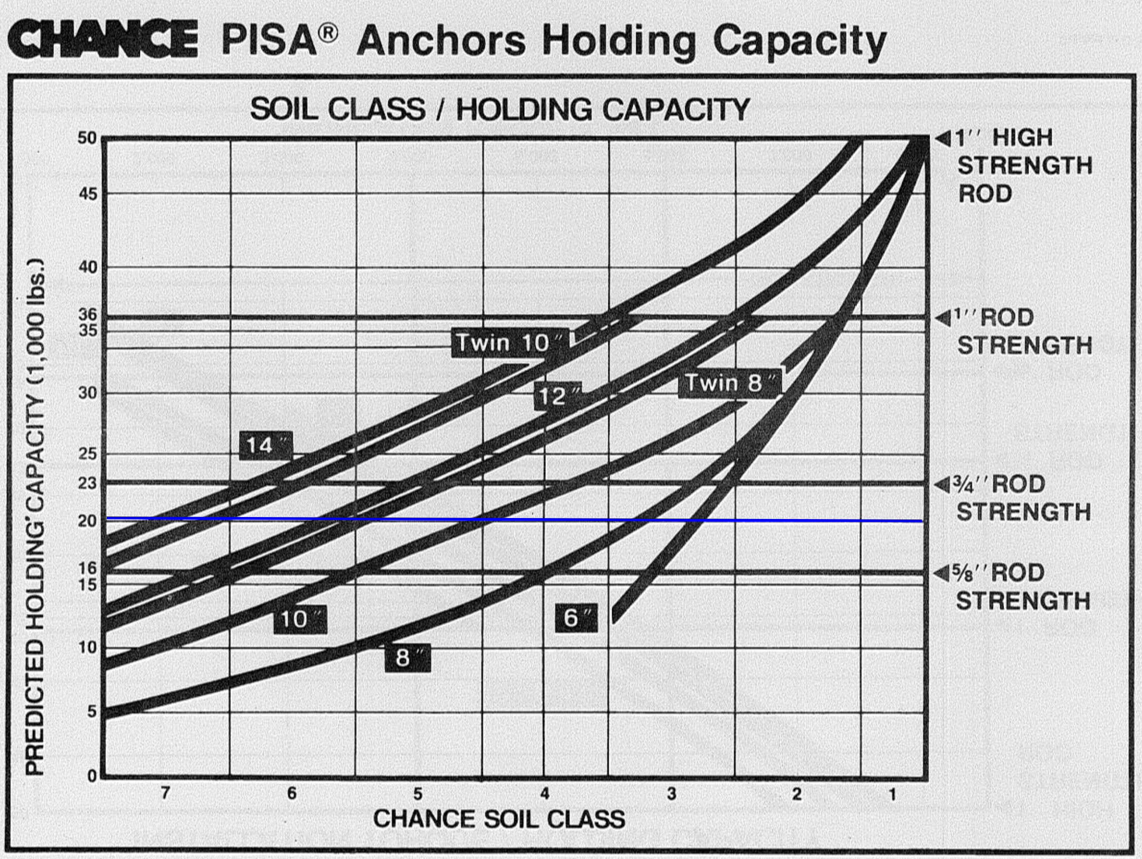
Note: Holding Capacities are based on average test data and are offered as an application guide only. These are ultimate values. They are the highest capacities that can be expected in a given soil class. Apply an appropriate safety factor against soil failure.

B-4 & B-7

Soil Class vs. Holding Capacity

www.hubbellpowersystems.com

PISA® & Tough One® Holding Capacity



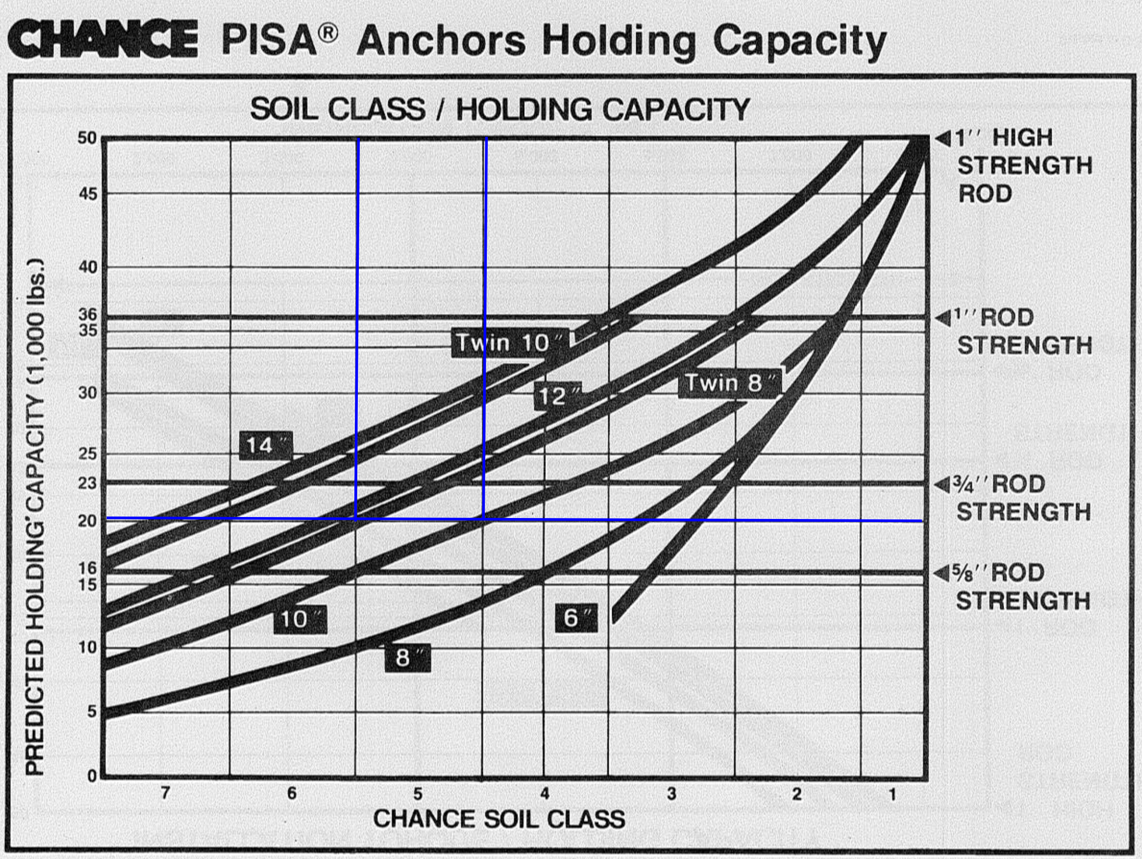
Note: Holding Capacities are based on average test data and are offered as an application guide only. These are ultimate values. They are the highest capacities that can be expected in a given soil class. Apply an appropriate safety factor against soil failure.

B-4 & B-7

Soil Class vs. Holding Capacity

www.hubbellpowersystems.com

PISA® & Tough One® Holding Capacity



Note: Holding Capacities are based on average test data and are offered as an application guide only. These are ultimate values. They are the highest capacities that can be expected in a given soil class. Apply an appropriate safety factor against soil failure.

B-4 & B-6

Soil Class vs. Holding Capacity

SQUARE-SHAFT "SS" SCREW ANCHORS

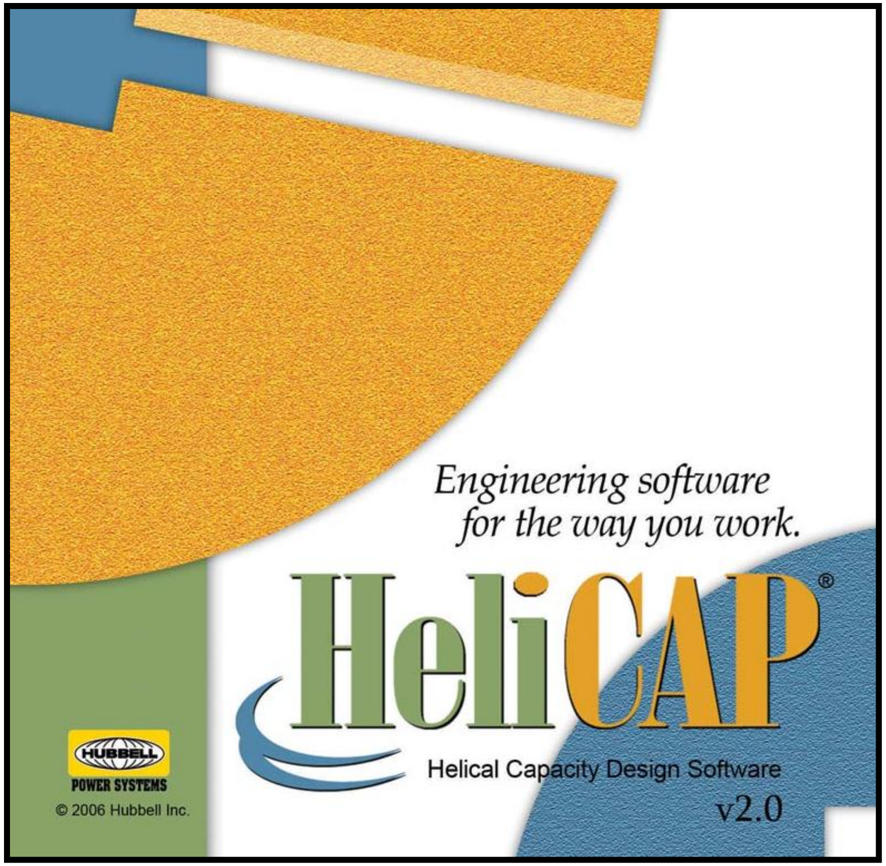
APPLICATION AND ORDERING INFORMATION

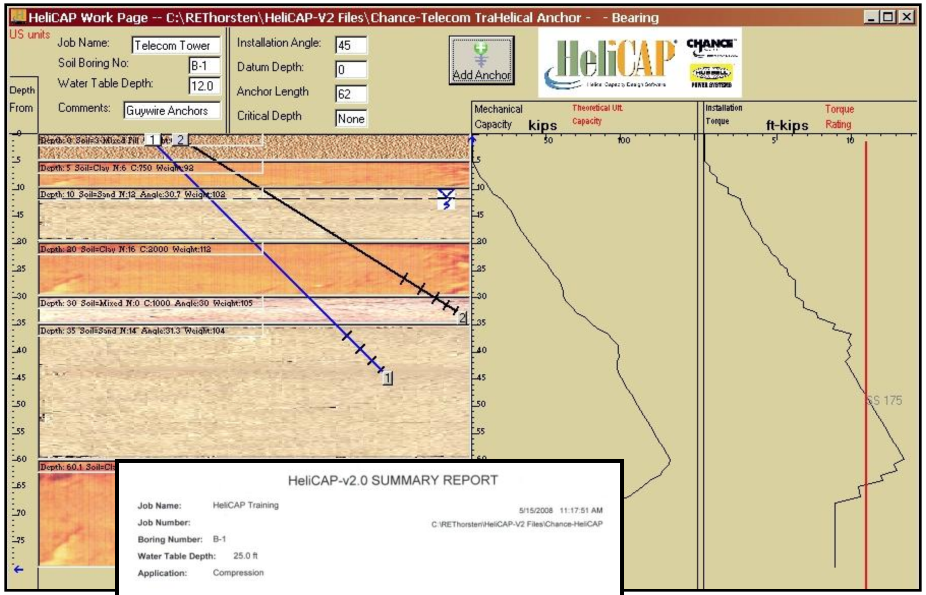
LEAD SECTIONS

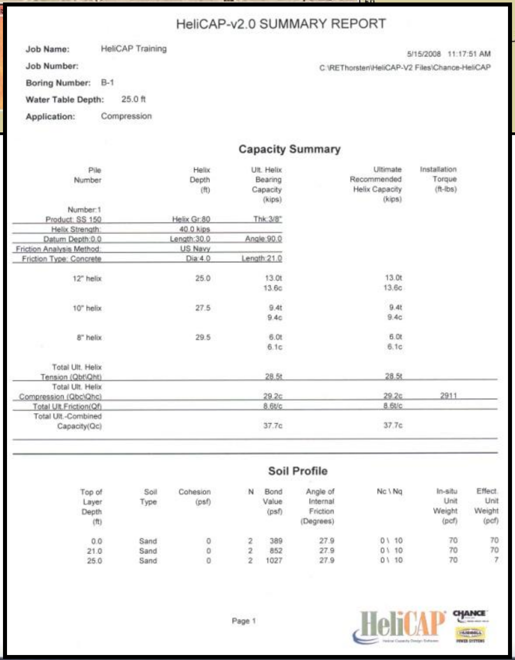
Catalog No.	Length	Helix Combinations	Std. Pkg./ Pallet	Soil Anchor Holding Strengths - (lbs.) vs. Chance Soil Class					
				Class 7	Class 6	Class 5	Class 4	Class 3	Class 2
P012642-AE*	3 ft.	8" - 10"	1/20	19,000	23,000	27,000	32,000	36,000	41,000
P012642-EJ	$3^{1}/_{2}$ ft.	10" - 12"	1/20	21,000	26,000	31,000	36,000	41,000	46,000
P012642-AEJ*	$5^{1}/_{2}$ ft.	8" - 10" - 12"	1/20	26,000	32,000	39,000	46,000	51,000	58,000
P012642-EJN*	7 ft.	10" - 12" - 14"	1/20	29,000	37,000	45,000	53,000	61,000	69,000
P012642-AEJN	$10^{1}/_{2}$ ft.	8" - 10" - 12" - 14"	1/20	31,000	40,000	49,000	58,000	67,000	
P012642-EJNS*	$10^{1}/_{2}$ ft.	10" - 12" - 14" - 14"	1/20	40,000	51,000	62,000	70,000		

Note: Holding capacities are based on average test data and are offered as an application guide only. These are ultimate values. They are the highest capacities that can be expected in a given soil class. Apply an appropriate safety factor against soil failure.

HeliCAP(R) v2.0 Helical Capacity Design Software







HeliCAP-v2.0 SUMMARY REPORT

Job Name: HeliCAP Training

5/15/2008 11:17:51 AM

Job Number:

C:\REThorsten\HeliCAP-V2 Files\Chance-HeliCAP

Boring Number: B-1

Water Table Depth: 25.0 ft

Application: Compression

Capacity Summary

Pile Number	Helix Depth (ft)	Ult. Helix Bearing Capacity (kips)	Ultimate Recommended Helix Capacity (kips)	Installation Torque (ft-lbs)
Number:1				
Product: SS 150	Helix Gr:80	Thk:3/8"		
Helix Strength:	40.0 kips			
Datum Depth:0.0	Length:30.0	Angle:90.0		
Friction Analysis Method:	US Navy			
Friction Type: Concrete	Dia:4.0	Length:21.0		
12" helix	25.0	13.0t 13.6c	13.0t 13.6c	
10" helix	27.5	9.4t 9.4c	9.4t 9.4c	
8" helix	29.5	6.0t 6.1c	6.0t 6.1c	
Total Ult. Helix Tension (Qbt\Qht)		28.5t	28.5t	
Total Ult. Helix Compression (Qbc\Qhc)		29.2c	29.2c	2911
Total Ult.Friction(Qf)		8.6t/c	8.6t/c	
Total Ult.-Combined Capacity(Qc)		37.7c	37.7c	

Soil Profile

Top of Layer Depth (ft)	Soil Type	Cohesion (psf)	N	Bond Value (psf)	Angle of Internal Friction (Degrees)	Nc \ Nq	In-situ Unit Weight (pcf)	Effect. Unit Weight (pcf)
0.0	Sand	0	2	389	27.9	0 \ 10	70	70
21.0	Sand	0	2	852	27.9	0 \ 10	70	70
25.0	Sand	0	2	1027	27.9	0 \ 10	70	7

Page 1

- Microsoft® Windows® Bearing & Uplift Capacity Software

•Based on soil and anchor/pile inputs. The program returns theoretical capacities and installation torque.

Special Soil Problems

- Organic Soils – highly compressible
- Expansive Soils – shrink/swell potential
- Collapsible soils
- Sensitive soils
- Deep fills
- Seasonally Frozen Ground and Permafrost

Conclusion

- PDH Credit
  - Send email to tmstaele@hubbell.com
  - Include
    - PDH in Subject
    - Topics for future Webinars
    - Feedback
- Questions