

Texas Tech University
Department of Civil and Environmental Engineering

Chapter 3: Part II

Soil Mechanics/Review

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Chapter 3: Soil Mechanics

Lecture No.1

- 3.1 Soil Composition
  - Soil-a 3-phase material
  - Soil Characterization (particle size, soil plasticity)
- 3.2 Soil Classification
- 3.3 Groundwater
- 3.4 Stress (Total vs. Effective)

Chapter 3: Soil Mechanics



Lecture No.2

- 3.5 Compressibility and settlement

Lecture No.3

- 3.6 Strength

3.5 Compressibility & Settlement

- Settlement requirements often control the design of foundations
- This chapter provides a general overview of principles involved in settlement analysis
- The subject will be dealt with in greater detail in Chapter 7.

Case Study

Settlement must be within acceptable limits .....



Palacio de las Bellas Artes, Mexico City
Built 1932-1934

Palace of Fine Arts in Mexico City Settled 3m!

- Lacustrine Clay deposited in former Lake Texcoco
- Av. Water content 281%, Void Ratio 6.90
- Groundwater withdrawal; increase in effective stress
- Resulting Consolidation
- 43-story Tower Latino Americana

Case Study

Tower of Latino Americana, Mexico City
Built ihn 1956
44 stories; 597-ft



Increase in Vertical Effective Stress

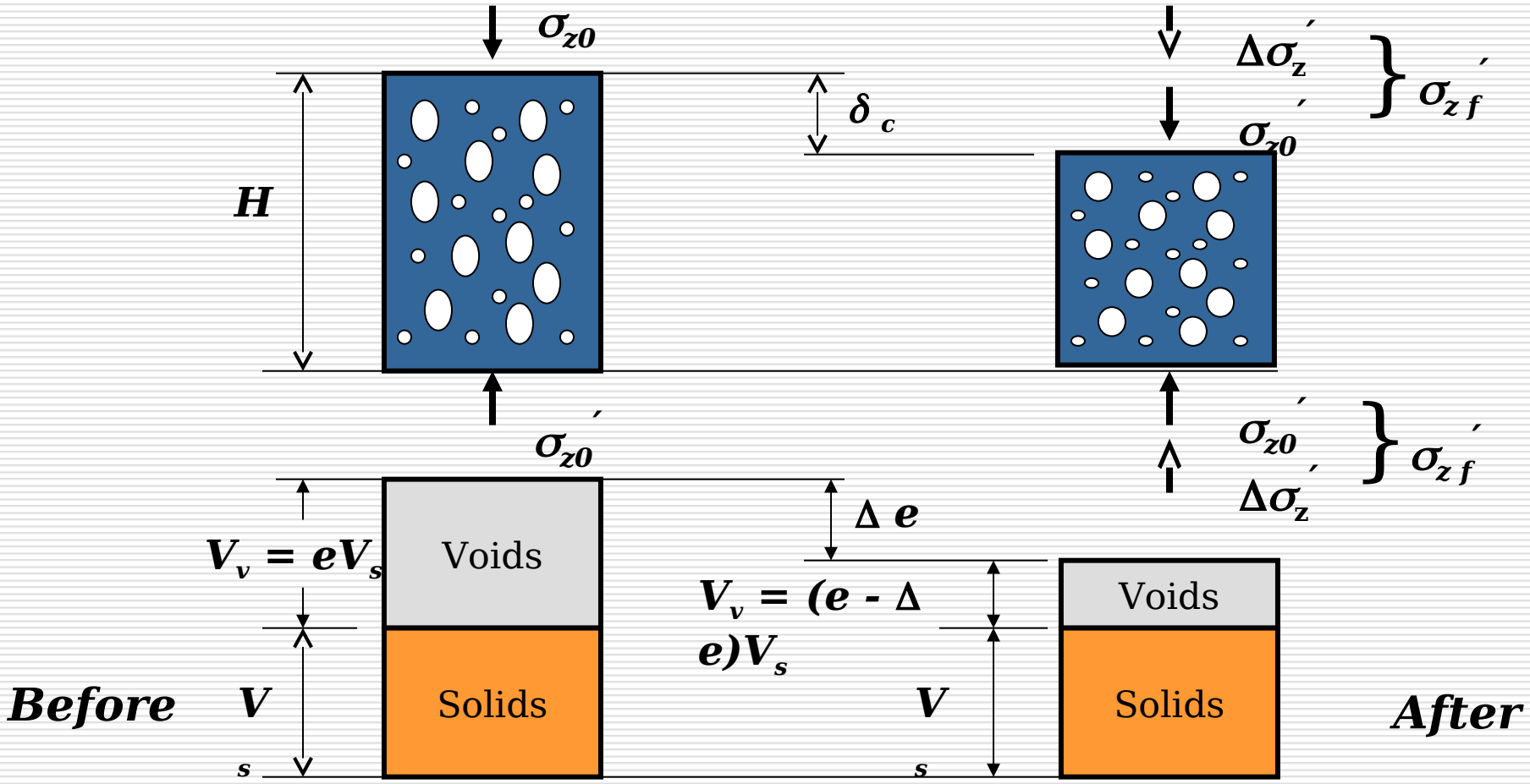
- Due to a Placement of a fill

$$\sigma'_{zf} = \sigma'_{z0} + \gamma_{fill} H_{fill}$$

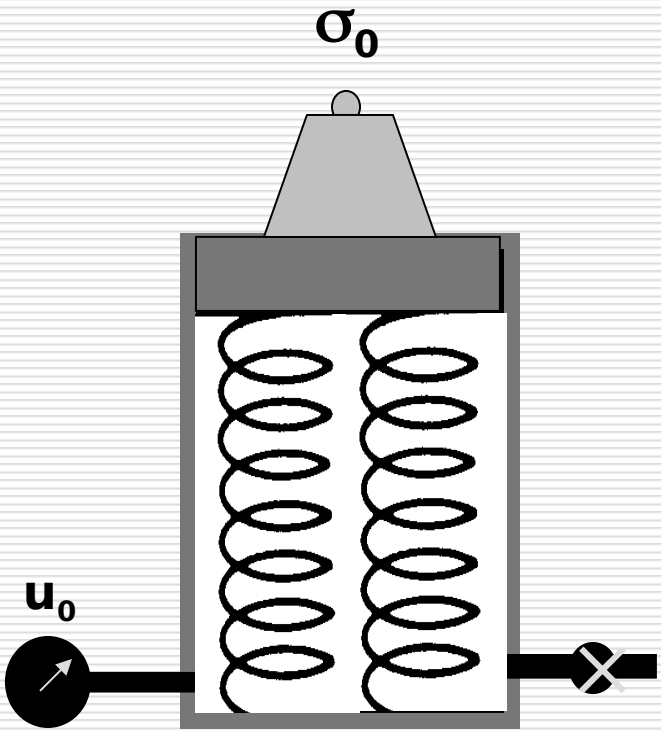
- Due to an external load

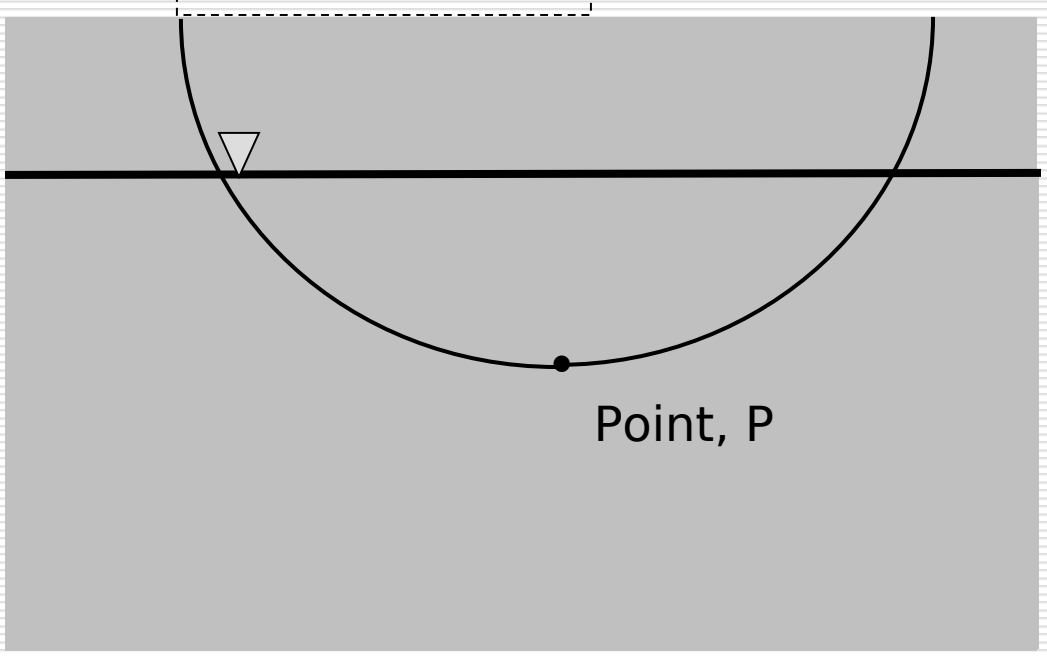
$$\sigma'_{zf} = \sigma'_{z0} + (\sigma_z)_{induced}$$

Consolidation

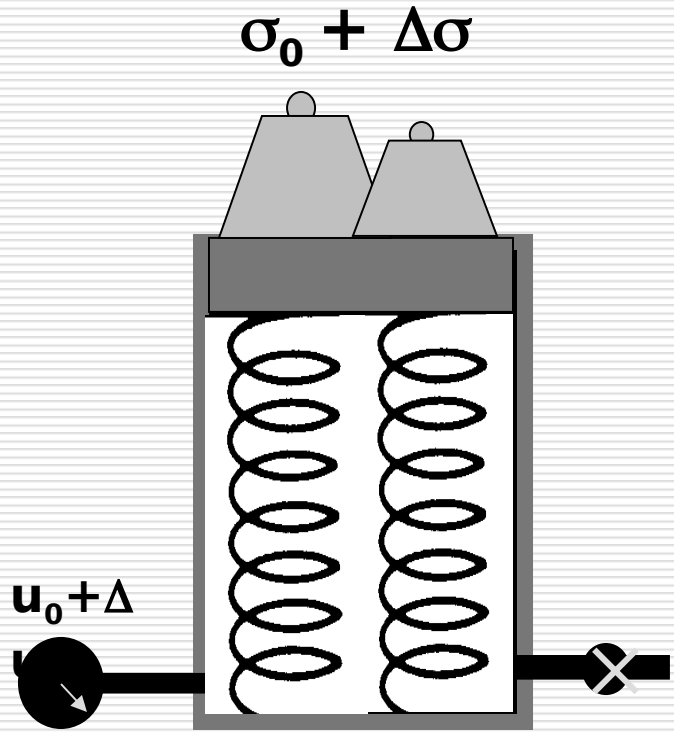


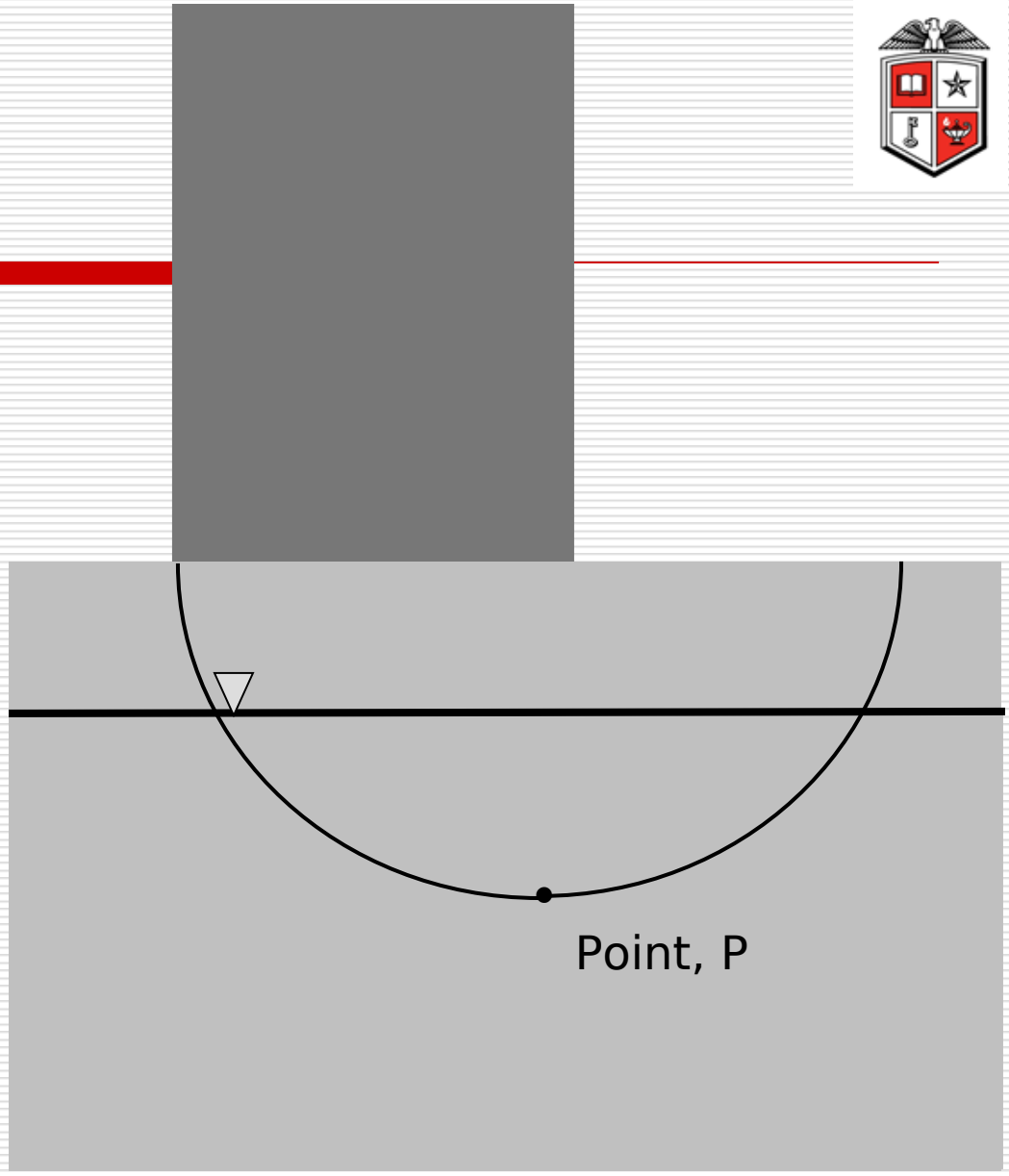
Before Loading





Immediately After Loading

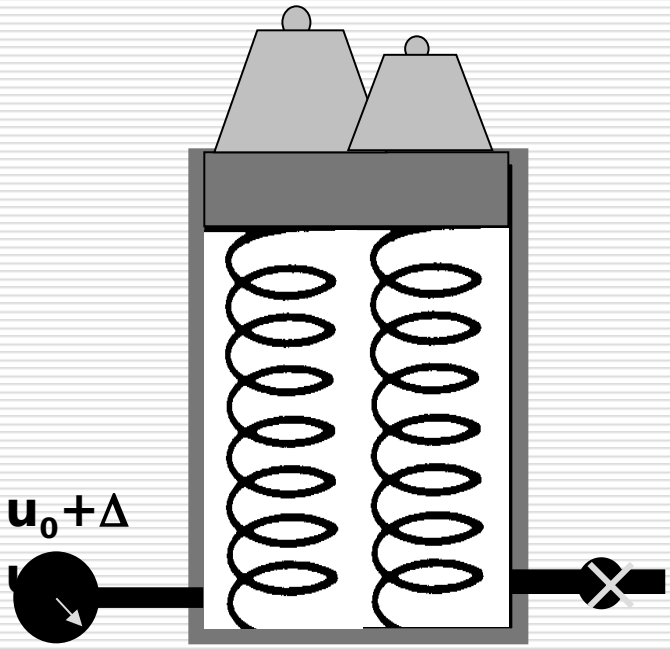




Shortly after Loading

No settlement

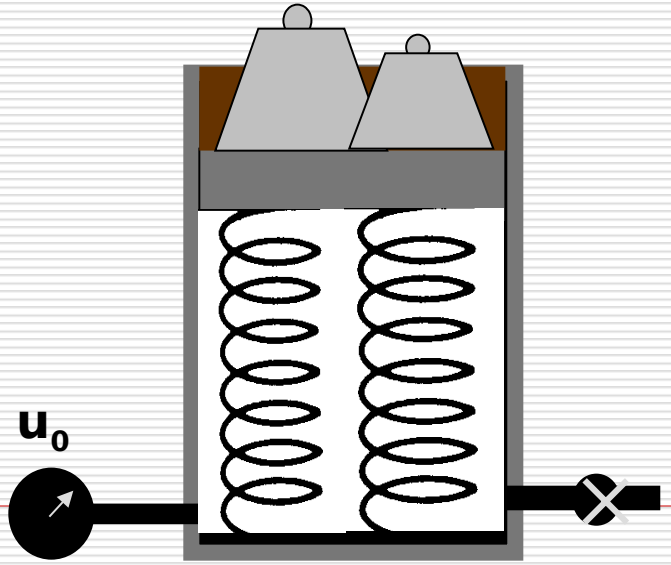
$\sigma_0 + \Delta\sigma$



Long after Loading

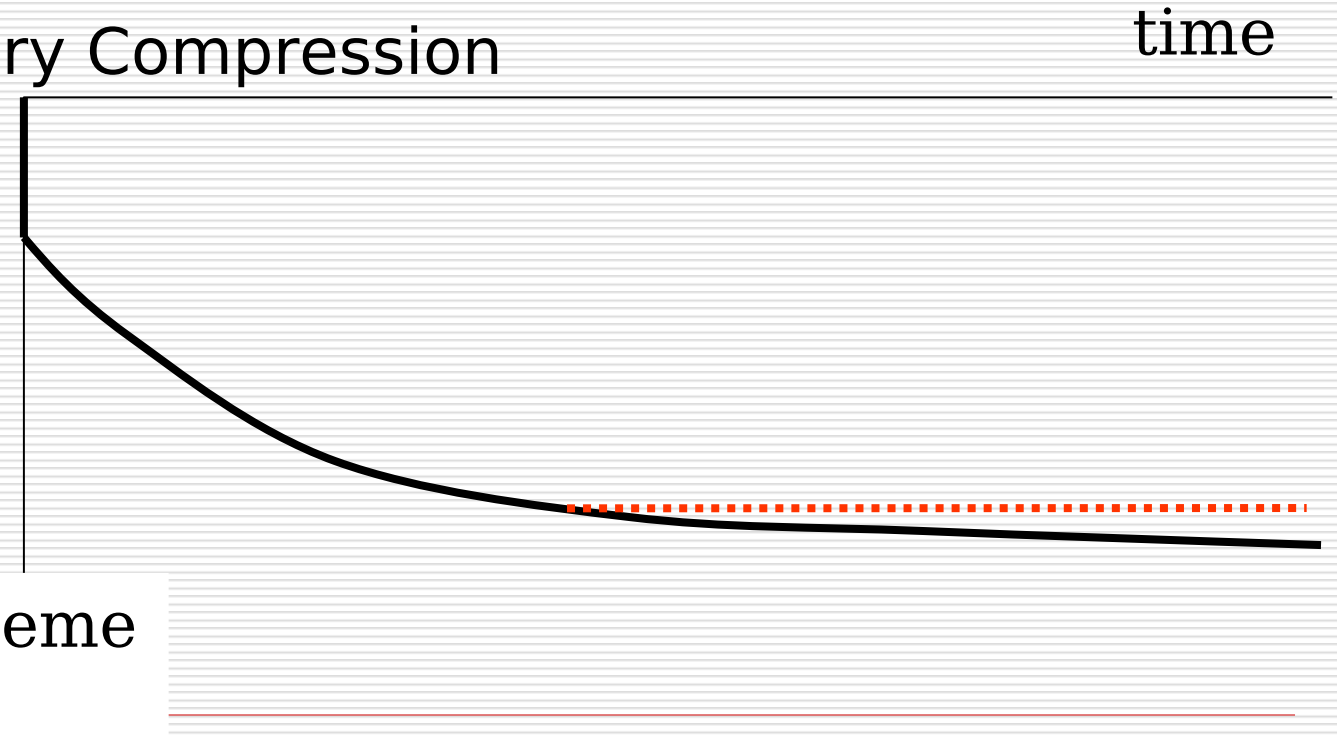
Settlement Complete

$\sigma_0 + \Delta\sigma$

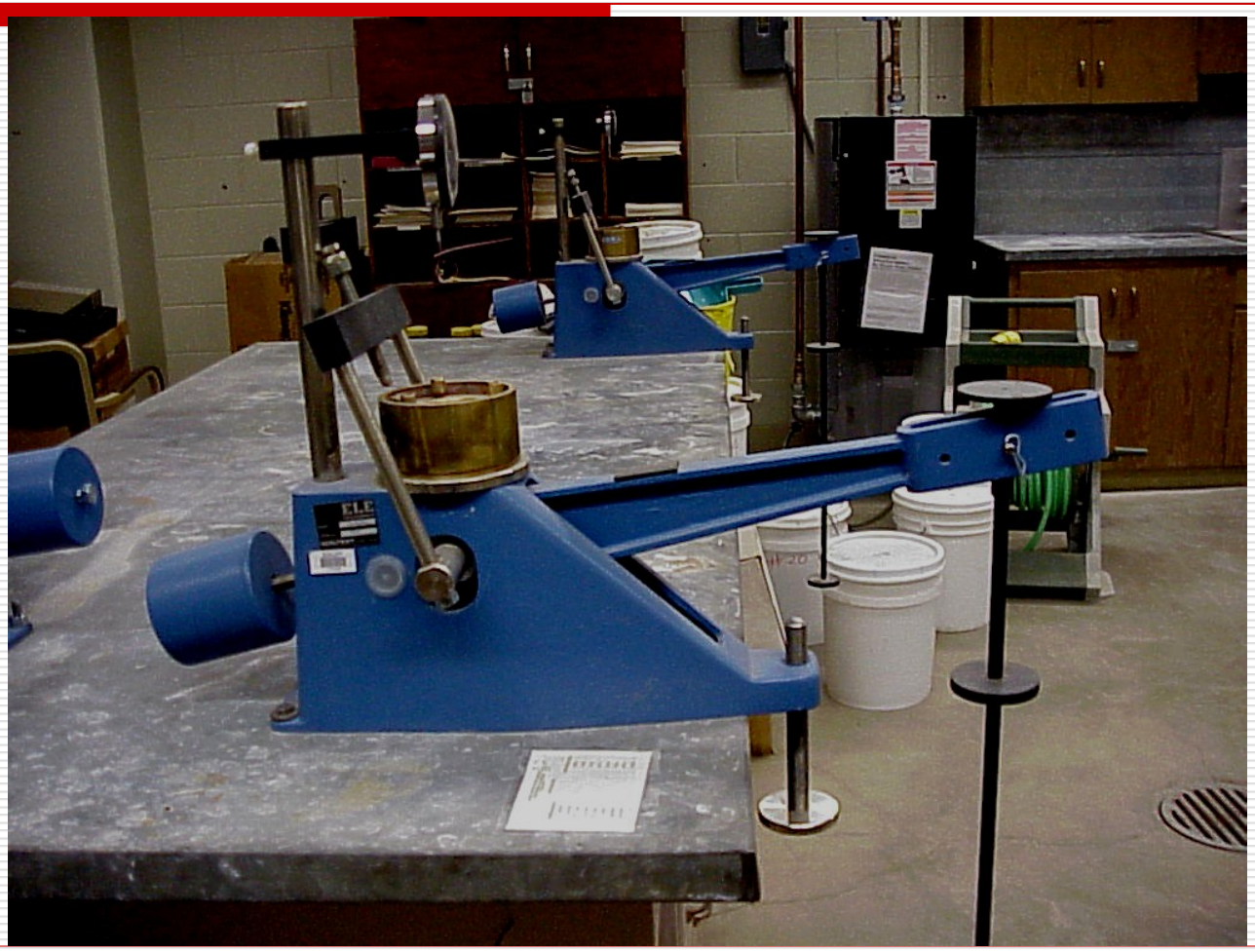


Settlement

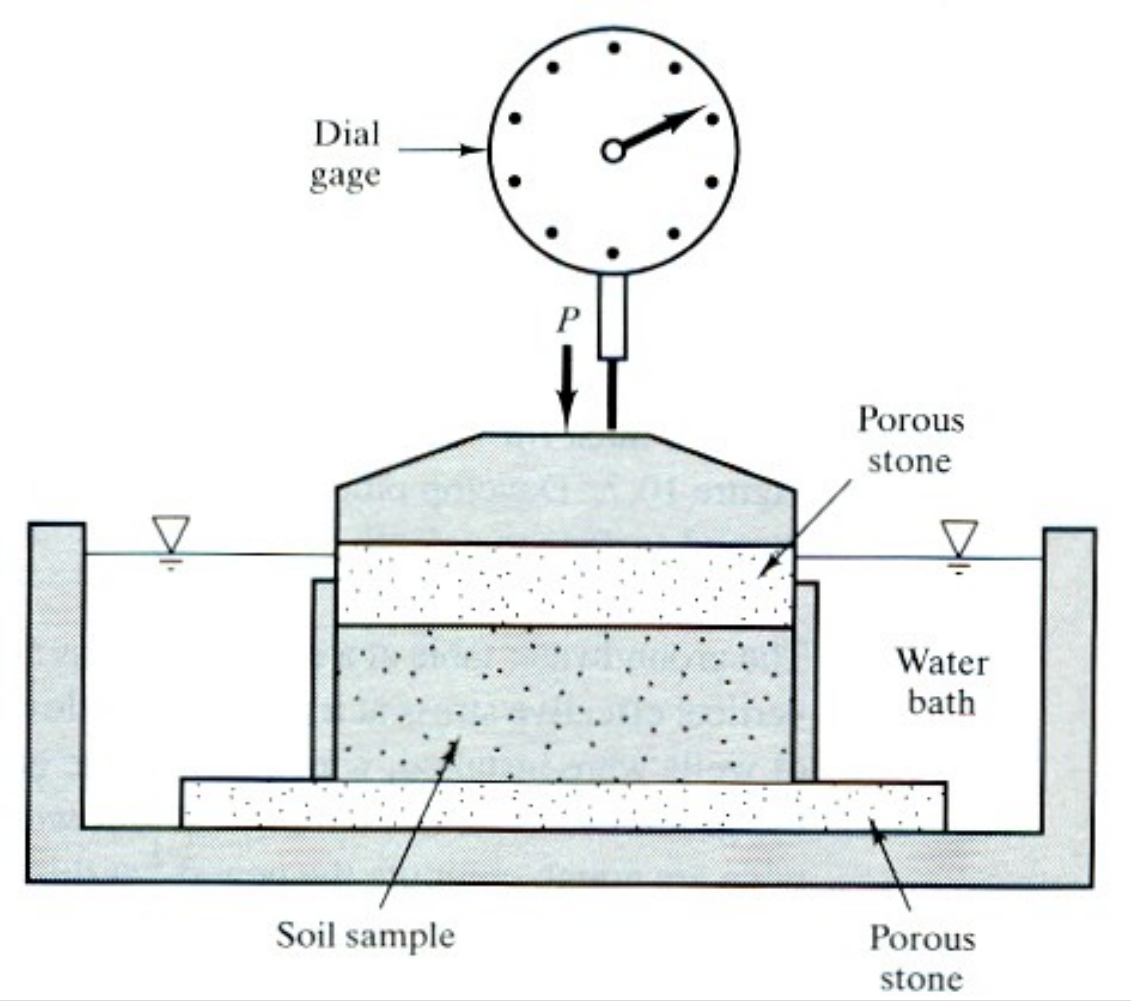
- Distortion Settlement (Immediate)
- Consolidation (Time Dependent)
- Secondary Compression



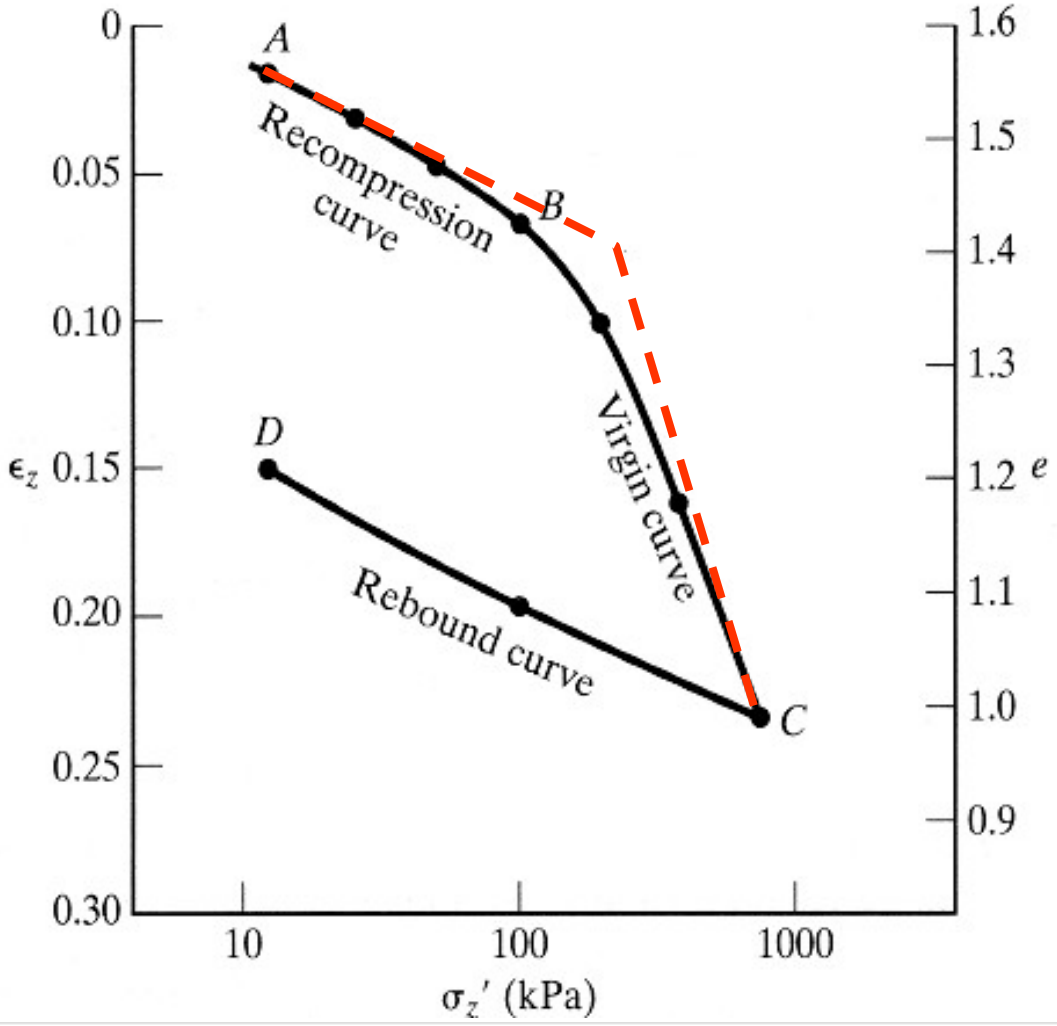
Laboratory Consolidation Test



Consolidation Test



Test Results



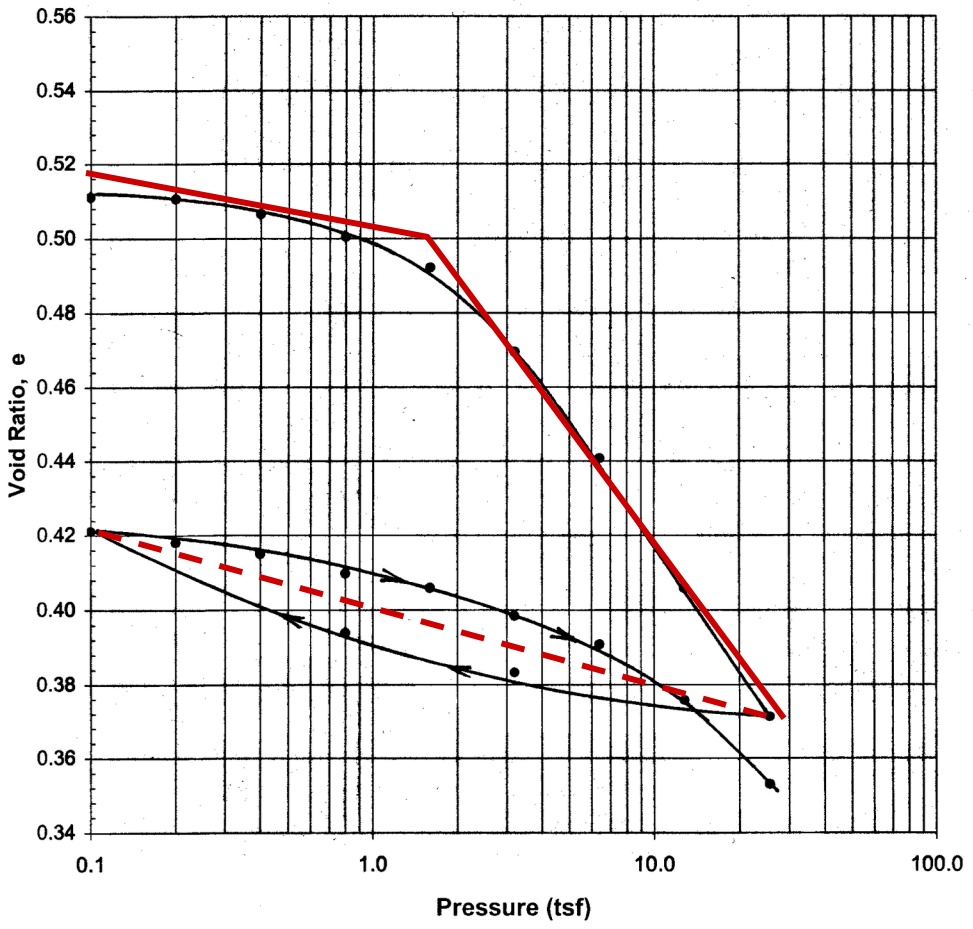
Consolidation Plot-Actual

CONSOLIDATION TEST REPORT

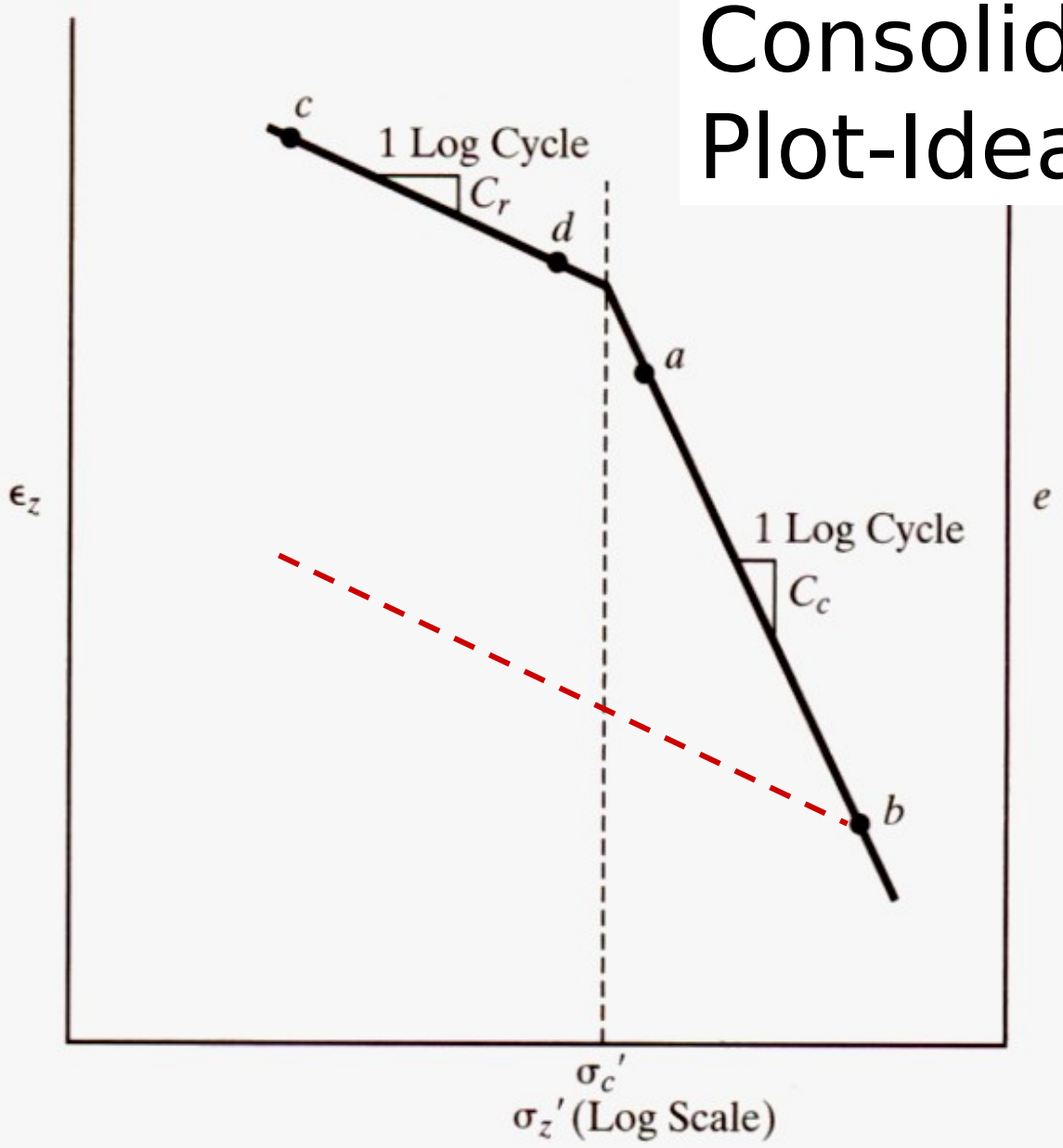
PROJECT: Austin Civic Center **SAMPLE:** B5, 6.5 - 8.0

LOCATION: Austin, Texas **DESCRIPTION:** Lean Clay w/sand

Sample Type:	Undisturbed		
Diameter:	2.5 inches	Classification:	CL
Height:	1.0 inch	Unit Dry Weight (pcf):	109.4
Initial Moisture Content (%):	17.1	Final Moisture Content (%):	13.4
Initial Void Ratio:	0.5118	Final Void Ratio:	0.3531
Initial Saturation (%):	88	Final Saturation (%):	101



Consolidation Plot-Idealized



Compression Index and Recompression Index

$$C_c = \frac{e_a - e_b}{(\log \sigma'_z)_b - (\log \sigma'_z)_a}$$

$$C_r = \frac{e_c - e_d}{(\log \sigma'_z)_d - (\log \sigma'_z)_c}$$

Compression Ratio and Recompression Ratio

$$C_{\varepsilon c} = \frac{C_c}{1+e_0} = \frac{(\varepsilon_z)_a - (\varepsilon_z)_b}{(\log \sigma'_z)_b - (\log \sigma'_z)_a}$$

$$C_{\varepsilon r} = \frac{C_r}{1+e_0} = \frac{(\varepsilon_z)_d - (\varepsilon_z)_c}{(\log \sigma'_z)_d - (\log \sigma'_z)_c}$$

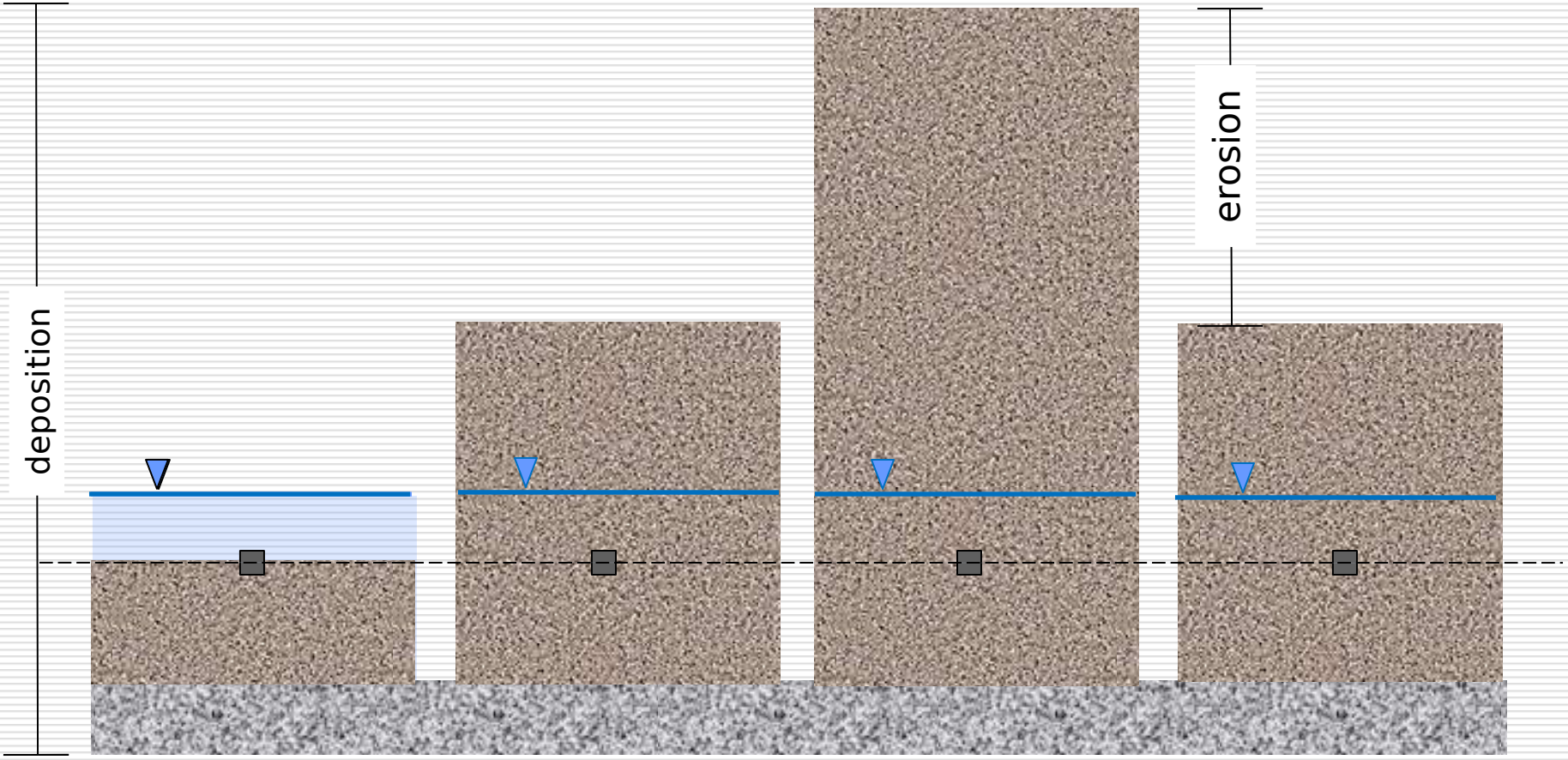
Normally and Over-Consolidated Soils

$\sigma'_{zo} = \sigma'_c$ ..... Normally consolidated

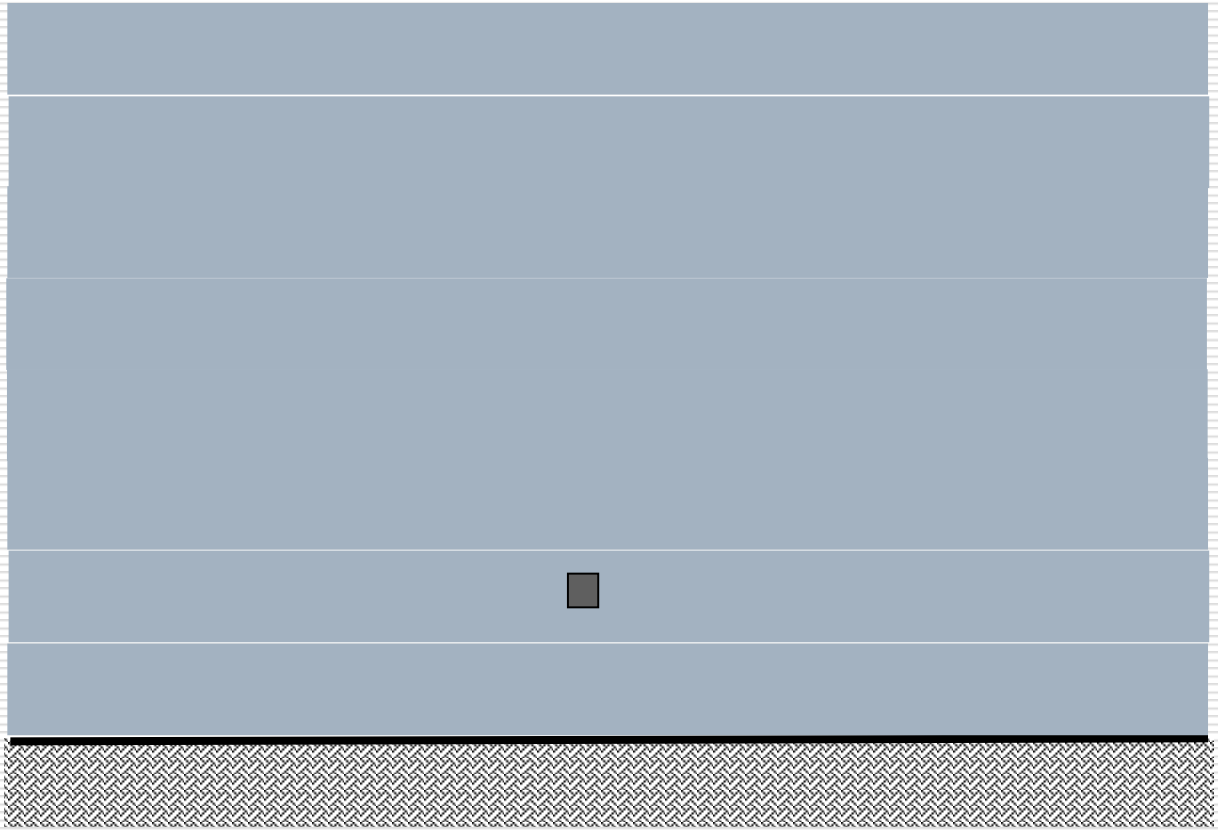
$\sigma'_{zo} < \sigma'_c$ ..... Over consolidated

$\sigma'_{zo} > \sigma'_c$ ..... Under consolidated

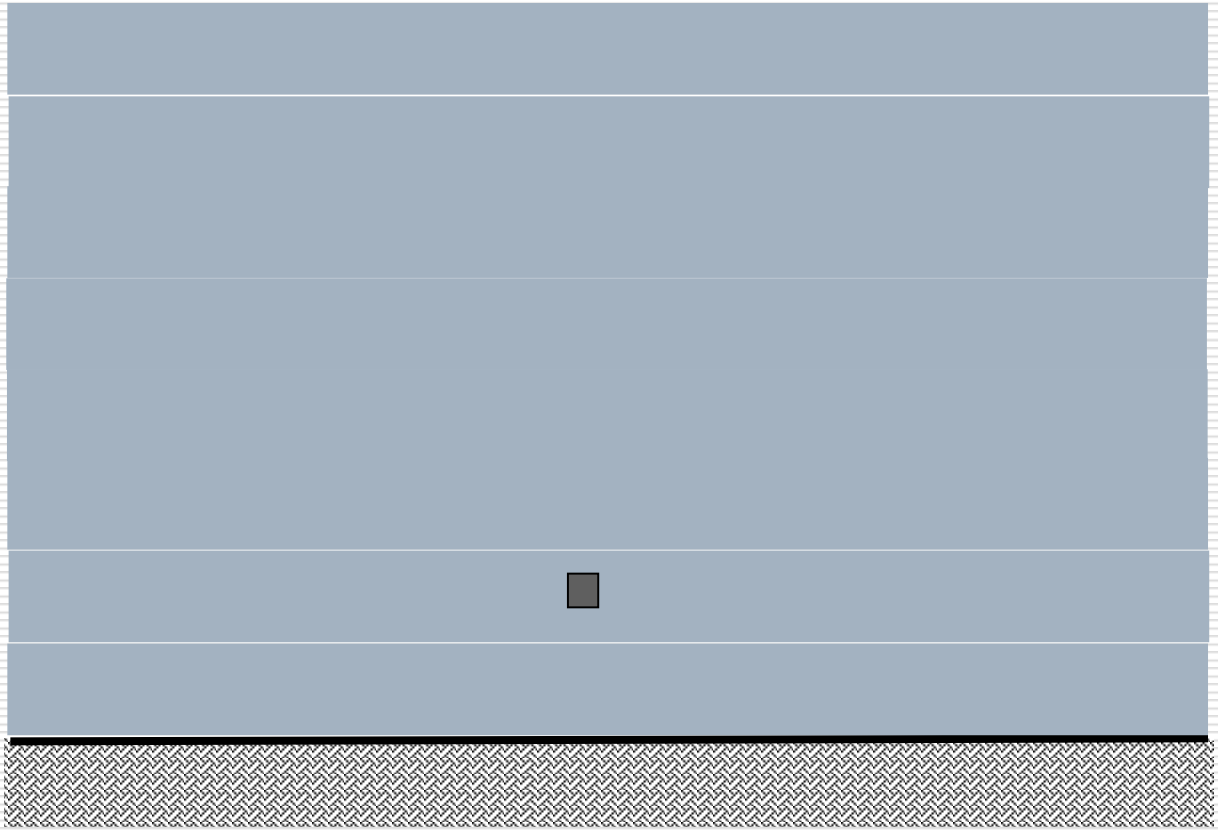
Normally and Over-Consolidated Soils



Normal vs. Over-Consolidation



Normal vs. Over-Consolidation



Over-Consolidation Margin & Over-consolidation Ratio

$$\sigma'_m = \sigma'_c - \sigma'_{zc}$$ ..... Over-consolidation Margin

$$OCR = \frac{\sigma'_c}{\sigma'_{zo}}$$ ..... Over consolidation ratio

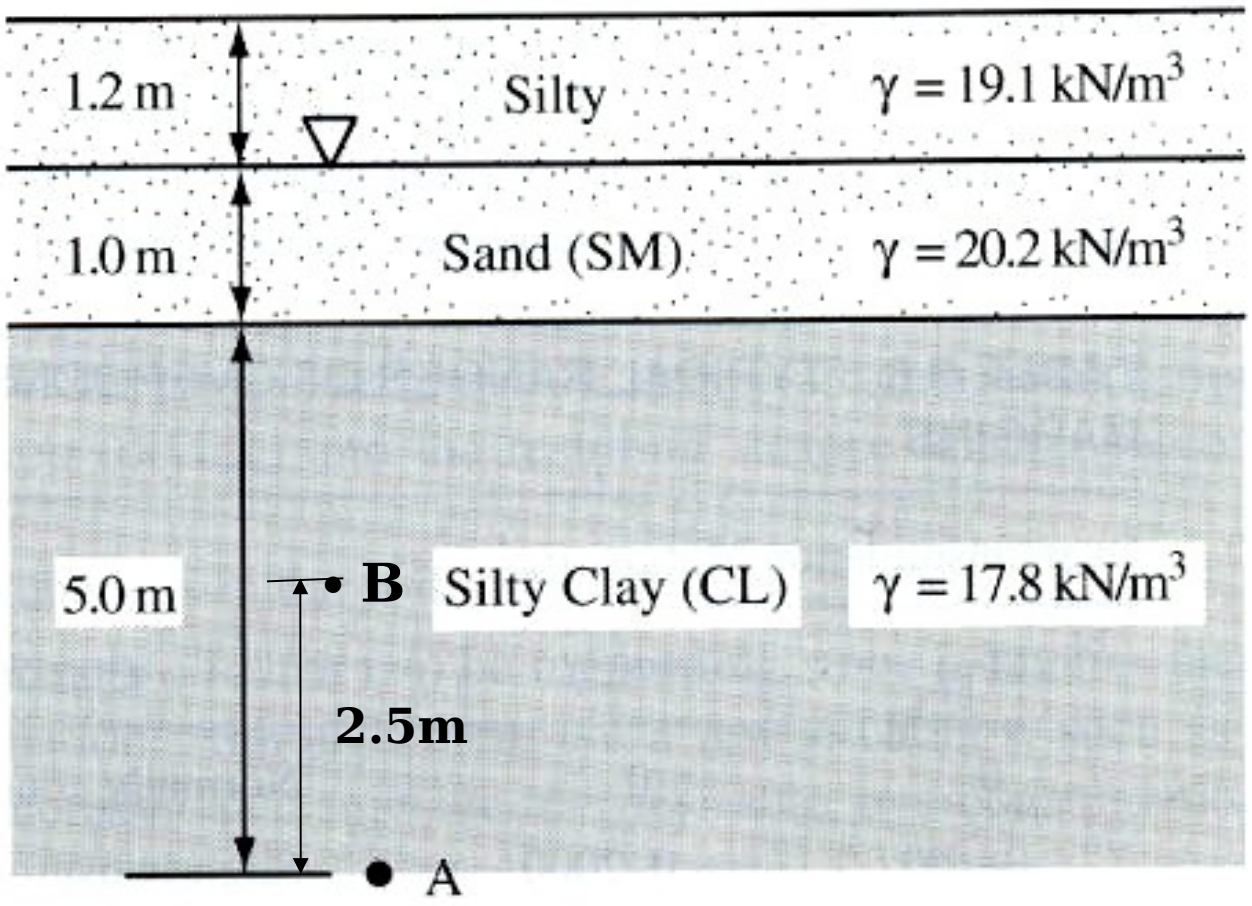
Typical Range of OC Margins

Overconsolidation Margin, σ_m' (kPa)	Overconsolidation Margin, σ_m' (lb/ft^2)	Classification
0	0	Normally consolidated
0 - 100	0 - 2000	Slightly overconsolidated
100 - 400	2000 - 8000	Moderately overconsolidated
> 400	> 8000	Heavily overconsolidated

Compressibility of Sand and Gravels (Table 3.7)

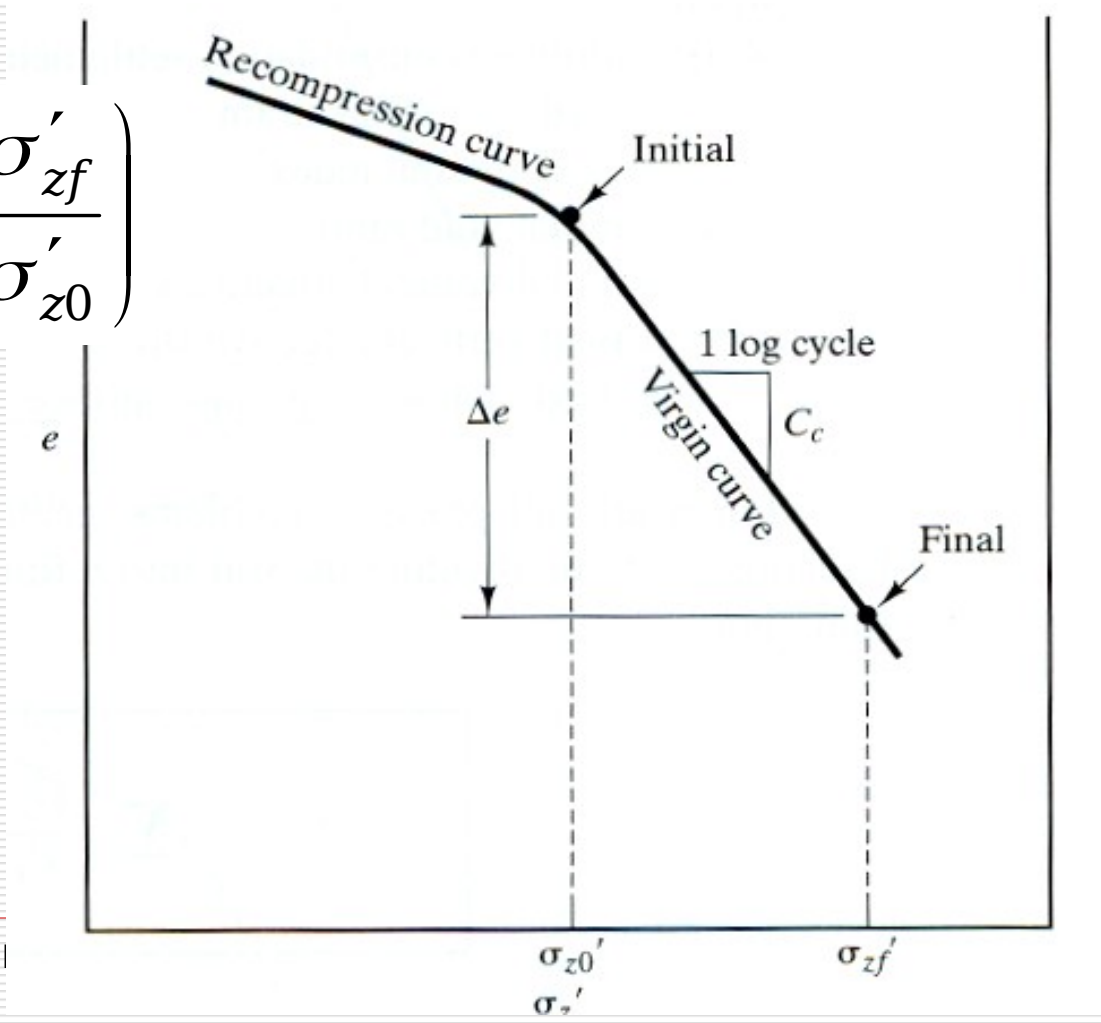
Soil Type	$C_c / (1+e_0)$					
	$D_r = 0\%$	$D_r = 20\%$	$D_r = 40\%$	$D_r = 60\%$	$D_r = 80\%$	$D_r = 100\%$
Medium to coarse sand, some fine gravel (SW)	-	-	0.005	-	-	-
Medium to coarse sand (SW/SP)	0.010	0.008	0.006	0.005	0.003	0.002
Fine to coarse sand (SW)	0.011	0.009	0.007	0.005	0.003	0.002
Fine to medium sand (SW/SP)	0.013	0.010	0.008	0.006	0.004	0.003
Fine sand (SP)	0.015	0.013	0.010	0.008	0.005	0.003
Fine sand with trace fine to coarse silt (SP-SM)	-	-	0.011	-	-	-
Find sand with little fine to coarse silt (SM)	0.017	0.014	0.012	0.009	0.006	0.003
Fine sand with some fine to coarse silt (SM)	-	-	0.014	-	-	-

Example 3.3


1.2 m
Silty
$\gamma = 19.1$ kN/m^3
1.0 m
Sand (SM)
$\gamma = 20.2$ kN/m^3
5.0 m
B
Silty Clay (CL)
$\gamma = 17.8$ kN/m^3
2.5m
A

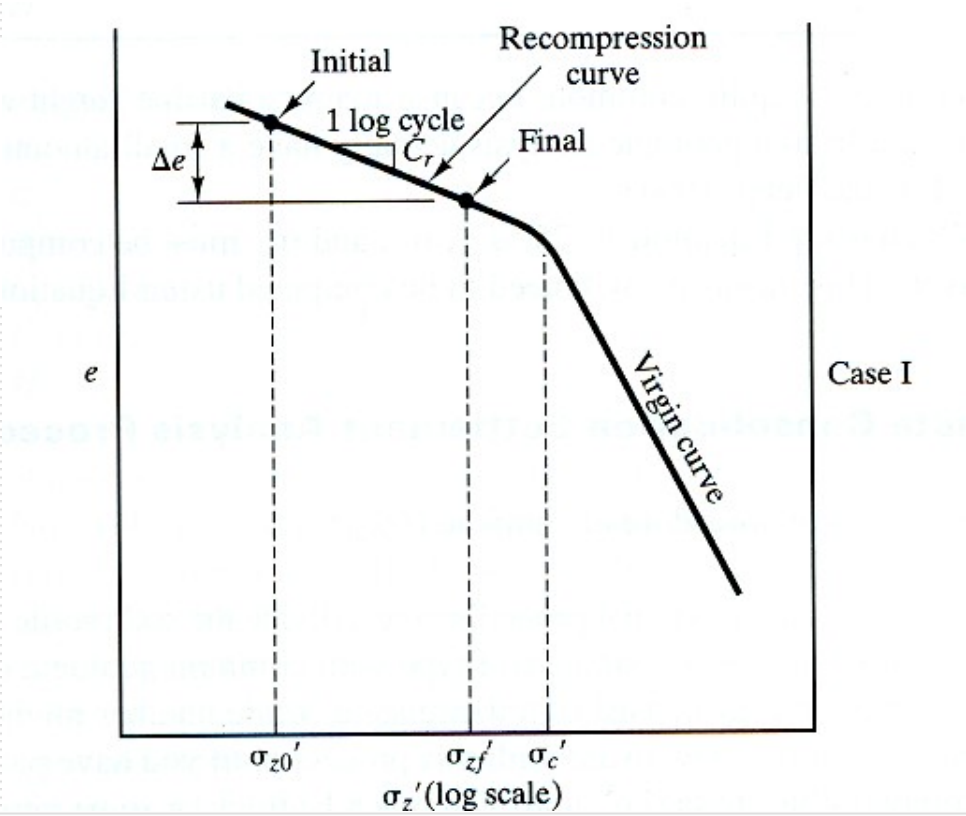
Settlement Predictions N.C. Clays

$$\delta_c = \sum \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_{zf}}{\sigma'_{z0}}\right)$$



Settlement Predictions O.C. Clays…… Case I

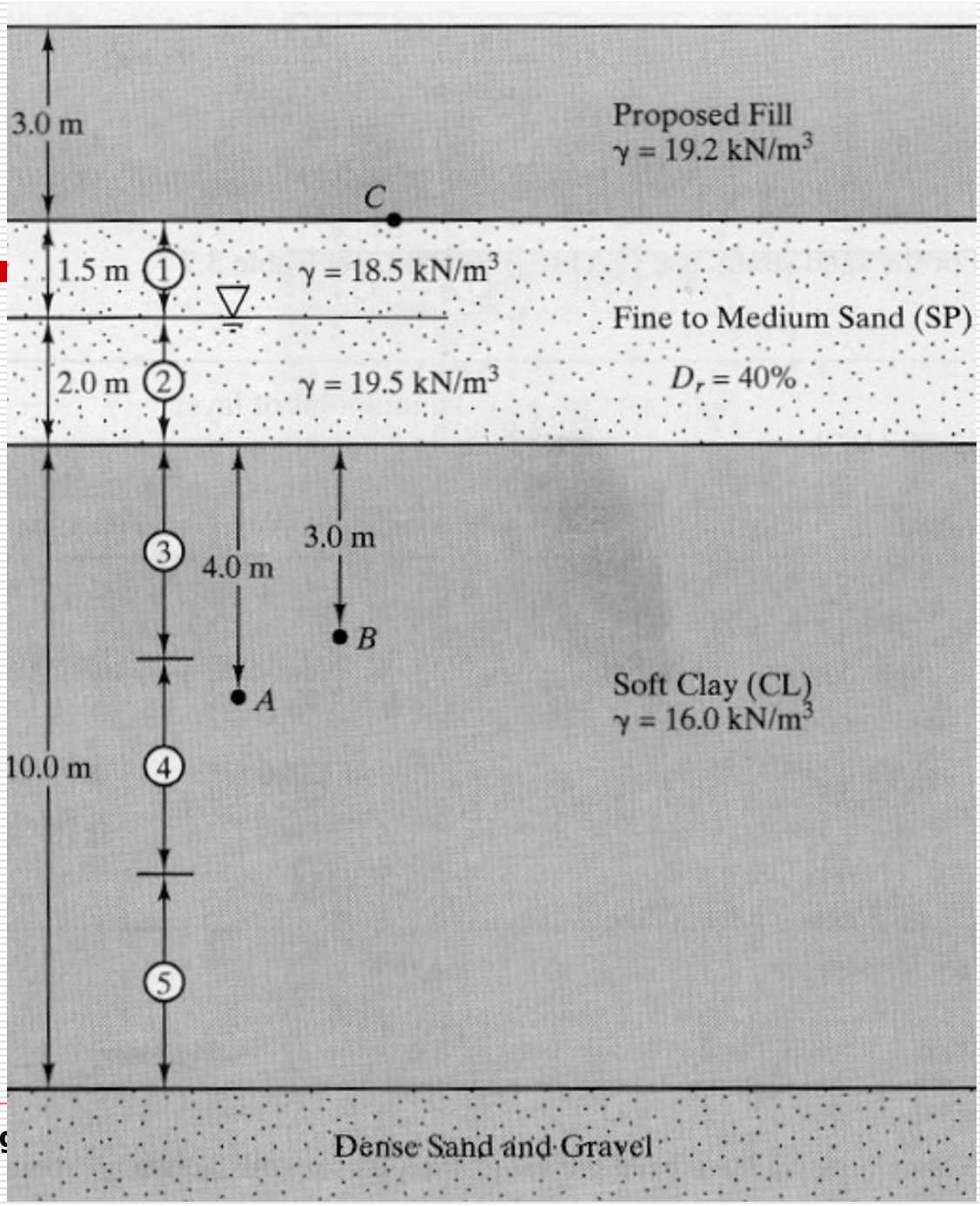
$$\delta_c = \sum \frac{C_r}{1+e_0} H \log\left(\frac{\sigma'_{zf}}{\sigma'_{z0}}\right)$$



Settlement Predictions O.C. Clays…… Case II

$$\delta_c = \sum \frac{C_r}{1+e_0} H \log\left(\frac{\sigma_c'}{\sigma_{z0}'}\right) + \frac{C_c}{1+e_0} H \log\left(\frac{\sigma_{zf}'}{\sigma_c'}\right)$$

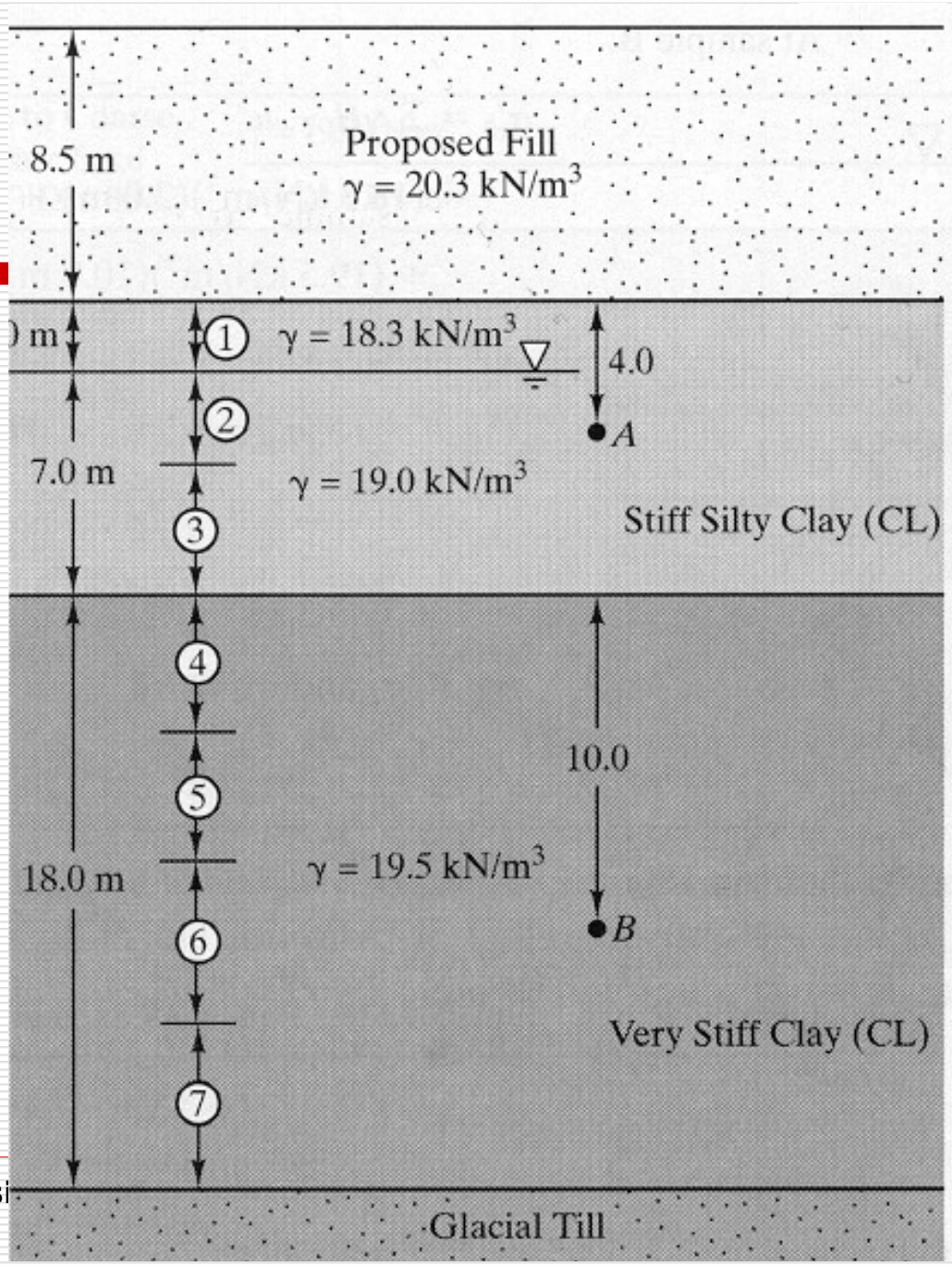
Ex. 3.4


3.0 m
Proposed Fill
γ = 19.2 kN/m³
C
1.5 m
1
γ = 18.5 kN/m³
Fine to Medium Sand (SP)
2.0 m
2
γ = 19.5 kN/m³
D_r = 40%
3
4.0 m
3.0 m
B
A
Soft Clay (CL)
γ = 16.0 kN/m³
10.0 m
4
5
Dense Sand and Gravel

Example 3.4

Layer	H (m)	At midpoint of layer: σ'_{z0} (kPa) Eqn 3.13	At midpoint of layer: σ'_{zf} (kPa)	At midpoint of layer: $\frac{C_c}{1+e_0}$	Eqn.	$(\delta_c)_{ult}$ (mm)
1	1.5	13.9	71.5	0.008	3.25	8
2	2.0	37.4	95.0	0.008	3.25	6
3	3.0	56.4	114.0	0.19	3.25	174
4	3.0	75.0	132.6	0.19	3.25	141
5	4.0	96.7	154.3	0.19	3.25	154
					$\delta_c =$	483

Ex. 3.5


8.5 m
Proposed Fill
γ = 20.3 kN/m³
m
1
γ = 18.3 kN/m³
4.0
A
2
7.0 m
γ = 19.0 kN/m³
3
Stiff Silty Clay (CL)
4
10.0
5
18.0 m
γ = 19.5 kN/m³
B
6
Very Stiff Clay (CL)
7
Glacial Till

Example 3.5

Layer	H (m)	At midpoint of layer: σ_{z0}' (kPa) Eqn. 3.13	At midpoint of layer: σ_c' (kPa) Eqn. 3.21	σ_{zf}' (kPa)	$\frac{C_r}{1+e_0}$	$\frac{C_c}{1+e_0}$	Eqn.	δ_c (mm)
1	2.0	18.3	64.3	190.9	0.05	0.15	3.27	196
2	3.0	50.4	96.4	223.0	0.05	0.15	3.27	206
3	4.0	82.6	128.6	255.2	0.05	0.15	3.27	217
4	4.0	120.4	—	293.0	0.04	0.14	3.26	62
5	4.0	159.2	—	331.8	0.04	0.14	3.26	51
6	5.0	202.8	—	375.4	0.04	0.14	3.26	53
7	5.0	251.4	—	424.0	0.04	0.14	3.26	45
							$\delta_c =$	830