P.E. Civil Exam Review:
GEOMECHANICS

Jerry Vandevelde, P.E.
gtv@gemeng.com

ASCE | KNOWLEDGE & LEARNING

GEOMECHANICS

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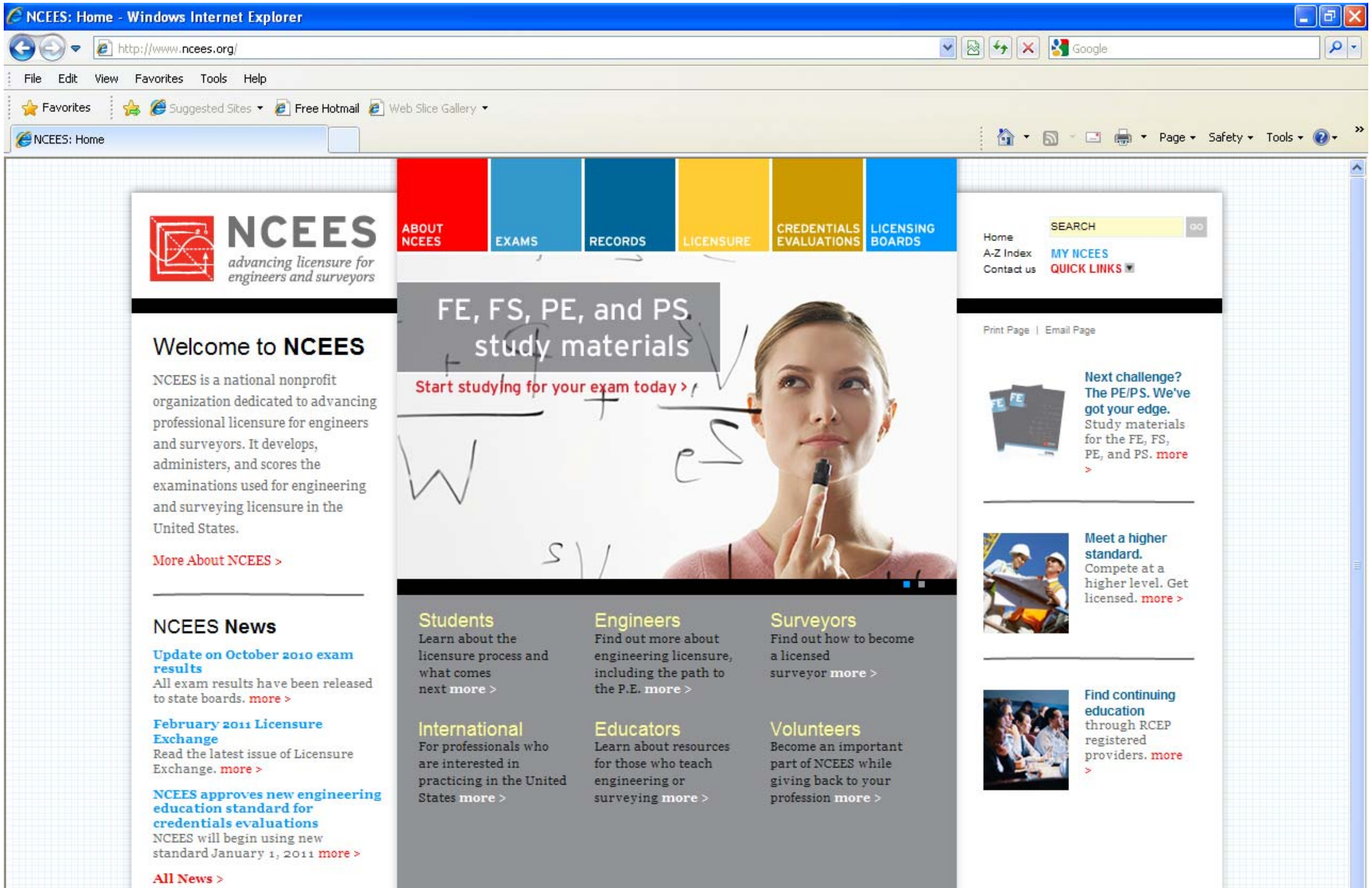


STUDY REFERENCES

- Foundation Engineering; Peck Hanson & Thornburn
- Introductory Soil Mechanics and Foundations; Sowers
- NAVFAC Design Manuals DM-7.1 & 7.2
- Foundation Analysis and Design; Bowles
- Practical Foundation Engineering Handbook; Brown

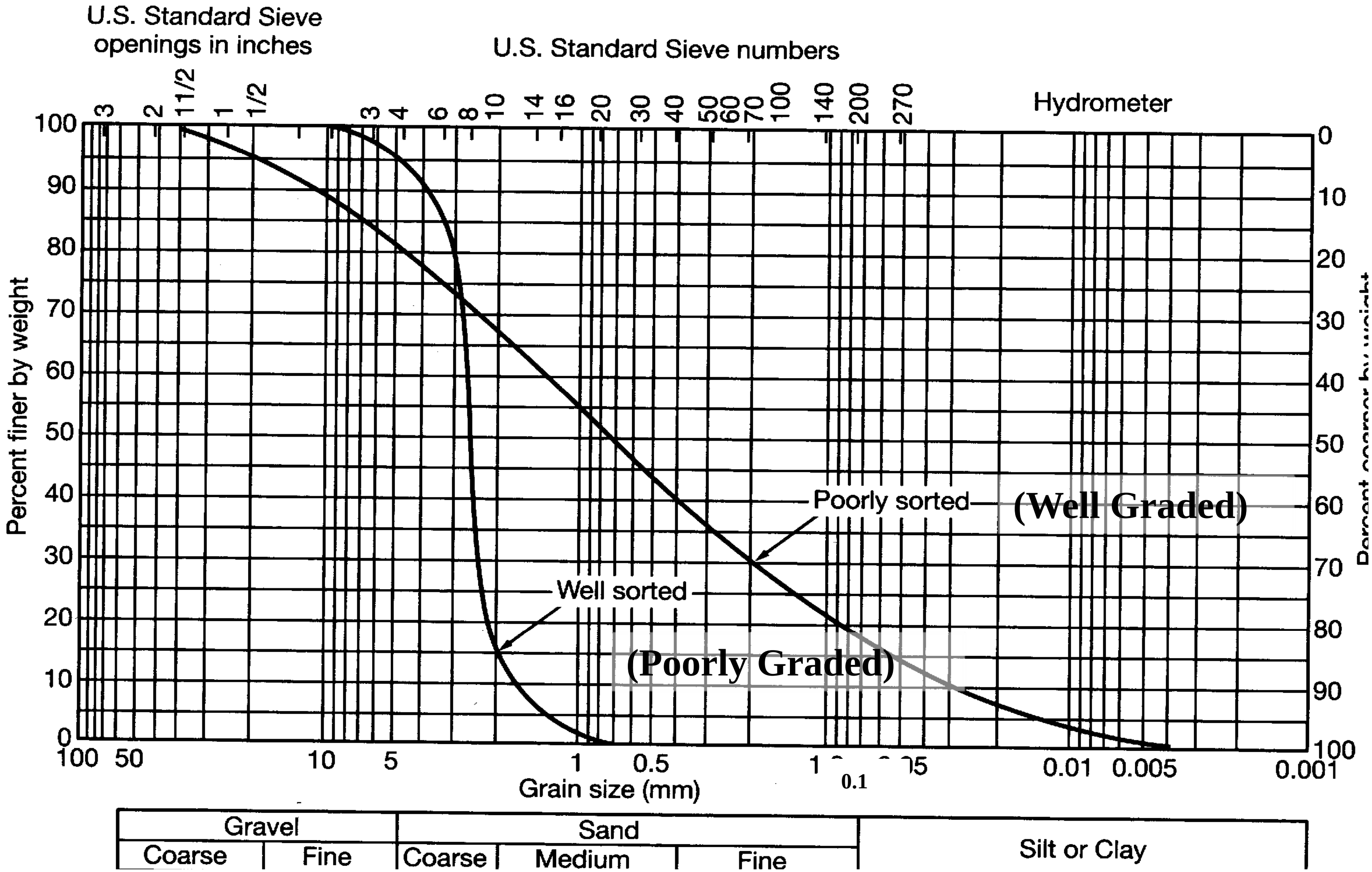
Soil Classification Systems

*** Unified Soil Classification System**

*** AASHTO**

Need: Particle Sizes and Atterberg Limits

Particle Sizes (Sieve Analysis)



Atterberg Limits

Liquid, Plastic & Shrinkage Limits

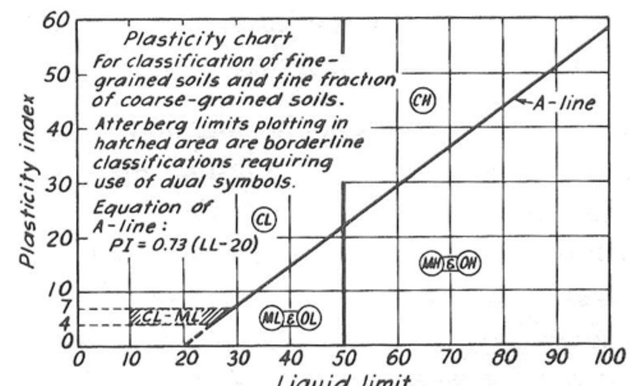
Plasticity Index (PI)

PI = Liquid Limit - Plastic Limit

(range of moisture content over which soil is plastic or malleable)

Major Divisions			Group Symbols	Typical Names	Classification Criteria	
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels 50% or more of coarse fraction retained on No. 4 sieve	Clean Gravels	*GW*	Well-graded gravels and gravel-sand mixtures, little or no fines	$C_u = D_{60}/D_{10}$ Greater than 4; $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines	Not meeting both criteria for *GW*	
		Gravels with Fines	*GM*	Silty gravels, gravel-sand-silt mixtures	Atterberg limits plot below "*A*" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures	Atterberg limits plot above "*A*" line and plasticity index greater than 7	
	Sands More than 50% of coarse fraction passes No. 4 sieve	Clean Sands	*SW*	Well-graded sands and gravelly sands, little or no fines	$C_u = D_{60}/D_{10}$ Greater than 6; $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP	Poorly graded sands and gravelly sands, little or no fines	Not meeting both criteria for *SW*	
		Sands with Fines	*SM*	Silty sands, sand-silt mixtures	Atterberg limits plot below "*A*" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures	Atterberg limits plot above "*A*" line and plasticity index greater than 7	
Fine-Grained Soils 50% or more passes No. 200 sieve	Silts and Clays Liquid limit 50% or less		*ML*	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands		
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			OL	Organic silts and organic silty clays of low plasticity		
	Silts and Clays Liquid limit greater than 50%		*MH*	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts		
			CH	Inorganic clays of high plasticity, fat clays		
			OH	Organic clays of medium to high plasticity		
Highly organic soils			*Pt*	Peat, muck and other highly organic soils	Visual-manual identification	

Classification on basis of percentage of fines
Less than 5% Pass No. 200 sieve — *GW, GP, SW, SP*
More than 12% Pass No. 200 sieve — *GM, GC, SM, SC*
5% to 12% Pass No. 200 sieve — Borderline classification requiring use of dual symbols



UNIFIED SOIL CLASSIFICATION SYSTEM

ASTM D-2487

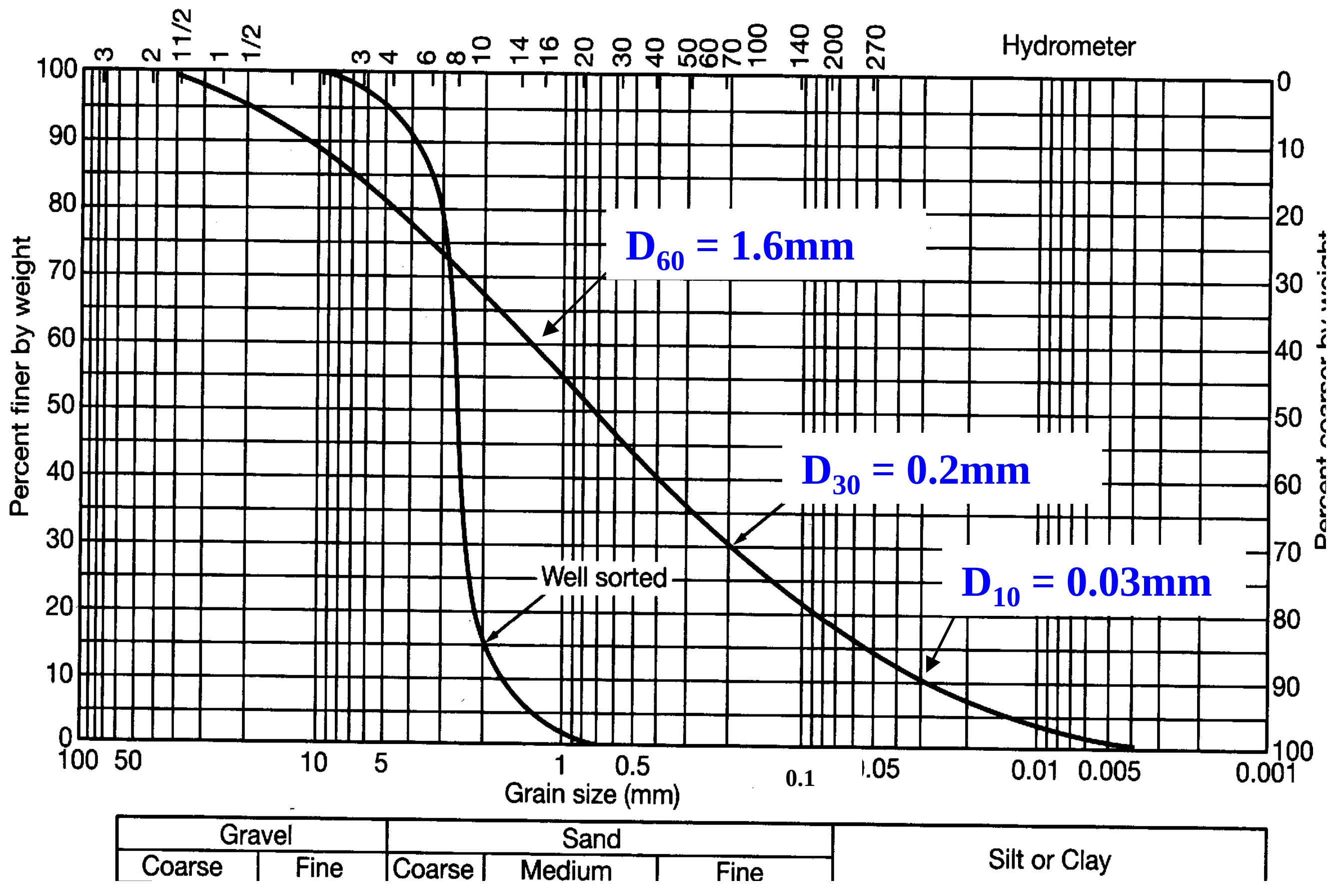
Group Symbols	Typical Names	Classification Criteria	
GW	Well-graded gravels and gravel-sand mixtures, little or no fines	$C_u = D_{60}/D_{10}$ Greater than 4 $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
GP	Poorly graded gravels and gravel-sand mixtures, little or no fines	Not meeting both criteria for *GW*	
GM	Silty gravels, gravel-sand-silt mixtures	Atterberg limits plot below "*A*" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
GC	Clayey gravels, gravel-sand-clay mixtures	Atterberg limits plot above "*A*" line and plasticity index greater than 7	
SW	Well-graded sands and gravelly sands, little or no fines	$C_u = D_{60}/D_{10}$ Greater than 6 $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
SP	Poorly graded sands and gravelly sands, little or no fines	Not meeting both criteria for *SW*	
SM	Silty sands, sand-silt mixtures	Atterberg limits plot below "*A*" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
SC	Clayey sands, sand-clay mixtures	Atterberg limits plot above "*A*" line and plasticity index greater than 7	

Classification on basis of percentage of fines
Less than 5% Pass No. 200 sieve *GW, GP, SW, SP*
More than 12% Pass No. 200 sieve *GM, GC, SM, SC*
5% to 12% Pass No. 200 sieve Borderline classification requiring use of dual symbols

Ref: Peck Hanson & Thornburn 2nd Ed.

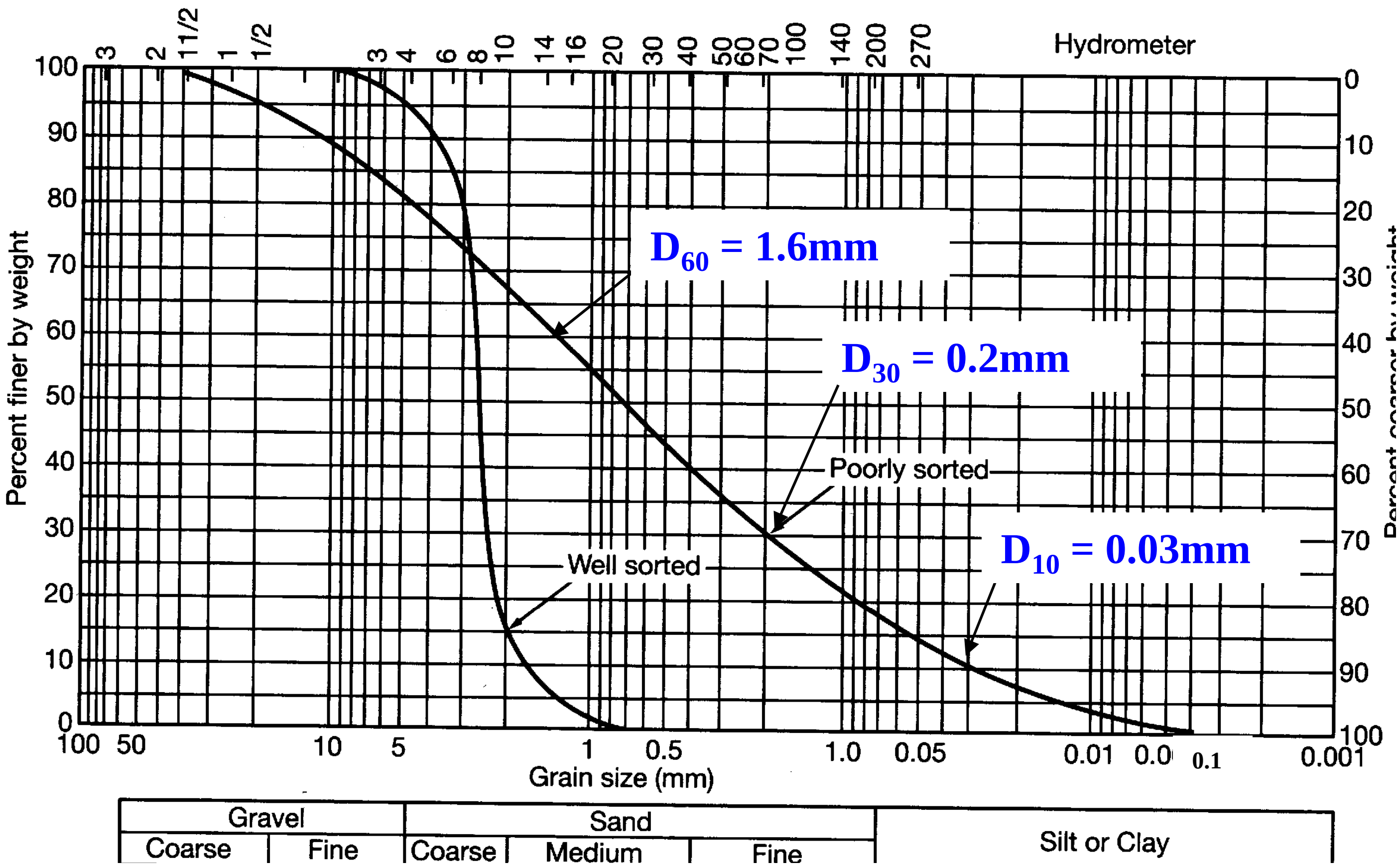
Effective Size = D_{10}

10 percent of the sample is finer than this size



Uniformity Coefficient (Cu) = D60/D10

Coefficient of Curvature (Cz) = $(D30)^2/(D10xD60)$



Well Graded - Requirements

50% coarser than No. 200 sieve

Uniformity Coefficient (Cu) D60/D10

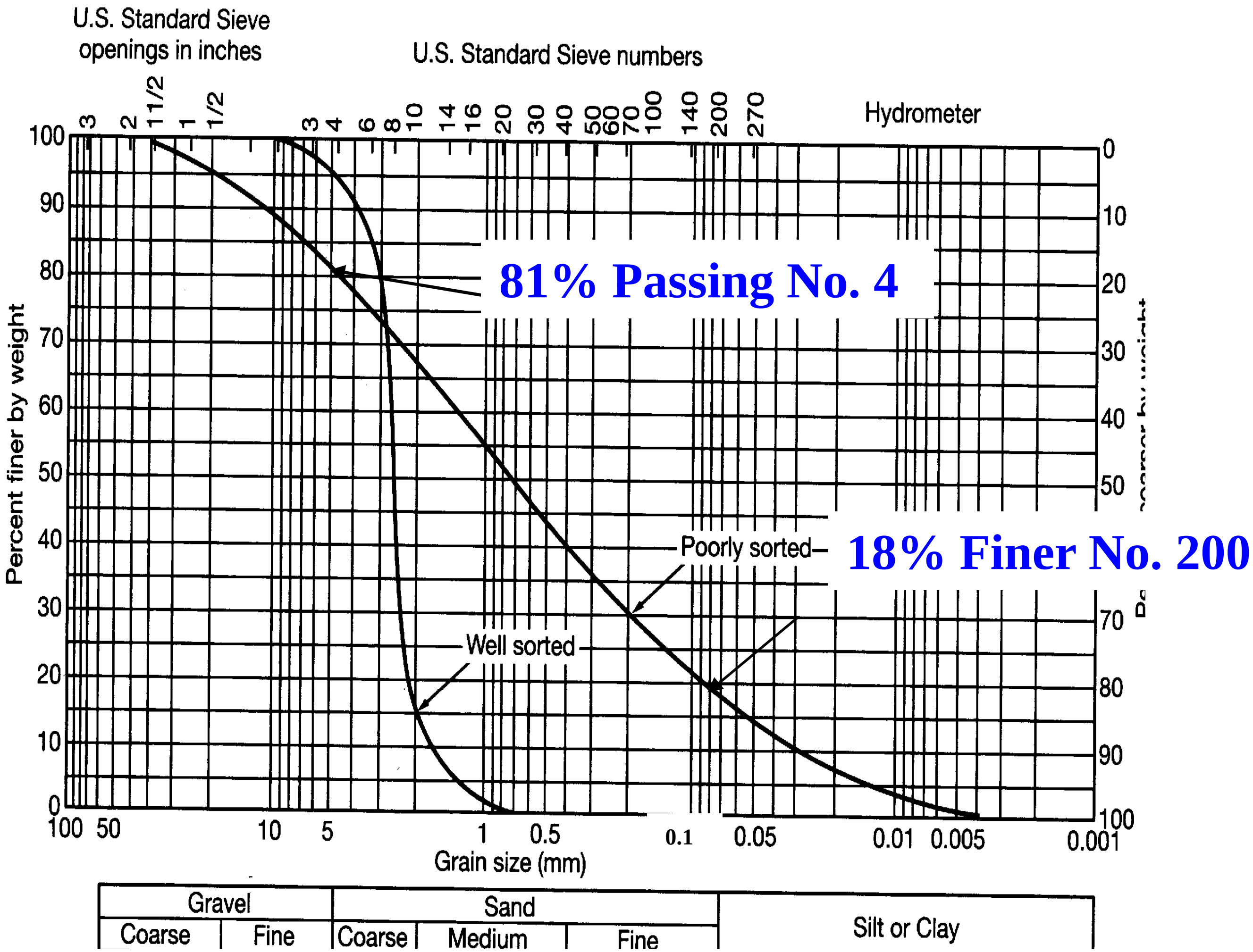
$\geq$4 for Gravel

$\geq$ 6 for Sand

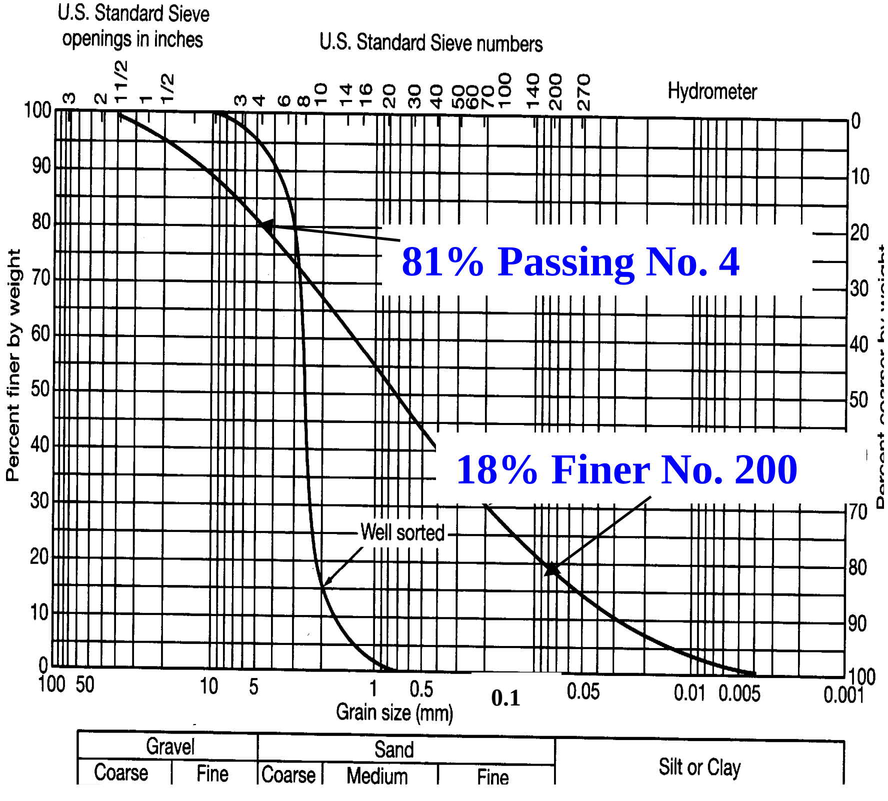
Coefficient of Curvature (Cz)

$= (D30)^2/(D10 x D60) = 1$ to 3

Is the better graded material a gravel?



Gravel if > 50 Percent Coarse Fraction retained on No. 4 sieve



% Retained on No. 200 = 82%

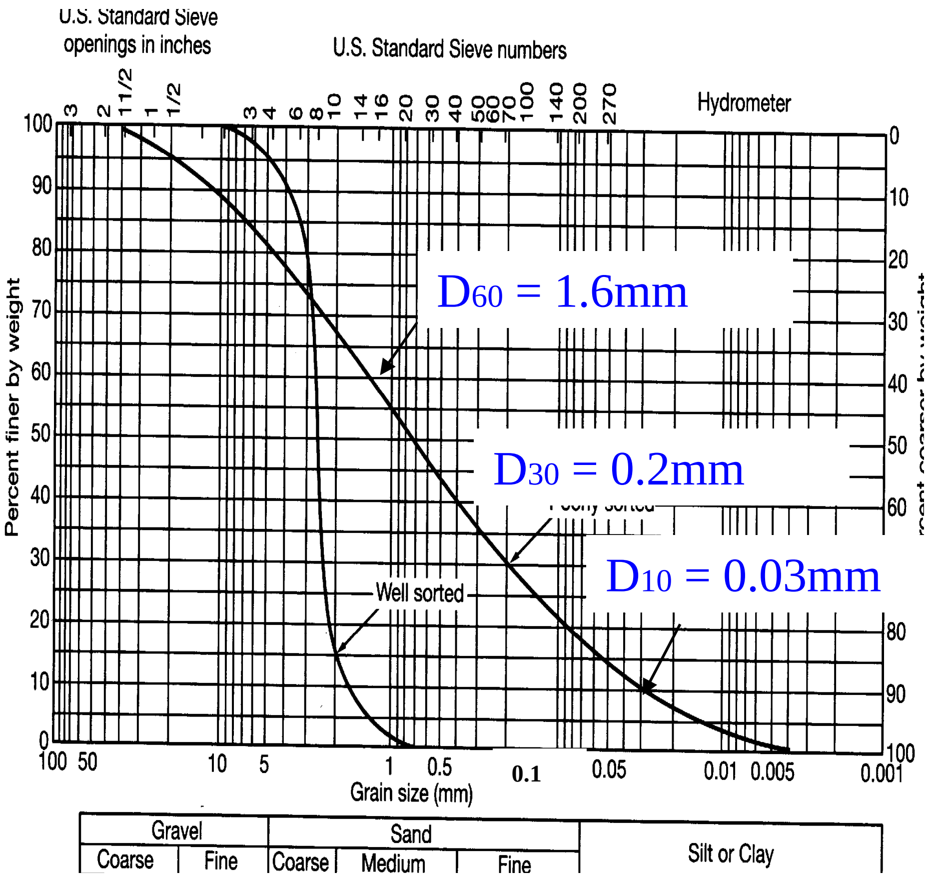
1/2 = 41%

19% (100-81) retained on No. 4 sieve (gravel)

19< 41 half of coarse fraction

∴ sand (“S”)

Well Graded Sand?



Uniformity Coefficient (Cu)

must be ≥ 6

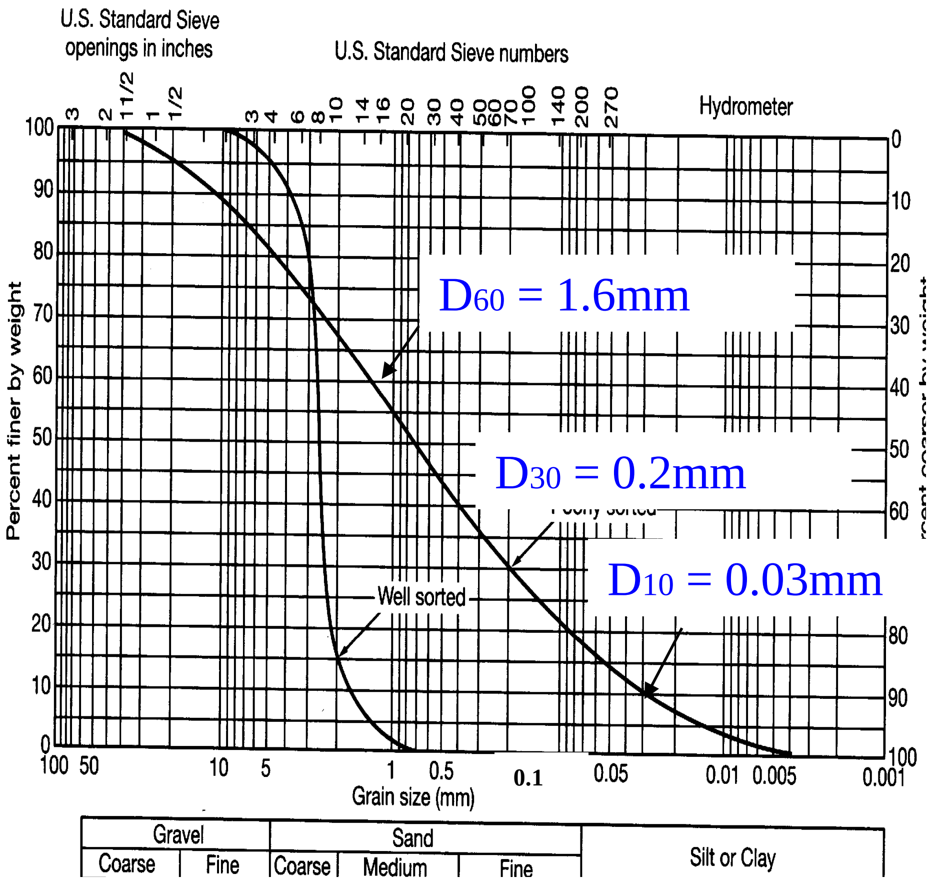
$= D_{60}/D_{10}$

Coefficient of Curvature (Cz)

must = 1 to 3

$= (D_{30})^2/(D_{10} \times D_{60})$

Well Graded Sand?



Uniformity Coefficient (Cu)

$D_{60}/D_{10} = 1.6/.03 = 53 > \mathbf{6}$

Coefficient of Curvature (Cz)

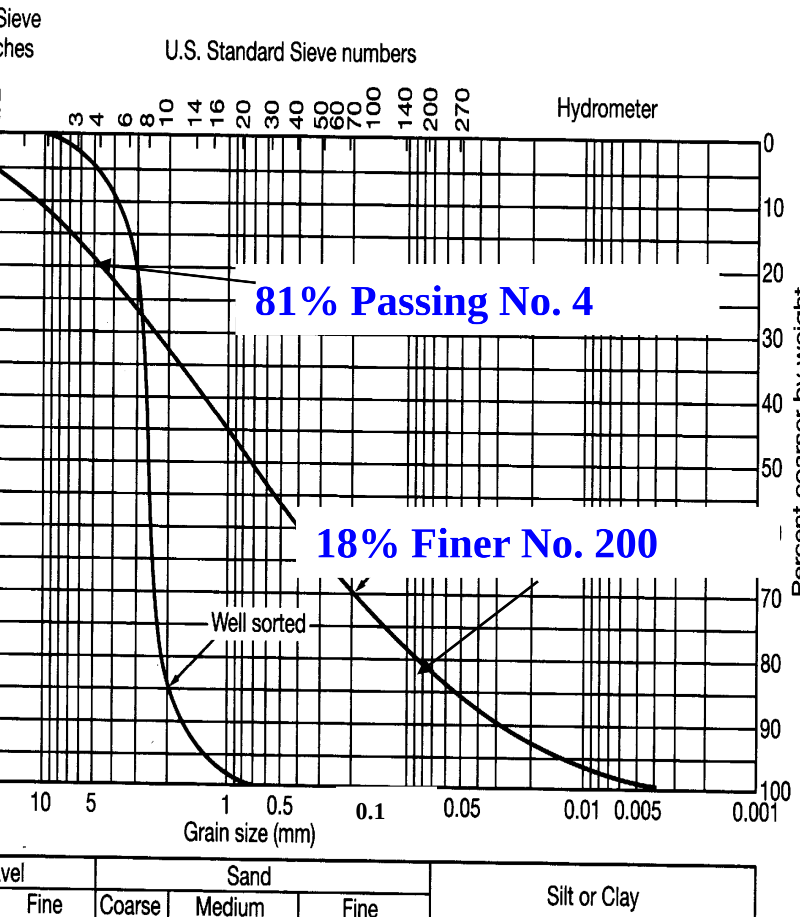
$= (D_{30})^2/(D_{10} x D_{60})$

$= 0.2^2/(.03x1.6)$

$= 0.83 <1 \text{ to } 3$

∴ Poorly graded

What classification?



Unified Classification of Coarse Soils with Fines

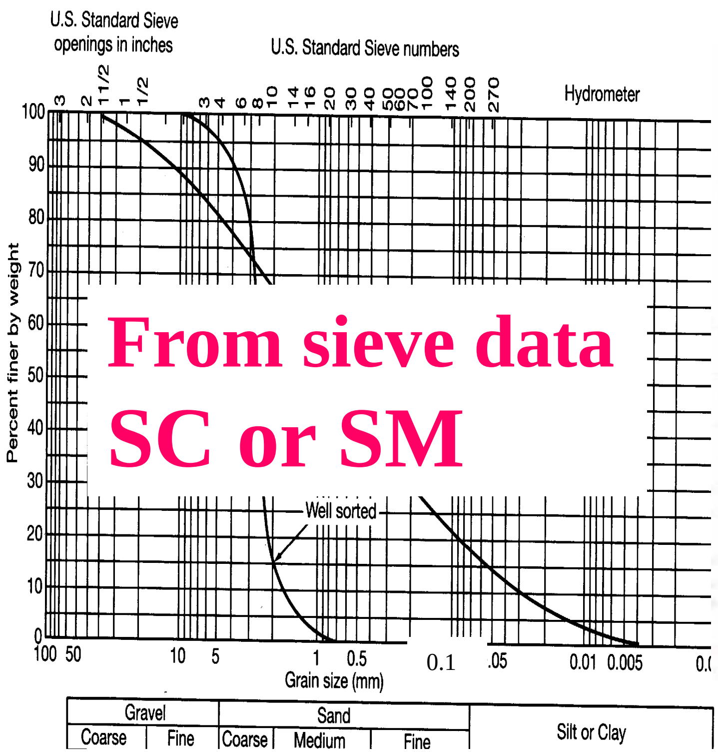
< 5% Passing No. 200 sieve: GW,GP, SW, SP

5% - 12% Passing No. 200 sieve:
Borderline- use dual symbols

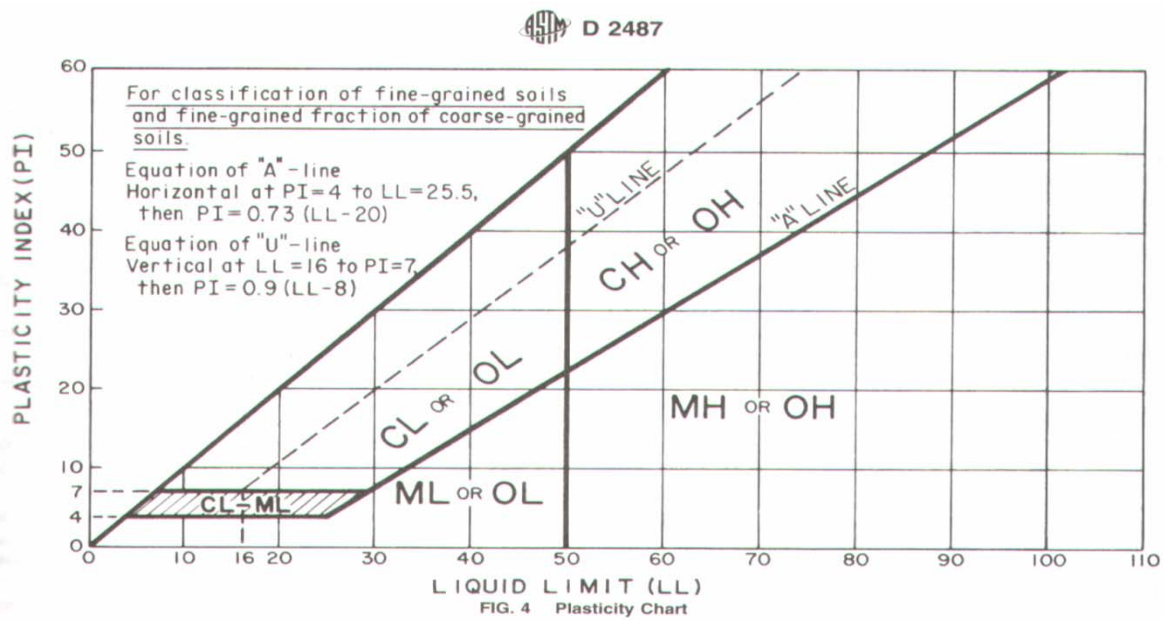
> 12% Passing No. 200 sieve: GM, GC, SM, SC

>12% passing No. 200 sieve
Since = “S” ∴ SC or SM

What Unified Classification if LL= 45 & PI = 25?



From sieve data SC or SM



A) "SC" B) "SM" C) "CL" or D) "SC & SM"

Unified Classification

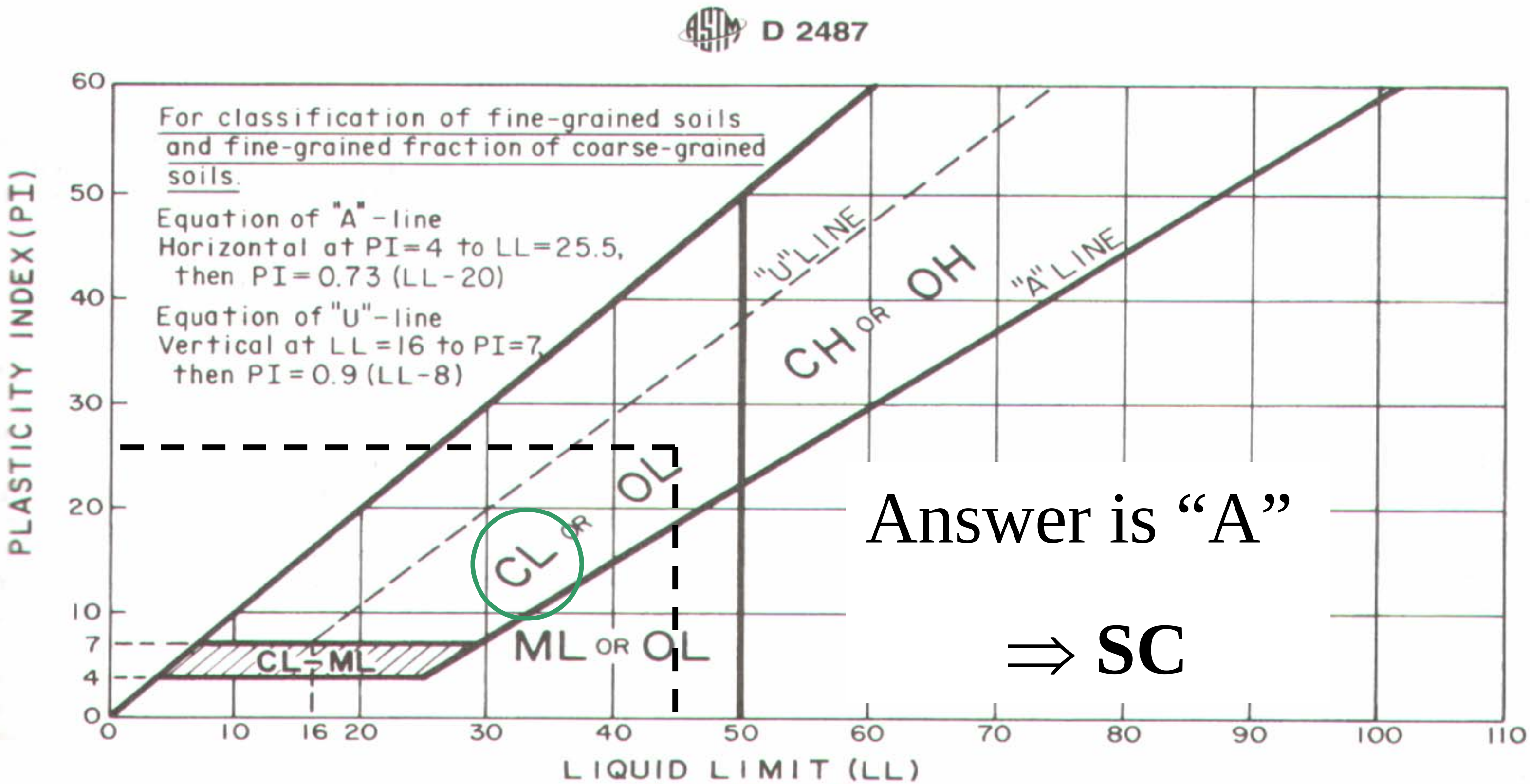


FIG. 4 Plasticity Chart

Answer is "A"

⇒ **SC**

AASHTO

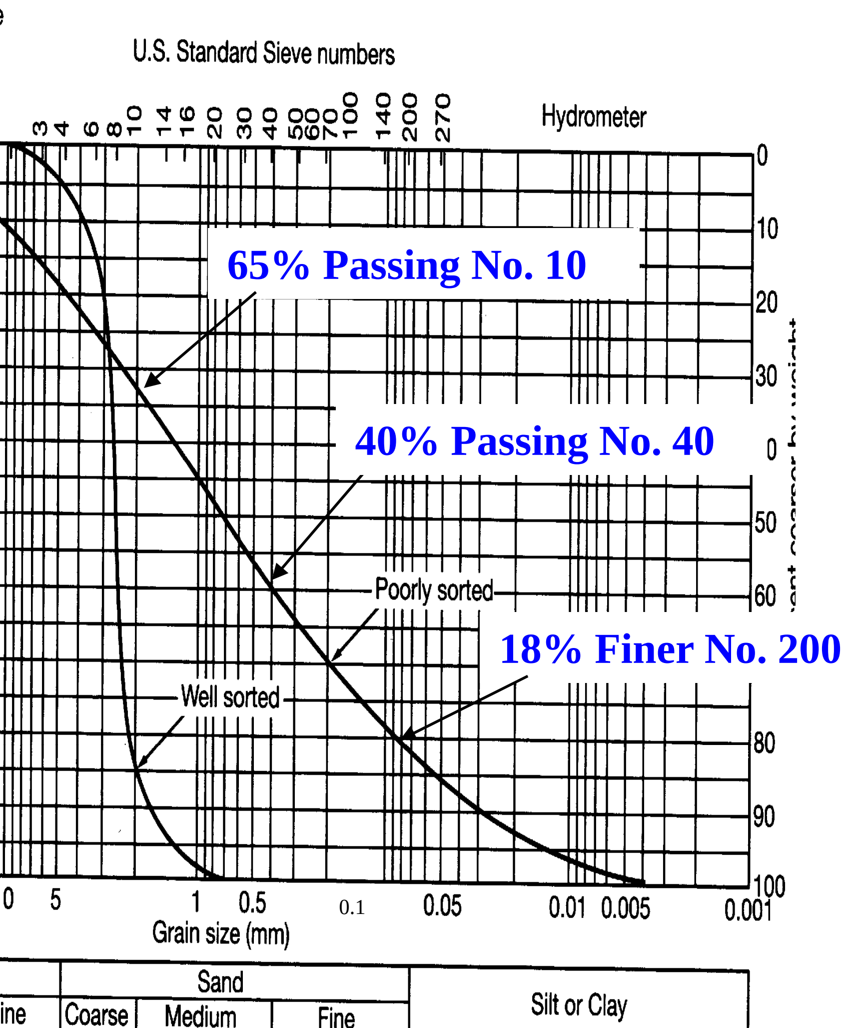
(American Association of State Highway and Transportation Officials)

Classification of Soils and Soil-Aggregate Mixtures

General classification	Granular materials (35% or less passing No 200)							Silt-clay materials (More than 35% passing No. 200)			
Group classification	A-1			A-2							A-7
	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5, A-7-6
Sieve analysis, percent passing:											
No. 10	50 max	—	—	—	—	—	—	—	—	—	—
No. 40	30 max	50 max.	51 min.	—	—	—	—	—	—	—	—
No. 200	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No 40:											
Liquid limit	—		—	40 max	41 min	40 max.	41 min	40 max.	41 min.	40 max	41 min.
Plasticity index	6 max.		N.P.	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.*
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to good						Fair to poor				

*Plasticity index of A-7-5 subgroup is equal to or less than L L. minus 30. Plasticity index of A-7-6 subgroup is greater than L L. minus 30.

What is the AASHTO Classification?



1) 18 % passing No. 200 sieve
2) 65% passing No. 10 sieve
3) 40% passing No. 40 sieve
4) assume LL = 45 & PI = 25

18 percent passing No. 200 sieve; 65 percent passing No. 10 sieve
40 percent passing No. 40 sieve; assume LL = 45 & PI = 25

Classification of Soils and Soil-Aggregate Mixtures

General classification	Granular materials (35% or less passing No 200)							Silt-clay materials (More than 35% passing No. 200)			
Group classification	A-1			A-2							A-7
	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5, A-7-6
Sieve analysis, percent passing:											
No. 10	50 max	—	—	—	—	—	—	—	—	—	—
No. 40	30 max	50 max.	51 min.	—	—	—	—	—	—	—	—
No. 200	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No 40:											
Liquid limit	—		—	40 max	41 min	40 max.	41 min	40 max.	41 min.	40 max	41 min.
Plasticity index	6 max.		N.P.	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.*
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to good					Fair to poor					

*Plasticity index of A-7-5 subgroup is equal to or less than L.L. minus 30. Plasticity index of A-7-6 subgroup is greater than L.L. minus 30.

AASHTO Classification

Classification of Soils and Soil-Aggregate Mixtures

General classification	Granular materials (35% or less passing No 200)							Silt-clay materials (More than 35% passing No. 200)
Group classification	A-1		A-3	A-2				
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7	
Sieve analysis, percent passing: No. 10 No. 40 No. 200	 50 max 30 max 15 max	 — 50 max. 25 max.	 — 51 min. 10 max.	 — — 35 max.	 — — 35 max.	 — — 35 max.	 — — 35 max	
Characteristics of fraction passing No 40: Liquid limit Plasticity index	 — 6 max.		 — N.P.	 40 max 10 max.	 41 min 10 max.	 40 max. 11 min.	 41 min 11 min.	
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				
General rating as subgrade	Excellent to good					Fair to poor		

*Plasticity index of A-7-5 subgroup is equal to or less than L L. minus 30. Plasticity index of A-7-6 subgroup is greater than L L. minus 30.

1) 18 % passing No. 200 sieve

2) 65% passing No. 10 sieve

3) 40% passing No. 40 sieve

4) assume LL = 45 & PI = 25

AASHTO Group Index

The first term is determined by the LL

$$GI = (F_{200} - 35)\left[0.2 + 0.005(LL - 40)\right]$$
$$+ 0.01(F_{200} - 15)(PI - 10)$$

The second term is determined by the PI

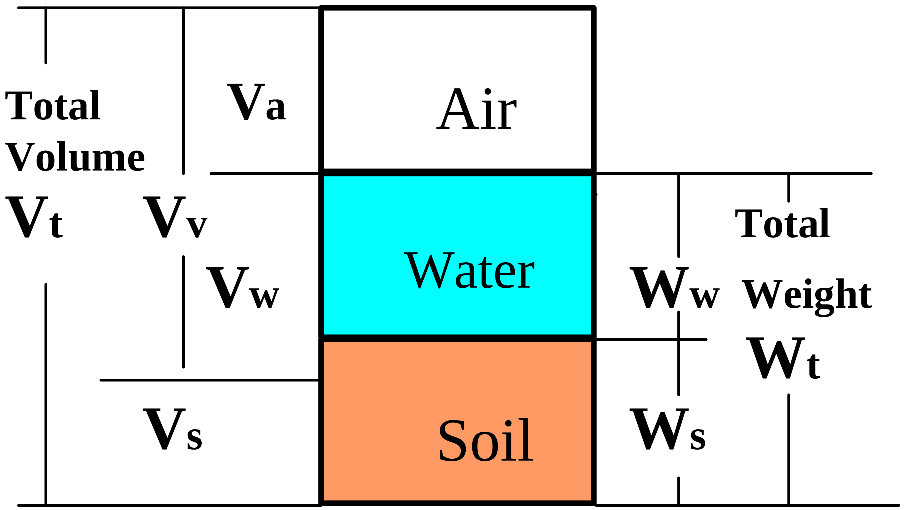
F200: percentage passing through the No.200 sieve

For Group A-2-6 and A-2-7 use the second term only

$$GI = 0.01(F_{200} - 15)(PI - 10)$$

In general, the rating for a pavement subgrade is inversely proportional to the group index, GI.

Mass-Volume (Phase Diagram)



- Unit volume of soil contains:
  - Air (gases)
  - Water (fluid)
  - Solid Particles

Moisture Content = ω

weight of water/ weight of dry soil

$$\omega = Ww/Wd$$

water loss/(moist soil weight - water loss)

$$\omega = Ww/(Wm-Ww)$$

and

$$\omega = (Wm-Wd)/Wd$$

Mass - Volume Relationships

Density or Unit Weight = γ

Moist Unit Weight = γm

$$\gamma m = Wm/Vt = \gamma d + \omega \gamma d$$

$$\omega = (\gamma m - \gamma d)/\gamma d$$

$$\omega \gamma d + \gamma d = \gamma m$$

$$\gamma m = (1+\omega)\gamma d$$

$$\gamma d = \gamma m/(1+\omega)$$

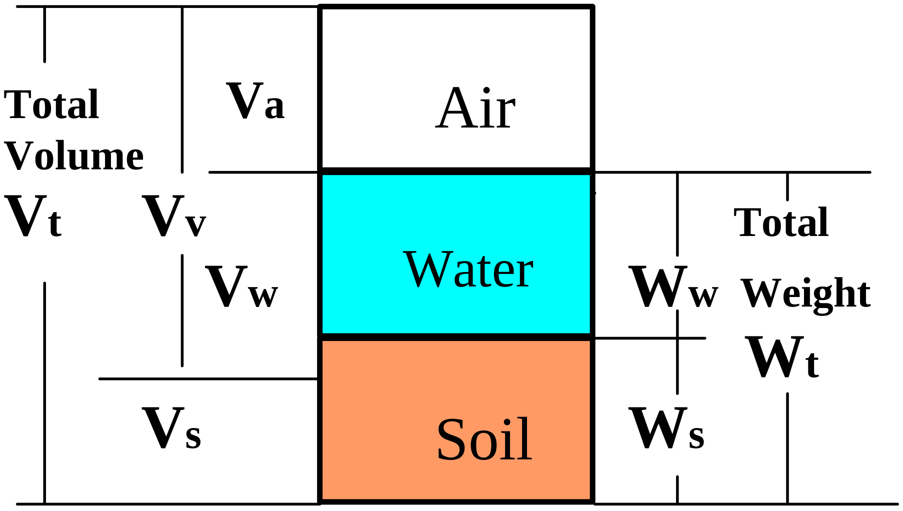
Total Volume =

$\sum$ Volume (solid + water + air)

$= V_s + V_w + V_a$

$\therefore$

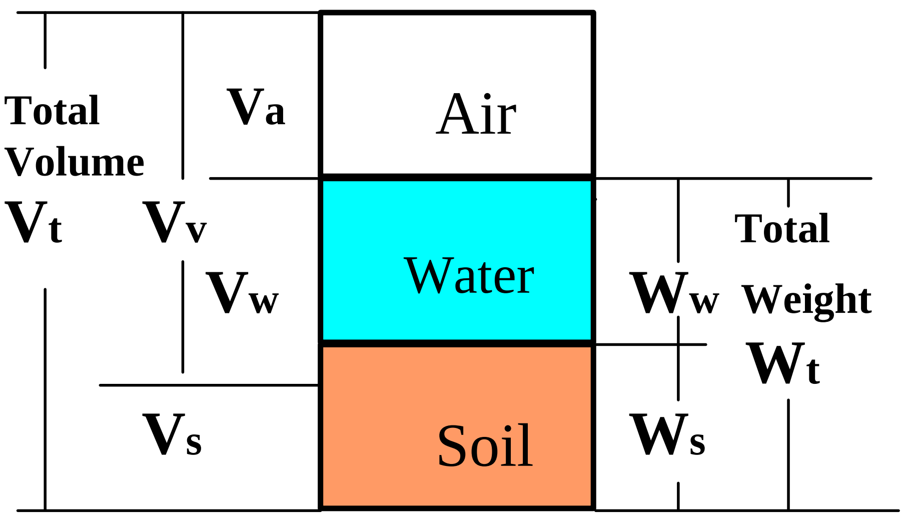
$V_a = V_t - V_s - V_w$



Relationship Between Mass & Volume

Volume = Mass/(Specific Gravity x Unit Weight of Water)

= Ws/(SGxWw)



Specific Gravity =

weight of material/ weight of same volume of water

Soil Specific Gravity

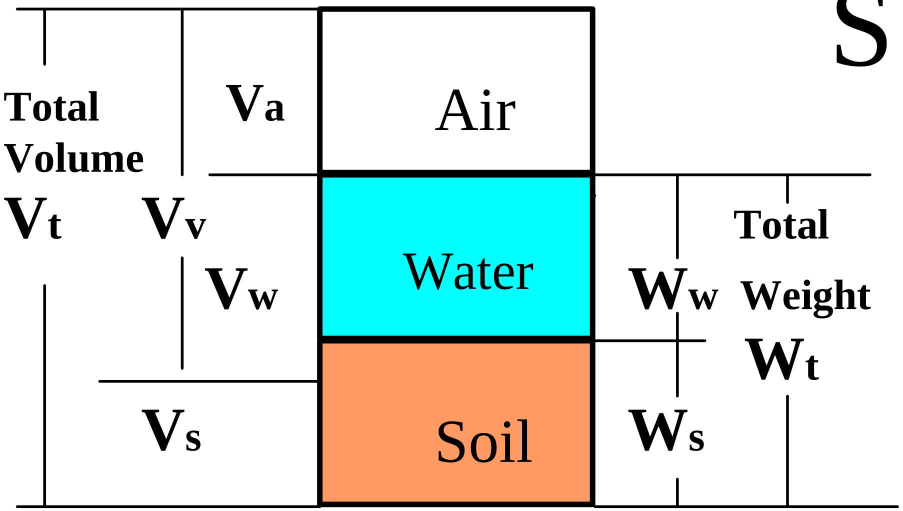
Typical Range

2.65 to 2.70

Specific Gravity of Water = 1

Saturation = S expressed as percent

S = volume of water/ volume of voids x 100



$S = Vw/Vv \times 100$

Always ≤ 100

Porosity

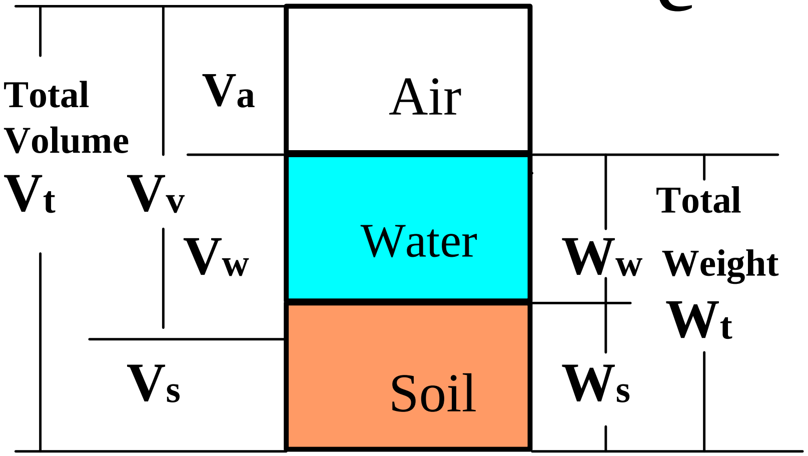
n = volume of voids/ total volume

$n = V_v/V_t$

Void Ratio

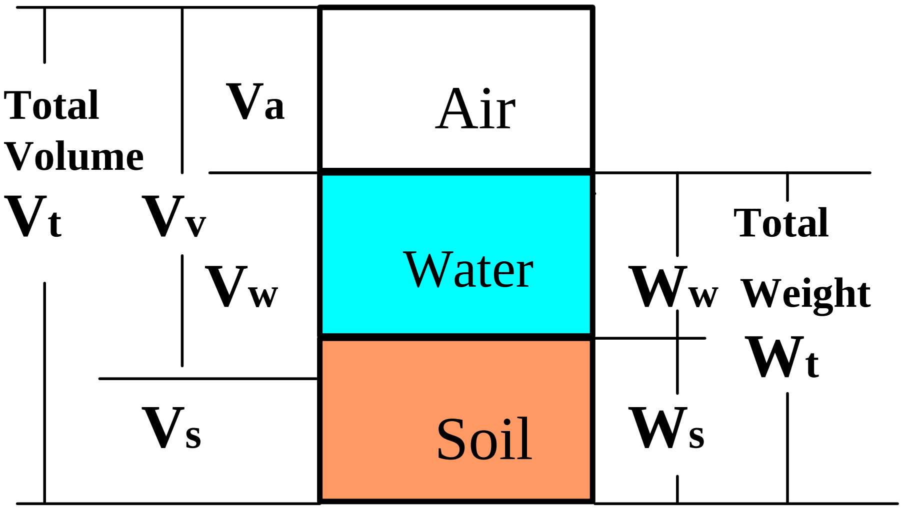
e = volume of voids/ volume of solids

$e = V_v/V_s$



What is the degree of saturation for a soil with:

SG = 2.68, γ_m = 127.2 pcf & ω = 18.6 percent



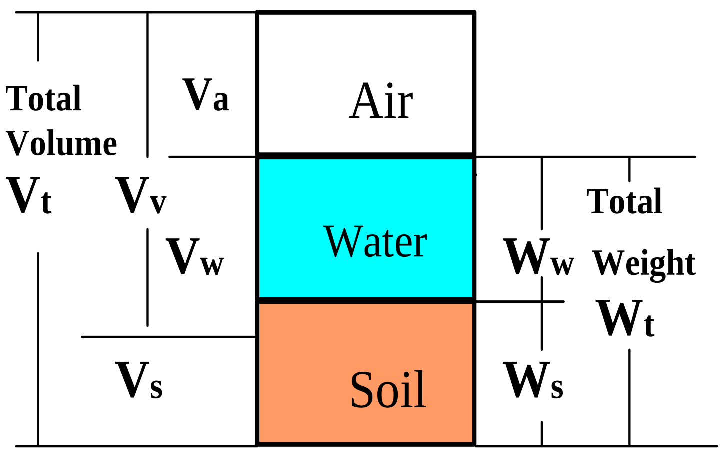
A) 88.4

B) 100.0

C) 89.1

What is degree of saturation for a soil with:

SG = 2.68, γ_m = 127.2 pcf & ω = 18.6 percent



$\gamma_d = \gamma_m/(1+\omega) = 127.2/(1.186)$

$= 107.3$pcf

$Ww = \gamma_m - \gamma_d = 19.9$ pcf

$Vw = Ww/62.4 = 0.319$ cf

$Vs = \gamma_d /(SG\times62.4) = 0.642$ cf

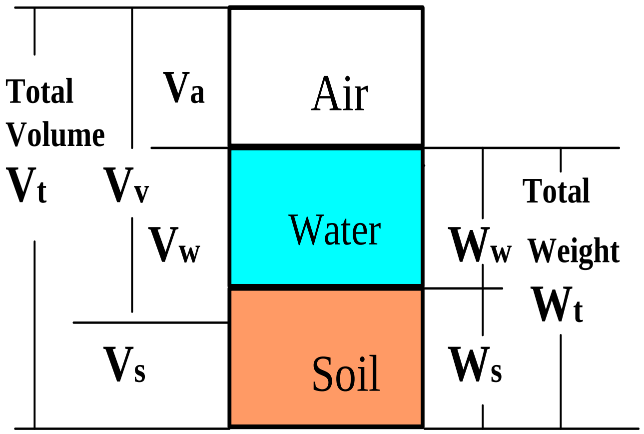
$Va = Vt - Vw - Vs$

$= 1 - 0.319 - 0.642 = 0.039$ cf

$Vv = Vw + Va = 0.358$ cf

What is degree of saturation for a soil with:

SG = 2.68, γ_m = 127.2 pcf & ω = 18.6 percent



Vw = 0.319 cf, Vs = 0.642 cf,

Vv = 0.358 cf

Degree of Saturation = Vw/Vv x 100

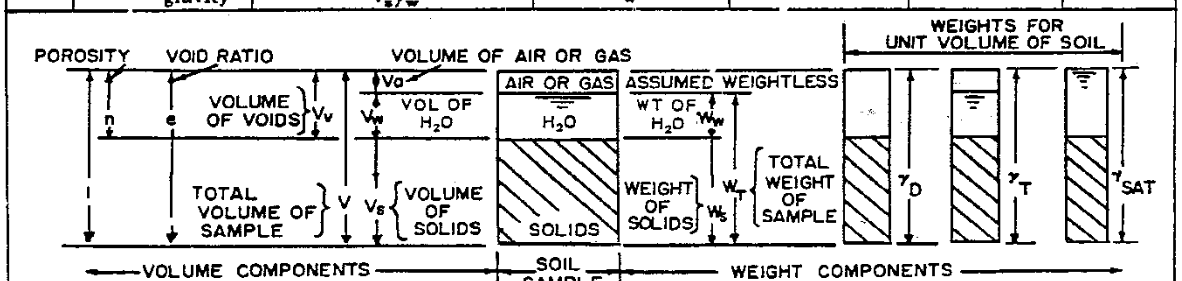
= 0.319/0.358 x 100 = **89.1%**

Answer is "C"

TABLE 3-5

Volume and Weight Relationships

		Property	Saturated sample (W_s, W_w, G, are known)	Unsaturated sample (W_s, W_w, G, V are known)	Supplementary formulas relating measured and computed factors			
Volume components	V_s	volume of solids	a $\frac{W_s}{G\gamma_w}$		$V-(V_a+V_w)$	$V(1-n)$	$\frac{V}{(1+e)}$	$\frac{V_v}{e}$
	V_w	volume of water	$\frac{W_w}{\gamma_w{}^*}$		V_v-V_a	SV_v	$\frac{SV_e}{(1+e)}$	$SV_s\,e$
	V_a	volume of air or gas	zero	$V-(V_s+V_w)$	V_v-V_w	$(1-S)V_v$	$\frac{(1-S)V_e}{(1+e)}$	$(1-S)V_s\,e$
	V_v	volume of voids	$\frac{W_w}{\gamma_w{}^*}$	$V-\frac{W_s}{G\gamma_w}$	$V-V_s$	$\frac{V_s\,n}{1-n}$	$\frac{V_e}{(1+e)}$	$V_s\,e$
	V	total volume of sample	V_s+V_w	measured	$V_s+V_a+V_w$	$\frac{V_s}{1-n}$	$V_s(1+e)$	$\frac{V_v(1+e)}{e}$
	n	porosity	$\frac{V_v}{V}$		$\frac{1-V_s}{V}$	$1-\frac{W_s}{GV\gamma_w}$	$\frac{e}{1+e}$	
	e	void ratio	$\frac{V_v}{V_s}$		$\frac{V}{V_s-1}$	$\frac{GV\gamma_w}{W_s}-1$	$\frac{W_wG}{W_sS}$	$\frac{n}{1-n}$ | $\frac{wG}{S}$
Weights for specific sample	W_s	weight of solids	measured		$\frac{W_T}{(1+w)}$	$GV\gamma_w(1-n)$	$\frac{W_wG}{eS}$	
	W_w	weight of water	measured		wW_s	$S\gamma_wV_v$	$\frac{eW_sS}{G}$	
	W_t	total weight of sample	W_s+W_w		$W_s(1+w)$			
Weights for sample of unit volume	γ_D	dry unit weight	$\frac{W_s}{V_s+V_w}$	$\frac{W_s}{V}$	$\frac{W_t}{V(1+w)}$	$\frac{G\gamma_w}{(1+e)}$	$\frac{G\gamma_w}{1+wG/S}$	
	γ_T	wet unit weight	$\frac{W_s+W_w}{V_s+V_w}$	$\frac{W_s+W_w}{V}$	$\frac{W_T}{V}$	$\frac{(G+Se)\gamma_w}{(1+e)}$	$\frac{(1+w)\gamma_w}{w/S+1/G}$	
	γ_{SAT}	saturated unit weight	$\frac{W_s+W_w}{V_s+V_w}$	$\frac{W_s+V_v\gamma_w}{V}$	$\frac{W_s}{V}+\left(\frac{e}{1+e}\right)\gamma_w$	$\frac{(G+e)\gamma_w}{(1+e)}$	$\frac{(1+w)\gamma_w}{w+1/G}$	
	γ_{SUB}	submerged (buoyant) unit weight	$\gamma_{SAT}-\gamma_w{}^*$		$\frac{W_s}{V}-\left(\frac{1}{1+e}\right)\gamma_w{}^*$	$\left(\frac{G+e}{1+e}-1\right)\gamma_w{}^*$	$\left(\frac{1-1/G}{w+1/G}\right)\gamma_w{}^*$	
Combined relations	w	moisture content	$\frac{W_w}{W_s}$		$\frac{W_t}{W_s}-1$	$\frac{Se}{G}$	$S\left[\frac{\gamma_w{}^*}{\gamma_D}-\frac{1}{G}\right]$	
	S	degree of saturation	1.00	$\frac{V_w}{V_v}$	$\frac{W_w}{V_v\gamma_w{}^*}$	$\frac{wG}{e}$	$\frac{w}{\left[\frac{\gamma_w{}^*}{\gamma_D}-\frac{1}{G}\right]}$	
	G	specific gravity	$\frac{W_s}{V_s\gamma_w}$		$\frac{Se}{w}$			



a—γ_w is unit weight of water, which equals 62.4 pcf for fresh water and 64 pcf for sea water (1.00 and 1.025 gm/cc). (Where noted with * the actual unit weight of water surrounding the soil is used.) In other cases use 62.4 pcf.
Values of w and s are used as decimal numbers.

Ref:

NAVFAC DM-7

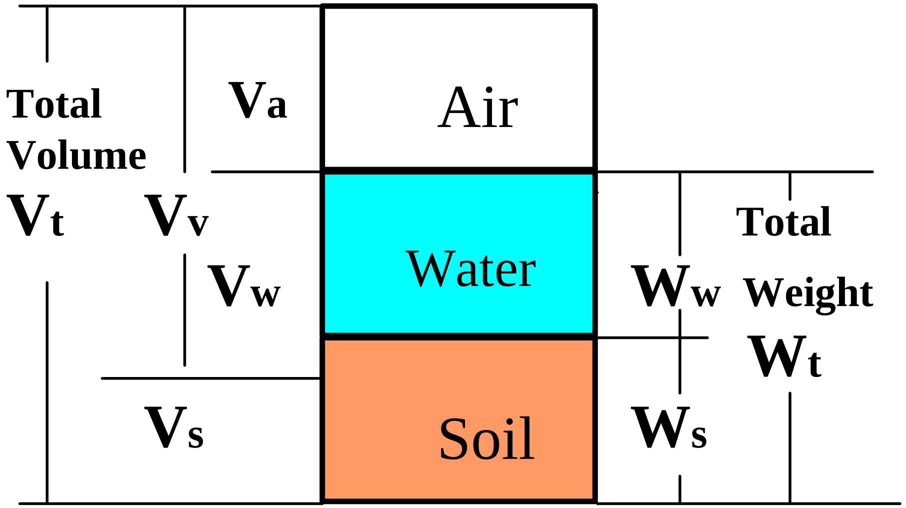
Borrow Fill Adjustments

Borrow Material Properties: γ_m = 110 pcf & ω = 10%

Placed Fill Properties: γ_d = 105 pcf & ω = 20%

How much borrow is needed to produce 30,000 cy of fill?

How much water must be added or removed from each cf of fill?



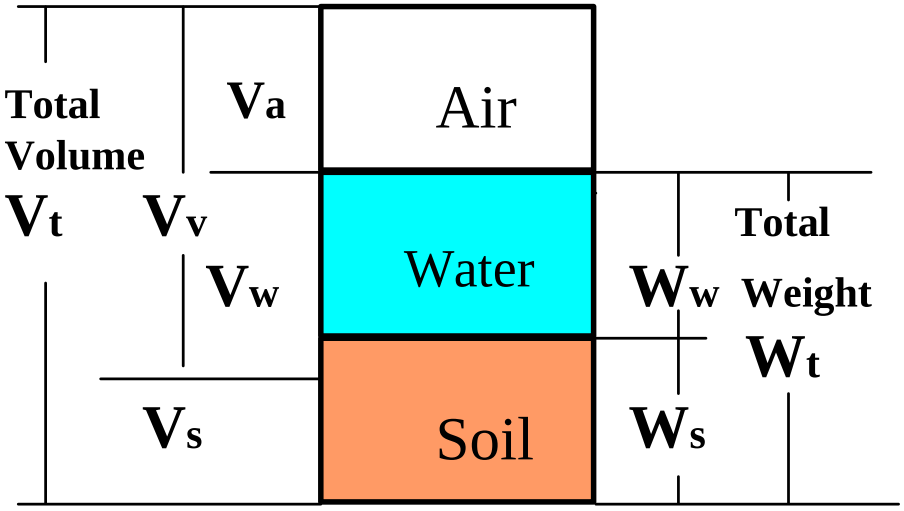
Borrow Fill Adjustments

Borrow Material Properties: γ_m = 110 pcf & ω = 10%

$\gamma_d = \gamma_m /(1+\omega)$ = 110/(1.10) =100 pcf; W_w = 110-100=10 lbs

Placed Fill Properties: γ_d = 105 pcf & ω = 17%

$W_w = \omega x\ \gamma_d$ = 0.17x 105 = 17.9 lbs



Borrow Fill Adjustments

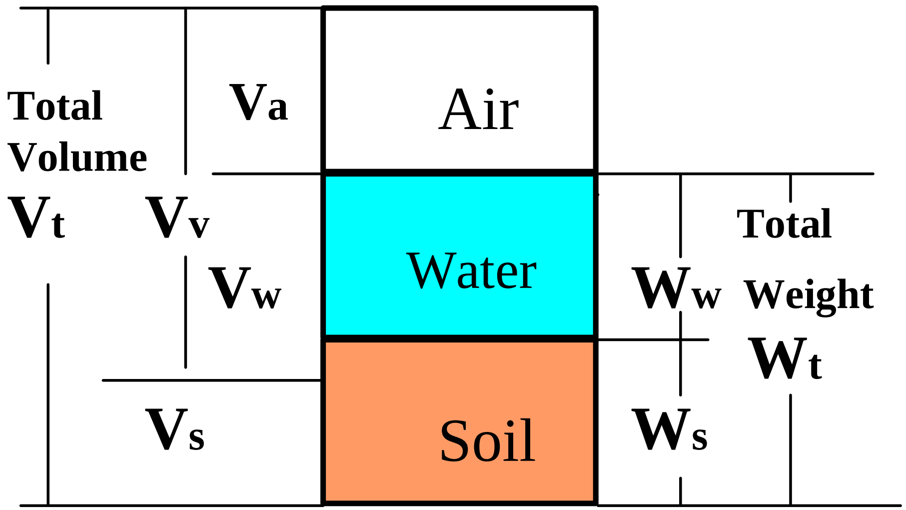
Borrow Properties: γ_m = 110 pcf, γ_d =100 & ω = 10%

Placed Fill Properties: γ_d = 105 pcf & ω = 20%

Since borrow γ_d =100pcf & fill γ_d =105pcf, 105/100 =1.05

It takes 1.05 cy of borrow to make 1.0 cy of fill

For 30,000 cy, 30,000 x 1.05 = 31,500 cy of borrow



Borrow Fill Adjustments

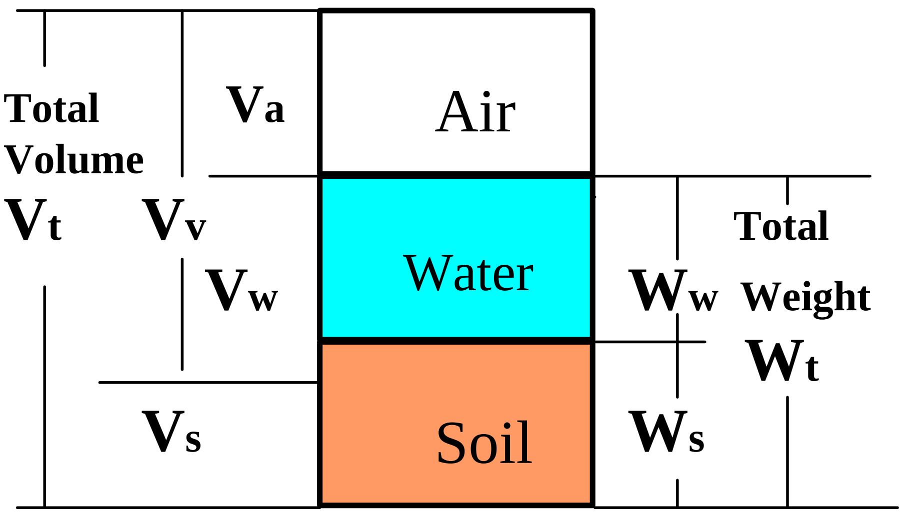
Borrow Material Properties: Ww = 10 lbs

Placed Fill Properties: Ww = 17.9 lbs

Water supplied from borrow in each cf of fill

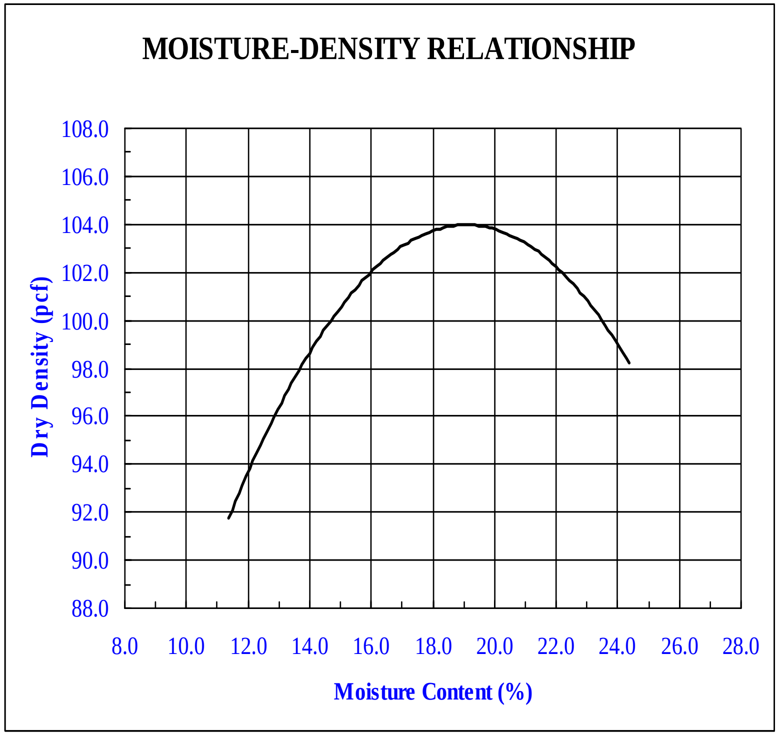
= 10 x 1.05 = 10.5 lbs; 17.9 lbs - 10.5 = 7.4 lbs short/1.05 cf

7.4 lbs/1.05 cf = 7.0 lbs of water to be added per cf borrow



Proctor: Moisture Density Relationships

Establishes the unique relationship of moisture to dry density for each specific soil at a specified compaction energy

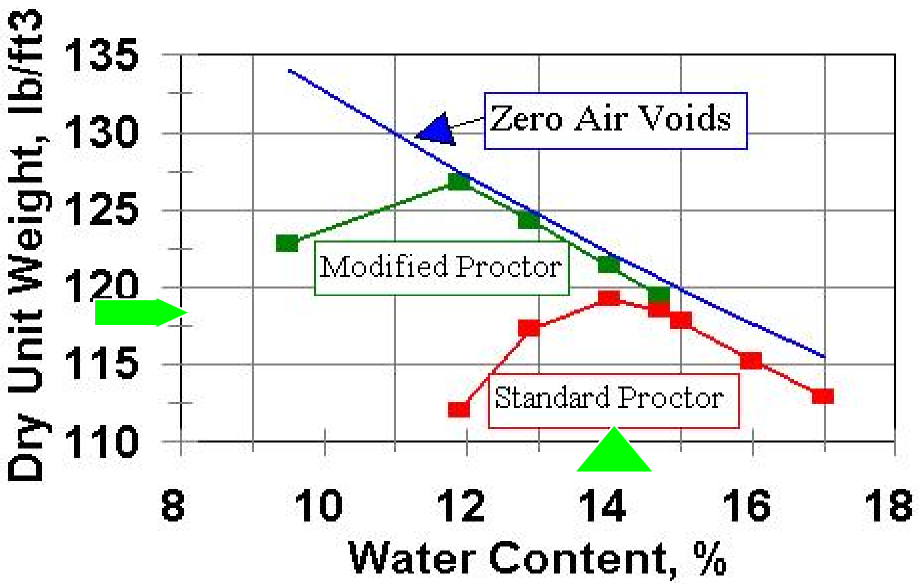


Proctor: Moisture Density Relationships

- 4” mold 25 blows
- 6” mold 56 blows
- Standard
  - 5.5 lb hammer
  - dropped 12 in
  - 3 layers
- Modified
  - 10 lb hammer
  - dropped 18 in
  - 5 layers

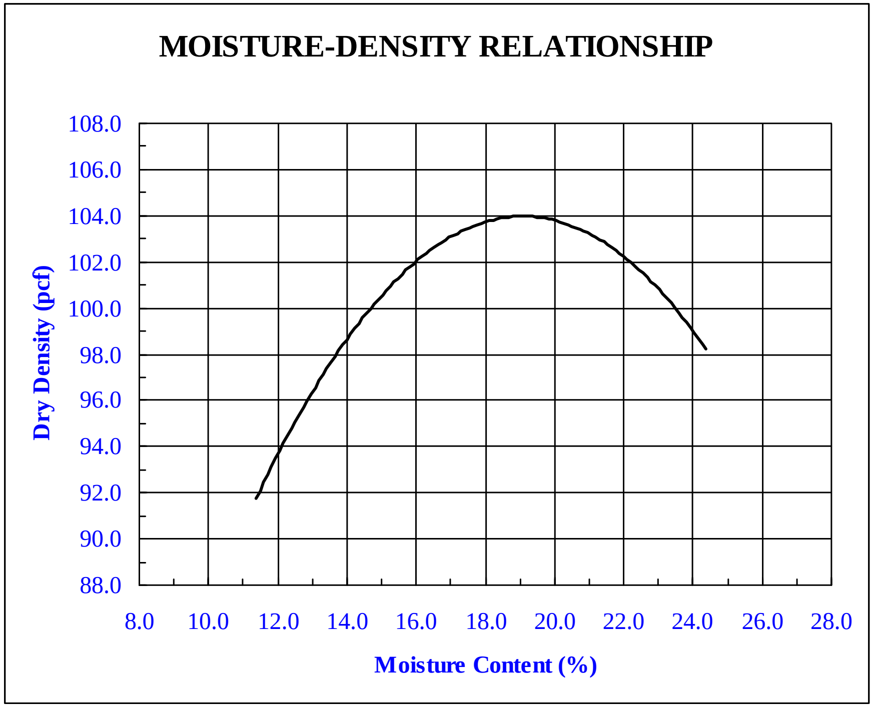
Standard: ASTM D-698
AASHTO T-99
Modified: ASTM D-1557
AASHTO T-180

PROCTOR COMPACTION TEST



- Maximum Dry Density - Highest density for that degree of compactive effort
- Optimum Moisture Content - Moisture content at which maximum dry density is achieved for that compactive effort

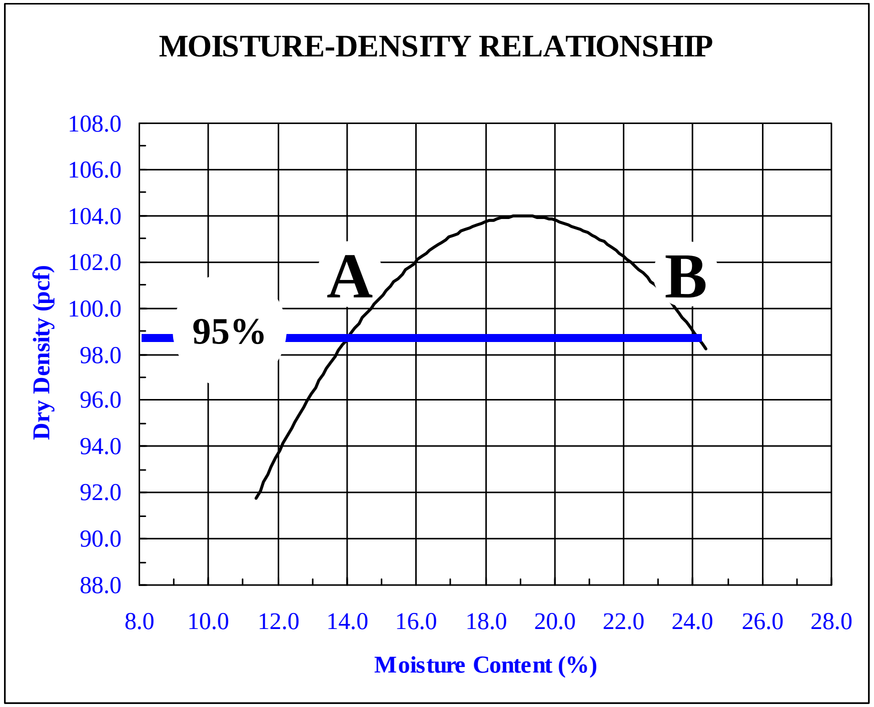
Proctor: Moisture Density Relationships



What density is required for 95% Compaction?

What range of moisture would facilitate achieving 95% compaction?

Proctor: Moisture Density Relationships

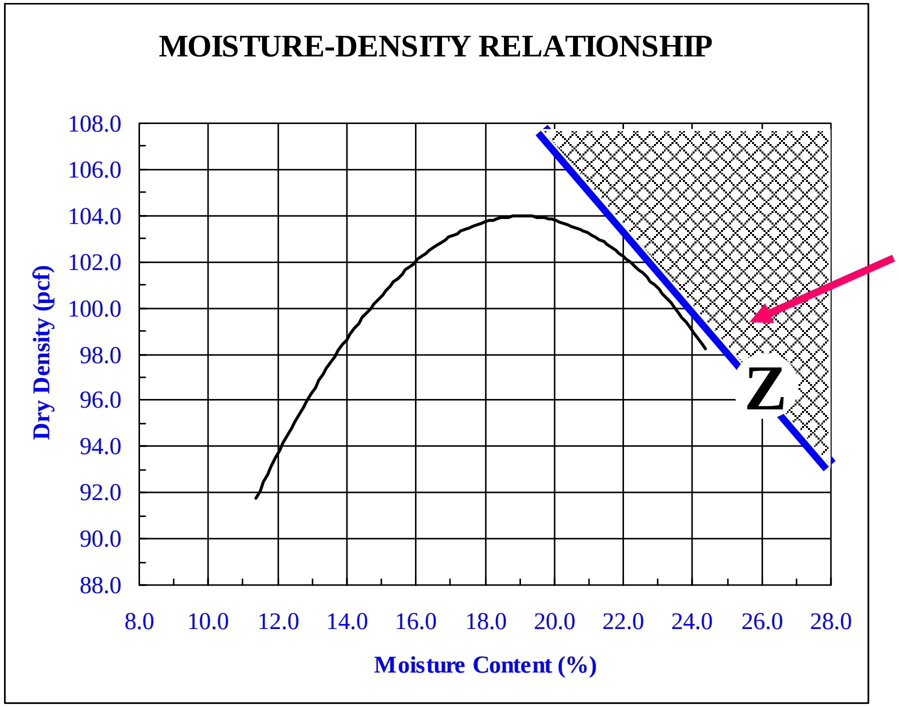


104 x .95 = 98.8 pcf

Range of moisture is within the curve A to B

(14 to 24 %)

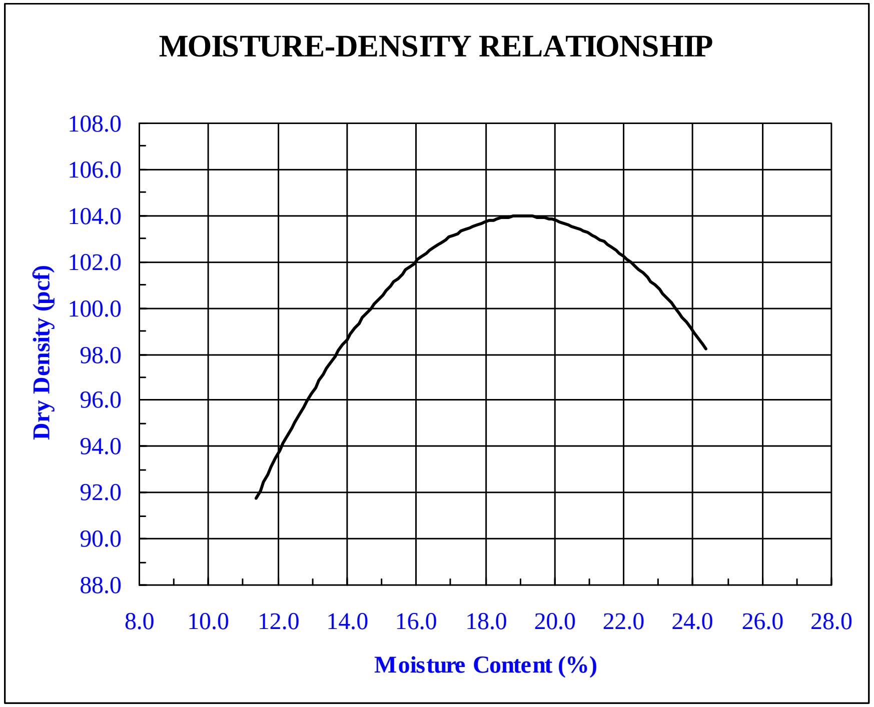
Proctor: Zero Air Voids Line



Relationship of density to moisture at saturation for constant specific gravity (SG)

Can't achieve fill in zone right of zero air voids line

Proctor: Moisture Density Relationships



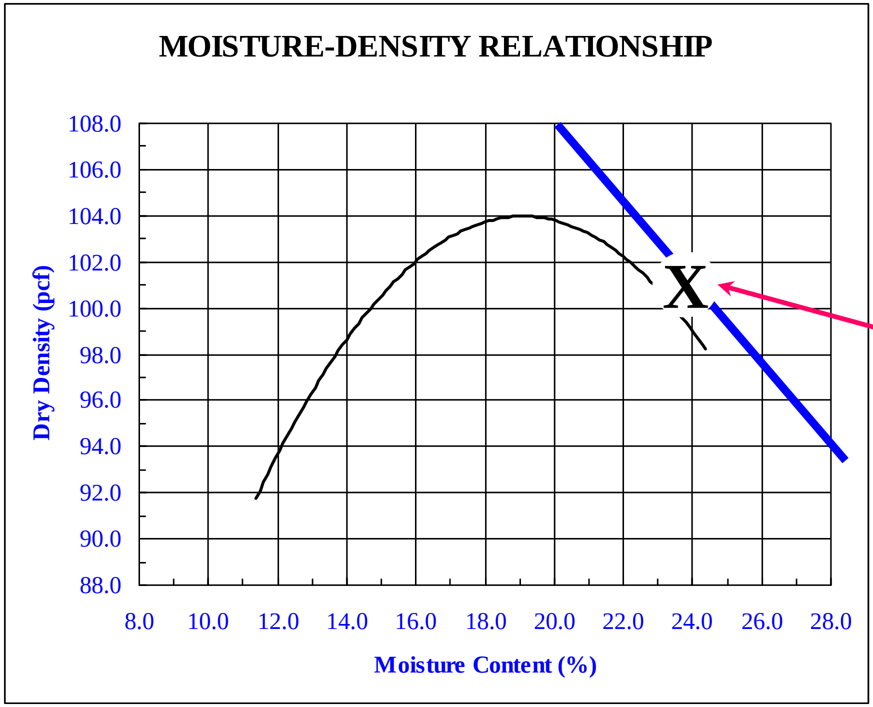
If SG = 2.65 & moisture content is 24%

What dry density achieves 100% saturation?

A) 100.0 pcf

B) 101.1 pcf

Proctor: Moisture Density Relationships



γd=SG62.4/(1+ωSG/100)

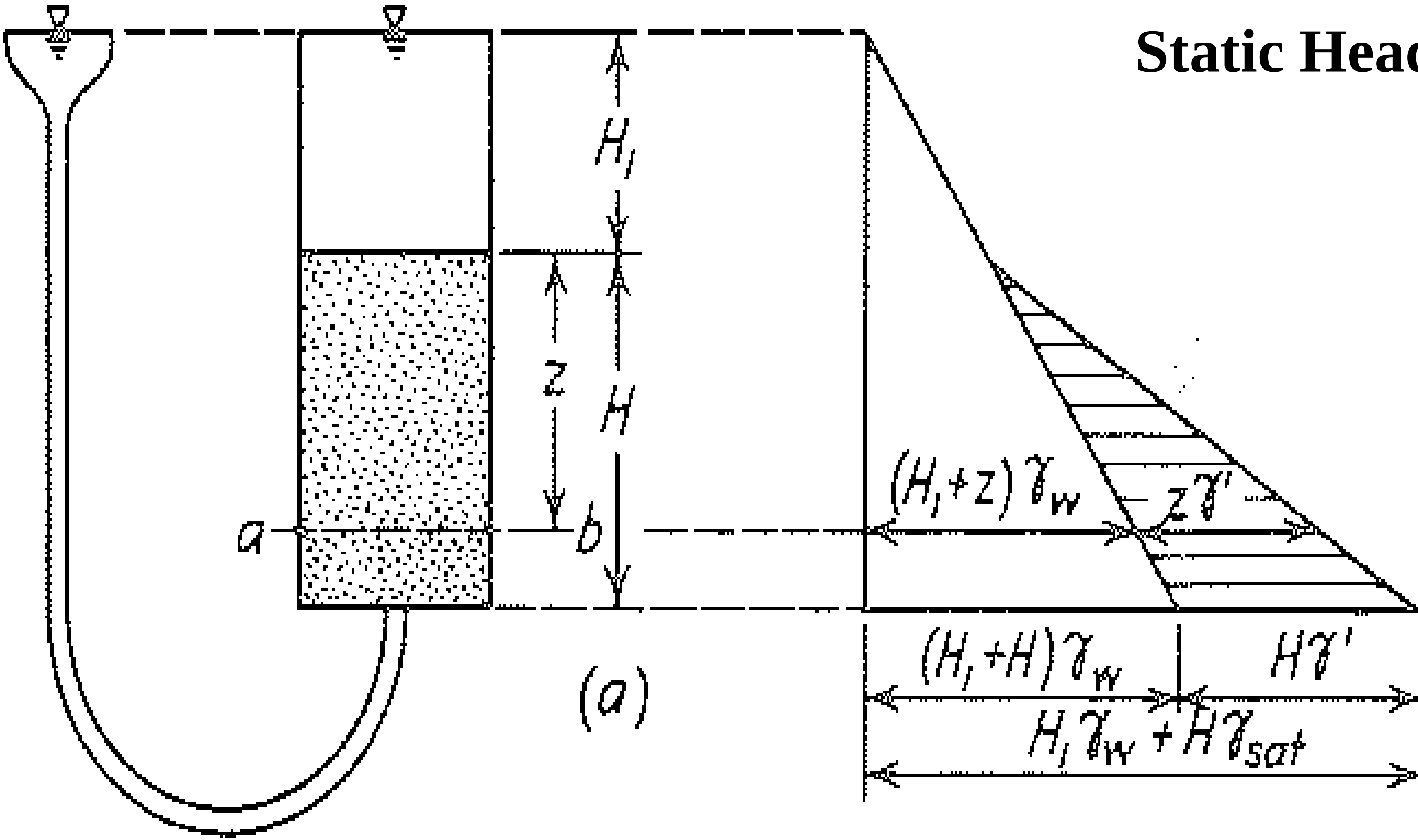
γd=2.65x62.4/(1+24x2.65/100)

γd=101.1 pcf

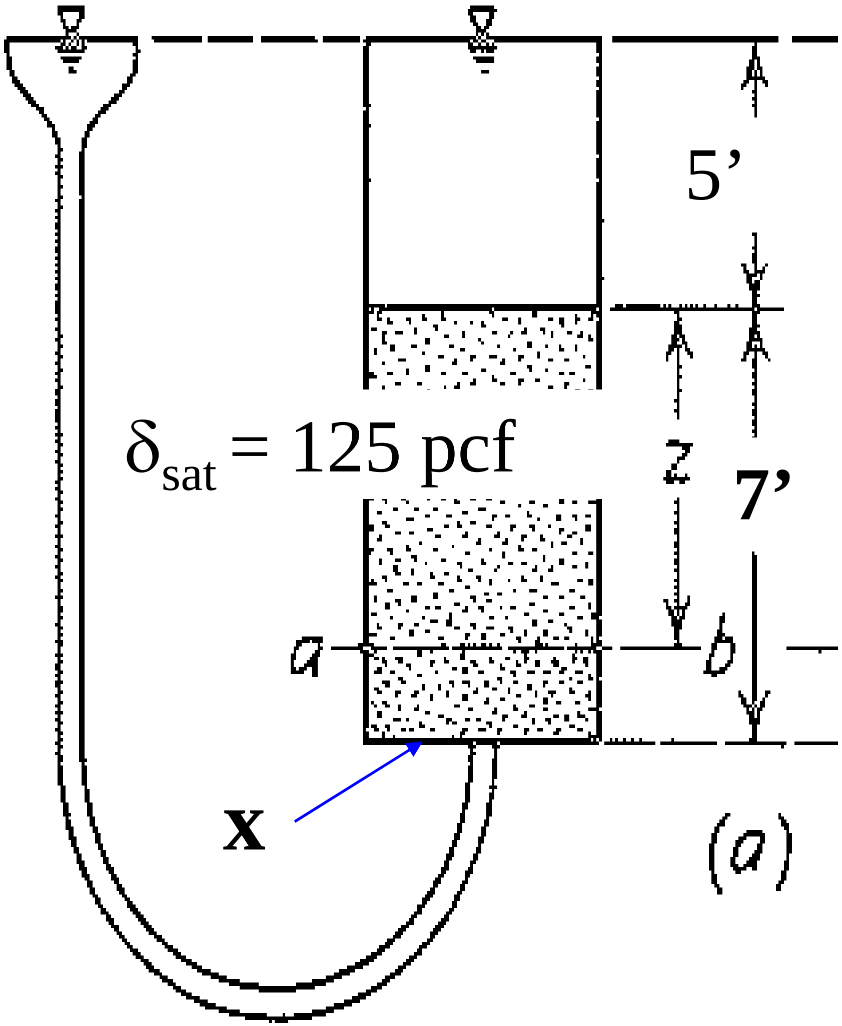
Answer is "B"

Effective and Porewater Pressures

Static Head



Calculate effective stress at point x



Saturated Unit Weight δ_{sat}

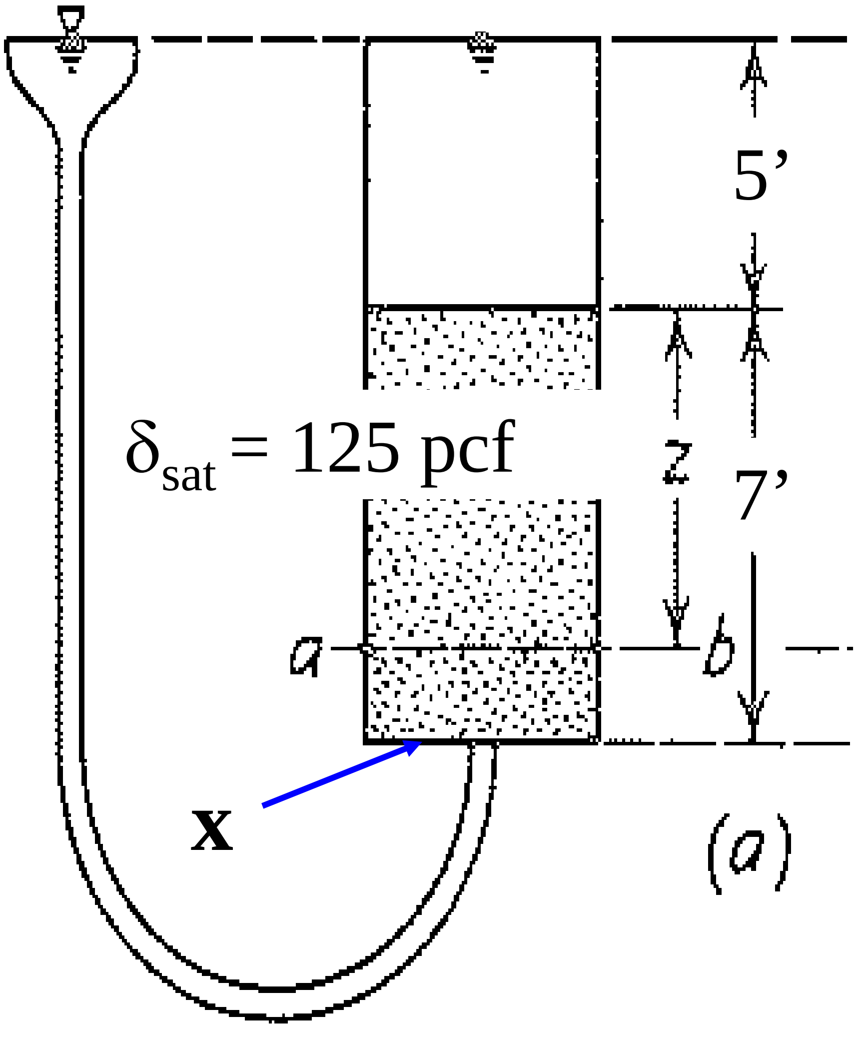
Moist Unit Weight δ_{M}

Dry Unit Weight δ_{Dry}

Submerged (buoyant) Unit Weight

$= \delta_{sat} - 62.4$

Calculate effective stress at point x



δ_{sat} = 125 pcf

Total Stress at X

= 5 x 62.4+ 7x 125= 1187psf

Pore Pressure at X

= 12 x 62.4 = 749 psf

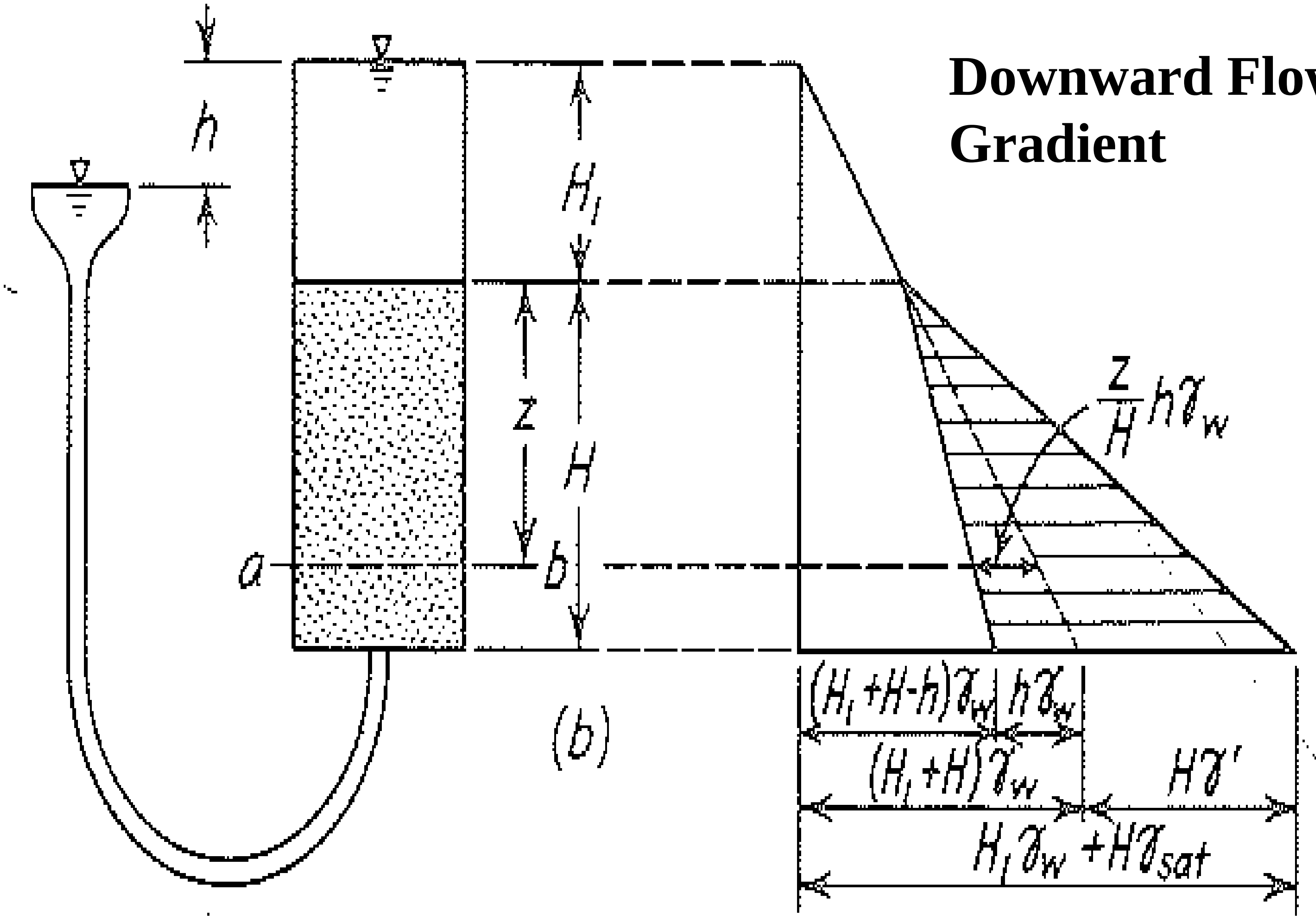
Effective Stress at X

= 1187-749= 438 psf

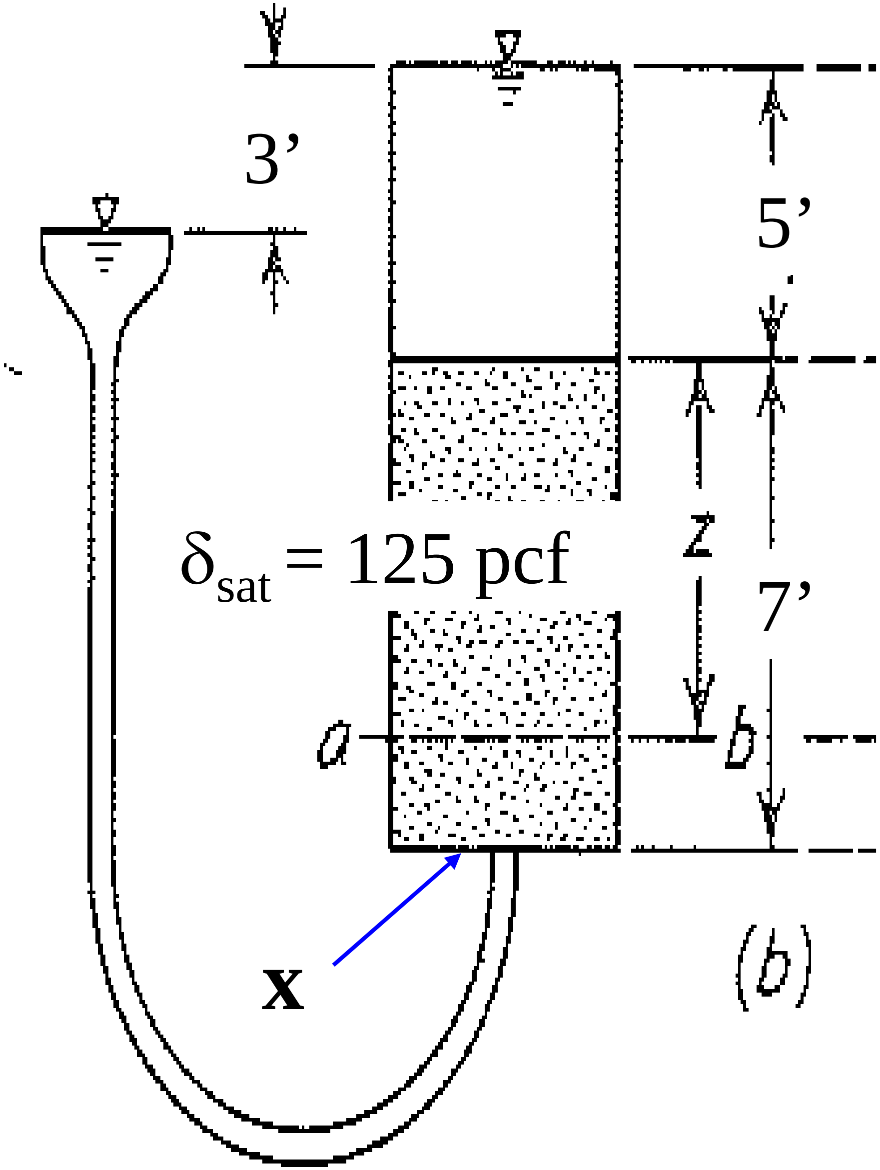
or (125-62.4) x 7=438 psf

Ref: Peck Hanson & Thornburn

Downward Flow Gradient



Downward Flow Gradient



Total Stress at X

= 5 x 62.4+ 7x 125= 1187psf

Pore Pressure at X

= (12-3) x 62.4 = 562 psf

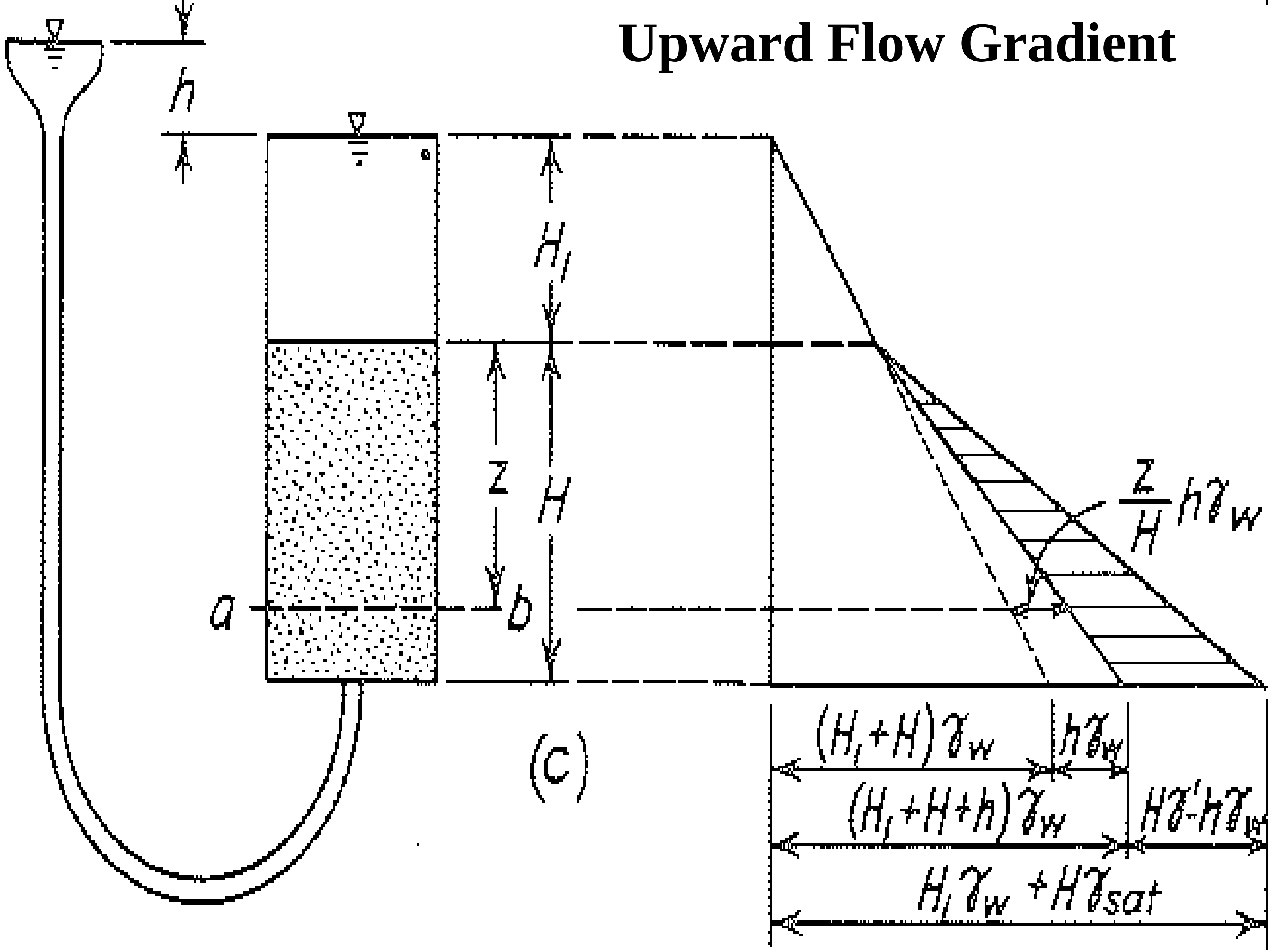
Effective Stress at X

= 1187-562 = 625 psf

or 438 + 3 x 62.4 = 625psf

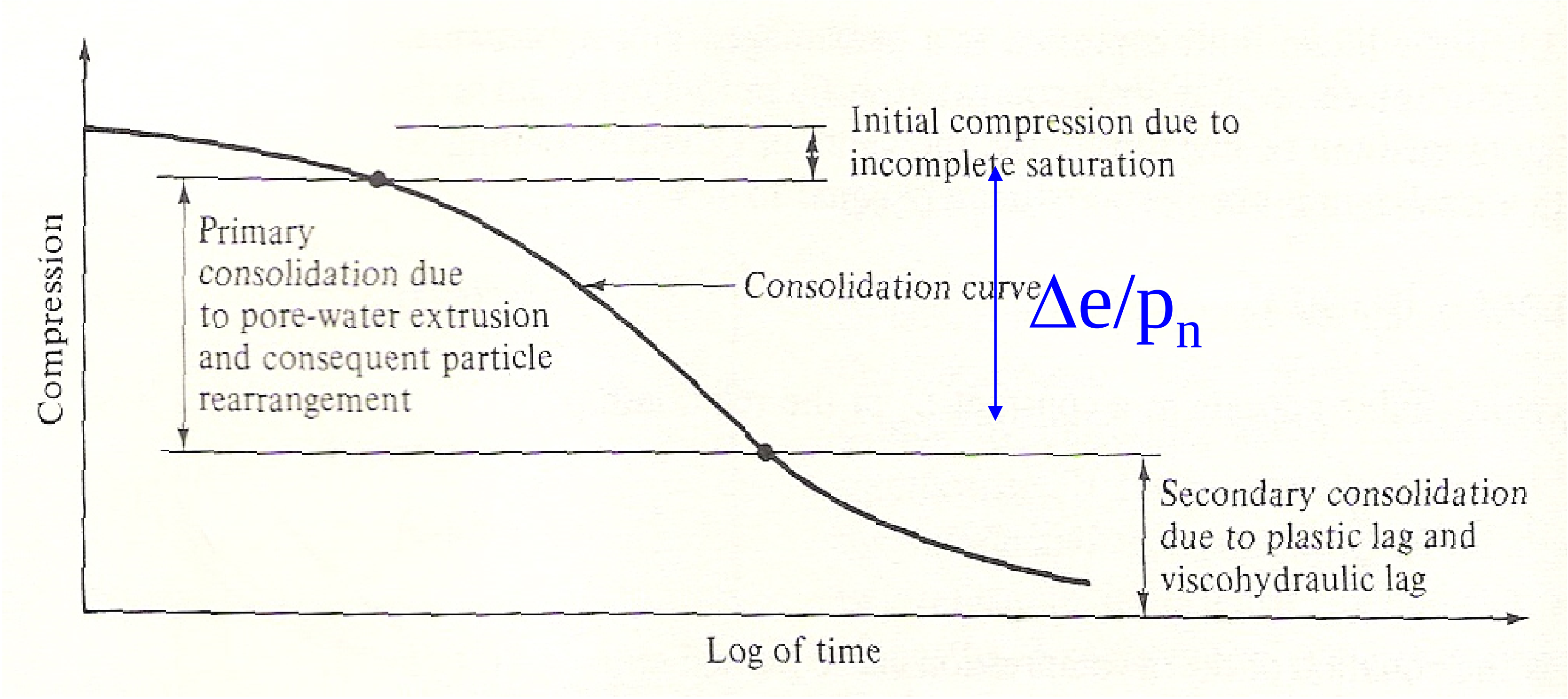
see previous problem

Upward Flow Gradient



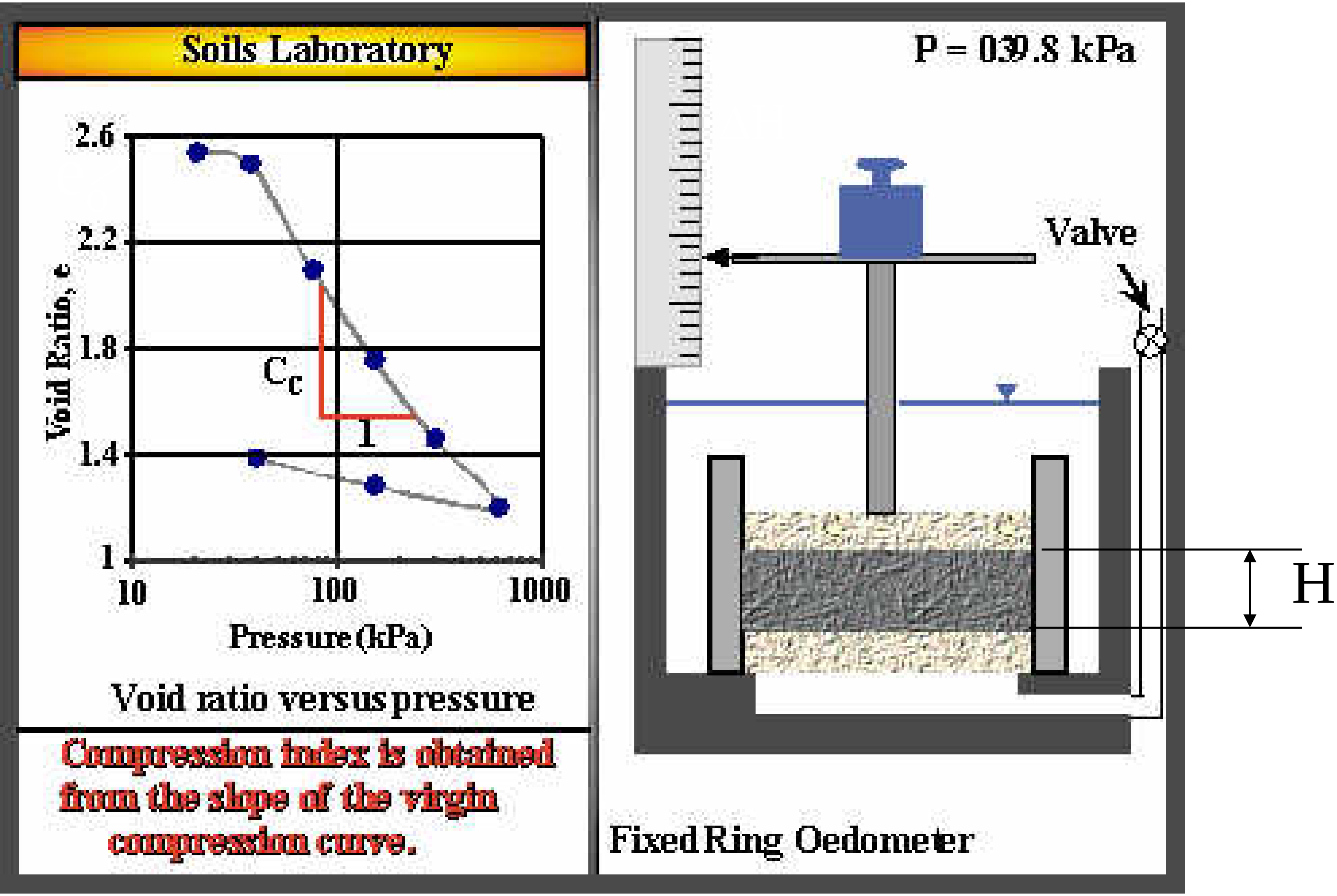
Ref: Peck Hanson & Thornburn

One Dimensional Consolidation

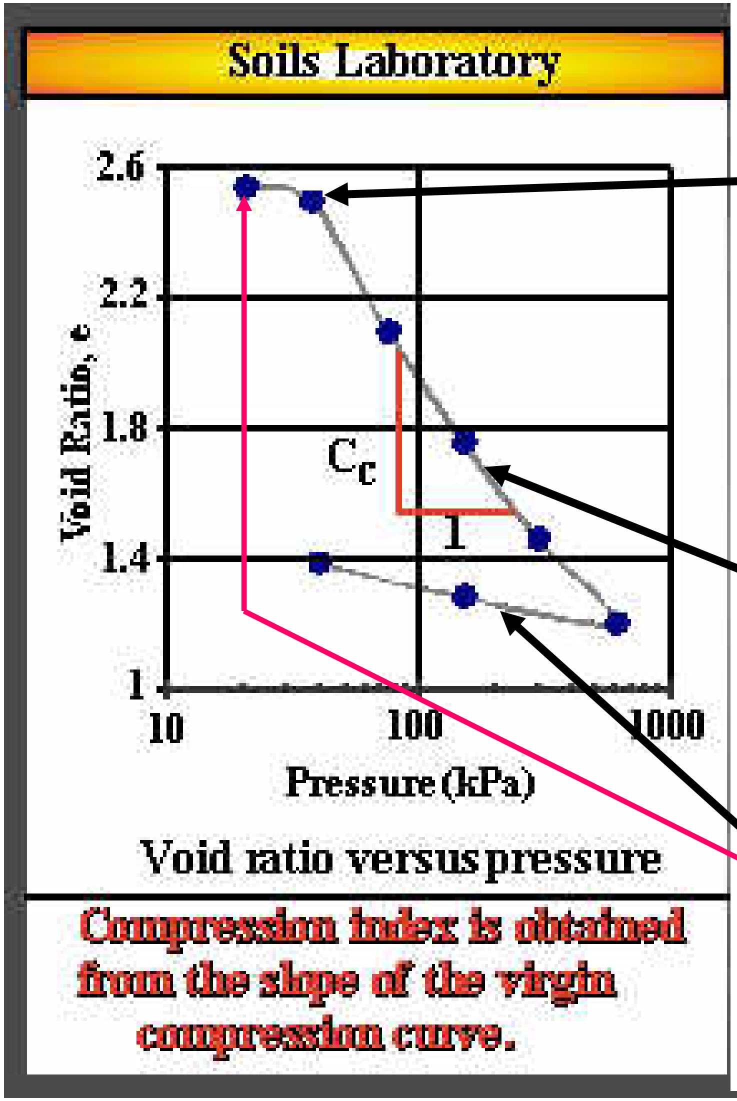


Primary Phase Settlement (e log p)

$$\Delta H = (H \times \Delta e)/(1+e_o)$$



Consolidation Test

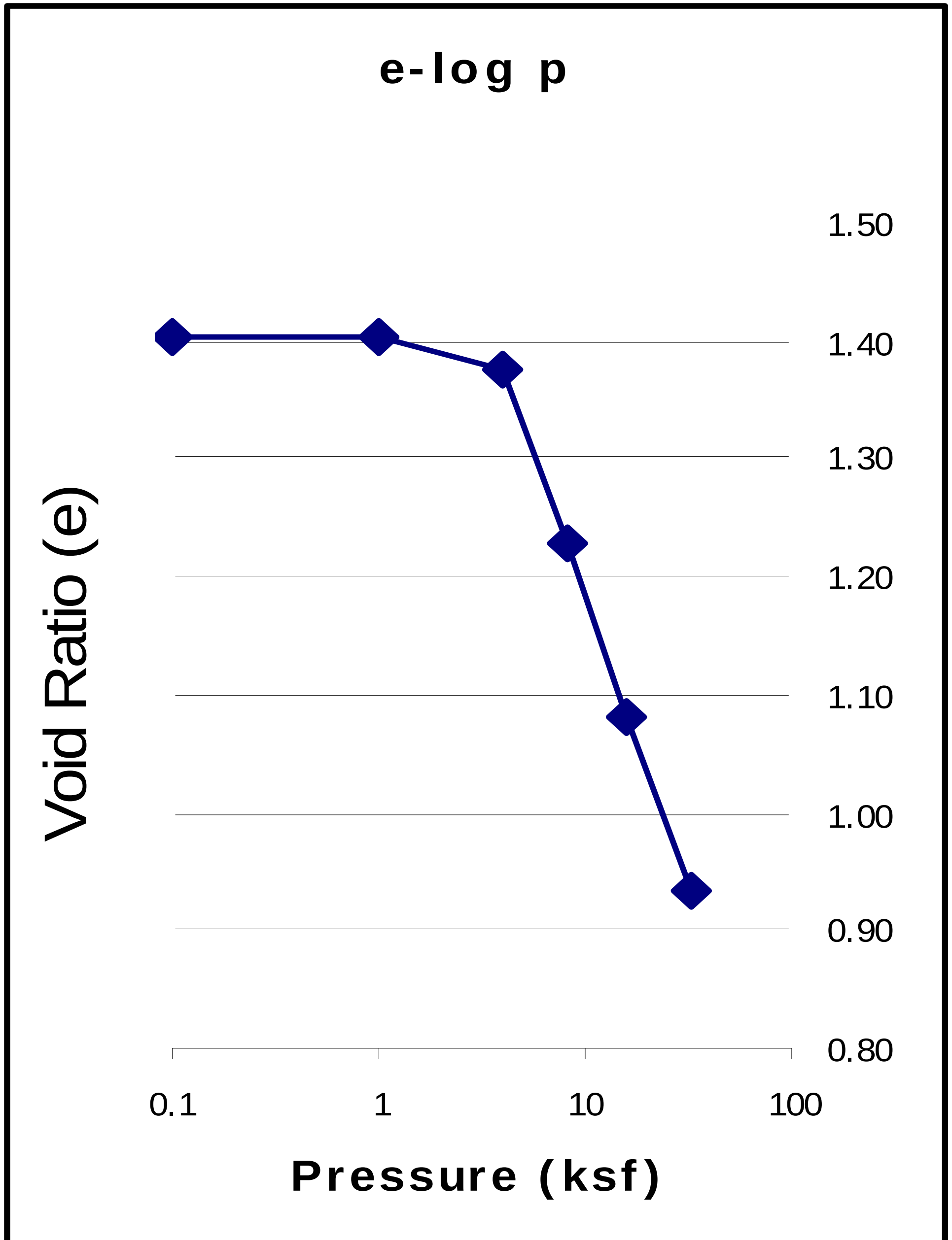


Pre-consolidation Pressure

C_c = slope of e log p virgin curve

est. $C_c = 0.009(LL-10\%)$ Skempton

Rebound or recompression curves



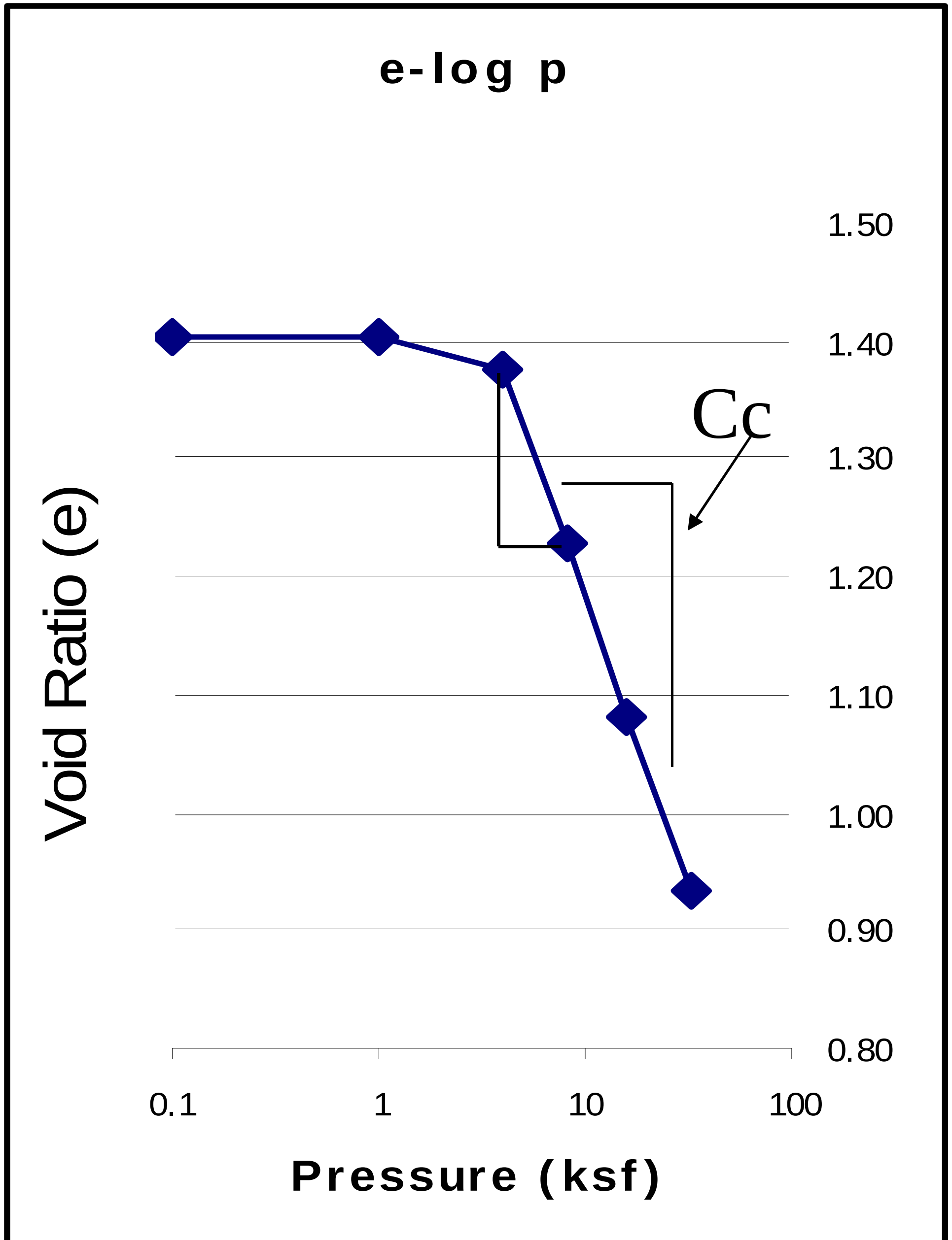
Calculate Compression Index; C_c

ksf	(e)
0.1	1.404
1	1.404
4	1.375
8	1.227
16	1.08
32	0.932

A) 0.21

B) 0.49

C_c is the slope of the virgin e-log p



$$Cc = -(e_1 - e_2)/\log(p_1/p_2)$$

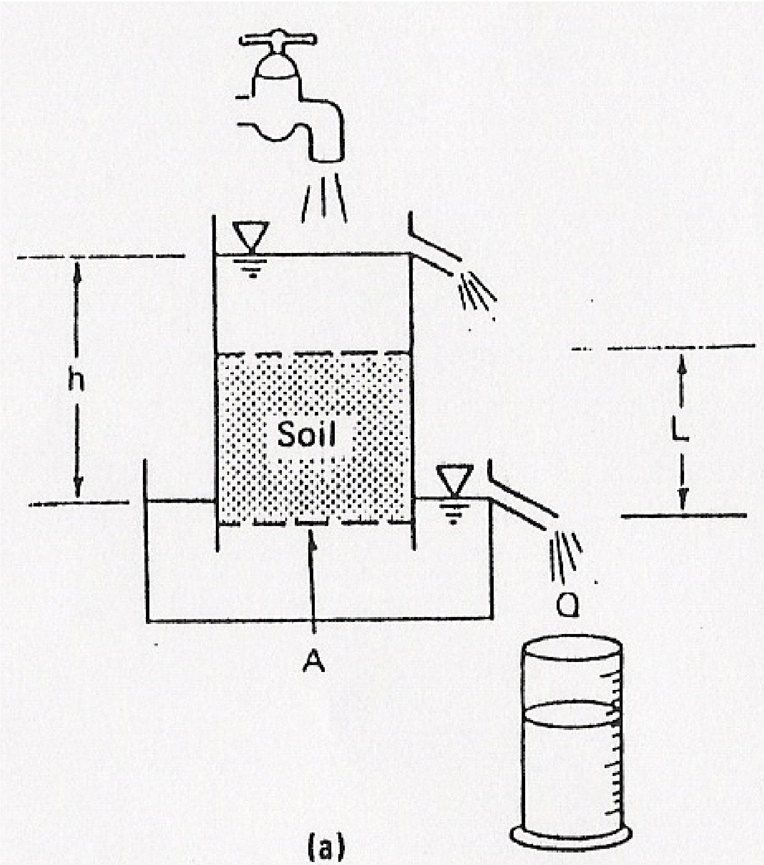
$$Cc = -(1.375 - 1.227)/\log(4/8)$$

$$Cc = 0.49$$

Answer is "B"

ksf	(e)
0.1	1.404
1	1.404
4	1.375
8	1.227
16	1.08
32	0.932

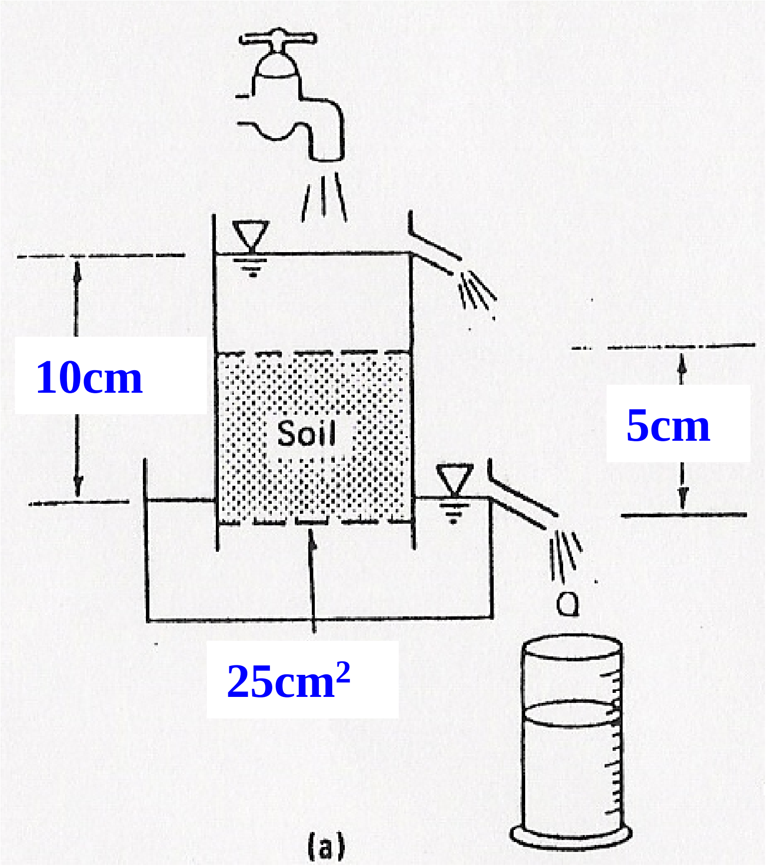
Permeability



Constant Head Conditions

- Q=kiAt
- Q= k (h/L)At
- k=QL/(Ath)
- Q= flow Volume
- k = permeability
- i = hydraulic gradient h/L
- A = x-sectional area
- t = time
- q = flow rate Q/t

If Q =15cc & t = 30 sec what is the permeability



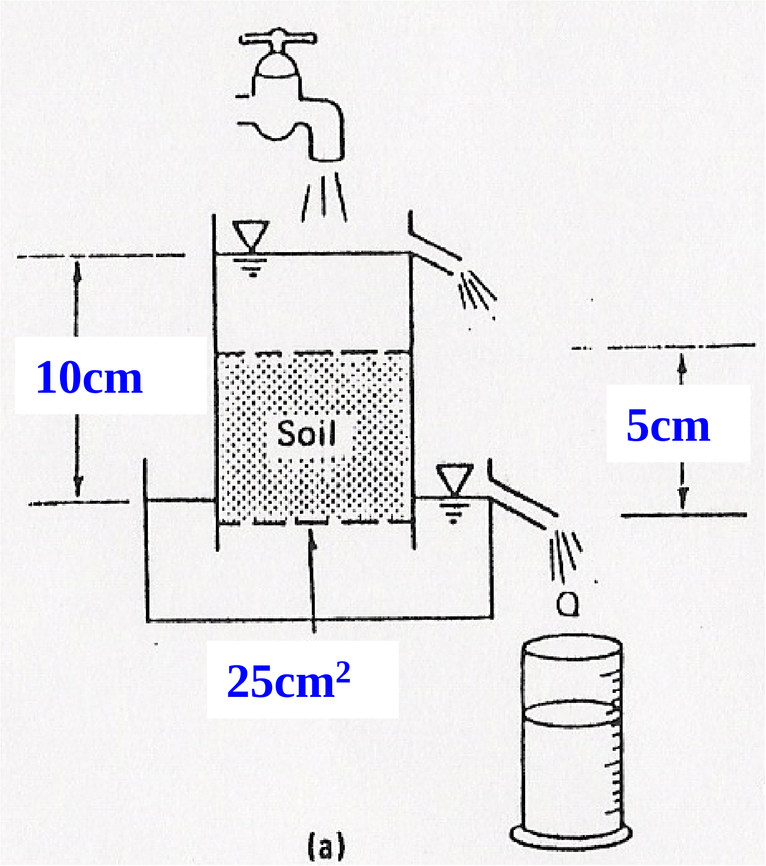
$k=QL/(Ath)$

A) 0.01 cm/sec

B) $0.01x10^{-2}$ cm/sec

C) 0.1 cm/sec

Constant Head Permeability



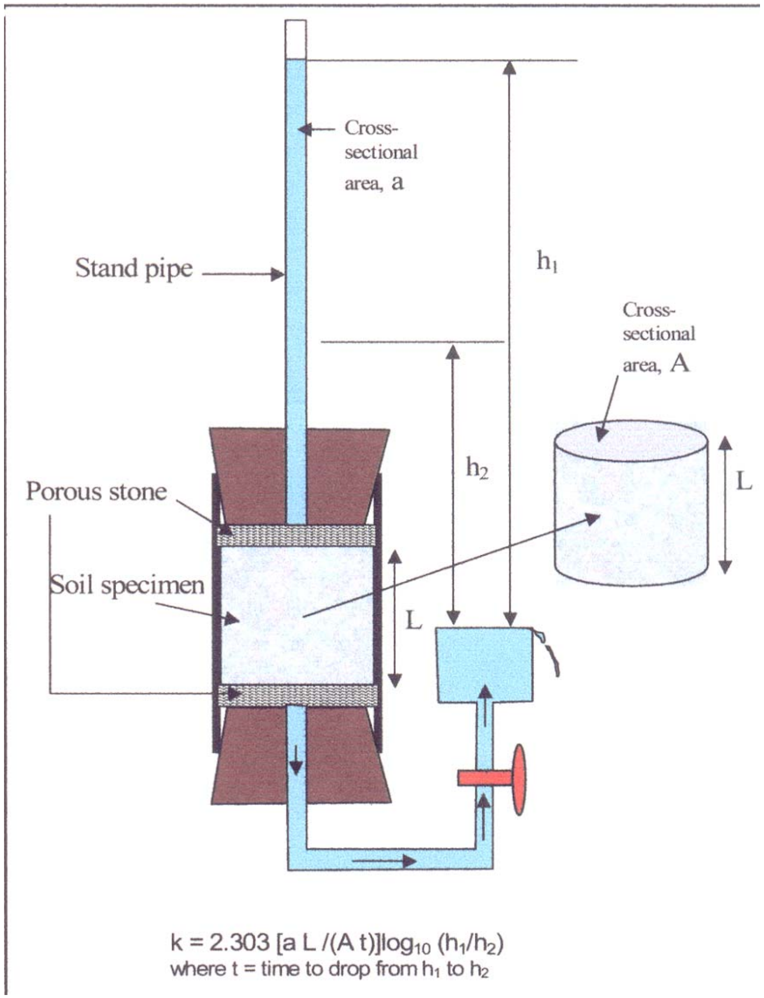
Calculate k

Q =15cc & t = 30 sec

- k=QL/(Ath)
- k= (15x5)/(25x30x10)
- k= 0.01 cm/sec

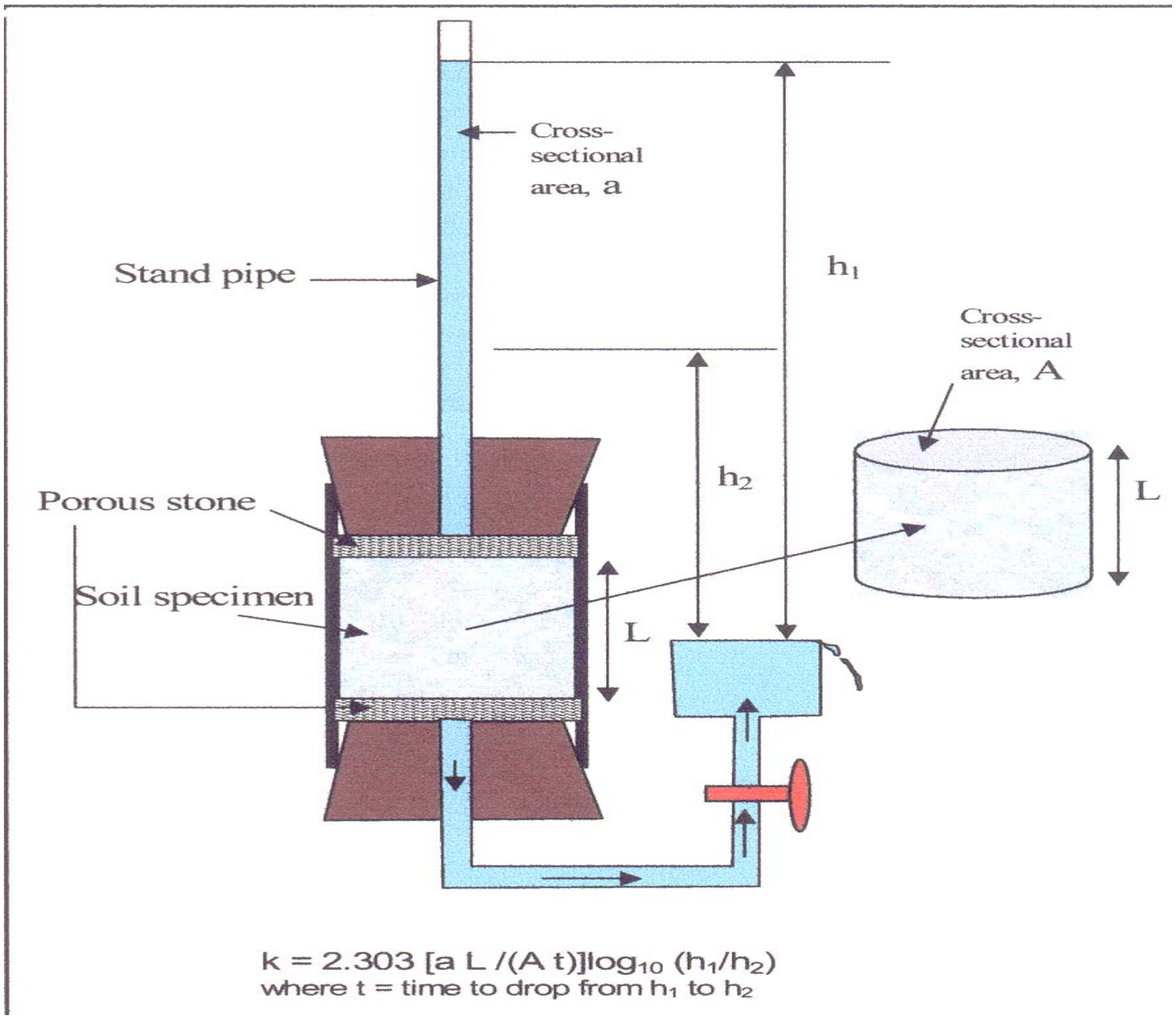
Answer is “A”

Falling Head Permeability



- k=QL/(Ath)
  (but h varies)
- k=(2.3aL/(At)) log (h1/h2)
- where a = pipette area
- h1 = initial head
- h2 = final head

If t = 30 sec; h1= 30 cm; h2 = 15 cm
L= 5 cm; a= 0.2 cm^2; A= 30 cm^2; calculate k

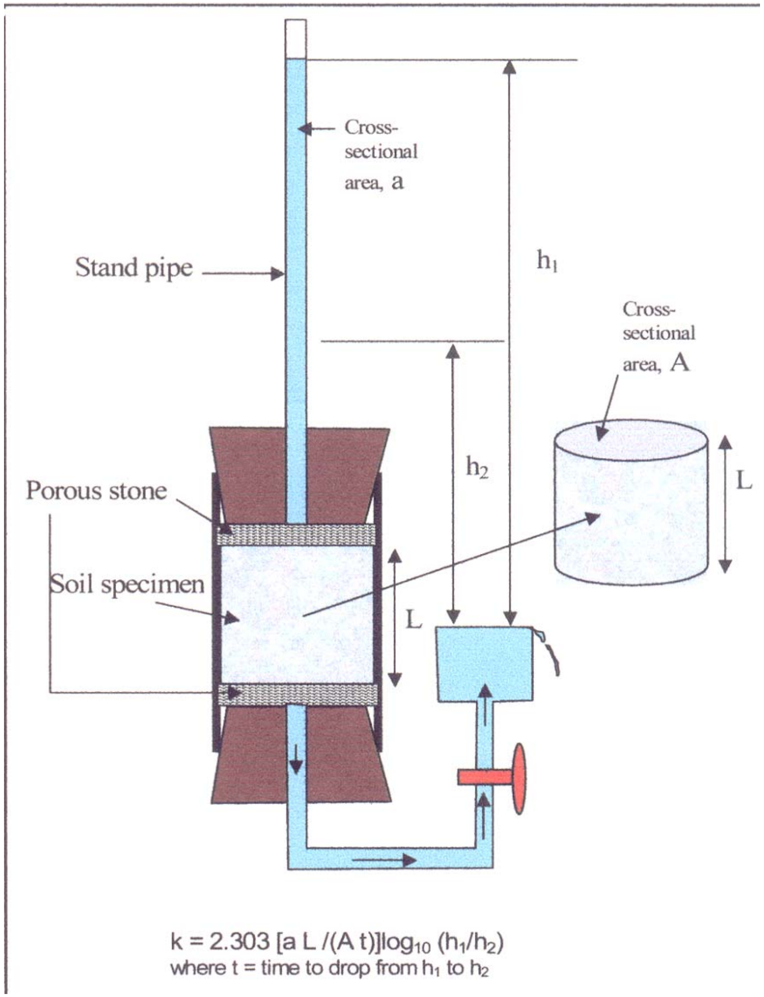


A) 2.3**x10^{-3} cm/sec**

B) 8.1**x10^{-6} cm/sec**

C) **7.7x10^{-4} cm/sec**

Falling Head Permeability



k=(2.3aL/(At)) log (h1/h2)

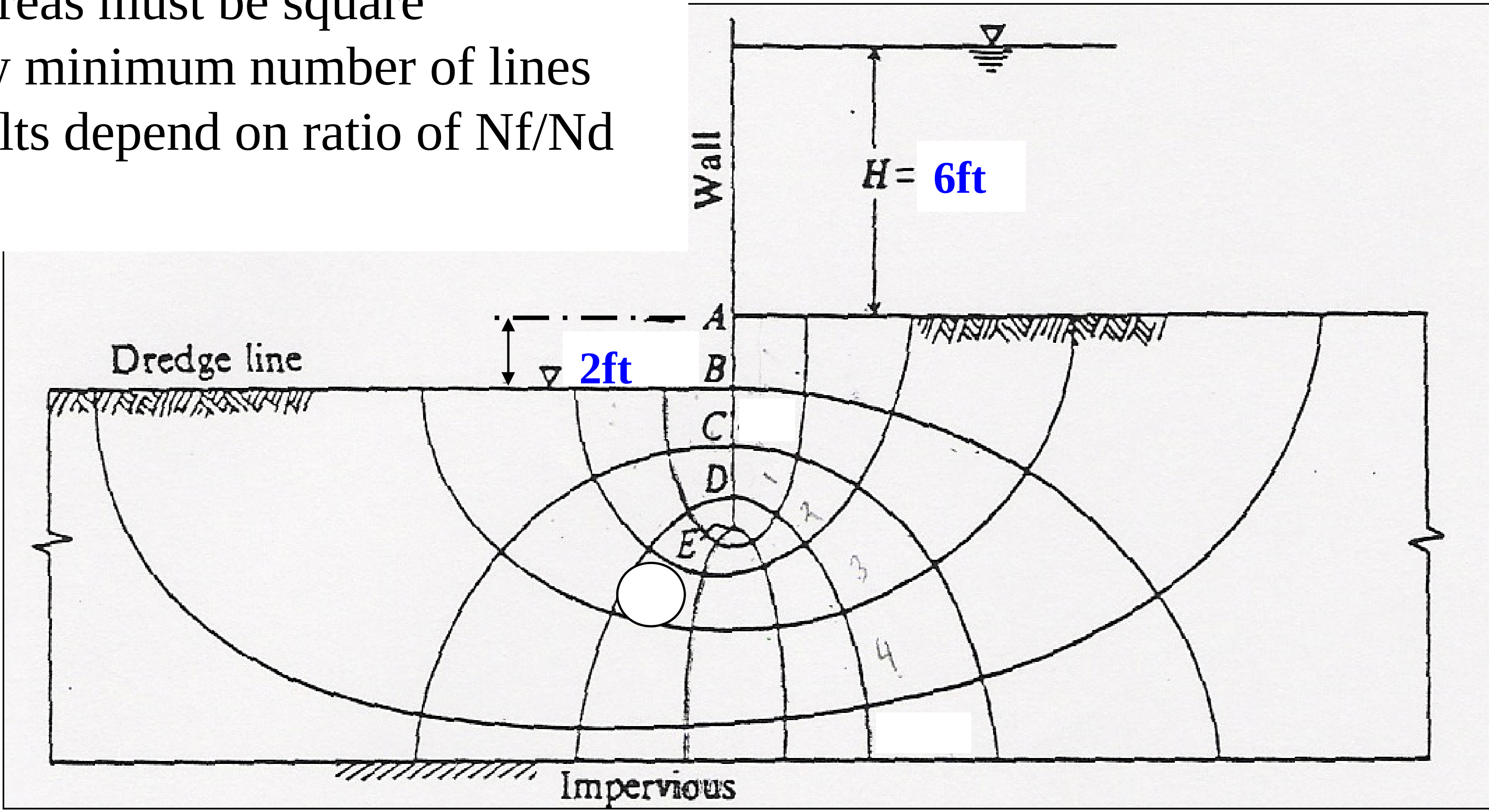
k= (2.3 (0.2) 5 /(30x30)) log (30/15)

$k = 7.7 \times 10^{-4}$ cm/sec

Answer is "C"

Flow Nets

- Flow lines & head drop lines must intersect at right angles
- All areas must be square
- Draw minimum number of lines
- Results depend on ratio of Nf/Nd

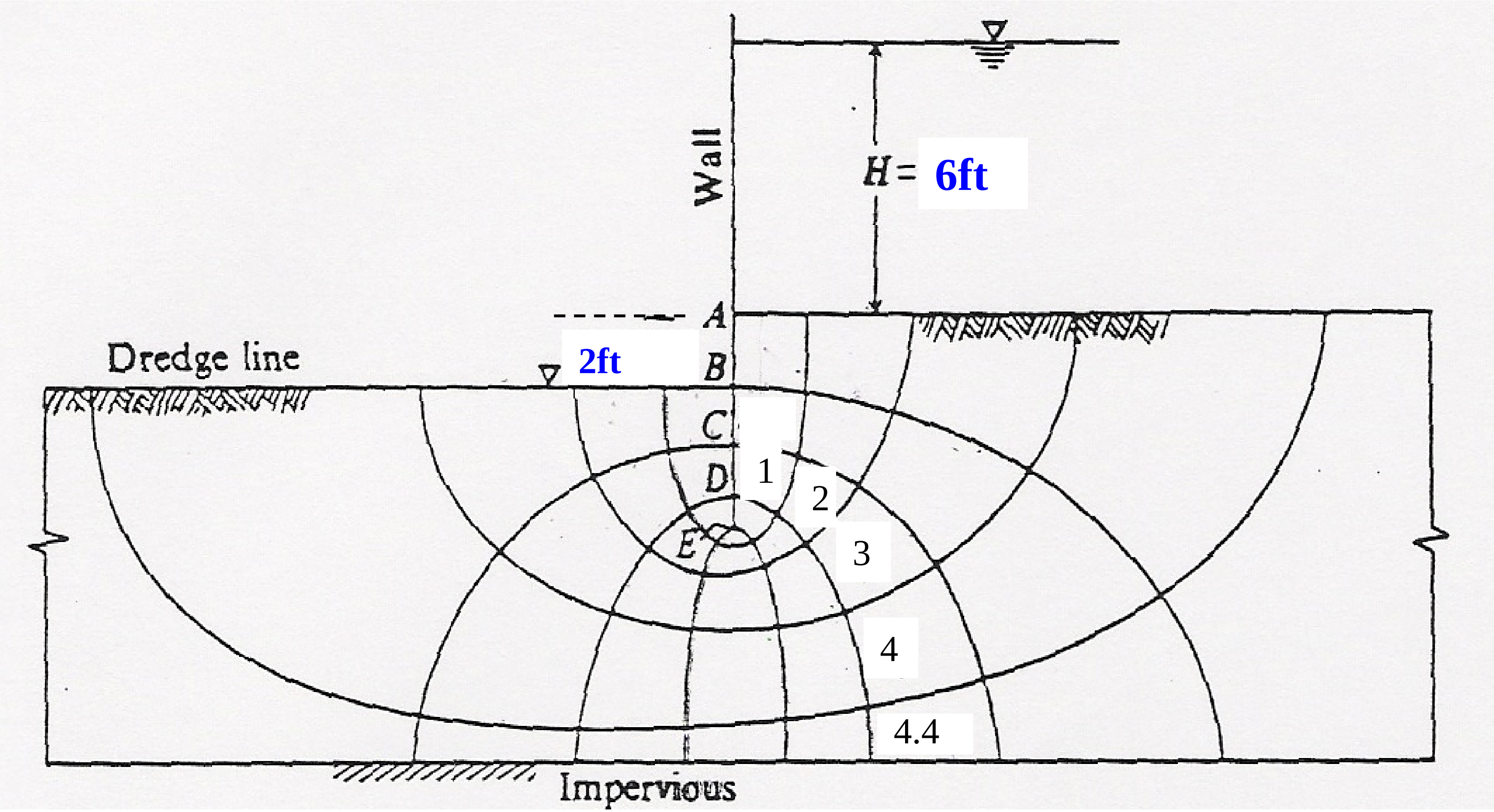


Flow Nets

$Q = kia = kHN_f/N_d\,wt$ (units = volume/time)

w= unit width of section

t=time



Flow Nets

What flow/day?

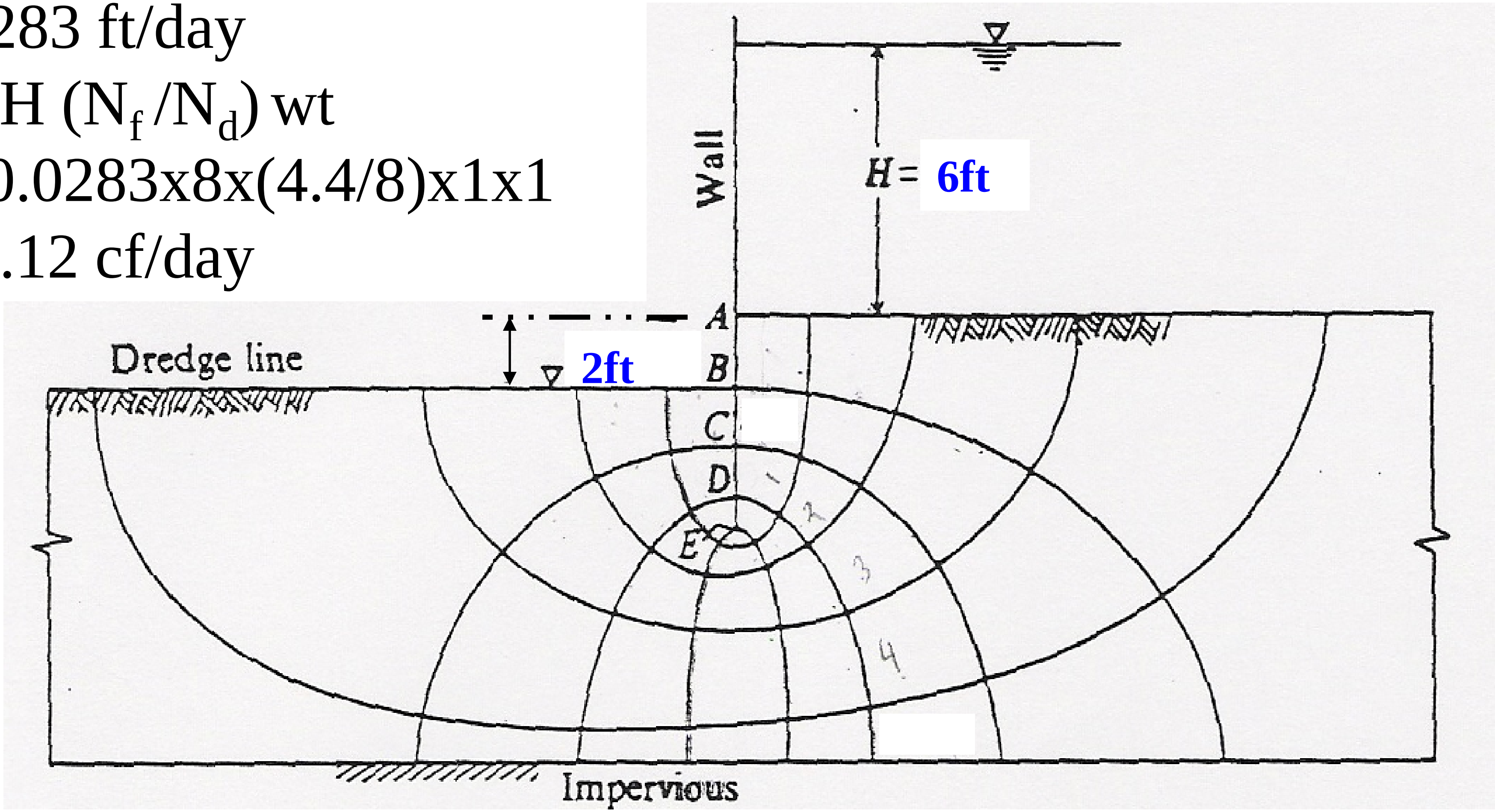
assume k= $1x10^{-5}$ cm/sec

=0.0283 ft/day

Q= kH (N_f/N_d) wt

Q= 0.0283x8x(4.4/8)x1x1

Q= 0.12 cf/day



Flow Nets

Check for “quick conditions”

p_c =2(120)= 240 psf (total stress)

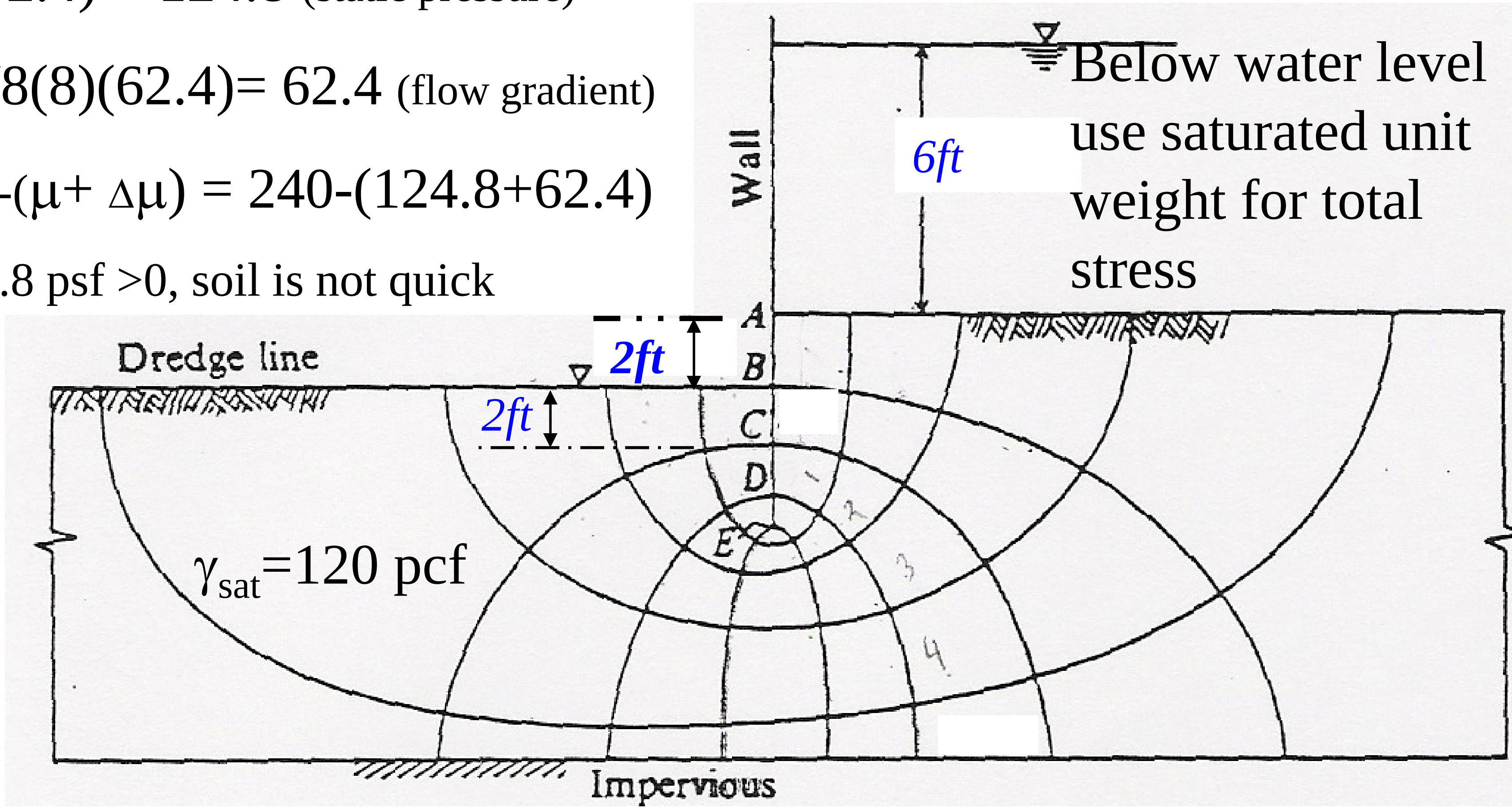
μ= 2(62.4) = 124.8 (static pressure)

$\Delta\mu$= 1/8(8)(62.4)= 62.4 (flow gradient)

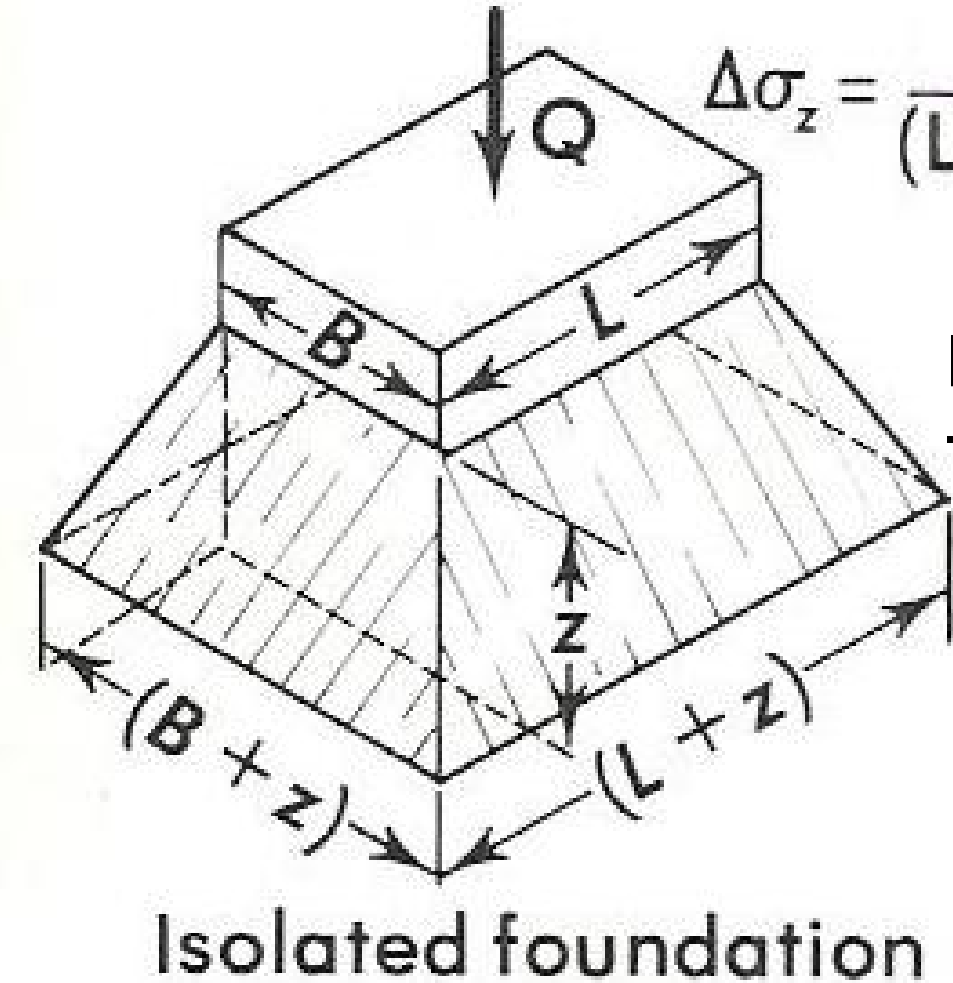
$p'_c = p_c - (\mu + \Delta\mu)$ = 240-(124.8+62.4)

p'_c = 52.8 psf >0, soil is not quick

Below water level use saturated unit weight for total stress



Stress Change Influence (1H:2V)

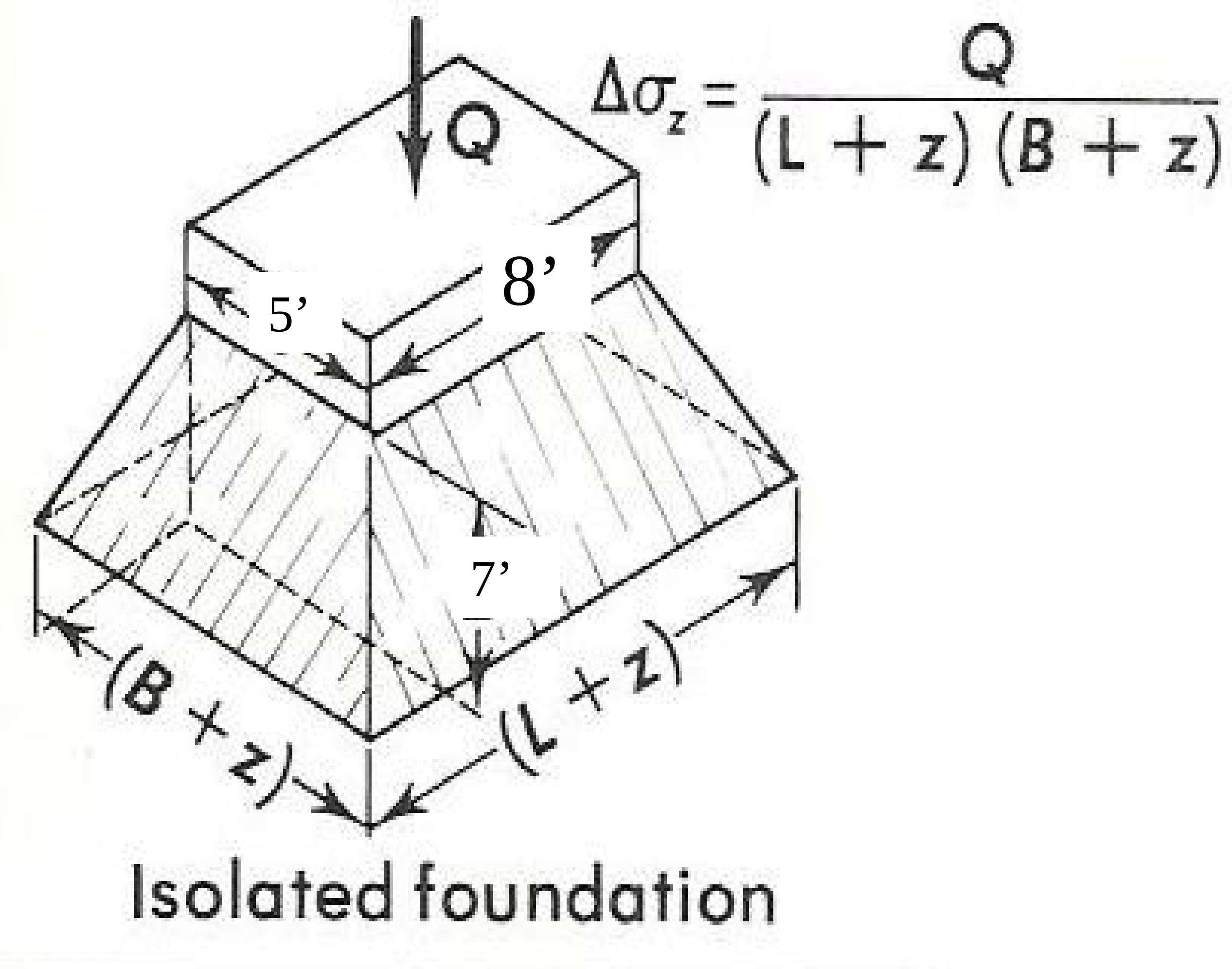


$$\Delta\sigma_z = \frac{Q}{(L+z)(B+z)}$$

For square footing

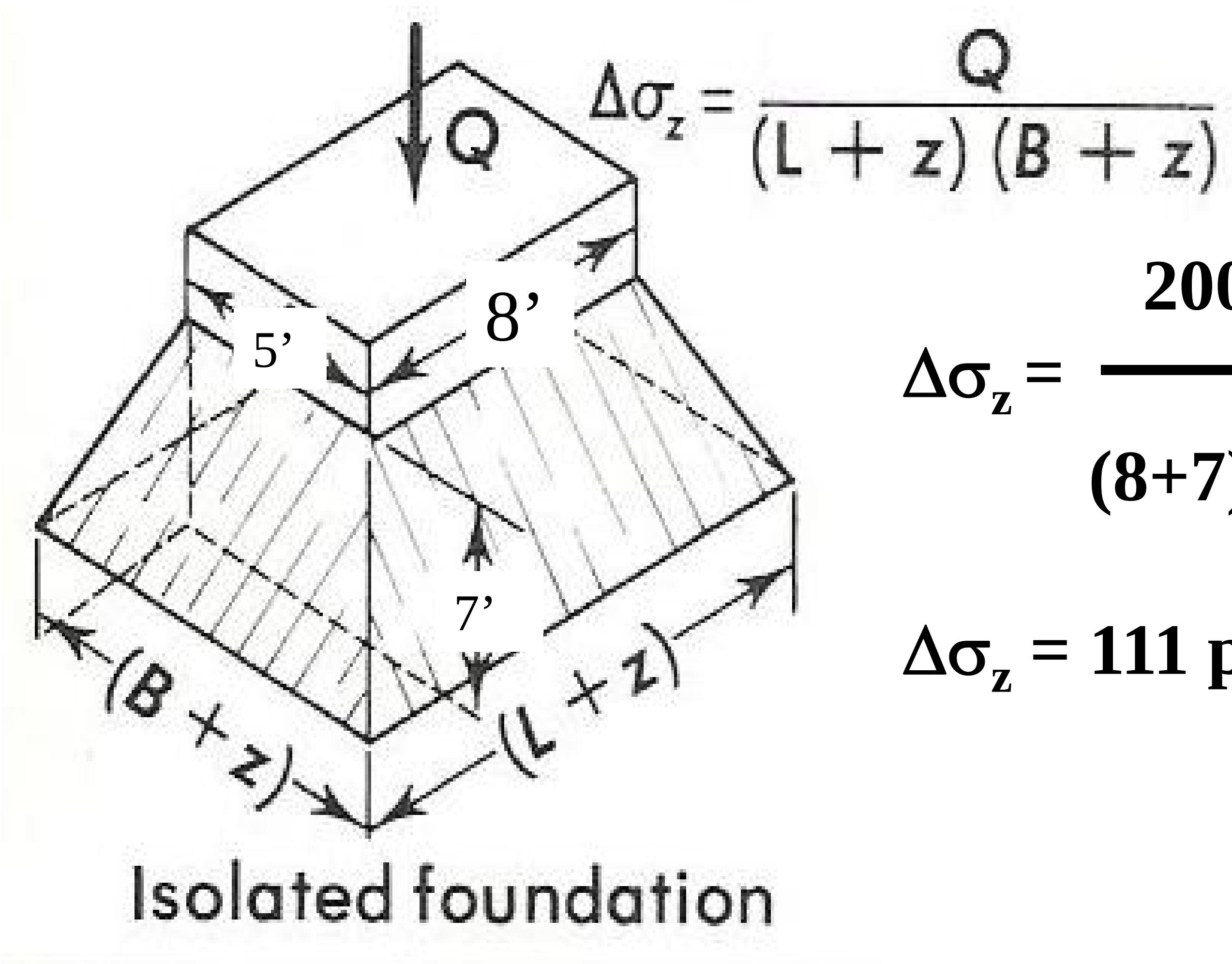
$$\Delta\sigma_z = Q/(B+z)^2$$

If Q= 20 kips, Calculate the vertical stress increase at 7 feet below the footing bottom



Isolated foundation

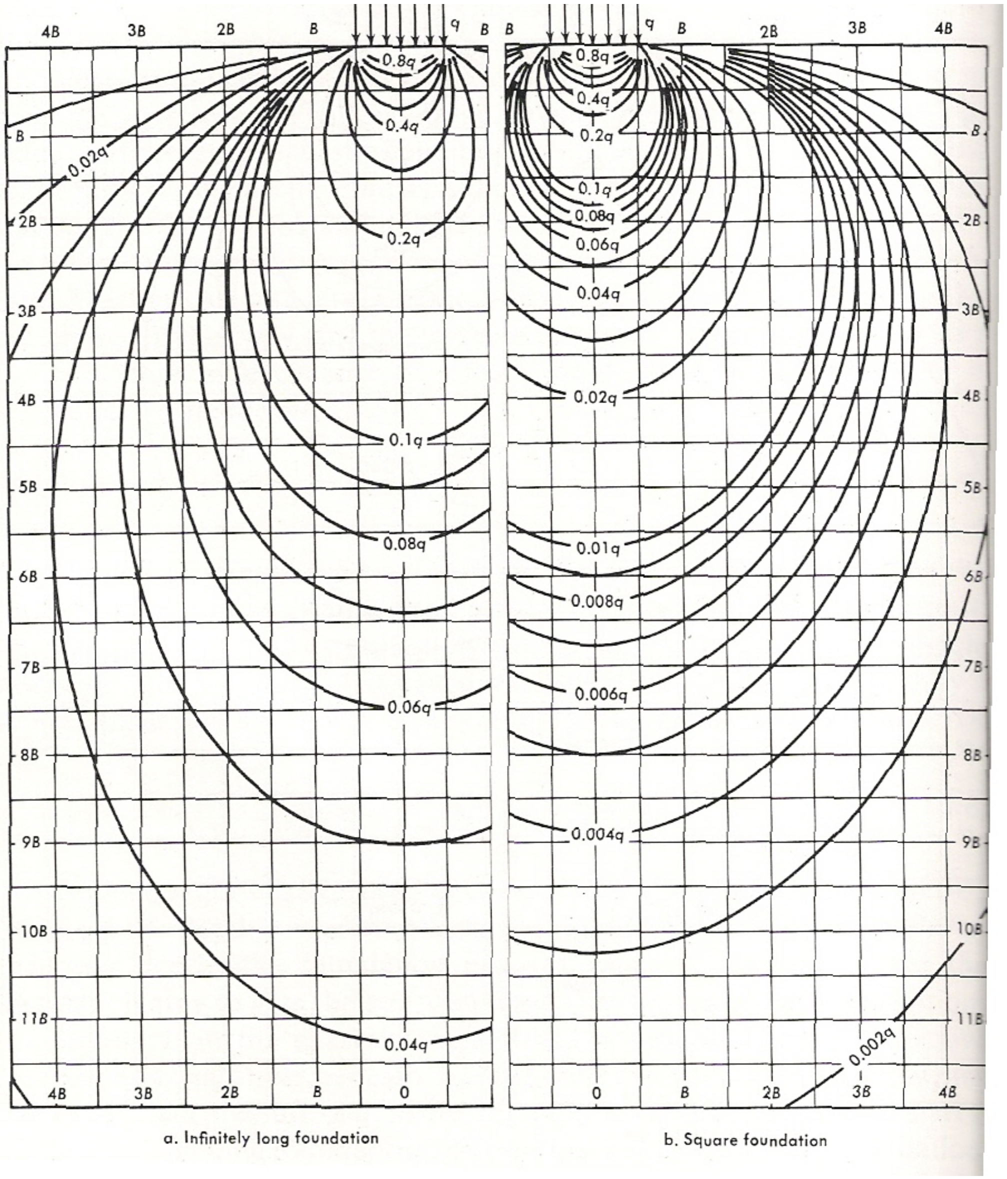
If Q= 20 kips, Calculate the vertical stress increase at 7 feet below the footing bottom



$$\Delta\sigma_z = \frac{20000}{(8+7)(5+7)}$$

$$\Delta\sigma_z = 111 \text{ psf}$$

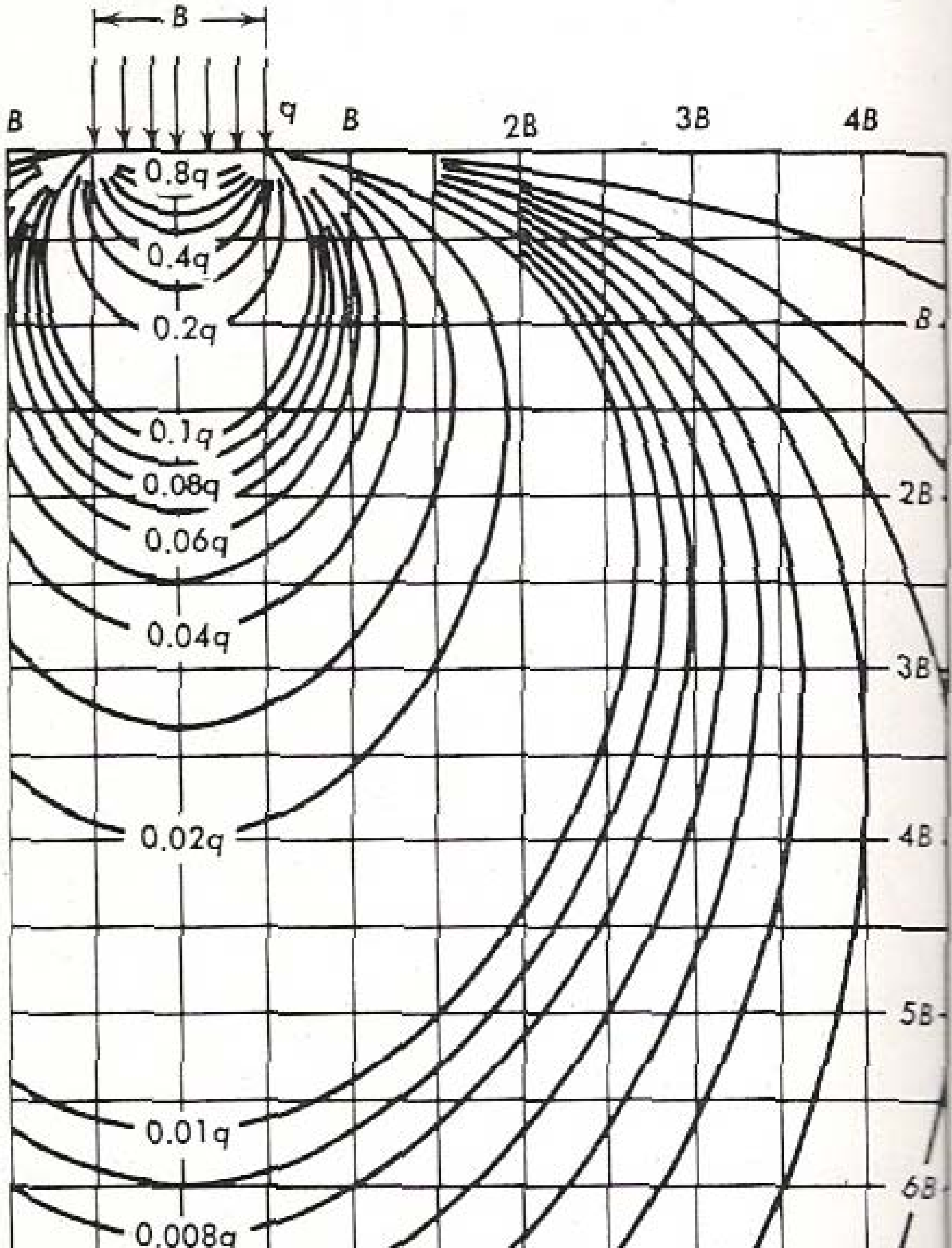
Westergaard (layered elastic & inelastic material)



If B= 6.3' in a square footing with 20 kips load, what is the vertical stress increase at 7' below the footing bottom?

Westergaard

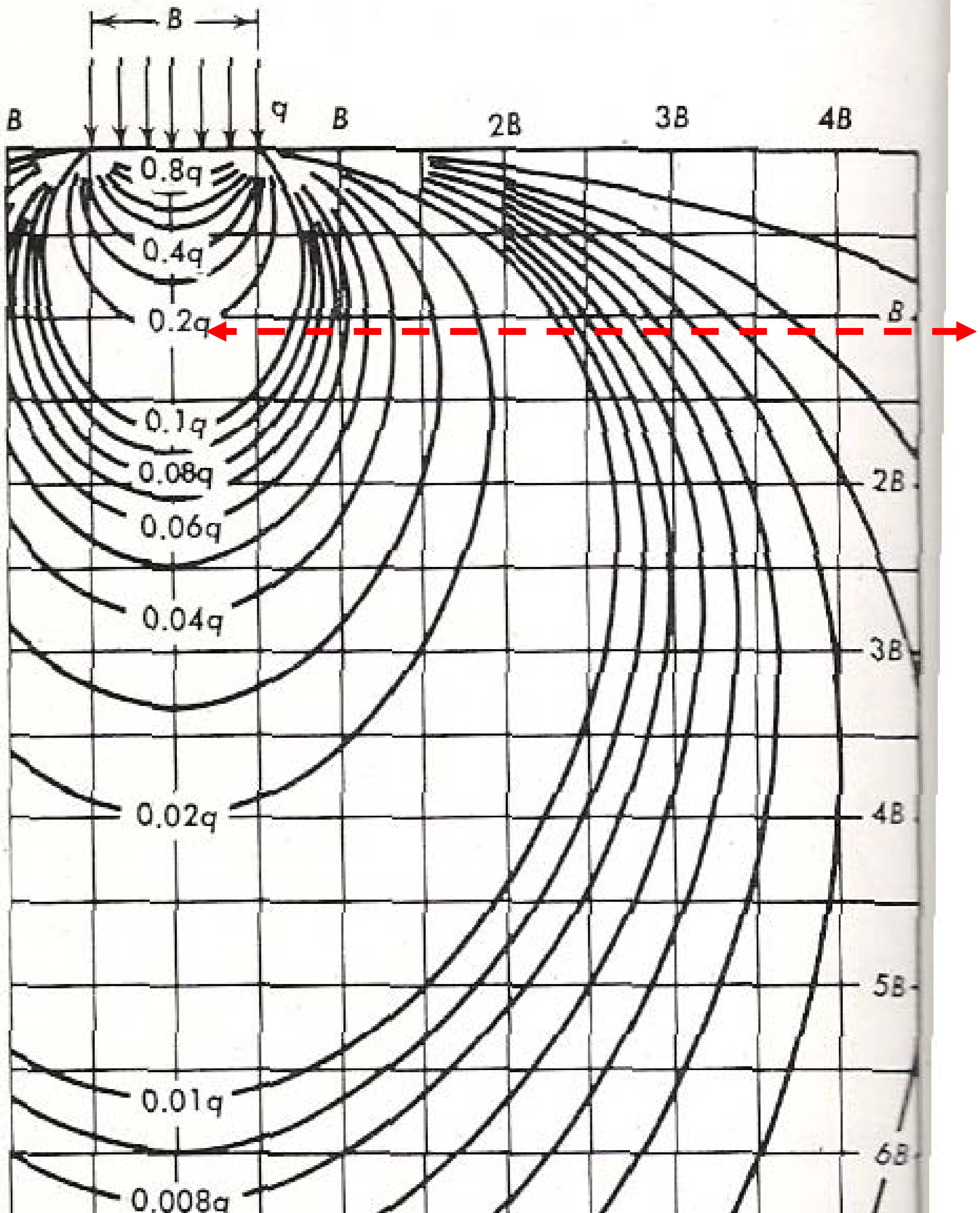
Square Footings



Q = 20 kips
B = 6.3’
Z = 7’

$\Delta\sigma_z = ?$

Westergaard



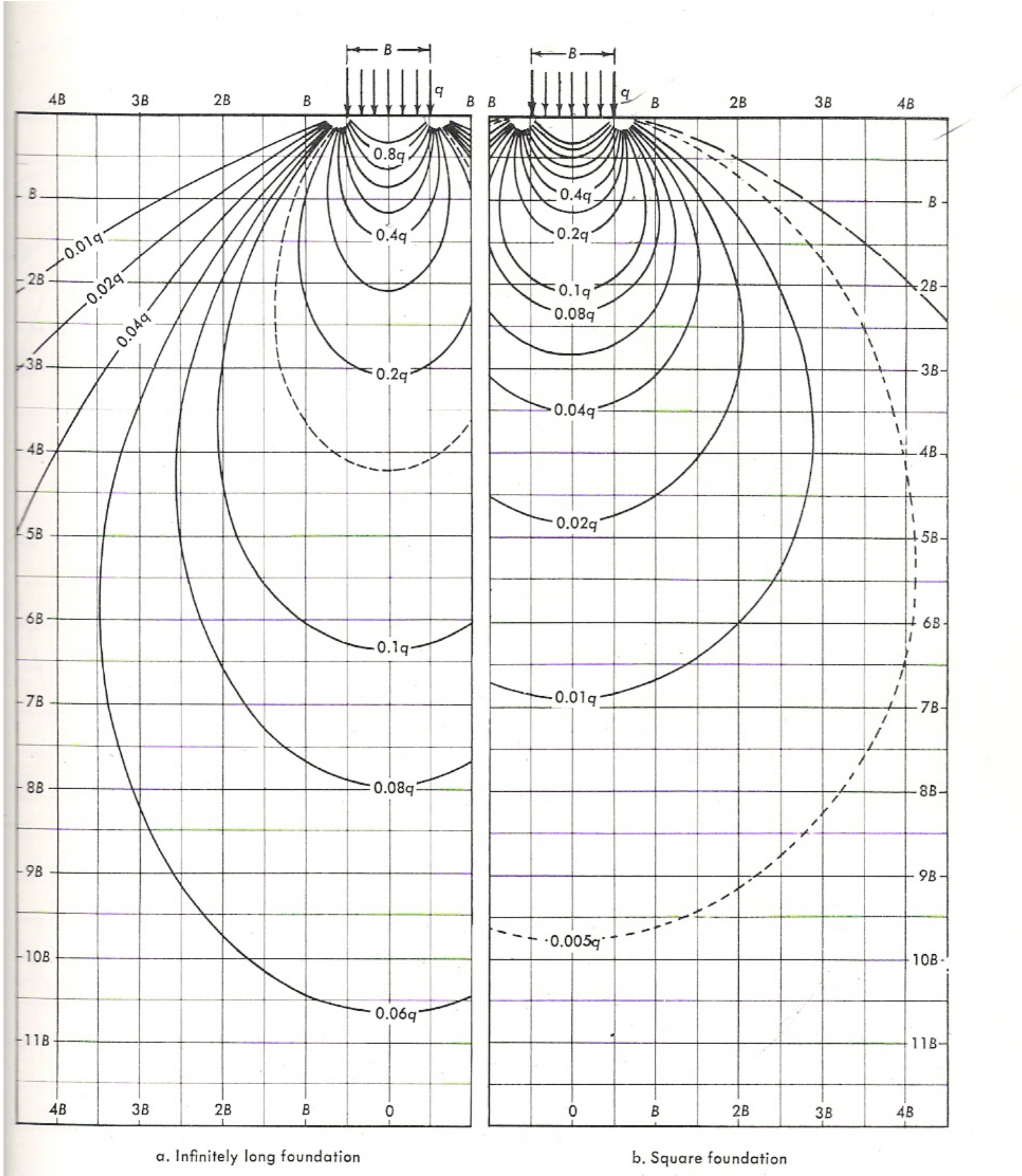
7'/6.3' = 1.1B

$\Delta\sigma_z = 0.18 \times 20000/6.3^2$

$= 90.7$ psf

Boussinesq

(homogeneous elastic)



Q = 20 kips

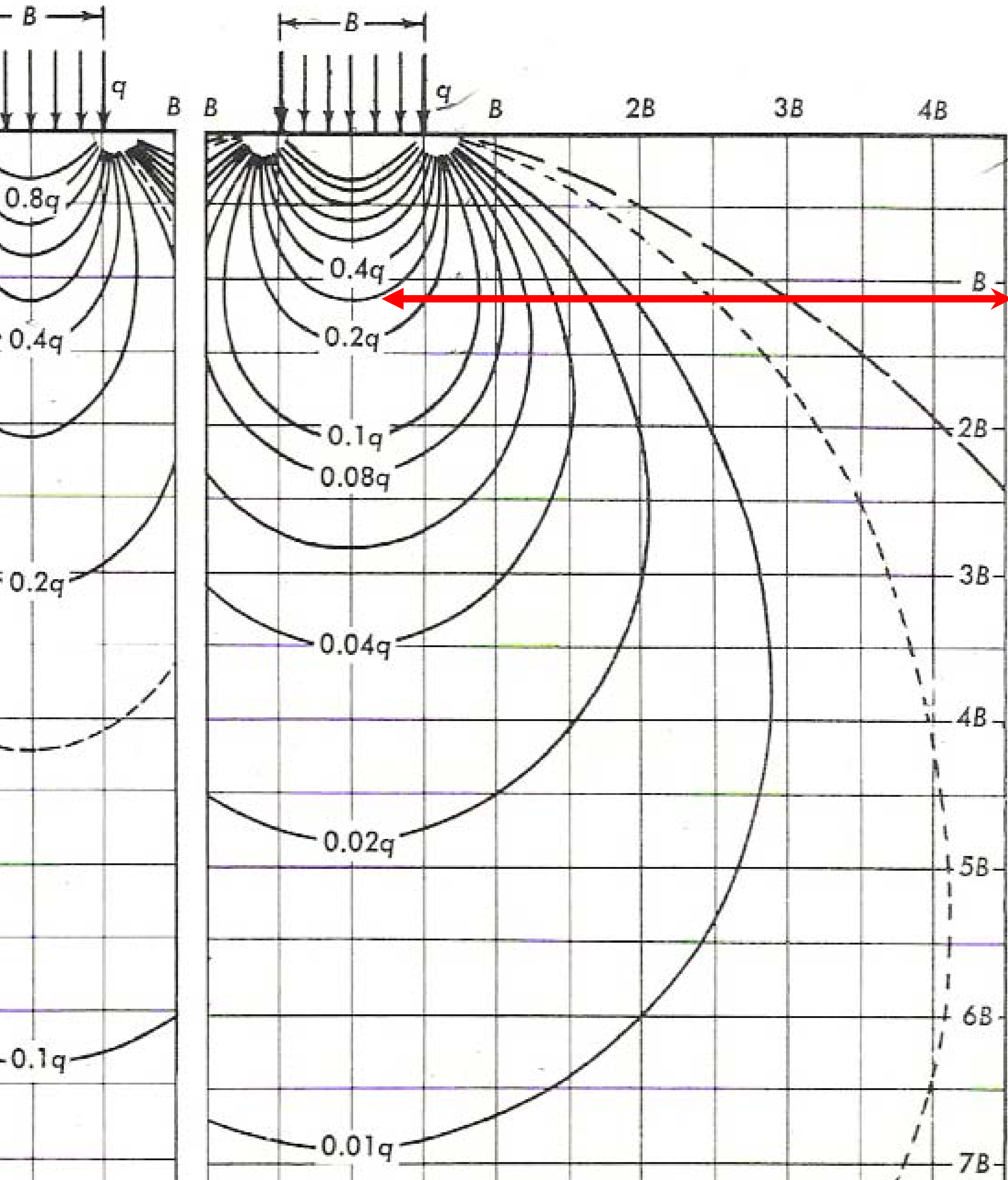
B = 6.3’

Z = 7’

$\Delta\sigma_z = ?$

Boussinesq

Square Footing



Z/B = 1.1

$\mathbf{\Delta\sigma_z = 0.3 \times 20000/6.3^2}$

= 151 psf

Thanks for participating in the PE review course on Soil Mechanics!

More questions or comments?

You can email me at:
gtv@gemeng.com