ARE Structural Presentation Part 2

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DCI ENGINEERS

Structural Systems

Concrete Systems

One-Way vs Two-Way systems

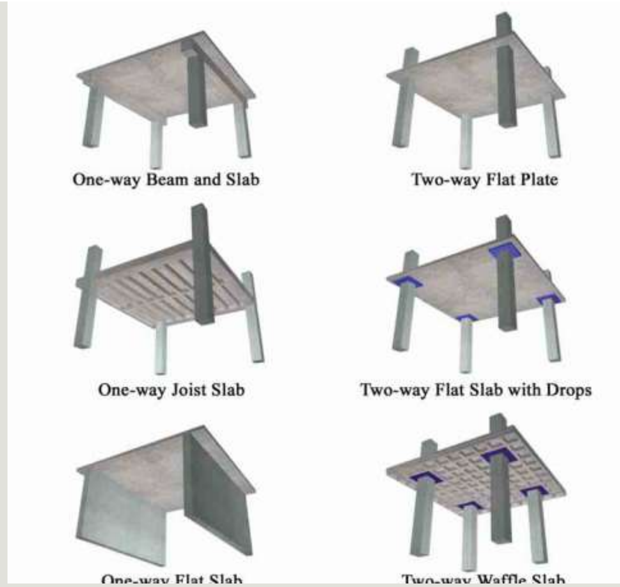
Flat plate systems

Beam and joist systems

PT vs Mild Reinforcing

Tilt Panels

Precast



Steel Systems

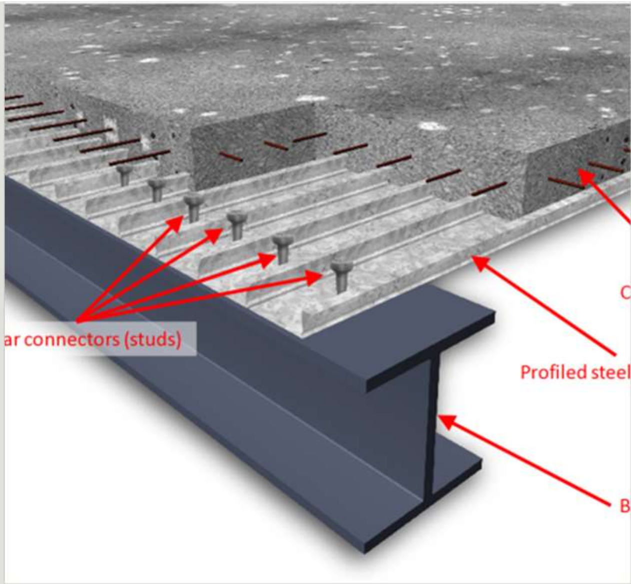
Composite Framing

Steel Joists

Steel deck

Metal Buildings

Bolts vs Welds



Wood Systems

Post and Beam vs Bearing Wall

Solid Sawn Lumber

Composite/Manufactured Lumber

Glulam Beams & Columns

Open web trusses (Floor and Roof)

Heavy Timber

Mass timber

CFS Systems

Stud & Joist sizes

Trusses

Deck & Plank

Load bearing vs non-load bearing

Proprietary Systems

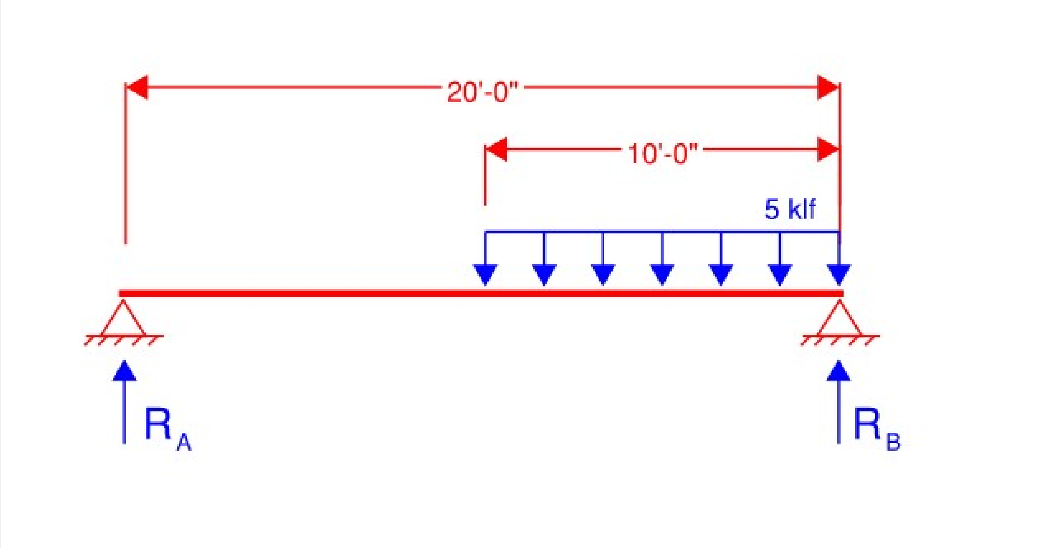
Questions?

Gravity Practice Problems

MELISSA SIBLEY, PE

BEAM ANALYSIS

1. R_A = ?
2. R_B = ?

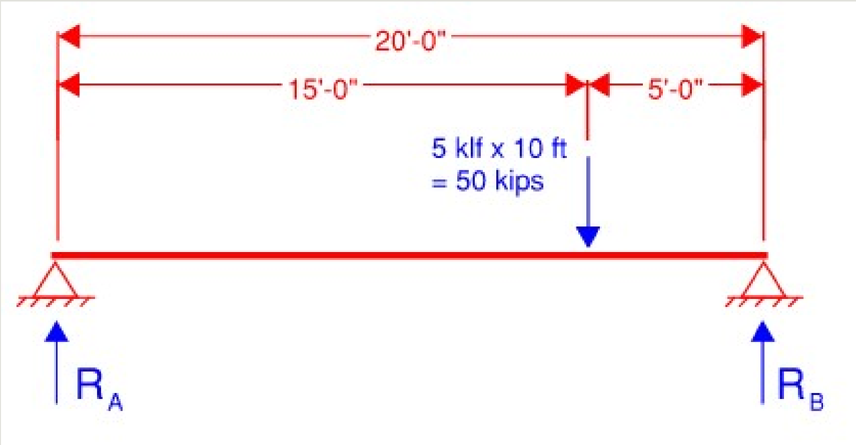


BEAM ANALYSIS

Simplify Loads.

Rules to Remember:

- $\Sigma F = 0$
- ΣM about one point = 0



BEAM ANALYSIS

ΣM about one point = 0

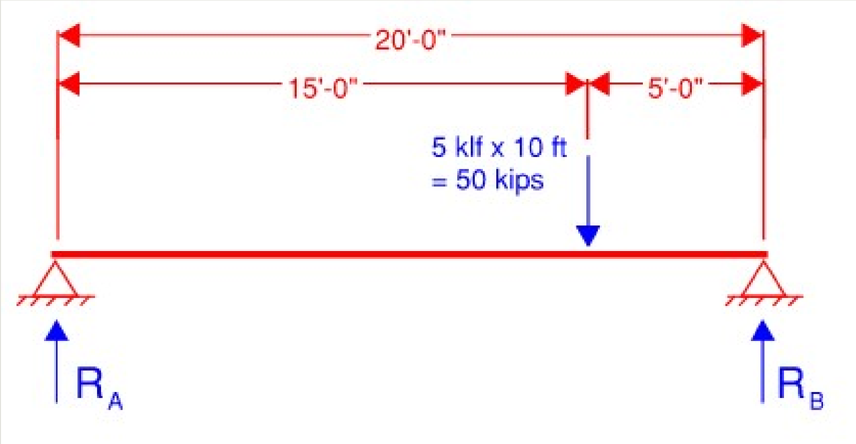
$\Sigma M_A = 0$

$\Sigma M_A = (50 \text{ kips} \times 15 \text{ ft}) + (R_B \times 20 \text{ ft}) = 0$

$\Sigma M_A = 750 \text{ kips} + 20R_B = 0$

$R_B = -750 \text{ kips} / 20$

$R_B =$ **37.5 kips**

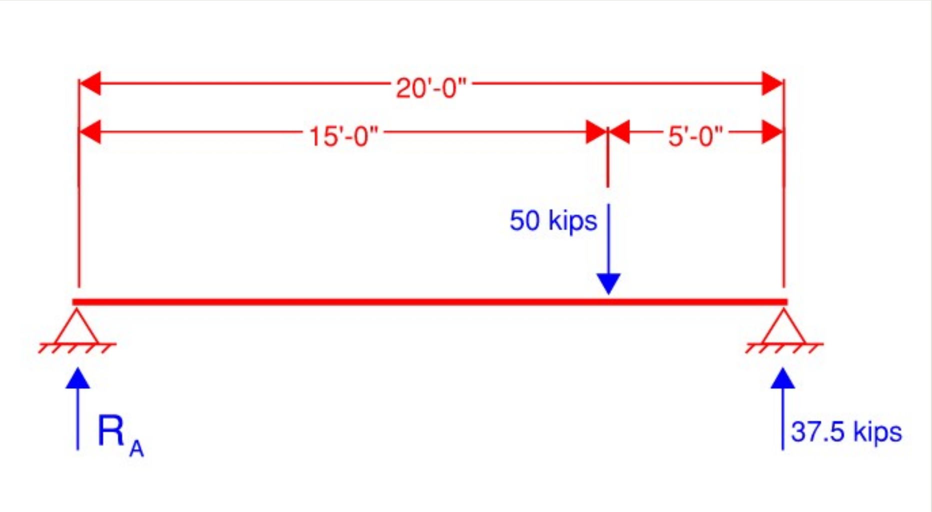


BEAM ANALYSIS

$\Sigma F = 0$

R_A – 50 Kips + 37.5 kips = 0

R_A = **12.5 kips**



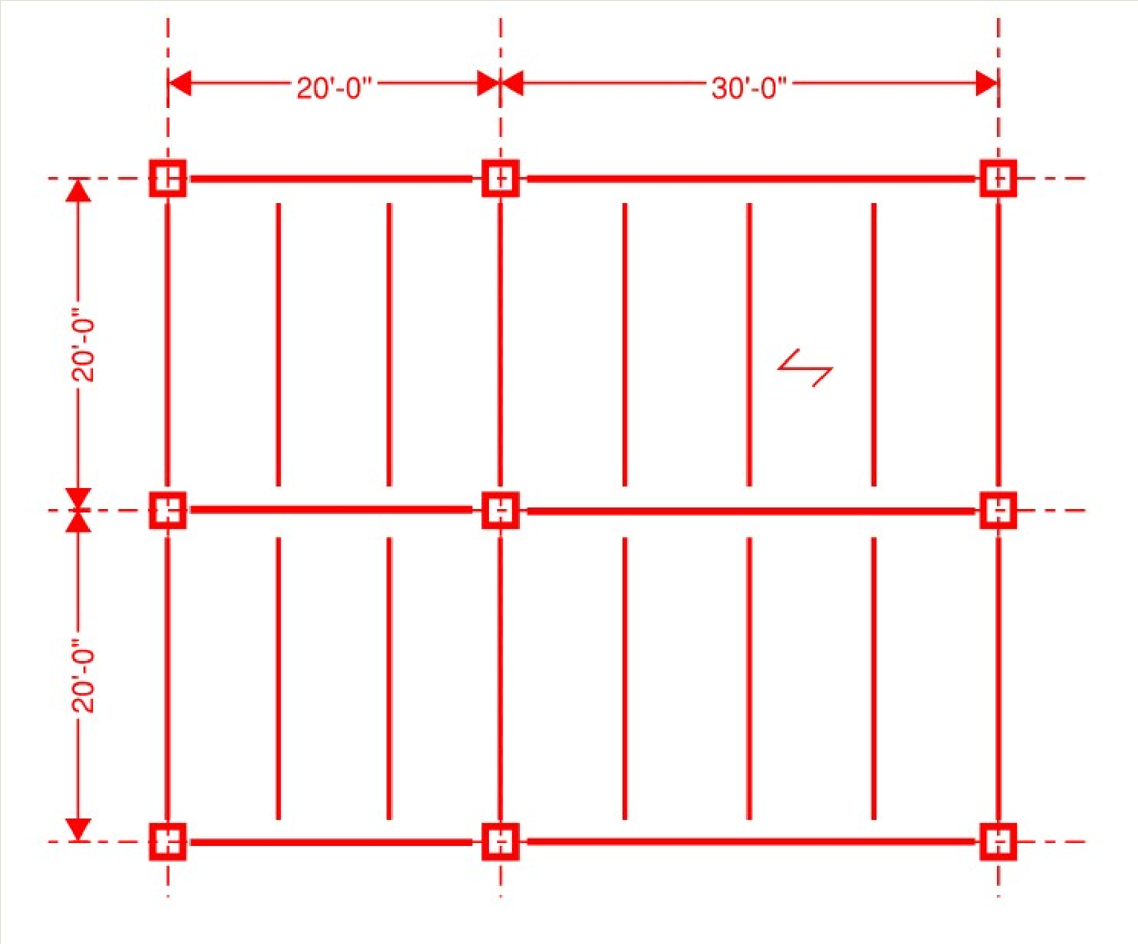
COLUMN ANALYSIS

Floor Dead Load = 35 psf

Floor Live Load = 40 psf

HSS6x6x1/4 columns; r = 2.34 in

1. What is the center column load?
2. What is the maximum allowable height of the column, considering stability?



COLUMN ANALYSIS

Determine Loads.

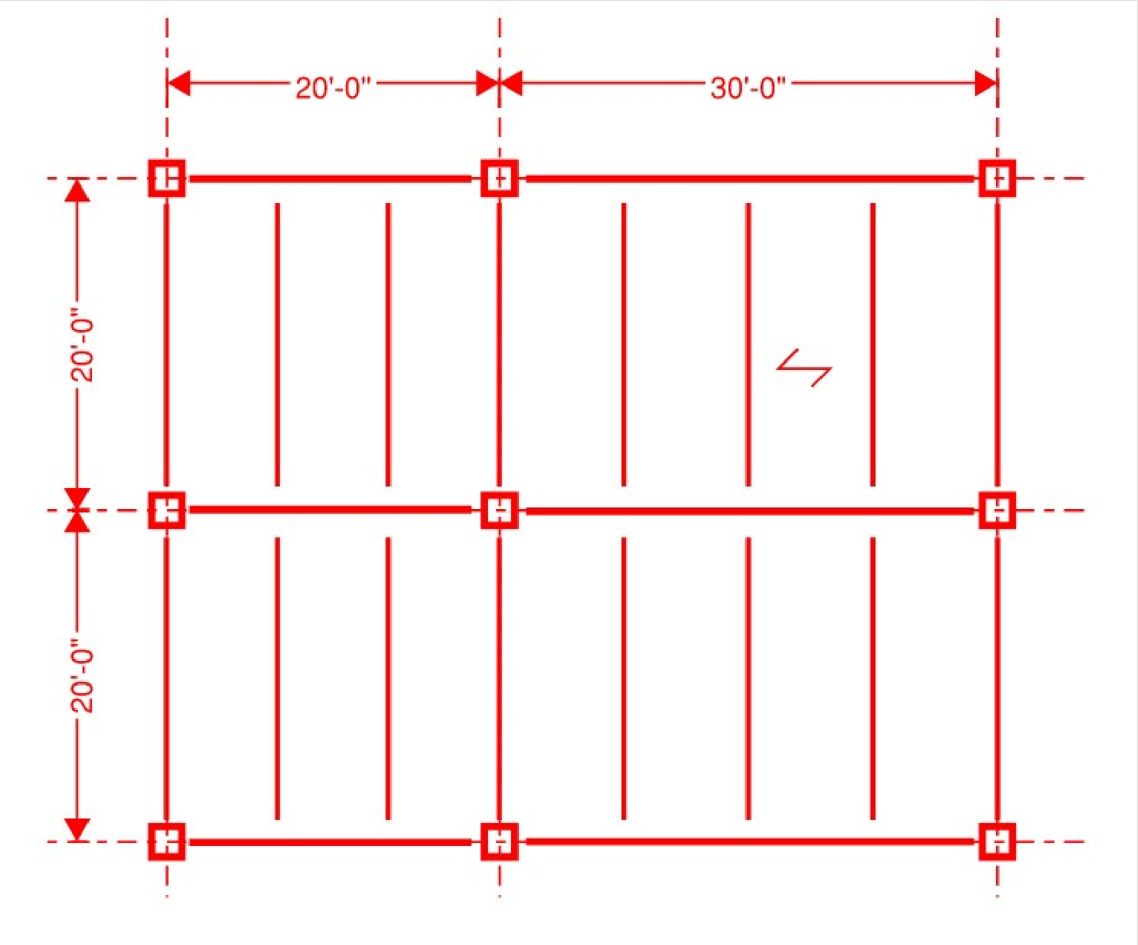
Floor Dead Load = 35 psf

Floor Live Load = 40 psf

Total Factored Area Load =

(1.2 x 35 psf) + (1.6 x 40 psf) =

106 psf

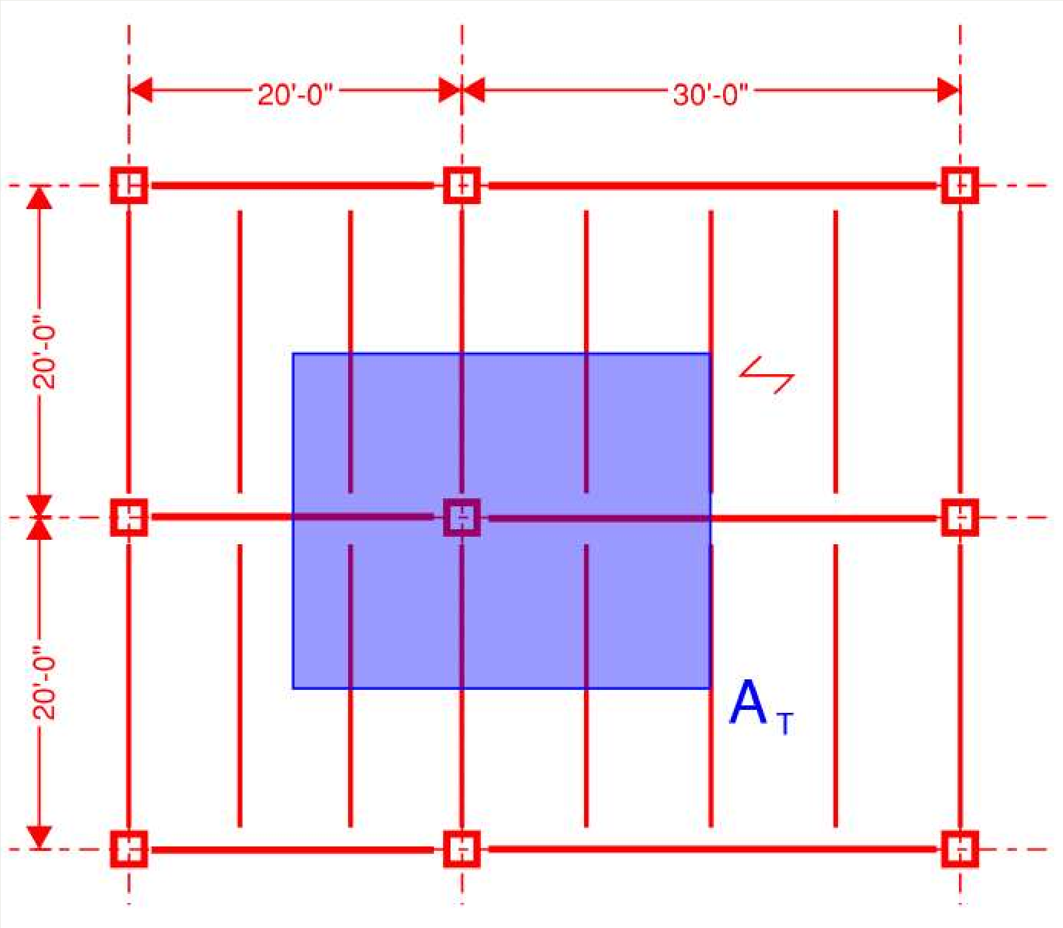


COLUMN ANALYSIS

Determine tributary area

A_T = [(20 ft+30 ft) / 2] x [(20 ft + 20 ft) / 2]

A_T = 500 sqft

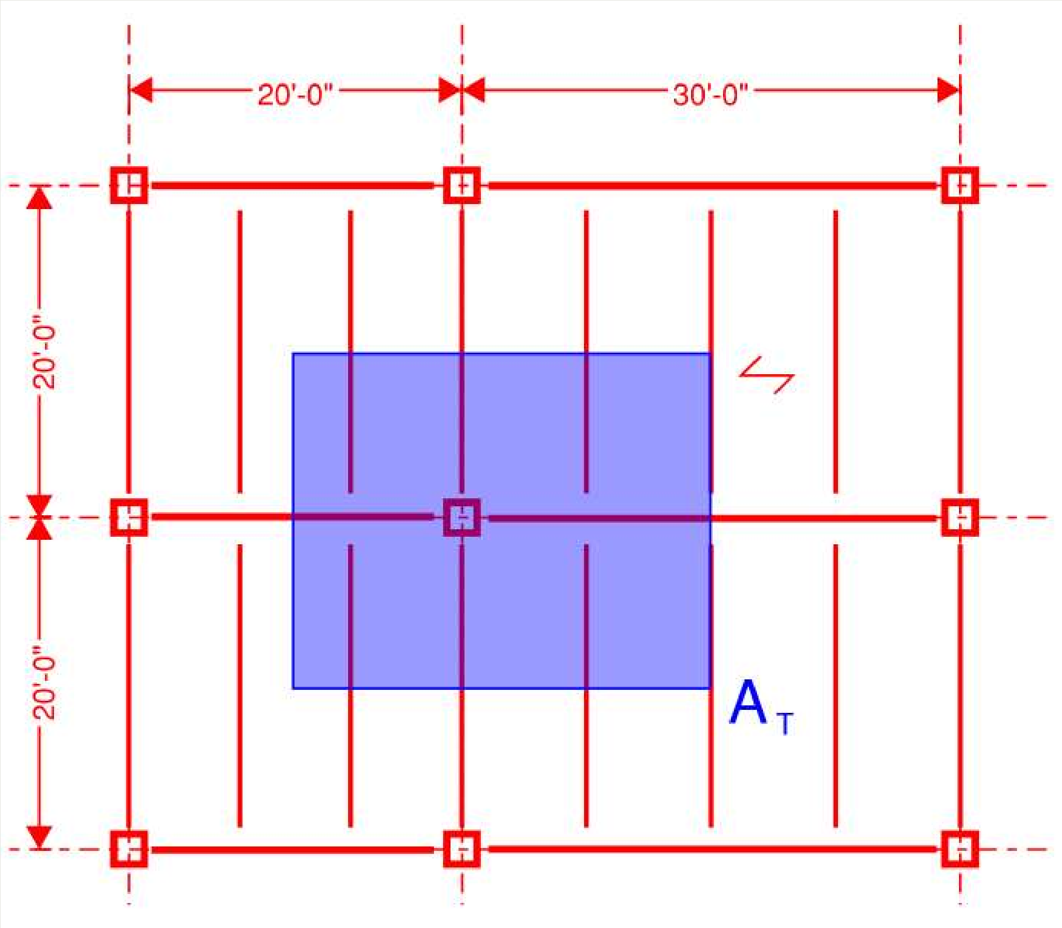


COLUMN ANALYSIS

Determine column load

P = A_T x area load = 106 psf x 500 sqft

P = **53 kips**



COLUMN ANALYSIS

Determine maximum column length for stability

For a steel column, this limit is as follows:

$KL/r < 200$

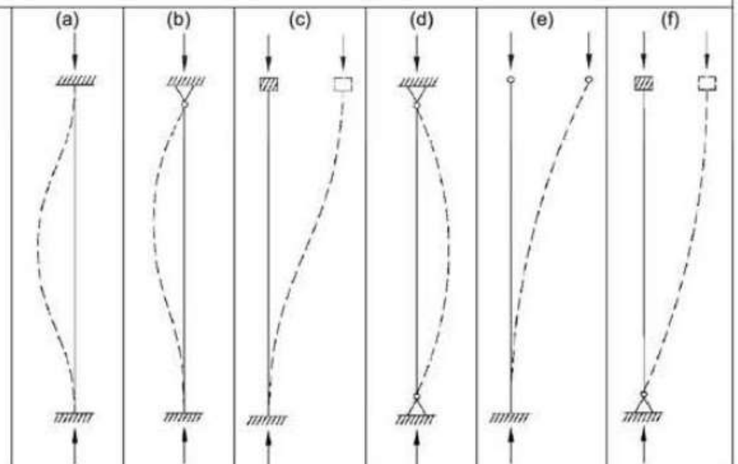
K = Effective Length Factor

L = Unbraced Length of Column

r = Radius of Gyration

TABLE C-A-7.1
Approximate Values of Effective Length Factor, *K*

Buckled shape of column is shown by dashed line



	(a)	(b)	(c)	(d)	(e)	(f)
Theoretical *K* value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design value when ideal conditions are approximated	0.65	0.80	1.2	1.0	2.1	2.0

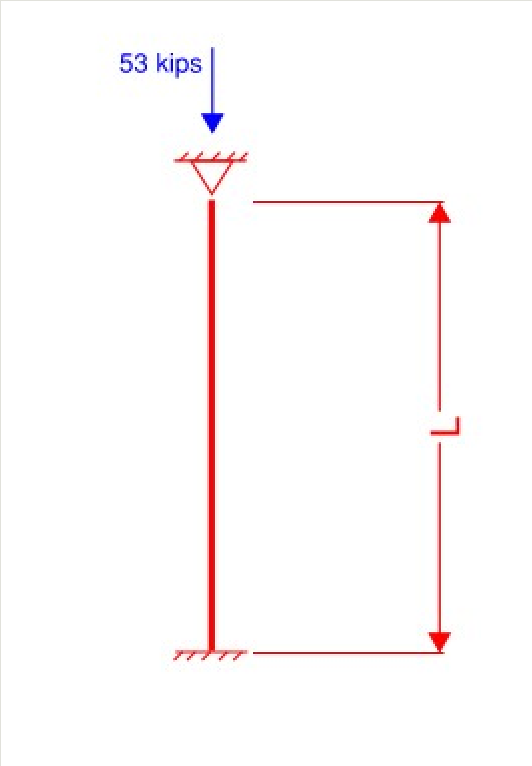
End condition code

- Rotation fixed and translation fixed
- Rotation free and translation fixed
- Rotation fixed and translation free
- Rotation free and translation free

COLUMN ANALYSIS

KL/r < 200

r = 2.34 in



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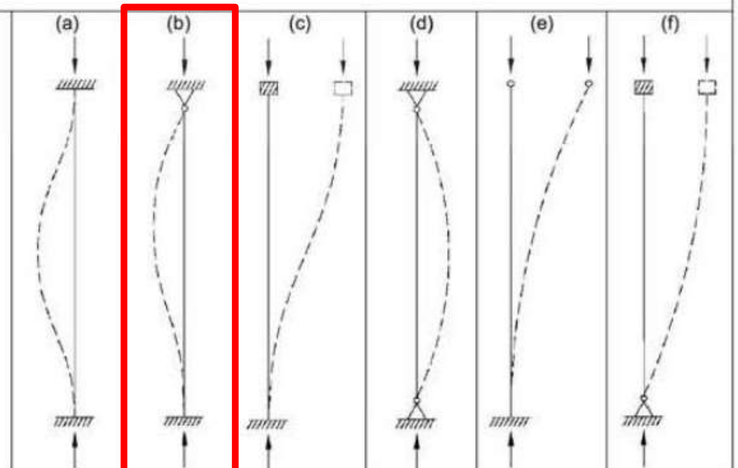

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End condition code

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- Rotation free and translation fixed
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COLUMN ANALYSIS

KL/r < 200

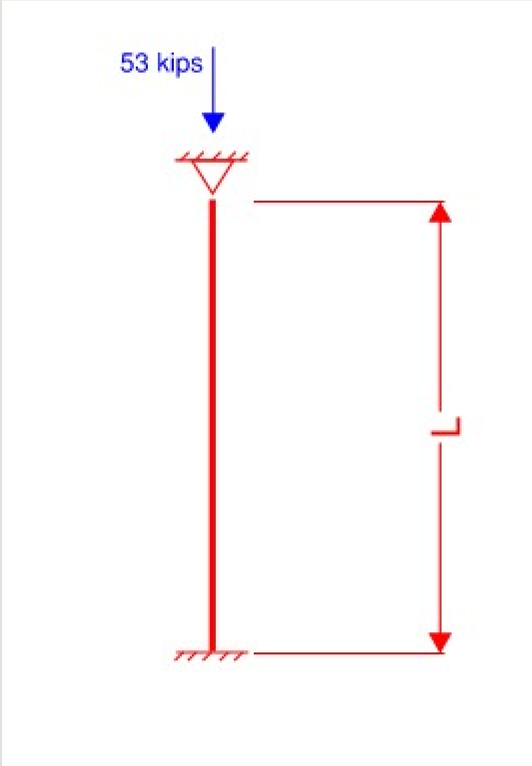
r = 2.34 in

K = 0.7

0.7 x L / 2.34 = 200

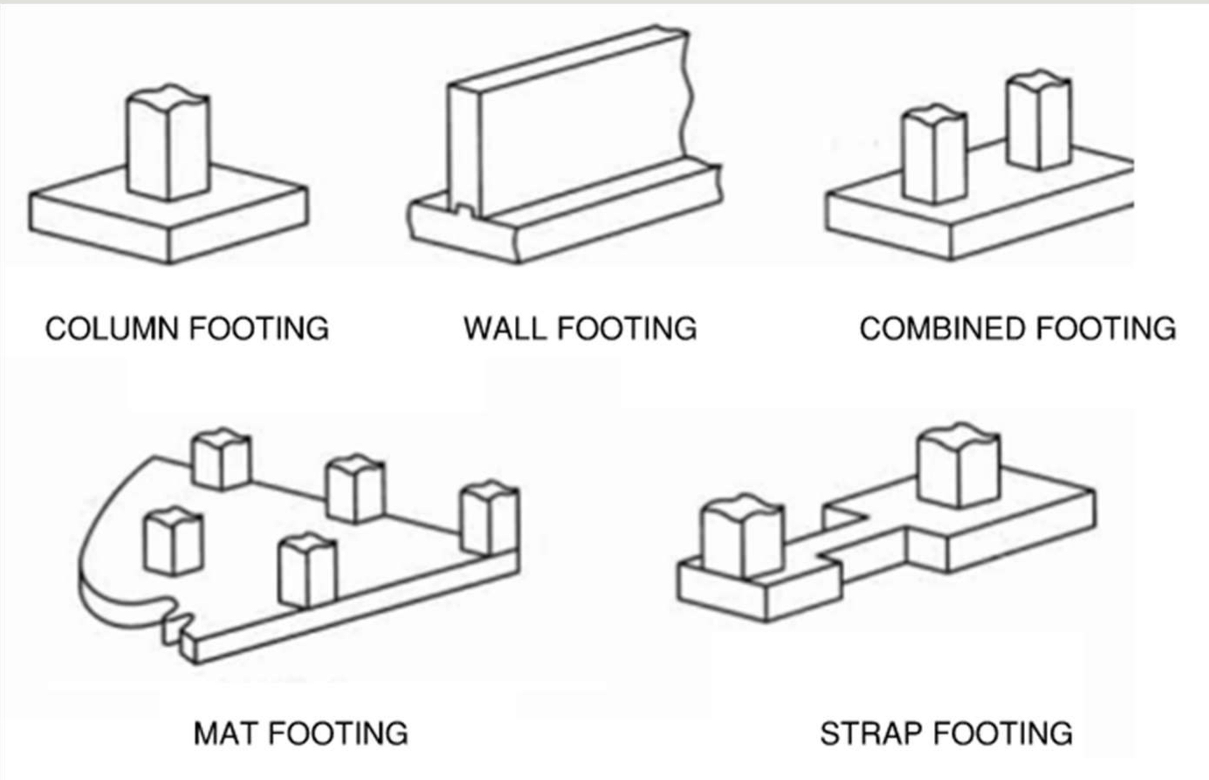
L = 200 x 2.34 / 0.7 = 668 in

668 in / 12 in/ft = **55 ft maximum**



Questions?

FOUNDATIONS



SHALLOW FOUNDATIONS

Shallow Foundation Design

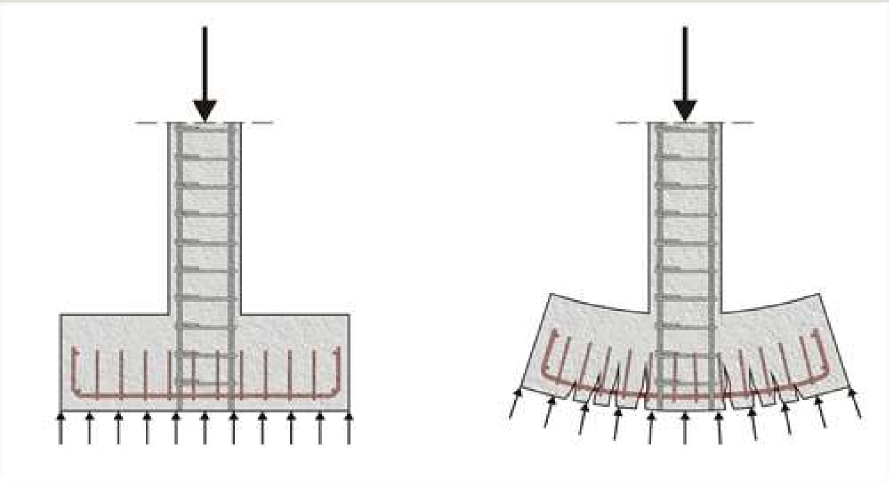
Shallow foundations are types of foundations that are supported from the soil.

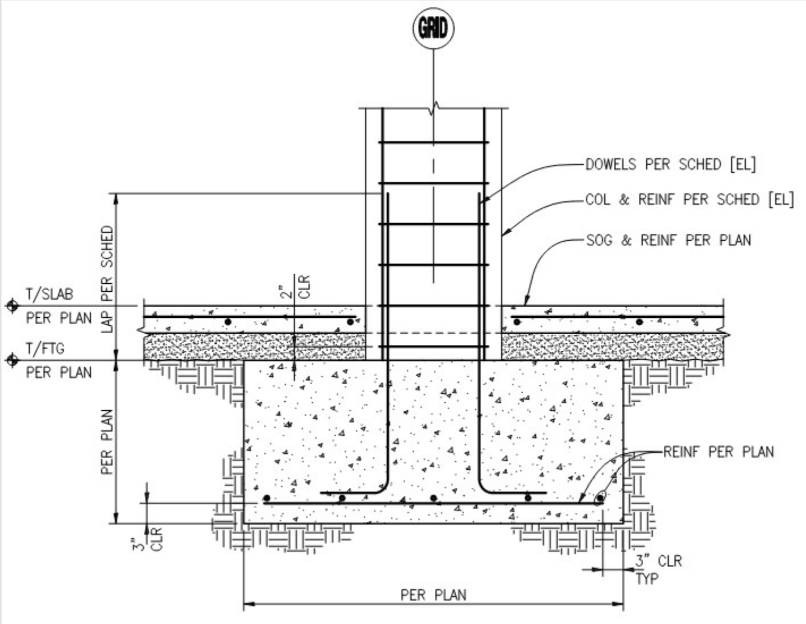
Typically used on lighter and shorter buildings.

Bearing pressures typically vary from 2,000 psf to 7,000 psf.

Typical to consider uniform distribution of load across full area of footing

Shape and proportion of footings can impact bearing capacity





TYPICAL SPREAD FOOTING AT COLUMN

Deep Foundation Design

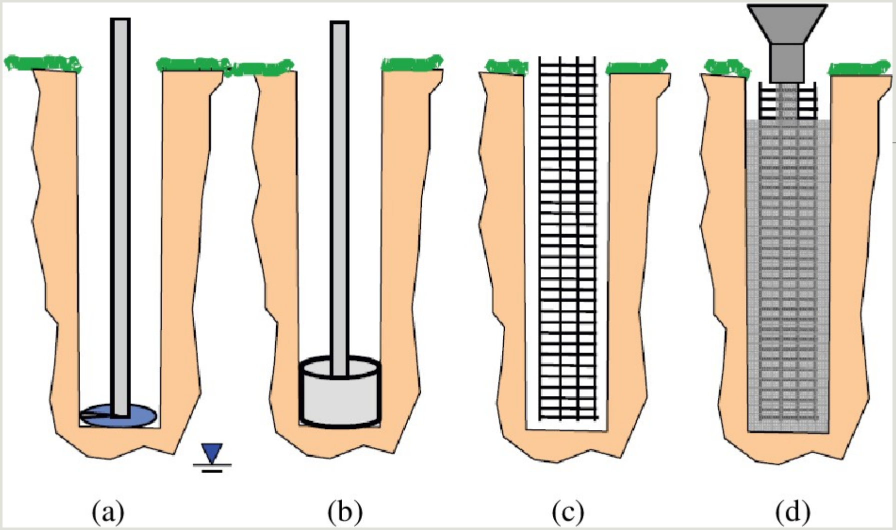
Deep foundations are defined as foundations whose depth is larger than its width

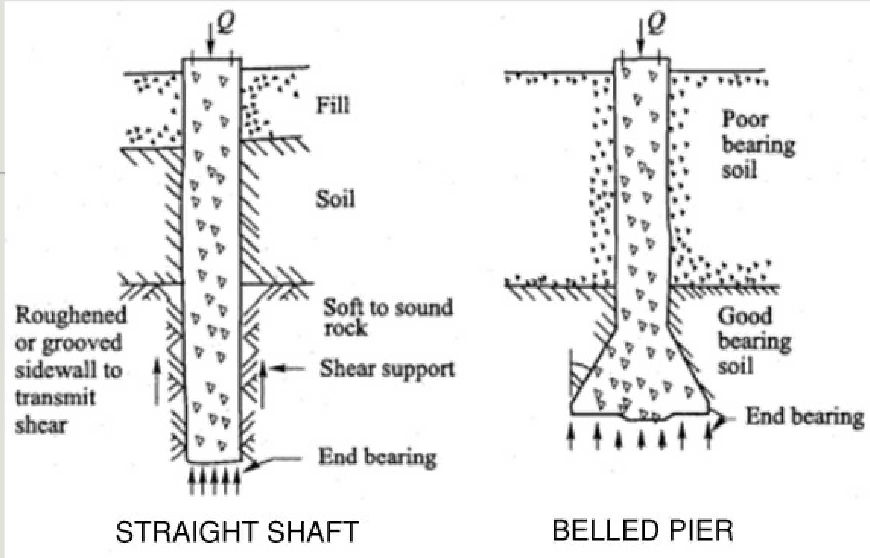
Typically used for higher capacities and reduced settlement

Simple terms is to consider installing columns into the ground

Capacities are distributed vertically rather than horizontally.

Can rely on both skin friction and end bearing





DRILLED PIER FOUNDATIONS

DRILLED PIERS

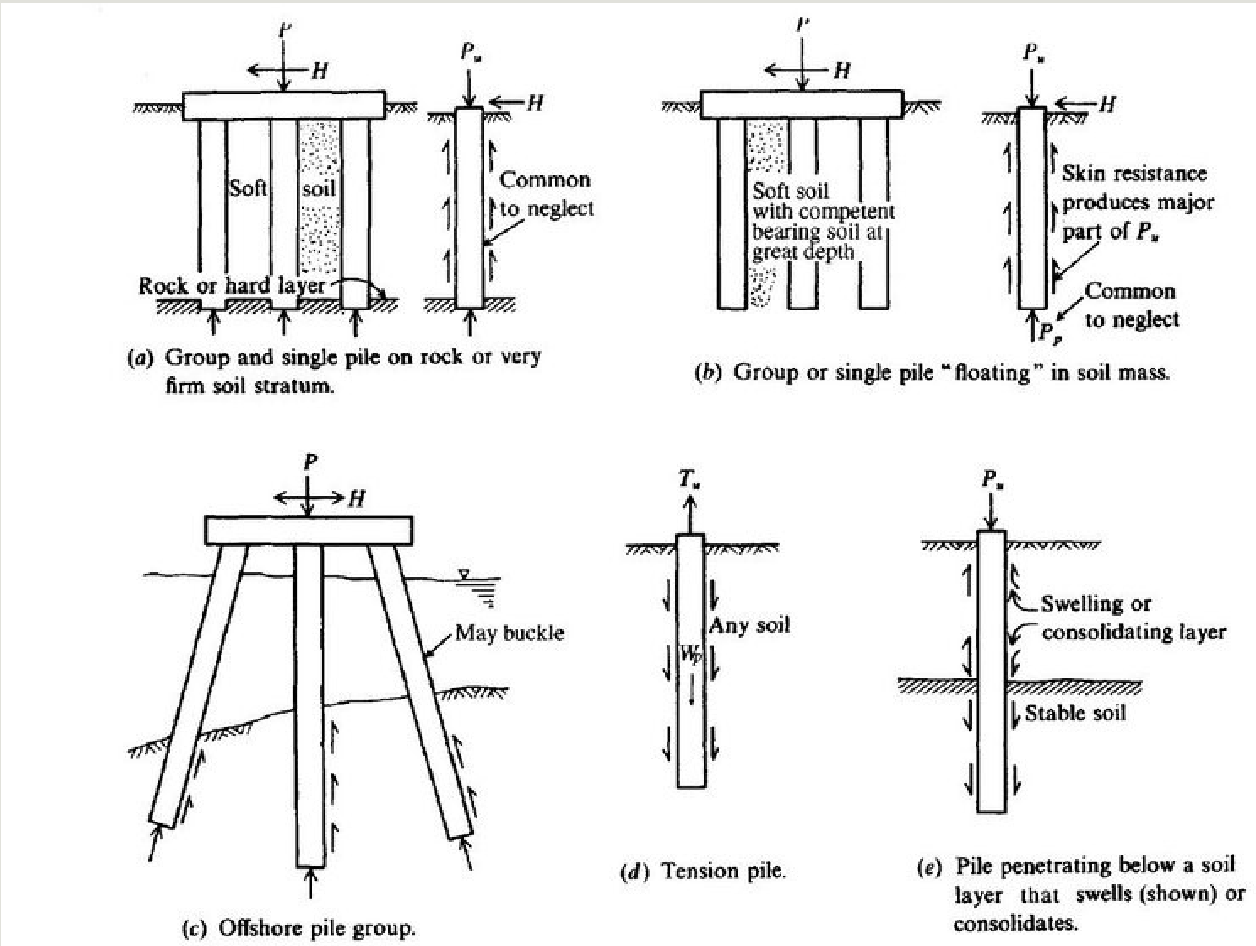
Typically use larger diameters and single piers vs grouped to increase capacity

Steel casing may be required if soils are prone to caving or if the water table is present

Casings will reduce skin friction resistance capacity

Caisson is just a drilled pier with full water-tight casing.

Reinforcing cages treated similar to a concrete column but do not necessarily need to go full depth



PILE FOUNDATIONS

PILES

Many types of Piles:

Augercast / CIP piles

Precast piles

Steel piles

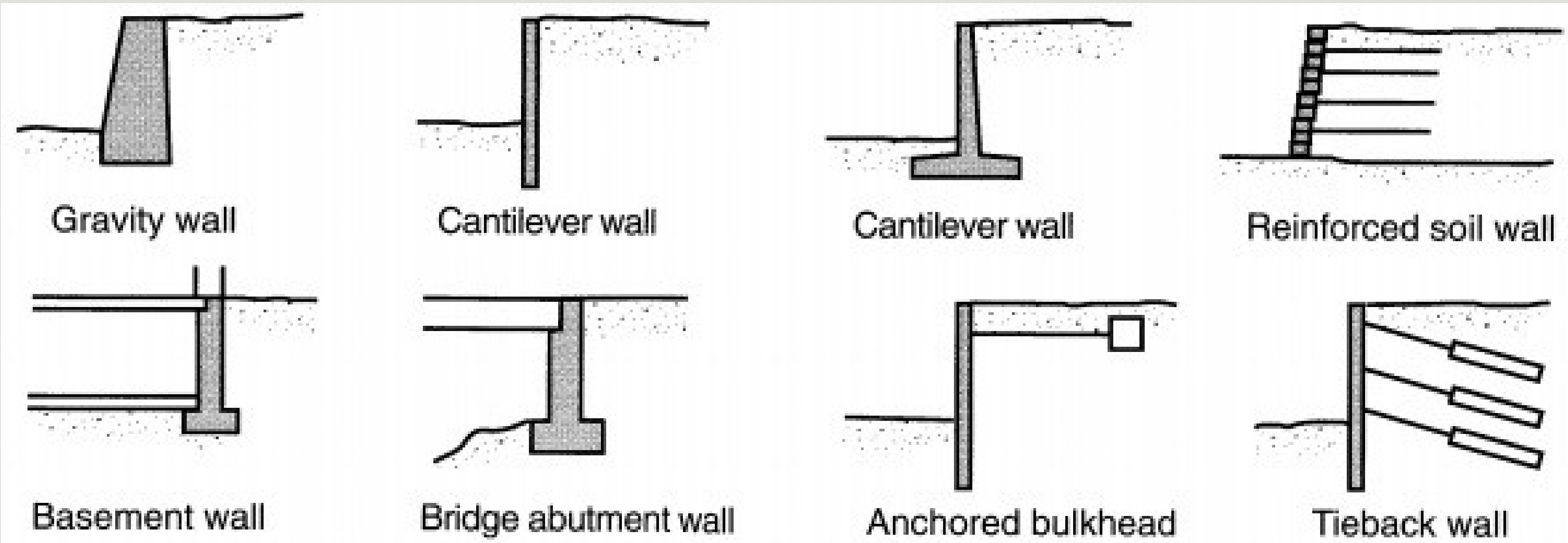
Wood Piles

Sheet Piles

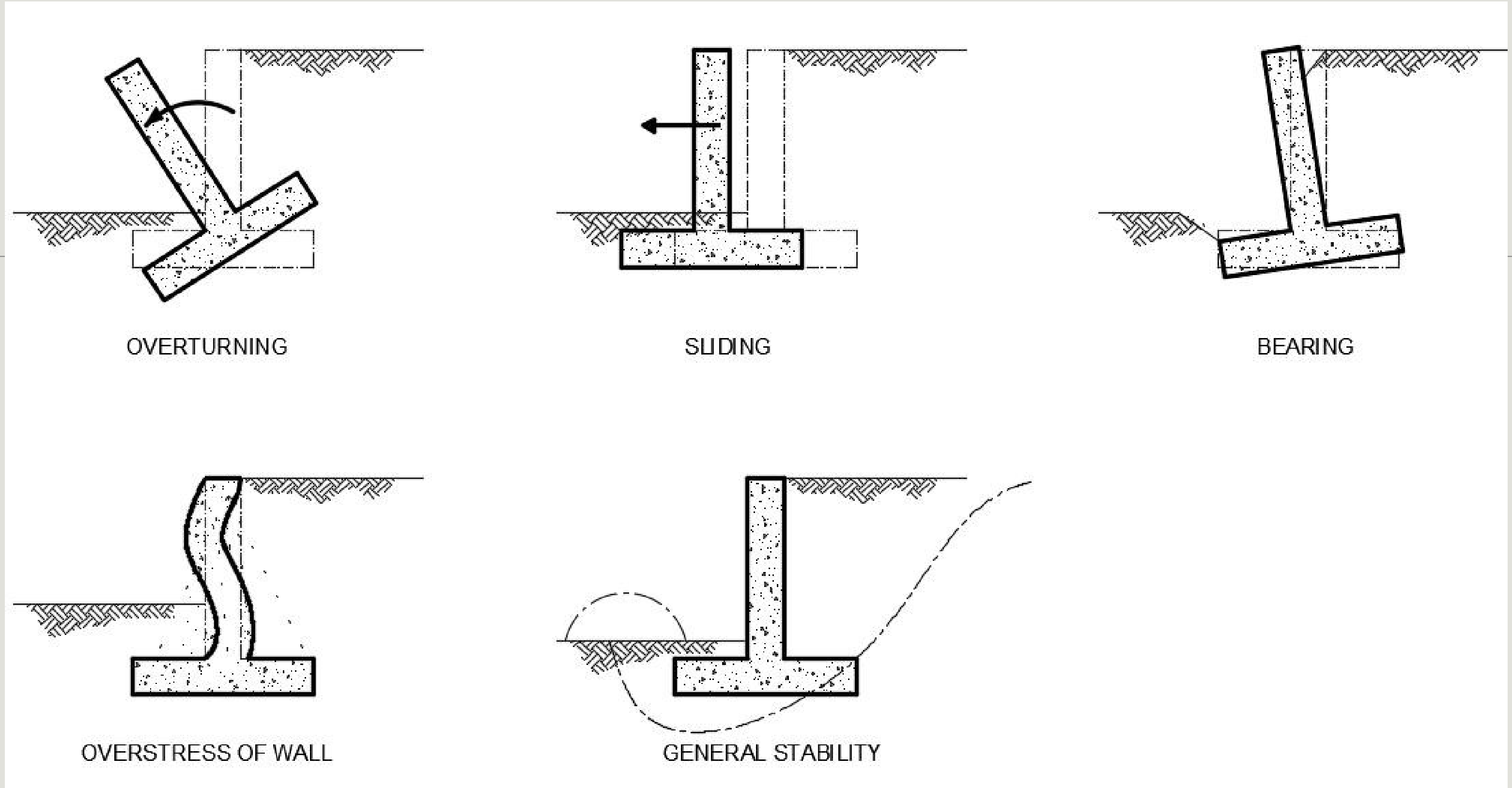
Micro/Macro Piles

Driven vs Drilled

RETAINING WALLS

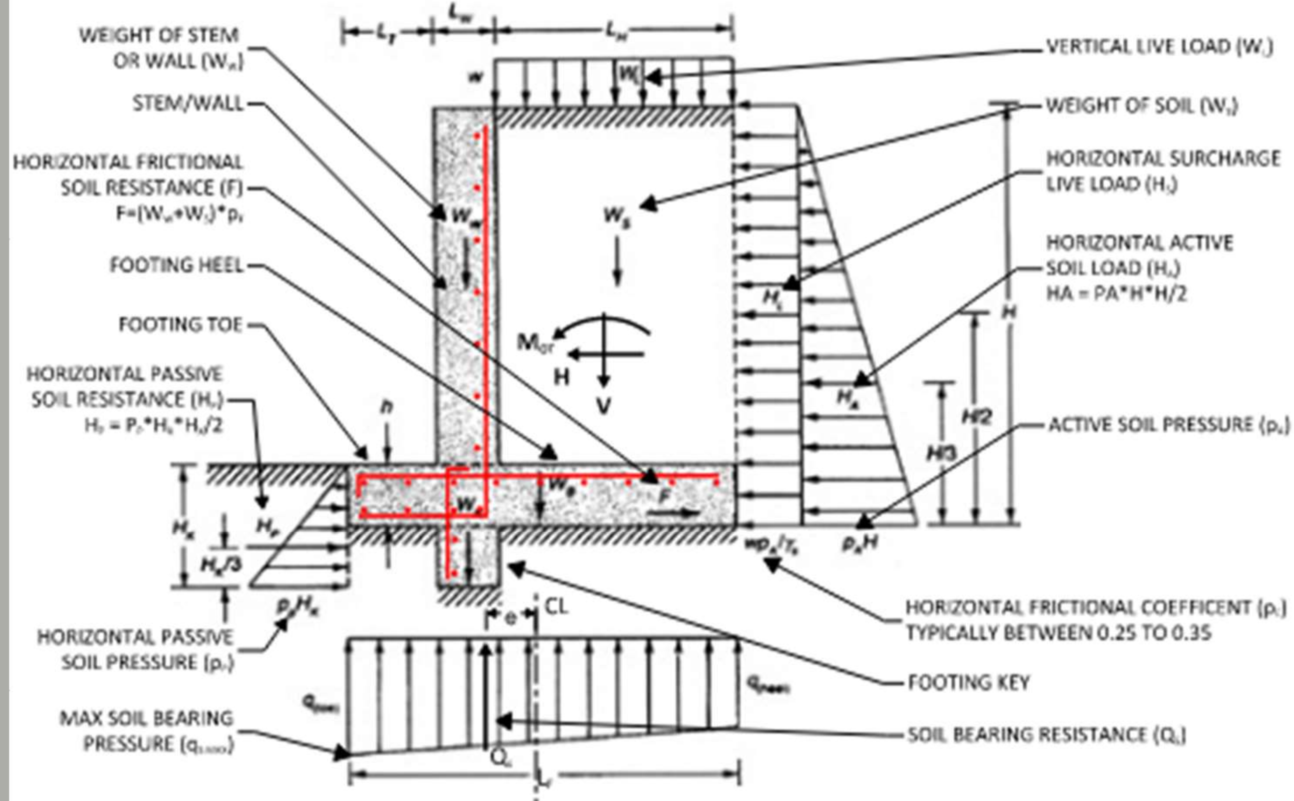


Types of Retaining Walls



Cantilevered Retaining Walls Modes of Failure

RETAINING WALL LOADING



DESIGN FORCES

V $= W_L * L_H + W_S + W_W$

H $= H_L + H_A$

M_OT $= H_S * H/2 + H_A * H/3$

DESIGN RESISTANCE

Q_MAX $= V/L_F + 6 * M_{OT}/L_F^2 <= q_{SMAX}$

H_R $= H_P + F >= 1.5 * H$

M_R $= W_S * (L_H/2 + L_W + L_T) + W_W * (L_T + L_W/2) >= 2 * M_{OT}$

e $= M_{OT} / V <= L_F/6$ - TO AVOID BACK OF FOOTING IN TENSION

Questions?

Retaining Wall Practice Problems

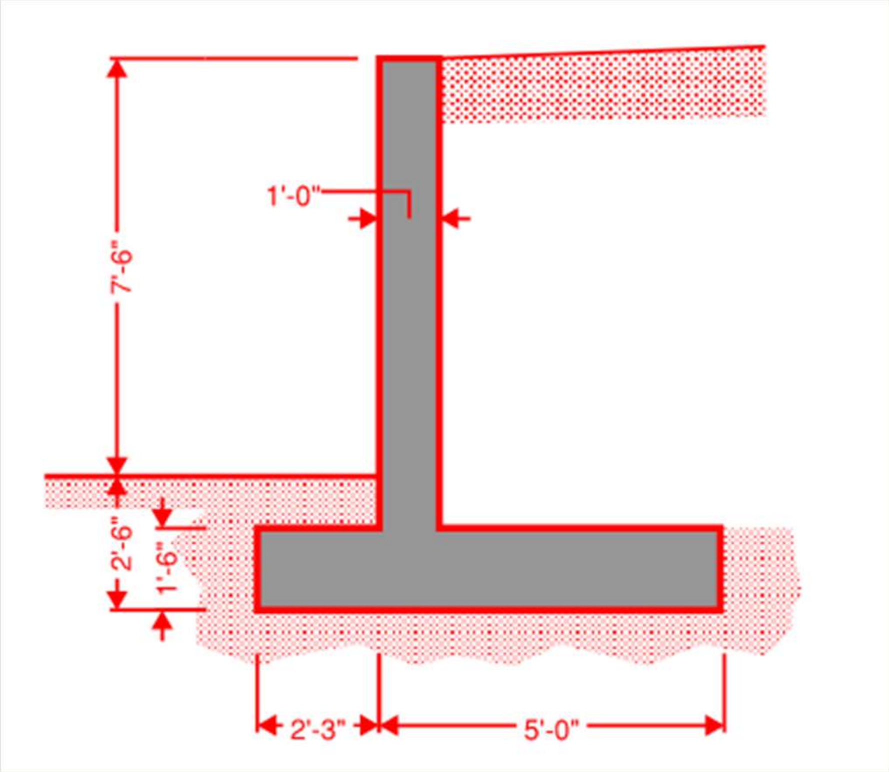
RETAINING WALL PROBLEMS

A. Determine the horizontal shear force acting on the wall
B. Determine overturning moment.
C. Does the wall require a shear key?

<u>GIVENS</u>

Active Earth Pressure = 35 psf/ft
Soil Density = 120 pcf
Coefficient of Friction = 0.35
Surcharge Lateral Load = 150 psf

Passive Earth Pressure = 375 psf/ft
Concrete Density = 150 pcf
Axial Dead Load = 20 plf psf



RETAINING WALL PROBLEMS

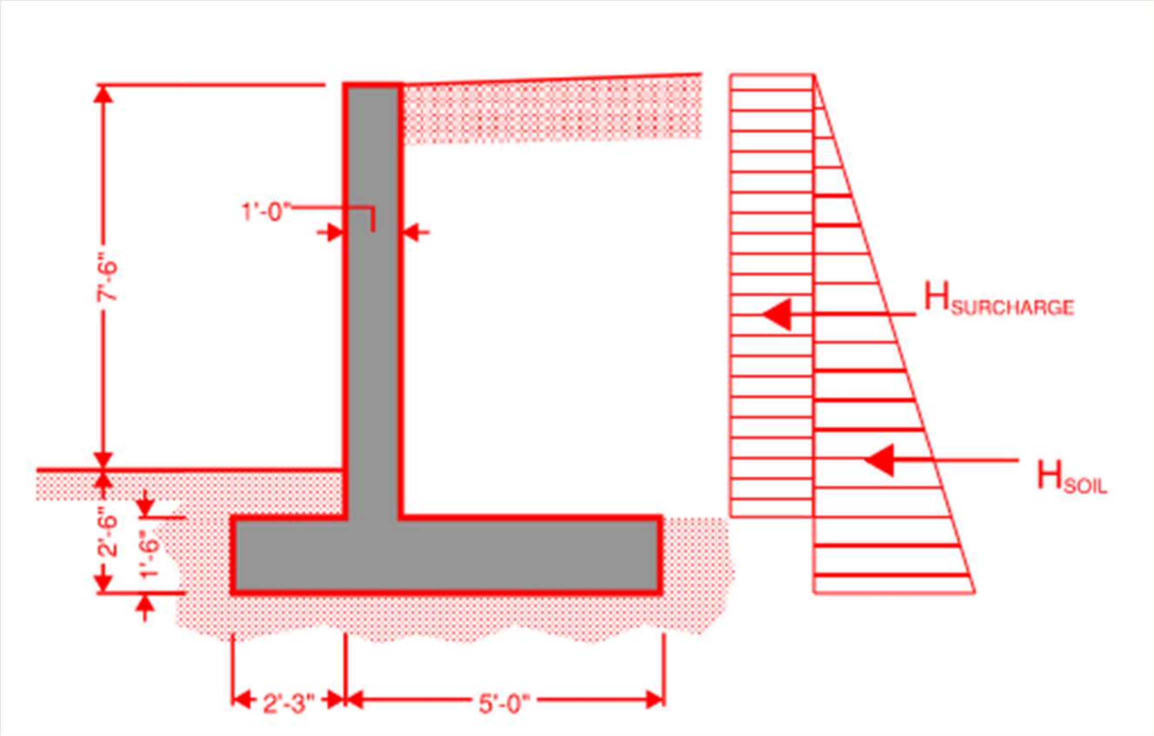
A. Horizontal Shear

H_{soil} = 35 * 10 * 10/2 = 1,750 lbs/ft

$H_{surcharge}$ = 150 * 8.5= 1,275 lbs/ft

$H_{total} = H_{soil} + H_{surcharge}$

H_{total} = 1,750 + 1,275 = 3,025lbs/ft



RETAINING WALL PROBLEMS

B. Overturning Moment

M_{soil} = 1,750 * 3.33 = 5,833 lb-ft/ft

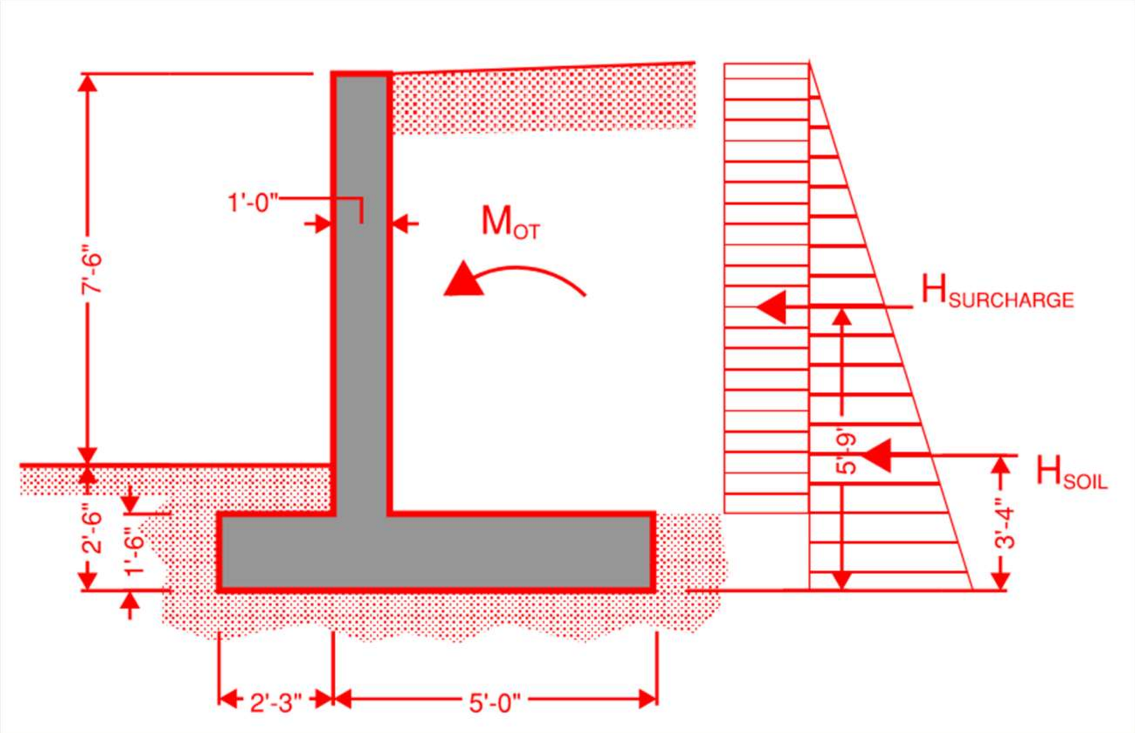
$M_{surcharge}$ = 1,275 * 5.75

= 7,331 lbs-ft/ft

$M_{total} = M_{soil} + M_{surcharge}$

M_{total} = 5,833 + 7,331

= <u>13,165lbs-ft/ft</u>



RETAINING WALL PROBLEMS

C. Sliding

H_p = 375 * 2.5 * 2.5/2 = 1,172 lb/ft

W_{soil} = 120 * 8.5 * 4 = 4,080 lb/ft

W_{wall} = 150 * 1 * 6 = 900 lb/ft

W_{ftg} = 150 * 1.5 * 7.25 = 1,631 lb/ft

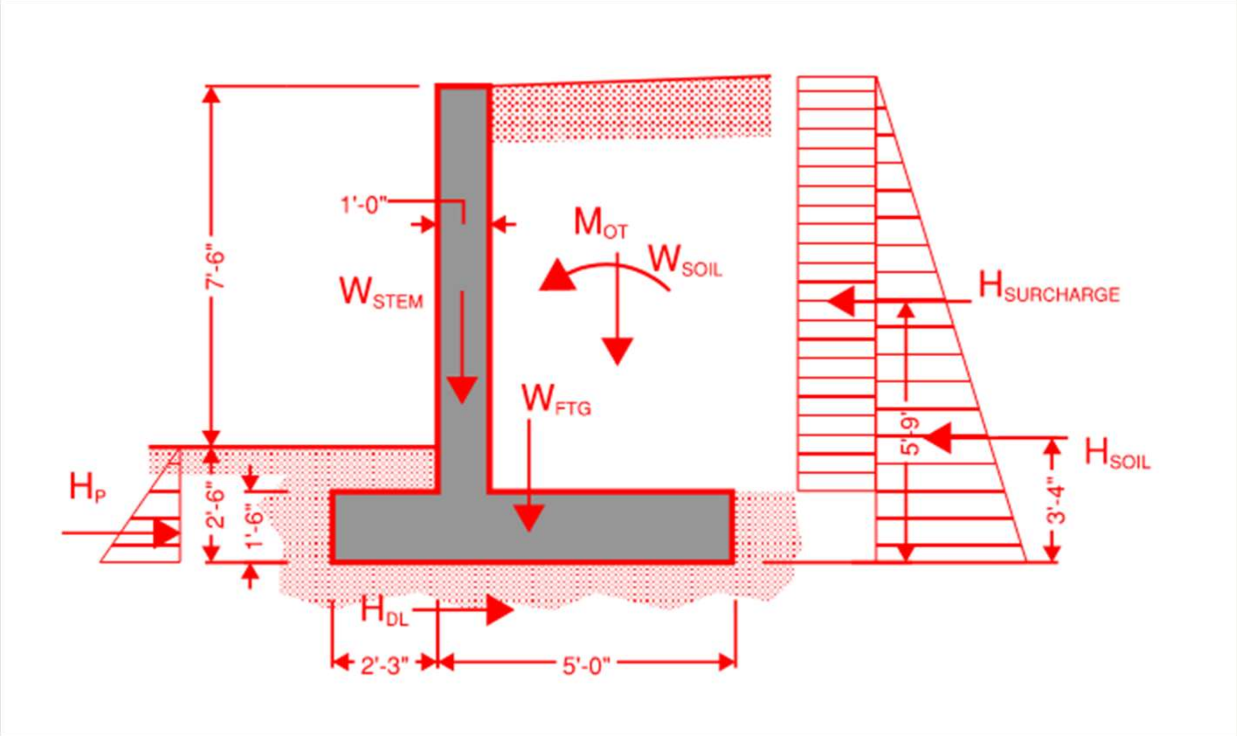
W_{total} = 4,080 + 900 + 1,631 = 6,611 lb/ft

H_{DL} = 0.35 * 6,611 = 2,314 lb/ft

$H_{resisting}$ = 1,172 + 2,314 = 3,486 lb/ft

$H_{resisting}/H_{total}$ = 3,486 / 3,025 lb/ft = 1.15

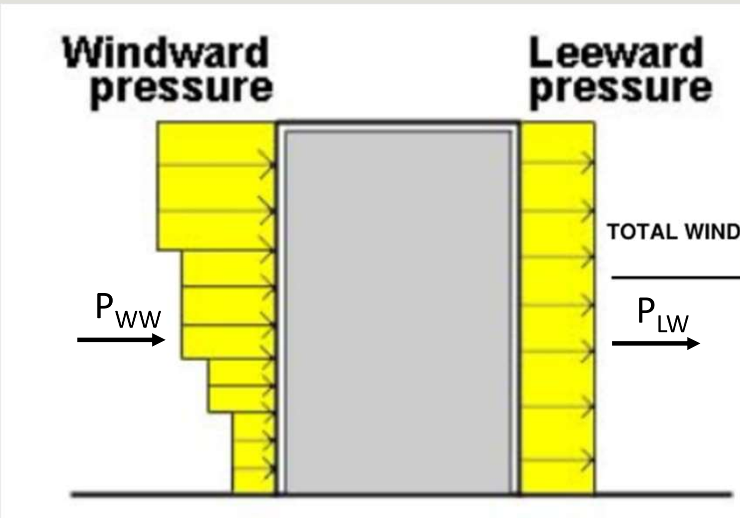
1.15 < 1.5 – NEED SHEAR KEY



Questions?

LATERAL FORCES

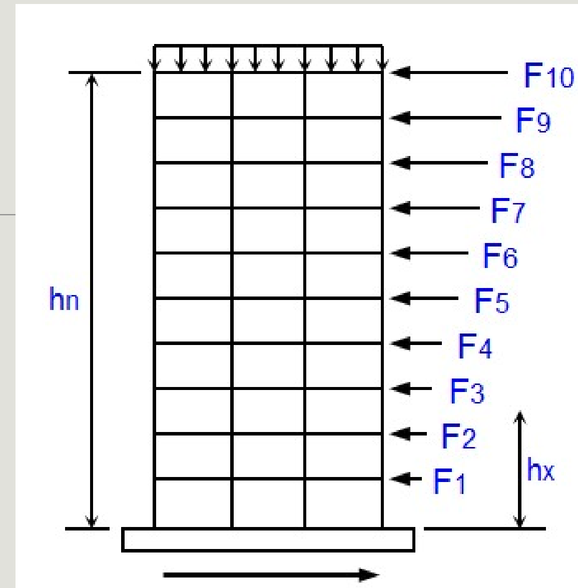
ROLAND HILL, P.E.



P →

P = Qs*(GCp +/- Gcpi)*A

Wind Base Shear



$V = C_s*W = \Sigma F$

Seismic Base Shear

Wind and Seismic Forces to Buildings

DETERMINING WIND FORCES

Main Wind Force Resisting System (MWFRS) Forces

VS

Components and Cladding (C&C)Forces

USE DIFFERENT MAGNITUDE FORCES FOR DESIGN

Wind Design (MWFRS) per ASCE 7

P_W = Qs*(GCp +/- Gcpi)*A

Q_s = Wind Velocity Pressure

$Q_s = 0.00256 * K_z * K_{zt} * K_d * V^2$

V = Basic Wind Speed (mph)

K factors = Height, Topography & Direction

GCp = Product of Gust Effect and Wind Pressure coefficients for external and internal pressures

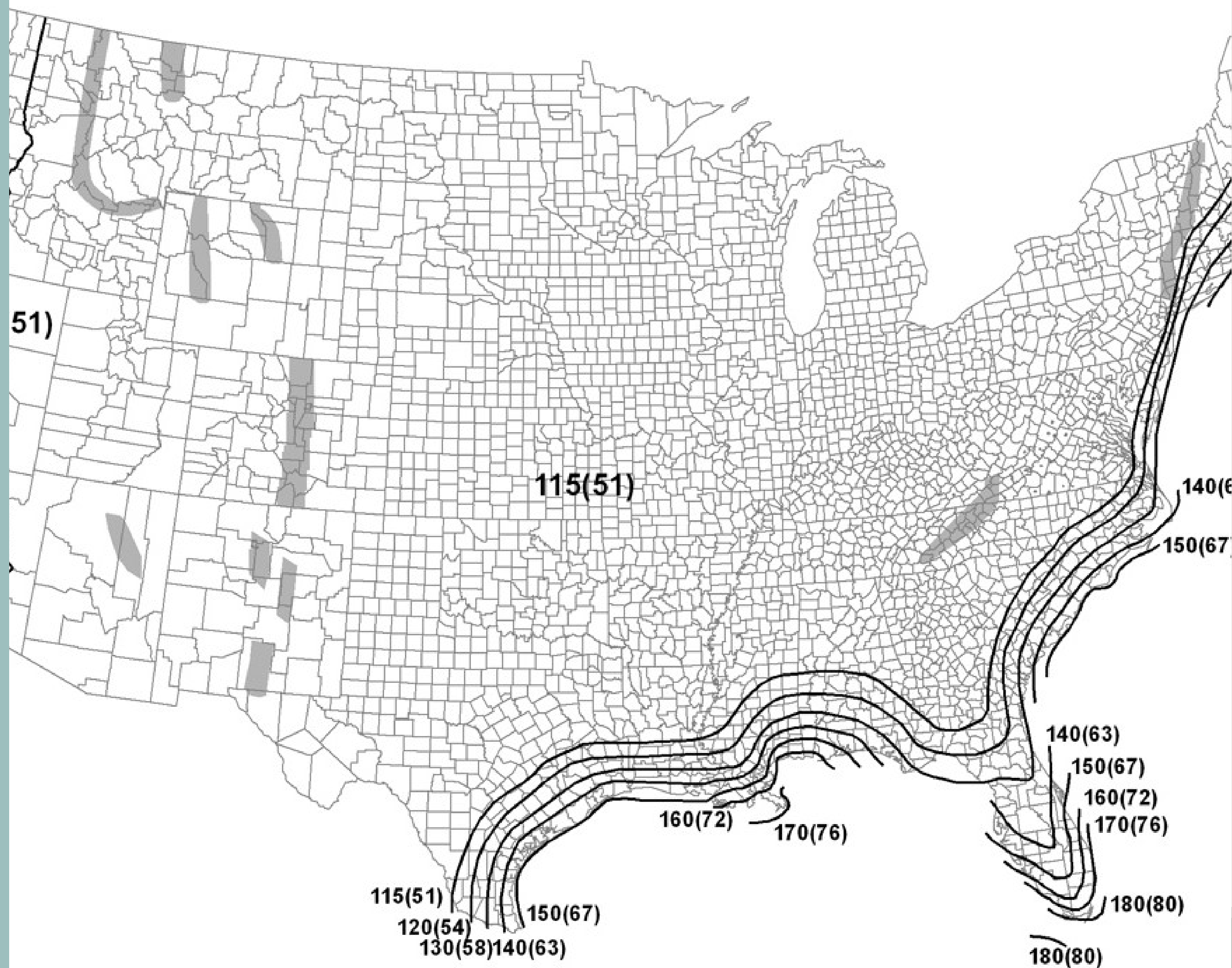
A = Surface Area

Basic Wind Speed Map V (mph)

Maps based on:

Location and

Building Risk Classification



K Factors Tables

Kz – Height Factor

varies on height and exposure

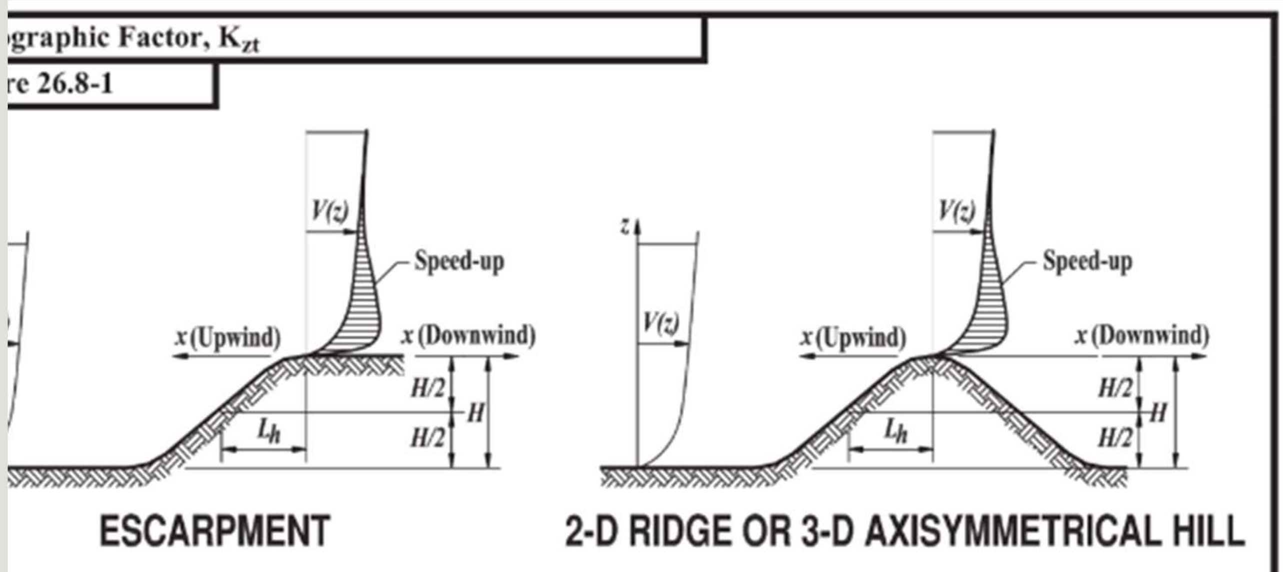
Kd – Directional Factor

varies on structure type

Kzt – Topographic Factor

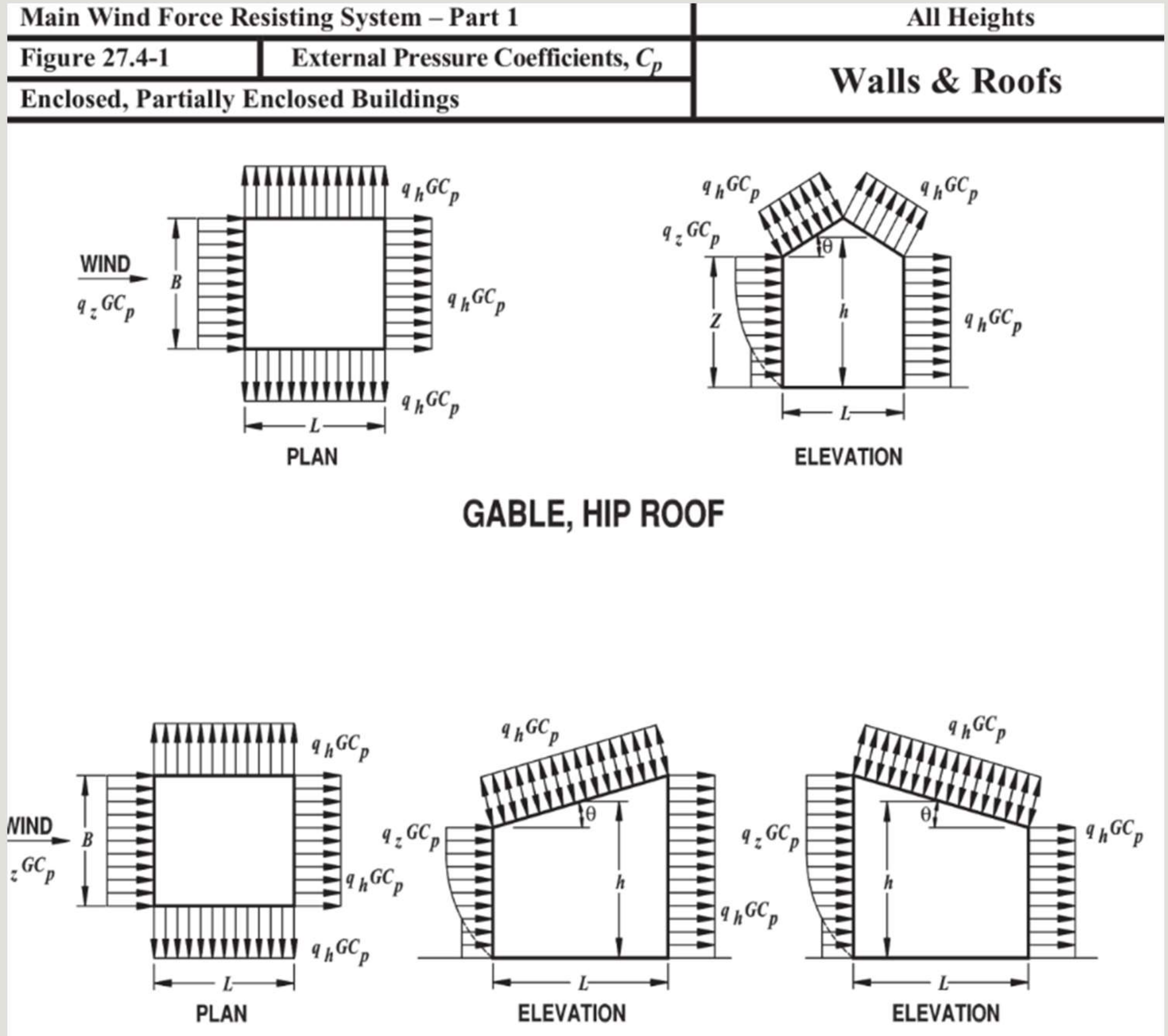
Structure Type	Directionality Factor K_d*
Buildings	
Main Wind Force Resisting System	0.85
Components and Cladding	0.85
Arched Roofs	0.85
Chimneys, Tanks, and Similar Structures	
Square	0.90
Hexagonal	0.95
Round	0.95
Solid Freestanding Walls and Solid Freestanding and Attached Signs	0.85
Open Signs and Lattice Framework	0.85
Trussed Towers	
Triangular, square, rectangular	0.85
All other cross sections	0.95

Height above ground level, z		Exposure		
ft	(m)	B	C	D
0-15	(0-4.6)	0.57	0.85	1.03
20	(6.1)	0.62	0.90	1.08
25	(7.6)	0.66	0.94	1.12
30	(9.1)	0.70	0.98	1.16
40	(12.2)	0.76	1.04	1.22
50	(15.2)	0.81	1.09	1.27
60	(18)	0.85	1.13	1.31
70	(21.3)	0.89	1.17	1.34
80	(24.4)	0.93	1.21	1.38
90	(27.4)	0.96	1.24	1.40
100	(30.5)	0.99	1.26	1.43
120	(36.6)	1.04	1.31	1.48
140	(42.7)	1.09	1.36	1.52
160	(48.8)	1.13	1.39	1.55
180	(54.9)	1.17	1.43	1.58
200	(61.0)	1.20	1.46	1.61
250	(76.2)	1.28	1.53	1.68
300	(91.4)	1.35	1.59	1.73
350	(106.7)	1.41	1.64	1.78
400	(121.9)	1.47	1.69	1.82
450	(137.2)	1.52	1.73	1.86
500	(152.4)	1.56	1.77	1.89



External Pressure Coefficients

WALLS AND ROOFS (MWFRS)



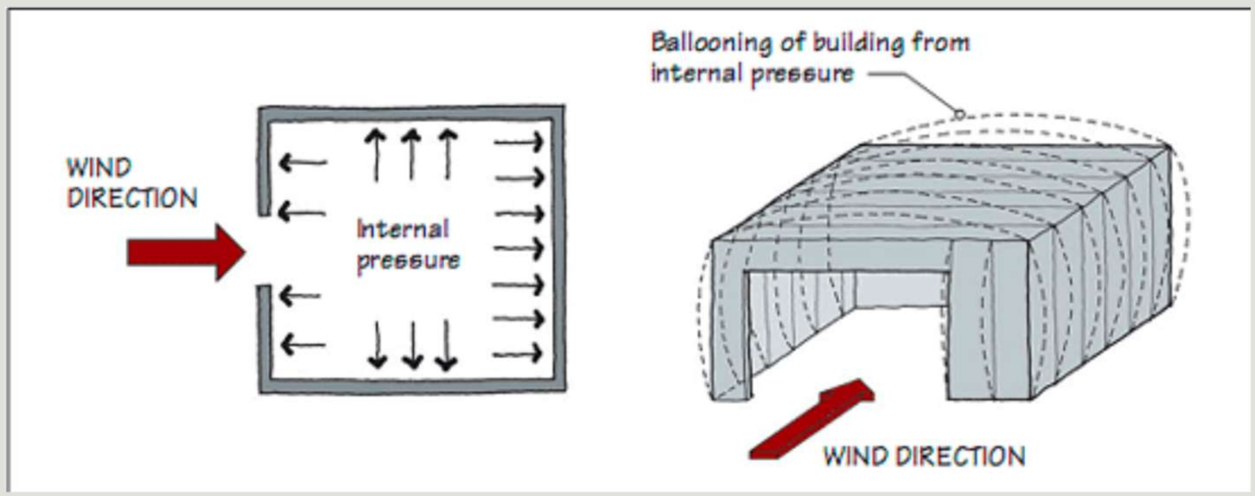
Internal Pressure Coefficients

Open

Enclosed

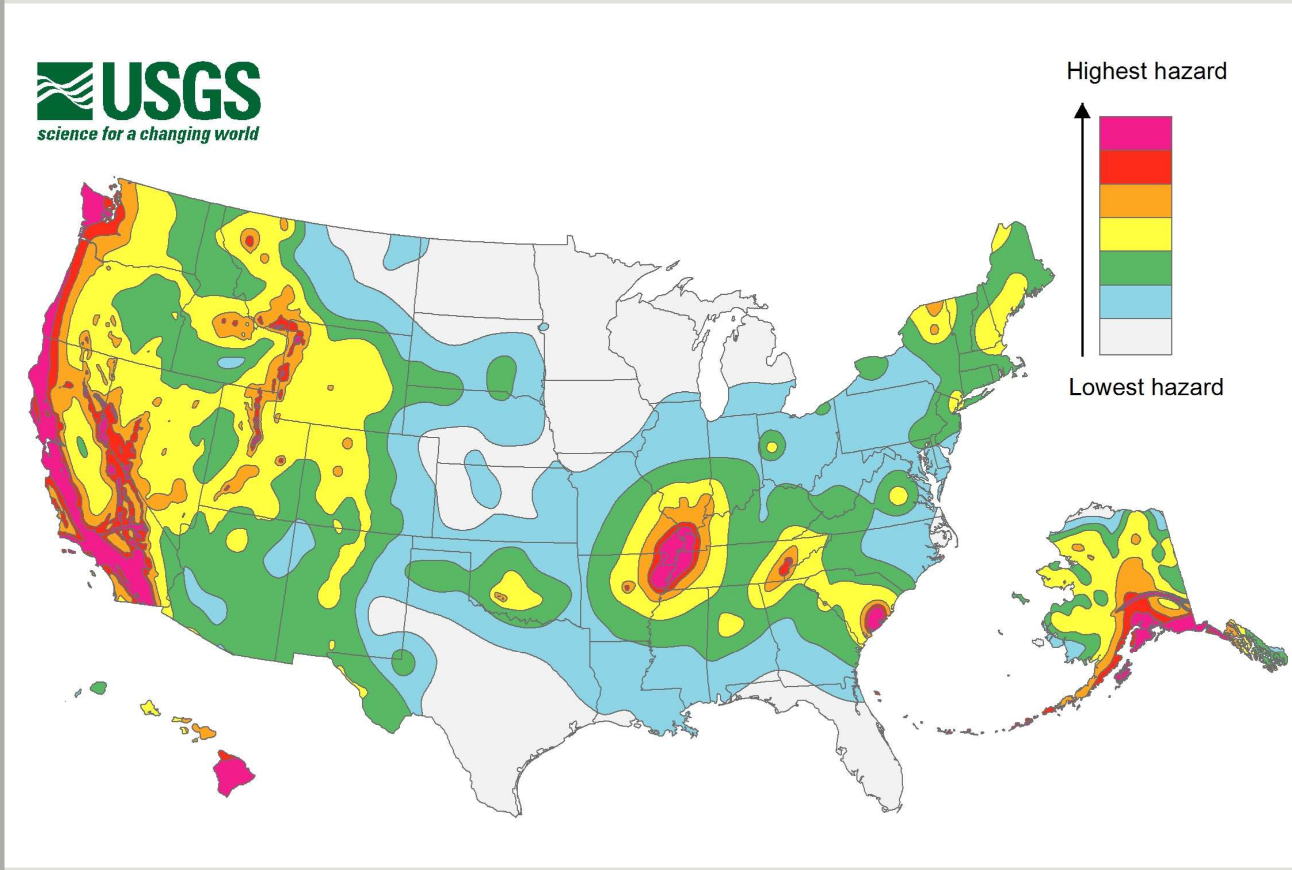
Partially Enclosed

Enclosure Classification	(GC_{pi})
Open Buildings	0.00
Partially Enclosed Buildings	+0.55 -0.55
Enclosed Buildings	+0.18 -0.18



DETERMINING SEISMIC FORCES

Seismic Hazard Map



Seismic Design

Equivalent Lateral Force Procedure per ASCE 7

$V = Cs*W$

V = Seismic Base Shear

C_s = Seismic Response Coefficient

W = Seismic Mass

Seismic Design Parameters

FEMA 454

- Ground Motion
- Site Class

SITE

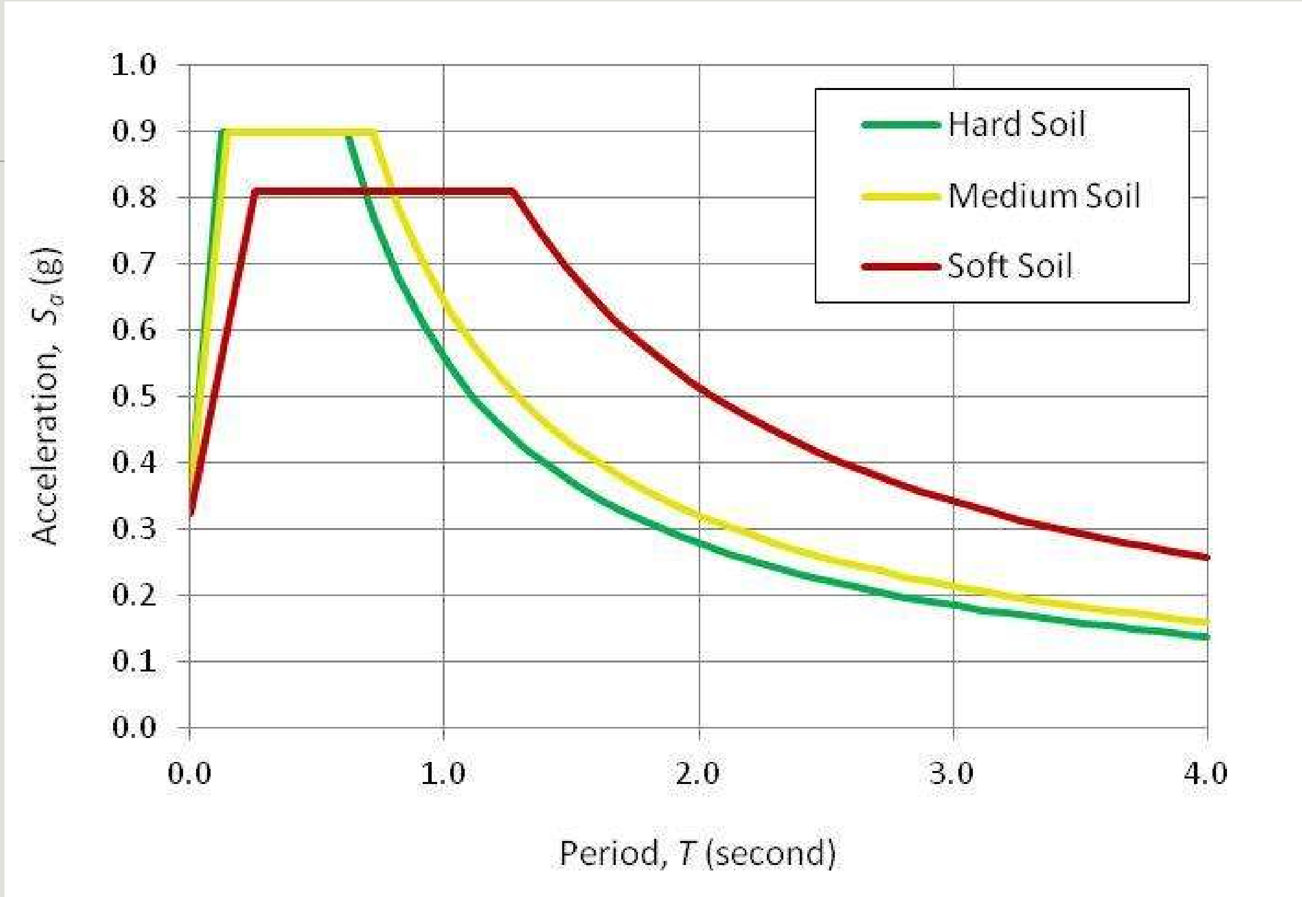
- Fundamental Period of Structure
- Seismic Use Group and Importance Factor
- Seismic Design Category
- Building Configuration
- Response Modification Factor

BUILDING

Soil Profile & Ground Motion

Harder Soils have larger and shorter accelerations

Soft soils have smaller but longer accelerations



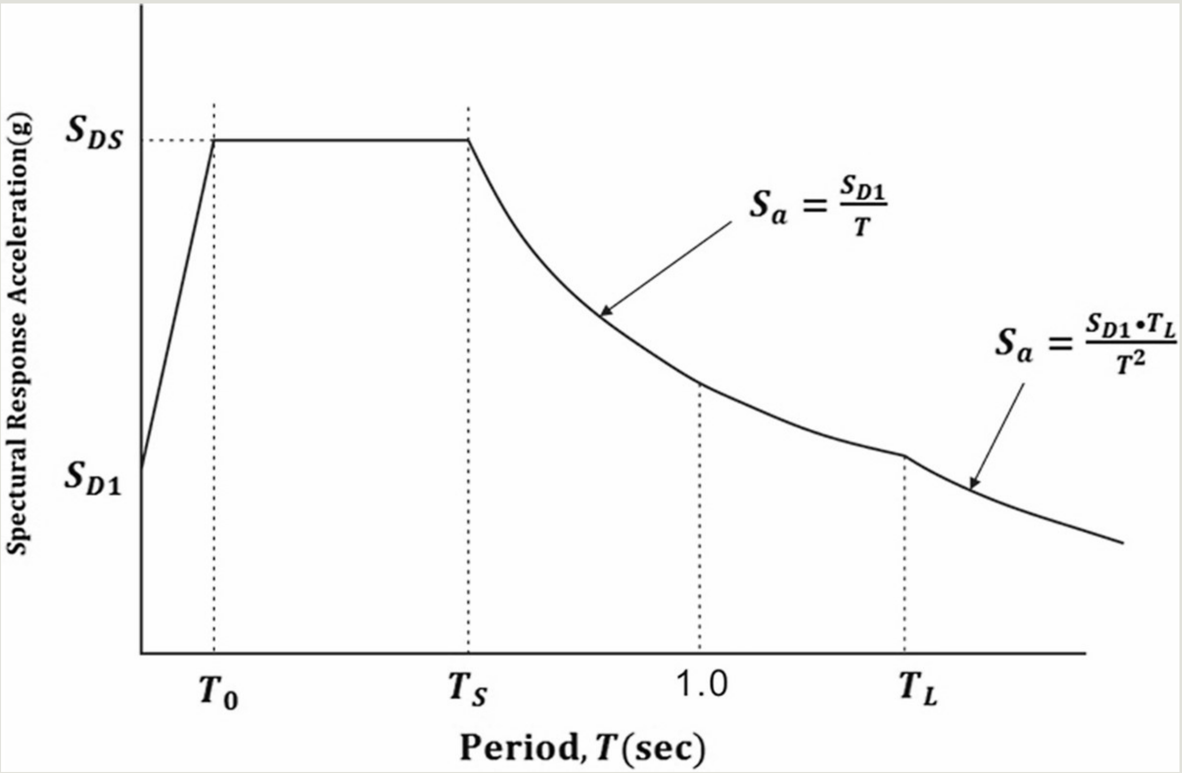
IBC Seismic Design Category

6 Site Categories –

A, B, C, **D**, E, & F

5 Design Categories –

A, B, C, D & E



Design Response Spectrum

Site Classification

- A: Hard Rock
- B: Rock
- C: Very Dense Soil, Soft Rock
- D: Stiff Soil (Default)
- E: Soft Clay Soil
- F: Soils Requiring Site Analysis (Basically Garbage)

Seismic Design Category

TABLE 11.6-1 SEISMIC DESIGN CATEGORY BASED ON SHORT PERIOD RESPONSE ACCELERATION PARAMETER

Value of S_{DS}	Occupancy Category		
	I or II	III	IV
$S_{DS} < 0.167$	A	A	A
$0.167 \le S_{DS} < 0.33$	B	B	C
$0.33 \le S_{DS} < 0.50$	C	C	D
$0.50 \le S_{DS}$	D	D	D

TABLE 11.6-2 SEISMIC DESIGN CATEGORY BASED ON 1-S PERIOD RESPONSE ACCELERATION PARAMETER

Value of S_{D1}	OCCUPANCY CATEGORY		
	I or II	III	IV
$S_{D1} < 0.067$	A	A	A
$0.067 \le S_{D1} < 0.133$	B	B	C
$0.133 \le S_{D1} < 0.20$	C	C	D
$0.20 \le S_{D1}$	D	D	D

- Design Category A — NO SPECIAL DETAILING
- Design Category B
- Design Category C — (B and C) MINIMAL SPECIAL DETAILING
- Design Category D
- Design Category E — (D and E) SPECIAL SEISMIC DETAILING

Response Modification R

Dependent on type of structural system and Seismic Design Category

Not all structural systems are allowed in Seismic Design Categories

Seismic Force Resisting Systems:

Shear Walls

Braced Frames

Moment-Resisting Frame

Dual Systems

Cantilevered Column

Undefined Systems

Seismic Response Coefficient Cs

Dependent on type of structural system and Seismic Design Category

Not all structural systems are allowed in Seismic Design Categories

Types of Structural Systems:

$Cs = S_{DS} / (R/I)$ (Max Value)

$Cs = S_{D1} / T*(R/I)$ $T < T_L$

$Cs = S_{D1}T_L / T*(R/I)$ $T > T_L$

$Cs_{min} = 0.044*S_{D1}*I_e$

Seismic Response Coefficient Cs

Dependent on type of structural system and Seismic Design Category

Not all structural systems are allowed in Seismic Design Categories

Different Equations Based On Building Period:

$$C_s = \frac{S_{DS}}{(\frac{R}{I_e})}$$ (Max Value)

$$C_s = \frac{S_{D1}}{T(\frac{R}{I_e})}$$ ($T<T_L$)

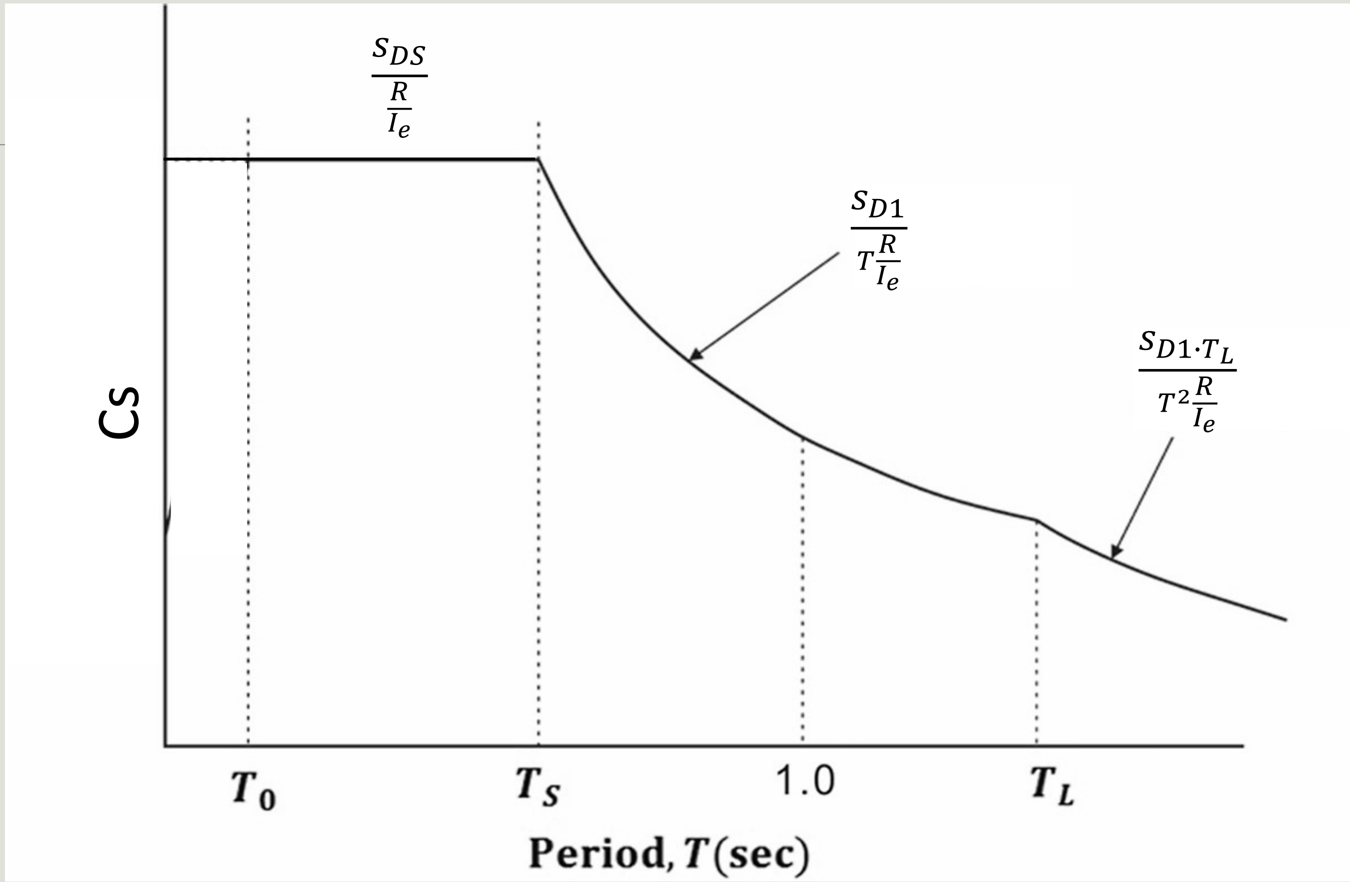
$$C_s = \frac{S_{D1} \cdot T_L}{T^2(\frac{R}{I_e})}$$ ($T>T_L$)

$$C_{S\,min} = 0.044 S_{DS} \cdot I_e > 0.01$$ (Min Value)

Seismic Response Coefficient Cs

Dependent on type of structural system and Seismic Design Category

Not all structural systems are allowed in Seismic Design Categories



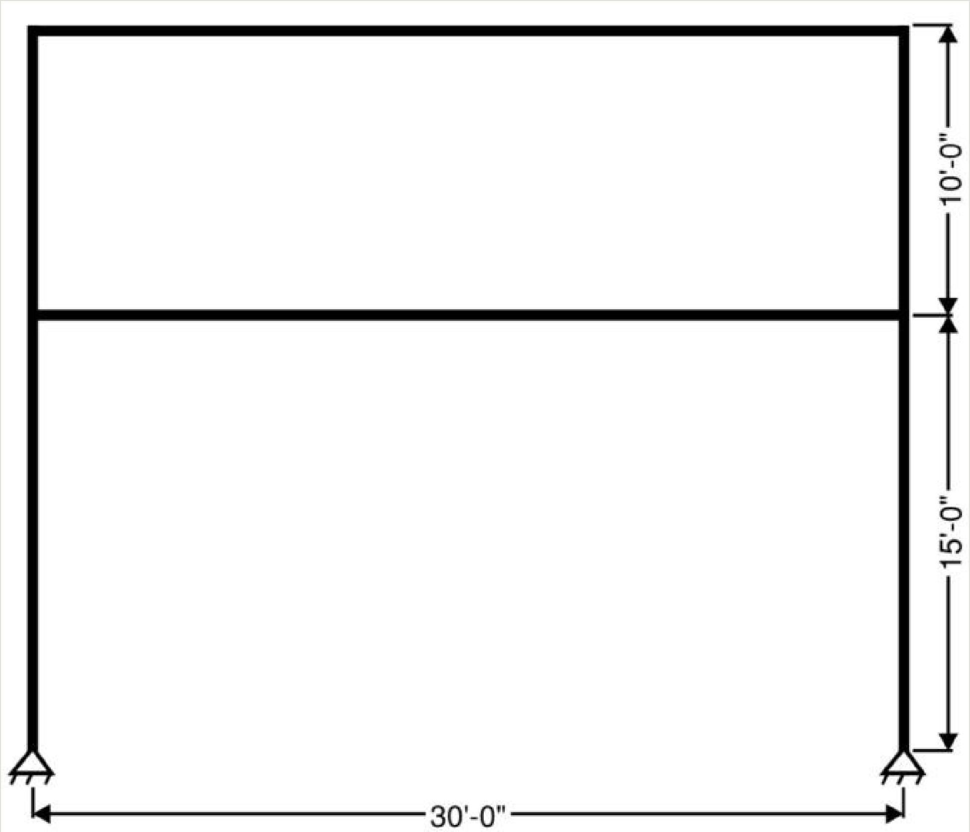
Questions?

Lateral
Practice Problems

LATERAL PROBLEMS

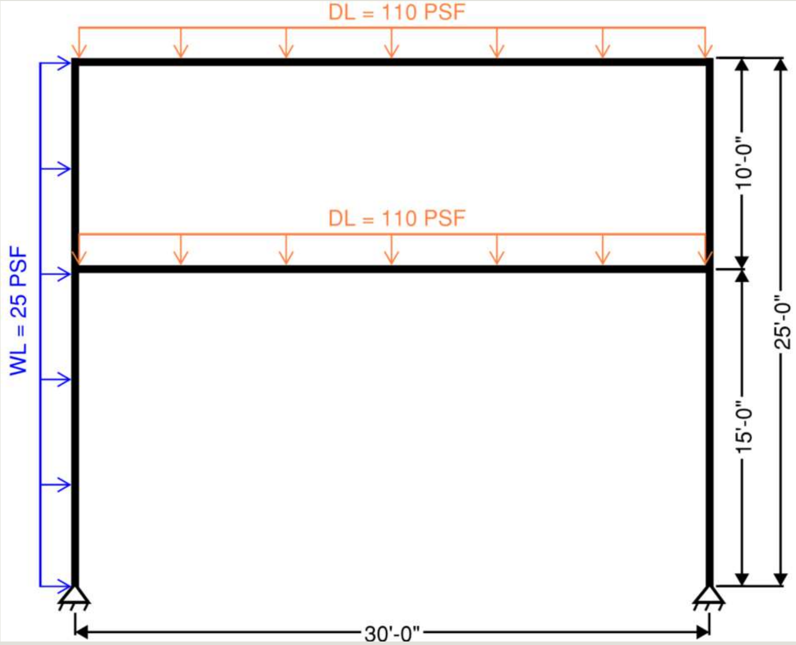
For a 2-storey square building in Austin, we want to determine the lateral load requirements that we will have for design.

We need to determine whether wind or seismic controls and figure out the design loads.



LATERAL PROBLEMS

1. Determine the base shears for both wind and seismic load cases.
2. For the controlling load case, determine the base overturning moment.



GIVENS

- 30’x30’ square building
- Uniform wind pressure of 25 psf
- Uniform DL=110 psf at both elevated floors
- Seismic Design Category “A” (C_S=0.01)

SEISMIC BASE SHEAR

Determine Floor Weight

$A_{L2} = A_{Roof} = (30')^2 = 900\ ft^2$

$W = 900\ ft^2\ x\ 110\ psf = 99{,}000\ lb$

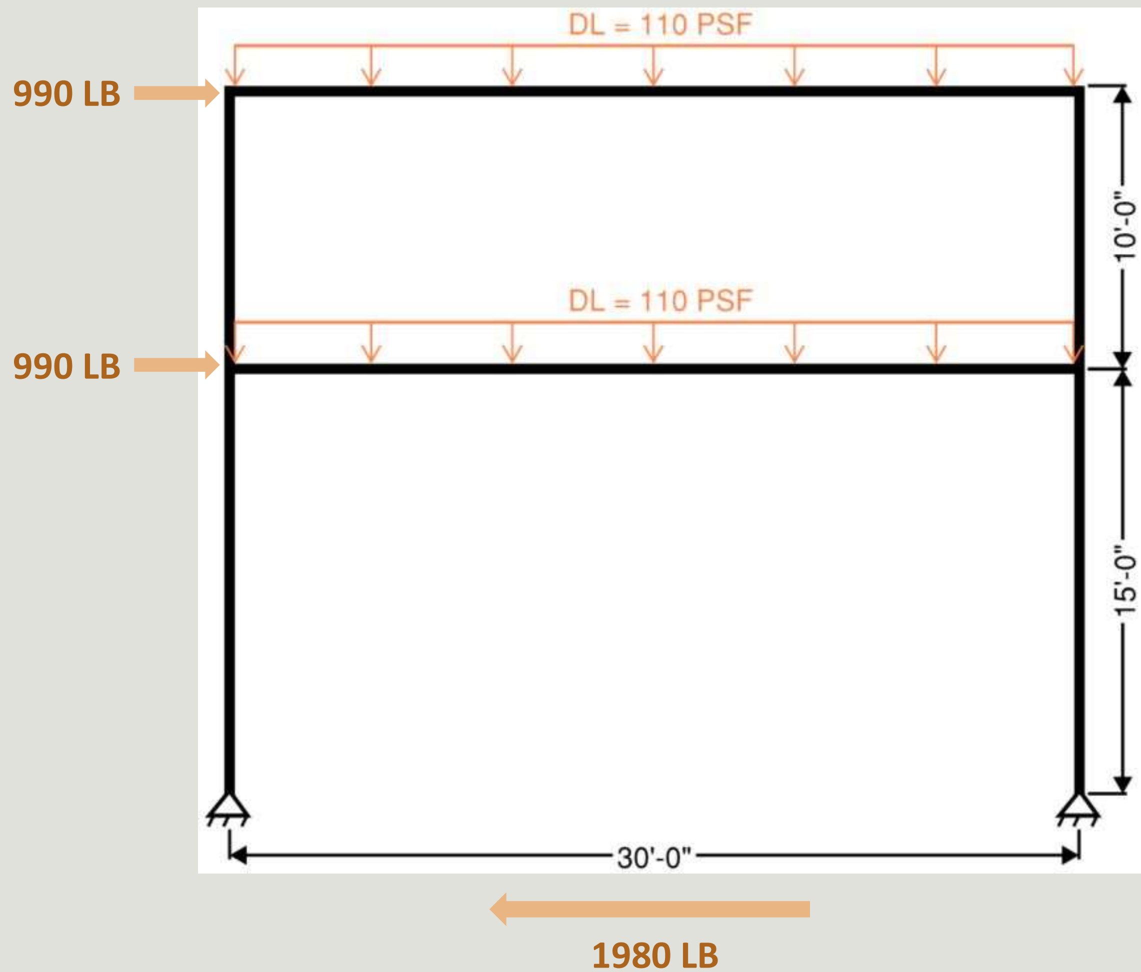
Determine Seismic Shear

$V = C_S W$

$V = 0.01\ x\ 99{,}000\ lbs$

$V_{L1} = V_{Roof} = 0.01\ x\ 99{,}000\ lb$
$= 990\ lb/floor$

$V_{BASE} = 2\ x\ 990\ lb = \mathbf{1980\ lb}$



WIND BASE SHEAR

Determine Tributary Areas

$$A_{L2} = 30ft\,[\frac{15\ ft}{2} + \frac{10\ ft}{2}] = 375\ ft^2$$

$$A_{Roof} = 30ft\,[\frac{10\ ft}{2}] = 150\ ft^2$$

Determine Wind Shears

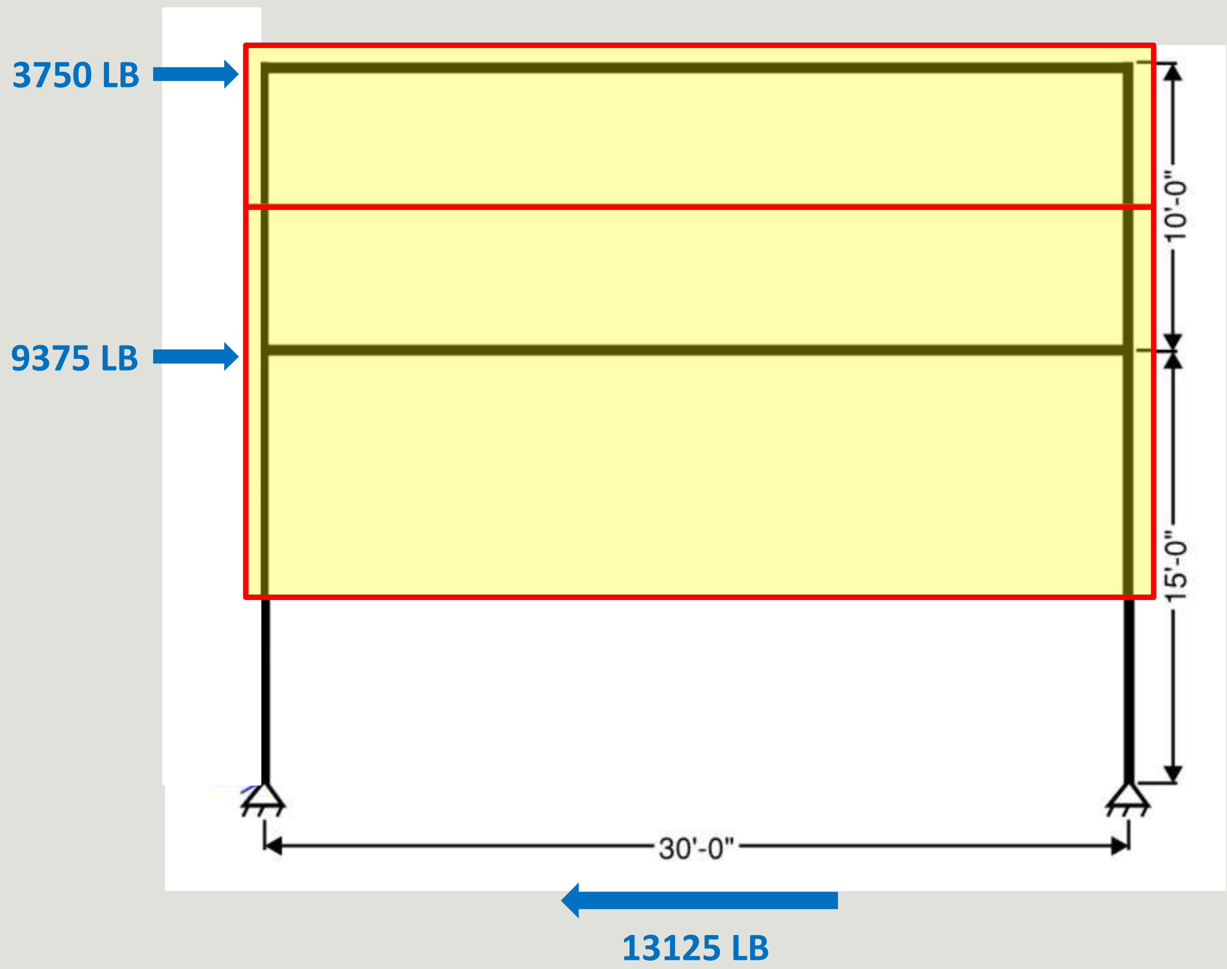
$$V = pA_T$$

$$V_{L2} = 25psf\ x\ 375\ ft^2 = 9375\ lb$$

$$V_{Roof} = 25psf\ x\ 150\ ft^2 = 3750\ lb$$

$$V_{BASE} = 9375\ lb + 3750\ lb = \mathbf{13125\ lb}$$

WIND CONTROLS!



OVERTURNING

Calculate Overturning Moment for Wind Load Case

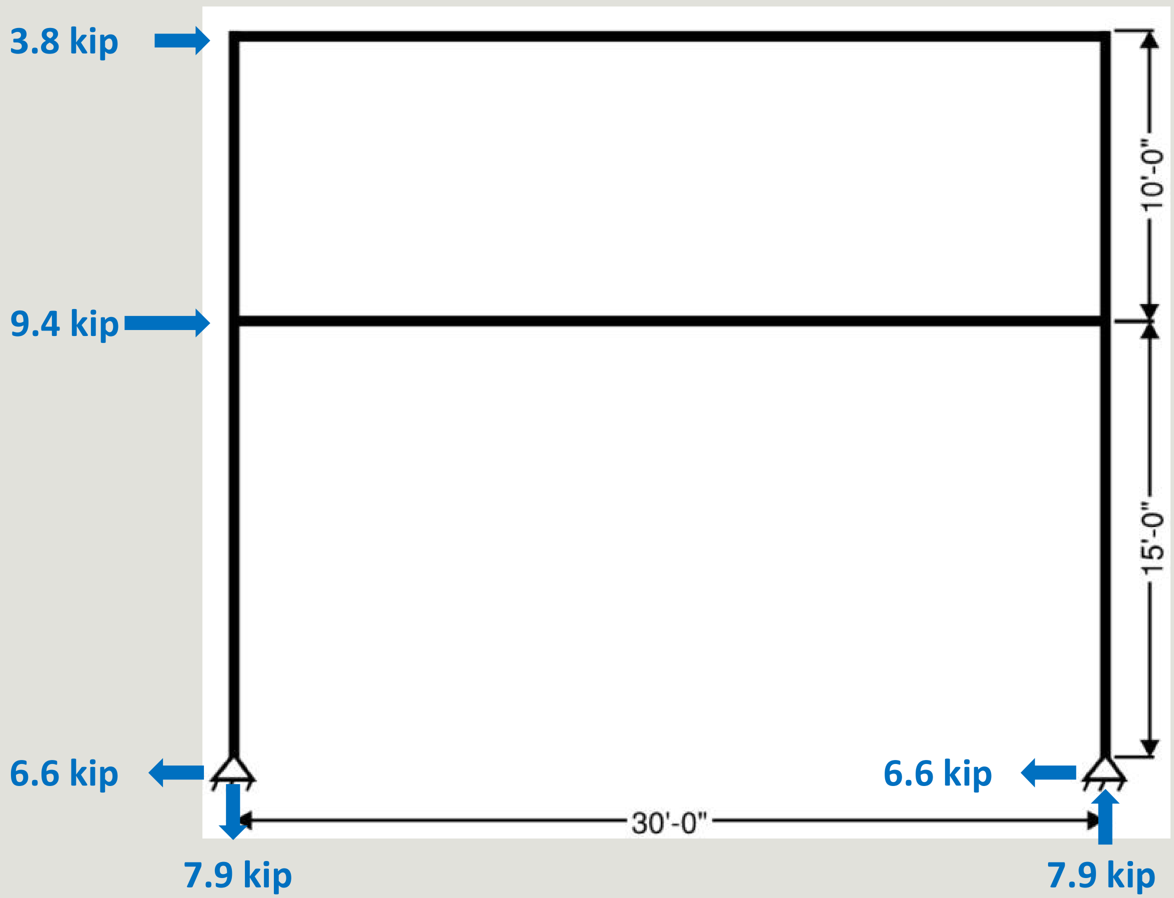
$M_O = Vh$

$M_O = (9.4\ kip)(15\ ft) + (3.8\ kip)(25\ ft)$

$M_O = 236\ kip \cdot ft$

Calculate Overturning Reactions

$R_y = \frac{236\ kip \cdot ft}{30\ ft} = \mathbf{7.9\ kip}$



Questions?

Thank You