Lecture 02

Design of One-way Slab System (Part – II)

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Design of 90′ X 60′ Hall

Option 2a

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Given Data

Dimensions of Hall : 90′ x 60′ (interior)

Story height, h = 20′

SDL: 3″ Mud layer and 2″ Tile layer

Live load: 40 psf

$f_c' = 3$ ksi

$f_y = 60$ ksi

$q_a = 2.204$ ksf

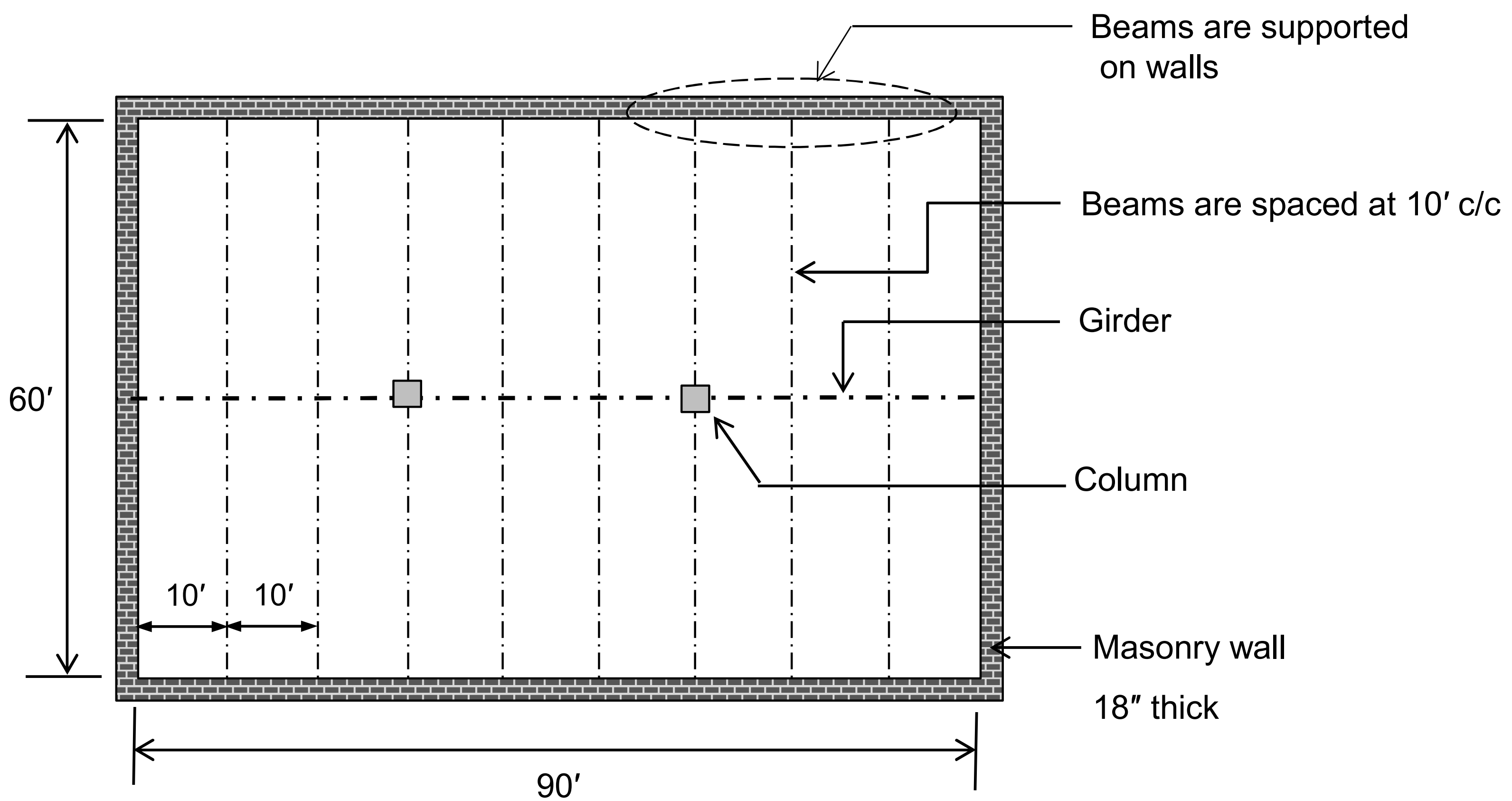
Required Data

Design the hall

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

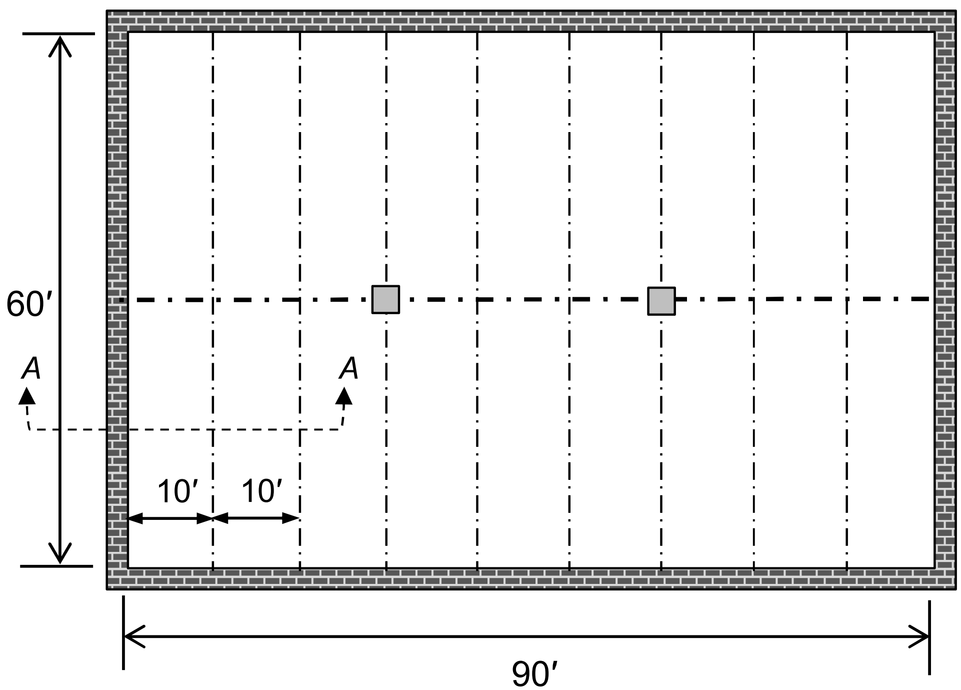
➢ Step 1: Selection of Structural Configuration



Design of 90′ X 60′ Hall

❑ Solution [option 2a]

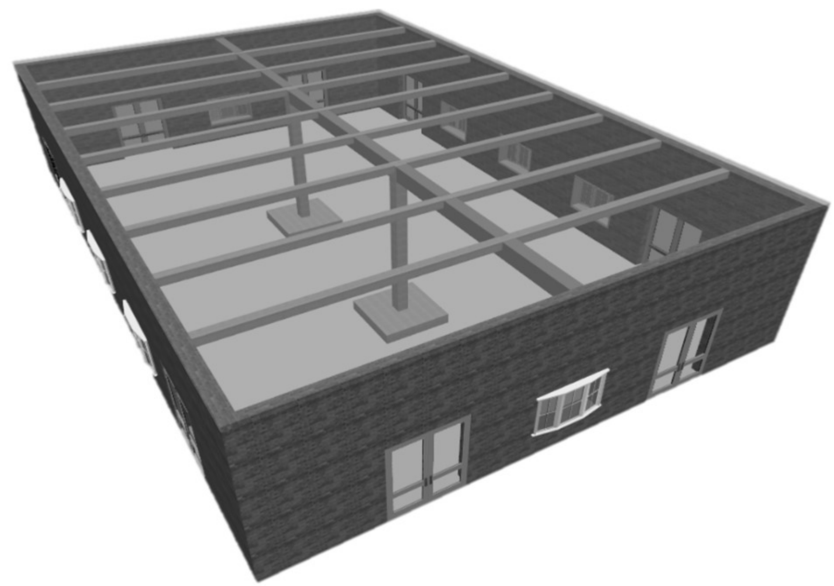
➢ Step 1: Selection of Structural Configuration

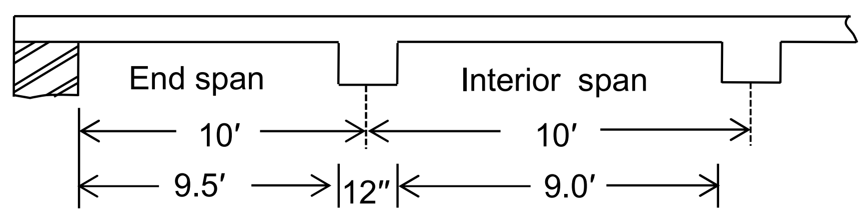


Assumed size of beam: 12″ x 24″

Assumed size of beam: 18″ x 36″

Assumed size of column: 18″ x 18″





Section A-A

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Slab Design

- **Step 2: Selection of Sizes**

$h_{min} = 5.4''$. Finally take $h = 6''$ (Same as that of Part I of this lecture)

- **Step 3: Calculation of Loads**

$W_u = 0.214$ ksf (Same as that of Part I of this lecture)

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Slab Design

➢ Step 4: Analysis

- Using ACI Approximate coefficients, the results obtained are shown in figure.

[1] For calculating negative moments, ℓ_n shall be the average of the adjacent clear span lengths (ACI:6.5.2)

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Slab Design

➢ Step 5: Determination of flexural steel area

Calculate moment capacity provided by minimum reinforcement

$A_{s,min} = 0.129 \text{ in}^2/\text{ft}$

$\emptyset M_{n,min} = 33.95 \text{ in.k/ft}$ (Same as that of Part I of this lecture)

$\emptyset M_{n,min}$ is greater than all moments calculated in Step No 4. Hence Minimum reinforcement governs.

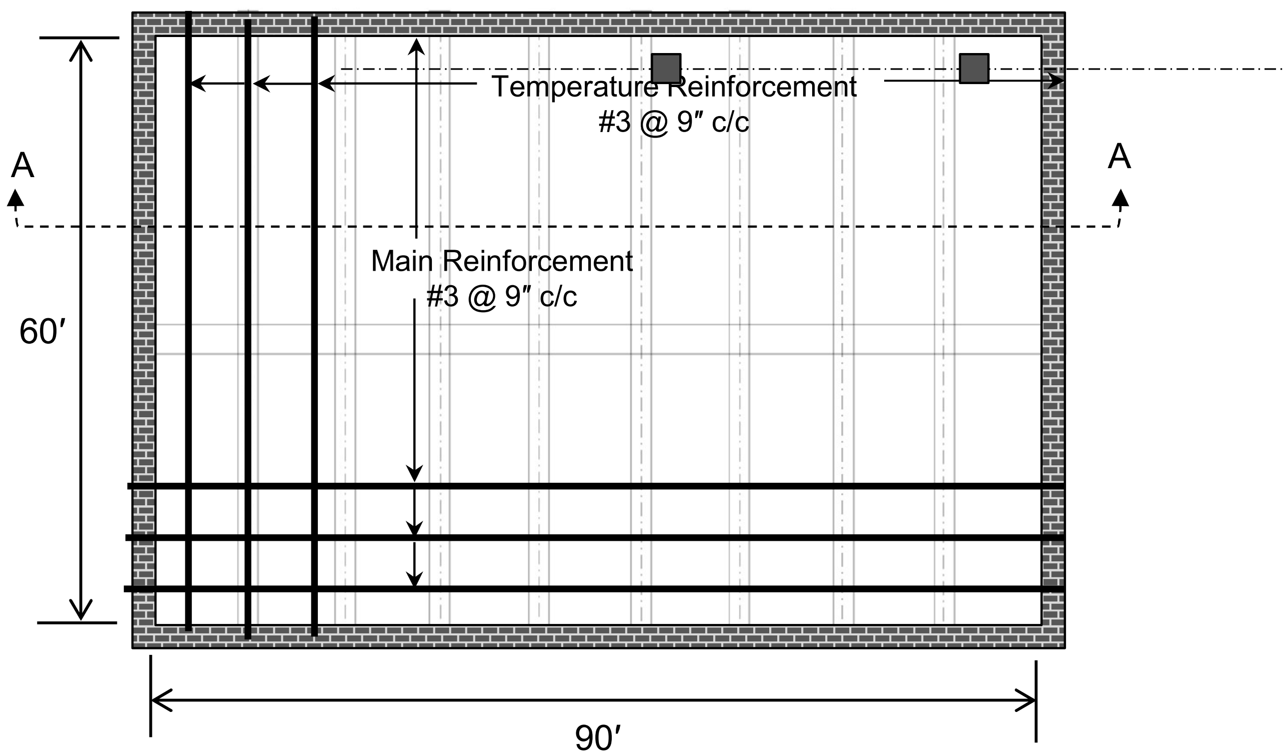
Finally provide #3 @ 9″ c/c for both main and shrinkage bars.

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Slab Design

➢ **Step 7: Drafting**

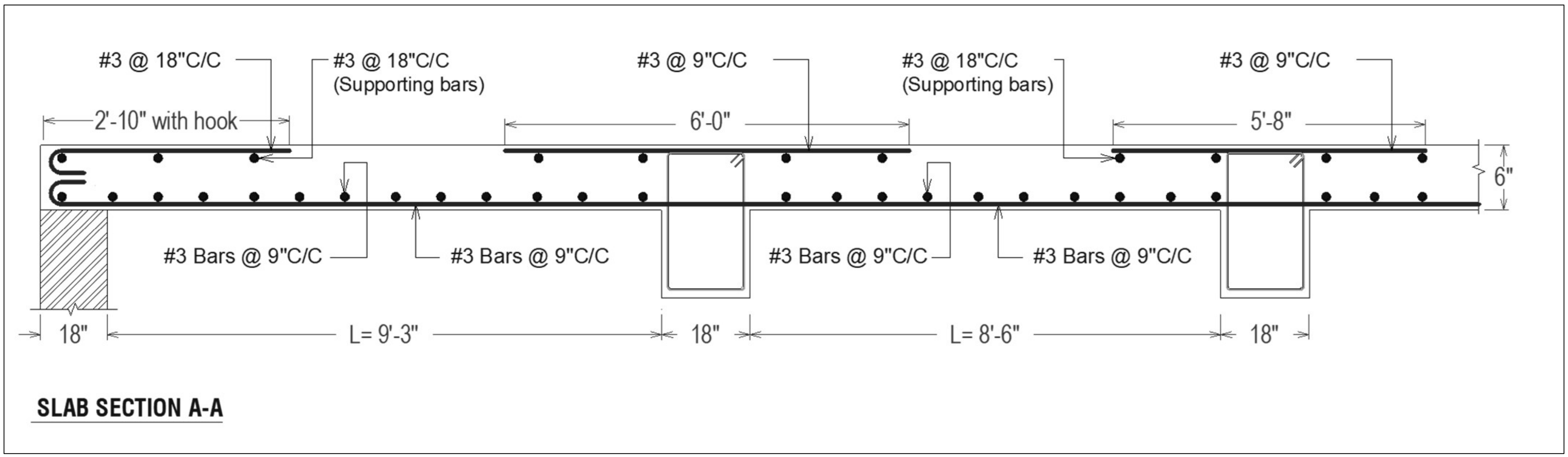


Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Slab Design

- Step 7: Drafting



Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Beam Design

➢ **Step 2: Selection of Sizes**

Assuming 12″ width of beam, The minimum depth of beam for a one end continuous beam is given by

$$h_{min} = \frac{l}{18.5} = \frac{30 + \left(\frac{9}{12}\right)}{18.5} = 1.66'$$

$$h_{min} = 19.92''$$

Take $h = 24''$

Effective depth, $d = 24 - 2.5 = 21.5''$

Design of 90′ X 60′ Hall

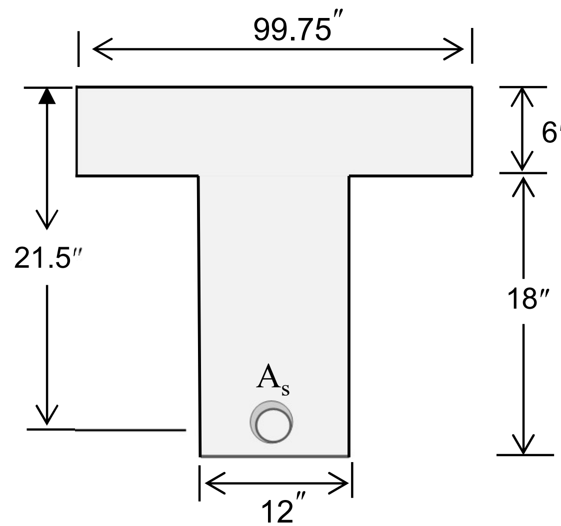
Solution [option 2a]

Beam Design

Step 2: Selection of Sizes

Effective width of T- beam b_f is minimum of:

- $b_w + 16h_f = 12 + 16(6) = 108"$
- $b_w + s_w = 12 + 9 \times 12 = 120"$
- $b_w + \frac{l_n}{4} = 12 + \frac{29.25}{4} \times 12 = 99.75"$



Therefore, $b_f = 99.75"$

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

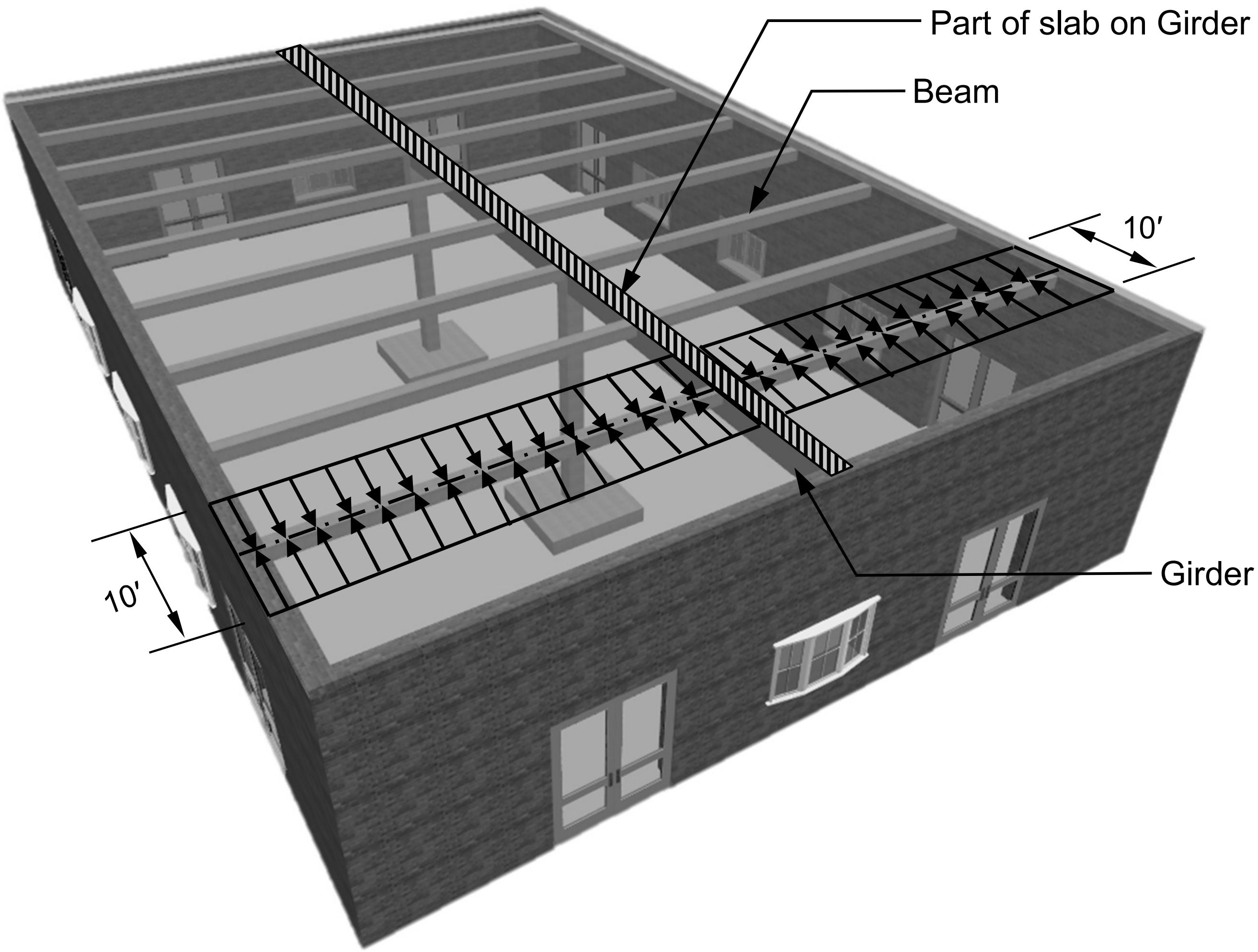
❖ Beam Design

➢ **Step 3: Calculation of Loads**

- Before performing any calculations for the load on a beam, it is essential to understand the Structural Idealization.
- For this, please pay close attention to the animation in the upcoming slides.

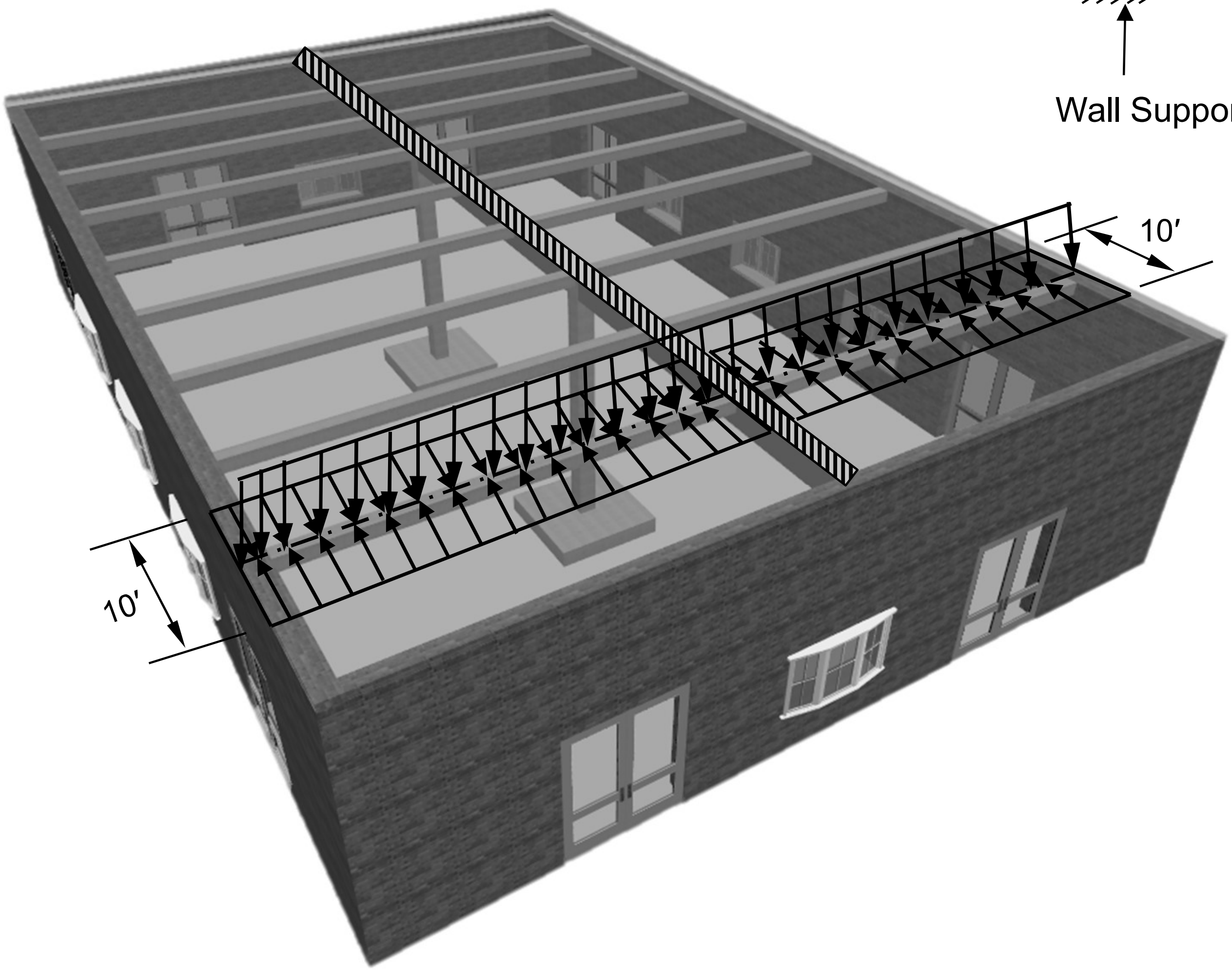
Design of 90′ X 60′ Hall

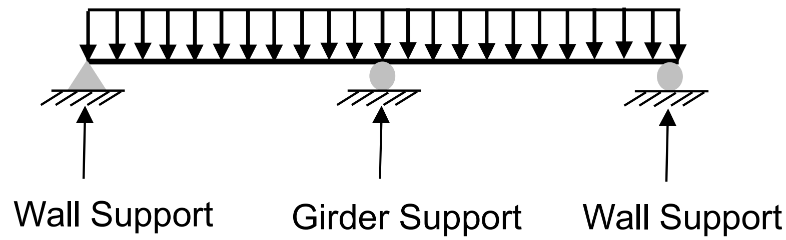
❑ Structural Idealization



Design of 90′ X 60′ Hall

❑ Structural Idealization

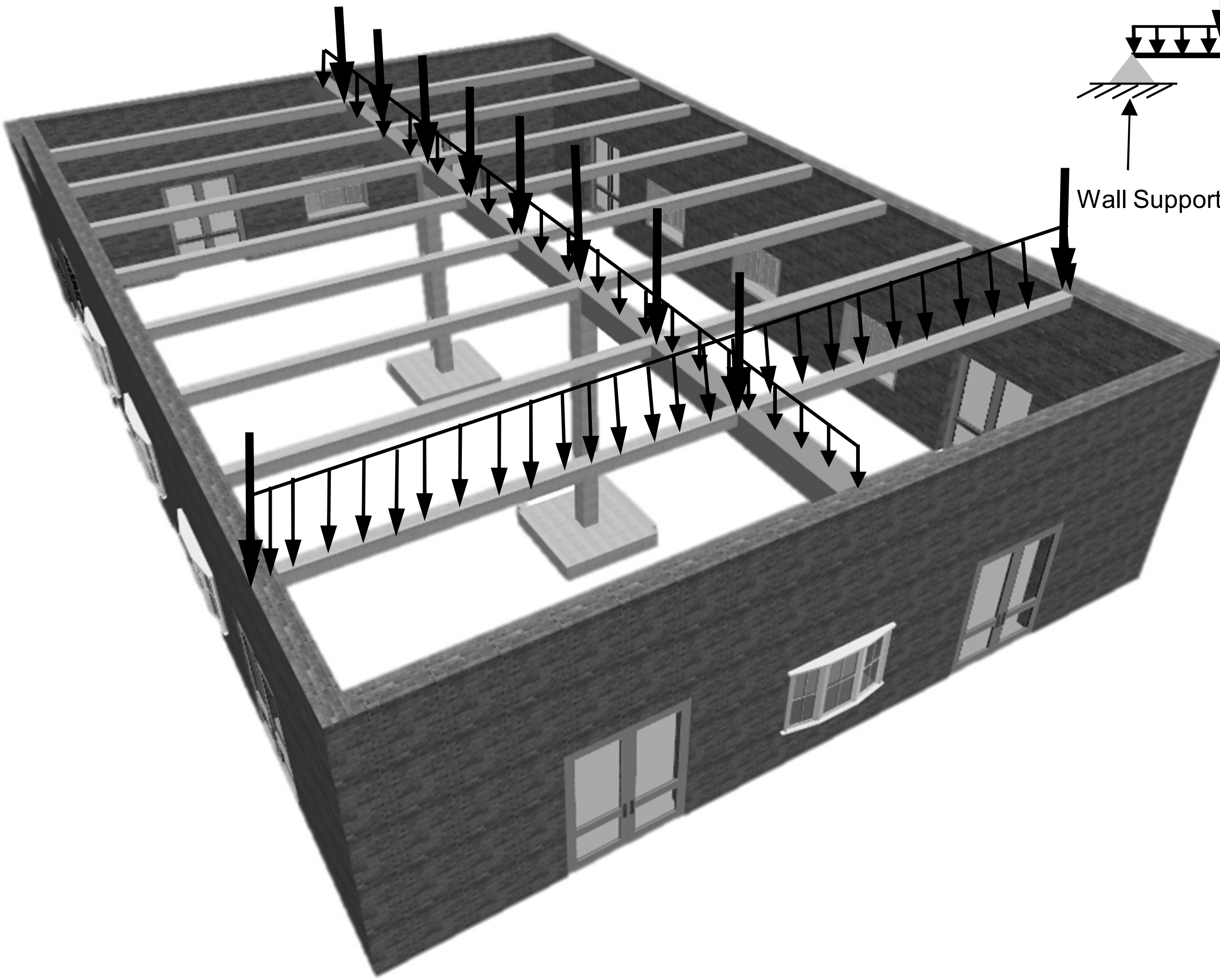


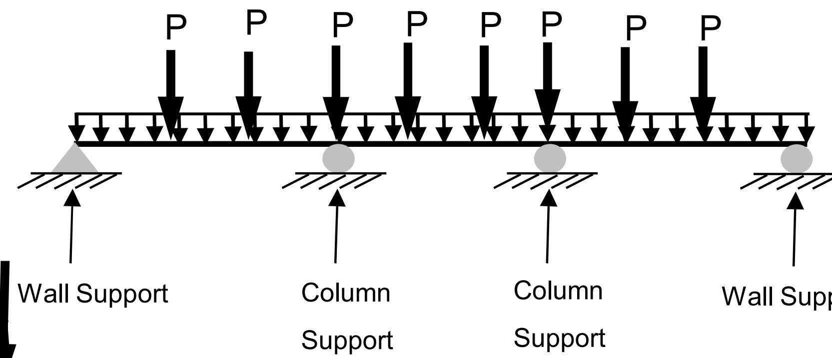


Idealized Beam

Design of 90′ X 60′ Hall

❑ Structural Idealization





Idealized Girder

Note that, Beam loads acting as a point load **"P"** on Girder.

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Beam Design

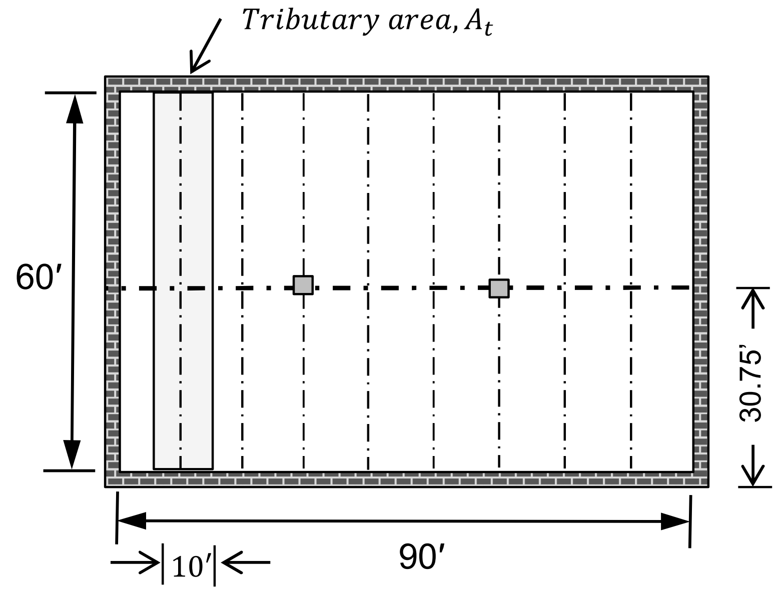
➢ Step 3: Calculation of Loads

$$SW = \frac{12(24-6)}{144} \times 0.150 = 0.225k/ft$$

Now,

$$W_{u,beam} = 0.214 \times 10 + 1.2(0.225)$$

$$W_{u,beam} = 2.41k/ft$$

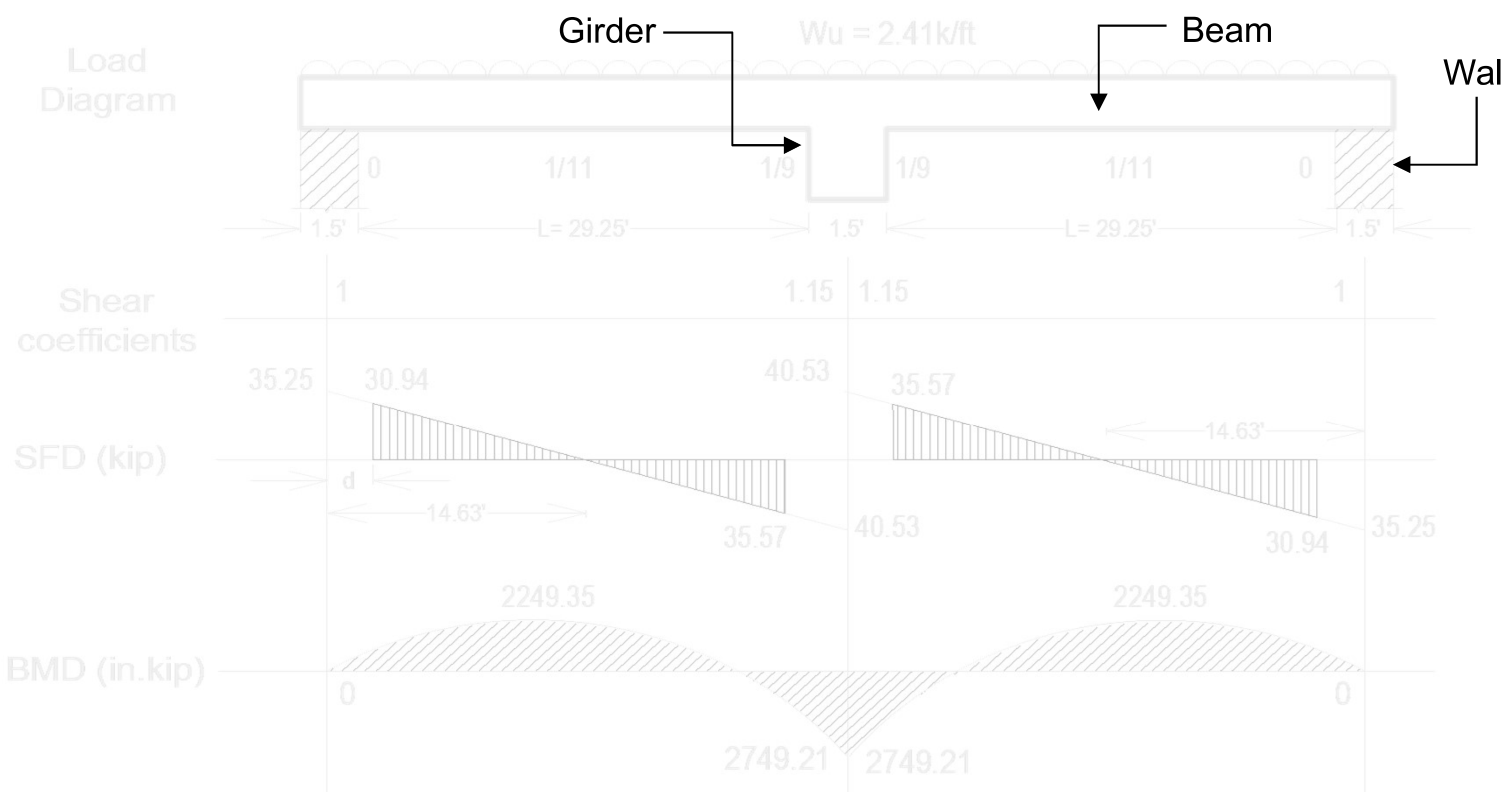


Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Beam Design

➢ **Step 4: Analysis**



Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Beam Design

➢ **Step 5: Determination of Reinforcement**

Flexural Reinforcement and Detailing				
Moment, in-kip	A_s, in^2	A_{min}, in^2	A_{max}, in^2	**Detailing**
$M_u(+)$ = 2249.35	1.96	0.86	3.47	3-#8
$M_u(-)$= 2749.21	2.7	0.86	3.47	4-#8

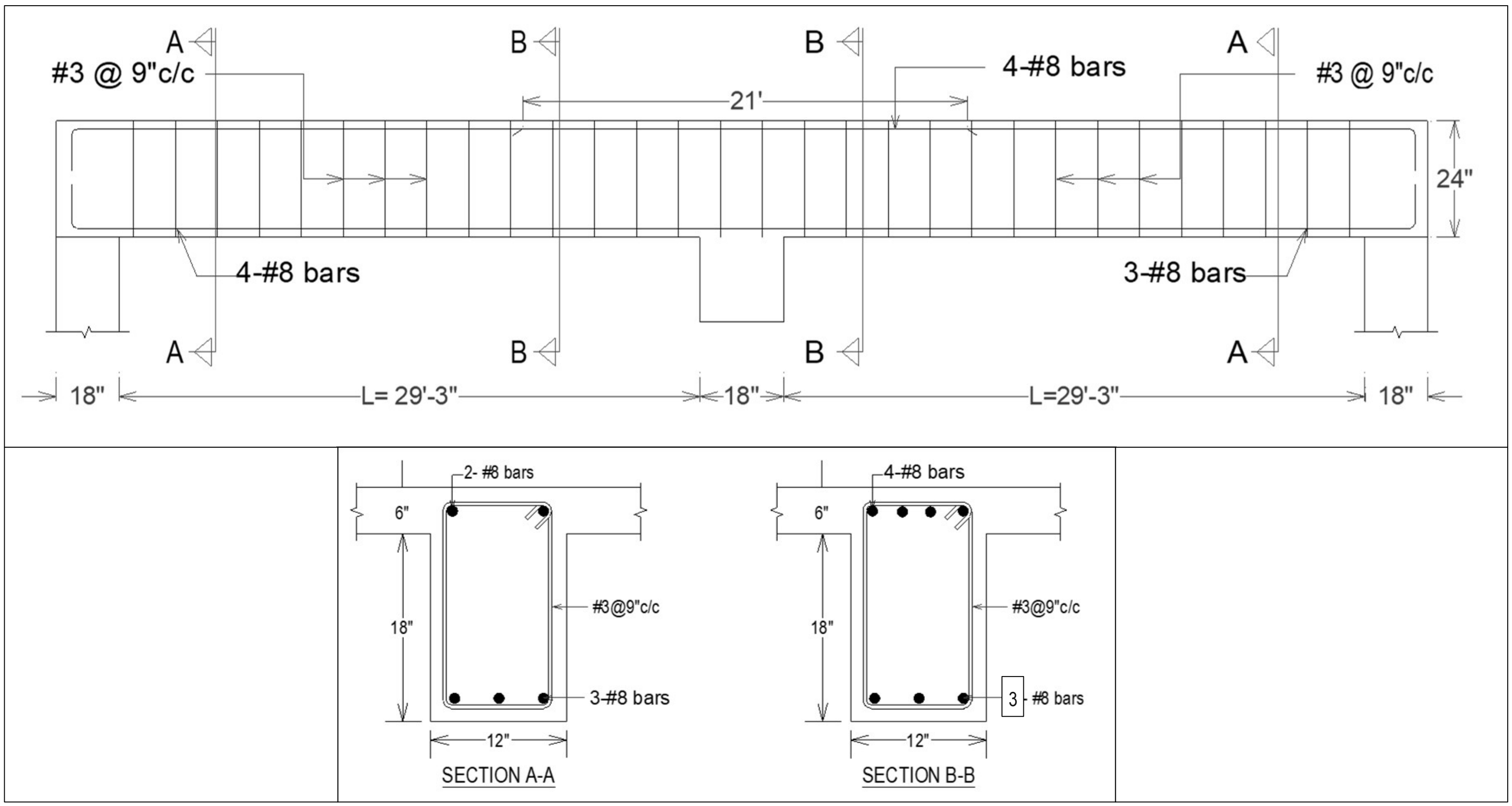
Shear Reinforcement and Detailing					
V_s (k)	$V@d$ (k)	$\emptyset V_c$ (k)	S_d (in.)	S_{max} (in.)	S **taken** (in.)
40.53	35.57	21.52	14.8	10.8	9
Provided reinforcement satisfies necessary shear checks					

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Beam Design

➢ Step 6: Drafting



Design of 90′ X 60′ Hall

❑ Solution [option 2a]

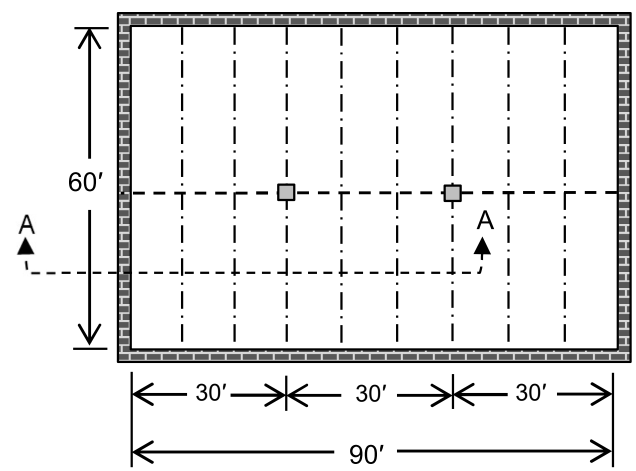
❖ Girder Design

➢ Step 2: Selection of Sizes

$$h_{min,1} = \frac{l}{18.5} = \frac{30.75}{18.5} = 1.66' \; or \; 19.9"$$ (for one end continuous members)

$$h_{min,2} = \frac{l}{21} = \frac{28.5}{21} = 1.36' \; or \; 16.3"$$ (for both end continuous members)

Take h = 36″



Design of 90′ X 60′ Hall

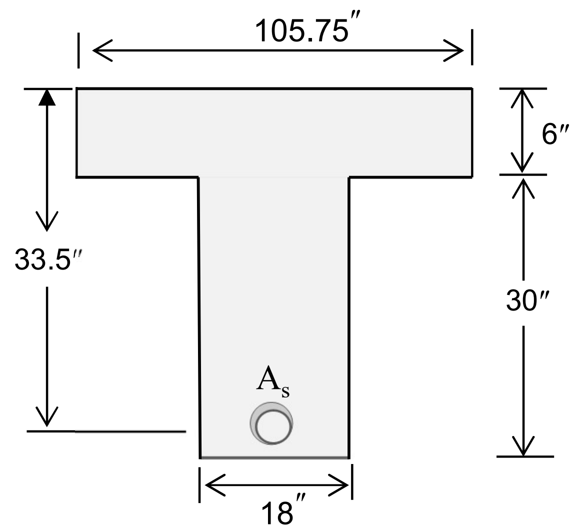
❑ Solution [option 2a]

❖ Girder Design

➢ Step 2: Selection of Sizes

Assume 18″ wide web . The effective width of T – beam, b_f is minimum of:

- $b_w + 16h_f = 18 + 16(6) = 114"$
- $b_w + s_w = Not\ applicable$
- $b_w + \frac{l_n}{4} = 18 + \frac{29.25}{4} \times 12 = 105.75"$



Therefore, $b_f = 105.75"$

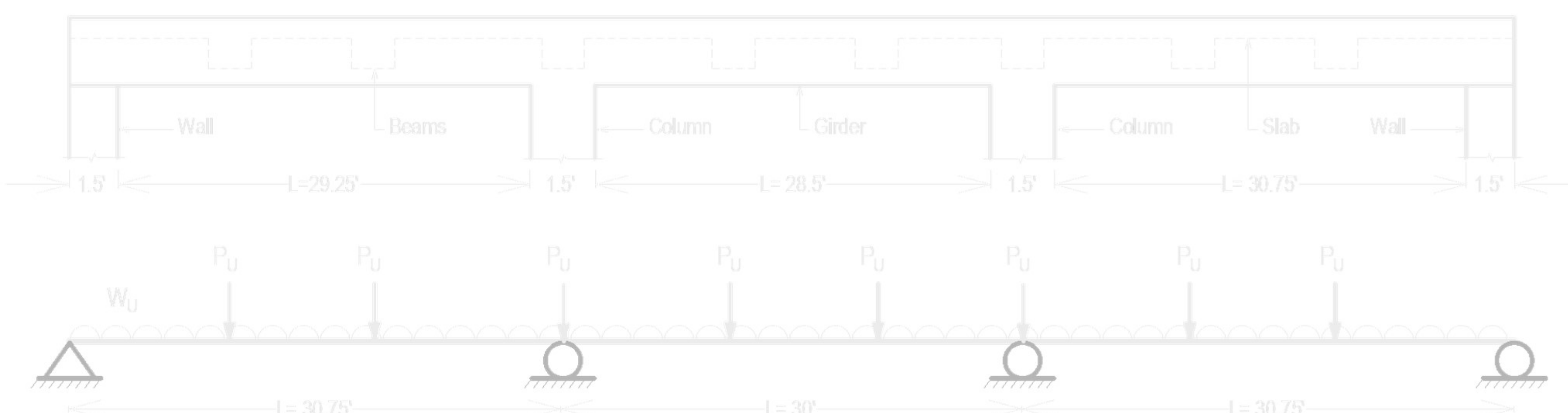
Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Girder Design

➢ Step 3: Calculation of Loads

- Beams load can be approximated as point loads on girder. The uniformly distributed load on girder is coming from self weight of girder rib plus weight of slab directly resting on girder.



Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Girder Design

➢ Step 3: Calculation of Loads

- Since the girder is subject to both uniform and pointed loads, the ACI coefficient method is not applicable here.
- For the analysis of such cases, any elastic analysis method, such as the slope deflection method, moment distribution method, flexibility method, stiffness method, etc., may be used.

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Girder Design

➢ Step 3: Calculation of Loads

- P is the point load on girder and is the reaction coming from the interior support of beam due to factored load. From below figure;

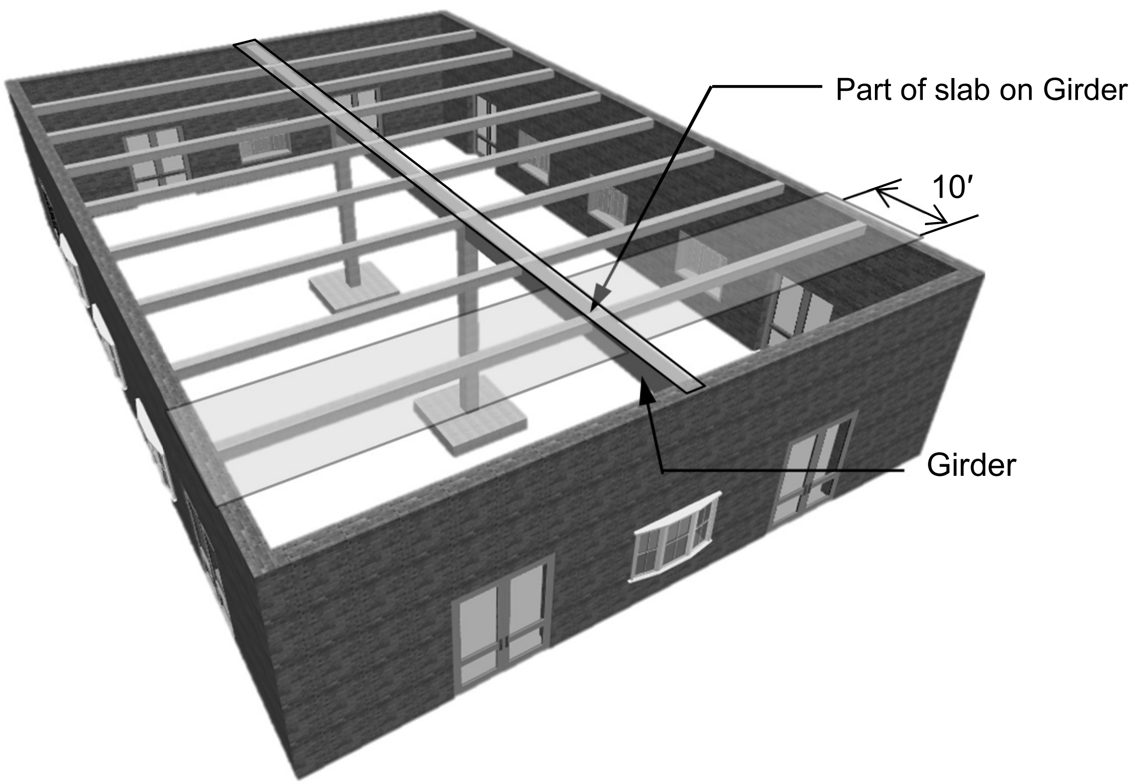
  P = 2(40.53) = 81.1k

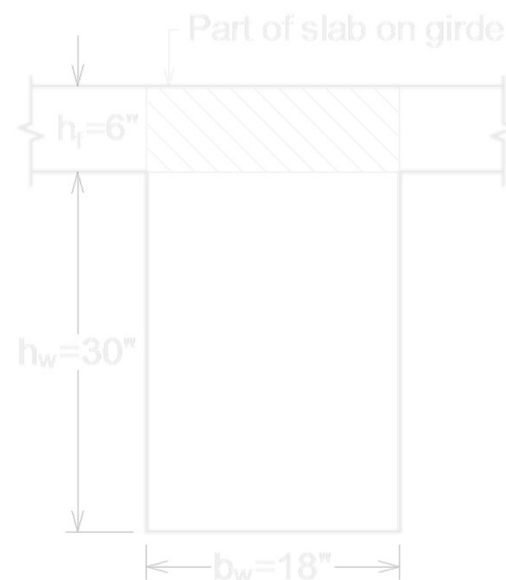
Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Girder Design

- ➢ **Step 3: Calculation of Loads**





Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Girder Design

➢ Step 3: Calculation of Loads

Self weight of girder can be calculated as follows

$$SW = \frac{18 \times (36-6)}{144} \times 0.150 = 0.563k/ft$$

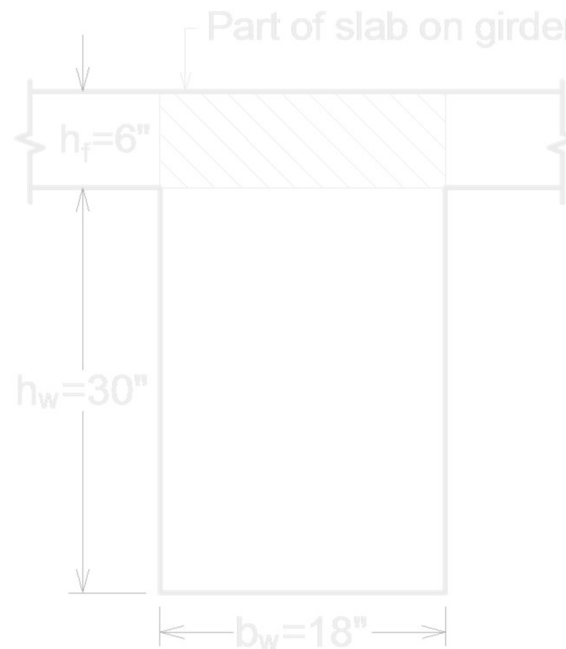
Load from part of slab on girder is given by

$$SDL = W_{u,slab} \times b_w = 0.214 \times \frac{18}{12}$$

$$= 0.321\text{k/ft}$$

Now,

$$W_{u,girder} = 0.321 + 1.2(0.563) = 1\ \text{k/ft}$$

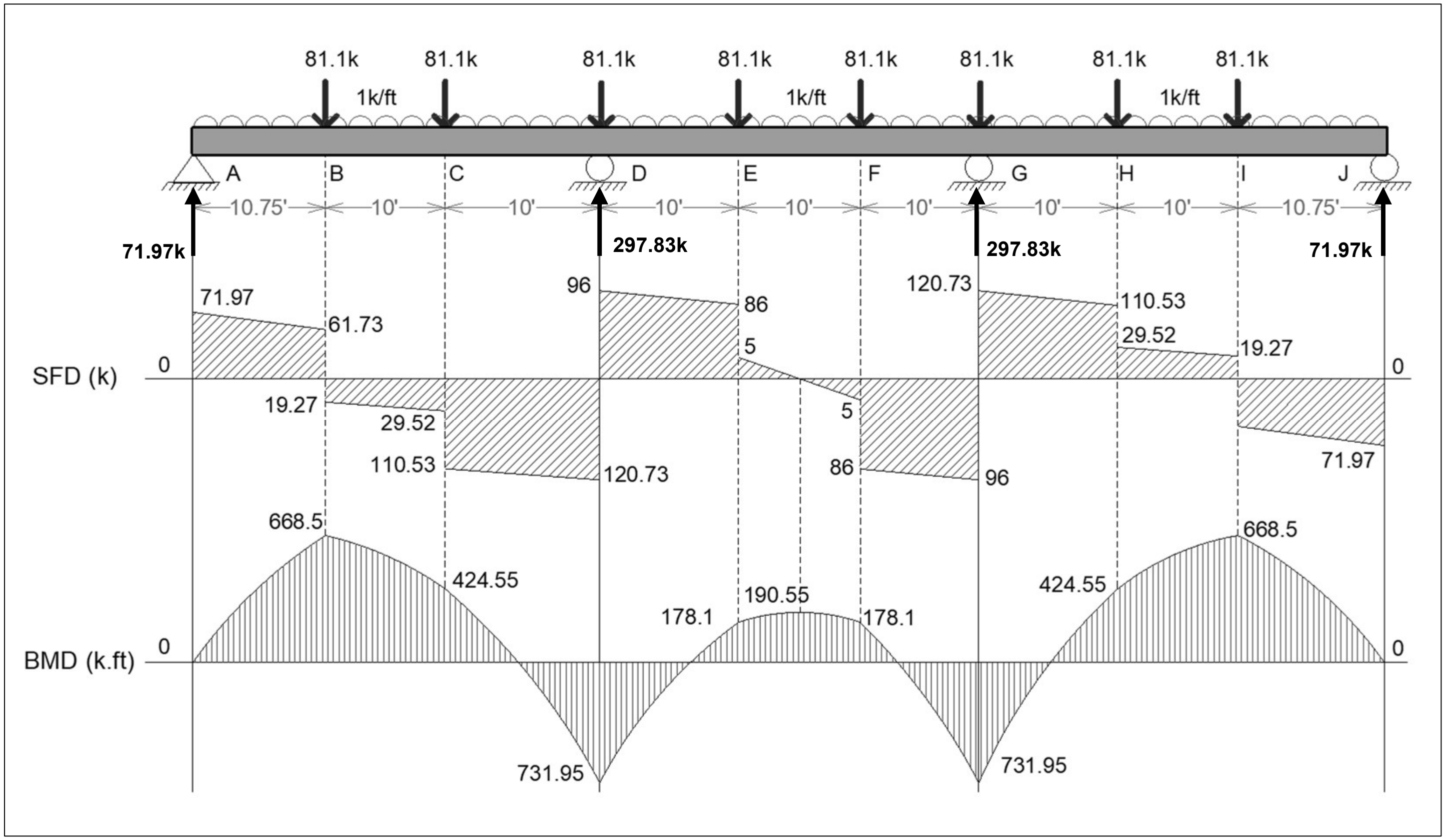


Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Girder Design

➢ Step 4: Analysis



Design of 90′ X 60′ Hall

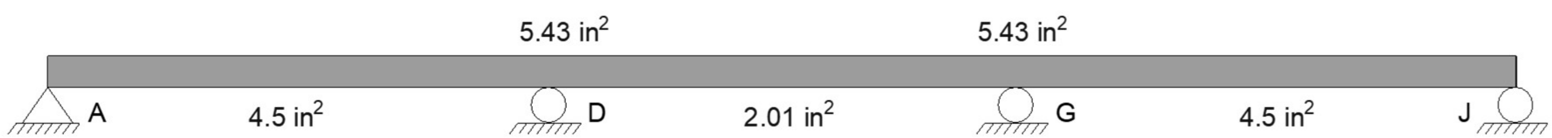
❑ Solution [option 2a]

❖ Girder Design

➢ Step 5: Determination of Flexural Reinforcement

- The required areas of steel for the maximum bending moments at key points are tabulated below.

Location	M_u (kip-ft)	d (in.)	b (in.)	A_s (in^2)	A_{smin} (in^2)	A_{smax} (in^2)	Detailing
Exterior +	668.5	33.5	105.75	4.5	2.01	8.11	(3+3) - #8
Interior −	731.95	33.5	18	5.43	2.01	8.11	(5+2) - #8
Interior +	190.55	33.5	105.75	1.26	2.01	8.11	3 - #8



Design of 90′ X 60′ Hall

Solution [option 2a]

Girder Design

Step 6: Determination of Shear Reinforcement

- Design shear capacity of reinforced concrete is given by

$$\emptyset V_c = 2\emptyset\sqrt{f_c'}b_w d = \frac{2 \times 0.75\sqrt{3000}\,(18 \times 33.5)}{1000} = 49.54 kip$$

- Because shear force values abruptly change at each key point, calculating spacing for each demand shear is time consuming and tedious.
- Therefore, we will adopt a different strategy in this case.

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Girder Design

➢ Step 6: Determination of Shear Reinforcement

Calculate maximum spacing s_{max} using #3 bar as stirrup.

$$s_{max} = Least\ of \left\{ \begin{array}{l} \dfrac{A_v f_y}{50 b_w} = \dfrac{0.22 \times 60000}{50 \times 18} = 14.6" \\[2ex] \dfrac{A_v f_y}{0.75\sqrt{f_c{'}}\, b_w} = \dfrac{0.22 \times 60000}{0.75\sqrt{3000} \times 18} = 17.8" \\[2ex] \dfrac{d}{2} = \dfrac{33.5}{2} = 16.8" \\[2ex] 24" \end{array} \right\} s_{max} = 14.6"$$

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Girder Design

➢ Step 6: Determination of Shear Reinforcement

The design shear capacity provided by stirrups using the maximum spacing S_{max} is calculated as;

$$\emptyset V_s = \frac{\emptyset A_v f_y d}{S_{max}} = \frac{0.75 \times 0.22 \times 60 \times 33.5}{14.6} = 22.72 \text{ kip}$$

Now, the overall design shear capacity of the girder is given by

$$\emptyset V_n = \emptyset V_c + \emptyset V_s = 49.54 + 22.72 = 72.3 \text{ kip} > max.shear\ at\ A\ \&\ C.$$

It means that maximum spacing of 14.6″ as permitted by ACI governs between point **A** and **C**. Finally, #3@ 9″ c/c will be provided.

Design of 90′ X 60′ Hall

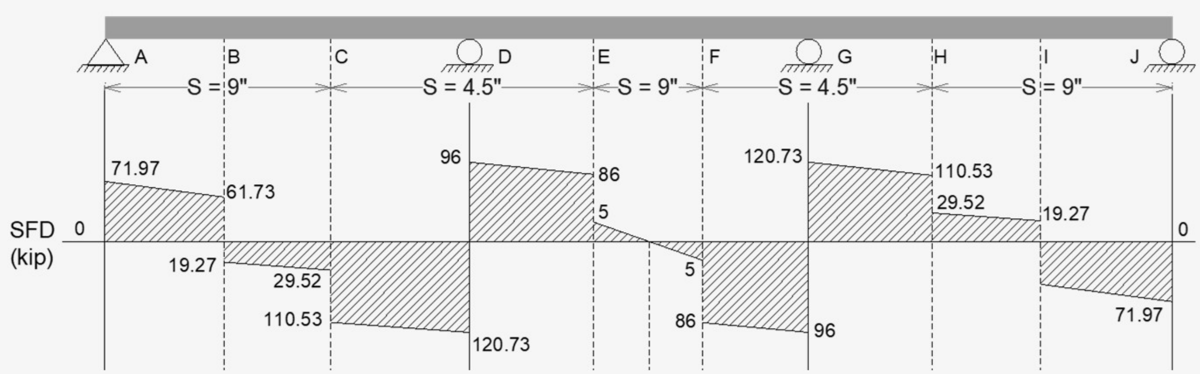
❑ Solution [option 2a]

❖ Girder Design

➢ Step 6: Determination of Shear Reinforcement

Calculate spacing for shear reinforcement between point **C** and **E.**

Location	V_{max} (k)	$V@d$ (k)	$\emptyset V_c$ (k)	S_d (in.)	S_{max} (in.)	S taken (in.)
CD	120.73	117.5	49.54	4.9	14.6	4.5
DE	96	94	49.54	7.5	14.6	4.5
Provided shear reinforcement satisfies necessary shear checks						

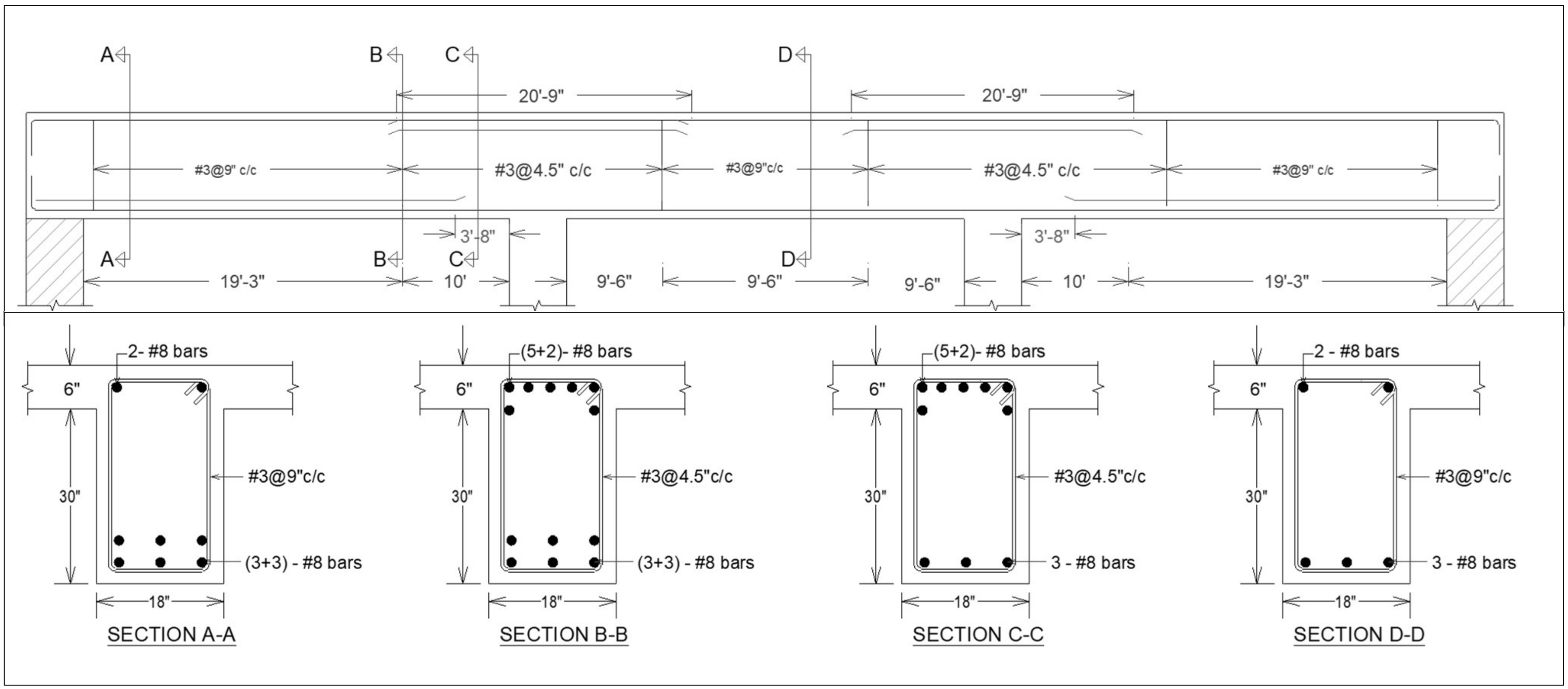


Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Girder Design

➢ Step 7: Drafting

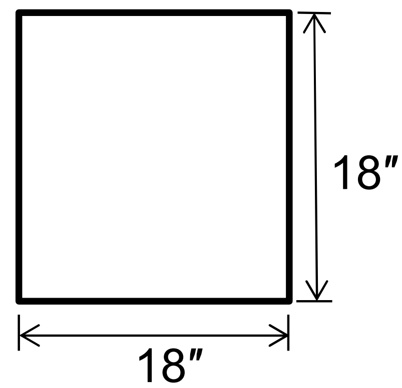


Design of 90′ X 60′ Hall

Solution [option 2a]

Column Design

- **Given Data**
  - Size of column : $18'' \times 18''$
  - Factored load = 297.8 kips (Reaction at the interior support)
  - Service load = 234 kips (Reaction at the support due to service load)
  - Compressive strength of concrete, $f_c' = 3\ ksi$
  - Yield Tensile strength of steel, $f_y = 60\ ksi$



Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Column Design

➢ Step 1 Determination of Main longitudinal reinforcement

Calculate design axial capacity of column by assuming 1% steel area and compare the calculated capacity with demand axial load

Assuming $A_{st} = 0.01A_g$;

$$\alpha \emptyset P_n = 0.80 \times 0.65\left[0.85 \times 3\ (A_g - 0.01A_g) + (60)0.01A_g\right] = 1.521A_g$$

$$\alpha \emptyset P_n = 1.521(324) = 526.42\ \text{kip} > P_u = 297.8\ \text{kip} \rightarrow$$ OK!

Therefore, $A_{st} = 0.01A_g = 0.01(324) = 3.24\ \text{in}^2$ (8 - #6 bars)

Design of 90′ X 60′ Hall

Solution [option 2a]

Column Design

Step 2 Determination of Spacing for shear reinforcement

Using #3 bar with $A_b = 0.11 \text{ in}^2$

i. $\frac{A_v f_y}{50 b_w}$ = 0.22 x 60,000/ (50x18) = 14.7″

ii. $\frac{A_v f_y}{0.75\sqrt{f_c{}'} b_w}$ = 0.22 x 60,000 / (0.75$\sqrt{3000}$ x18) = 17.9″

iii. 16d_b of longitudinal bar = 16 x 0.75 = 12″

iv. 48 d_b of tie bar = 48 x 3/8 = 18″

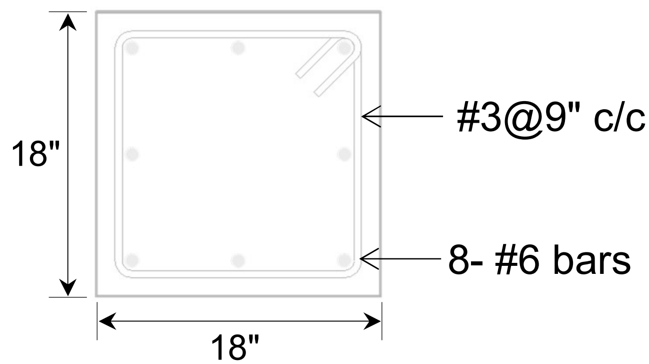
v. Smallest dimension of member = 18″

$S_{max} = 12''$. Finally use #3 ties @ 9″ c/c

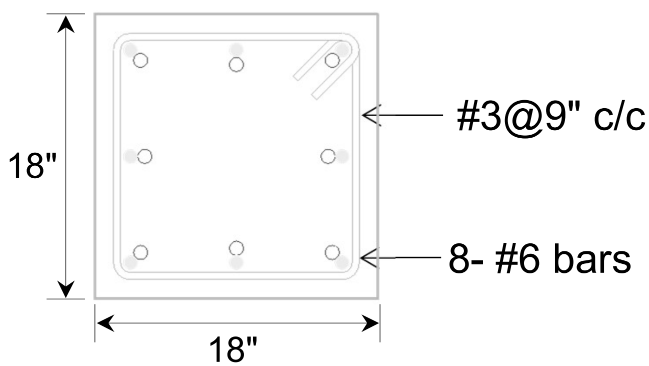
Design of 90′ X 60′ Hall

❑ Solution [option 2a]

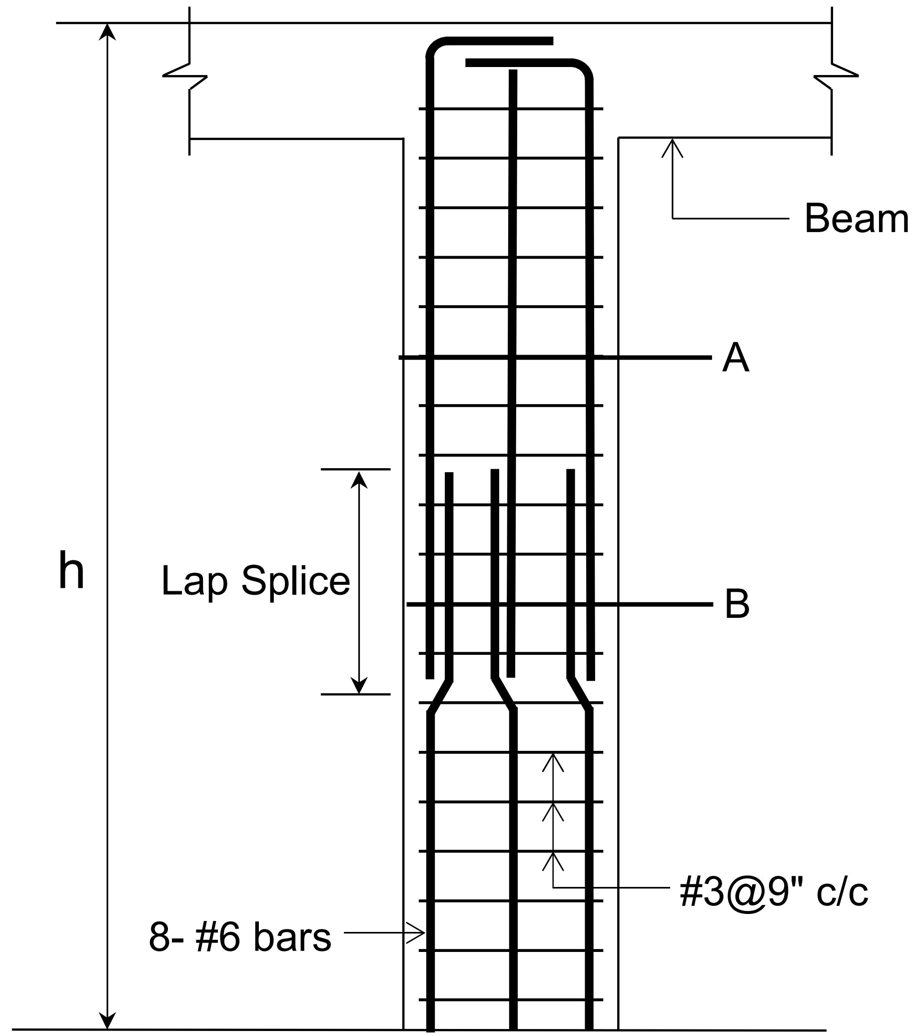
❖ Column Design



Section A-A



Section B-B



Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Footing Design

- **Given Data**
  - Size of column : 18″ x 18″
  - Factored load = 297.8 kips
  - Service load = 234 kips
  - Compressive strength of concrete, $f_c' = 3$ ksi
  - Yield Tensile strength of steel, $f_y = 60$ ksi
  - Allowable bearing capacity of soil, $q_a = 2.204$ ksf
  - Depth of footing from base level, $Z = 5'$

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Footing Design

STEP WISE ANALYSIS

Estimation of footing thickness and d_{avg}

d_{avg} = 20.50 in

Overburden pressure

W = 0.600 ksf

Effective bearing capacity

q_e = 1.604 ksf

Bearing Area

A_{req} = 145.89sq.ft (B = 12' - 2")

Critical shear Parameter

b_o = 154.00 in

Design pressure qu

q_u = 2.034 ksf

Punching shear force V_{up}

Vup = 276.9 kip

Check for Punching Shear

ΦVcp = 518.7 kip →OK!

Calculation of Maximum Moment Mu

M_u = 4148.034 in.kip

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Footing Design

Using Direct Method;

$$a = d - \sqrt{d^2 - \frac{2.614M_u}{f_c'B}} = 20.5 - \sqrt{20.5^2 - \frac{2.614 \times 4148.03}{3 \times (146)}} = 0.61"$$

$$A_s = \frac{M_u}{\emptyset f_y(d - \frac{a}{2})} = \frac{4148.03}{0.9 \times 60\left(20.5 - \frac{0.61}{2}\right)} = 3.8 \text{ in}^2$$

Now,

$$A_{s,min} = 0.0018\,Bh = 0.0018(146)(24) = 6.30\,in^2$$

$$A_s < A_{s,min} \rightarrow A_{s,min}\ governs$$

Design of 90′ X 60′ Hall

Solution [option 2a]

Footing Design

Using #4 bar with $A_b = 0.20\ in^2$

$$n = \frac{6.3}{0.20} = 31.5 \approx 32$$

$$S = \frac{B - 2C_c}{n - 1} = \frac{146 - 6}{31} = 4.5''c/c$$

Check for maximum bar spacing

$$s_{max} = Least\ of\ 3h = 3 \times 24 = 72''\ or\ 18'' = 18''$$

Provided spacing is OK!

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Footing Design

For crack control, the maximum spacing between the adjacent bars shall not exceed S_{max} (Table 24.3.2).

$$s_{max} = \text{Least of } 15\left(\frac{40{,}000}{f_s}\right) - 2.5C_c \quad \text{and} \quad 12\left(\frac{40{,}000}{f_s}\right)$$

$$f_s = \frac{2}{3}f_y = \frac{2}{3}(60{,}000) = 40000 \text{ psi}$$

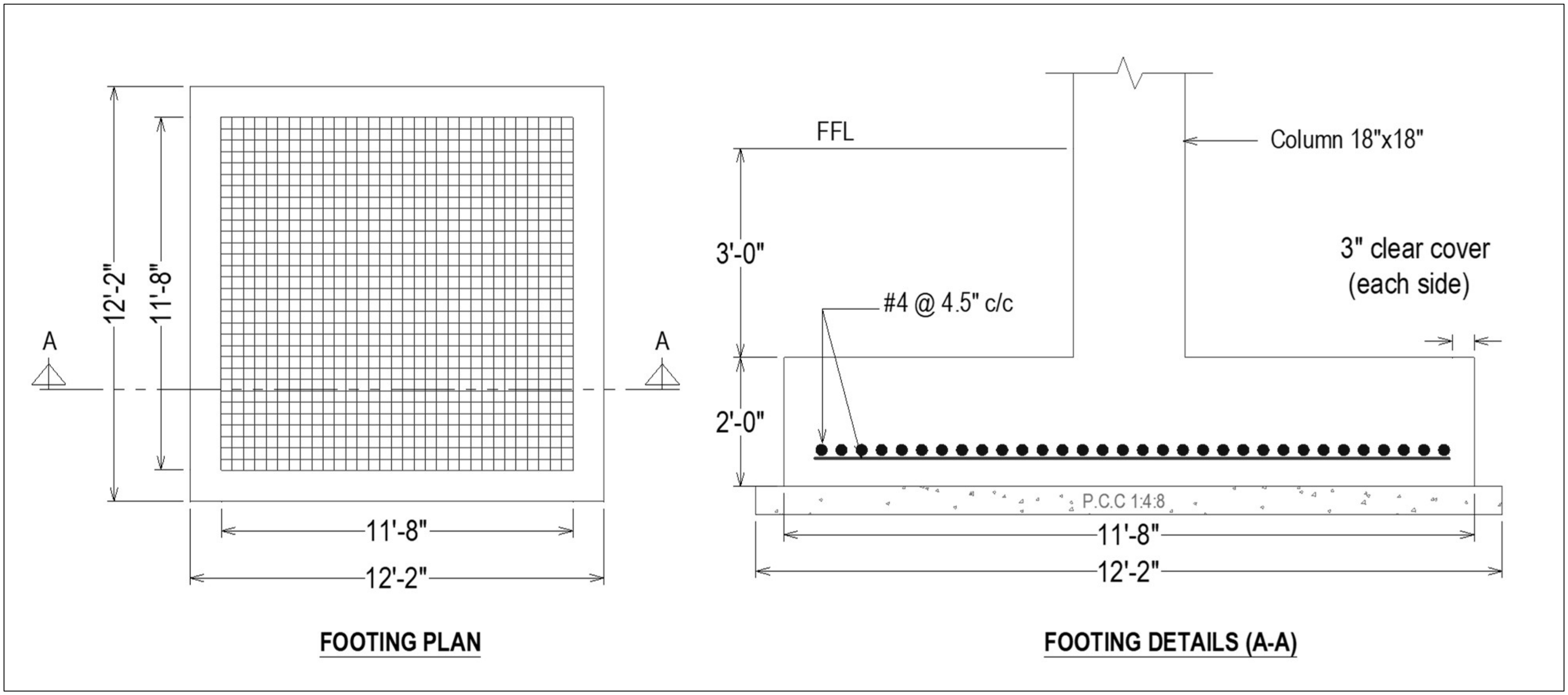
$$s_{max} = \text{Least of } 15\left(\frac{40{,}000}{40{,}000}\right) - 2.5(3) \text{ and } 12\left(\frac{40{,}000}{40{,}000}\right) = 7.5''$$

Provided spacing of 4.5″ is OK.

Design of 90′ X 60′ Hall

❑ Solution [option 2a]

❖ Footing Design



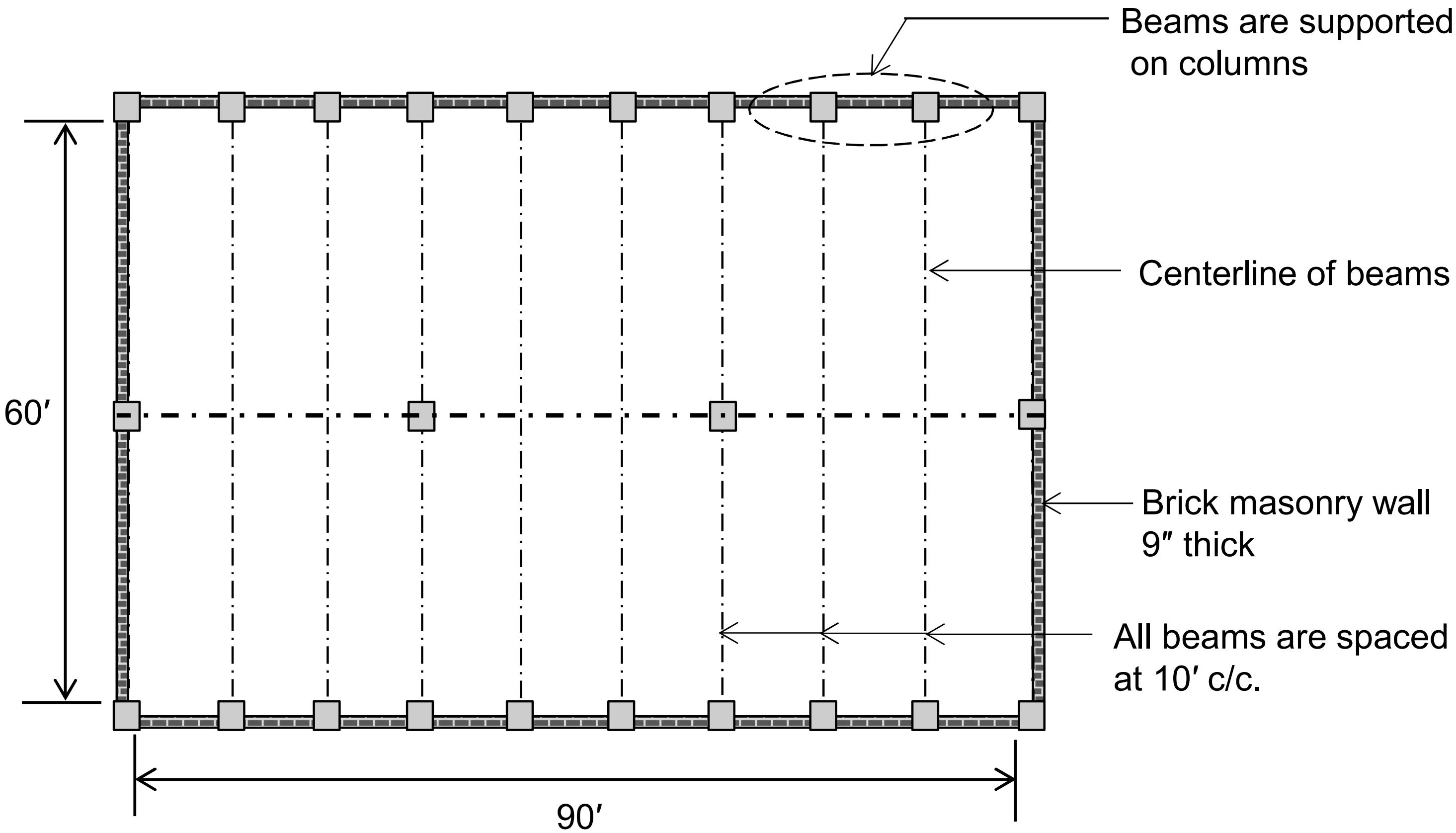
Design of 90′ X 60′ Hall

Option 2b

Design of 90′ X 60′ Hall

❑ Solution [option 2b]

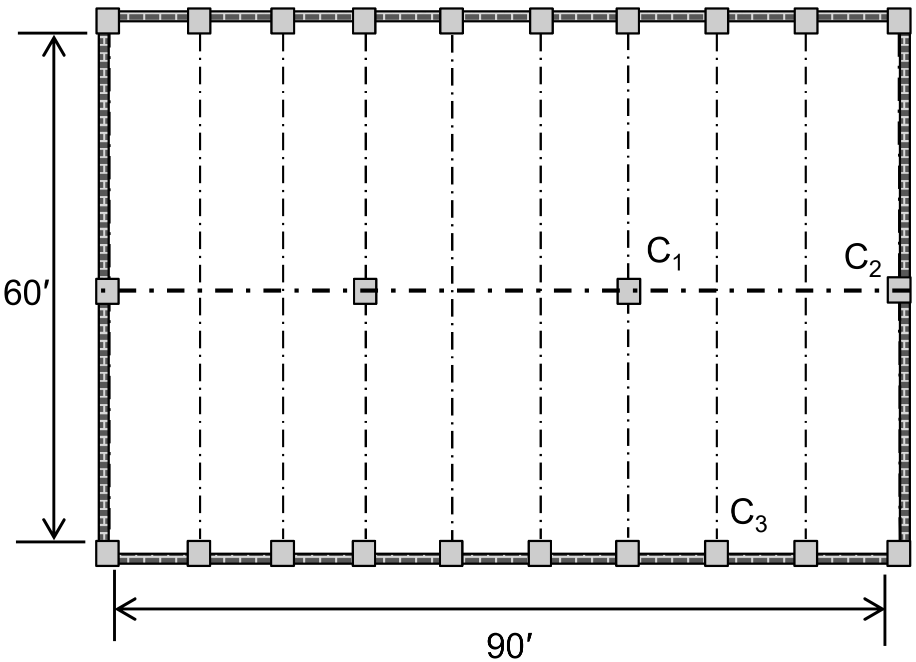
➢ Step 1: Selection of Structural Configuration

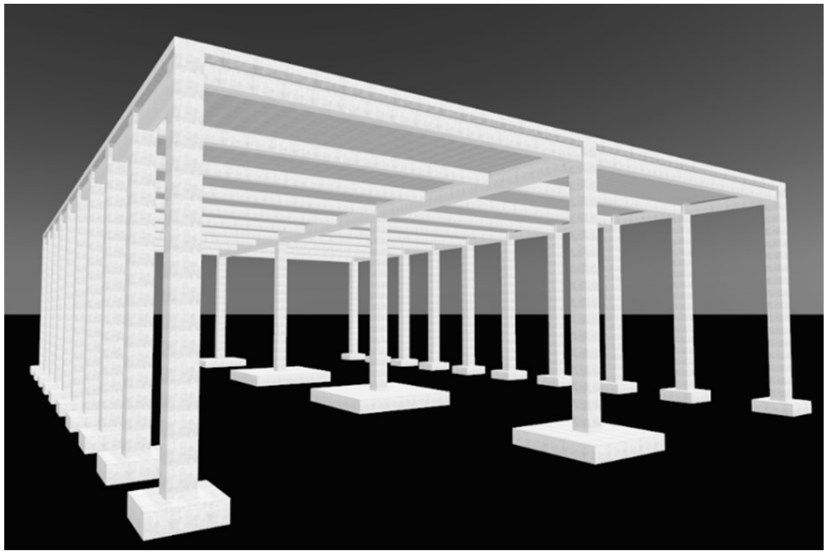


Design of 90′ X 60′ Hall

❑ Solution [option 2b]

➢ **Step 1: Selection of Structural Configuration**





Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Slab Design

- As seen in the figure, each slab panel is now 10 feet by 30 feet as opposed to the previous case. Because the design of a one-way slab is only dependent on the short side, the slab analysis and design will remain unchanged.

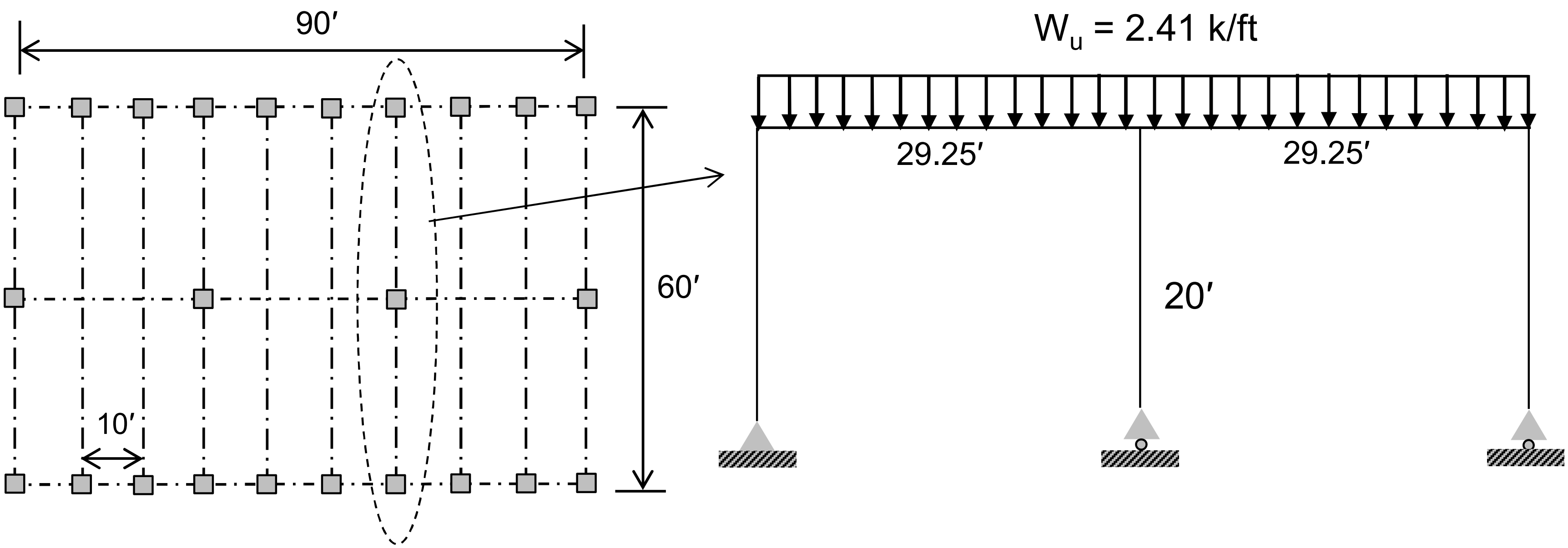
Summary of Slab Design				
Sizes h, in.	**Loads** W_u, (ksf)	**Analysis** Moment, in. kip	$\emptyset M_{n,min}$ (in. kip)	**Detailing of reinforcement** (main and shrinkage)
h_{min} = 4.8″ Take h = 4.8″	$W_u = 0.214$	$M^{+}_{u,ext} = 21.07$ $M^{-}_{u,int} = 18.31$ $M^{+}_{u,int} = 13.0$	33.95	#3 @9″ c/c
Drafting is same as in Option 2a				

Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Frame Design

- 2D frame can be detached from a 3D system as follows

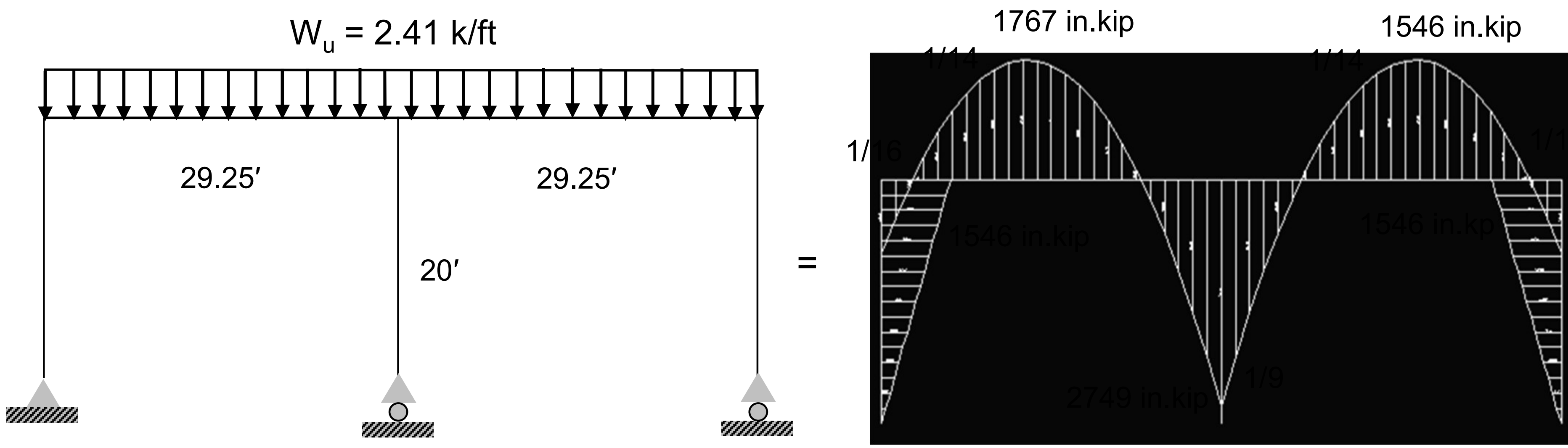


Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Frame Design

- Analysis for Beam (using ACI Moment Coefficients)



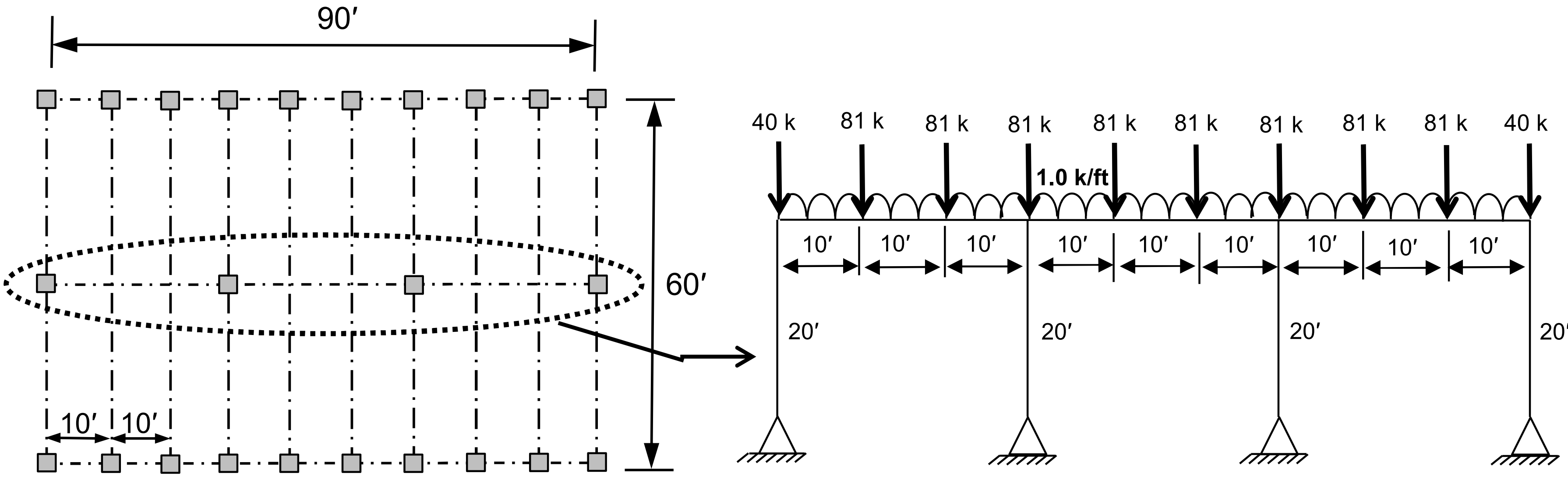
Note: The interior support conditions of the beam (whether supported on a column or a roller) have no effect on the analysis results.

Design of 90′ X 60′ Hall

Solution [option 2b]

Frame Design

- Analysis for Girder

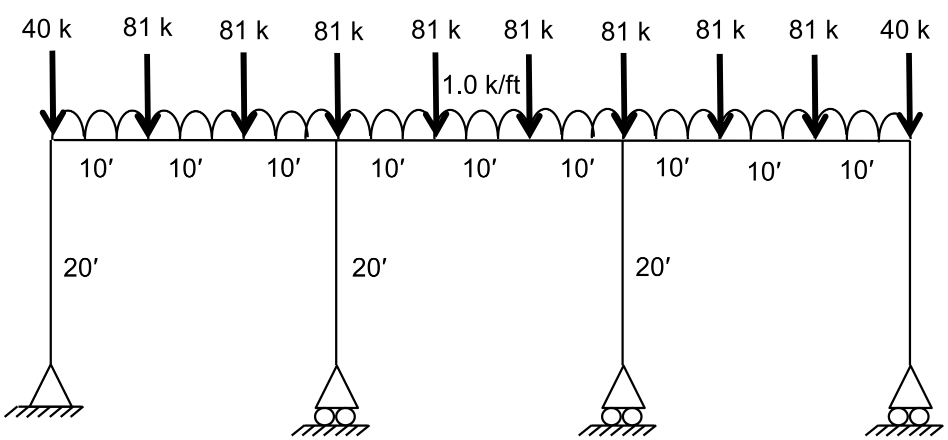


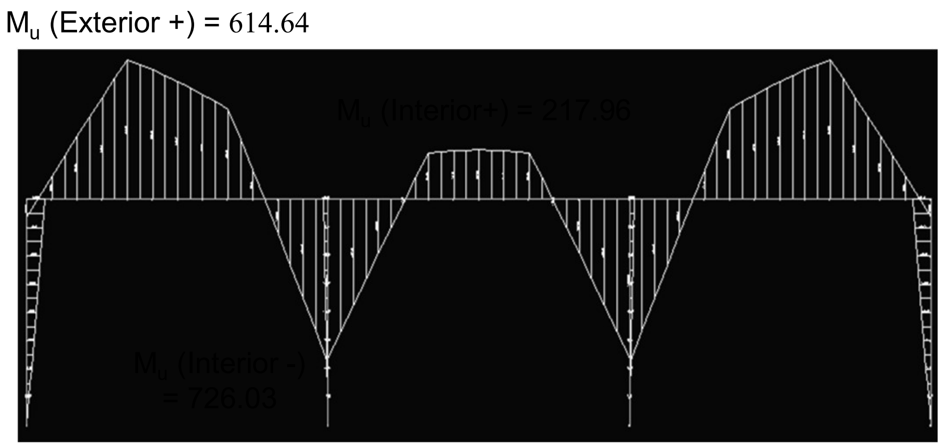
Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Frame Design

- Analysis for Girder





Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Frame Design

Design of Beam for Flexure							
Location	Moment in.kip	b in.	d in.	A_s in^2	$A_{s,min}$ in^2	$A_{s,max}$ in^2	Detailing
Exterior support (-)	1546	12	21.5	1.42	---	3.47	4 - #6
Midspan (+)	1767	99.75	21.5	1.53	0.86	3.47	4 - #8
Interior Support (-)	2749	12	21.5	2.70	0.86	3.47	2 - #8

Design of Beam for Shear (same as in option 2a)					
V_s (k)	$V@d$ (k)	$\emptyset V_c$ (k)	S_d (in.)	S_{max} (in.)	S taken (in.)
40.53	35.57	21.52	14.8	10.8	9
Provided reinforcement satisfies necessary shear checks					

Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Frame Design

Design of Girder for Flexure							
Location	M_u (in.kip)	d (in.)	b (in.)	A_s (in^2)	$A_{s,min}$ (in^2)	$A_{s,max}$ (in^2)	Detailing
Exterior +	7375.64	33.5	105.75	4.13	3.01	8.11	6 - #8
Interior −	8712.36	33.5	18	5.38	3.01	8.11	7 - #8
Interior +	2615.52	33.5	105.75	1.45	3.01	8.11	2 - #8

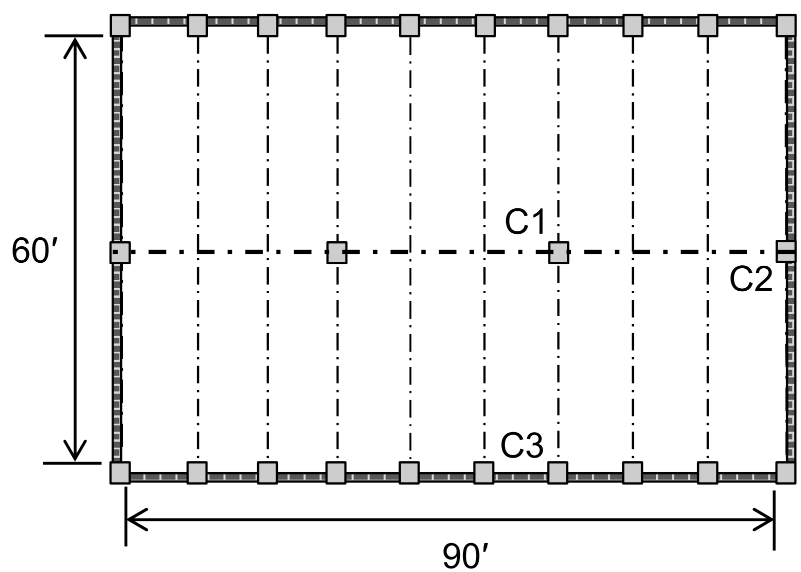
The Shear reinforcement remain the same as in Option 2a.

Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Column Design

- Column **C1** is concentric, and its design is the same as in the previous case. (slides 34–37). Columns **C2** and **C3** are uniaxially eccentric, so they will be designed using Design Aids.
- Design C2 by yourself. Design of C3 is carried out in the subsequent slides

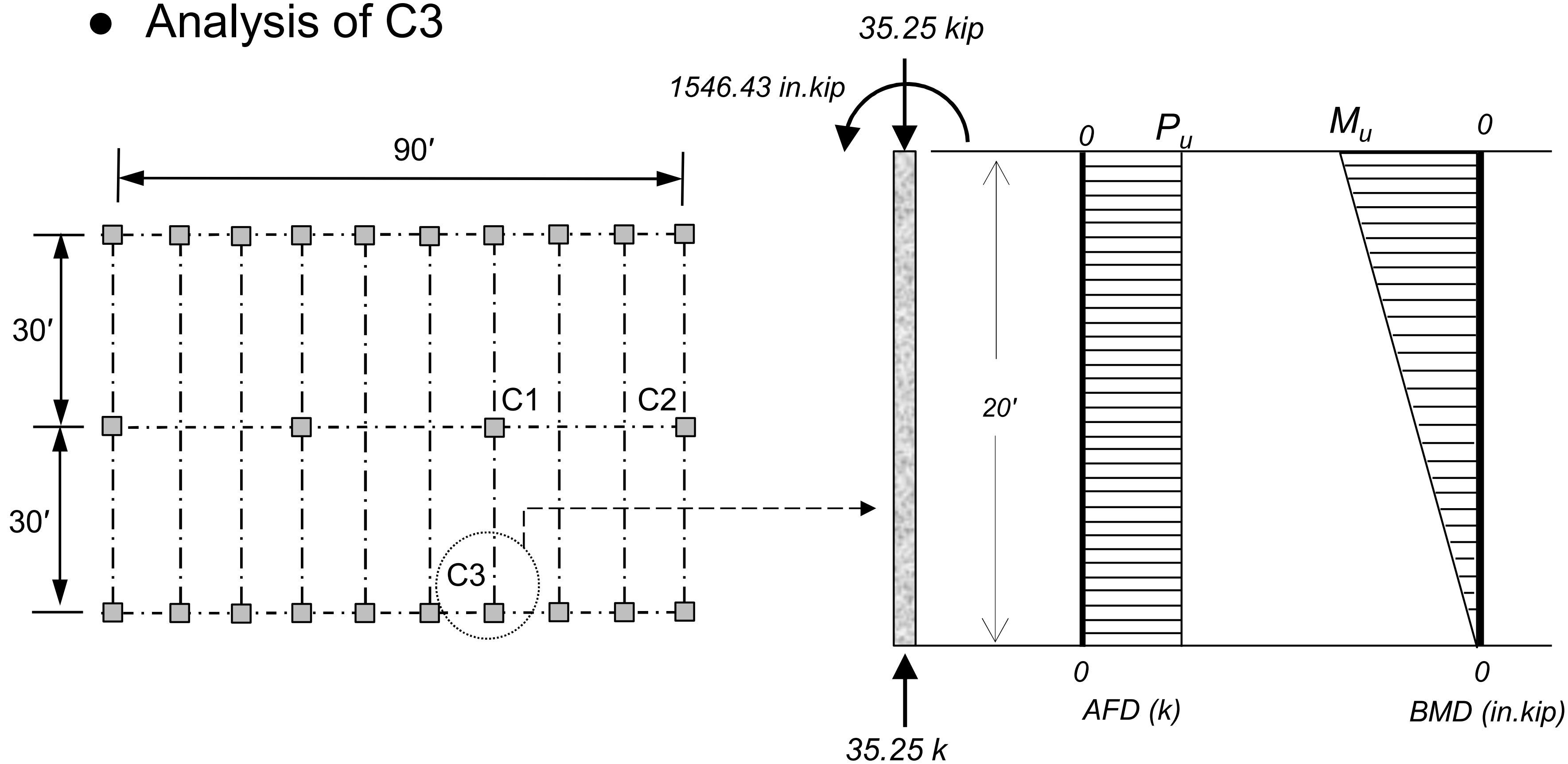


Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Column Design

- Analysis of C3



Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Column Design

- **Determination of Longitudinal reinforcement**

Taking b = h = 18″ and Assuming $d' = 2.5in$

$$\gamma = \frac{18 - 2(2.5)}{18} = 0.72 \approx 0.70$$

$$K_n = \frac{P_u}{\emptyset f_c' bh} = \frac{35.25}{0.65 \times 3 \times 18 \times 18} = 0.06$$

$$R_n = \frac{M_u}{\emptyset f_c' bh^2} = \frac{1546.43}{0.65 \times 3 \times 18 \times 18^2} = 0.14$$

The relevant Design Aid from the Appendix is DA – 2.

Design of 90′ X 60′ Hall

Solution [option 2b]

Column Design

- **Determination of Longitudinal reinforcement**

4. Read ρ_g from the graph

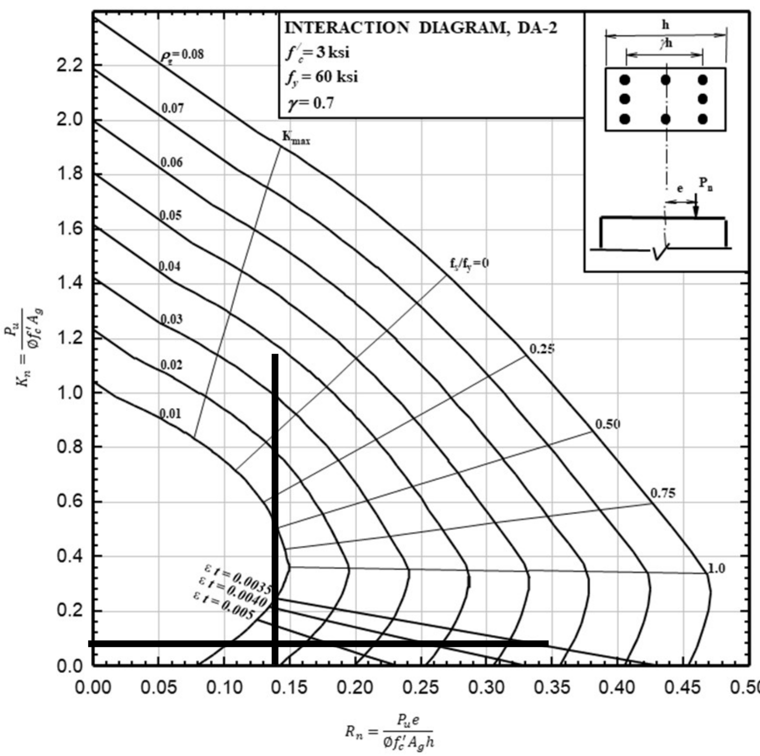
$\rho_g = 0.018$

$A_{st} = 5.83\ in^2$

Using #8 bar with A_b = 0.79 in^2

No. of bars = $5.83/0.79 \approx 8$

Hence Provide 12 - #8 bars



Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Column Design

- **Determination of Spacing for Shear Reinforcement**

Using #3 bar with $A_b = 0.11\ in^2$

i. $\frac{A_v f_y}{50 b_w}$ = 0.22 x 60,000/ (50x18) = 14.7″

ii. $\frac{A_v f_y}{0.75\sqrt{f_c'} b_w}$ = 0.22 x 60,000 / (0.75$\sqrt{3000}$ x18) = 17.9″

iii. $16 d_b$ of longitudinal bar = 16 x 1 = 16″

iv. 48 d_b of tie bar = 48 x 3/8 = 18″

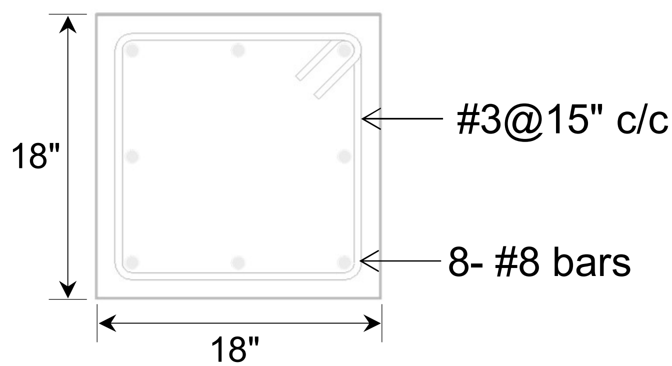
v. Smallest dimension of member = 18″

$S_{max} = 16''$. Finally use #3 ties @ 15″ c/c

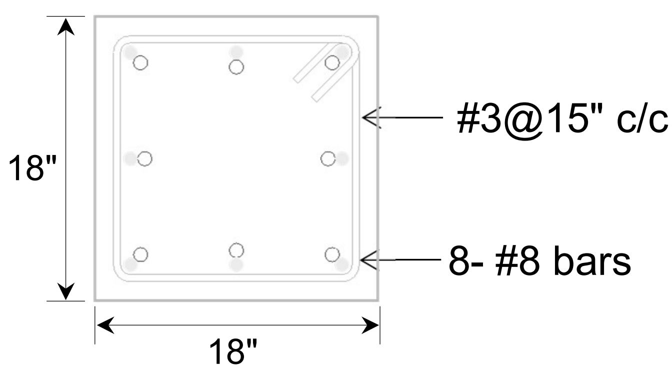
Design of 90′ X 60′ Hall

❑ Solution

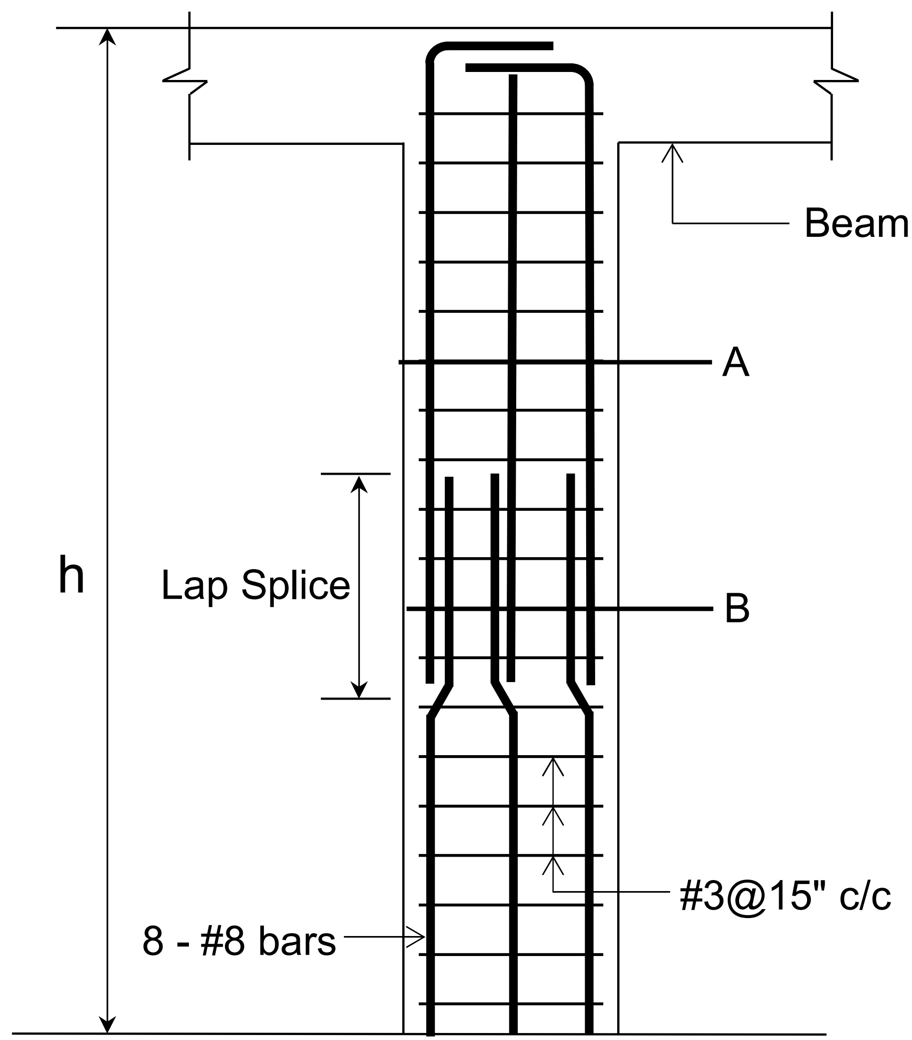
❖ Column Design (Drafting)



Section A-A



Section B-B



Design of 90′ X 60′ Hall

Solution [option 2b]

Footing Design

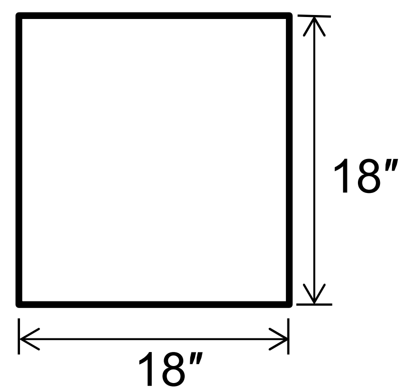
- Design of footing for the column C1 has already been done (refer to slides 38 to 43).
- Design footing for column C2 by yourself.
- A summarized design of footing for C3 is shown on next slides.

Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Footing Design

- **Given Data for C3**
  - Size of column : $18'' \times 18''$
  - Factored load = 35.25 kip
  - Service load = 27.42 kip
  - Compressive strength of concrete, $f_c' = 3\text{ksi}$
  - Yield Tensile strength of steel, $f_y = 60\text{ ksi}$
  - Allowable bearing capacity of soil, $q_a = 2.204\text{ ksf}$
  - Depth of footing from base level, $Z = 5\text{ ft}$.



Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Footing Design

- Analysis of C3 – Footing

STEP WISE ANALYSIS

Estimation of footing thickness and d_{avg}

d_{avg} = 11.50 in

Overburden pressure

W = 0.563 ksf

Effective bearing capacity

q_e = 1.642 ksf

Bearing Area

A_{req} = 16.7sq.ft (B = 4' - 2")

Critical shear Parameter

b_o = 118.00 in

Design pressure qu

q_u = 2.097 ksf

Punching shear force V_{up}

Vup = 22.6 kip

Check for Punching Shear

ΦVcp = 223.0 kip →OK!

Calculation of Maximum Moment Mu

M_u = 87.179 in.kip

Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Footing Design

Using Direct Method;

$$a = d - \sqrt{d^2 - \frac{2.614M_u}{f_c'B}} = 11.5 - \sqrt{11.5^2 - \frac{2.614 \times 87.18}{3 \times (50)}} = 0.07"$$

$$A_s = \frac{M_u}{\emptyset f_y\left(d - \frac{a}{2}\right)} = \frac{87.18}{0.9 \times 60\left(11.5 - \frac{0.07}{2}\right)} = 0.14 \text{ in}^2$$

Now,

$$A_{s,min} = 0.0018\,Bh = 0.0018(50)(15) = 1.35\,in^2$$

$$A_s < A_{s,min} \rightarrow A_{s,min} \text{ governs}$$

Design of 90′ X 60′ Hall

❑ Solution [option 2b]

❖ Footing Design

Using #4 bar with $A_b = 0.20\ in^2$

$$n = \frac{1.35}{0.20} = 7 \quad or\ \ S = \frac{50 - 6}{6} = 7.3"$$

Maximum spacing shall not exceed the lesser of 3h or 18″.

$$S_{max} = \min(3 \times 15 = 45{,}18) = 18'' \rightarrow OK$$

Also, for crack control spacing shall not exceed the following

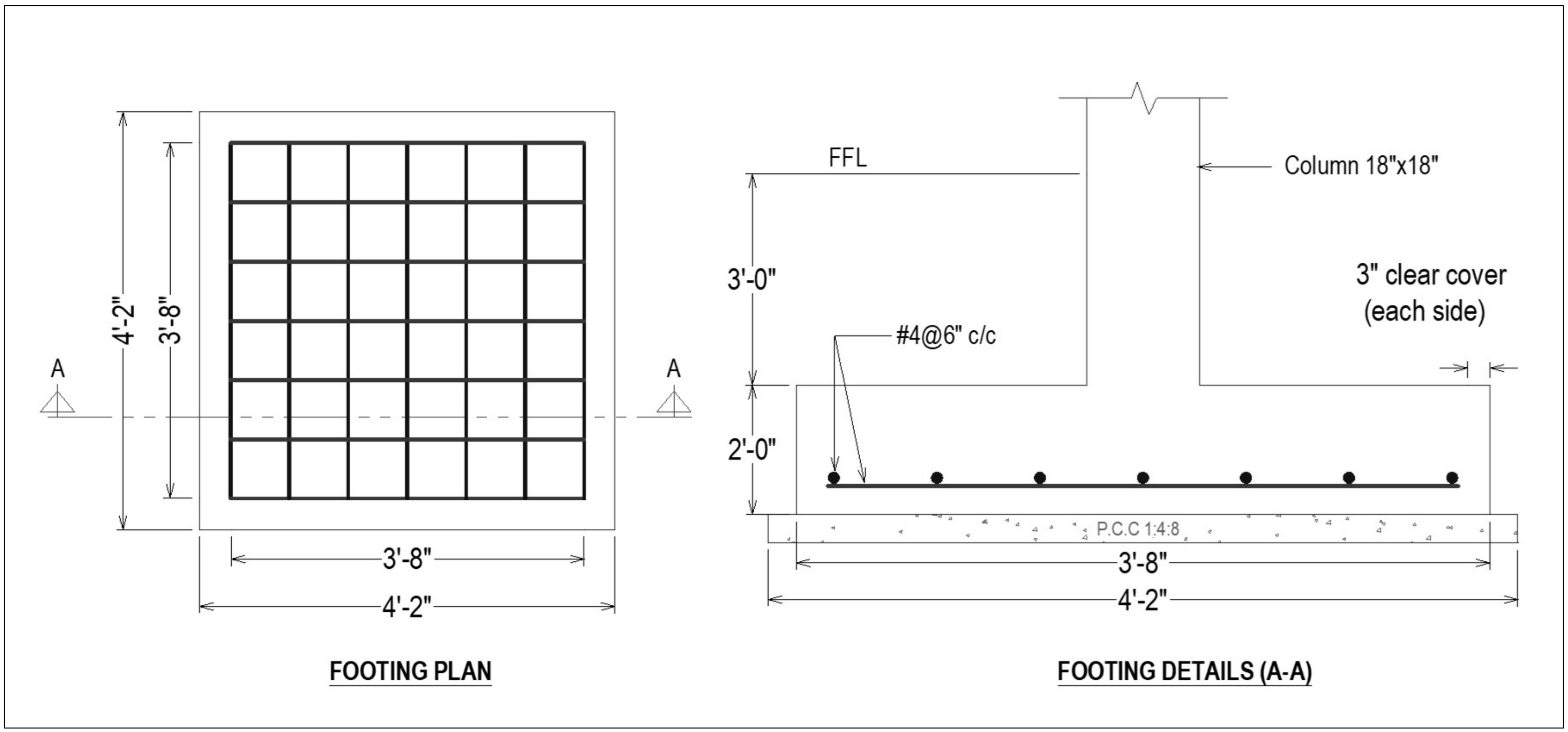
$$s_{max} = \text{Least of }\ 15\left(\frac{40{,}000}{40{,}000}\right) - 2.5(3)\ \text{ and }\ 12\left(\frac{40{,}000}{40{,}000}\right) = 7.5'' \rightarrow OK$$

Provided spacing is OK. Finally provide #4@6″ c/c.

Design of 90′ X 60′ Hall

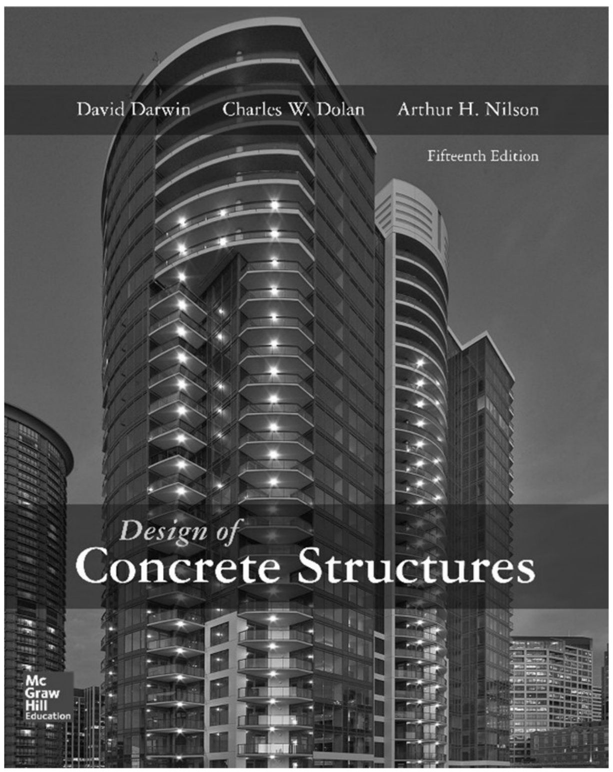
❑ Solution [option 2b]

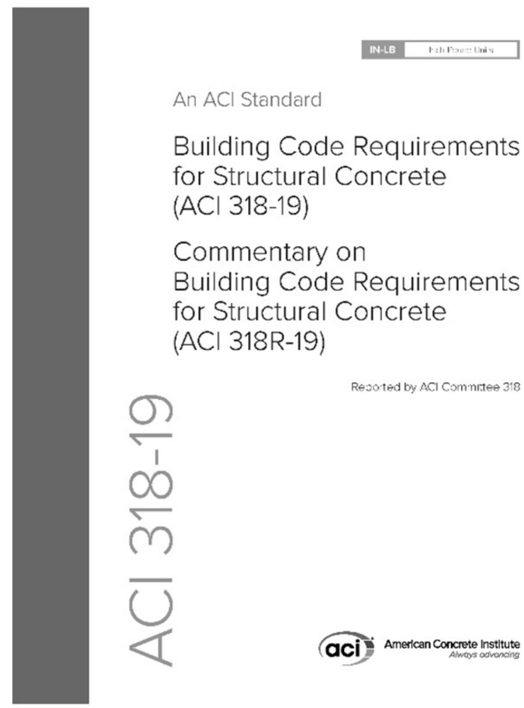
❖ Footing Design



References

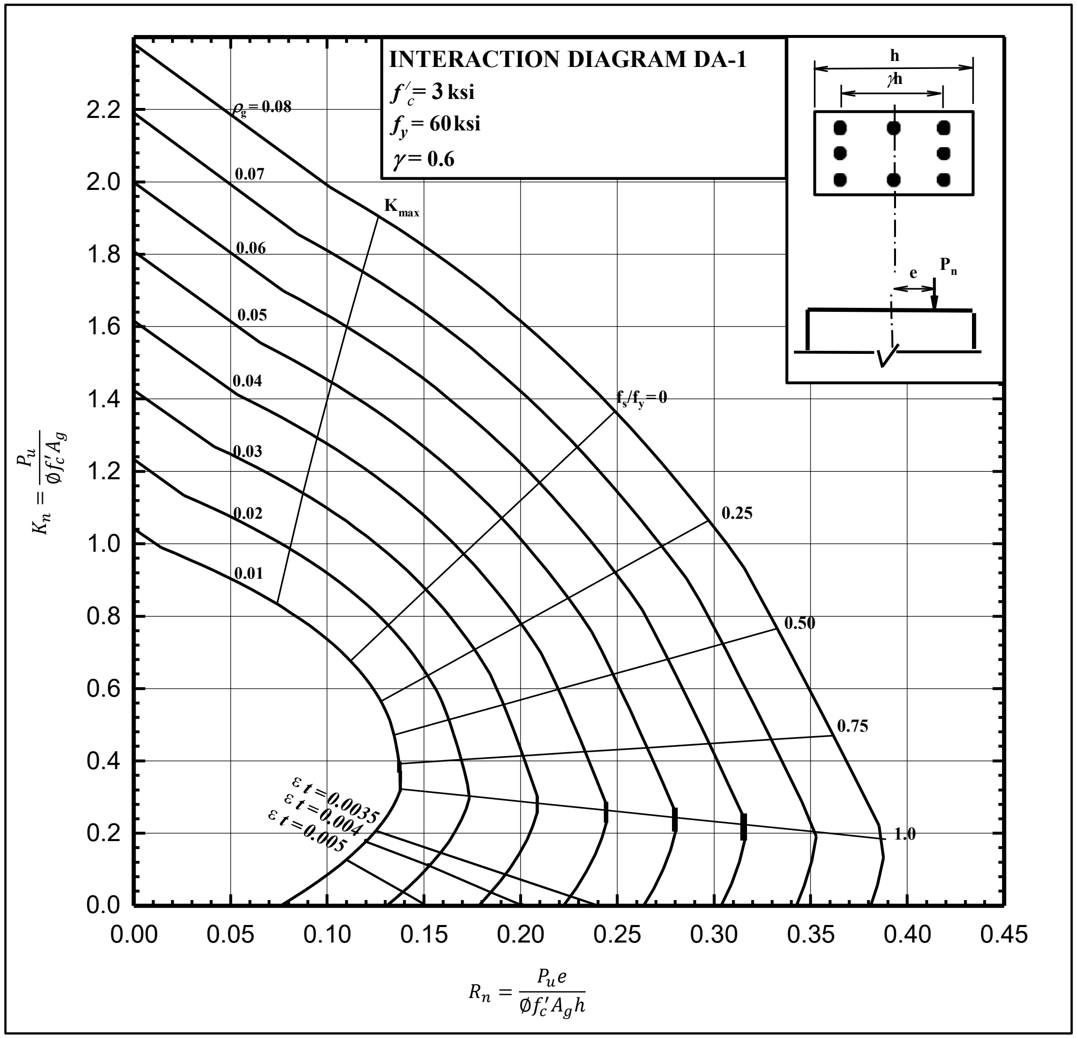
- Design of Concrete Structures 14th / 15th edition by Nilson, Darwin and Dolan.
- Building Code Requirements for Structural Concrete (ACI 318-19)





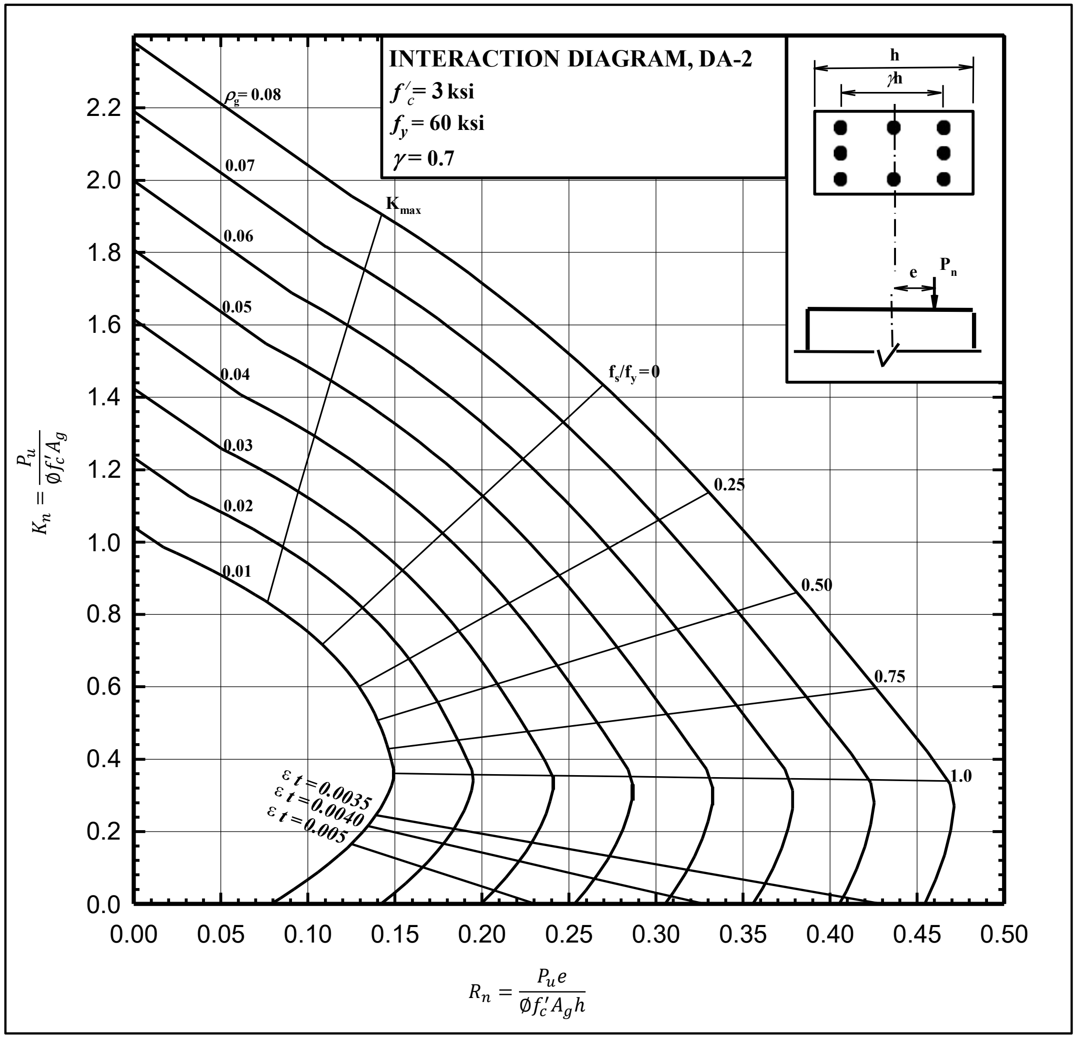
Appendix

❑ DESIGN AIDS (DA – 1)



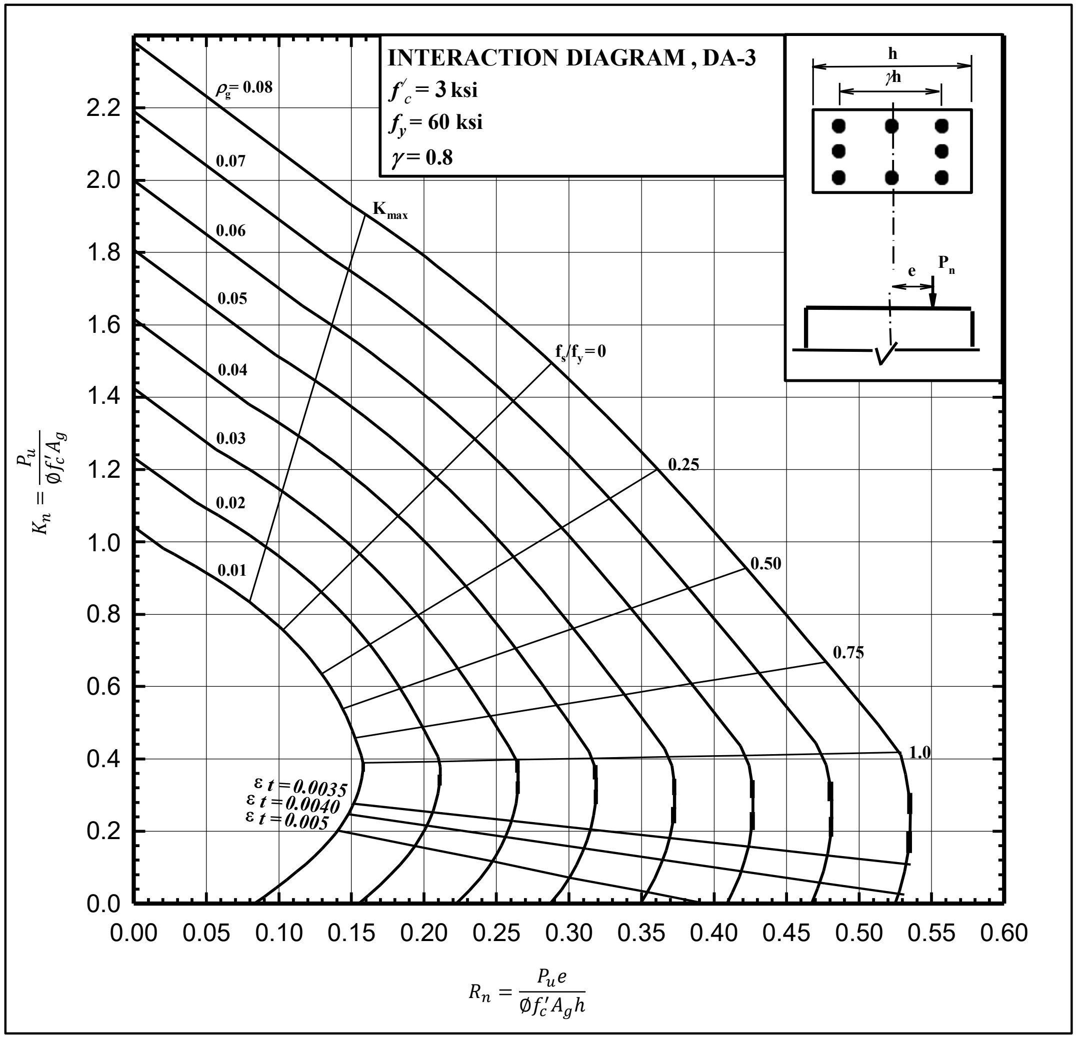
Appendix

❑ DESIGN AIDS (DA – 2)



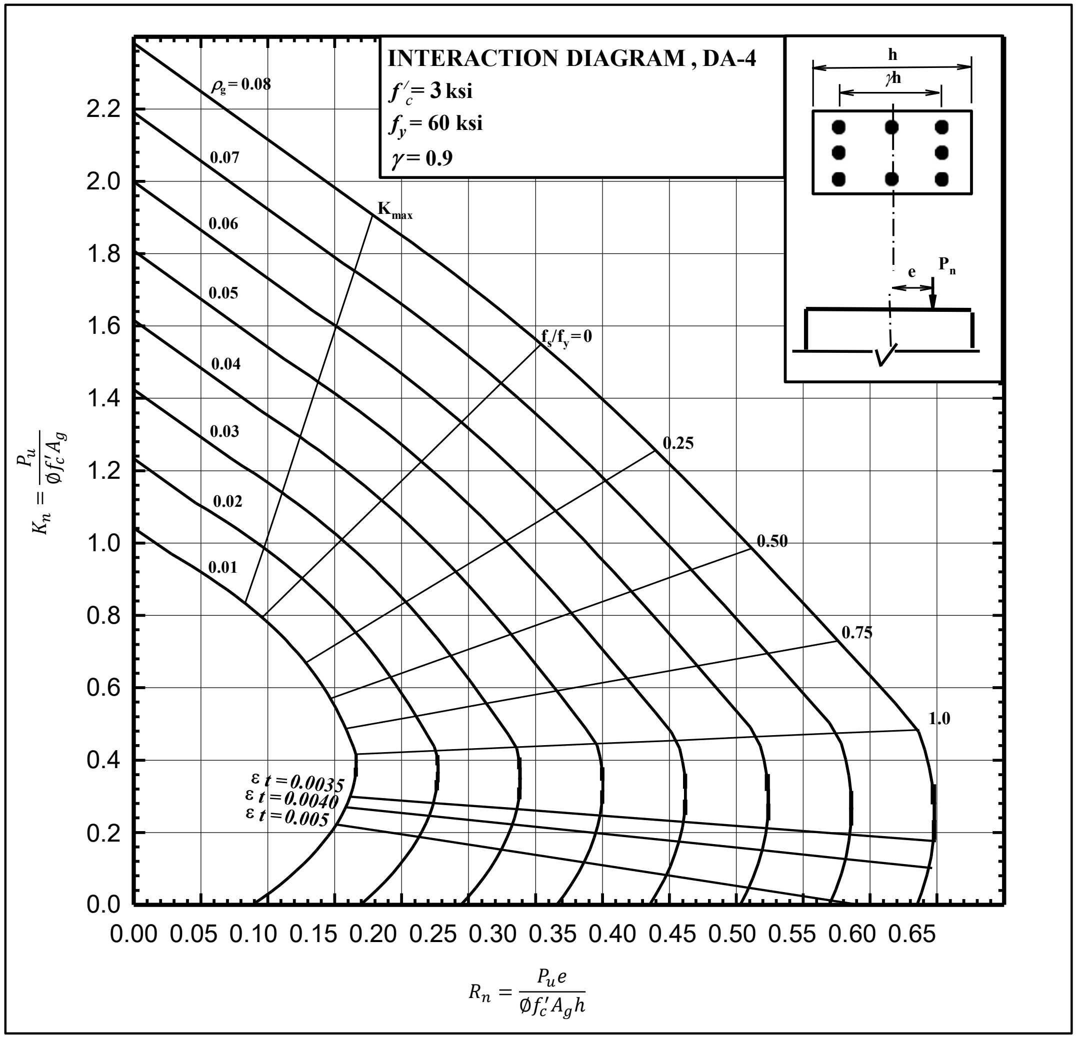
Appendix

❑ DESIGN AIDS (DA – 3)



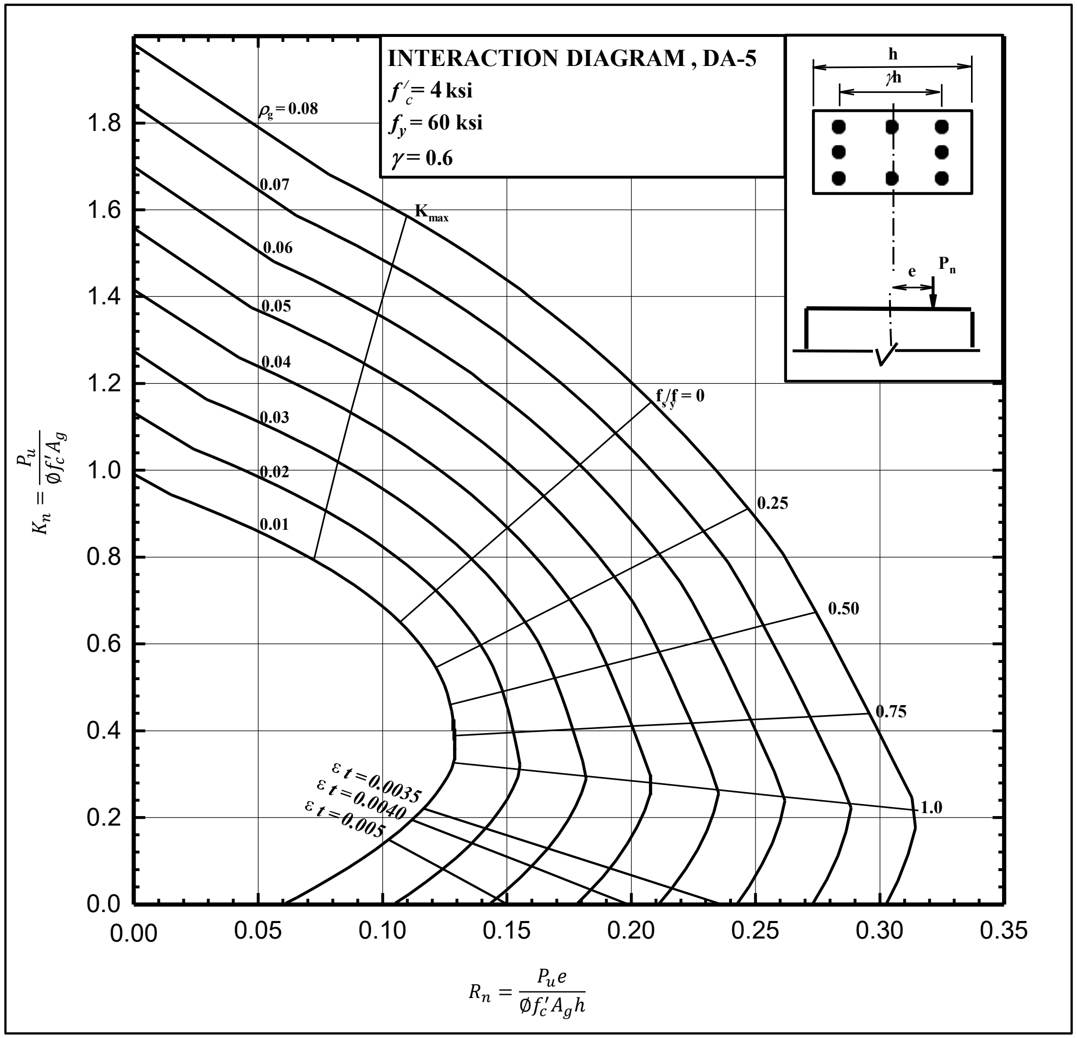
Appendix

❑ DESIGN AIDS (DA – 4)



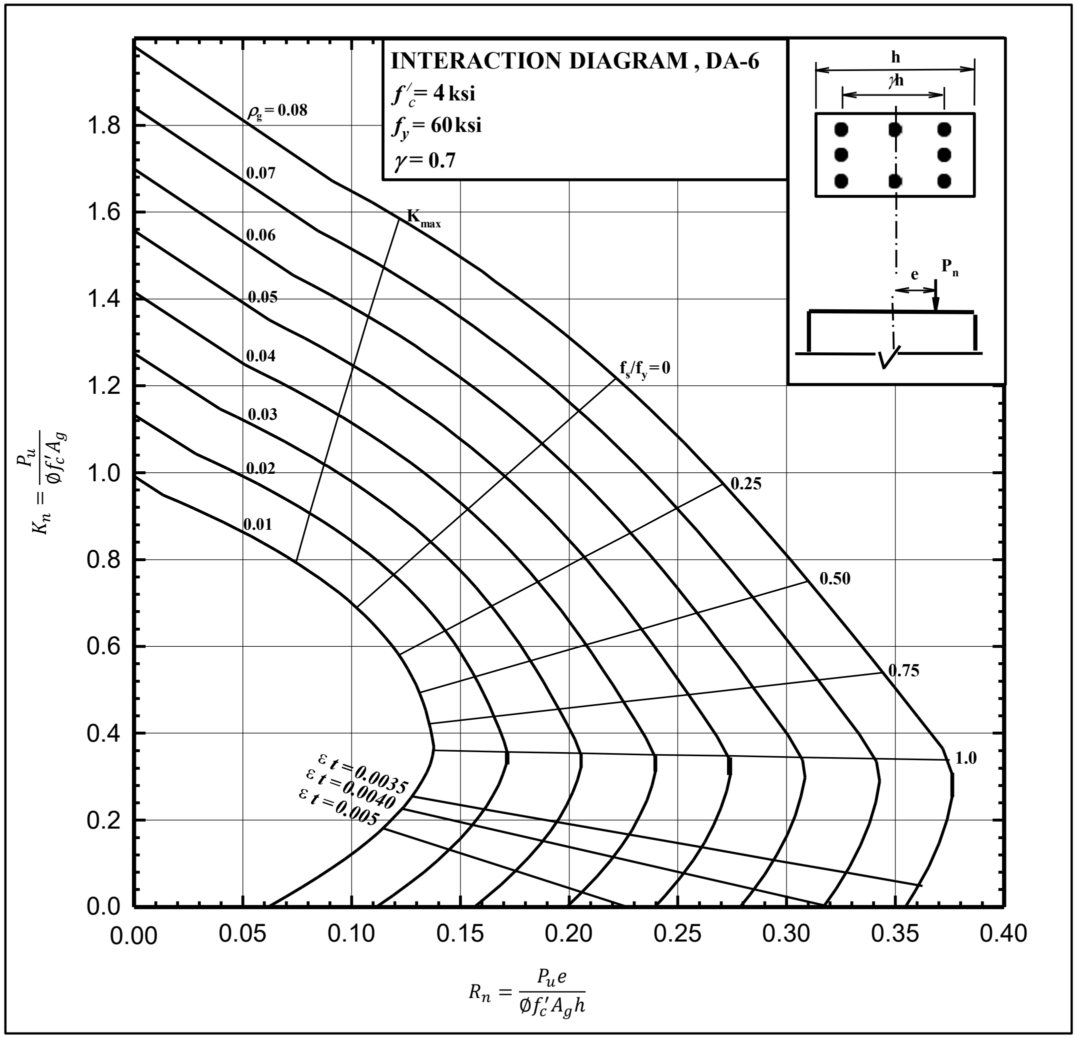
Appendix

❑ DESIGN AIDS (DA – 5)



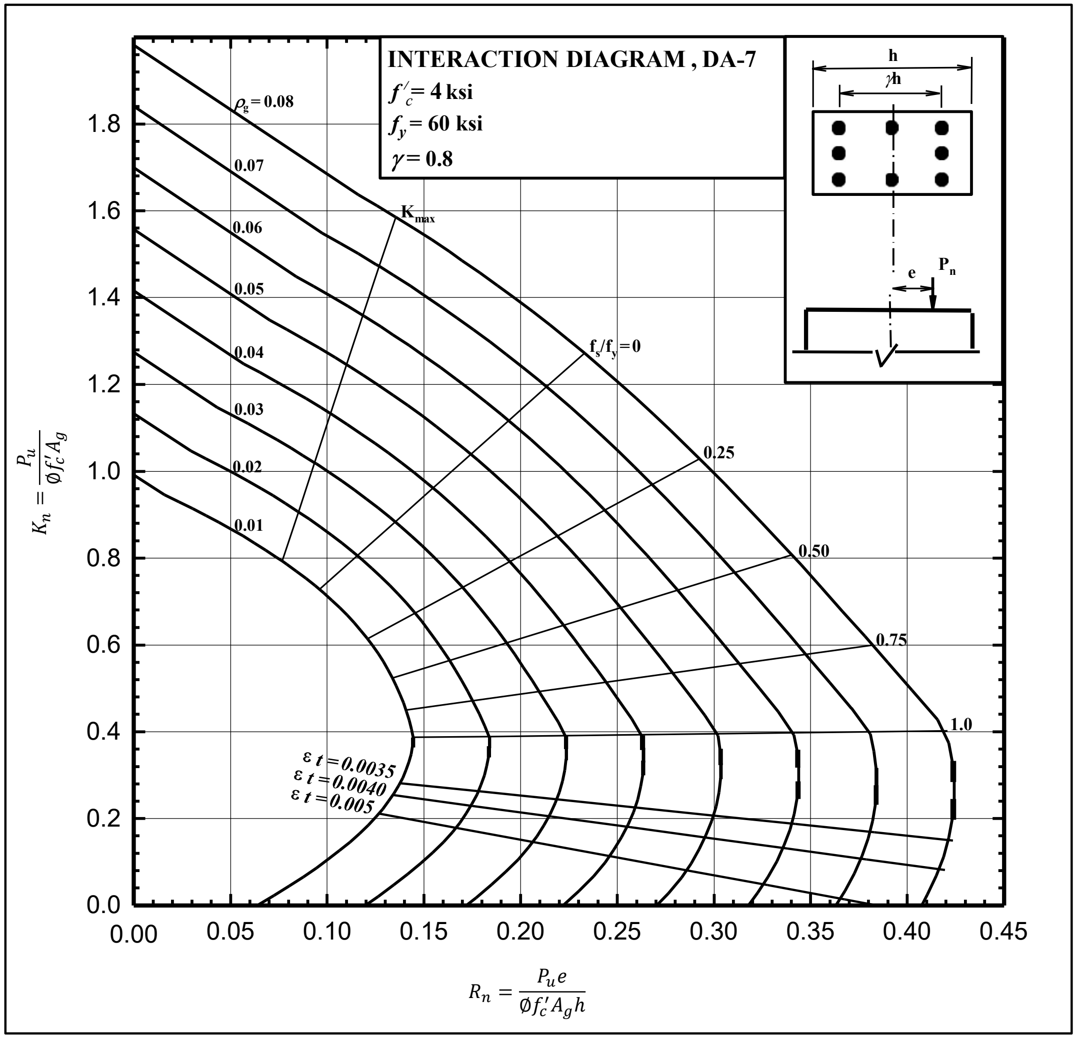
Appendix

❑ DESIGN AIDS (DA – 6)



Appendix

❑ DESIGN AIDS (DA – 7)



Appendix

❑ DESIGN AIDS (DA – 8)