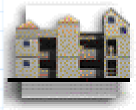


CHAPTER 3: Reinforced Concrete Slabs and Beams

3.1 Continuous One Way Slabs

Description

This application calculates bending moments using ACI coefficients, and determines the required reinforcing-bar spacing for continuous one way slabs. Intermediate values calculated include slab weight, service and factored loads, shear, minimum slab thickness required for deflection, shear and flexure, required areas of flexural reinforcement, and maximum and minimum permissible bar spacings. The application uses the strength design method of ACI 318.

The required input includes the strengths of the concrete and the reinforcement, the unit weight of concrete, design live load per unit area, superimposed dead load per unit area, crack control factor, span length, span type, and top and bottom bar sizes. Three continuous slabs with their first three spans are shown for illustrative purposes, however any practical number of slabs may be entered at one time. The application covers any combination of span types which meet the limitations for use of ACI coefficients.

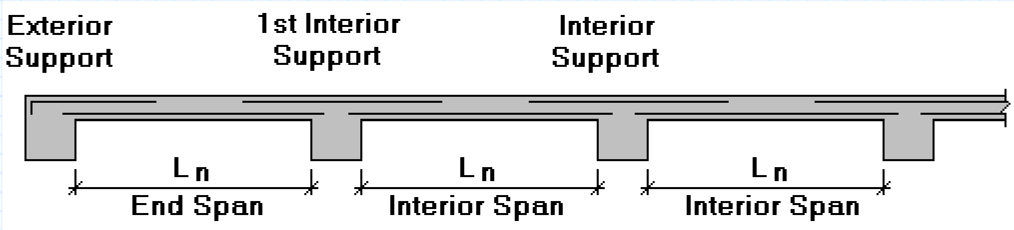
A summary of input and calculated values is shown on pages 16 -18.

Reference:

ACI 318-89 "Building Code Requirements for Reinforced Concrete." (Revised 1992)

Input

Notation



Input Variables

Enter uniformly distributed loads.

Service live load per unit area: $w_l := 200 \cdot psf$

Service dead load per unit area excluding slab weight: $w_{sd} := 15 \cdot psf$

Enter bar size numbers.

Top bar size: $TopBar := 6$

Bottom bar size $BotBar := 4$

Numbers Designating "Span Type"	
Simple Span	0
End Span, Spandrel Beam Exterior Support	1
End Span, Column Exterior Support	11
End Span, Unrestrained Exterior Support	12
Interior Span	2
Cantilever Span	3

Enter span lengths and span types as three column matrices, with the number of rows equal to the number of continuous slabs entered. The first column of the matrix must be end spans, the second column may be an adjacent interior span or the second end span of a two span continuous slab, and the third column may be an end span for a three span continuous slab or an interior span for four or more spans. Enter zeros for span length and type in the third columns for two span continuous slabs.

Clear span lengths: $$L_n := \begin{bmatrix} 14 & 14 & 14 \\ 10 & 11.5 & 11.5 \\ 12 & 12 & 12 \end{bmatrix} \cdot ft$$

Span types: $$SpanType := \begin{bmatrix} 1 & 2 & 2 \\ 1 & 2 & 2 \\ 1 & 2 & 2 \end{bmatrix}$$

Notes ⇒ Negative moments are calculated using the average length of adjacent spans. The larger adjacent span may not be more than 20% longer than the shorter span. See ACI 318, Section 8.3.3 (b).

Computed Variables

h overall slab thickness

w_s total service per unit area

w_u total factored per unit area

v_u shear stress per unit area at factored load

ρ steel reinforcement ratio

A_s reinforcement areas per unit width of slab

s reinforcing bar spacing

Material Properties and Constants

Enter values for f'_c, f_y, w_c, k_v and k_w if different from that shown.

Specified compressive strength of concrete:	$f'_c := 4 \cdot ksi$
Specified yield strength of reinforcement (f_y may not exceed 60 ksi, ACI 318 11.5.2):	$f_y := 60 \cdot ksi$
Unit weight of concrete:	$w_c := 145 \cdot pcf$
Weight of reinforced concrete:	$w_{rc} := 150 \cdot pcf$
Shear strength reduction factor for lightweight concrete where k_v = 1 for normal weight, k_v = 0.75 for all-lightweight, and k_v = 0.85 for sand-lightweight concrete (ACI 318, 11.2.1.2.):	$k_v := 1$
Weight factor for increasing development and splice lengths k_w = 1 for normal weight and k_w =1.3 for lightweight aggregate concrete (ACI 318, 12.2.4.2):	$k_w := 1$
Modulus of elasticity of reinforcement (ACI 318, 8.5.2):	$E_s := 29000 \cdot ksi$
Strain in concrete at compression failure (ACI 318, 10.3.2):	$\varepsilon_c := 0.003$
Strength reduction factor for flexure (ACI 318, 9.3.2.1):	$\phi_f := 0.90$
Strength reduction factor for shear (ACI 318, 9.3.2.3):	$\phi_v := 0.85$
Sizing factor for rounding slab thickness:	$SzF := \frac{1}{2} \cdot in$
Sizing factor for rounding bar spacing:	$SpF := 1 \cdot in$

Clear concrete cover of reinforcement: $cl := \frac{3}{4} \cdot in$

Crack control factor
(175 kip/in interior, 145 kip/in exterior)
(ACI 318,10.6.4): $z := 175 \cdot \frac{kip}{in}$

Reinforcing bar number designations, diameters and areas:

$$No := [0\ \ 1\ \ 2\ \ 3\ \ 4\ \ 5\ \ 6\ \ 7\ \ 8\ \ 9\ \ 10\ \ 11\ \ 12\ \ 13\ \ 14\ \ 15\ \ 16\ \ 17\ \ 18]^{T}$$

$$d_b := [0\ \ 0\ \ 0\ \ 0.375\ \ 0.5\ \ 0.625\ \ 0.75\ \ 0.875\ \ 1.00\ \ 1.128\ \ 1.27\ \ 1.41\ \ 0\ \ 0\ \ 1.693\ \ 0\ \ 0\ \ 0\ \ 2.257]^{T} \cdot in$$

$$A_b := [0\ \ 0\ \ 0\ \ 0.11\ \ 0.20\ \ 0.31\ \ 0.44\ \ 0.60\ \ 0.79\ \ 1.00\ \ 1.27\ \ 1.56\ \ 0\ \ 0\ \ 2.25\ \ 0\ \ 0\ \ 0\ \ 4.00]^{T} \cdot in^2$$

Bar numbers, diameters and areas are in the vector rows (or columns in the transposed vectors shown) corresponding to the bar numbers. Individual bar numbers, diameters, areas and development lengths and splices of a specific bar can be referred to by using the vector subscripts as shown in the example below.

Example: $No_5 = 5$ $\quad d_{b_5} = 0.625\ in$ $\quad A_{b_5} = 0.31\ in^2$

Limit the value of f'_c for computing shear and development lengths to 10 ksi by substituting f'_{c_max} for f'_c in formulas for computing shear (ACI 318, 11.1.2, 12.1.2):

$$f'_{c\_max} := \mathbf{if}\left(f'_c > 10 \cdot ksi, 10 \cdot ksi, f'_c\right)$$

The following values are computed from the entered material properties.

Nominal "one way" shear strength per unit area in concrete:
(ACI 318, 11.3.1.1, Eq. (11-3), 11.5.4.3)

$$v_c := k_v \cdot 2 \cdot \sqrt{\frac{f'_{c\_max}}{psi}} \cdot psi \qquad v_c = 126\ psi$$

Modulus of elasticity of concrete for values of wc between 90 pcf and
155 pcf (ACI 318, 8.5.1):

$$E_c := \left(\frac{w_c}{pcf}\right)^{1.5} \cdot 33 \cdot \sqrt{\frac{f'_c}{psi}} \cdot psi \qquad E_c = 3644\ ksi$$

Strain in reinforcement at yield stress:

$$\varepsilon_y := \frac{f_y}{E_s} \qquad \varepsilon_y = 0.00207$$

Factor used to calculate depth of equivalent rectangular stress block (ACI 318, 10.2.7.3):

$$\beta_1 := \mathbf{if}\left(\left(f'_c \ge 4 \cdot ksi\right) \cdot \left(f'_c \le 8 \cdot ksi\right), 0.85 - 0.05 \cdot \frac{f'_c - 4 \cdot ksi}{ksi}, \mathbf{if}\left(\left(f'_c \le 4 \cdot ksi\right), 0.85, 0.65\right)\right)$$

$$\beta_1 = 0.85$$

Reinforcement ratio producing balanced strain conditions (ACI 318, 10.3.2):

$$\rho_b := \frac{\beta_1 \cdot 0.85 \cdot f'_c}{f_y} \cdot \frac{E_s \cdot \varepsilon_c}{E_s \cdot \varepsilon_c + f_y} \qquad \rho_b = 2.851\ 1\%$$

Maximum reinforcement ratio (ACI 318, 10.3.3):

$$\rho_{max} := \frac{3}{4} \cdot \rho_b \qquad \rho_{max} = 2.138\ 1\%$$

Minimum reinforcement ratio for beams (ACI 318, 10.5.1, Eq. (10-3)):

$$\rho_{min} := \frac{200}{f_y} \cdot psi \qquad \rho_{min} = 0.333\ 1\%$$

Shrinkage and temperature reinforcement ratio (ACI 318, 7.12.2.1):

$$\rho_{temp} := \mathbf{if}\left(f_y \le 50 \cdot \boldsymbol{ksi}, .002, \mathbf{if}\left(f_y \le 60 \cdot \boldsymbol{ksi}, .002 - \frac{f_y}{60 \cdot \boldsymbol{ksi}} \cdot .0002, \mathbf{if}\left(\frac{.0018 \cdot 60 \cdot \boldsymbol{ksi}}{f_y} \ge .0014, \frac{.0018 \cdot 60 \cdot \boldsymbol{ksi}}{f_y}\right.\right.\right.$$

$$\rho_{temp} = 0.18\ 1\%$$

Flexural coefficient K, for rectangular beams or slabs, as a function of ρ (ACI 318, 10.2):
(Moment capacity $\phi M_n = K(\rho)F$, where $F = bd^2$)

$$K(\rho) := \phi_f \cdot \rho \cdot \left(1 - \frac{\rho \cdot f_y}{2 \cdot 0.85 \cdot f'_c}\right) \cdot f_y$$

Factors for adjusting minimum beam and slab thickness h_{min} for use of lightweight concrete and yield strengths other than 60 ksi (ACI 318, 9.5.2.1, see footnotes to Table 9.5(a)):

Adjustment factor for minimum thickness for concrete weights between 90 and 120 pcf:

$$q_1 := \mathbf{if}\left(w_c \le 112 \cdot \boldsymbol{pcf}, 1.65 - 0.005 \cdot \frac{w_c}{\boldsymbol{pcf}}, \mathbf{if}\left(w_c \le 120 \cdot \boldsymbol{pcf}, 1.09, 1\right)\right)$$

$$q_1 = 1$$

Adjustment factor for minimum thickness for yield strengths other than 60 ksi:

$$q_2 := 0.4 + \frac{f_y}{100 \cdot ksi} \qquad q_2 = 1$$

Adjustment factor for minimum thickness combining factors for concrete weight and for yield strengths other than 60 ksi:

$$Q := q_1 \cdot q_2 \qquad Q = 1$$

Defined Units

$$pcf := lbf \cdot ft^{-3}$$

$$psf := lbf \cdot ft^{-2}$$

Calculations

Define xt and xb as the top and bottom bar sizes:

$$xt := TopBar \qquad xb := BotBar$$

Largest span to thickness ratios permitted by ACI 318-89 unless deflections are computed:

$$i := 0 .. \text{last}\left(L_n^{\langle 0 \rangle}\right) \qquad j := 0 .. 2 \qquad S := SpanType$$

$$k_{i,j} := \textbf{if}\left(S_{i,j} = 2, 28, 24\right)$$

Minimum slab thickness for each span of each continuous strip:

$$h1_{min_{i,j}} := \frac{Q \cdot L_{n_{i,j}}}{k_{i,j}} \qquad h1_{min} = \begin{bmatrix} 7 & 6 & 6 \\ 5 & 4.929 & 4.929 \\ 6 & 5.143 & 5.143 \end{bmatrix} in$$

Minimum required slab thickness for each continuous strip entered, defined as the maximum for any span within the continuous strip:

$$h_{min_i} := \max\left(\left(\frac{h1_{min}^{\mathrm{T}}}{\boldsymbol{in}}\right)^{\langle i \rangle}\right) \cdot \boldsymbol{in} \qquad h_{min}^{\mathrm{T}} = [7 \;\; 5 \;\; 6] \; \boldsymbol{in}$$

Slab thickness h = h_{min} rounded to the nearest upper multiple of SzF,
(unless the lower multiple is within 1/2% of the lower multiple of SzF):

$$h_i := SzF \cdot \mathrm{ceil}\left(0.995 \cdot \frac{h_{min_i}}{SzF}\right) \qquad h^{\mathrm{T}} = [7 \;\; 5 \;\; 6] \; \boldsymbol{in}$$

Factored design load w_u and service load w_s:

$$w_{u_i} := 1.7 \cdot w_l + 1.4 \cdot \left(w_{sd} + h_i \cdot w_{rc}\right)$$

$$w_u^{\mathrm{T}} = [0.484 \;\; 0.449 \;\; 0.466] \; \frac{\boldsymbol{kip}}{\boldsymbol{ft}^2}$$

$$w_{s_i} := w_l + w_{sd} + h_i \cdot w_{rc}$$

$$w_s^{\mathrm{T}} = [0.303 \;\; 0.278 \;\; 0.29] \; \frac{\boldsymbol{kip}}{\boldsymbol{ft}^2}$$

Shear at exterior face of 1st interior support, and at faces of interior supports:

$$V_{u_{i,j}} := \mathbf{if}\left(S_{i,j} = 2, \frac{1}{2} \cdot w_{u_i} \cdot 1 \cdot \boldsymbol{ft} \cdot L_{n_{i,j}}, 1.15 \cdot \left(\frac{1}{2} \cdot w_{u_i} \cdot 1 \cdot \boldsymbol{ft} \cdot L_{n_{i,j}}\right)\right)$$

$$V_u = \begin{bmatrix} 3.892 & 3.385 & 3.385 \\ 2.579 & 2.579 & 2.579 \\ 3.215 & 2.796 & 2.796 \end{bmatrix} \boldsymbol{kip}$$

Effective slab depth at supports:

$$d1_{i,j} := h_i - cl - \text{if}\left(S_{i,j} = 0, d_{b_{xb}}, d_{b_{xt}}\right)$$

$$d1 = \begin{bmatrix} 5.5 & 5.5 & 5.5 \\ 3.5 & 3.5 & 3.5 \\ 4.5 & 4.5 & 4.5 \end{bmatrix} \; in$$

Maximum shear stress at distance d from support, all spans:

$$v_{u_{i,j}} := \frac{V_{u_{i,j}} - w_{u_i} \cdot ft \cdot d1_{i,j}}{ft \cdot d1_{i,j}}$$

$$v_u = \begin{bmatrix} 55.615 & 47.923 & 47.923 \\ 58.287 & 58.287 & 58.287 \\ 56.308 & 48.542 & 48.542 \end{bmatrix} \; psi$$

Maximum shear stress:

$$\max\left(v_u\right) = 58.287 \; psi$$

Useable shear stress at factored load:

$$\phi_v \cdot v_c = 107.517 \; psi$$

Note ⇒ If maximum shear stress exceeds $\phi_v v_c$, increase h accordingly.

Coefficients and Moments

Exterior support:

$$km_{i,0} := \text{if}\left(\left(S_{i,0} = 12\right), 0, \text{if}\left(\left(L_{n_{i,0}} \le 10 \cdot ft\right), \frac{1}{12}, \text{if}\left(S_{i,0} = 1, \frac{1}{24}, \frac{1}{16}\right)\right)\right)$$

$$M_{u_{i,0}} := km_{i,0} \cdot w_{u_i} \cdot 1 \cdot ft \cdot \left(L_{n_{i,0}}\right)^2$$

Exterior span:

$$km_{i,1} := \text{if}\left(S_{i,0} = 12, \frac{1}{11}, \frac{1}{14}\right)$$

$$M_{u_{i,1}} := km_{i,1} \cdot w_{u_i} \cdot 1 \cdot ft \cdot \left(L_{n_{i,0}}\right)^2$$

1st interior support:

$$km_{i,2} := \text{if}\left(\left(L_{n_{i,0}} \le 10 \cdot ft\right) \cdot \left(L_{n_{i,1}} \le 10 \cdot ft\right), \frac{1}{12}, \text{if}\left(\left(S_{i,1} = 1\right) + \left(S_{i,1} = 11\right) + \left(S_{i,1} = 12\right), \frac{1}{9}, \frac{1}{10}\right)\right)$$

$$M_{u_{i,2}} := km_{i,2} \cdot w_{u_i} \cdot 1 \cdot ft \cdot \left(\frac{L_{n_{i,0}} + L_{n_{i,1}}}{2}\right)^2$$

2nd span (interior for 3 or more spans, end span for 2 spans):

$$km_{i,3} := \text{if}\left(S_{i,1} = 2, \frac{1}{16}, \text{if}\left(S_{i,1} = 12, \frac{1}{11}, \frac{1}{14}\right)\right)$$

$$M_{u_{i,3}} := km_{i,3} \cdot w_{u_i} \cdot 1 \cdot ft \cdot \left(L_{n_{i,1}}\right)^2$$

3rd support (interior support for 3 or more spans, exterior support for 2 span):

$$km_{i,4} := \text{if}\left(S_{i,1} = 2, \frac{1}{11}, \text{if}\left(S_{i,1} = 1, \frac{1}{24}, \text{if}\left(S_{i,0} = 12, 0, \frac{1}{16}\right)\right)\right)$$

$$M_{u_{i,4}} := km_{i,4} \cdot w_{u_i} \cdot 1 \cdot ft \cdot \left(\frac{L_{n_{i,1}} + L_{n_{i,2}}}{2}\right)^2$$

3rd span (interior for 4 or more spans, end span for 3 spans):

$$km_{i,5} := \textbf{if}\left(S_{i,2} = 2, \frac{1}{16}, \textbf{if}\left(S_{i,2} = 12, \frac{1}{11}, \frac{1}{14}\right)\right)$$

$$M_{u_{i,5}} := km_{i,5} \cdot w_{u_i} \cdot 1 \cdot ft \cdot \left(L_{n_{i,2}}\right)^2$$

Moment coefficients, (the columns from left to right are exterior support, exterior span, 1st interior support, interior span, 2nd interior support, and 2nd interior span:

$\frac{1}{9} = 0.111$ $\frac{1}{10} = 0.1$ $\frac{1}{11} = 0.091$ $\frac{1}{12} = 0.083$

$\frac{1}{14} = 0.071$ $\frac{1}{16} = 0.063$ $\frac{1}{24} = 0.042$

Moment coefficients:

$$km = \begin{bmatrix} 0.042 & 0.071 & 0.1 & 0.063 & 0.091 & 0.063 \\ 0.083 & 0.071 & 0.1 & 0.063 & 0.091 & 0.063 \\ 0.042 & 0.071 & 0.1 & 0.063 & 0.091 & 0.063 \end{bmatrix}$$

Factored load moments:

$$M_u = \begin{bmatrix} 3.949 & 6.769 & 9.477 & 5.923 & 8.615 & 5.923 \\ 3.738 & 3.204 & 5.183 & 3.707 & 5.392 & 3.707 \\ 2.796 & 4.793 & 6.71 & 4.194 & 6.1 & 4.194 \end{bmatrix} kip \cdot ft$$

Effective slab depths at positive and negative moment sections:

$$j := 0..5$$

$$d_{i,j} := h_i - cl - \frac{1}{2} \cdot \left(((j=0)+(j=2)+(j=4)) \cdot d_{b_{xt}} + ((j=1)+(j=3)+(j=5)) \cdot d_{b_{xb}}\right)$$

$$d = \begin{bmatrix} 5.875 & 6 & 5.875 & 6 & 5.875 & 6 \\ 3.875 & 4 & 3.875 & 4 & 3.875 & 4 \\ 4.875 & 5 & 4.875 & 5 & 4.875 & 5 \end{bmatrix} in$$

Reinforcement ratios at all positive and negative moment sections:

$$\rho1_{i,j} := \left(1 - \left(\sqrt{1 - \frac{2 \cdot M_{u_{i,j}}}{\phi_f \cdot 1 \cdot ft \cdot \left(d_{i,j}\right)^2 \cdot 0.85 \cdot f'_c}}\right)\right) \cdot \frac{0.85 \cdot f'_c}{f_y}$$

$$\rho2_{i,j} := \frac{\rho_{temp} \cdot h_i}{d_{i,j}}$$

$$\rho3_{i,j} := \textbf{if}\left(\rho1_{i,j} < \rho2_{i,j}, \rho2_{i,j}, \rho1_{i,j}\right)$$

$$\rho3 = \begin{bmatrix} 0.216 & 0.36 & 0.534 & 0.313 & 0.483 & 0.313 \\ 0.481 & 0.384 & 0.68 & 0.447 & 0.709 & 0.447 \\ 0.222 & 0.367 & 0.55 & 0.32 & 0.497 & 0.32 \end{bmatrix} 1\%$$

Maximum reinforcement ratio: $\max(\rho3) = 0.709\ 1\%$

Maximum useable reinforcement ratio: $\rho_{max} = 2.138\ 1\%$

Note ⇒ If maximum reinforcement ratio is greater than ρmax, h must be revised accordingly.

Required reinforcement areas at all positive and negative design sections:

$$A_{s_{i,j}} := \rho 3_{i,j} \cdot ft \cdot d_{i,j}$$

$$A_s = \begin{bmatrix} 0.152 & 0.259 & 0.376 & 0.226 & 0.34 & 0.226 \\ 0.224 & 0.184 & 0.316 & 0.214 & 0.33 & 0.214 \\ 0.13 & 0.22 & 0.321 & 0.192 & 0.291 & 0.192 \end{bmatrix} in^2$$

Theoretical reinforcing bar spacing:

$$Sp\_1_{i,j} := \mathbf{if}\left((j=0)+(j=2)+(j=4), \frac{A_{b_{xt}}}{A_{s_{i,j}}}, \frac{A_{b_{xb}}}{A_{s_{i,j}}}\right) \cdot ft$$

Maximum bar spacing for crack control as a function of standard bar size number, No:

$$Sp(No) := \overrightarrow{\left(\frac{z}{0.6 \cdot f_y}\right)^3 \cdot \left(2 \cdot \left(cl + 0.5 \cdot d_{b_{No}}\right)^2\right)^{-1}}$$

Top bars: $Sp(xt) = 3.782\ ft$

Bottom bars: $Sp(xb) = 4.786\ ft$

Spacing for crack control at all design sections:

$$Sp\_2_{i,j} := \mathbf{if}((j=0)+(j=2)+(j=4), Sp(xt), Sp(xb))$$

The lesser of the theoretical reinforcing bar spacing or the spacing for crack control:

$$Sp\_3_{i,j} := \mathbf{if}\left(Sp\_1_{i,j} > Sp\_2_{i,j}, Sp\_2_{i,j}, Sp\_1_{i,j}\right)$$

Maximum reinforcing bar spacing with spacing limited for crack control and the lesser of 3 times the slab thickness or 18 inches.
(Spacing may be reduced to any preferred value, such as 2 x h or 12 inches.):

$$Sp\_4_i := \mathbf{if}\left(3 \cdot h_i < 18 \cdot in, 3 \cdot h_i, 18 \cdot in\right)$$

$$Sp\_5_{i,j} := \mathbf{if}\left(Sp\_3_{i,j} > Sp\_4_i, Sp\_4_i, Sp\_3_{i,j}\right)$$

Spacing rounded to the nearest lower multiple of SpF, unless the upper multiple is within 1/2 % of the required spacing:

$$s_{i,j} := \text{floor}\left(\frac{1.005 \cdot Sp\_5_{i,j}}{SpF}\right) \cdot SpF$$

$$s = \begin{bmatrix} 1.5 & 0.75 & 1.167 & 0.833 & 1.25 & 0.833 \\ 1.25 & 1.083 & 1.25 & 0.917 & 1.25 & 0.917 \\ 1.5 & 0.833 & 1.333 & 1 & 1.5 & 1 \end{bmatrix} \boldsymbol{ft}$$

Reinforcement ratios at all sections based on final selected bar spacing:

$$\rho_{i,j} := \mathbf{if}\left((j=0)+(j=2)+(j=4), \frac{A_{b_{xt}}}{s_{i,j} \cdot d_{i,j}}, \frac{A_{b_{xb}}}{s_{i,j} \cdot d_{i,j}}\right)$$

$$\rho = \begin{bmatrix} 0.004 & 0.004 & 0.005 & 0.003 & 0.005 & 0.003 \\ 0.008 & 0.004 & 0.008 & 0.005 & 0.008 & 0.005 \\ 0.005 & 0.004 & 0.006 & 0.003 & 0.005 & 0.003 \end{bmatrix}$$

Useable shear at factored load:

$$\phi V_n := \overrightarrow{\phi_v \cdot v_c \cdot 1 \cdot \boldsymbol{ft} \cdot d1} \qquad \phi V_n = \begin{bmatrix} 7.1 & 7.1 & 7.1 \\ 4.52 & 4.52 & 4.52 \\ 5.81 & 5.81 & 5.81 \end{bmatrix} \boldsymbol{kip}$$

Useable moment at factored load:

$$\phi M_n := \overrightarrow{K(\rho) \cdot 1 \cdot \boldsymbol{ft} \cdot d^2}$$

$$\phi M_n = \begin{bmatrix} 1.01 \cdot 10^4 & 9.44 \cdot 10^3 & 1.29 \cdot 10^4 & 8.53 \cdot 10^3 & 1.21 \cdot 10^4 & 8.53 \cdot 10^3 \\ 7.77 \cdot 10^3 & 4.35 \cdot 10^3 & 7.77 \cdot 10^3 & 5.11 \cdot 10^3 & 7.77 \cdot 10^3 & 5.11 \cdot 10^3 \\ 8.34 \cdot 10^3 & 7.06 \cdot 10^3 & 9.33 \cdot 10^3 & 5.92 \cdot 10^3 & 8.34 \cdot 10^3 & 5.92 \cdot 10^3 \end{bmatrix} \frac{\boldsymbol{kg} \cdot \boldsymbol{m}^2}{\boldsymbol{s}^2}$$

Larger shear per span, and moments at all positive and negative design sections:

$$V_u = \begin{bmatrix} 3.89 & 3.38 & 3.38 \\ 2.58 & 2.58 & 2.58 \\ 3.22 & 2.8 & 2.8 \end{bmatrix} \textbf{\textit{kip}}$$

$$M_u = \begin{bmatrix} 3.95 & 6.77 & 9.48 & 5.92 & 8.62 & 5.92 \\ 3.74 & 3.2 & 5.18 & 3.71 & 5.39 & 3.71 \\ 2.8 & 4.79 & 6.71 & 4.19 & 6.1 & 4.19 \end{bmatrix} \textbf{\textit{kip}} \cdot \textbf{\textit{ft}}$$

Summary

Input

Specified compressive strength of concrete:	$f'_c = 4$ ***ksi***
Specified yield strength of reinforcement:	$f_y = 60$ ***ksi***
Unit weight of concrete:	$w_c = 145$ ***pcf***
Unit weight of reinforced concrete:	$w_{rc} = 150$ ***pcf***
Service live load per unit area:	$w_l = 200$ ***psf***
Service dead load per unit area excluding slab weight:	$w_{sd} = 15$ ***psf***
Clear concrete cover of reinforcement:	$cl = 0.75$ ***in***
Shear strength reduction factor for lightweight concrete:	$k_v = 1$
Weight factor for increasing development and splice lengths for lightweight aggregate concrete:	$k_w = 1$

Crack control factor (175 kip/ in interior, 145 kip/in exterior): $z = 175\ \frac{kip}{in}$

Sizing factor for rounding slab thickness: $SzF = 0.5\ in$

Sizing factor for rounding bar spacing: $SpF = 1\ in$

Top bar size: $TopBar = 6$

Bottom bar size: $BotBar = 4$

Clear span lengths and span types (Slab design strips are in rows. Exterior spans are in the 1st column, 1st interior spans are in the 2nd column and the third spans are in the third column):

$$L_n = \begin{bmatrix} 14 & 14 & 14 \\ 10 & 11.5 & 11.5 \\ 12 & 12 & 12 \end{bmatrix} ft \qquad SpanType = \begin{bmatrix} 1 & 2 & 2 \\ 1 & 2 & 2 \\ 1 & 2 & 2 \end{bmatrix}$$

Computed Variables

Total uniformly distributed service and factored loads. The first slab design strip is in the first column of the transposed vector followed in sequence by the remaining design strips.

Total service dead + live: $w_s^{T} = \begin{bmatrix} 302.5 & 277.5 & 290 \end{bmatrix} psf$

Total factored dead + live: $w_u^{T} = \begin{bmatrix} 483.5 & 448.5 & 466 \end{bmatrix} psf$

Maximum shear stress and useable shear stress at factored load:

$\max\left(v_u\right) = 58.287\ psi$ $\qquad \phi_v \cdot v_c = 107.517\ psi$

Maximum reinforcement ratio and maximum useable reinforcement ratio at factored load:

$\max\left(\rho\right) = 0.757\ 1\%$ $\qquad \rho_{max} = 2.138\ 1\%$

Slab thicknesses and reinforcing bar spacing

The required slab thickness for the first design strip is in the first row followed by the remaining strips in sequence. For bar spacing, the 1st column is the exterior support, 2nd is the exterior span (positive reinforcement), 3rd is the 1st interior support, 4th is the first interior span (positive reinforcement), 5th is the 2nd interior support, and the 6th is the 3rd span (positive reinforcement):

$$h=\begin{bmatrix}0.178\\0.127\\0.152\end{bmatrix}\ m \qquad s=\begin{bmatrix}18 & 9 & 14 & 10 & 15 & 10\\15 & 13 & 15 & 11 & 15 & 11\\18 & 10 & 16 & 12 & 18 & 12\end{bmatrix}\ in$$

Top bar size: $TopBar=6$

Bottom bar size: $BotBar=4$

Calculated required reinforcement areas:

$$A_s=\begin{bmatrix}0.152 & 0.259 & 0.376 & 0.226 & 0.34 & 0.226\\0.224 & 0.184 & 0.316 & 0.214 & 0.33 & 0.214\\0.13 & 0.22 & 0.321 & 0.192 & 0.291 & 0.192\end{bmatrix}\ in^2$$

Actual reinforcement ratios provided:

$$\rho=\begin{bmatrix}0.004 & 0.004 & 0.005 & 0.003 & 0.005 & 0.003\\0.008 & 0.004 & 0.008 & 0.005 & 0.008 & 0.005\\0.005 & 0.004 & 0.006 & 0.003 & 0.005 & 0.003\end{bmatrix}$$

Actual reinforcement areas provided:

$$\overrightarrow{\rho\cdot ft\cdot d}=\begin{bmatrix}0.293 & 0.267 & 0.377 & 0.24 & 0.352 & 0.24\\0.352 & 0.185 & 0.352 & 0.218 & 0.352 & 0.218\\0.293 & 0.24 & 0.33 & 0.2 & 0.293 & 0.2\end{bmatrix}\ in^2$$