Simply Supported Reinforced Concrete Beam Analysis and Design (ACI 318-14)
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Simply supported beams consist of one span with one support at each end, one is a pinned support and the other is a roller support. The ends of these beams are free to rotate and have no moment resistance. There are numerous typical and practical applications of simply supported beams in buildings, bridges, industrial and special structures.

This example will demonstrate the analysis and design of the rectangular simply supported reinforced concrete beam shown below using ACI 318-14 provisions. Steps of the structural analysis, flexural design, shear design, and deflection checks will be presented. The results of hand calculations are then compared with the reference results and numerical analysis results obtained from the spBeam engineering software program by StructurePoint.

![Figure 1](image-url)
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Code

Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14)

References


spBeam Engineering Software Program Manual v5.00, STRUCTUREPOINT, 2015

Design Data

\[ f' = 4.35 \text{ ksi normal weight concrete} \quad (w_c = 150 \text{ lb/ft}^3) \]
\[ f_y = 60 \text{ ksi} \]

Uniform dead load, \( DL = 0.82 \text{ kip/ft} \) (Reference neglected self-weight)

Uniform Live load, \( LL = 1.00 \text{ kip/ft} \)

Beam span length, \( L = 25 \text{ ft} \)

Use #9 bars for longitudinal reinforcement \( (A_s = 1.00 \text{ in.}^2, d_b = 1.128 \text{ in.}) \)

Use #3 bars for stirrups \( (A_s = 0.11 \text{ in.}^2, d_b = 0.375 \text{ in.}) \)

Clear cover = 1.5 in. \( \quad ACI 318-14 \) (Table 20.6.1.3.1)

\[ a_{max} = \text{maximum aggregate size} = 0.75 \text{ in.} \]
Solution

1. Preliminary Member Sizing

Check the minimum beam depth requirement of ACI 318-14 (Table 9.3.1.1) to waive deflection computations. 
Using the minimum depth for non-prestressed beams in Table 9.3.1.1.

\[
h_{\text{min}} = \frac{L_n}{16} = \frac{300 \text{ in.}}{16} = 18.75 \text{ in.} \quad \text{(For simply supported beams)} \quad \text{ACI 318-14 (Table 9.3.1.1)}
\]

Therefore, since \( h_{\text{min}} = 18.75 \text{ in.} < h = 20 \text{ in.} \) the preliminary beam depth satisfies the minimum depth requirement, and the beam deflection computations are not required.

In absence of initial dimensions, the width of the rectangular section (b) may be chosen in the following range recommended by the reference:

\[
\left( \frac{1}{2} \times h = 10 \text{ in.} \right) \leq b = 12 \text{ in.} \leq \left( \frac{2}{3} \times h = 13.33 \text{ in.} \right)
\]

o.k.

2. Load and Load combination

For the factored Load

\[
w_u = 1.2 \times DL + 1.6 \times LL \quad \text{ACI 318-14 (Eq. 5.3.1b)}
\]
\[
w_u = 1.2 \times 0.82 + 1.5 \times 1.00 = 2.58 \text{ kip/ft}
\]
3. **Structural Analysis**

Simply supported beams can be analyzed by calculating shear and moment diagrams or using Design Aid tables as shown below:

**Shear and Moment Diagrams:**

![Shear and Bending Moment Diagrams](image-url)

- $w_a = 2.58 \text{ kip/ft}$
- $R_A = 32.2 \text{ kip}$
- $R_B = 32.3 \text{ kip}$
- $V_u, \text{ kip}$
- $M_u, \text{ kip-ft}$
- 25 ft (300 in.)

Figure 2 – Shear and Bending Moment Diagrams
Using Design Aid Tables:

\[ V_u = R_A = R_B = \frac{w_u \times L}{2} = \frac{2.58 \times 25}{2} = 32.3 \text{ kip} \]
\[ M_u = \frac{w_u \times L^2}{8} = \frac{2.58 \times 25^2}{8} = 201.88 \text{ kip-ft} \]

**SIMPLE BEAM – UNIFORMLY DISTRIBUTED LOAD**

\[ R - V = \frac{w \ell}{2} \]
\[ V_x = \frac{w}{2} (\ell - x) \]
\[ M_{\text{max}} \text{ (at center)} = \frac{w \ell^2}{8} \]
\[ M_k = \frac{wx}{2} (\ell - x) \]
\[ \Delta_{\text{max}} \text{ (at center)} = \frac{5w \ell^4}{384EI} \]
\[ \Delta_k = \frac{wx}{24EI} (\ell^3 - 2\ell^2 x^2 + x^3) \]

Figure 3 – Design Aid Tables (Beam Design Equations and Diagrams) – PCI Design Handbook

4. **Flexural Design**

4.1. **Required and Provided Reinforcement**

For this beam, the moment at the midspan governs the design as shown in the previous Figure.

\[ M_u = 201.88 \text{ kip-ft} \]

Use #9 bars with 1.5 in. concrete clear cover per **ACI 318-14 (Table 20.6.1.3.1)**. The distance from extreme compression fiber to the centroid of longitudinal tension reinforcement, \( d \), is calculated below:

\[ d = h - \left( \text{clear cover} + d_{\text{stirrups}} + \frac{d_{\text{longitudinal bar}}}{2} \right) \]

\[ d = 20 - \left( 1.50 + 0.375 + \frac{1.128}{2} \right) = 17.56 \text{ in.} \]

To determine the area of steel, assumptions have to be made whether the section is tension or compression controlled, and regarding the distance between the resultant compression and tension forces along the beam section (\( jd \)). In this example, tension-controlled section will be assumed so the reduction factor \( \phi \) is equal to 0.9, and \( jd \) will be taken equal to 0.889\( d \). The assumptions will be verified once the area of steel is finalized.

\[ jd = 0.889 \times d = 0.889 \times 17.56 = 15.62 \text{ in.} \]
The required reinforcement at initial trial is calculated as follows:

\[
A_r = \frac{M_u}{\phi f_y x d} = \frac{201.88 \times 12,000}{0.9 \times 60,000 \times 15.62} = 2.872 \text{ in.}^2
\]

Recalculate ‘a’ for the actual \(A_s = 2.872 \text{ in.}^2\):

\[
a = \frac{A_r \times f_y}{0.85 \times f'_c \times b} = \frac{2.872 \times 60,000}{0.85 \times 4,350 \times 12} = 3.88 \text{ in.}
\]

\[
c = \frac{a}{\beta_t} = \frac{3.88}{0.83} = 4.67 \text{ in.}
\]

Where:

\[
\beta_t = 0.85 - \frac{0.05 \times (f'_c - 4000)}{1000} \quad \text{ACI 318-14 (Table 22.2.4.3)}
\]

\[
\beta_t = 0.85 - \frac{0.05 \times (4350 - 4000)}{1000} = 0.83
\]

\[
e_i = \left(\frac{0.003}{c}\right) \times d_i - 0.003 = \left(\frac{0.003}{4.67}\right) \times 17.56 - 0.003 = 0.0083 > 0.005
\]

Therefore, the assumption that section is tension-controlled is valid.

\[
A_r = \frac{M_u}{\phi f_y \left(\frac{d - a}{2}\right)} = \frac{201.88 \times 12,000}{0.9 \times 60,000 \times \left(17.56 - \frac{3.88}{2}\right)} = 2.872 \text{ in.}^2
\]

The minimum reinforcement shall not be less than

\[
A_{r,min} = \frac{3 \times f'_c}{f_y} b_w \times d = \frac{3 \times 4350}{60000} \times 12 \times 17.56 = 0.695 \text{ in.}^2 \quad \text{ACI 318-14 (9.6.1.2(a))}
\]

And not less than

\[
A_{r,min} = \frac{200}{f_y} b_w \times d = \frac{200}{60000} \times 12 \times 17.56 = 0.702 \text{ in.}^2 \quad \text{ACI 318-14 (9.6.1.2(b))}
\]

\[
\therefore A_{r,min} = 0.702 \text{ in.}^2
\]

\[
A_{r,req} = \max \left\{ \frac{A_r}{A_{r,min}} \right\} = \max \left\{ \frac{2.872}{0.702} \right\} = 2.872 \text{ in.}^2
\]

Provide 3 – #9 bars:

\[
A_{s,prov} = 3 \times 1.00 = 3.00 \text{ in.}^2 > A_{r,req} = 2.872 \text{ in.}^2
\]
4.2. Spacing of Longitudinal Reinforcement

\[
 s_{\text{provided}} = \frac{(b - 2 \times d_s)}{\text{# of bars} - 1} = \frac{\left(12 - 2 \times \left(\frac{2}{8}\right)\right)}{3 - 1} = 3.38 \, \text{in.}
\]

Where \( d_s \) = 2.625 in. for #3 stirrup as shown in the following Figure.  

**CRSI 2002 (Figure 12-9)**

\[ \text{Figure 4 - Maximum number of bars in beams} \]

The maximum allowed spacing (\( s_{\text{max}} \)):

\[
 s_{\text{max}} = 15 \left(\frac{40000}{f_s}\right) - 2.5c_c \leq 12 \left(\frac{40000}{f_s}\right)
\]

\( c_c = 1.5 \, \text{in.} \)

Use \( f_s = \frac{2}{3} f_y = 40000 \, \text{psi} \)

\[
 s_{\text{max}} = \min \left\{ 15 \times \left(\frac{40000}{40000}\right) - 2.5 \times 1.5 \right\} = \min \left\{ 10.31 \right\} = 10.31 \, \text{in.}
\]

The minimum allowed spacing (\( s_{\text{min}} \)):

\[
 s_{\text{min}} = d_b + \max \left\{ \frac{1}{1.33 \times \text{max. agg.}} d_b \right\}
\]

Where the maximum aggregate size is \( \frac{3}{4}'' \)

\[
 s_{\text{min}} = 1.00 + \max \left\{ \frac{1.00}{1.128} \right\} = 1.00 + 1.128 = 2.26 \, \text{in.}
\]

\[
 s_{\text{min}} = 2.26 \, \text{in.} \quad < s_{\text{provided}} = 3.38 \, \text{in.} \quad < s_{\text{max}} = 10.31 \, \text{in.}
\]

Therefore, 3 - #9 bars are o.k.
5. Shear Design

Figure 5 – Shear Diagram for Simply Supported Beam

\[ V_u = 32.3 \text{ kips} \]

\[ V_{u@d} = 32.3 \times \frac{150 - 17.56}{150} = 28.52 \text{ kips} \]

Shear strength provided by concrete

\[ \phi \nu_c = \phi \times 2 \times \sqrt{f'_c \times b_w \times d} \]

\[ \phi \nu_c = 0.75 \times 2 \times \sqrt{4350 \times 12 \times 17.56} = 20.85 \text{ kips} \]

\[ \frac{\phi \nu_c}{2} = 10.42 \text{ kips} < V_u = 32.3 \text{ kips} \]

Since \( V_u > \phi \nu_c/2 \), shear reinforcement is required.

Try # 3, Grade 60 two-leg stirrups (\( A_v = 2 \times 0.11 = 0.22 \text{ in.}^2 \)).

The nominal shear strength required to be provided by shear reinforcement is

\[ V_s = V_n - V_c = \frac{V_{u@d}}{\phi} - \frac{\phi \nu_c}{\phi} = \frac{28.52}{0.75} - \frac{20.85}{0.75} = 10.23 \text{ kips} \]
If $V_s$ is greater than $8\sqrt{f'_c b_w d}$, then the cross-section has to be revised as **ACI 318-14** limits the shear capacity to be provided by stirrups to $8\sqrt{f'_c b_w d}$.

$$8\times\sqrt{f'_c b_w d} = \sqrt{4350\times12\times17.56} = 111.19 \text{ kips} \rightarrow \text{section is adequate}$$

$$\frac{A_c}{s}_{\text{req}} = \frac{V_u - \phi V_c}{\phi \times f_{\text{yt}} \times d} = \frac{28.52 - 20.85}{0.75\times60\times17.56} = 0.0097 \text{ in.}^2 / \text{in.}$$

**ACI 318-14 (22.5.10.5.3)**

$$s_{\text{req}} = \frac{A_c}{\frac{A_c}{s}_{\text{req}}} = \frac{0.22}{0.0097} = 22.67 \text{ in.}$$

**ACI 318-14 (10.6.2.2)**

$$\left(\frac{A_c}{s}\right)_{\text{min}} = \max \left\{ \frac{0.75\times\sqrt{f'_c b_w}}{f_{\text{yt}}} \right\} \frac{50\times b_w}{f_{\text{yt}}}$$

$$\left(\frac{A_c}{s}\right)_{\text{min}} = \max \left\{ \frac{0.75\times\sqrt{4350\times12}}{60\times12} \right\} = \max \left\{ \frac{0.0099}{0.0100} \right\} = 0.0100 \text{ in.}^2 / \text{in.} > \left(\frac{A_c}{s}\right)_{\text{req}} = 0.0097 \text{ in.}^2 / \text{in.}$$

$$\therefore \left(\frac{A_c}{s}\right)_{\text{req}} = 0.0100 \text{ in.}^2 / \text{in.}$$

Check whether the required spacing based on the shear demand meets the spacing limits for shear reinforcement per **ACI 318-14 (9.7.6.2.2)**.

$$4\times\sqrt{f'_c b_w d} = 4\times\sqrt{4350\times12\times17.56} = 55.59 \text{ kips} > V_s = 10.23 \text{ kips}$$

Therefore, maximum stirrup spacing shall be the smallest of $d/2$ and 24 in. **ACI 318-14 (Table 9.7.6.2.2)**

$$s_{\text{max}} = \min \left\{ \frac{d}{2}, \frac{17.56}{24 \text{ in.}} \right\} = \min \left\{ 8.78 \text{ in.}, \frac{8.78}{24 \text{ in.}} \right\} = 8.78 \text{ in.}$$

This value governs over the required stirrup spacing of 22.67 in which was based on the demand.

Therefore, $s_{\text{max}}$ value is governed by the spacing limit per **ACI 318-14 (9.7.6.2.2)**, and is equal to 8.78 in.

Use # 3 @ 8.3 in. stirrups

$$\phi V_n = \frac{\phi \times A_v \times f_{\text{yt}} \times d}{s} + \phi V_c$$

**ACI 318-14 (22.5.1.1 and 22.5.10.5.3)**

$$\phi V_n = \frac{0.75\times0.22\times60\times17.56}{8.30} + 20.85 = 20.95 + 20.85 = 41.79 \text{ kips} > V_u @ d = 28.52 \text{ kips} \rightarrow \text{O.K.}$$
Compute where \( \frac{V_u}{\phi} \) is equal to \( \frac{V_c}{2} \), and the stirrups can be stopped

\[
x = \frac{\frac{V_u}{\phi} - \frac{V_c}{2}}{l} \times \frac{I}{2} = \frac{32.3}{0.75} \times \frac{20.85}{0.75 \times 2} \times \frac{25 \times 12}{2} = 101.59 \text{ in.}
\]

Use 16 - # 3 @ 8.30 in. o.c., Place 1\(^{st}\) stirrup 3 in. from the face of the column.
6. Deflection Control (Serviceability Requirements)

Since the preliminary beam depth met minimum depth requirement, the deflection calculations are not required. However, the calculations of immediate and time-dependent deflections are covered in detail in this section for illustration and comparison with spBeam model results for simply supported beam.

6.1. Immediate (Instantaneous) Deflections

Elastic analysis for three service load levels \( (D, D + L_{\text{sustained}}, D+L_{\text{Full}}) \) is used to obtain immediate deflections of the simply supported beam in this example. However, other procedures may be used if they result in predictions of deflection in reasonable agreement with the results of comprehensive tests.

The effective moment of inertia procedure described in the Code is considered sufficiently accurate to estimate deflections. The effective moment of inertia, \( I_e \), was developed to provide a transition between the upper and lower bounds of \( I_g \) and \( I_{cr} \) as a function of the ratio \( M_{cr}/M_a \).

Unless deflections are determined by a more comprehensive analysis, immediate deflection shall be computed using elastic deflection equations using \( I_e \) from Eq. (24.2.3.5a) at midspan for simple and continuous spans, and at the support for cantilevers.

The effective moment of inertia \( (I_e) \) is used to account for the cracking effect on the flexural stiffness of the beam. \( I_e \) for uncracked section \( (M_{cr} > M_a) \) is equal to \( I_g \). When the section is cracked \( (M_{cr} < M_a) \), then the following equation should be used:

\[
I_e = \left( \frac{M_{cr}}{M_a} \right)^3 I_g + \left[ 1 - \left( \frac{M_{cr}}{M_a} \right)^3 \right] I_{cr} \leq I_g
\]

\[\text{ACI 318-14 (Eq. 24.2.3.5a)}\]

Where:

\( M_a = \) Maximum moment in member due to service loads at stage deflection is calculated.

The values of the maximum moments for the three service load levels are calculated from structural analysis as shown previously (sustained live load = 0).

\[
M_{pl} = M_{pl+LL_{\text{sustained}}} = \frac{w_{pl} \times L^2}{8} = \frac{0.82 \times (25)^2}{8} = 64.06 \text{ kip-ft}
\]

\[
M_{pl+LL} = \frac{(w_{pl} + w_{LL}) \times L^2}{8} = \frac{(0.82 + 1.00) \times (25)^2}{8} = 142.19 \text{ kip-ft}
\]

\( M_{cr} = \) cracking moment.

\[
M_{cr} = \frac{f_r I_g}{Y_f} = \frac{(494.66) \times (8000)}{10} \times \frac{1}{12000} = 32.98 \text{ kip-ft}
\]

\[\text{ACI 318-14 (Eq. 24.2.3.5b)}\]

\( f_r = \) Modulus of rapture of concrete.
\[ f_c = 7.5 \sqrt[6]{f'_c} = 7.5 \times 1.0 \times \sqrt[6]{4350} = 494.66 \text{ psi} \]

\[ I_g = \text{Moment of inertia of the gross uncracked concrete section} \]

\[ I_g = \frac{b \times h^3}{12} = \frac{12 \times 20^3}{12} = 8000 \text{ in}^4 \]

\[ y_g = \frac{h}{2} = \frac{20}{2} = 10 \text{ in.} \]

\[ I_{cr} = \text{moment of inertia of the cracked section transformed to concrete.} \]

**ACI 318-14 (Eq. 19.2.3.1)**

The critical section at midspan is reinforced with 3 – #9 bars.

**Figure 6 – Gross and Cracked Moment of Inertia of Rectangular Section (PCA Notes Table 10-2)**

\[ E_c = \text{Modulus of elasticity of concrete.} \]

\[ E_c = w_c \times 33 \times \sqrt{f'_c} = 150^{1/3} \times 33 \times \sqrt{4350} = 3998.5 \text{ ksi} \]

\[ n = \frac{E_e}{E_c} = \frac{29000}{3998.5} = 7.25 \]

\[ B = \frac{b}{n A_s} = \frac{12}{7.25 \times (3 \times 1.00)} = 0.552 \text{ in}^{-1} \]

\[ kd = \frac{\sqrt{2dB + 1} - 1}{B} = \frac{\sqrt{2 \times 7.56 \times 0.552 + 1} - 1}{0.552} = 6.37 \text{ in.} \]

\[ I_{cr} = \frac{b(kd)^3}{3} + n A_s (d - kd)^2 \]

\[ I_{cr} = \frac{12 \times 6.37^3}{3} + 7.25 \times (3 \times 1.00) \times (17.56 - 6.37)^2 = 3759 \text{ in}^4 \]
For dead load service load level:

\[ I_{ec} = I_{cr} \left[ \left( I_g - I_{cr} \right) \frac{M_{cr}}{M_a} \right]^3, \]  

since \( M_{cr} = 32.98 \text{ kip-ft} < M_a = 64.06 \text{ kip-ft} \) \hspace{1cm} ACI 318-14 (24.2.3.5a)

\[ I_e = 3759 + (8000 - 3759) \left( \frac{32.98}{64.06} \right)^3 = 4337 \text{ in.}^4 \]

The following Table provides a summary of the required parameters and calculated values needed for deflection calculation.

<table>
<thead>
<tr>
<th>( I_g ); in.(^4)</th>
<th>( I_{cr} ); in.(^4)</th>
<th>( M_{cr} ); kip-ft</th>
<th>( I_e ); in.(^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8000</td>
<td>3759</td>
<td>64.06</td>
<td>4337</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64.06</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>142.19</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td>32.98</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4337</td>
<td>3812</td>
</tr>
</tbody>
</table>

After obtaining the effective moment of inertia, the maximum span deflection for the simply supported beam can be obtained from any available procedures or design aids (see Figure 3).

\[ \Delta_{max} = \frac{5}{384} \times \frac{w \times L^4}{E \times I_e} \]

\[ \Delta_{re} = \frac{5}{384} \times \frac{820 \times 300^4}{(3998.48 \times 10^3) \times 4337} = 0.416 \text{ in.} \]

\[ \Delta_{total} = \frac{5}{384} \times \frac{(820 + 1000) \times 300^4}{(3998.48 \times 10^3) \times 3812} = 1.050 \text{ in.} \]

\[ \Delta_{LL} = \Delta_{total} - \Delta_{re} = 1.050 - 0.416 = 0.634 \text{ in.} < \frac{L}{360} = \frac{300}{360} = 0.833 \text{ in. \ a.k.} \] \hspace{1cm} ACI 318-14 (Table 24.2.2)
6.2. **Time-Dependent (Long-Term) Deflections ($\Delta_{lt}$)**

The additional time-dependent (long-term) deflection resulting from creep and shrinkage ($\Delta_{cs}$) are estimated as follows.

$$\Delta_{cs} = \lambda_\Delta \times (\Delta_{sust})_{Inst}$$  

*PCA Notes on ACI 318-11 (9.5.2.5 Eq. 4)*

The total time-dependent (long-term) deflection is calculated as:

$$\Delta_{total} = (\Delta_{sust})_{Inst} \times (1 + \lambda_\Delta) + (\Delta_{total})_{Inst} - (\Delta_{total})_{Inst}$$  

*CSA A23.3-04 (N9.8.2.5)*

Where:

$(\Delta_{sust})_{Inst} =$ Immediate (instantaneous) deflection due to sustained load, in.

$$\lambda_\Delta = \frac{\xi}{1 + 50\rho'}$$  

*ACI 318-14 (24.2.4.1.1)*

$(\Delta_{total})_{Inst} =$ Time-dependent (long-term) total deflection, in.

$(\Delta_{total})_{Inst} =$ Total immediate (instantaneous) deflection, in.

For the exterior span

$$\xi = 2, \text{ consider the sustained load duration to be 60 months or more.}$$  

*ACI 318-14 (Table 24.2.4.1.3)*

$$\rho' = 0, \text{ conservatively.}$$

$$\lambda_\Delta = \frac{2}{1 + 50 \times 0} = 2$$

$$\Delta_{cs} = 2 \times 0.416 = 0.831 \text{ in.}$$

$$\Delta_{cs} + \Delta_{LL} = 0.831 + 0.634 = 1.465 \text{ in.} \quad \frac{L}{240} = \frac{25 \times 12}{240} = 1.25 \text{ in.} \quad (Exceeded)$$  

*ACI 318-14 (Table 24.2.2)*

$$(\Delta_{total})_{Inst} = 0.416 \times (1 + 2) + (1.050 - 0.416) = 1.881 \text{ in.}$$
7. **Simply Supported Beam Analysis and Design – spBeam Software**

*spBeam* is widely used for analysis, design and investigation of beams, and one-way slab systems (including standard and wide module joist systems) per latest American (ACI 318-14) and Canadian (CSA A23.3-14) codes. *spBeam* can be used for new designs or investigation of existing structural members subjected to flexure, shear, and torsion loads. With capacity to integrate up to 20 spans and two cantilevers of wide variety of floor system types, *spBeam* is equipped to provide cost-effective, accurate, and fast solutions to engineering challenges.

*spBeam* provides top and bottom bar details including development lengths and material quantities, as well as live load patterning and immediate and long-term deflection results. Using the moment redistribution feature engineers can deliver safe designs with savings in materials and labor. Engaging this feature allows up to 20% reduction of negative moments over supports reducing reinforcement congestions in these areas.

Beam analysis and design requires engineering judgment in most situations to properly simulate the behavior of the targeted beam and take into account important design considerations such as: designing the beam as rectangular or T-shaped sections; using the effective flange width or the center-to-center distance between the beam and the adjacent beams. Regardless which of these options is selected, *spBeam* provide users with options and flexibility to:

1. Design the beam as a rectangular cross-section or a T-shaped section.
2. Use the effective or full beam flange width.
3. Include the flanges effects in the deflection calculations.
4. Invoke moment redistribution to lower negative moments
5. Using gross (uncracked) or effective (cracked) moment of inertia

For illustration and comparison purposes, the following figures provide a sample of the results obtained from an *spBeam* model created for the simply supported beam discussed in this example.
spBeam v6.50
A Computer Program for Analysis, Design, and Investigation of
Reinforced Concrete Beams and One-way Slab Systems
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1. Input Echo

1.1. General Information

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<thead>
<tr>
<th>File Name</th>
<th>C:\Structures\Simply Supported RC Beam - ACI.slb</th>
</tr>
</thead>
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<td>Simply Supported RC Beam</td>
</tr>
<tr>
<td>Frame</td>
<td>Simply Supported RC Beam</td>
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<tr>
<td>Engineer</td>
<td>SP</td>
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<tr>
<td>Code</td>
<td>ACI 318-14</td>
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<td>Database</td>
<td>ASTM A615</td>
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<td>Mode</td>
<td>Design</td>
</tr>
<tr>
<td>Number of supports =</td>
<td>2</td>
</tr>
<tr>
<td>Floor System</td>
<td>One-Way/Beam</td>
</tr>
</tbody>
</table>

1.2. Solve Options

- Live load pattern ratio = 0%
- Deflections are based on cracked section properties.
- In negative moment regions, k and M or DO NOT include flange/slab contribution (if available)
- Long-term deflections are calculated for load duration of 60 months.
- 0% of live load is sustained.
- Compression reinforcement calculations NOT selected.
- Default incremental rebar design selected.
- Moment redistribution NOT selected.
- Effective flange width calculations NOT selected.
- Rigid beam-column joint NOT selected.
- Torsion analysis and design NOT selected.

1.3. Material Properties

1.3.1. Concrete: Slabs / Beams

<table>
<thead>
<tr>
<th>$w_c$</th>
<th>150 lb/ft²</th>
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</thead>
<tbody>
<tr>
<td>$f_c$</td>
<td>4.35 ksi</td>
</tr>
<tr>
<td>$E_c$</td>
<td>3988.5 ksi</td>
</tr>
<tr>
<td>$f_t$</td>
<td>0.49468 ksi</td>
</tr>
</tbody>
</table>

1.3.2. Concrete: Columns

<table>
<thead>
<tr>
<th>$w_c$</th>
<th>150 lb/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_c$</td>
<td>4.35 ksi</td>
</tr>
<tr>
<td>$E_c$</td>
<td>3988.5 ksi</td>
</tr>
<tr>
<td>$f_t$</td>
<td>0.49468 ksi</td>
</tr>
</tbody>
</table>

1.3.3. Reinforcing Steel

<table>
<thead>
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<th>$f_y$</th>
<th>60 ksi</th>
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</thead>
<tbody>
<tr>
<td>$f_y$</td>
<td>60 ksi</td>
</tr>
<tr>
<td>$E_s$</td>
<td>29000 ksi</td>
</tr>
<tr>
<td>Epoxy coated bars</td>
<td>No</td>
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### 1.4. Reinforcement Database

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<tr>
<th>Size</th>
<th>Db</th>
<th>Ab</th>
<th>Wb</th>
<th>Size</th>
<th>Db</th>
<th>Ab</th>
<th>Wb</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3</td>
<td>0.38</td>
<td>0.11</td>
<td>0.38</td>
<td>#4</td>
<td>0.50</td>
<td>0.20</td>
<td>0.67</td>
</tr>
<tr>
<td>#5</td>
<td>0.63</td>
<td>0.31</td>
<td>1.04</td>
<td>#6</td>
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<td>#7</td>
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<td>0.79</td>
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<tr>
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<td>1.13</td>
<td>1.00</td>
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<td>1.27</td>
<td>1.27</td>
<td>4.30</td>
</tr>
<tr>
<td>#11</td>
<td>1.41</td>
<td>1.56</td>
<td>5.31</td>
<td>#14</td>
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### 1.5. Span Data
#### 1.5.1. Slabs

<table>
<thead>
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<th>Span</th>
<th>Loc</th>
<th>L1 ft</th>
<th>t in</th>
<th>wL ft</th>
<th>wR in</th>
<th>Hmax in</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Int</td>
<td>25.00</td>
<td>0.00</td>
<td>0.500</td>
<td>0.500</td>
<td>0.00</td>
</tr>
</tbody>
</table>

#### 1.5.2. Ribs and Longitudinal Beams

<table>
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<tr>
<th>Span</th>
<th>Rib b in</th>
<th>Rib h in</th>
<th>Sp in</th>
<th>Beams b in</th>
<th>h in</th>
<th>Span Hmax in</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>12.00</td>
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<td>18.75</td>
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### 1.6. Support Data
#### 1.6.1. Columns

<table>
<thead>
<tr>
<th>Support</th>
<th>c1a in</th>
<th>c2a in</th>
<th>Ha ft</th>
<th>c1b in</th>
<th>c2b in</th>
<th>Hb ft</th>
<th>Red %</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.000</td>
<td>0.00</td>
<td>0.00</td>
<td>0.000</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>0.00</td>
<td>0.00</td>
<td>0.000</td>
<td>0.00</td>
<td>0.00</td>
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<td>100</td>
</tr>
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</table>

### 1.6.2. Boundary Conditions

<table>
<thead>
<tr>
<th>Support</th>
<th>Spring Kc kip/in</th>
<th>Spring Ky kip/ft-rad</th>
<th>Far End Above</th>
<th>Far End Below</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>Fixed</td>
<td>Fixed</td>
</tr>
<tr>
<td>2</td>
<td>0.00</td>
<td>0.00</td>
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### 1.7. Load Data
#### 1.7.1. Load Cases and Combinations

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<th>Live</th>
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</thead>
<tbody>
<tr>
<td>Type</td>
<td>DEAO</td>
<td>LIVE</td>
</tr>
<tr>
<td>U1</td>
<td>1.200</td>
<td>1.600</td>
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</table>

#### 1.7.2. Line Loads

<table>
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<tr>
<th>Case/Patt</th>
<th>Span</th>
<th>Wa lb/ft</th>
<th>La ft</th>
<th>Wb lb/ft</th>
<th>Lb ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead</td>
<td>1</td>
<td>820.00</td>
<td>0.000</td>
<td>820.00</td>
<td>25.000</td>
</tr>
<tr>
<td>Live</td>
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<td>1000.00</td>
<td>0.000</td>
<td>1000.00</td>
<td>25.000</td>
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1.8. Reinforcement Criteria

1.8.1. Slabs and Ribs

<table>
<thead>
<tr>
<th>Units</th>
<th>Top Bars</th>
<th>Bottom Bars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min.</td>
<td>Max.</td>
</tr>
<tr>
<td>Bar Size</td>
<td>#5</td>
<td>#6</td>
</tr>
<tr>
<td>Bar spacing</td>
<td>in.</td>
<td>1.00</td>
</tr>
<tr>
<td>Reinf ratio</td>
<td>%</td>
<td>0.14</td>
</tr>
<tr>
<td>Clear Cover</td>
<td>in.</td>
<td>1.50</td>
</tr>
</tbody>
</table>

There is NOT more than 12 in of concrete below top bars.

1.8.2. Beams

<table>
<thead>
<tr>
<th>Units</th>
<th>Top Bars</th>
<th>Bottom Bars</th>
<th>Stirrups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar Size</td>
<td>#9</td>
<td>#9</td>
<td>#9</td>
</tr>
<tr>
<td>Bar spacing</td>
<td>in.</td>
<td>1.55</td>
<td>18.00</td>
</tr>
<tr>
<td>Reinf ratio</td>
<td>%</td>
<td>0.14</td>
<td>2.63</td>
</tr>
<tr>
<td>Clear Cover</td>
<td>in.</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>Layer dist.</td>
<td>in.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of legs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side cover</td>
<td>in.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st Stirrup</td>
<td>in.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There is NOT more than 12 in of concrete below top bars.

2. Design Results

2.1. Top Reinforcement

<table>
<thead>
<tr>
<th>Span</th>
<th>Zone</th>
<th>Width</th>
<th>$M_{max}$</th>
<th>$X_{max}$</th>
<th>$A_{s,req}$</th>
<th>$A_{s,net}$</th>
<th>$Sp_{prox}$</th>
<th>Bars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>4.053</td>
<td>0.000</td>
<td>0.000</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Midspan</td>
<td>1.00</td>
<td>0.00</td>
<td>12.500</td>
<td>0.000</td>
<td>4.053</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>1.00</td>
<td>0.00</td>
<td>25.000</td>
<td>0.000</td>
<td>4.053</td>
<td>0.000</td>
<td>0.000</td>
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</tbody>
</table>

2.2. Top Bar Details

<table>
<thead>
<tr>
<th>Span</th>
<th>Bars</th>
<th>Length</th>
<th>Bars</th>
<th>Length</th>
<th>Continuous Bars</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ft</td>
<td></td>
<td>ft</td>
<td>Bar</td>
<td>ft</td>
</tr>
<tr>
<td>1</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
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</tbody>
</table>

2.3. Top Bar Development Lengths

<table>
<thead>
<tr>
<th>Span</th>
<th>Bars</th>
<th>DevLen</th>
<th>Bars</th>
<th>DevLen</th>
<th>Continuous Bars</th>
<th>Bars</th>
<th>DevLen</th>
<th>Bars</th>
<th>DevLen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>in</td>
<td></td>
<td>in</td>
<td>Bar</td>
<td>Bar</td>
<td>DevLen</td>
<td>Bar</td>
<td>DevLen</td>
</tr>
<tr>
<td>1</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
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</tbody>
</table>

2.4. Bottom Reinforcement

<table>
<thead>
<tr>
<th>Span</th>
<th>Width</th>
<th>$M_{max}$</th>
<th>$X_{max}$</th>
<th>$A_{s,req}$</th>
<th>$A_{s,net}$</th>
<th>$Sp_{prox}$</th>
<th>Bars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft</td>
<td>k-ft</td>
<td>ft</td>
<td>m²</td>
<td>m²</td>
<td>m</td>
<td>---</td>
</tr>
<tr>
<td>1</td>
<td>1.00</td>
<td>201.88</td>
<td>12.500</td>
<td>0.702</td>
<td>4.053</td>
<td>2.873</td>
<td>3-49</td>
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</table>
2.5. Bottom Bar Details

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<th>Short Bars</th>
</tr>
</thead>
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<td></td>
<td>Bars</td>
<td>Start</td>
</tr>
<tr>
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<td>3-49</td>
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</tr>
</tbody>
</table>

2.6. Bottom Bar Development Lengths

<table>
<thead>
<tr>
<th>Span</th>
<th>Long Bars</th>
<th>Short Bars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bars</td>
<td>DevLen</td>
</tr>
<tr>
<td>1</td>
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2.7. Flexural Capacity

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<tr>
<th>Span</th>
<th>x</th>
<th>$A_{sb}$</th>
<th>$\Phi M_c$</th>
<th>M_c</th>
<th>Comb Pat</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft</td>
<td>in^2</td>
<td>k-ft</td>
<td>k-ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>U1 All</td>
<td>OK</td>
</tr>
<tr>
<td>8.750</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>U1 All</td>
<td>OK</td>
</tr>
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<td>12.250</td>
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<td>0.00</td>
<td>U1 All</td>
<td>OK</td>
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<td>16.250</td>
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<td>0.00</td>
<td>0.00</td>
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</tr>
<tr>
<td>25.000</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>U1 All</td>
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</tbody>
</table>

2.8. Longitudinal Beam Transverse Reinforcement Demand and Capacity

2.8.1. Section Properties

<table>
<thead>
<tr>
<th>Span</th>
<th>$\phi V_c$</th>
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<tbody>
<tr>
<td></td>
<td>kip</td>
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<tr>
<td>1</td>
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</table>

2.8.2. Beam Transverse Reinforcement Demand

Notes:
*8 - Minimum transverse (stirrup) reinforcement governs.

<table>
<thead>
<tr>
<th>Span</th>
<th>Start</th>
<th>End</th>
<th>$X_c$</th>
<th>$V_c$</th>
<th>CombPatt</th>
<th>$A_{s}$/in</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft</td>
<td>ft</td>
<td>ft</td>
<td>kip</td>
<td></td>
<td>in^2/in</td>
<td>in^2/in</td>
</tr>
<tr>
<td>1</td>
<td>0.250</td>
<td>4.616</td>
<td>1.463</td>
<td>28.52</td>
<td>U1/All</td>
<td>0.00697</td>
<td>0.0100</td>
</tr>
<tr>
<td></td>
<td>4.616</td>
<td>7.770</td>
<td>4.616</td>
<td>25.37</td>
<td>U1/All</td>
<td>0.00600</td>
<td>0.0100</td>
</tr>
<tr>
<td></td>
<td>7.770</td>
<td>10.923</td>
<td>7.770</td>
<td>12.22</td>
<td>U1/All</td>
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<td>0.0100</td>
</tr>
<tr>
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<td>14.077</td>
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<td>U1/All</td>
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<td>0.0000</td>
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<td>17.230</td>
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<td>0.0100</td>
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<td>0.0100</td>
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<td>0.0100</td>
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2.8.3. Beam Transverse Reinforcement Details

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<tr>
<th>Span</th>
<th>Size</th>
<th>Stirrup (2 legs each unless otherwise noted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>#3</td>
<td>16 @ 8.3 - 37.8 - 16 @ 8.3</td>
</tr>
</tbody>
</table>
2.8.4. Beam Transverse Reinforcement Capacity

Notes:
*8 - Minimum transverse (strip) reinforcement governs.

<table>
<thead>
<tr>
<th>Span</th>
<th>Start</th>
<th>End</th>
<th>$X_u$</th>
<th>$V_u$</th>
<th>Com/patt</th>
<th>$A/s$</th>
<th>$A_c$</th>
<th>$S_p$</th>
<th>$A/s'$</th>
<th>$\Phi V_u$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ft</td>
<td>ft</td>
<td></td>
<td>in²/lin</td>
<td>kip</td>
<td>U1/All</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.000</td>
<td>0.250</td>
<td>1.453</td>
<td>28.52</td>
<td>U1/All</td>
<td>0.0097</td>
<td>0.22</td>
<td>8.3</td>
<td>0.0266</td>
<td>41.88 *8</td>
</tr>
<tr>
<td>0.250</td>
<td>10.923</td>
<td></td>
<td>1.453</td>
<td>28.52</td>
<td>U1/All</td>
<td>0.0097</td>
<td>0.22</td>
<td>8.3</td>
<td>0.0266</td>
<td>41.88 *8</td>
</tr>
<tr>
<td>10.923</td>
<td>14.077</td>
<td></td>
<td>14.077</td>
<td>4.07</td>
<td>U1/All</td>
<td>0.0090</td>
<td>0.22</td>
<td>8.3</td>
<td>0.0266</td>
<td>41.88 *8</td>
</tr>
<tr>
<td>14.077</td>
<td>24.750</td>
<td></td>
<td>23.537</td>
<td>28.52</td>
<td>U1/All</td>
<td>0.0097</td>
<td>0.22</td>
<td>8.3</td>
<td>0.0266</td>
<td>41.88 *8</td>
</tr>
<tr>
<td>24.750</td>
<td>25.000</td>
<td></td>
<td>23.537</td>
<td>28.52</td>
<td>U1/All</td>
<td>0.0097</td>
<td>0.22</td>
<td>8.3</td>
<td>0.0266</td>
<td>41.88 *8</td>
</tr>
</tbody>
</table>

2.9. Slab Shear Capacity

<table>
<thead>
<tr>
<th>Span</th>
<th>$b$</th>
<th>$d$</th>
<th>$V_{net}$</th>
<th>$\Phi V_u$</th>
<th>$V_u$</th>
<th>$X_u$</th>
</tr>
</thead>
<tbody>
<tr>
<td>in</td>
<td>in</td>
<td></td>
<td>kip</td>
<td>kip</td>
<td>ft</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>---</td>
<td>---</td>
<td>Not checked</td>
<td>---</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.10. Material TakeOff

2.10.1. Reinforcement in the Direction of Analysis

| Top Bars | 0.0 lb | <!-- | 0.0 lb/ft | <!-- | 0.0 lb/ft² | <!-- | 0.0 lb/ft³ |
| Bottom Bars | 255.0 lb | <!-- | 10.20 lb/ft | <!-- | 10.20 lb/ft² | <!-- | 10.20 lb/ft³ |
| Strips | 52.1 lb | <!-- | 2.06 lb/ft | <!-- | 2.06 lb/ft² | <!-- | 2.06 lb/ft³ |
| Total Steel | 307.1 lb | <!-- | 12.29 lb/ft | <!-- | 12.29 lb/ft² | <!-- | 12.29 lb/ft³ |
| Concrete | 417.7 ft³ | <!-- | 1.67 ft³/ft | <!-- | 1.67 ft³/ft² | <!-- | 1.67 ft³/ft³ |

3. Deflection Results: Summary

3.1. Section Properties

3.1.1. Frame Section Properties

Notes:
M-ve values are for positive moments (tension at bottom face).
M-ve values are for negative moments (tension at top face).

<table>
<thead>
<tr>
<th>Span</th>
<th>Zone</th>
<th>$M_{max}$</th>
<th>$I_p$</th>
<th>$M_{max}$</th>
<th>$I_p$</th>
<th>$M_{max}$</th>
<th>$I_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$in^4$</td>
<td></td>
<td>$in^4$</td>
<td></td>
<td>$k-ft$</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Left</td>
<td>8000</td>
<td>3756</td>
<td>32.98</td>
<td>8000</td>
<td>0</td>
<td>32.98</td>
</tr>
<tr>
<td></td>
<td>Midspan</td>
<td>8000</td>
<td>3756</td>
<td>32.98</td>
<td>8000</td>
<td>0</td>
<td>32.98</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>8000</td>
<td>3756</td>
<td>32.98</td>
<td>8000</td>
<td>0</td>
<td>32.98</td>
</tr>
</tbody>
</table>

3.1.2. Frame Effective Section Properties

<table>
<thead>
<tr>
<th>Span</th>
<th>Zone</th>
<th>Weight</th>
<th>Dead Load</th>
<th>Sustained Load</th>
<th>Dead+Live Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$M_{max}$</td>
<td>$I_p$</td>
<td>$M_{max}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$k-ft$</td>
<td>$in^4$</td>
<td>$k-ft$</td>
</tr>
<tr>
<td>1</td>
<td>Middle</td>
<td>1.000</td>
<td>64.06</td>
<td>4335</td>
<td>64.06</td>
</tr>
<tr>
<td></td>
<td>Span Avg</td>
<td></td>
<td>4335</td>
<td>4335</td>
<td>142.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3869</td>
</tr>
</tbody>
</table>

3.2. Instantaneous Deflections

3.2.1. Extreme Instantaneous Frame Deflections and Corresponding Locations

<table>
<thead>
<tr>
<th>Span</th>
<th>Direction</th>
<th>Value</th>
<th>Units</th>
<th>Dead</th>
<th>Sustained</th>
<th>Live</th>
<th>Unsustained</th>
<th>Total</th>
<th>Sustained</th>
<th>Dead+Live</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Down</td>
<td>Def</td>
<td>in</td>
<td>0.416</td>
<td>0.634</td>
<td>0.634</td>
<td>0.416</td>
<td>1.050</td>
<td>0.416</td>
<td>1.050</td>
</tr>
</tbody>
</table>
### 3.3. Long-term Deflections

#### 3.3.1. Long-term Deflection Factors

Notes:
Deflection multiplier, Lambda, depends on moment sign at sustained load level and Rho' in given zone.
Rho' is assumed zero because Compression Reinforcement option is NOT selected in Solve Options.

Time dependent factor for sustained loads = 2.000

<table>
<thead>
<tr>
<th>Span</th>
<th>Zone</th>
<th>$A_{net}$</th>
<th>$b$</th>
<th>$d$</th>
<th>Rho'</th>
<th>Lambda</th>
<th>$M_{rel}$</th>
<th>$b$</th>
<th>$d$</th>
<th>Rho'</th>
<th>Lambda</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>in$^2$</td>
<td>in</td>
<td>in</td>
<td>%</td>
<td></td>
<td>in$^2$</td>
<td>in</td>
<td>in</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>1 Midspan</td>
<td></td>
<td>0.000</td>
<td>2.000</td>
<td>0.000</td>
<td>2.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 3.3.2. Extreme Long-term Frame Deflections and Corresponding Locations

Notes:
Incremental deflections due to creep and shrinkage (cs) based on sustained load level values.
Incremental deflections after partitions are installed can be estimated by deflections due to:
- creep and shrinkage plus sustained live load (cs+lu), if live load applied before partitions,
- creep and shrinkage plus live load (cs+l), if live load applied after partitions.

Total deflections consist of dead, live, and creep and shrinkage deflections.

<table>
<thead>
<tr>
<th>Span</th>
<th>Direction</th>
<th>Value</th>
<th>Units</th>
<th>$cs$</th>
<th>$cs+lu$</th>
<th>$cs+l$</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Down</td>
<td>Def</td>
<td>in</td>
<td>0.831</td>
<td>1.466</td>
<td>1.466</td>
<td>1.881</td>
</tr>
<tr>
<td></td>
<td>Loc</td>
<td>ft</td>
<td>12.500</td>
<td>12.500</td>
<td>12.500</td>
<td>12.500</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Up</td>
<td>Def</td>
<td>in</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Loc</td>
<td>ft</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>
4. Diagrams

4.1. Loads

CASE: Live

1000 lb/ft

CASE: Dead

800 lb/ft
4.2. Internal Forces
4.3. Moment Capacity

Legend:
- Envelope Curve
- Capacity Curve
- Support Centerline
- Face of Support
- Zone Limits

File: C:\StructurePoint\Simply Supported RC Beam - ACI.lib
Project: Simply Supported RC Beam
Frame: Simply Supported RC Beam
Engineer: SP
Code: ACI 318-14
Date: 04/08/21
Time: 10:41:11
4.4. Shear Capacity

![Graph showing shear capacity analysis for a beam.]

**LEGEND:**
- Envelope Curve
- Capacity Curve
- Support Centerline
- Face of Support
- Critical Section

---

File: C:\StructurePoint\Simply Supported RC Beam - ACI.slb
Project: Simply Supported RC Beam
Frame: Simply Supported RC Beam
Engineer: SP
Code: ACI 318-14
Date: 04/08/21
Time: 10:41:11
4.5. Deflection
4.6. Reinforcement

Reinforcement and Transverse Reinforcement

spBeam v5.50. Licensed to: StructurePoint. License ID: 00000-000000-4-23D6E-23D6E

File: C:\StructurePoint\Simply Supported RC Beam - ACI.slb
Project: Simply Supported RC Beam
Frame: Simply Supported RC Beam
Engineer: SP
Code: ACI 318-14
Date: 04/08/21
Time: 10:41:11
8. Analysis and Design Results Comparison and Conclusions

The following tables show the comparison between hand results and spBeam model results.

### Table 2 - Comparison of Moments and Flexural Reinforcement (At Midspan)

<table>
<thead>
<tr>
<th>Location</th>
<th>M_u, kip-ft</th>
<th>A_s,required, in.^2</th>
<th>Reinforcement</th>
<th>A_s,provided, in.^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand</td>
<td>201.88</td>
<td>2.872</td>
<td>3 – #9</td>
<td>3.000</td>
</tr>
<tr>
<td>spBeam</td>
<td>201.88</td>
<td>2.873</td>
<td>3 – #9</td>
<td>3.000</td>
</tr>
</tbody>
</table>

### Table 3 - Comparison of Shear and lateral Reinforcement

<table>
<thead>
<tr>
<th>V_u @ d, kip</th>
<th>(A_v/s)_req', in.^2</th>
<th>(A_v/s)_min', in.^2</th>
<th>Reinforcement</th>
<th>φV_n, kip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand</td>
<td>28.52</td>
<td>0.0097</td>
<td>0.0100</td>
<td>41.79</td>
</tr>
<tr>
<td>spBeam</td>
<td>28.52</td>
<td>0.0097</td>
<td>0.0100</td>
<td>41.88</td>
</tr>
</tbody>
</table>

* Minimum transverse reinforcement governs

### Table 4 - Comparison of Section Properties

<table>
<thead>
<tr>
<th>Location</th>
<th>I_cr, in.^4</th>
<th>I_s, in.^4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand</td>
<td>spBeam</td>
<td></td>
</tr>
<tr>
<td>Midspan</td>
<td>3759</td>
<td>3812</td>
</tr>
</tbody>
</table>

### Table 5 - Comparison of Maximum Instantaneous Deflection (At Midspan), in.

<table>
<thead>
<tr>
<th>Deflection Type</th>
<th>Hand</th>
<th>spBeam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ_DL</td>
<td>0.416</td>
<td>0.416</td>
</tr>
<tr>
<td>Δ_LL</td>
<td>0.634</td>
<td>0.634</td>
</tr>
<tr>
<td>Δ_total</td>
<td>1.050</td>
<td>1.050</td>
</tr>
</tbody>
</table>

### Table 6 - Comparison of Maximum Long-Term Deflection (At Midspan), in.

<table>
<thead>
<tr>
<th>Deflection Type</th>
<th>Hand</th>
<th>spBeam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ_cs</td>
<td>0.831</td>
<td>0.831</td>
</tr>
<tr>
<td>Δ_cs + Δ_LL</td>
<td>1.465</td>
<td>1.466</td>
</tr>
<tr>
<td>(Δ_total)lt</td>
<td>1.881</td>
<td>1.881</td>
</tr>
</tbody>
</table>

The results of all the hand calculations used illustrated above are in agreement with the automated exact results obtained from the spBeam program.