

ACI 318-14 Example 001

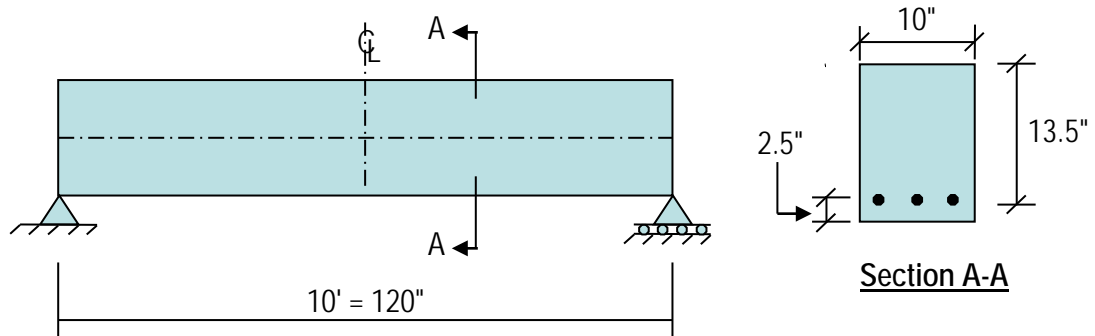
SHEAR AND FLEXURAL REINFORCEMENT DESIGN OF A SINGLY REINFORCED RECTANGLE

EXAMPLE DESCRIPTION

The flexural and shear design of a rectangular concrete beam is calculated in this example.

A simply supported beam is subjected to an ultimate uniform load of 9.736 k/ft. This example is tested using the ACI 318-14 concrete design code. The flexural and shear reinforcing computed is compared with independent hand calculated results.

GEOMETRY, PROPERTIES AND LOADING



Material Properties

$E =$	3600 k/in ²
$\nu =$	0.2
$G =$	1500 k/in ²

Section Properties

$d =$	13.5 in
$b =$	10.0 in
$I =$	3,413 in ⁴

Design Properties

$f'_c =$	4 k/in ²
$f_y =$	60 k/in ²

TECHNICAL FEATURES TESTED

- Calculation of Flexural reinforcement, A_s
- Enforcement of Minimum tension reinforcement, $A_{s,min}$
- Calculation of Shear reinforcement, A_v
- Enforcement of Minimum shear reinforcing, $A_{v,min}$

PROGRAM NAME: ETABS
 REVISION NO.: 0

RESULTS COMPARISON

Independent results are hand calculated based on the equivalent rectangular stress distribution described in Example 6.1 in Notes on ACI 318-14 Building Code.

Output Parameter	ETABS	Independent	Percent Difference
Design Moment, M_u (k-in)	1460.4	1460.4	0.00%
Tension Reinf, A_s (in ²)	2.37	2.37	0.00%
Design Shear Force, V_u	37.73	37.73	0.00%
Shear Reinf, A_v/s (in ² /in)	0.041	0.041	0.00%

COMPUTER FILE: ACI 318-14 Ex001

CONCLUSION

The computed results show an exact match for the flexural and the shear reinforcing.

HAND CALCULATION

Flexural Design

The following quantities are computed for all the load combinations:

$$\phi = 0.9, A_g = 160 \text{ sq-in}$$

$$A_{s,\min} = \frac{200}{f_y} b_w d = 0.450 \text{ sq-in (Govern)}$$

$$= \frac{3\sqrt{f'_c}}{f_y} b_w d = 0.427 \text{ sq-in}$$

$$\beta_1 = 0.85 - 0.05 \left(\frac{f'_c - 4000}{1000} \right) = 0.85$$

$$c_{\max} = \frac{0.003}{0.003 + 0.005} d = 5.0625 \text{ in}$$

$$a_{\max} = \beta_1 c_{\max} = 4.303 \text{ in}$$

Combo1

$$w_u = (1.2w_d + 1.6w_l) = 9.736 \text{ k/ft}$$

$$M_u = \frac{w_u l^2}{8} = 9.736 \cdot 10^2 / 8 = 121.7 \text{ k-ft} = 1460.4 \text{ k-in}$$

The depth of the compression block is given by:

$$a = d - \sqrt{d^2 - \frac{2|M_u|}{0.85 f'_c \phi b}} = 4.183 \text{ in } (a < a_{\max})$$

The area of tensile steel reinforcement is given by:

$$A_s = \frac{M_u}{\phi f_y \left(d - \frac{a}{2} \right)} = \frac{1460.4}{0.9 \cdot 60 \cdot (13.5 - 4.183/2)}$$

$$A_s = 2.37 \text{ sq-in}$$

Shear Design

The following quantities are computed for all of the load combinations:

$$\phi = 0.75$$

Check the limit of $\sqrt{f'_c}$:

$$\sqrt{f'_c} = 63.246 \text{ psi} < 100 \text{ psi}$$

The concrete shear capacity is given by:

$$\phi V_c = \phi 2 \sqrt{f'_c} b d = 12.807 \text{ k}$$

The maximum shear that can be carried by reinforcement is given by:

$$\phi V_s = \phi 8 \sqrt{f'_c} b d = 51.229 \text{ k}$$

The following limits are required in the determination of the reinforcement:

$$(\phi V_c/2) = 6.4035 \text{ k}$$

$$(\phi V_c + \phi 50 b d) = 11.466 \text{ k}$$

$$\phi V_{\max} = \phi V_c + \phi V_s = 64.036 \text{ k}$$

Given V_u , V_c and V_{\max} , the required shear reinforcement in area/unit length for any load combination is calculated as follows:

If $V_u \leq \phi (V_c/2)$,

$$\frac{A_v}{s} = 0,$$

else if $\phi (V_c/2) < V_u \leq \phi V_{\max}$

$$\frac{A_v}{s} = \frac{(V_u - \phi V_c)}{\phi f_{ys} d} \geq \left(\frac{A_v}{s} \right)_{\min}$$

where:

$$\left(\frac{A_v}{s} \right)_{\min} = \max \left\{ 50 \left(\frac{b_w}{f_{yr}} \right), \left(\frac{b_w}{f_{yr}} \right) \cdot \frac{3}{4} \sqrt{f'_c} \right\}$$

else if $V_u > \phi V_{\max}$,

a failure condition is declared.

Combo1

$$V_u = 9.736 \cdot (5 - 13.5/12) = 37.727 \text{ k}$$

$$\phi(V_c / 2) = 6.4035 \text{ k} \leq V_u = 37.727 \text{ k} \leq \phi V_{\max} = 64.036 \text{ k}$$

$$\left(\frac{A_v}{s}\right)_{\min} = \max \left\{ 50 \left(\frac{10}{60,000} \right), \left(\frac{10}{60,000} \right) \cdot \frac{3}{4} \sqrt{4,000} \right\}$$

$$\left(\frac{A_v}{s}\right)_{\min} = \max \{0.0083, 0.0079\} = 0.0083 \frac{\text{in}^2}{\text{in}}$$

$$\frac{A_v}{s} = \frac{(V_u - \phi V_c)}{\phi f_{ys} d} = 0.041 \frac{\text{in}^2}{\text{in}} = 0.492 \frac{\text{in}^2}{\text{ft}}$$