ACI 318-11 Example 001

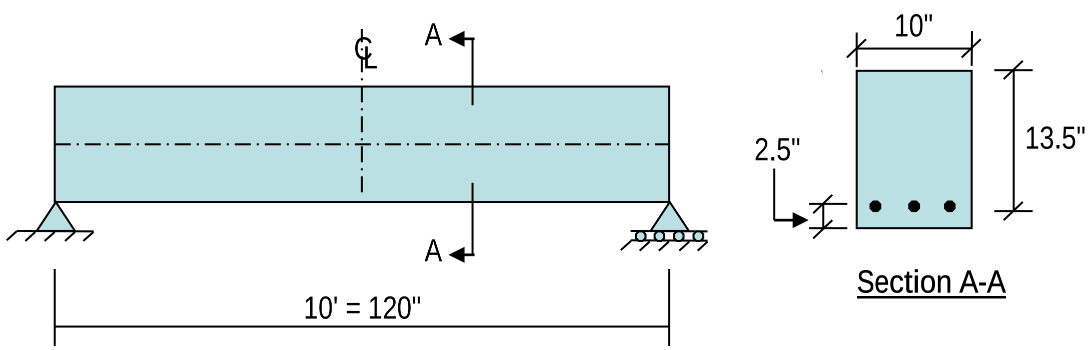
SHEAR AND FLEXURAL REINFORCEMENT DESIGN OF A SINGLY REINFORCED RECTANGLE

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 318-11 concrete design code. The flexural and shear reinforcing computed is compared with independent hand calculated results.

GEOMETRY, PROPERTIES AND LOADING



Material Properties		Section Properties		Design Properties
E =	3600 k/in^2	d =	13.5 in	f'_c = 4 k/in^2
v =	0.2	b =	10.0 in	f_y = 60 k/in^2
G =	1500 k/in^2	I =	3,413 in^4	

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, $A_{v,min}$

RESULTS COMPARISON

Independent results are hand calculated based on the equivalent rectangular stress distribution described in Example 6.1 in Notes on ACI 318-11 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 318-11 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:

$\varphi = 0.9,\ A_g = 160$ 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

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

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

The depth of the compression block is given by:

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

The area of tensile steel reinforcement is given by:

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

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

Shear Design

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

$\varphi = 0.75$

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

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

The concrete shear capacity is given by:

$\varphi V_c = \varphi 2 \sqrt{f'_c}\, bd = 12.807 \text{ k}$

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

$\varphi V_s = \varphi 8 \sqrt{f'_c}\, bd = 51.229 \text{ k}$

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

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

$(\varphi V_c + \varphi 50\, bd) = 11.466 \text{ k}$

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

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 $V_u \le \varphi (V_c/2)$,

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

else if $\varphi (V_c/2) < V_u \le \varphi V_{\max}$

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

where:

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

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

a failure condition is declared.

Combo1

V_u = 9.736•(5-13.5/12) = 37.727 k

$$\phi\left(V_c/2\right)=6.4035\,k\le V_u=37.727\,k\le\phi V_{\max}=64.036\,k$$

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

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

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