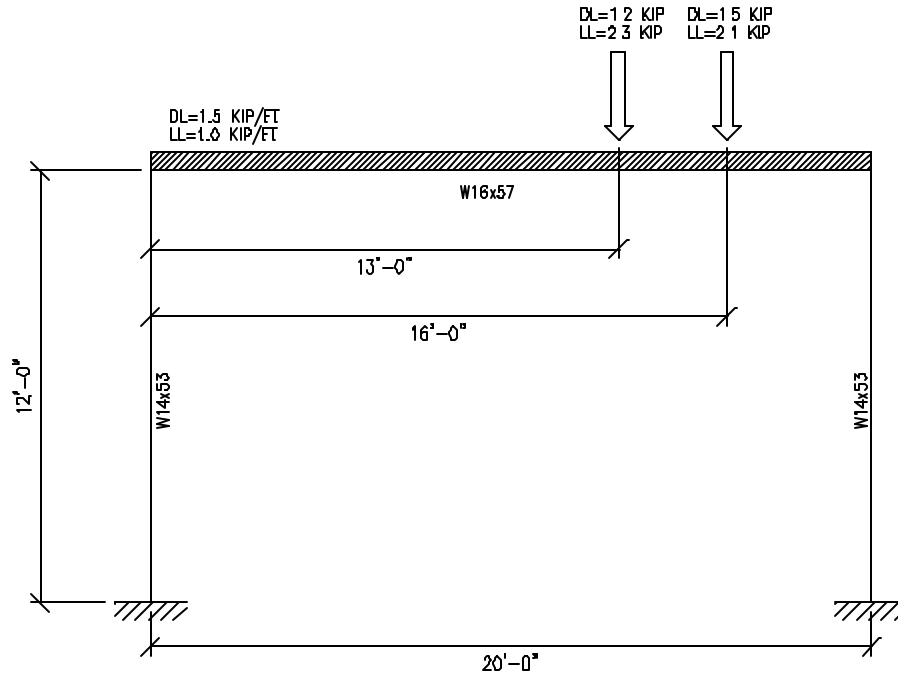


The sample calculation below, outlines the formulas and the methods used by the RBSection software (www.sdceng.com/software.html) for compliance with the requirements of FEMA 350 (July 2000), for a Reduced Beam Section Connection for a single bay moment frame.

October, 2003

Problem:

Note: Initial sizes are from a frame analysis program using code specified lateral forces.



Beam W16x57

$d_b = 16.4$ in	$t_{fb} = 0.715$ in	$S_{xb} = 92.2$ in ³	$I_{xb} = 758$ in ³
$b_b = 7.12$ in	$t_{wb} = 0.43$ in	$Z_{xb} = 105$ in ³	$R_{yb} = 1.6$ in ³

Column W14x53

$d_c = 13.9$ in	$t_{fc} = 0.66$ in	$S_{xc} = 77.8$ in ³	$I_{xc} = 541$ in ³
$b_c = 8.06$ in	$t_{wc} = 0.37$ in	$Z_{xc} = 87.1$ in ³	$R_{yc} = 1.92$ in ³

Frame Properties

Col/Col distance	20 ft
Loads	As shown above
Frame height	12 ft
Steel Grade	A992 $F_y = 50$ ksi $F_u = 65$ ksi

$$C_{pr} = \frac{F_y + F_u}{2 \times F_y} = \frac{50 + 65}{2 \times 50} = 1.15$$

$$R_y = 1.1$$

Calculate the Reduced Beam Section (RBS) geometry:

$$a = b_b \times 0.60 = 7.12 \times 0.60 = 4.272 \text{ say } 4.25 \text{ in}$$

$$b = d_b \times 0.75 = 16.4 \times 0.75 = 12.3 \text{ say } 12.25 \text{ in}$$

$$c = b_b \times 0.20 = 7.12 \times 0.20 = 1.424 \text{ say } 1.5 \text{ in}$$

$$\text{Radius} = \frac{4c^2 + b^2}{8c} = \frac{4 \times 1.5^2 + 12.25^2}{8 \times 1.5} = 13.255 \text{ in}$$

$$x = a + \frac{b}{2} = 4.25 + \frac{12.25}{2} = 10.38 \text{ in}$$

$$L' = 20 - \left(\frac{13.9}{12}\right) - 2 \times \frac{10.38}{12} = 17.11 \text{ ft}$$

$$Z_{rbs} = Z_{xb} - 2 \times c \times t_{fb} (d_b - t_{fb}) = 105 - 2 \times 1.5 \times 0.715 \times (16.4 - 0.715) = 71.36 \text{ in}^3$$

$$S_{rbs} = 59.22 \text{ in}^3 \text{ (Details not shown)}$$

Code Checks:

Beam and column parameters:

1. Beam depth less than 36"? *Beam is 16.4" deep* **OK**
2. Beam weight less than 300 lb/ft? *Beam is 57 lb/ft* **OK**
3. Beam's span to depth ratio greater than 7?

$$\text{Span Ratio} = \frac{\text{Beam Length}}{\text{Beam Depth}} = \frac{20 \times 12 - 13.9}{16.4} = 13.79 \text{ OK}$$

4. Beam's flange less than 1-3/4 inches thick? *Beam's flange is 0.715" thick* **OK**
5. Moment capacity of BM's flange less than 0.7xMplastic?

$$\text{Mom. Ratio} = \frac{\text{Plastic section modulus of beam's flange}}{\text{Plastic section modulus of beam}} = \frac{Z_{xbf}}{Z_{xb}} = \frac{79.83}{105} = 0.76 \text{ OK}$$

$$Z_{xb} = A_{fb} \times (d_b - t_{fb}) = (b_b \times t_{fb}) \times (d_b - t_{fb}) = (7.12 \times 0.715) \times (16.4 - 0.715) = 79.83 \text{ in}^3$$

6. Flange reduction less than 50% of flange width?

$$\text{Flange reduction ratio} = \frac{(b_{fb} - 2 \times c)}{b_{fb}} = \frac{7.12 - 2 \times 1.5}{7.12} = 0.579 = 57.9\% \text{ OK}$$

7. Column's size W12x or W14x? *Column is W14x53* **OK**
8. Column Width less than beam Width? *8.06 in vs. 7.12 in* **OK**

Calculated values:

$$V_{g1} = \frac{(L - \frac{d_c}{12}) \times (1.2 \times W_{dl} + 0.5 \times W_{ll})}{2} = \frac{(20 - \frac{13.98}{12}) \times (1.2 \times 1.5 + 0.5 \times 1.0)}{2} = 21.65 \text{ kip From Dist Loads}$$

$$V_{g2} = \frac{\text{Load} \times \text{Arm}}{\text{Beam Length}} = (1.2 * 1.2 * (13 - \frac{13.98}{2})) + (0.5 * 2.3 * (13 - \frac{13.98}{2})) + (1.2 * 1.5 * (16 - \frac{13.98}{2})) + (0.5 * 2.1 * (16 - \frac{13.98}{2})) = \frac{17.88 + 14.27 + 27.73 + 16.18}{20 - \frac{13.98}{12}} = 4.04 \text{ kip}$$

$$\text{Total} = 21.65 + 4.04 = 25.69 \text{ kip}$$

$$M_{pr} = C_{pr} \times R_{yb} \times Z_{rbs} \times F_y = \frac{1.15 \times 1.1 \times 71.36 \times 50}{12} = 376.12 \text{ ft-kip}$$

$$V_p = 68.0 \text{ kip (Calculated similar to } V_g \text{ above)}$$

$$M_f = M_{pr} + V_p \times x = 376.12 + 68.0 \times \frac{10.38}{12} = 434.94 \text{ ft-kip}$$

$$M_c = M_{pr} + V_p \left(X + \frac{d_c}{2} \right) = 376.12 + 68.0 \left(\frac{10.38}{12} + \frac{13.9}{2 \times 12} \right) = 474.3 \text{ ft-kip}$$

$$V_f = 2 \times \frac{M_f}{L - d_c} + V_g = 2 \times \frac{434.94}{20 - \frac{13.9}{12}} + 25.69 = 71.85 \text{ kip}$$

$$d_s = 0.09 \times \left(\frac{c}{c_{\max}} \right) = 0.09 \times \left(\frac{1.5}{\frac{0.5 \times 7.12}{2}} \right) = 0.758 = 7.58\%$$

Design checks:

1. Mf

$$M_f < R_r \times Z_b \times F_y \div 12 = 1.1 \times 105 \times 50 \div 12 = 481.25 \text{ ft-kip OK}$$

2. Doubler Plates

$$C_y = \frac{1}{C_{pr} \times \frac{Z_{be}}{S_b}} = \frac{1}{1.15 \times \frac{71.36}{59.22}} = 0.72$$

$$t = \frac{C_y \times M_c \times \frac{h - h_d}{d}}{(0.9) \times 0.6 \times F_{yc} \times R_{yc} \times d_c \times (d_b - t_{fb})} = \frac{0.72 \times 474.3 \times 12 \times \frac{(12 \times 12) - 16.4}{(12 \times 12)}}{(0.9) \times 0.6 \times 50 \times 1.1 \times 13.9 \times (16.4 - 0.71)} = 0.561 \text{ in} < 0.27 \text{ in}$$

FAIL- Doubler Plates Required

3. Continuity plates

$$t_{cf} < 0.4 \times \sqrt{1.8 \times b_f \times t_f \times \frac{F_{yb} \times R_{yb}}{F_{yc} \times R_{yc}}} = 0.4 \times \sqrt{1.8 \times 7.12 \times 0.715 \times \frac{50 \times 1.1}{50 \times 1.1}} = 1.21 \text{ in} > 0.66 \text{ in}$$

$$t_{cf} < \frac{b_f}{6} = \frac{7.12}{6} = 1.187 \text{ in} > 0.66 \text{ in}$$

FAIL- Continuity Plates Required

4. Beam flange

$$\frac{2 \times (R - c) + b_b - 2 \times \sqrt{R^2 - \left(\frac{b_b}{3}\right)^2}}{2 \times t_f} = \frac{2 \times (13.255 - 1.5) + 7.12 - 2 \times \sqrt{13.255^2 - \left(\frac{7.12}{3}\right)^2}}{2 \times 0.715} = 3.22$$

$$\frac{52}{\sqrt{F_y}} = \frac{52}{\sqrt{50}} = 7.35 > 3.22 \text{ OK}$$

5. Beam Web

$$\frac{h_c}{t_w} = \frac{d_b - (2 \times t_{fb})}{t_{wb}} = \frac{16.4 - (2 \times 0.715)}{0.43} = 34.81$$

$$\frac{418}{\sqrt{F_y}} = \frac{418}{\sqrt{50}} = 59.11 > 34.81 \text{ OK}$$

6. Allowable Beam Shear

$$\Phi V_n = \Phi \times 0.6 \times F_y \times d \times t_w = 0.9 \times 0.6 \times 50 \times 16.4 \times 0.43 = 190.40 \text{ kip} > V_f = 71.87 \text{ kip} \text{ OK}$$

7. Allowable Beam Moment

$$\Phi M_n = \Phi \times Z_x \times F_y = \frac{0.9 \times 105 \times 50}{12} = 393.75 \text{ ft.kip} \text{ Check frame analysis software}$$

8. Allowable Beam Moment at RBS

$$\Phi M_{RBS} = \Phi \times Z_{RBS} \times F_y = \frac{0.9 \times 71.36 \times 50}{12} = 267.60 \text{ ft.kip} \text{ Check frame analysis software}$$

END