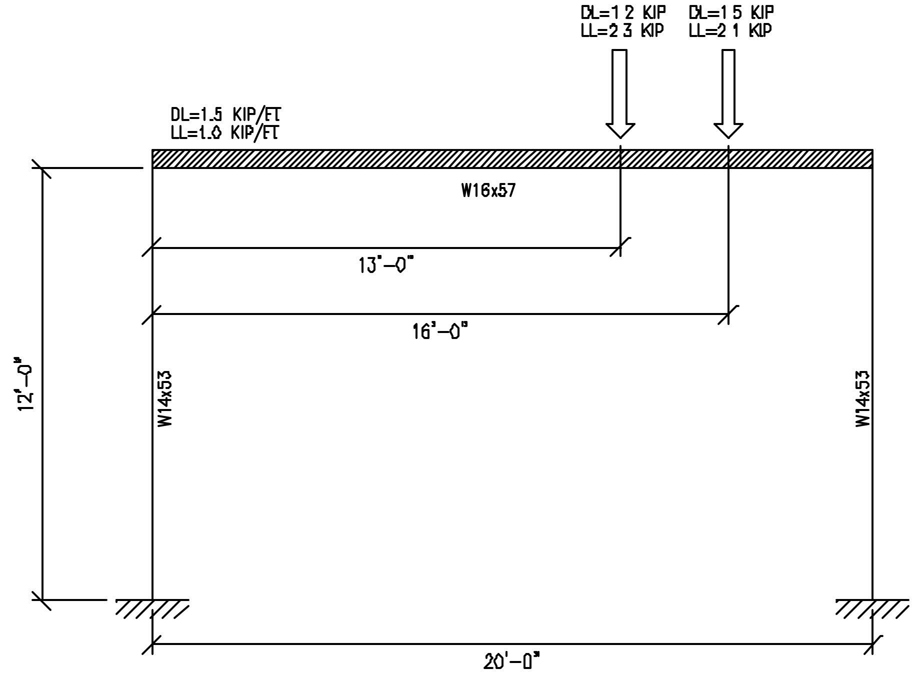
The sample calculation below, outlines the formulas and the methods used by the RBSection software (www.sdceng.com/software.html) for compliance with the requirements of FEMA 350 (July 2000), for a Reduced Beam Section Connection for a single bay moment frame.

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	$A992 \;\; F_y = 50 \; ksi \;\; F_u = 65 \; ksi$

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

$$Ry = 1.1$$

Calculate the Reduced Beam Section (RBS) geometry:

$$a = b_b \times 0.60 = 7.12 \times 0.60 = 4.272 \ say\, 4.25 \ in$$
$$b = d_b \times 0.75 = 16.4 \times 0.75 = 12.3 \ say\, 12.25 \ in$$
$$c = b_b \times 0.20 = 7.12 \times 0.20 = 1.424 \ say\, 1.5 \ in$$
$$Radius = \frac{4c^2 + b^2}{8c} = \frac{4 \times 1.5^2 + 12.25^2}{8 \times 1.5} = 13.255 \ in$$
$$x = a + \frac{b}{2} = 4.25 + \frac{12.25}{2} = 10.38 in$$
$$L' = 20 - (\frac{13.9}{12}) - 2 \times \frac{10.38}{12} = 17.11 \ ft$$

$$Z_{rbs} = Z_{xb} - 2 \times c \times t_{fb}(d_b - t_{fb}) = 105 - 2 \times 1.5 \times 0.715 \times (16.4 - 0.715) = 71.36 \ in^3$$
$S_{rbs} = 59.22 \ in^3$ (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?

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

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

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

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

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

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

$$V_{g2} = \frac{Load \times Arm}{Beam\, Length} = (1.2 * 1.2 * (13 - \frac{\frac{13.98}{12}}{2}) + (0.5 * 2.3 * (13 - \frac{\frac{13.98}{12}}{2}) + (1.2 * 1.5 * (16 - \frac{\frac{13.98}{12}}{2})$$

$$+ (0.5 * 2.1 * (16 - \frac{\frac{13.98}{12}}{2}) = \frac{17.88 + 14.27 + 27.73 + 16.18}{20 - \frac{13.98}{12}} = 4.04\, kip$$

$$Total = 21.65 + 4.04 = 25.69\, kip$$

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

$V_p = 68.0\, kip$ (Calculated similar to Vg above)

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

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

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

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

Design checks:

1. Mf

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

2. Doubler Plates

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

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

   FAIL- Doubler Plates Required

3. Continuity plates

$$t_{cf} < 0.4\times\sqrt{1.8\times b_f \times t_f \times \frac{F_{yb}\times R_{yb}}{F_{yc}\times R_{yc}}} = 0.4\times\sqrt{1.8\times 7.12\times .715\times\frac{50\times 1.1}{50\times 1.1}} = 1.21\, in > 0.66\, in$$

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

FAIL- Continuity Plates Required

4. Beam flange

$$\frac{2\times(\mathrm{R}-\mathrm{c})+\mathrm{b_b}-2\times\sqrt{\mathrm{R}^2-(\frac{\mathrm{b_b}}{3})^2}}{2\times t_f} = \frac{2\times(13.255-1.5)+7.12-2\times\sqrt{13.255^2-(\frac{7.12}{3})^2}}{2\times .715} = 3.22$$

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

5. Beam Web

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

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

6. Allowable Beam Shear

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

7. Allowable Beam Moment

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

8. Allowable Beam Moment at RBS

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

END