Group 11
CIV 312 Final Submission

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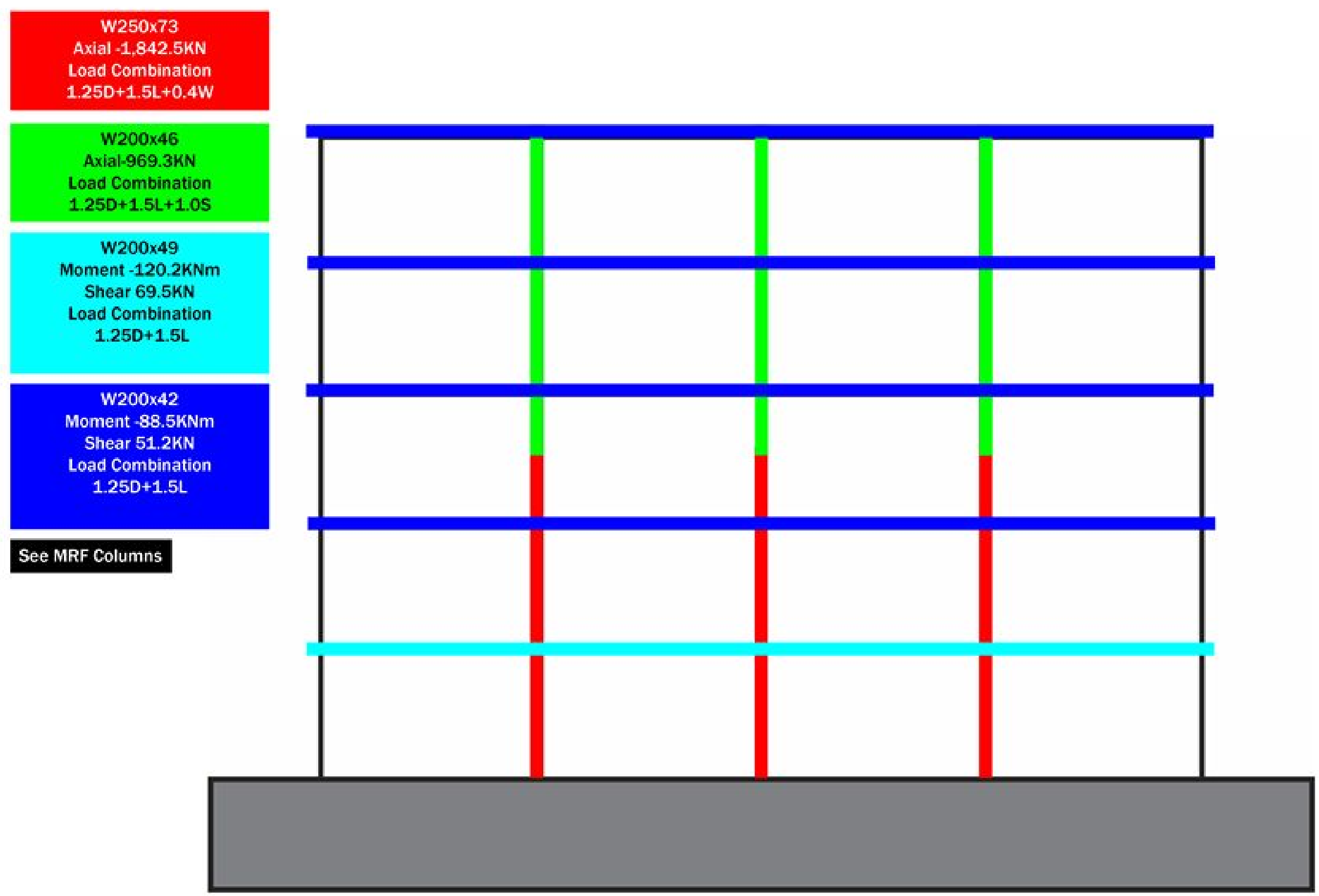
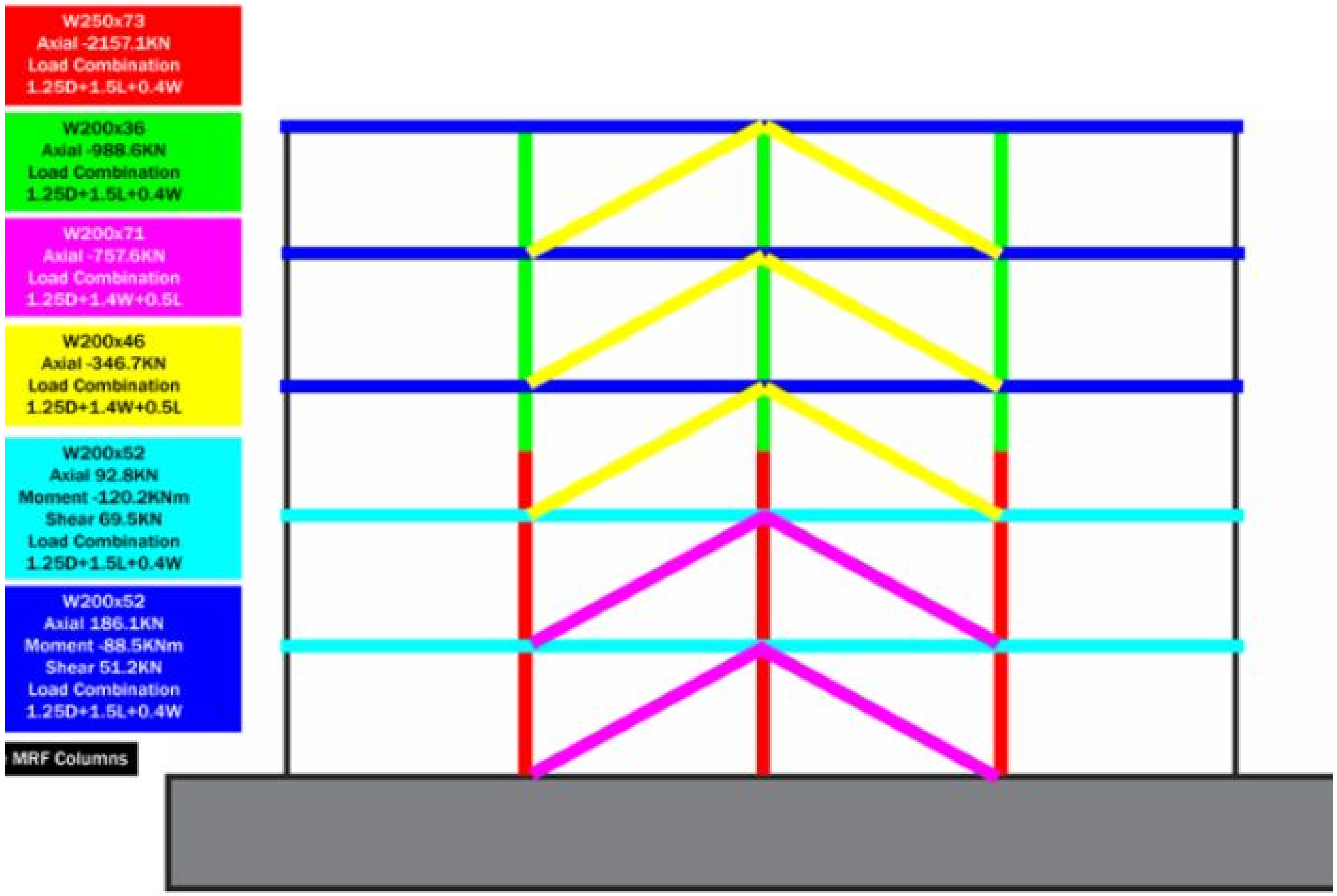
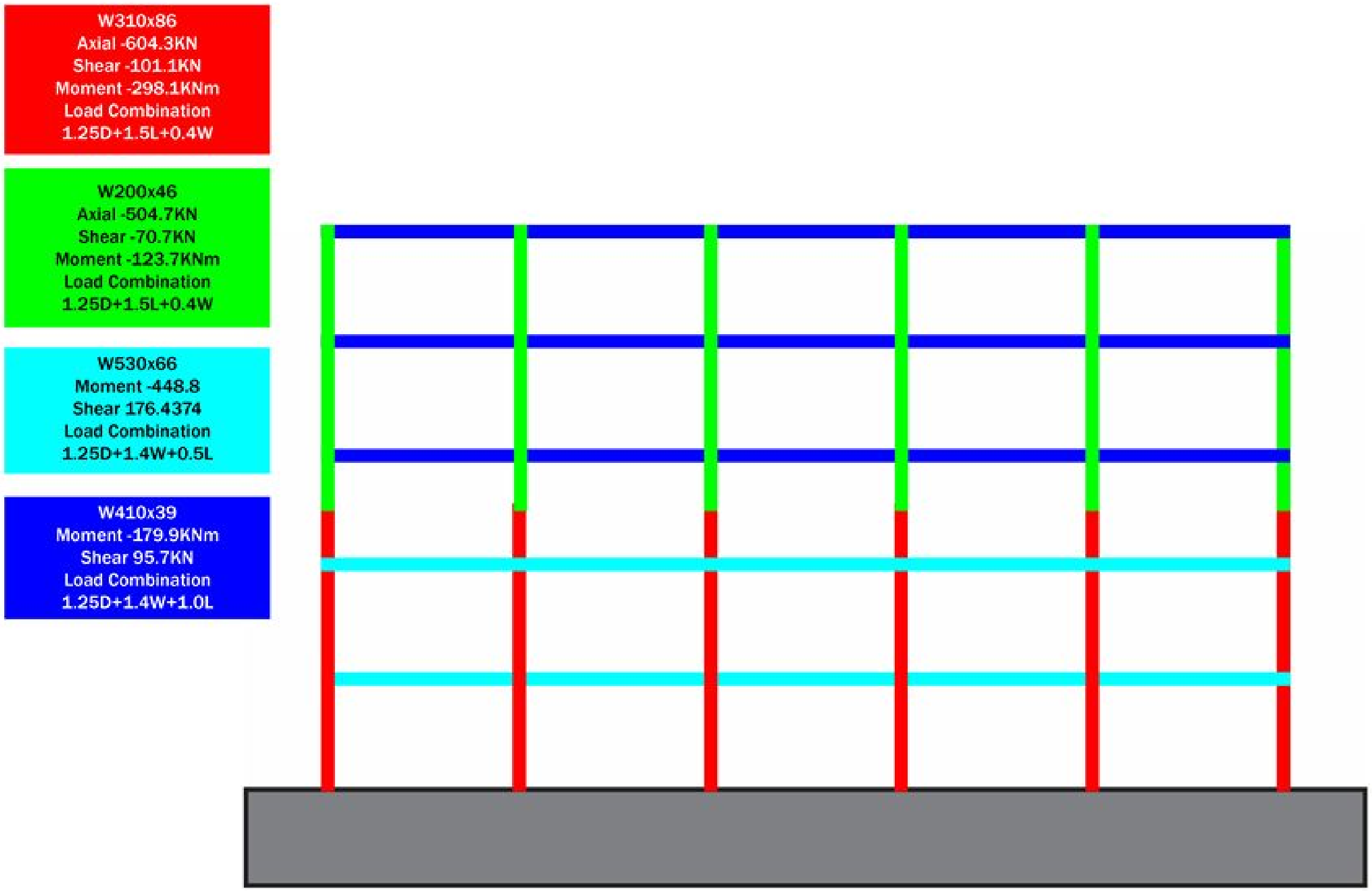


Gravity Frame (Line D)



Concentrically Braced Frame



Moment Resisting Frame (Line 1)

lower CBF column calculation (W200×52)

Section Class (1-165 Table 1)

flange: $\frac{b_{el}}{t} = \frac{204}{2(12.6)} = 8.09 < \frac{200}{\sqrt{350}} = 10.6$

web: $h/w = \frac{147}{7.9} = 18.6 < \frac{670}{\sqrt{350}} = 35.8$

∴ class higher than 3

Cl 13.3.3.1 C_{rx} = ?

$$C_{rx} = \frac{\phi A F_y}{(1+\lambda^{2n})^{-1/n}} = 2473.3\,kN$$

$C_{rx}(200\times52) > P_{cr}(-1842.47kN)$ ∴ ✓ok

Slenderness (cl 10.4.2.1)

$(KL/r)_x = \frac{1(6000)}{89} = 67.4mm < 200$ ✓ok

$$F_e = \frac{\pi^2 E}{(\frac{KL}{r})_x^2} = 434MPa$$

$$\lambda = \sqrt{\frac{F_y}{F_e}} = 0.8975$$

$n = 1.34$

$A = 6650mm^2$

$E = 200\,000MPa$

$F_y = 350MPa$

lower Gravity Beam

- laterally unsupported
- Pin connected at ends

W250x49

$S_x = 572\times10^3 mm^3$ $\quad w = 26.67kN/m$

$I_y = 15.1\times10^6 mm^4$

$J = 241\times10^3 mm^4$

$C_w = 211\times10^9 mm^6$

$M_{max} = 120.0323kN{\cdot}m = M_B$

$M_A = M_C = \frac{wx}{2}(l-x)$, $x = 1.5m$, $l = 6m$

$= 90.01125kN{\cdot}m$

$M_y = 200.2kN{\cdot}m$

section class 3 according to blue book

Cl 13.6

$$\omega_2 = \frac{4M_{max}}{\sqrt{M_{max}^2 + 4M_a^2 + 7M_b^2 + 4M_c^2}}$$

$= 1.131429553$

$$M_u = \frac{\omega_2 \pi}{l}\sqrt{EI_yGJ + (\frac{E\pi}{l})^2 I_y C_w}$$

$= 178.7kN{\cdot}m$

$M_u > 0.67M_y = 134.134kN{\cdot}m$

∴ cl 13.6 b) i)

$$M_r = 1.15\phi M_y\left[1 - \frac{0.28M_y}{M_u}\right]$$

$= 142.2kN{\cdot}m$

$M_r(W250\times49) > M_f(120.0323)$ ✓ok

Serviceability

$$\Delta = \frac{5wl^4}{384EI_y}, \quad w(\text{snow, live})$$

$$= \frac{5(-1.64+0.5)l^4}{384EI_y}$$

$= -6.37mm$

1-188 Table D1 (office)

$\Delta < L/300 = 20$ ✓ok

Shear resistance (cl 13.4.1.1)

$h/w = 184/7.4 = 24.865 < \frac{1014}{\sqrt{F_y}} = 54.2$

∴ $F_s = 0.66F_y$

$V_r = \phi A_w F_s$

$= 0.9(hw)(231MPa)$

$= 283kN$

$V_r >$ Shear analyzed (69.4437) ✓ok

W530x66

- Assume braced at every joist (top & bottom)

$M_{max} = 438.58$ kN.m $\quad V_{max} = 181.98$ kN.m.

W530x66

Class check

$\frac{b_{el}}{t} = \frac{165}{2 \cdot 11.4} = 7.24 \qquad \frac{170}{\sqrt{350}} = 9.1 \qquad 7.24 < 9.1 \quad \therefore$ at least class 2

$\frac{h}{w} = \frac{502}{8.9} = 56.4 \qquad \frac{1100}{\sqrt{350}} = 58.8 \qquad 56.4 < 58.8$ – at least class 2

Cl. 13.6 $\quad M_p = Z_x F_y = 1560 \cdot 10^3 \cdot 350 = 546$ kN.m

$$\omega_2 = \frac{4(438.58)}{\sqrt{438.58^2 + 4(352.1) + 7(266.9) + 4(183.7)}} = 1.53$$

Cl. 13.6 a) ii)

$$M_u = \frac{1.53 \cdot \pi}{2000} \sqrt{E I_y G J + \left(\frac{\pi E}{2000}\right)^2 I_y C_w} = 1733.4 \text{ kN.m.}$$

$M_u > 0.67 M_r$

$$M_r = 1.15(0.9)(546)\left[1 - \frac{0.28(546)}{1733.4}\right] = 672.1 \text{ kN.m} \leq 0.9 \cdot 546 = 491.4 \text{ kN}$$

$M_r = 491.4$ kN.m $> M_{max} = 438.58$ kN.m

Shear Check

$V_r = \phi A_w F_s$ – Cl 13.4.1.1

$\frac{1014}{\sqrt{F_y}} = 54.2 \qquad \frac{h}{w} = 56.4 \qquad \frac{1435}{\sqrt{F_y}} = 76.7$

$F_s = \frac{670\sqrt{350}}{56.4} = 222.24$

$V_r = 0.9(502 \cdot 8.9)\,222.24 = 893.6$ kN $> V_{max} = 181.98$ kN

$\therefore$ Safe

W 310 x 86

$C_f = 751.5\,KN$ $M_f = 365.48$

Class check - table 2

$\frac{bel}{t} = \frac{254}{2 \cdot 16.3} = 7.79$ $\frac{170}{\sqrt{350}} = 9.09$ $7.79 < 9.09 \rightarrow$ at least Class 2

$\frac{h}{w} = \frac{277}{9.1} = 30.44$ $\frac{1100}{\sqrt{350}}\left(1 - 0.39 \cdot \frac{751 \cdot 10^3}{11000 \cdot 350 \cdot 0.9}\right) = 53.8$

$30.44 < 53.8 \rightarrow$ at least Class 2

(c) LTB / weak Axis - Cl. 13.8.2 (c)

$\left(\frac{KL}{r}\right)_y = \frac{1 \cdot 3500}{63.6} = 55.03 < 200$ ✓ good

$F_{ey} = \frac{\pi^2 \cdot E}{55.03^2} = 651.82\,KN \cdot m$ $\lambda = \sqrt{\frac{350}{651.82}} = 0.733$

$C_r = \frac{0.9 \cdot 11000 \cdot 350}{(1 + 0.733^{2 \cdot 1.34})^{\frac{1}{1.34}}} = 2646.4\,KN$

$\phi M_p = 1420 \cdot 10^3 \cdot 350 \cdot 0.9 = 447.3\,MPa$

$W_2 = \frac{4 \cdot 365.48}{\sqrt{365.48^2 + 4(91.36) + 7(182.73) + 4(274.1)}} = 3.96 \leq 2.5$

$W_2 = 2.5$

$M_u = \frac{2.5\pi}{3500}\sqrt{5.99 \cdot 10^{23} + 1.38 \cdot 10^{24}} = 3156$

$M_r = 1.15 \cdot 0.9 \cdot 447.3\left[1 - \frac{0.28(447.3)}{3156}\right] \leq 447.3$
$= 445\,KN \cdot m$

$M_r = 445$ m

$W_{1x} = 0.252$ $K_1 = \frac{36.45}{42} = 0.87$ $C_{ex} = \frac{\pi^2 \cdot EI_x}{L_x} = 31905$

$U_{1x} = \frac{0.252}{1 - \frac{751.5}{31905}} = 0.26 \rightarrow$ use $U_{1x} = 1.0$

$\frac{751.5}{2646.4} + \frac{0.8 \cdot 1.0 \cdot 365.48}{445} = \boxed{0.94}$

✓ Safe

(a) cl 13.8.2 (a)

C_r with $\lambda = 0$ $\quad C_r = 0.9 \cdot 11000 \cdot 350 = 3465$ kN

$M_r = \phi Z F_y = 0.9 \cdot 1420 \cdot 10^3 \cdot 350 = 447.3$ kN·m

$U_{1x} = 0.26$

$$\frac{751.5}{3465} + \frac{0.85 \cdot 0.26 \cdot 365.48}{447.3} = 0.4 < 1.0 \quad \checkmark \text{ good}$$

(b) cl 13.8.2 – Strong Axis Buckling

$$\left(\frac{KL}{r}\right)_x = \frac{3500}{205} = 17.1 < 200 \quad \checkmark \text{ good}$$

$$F_{ex} = \frac{\pi^2 E}{17.1^2} = 6750.52 \qquad \lambda_x = \sqrt{\frac{350}{6750.52}} = 0.23$$

$$C_r = \frac{0.9 \cdot 11000 \cdot 350}{\left(1+0.23^{2 \cdot 1.34}\right)^{\frac{1}{1.34}}} = 3415$$

$$\frac{751.5}{3415} + \frac{0.85 \cdot 0.26 \cdot 365.48}{447.3} = 0.4 < 1.0 \quad \checkmark \text{ good}$$

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CBF Beams | Assume the beam is not laterally braced. $\boxed{W200\times52 @ 6000\,mm}$

· check for slenderness: $\frac{kL}{r_y} = \frac{6000}{51.8} < 300$, and $r_x > r_y$, ∴ ok for slenderness 10.4.2.2

· class check: $\frac{bel}{t} = \frac{\frac{204}{2}}{12.6} = 8.09 \le \frac{170}{\sqrt{F_y}} = 9.08$. ∴ class 2 flange.

Table 2: $\frac{h}{w} = \frac{147.6}{7.9} = 18.6 \le \frac{1100}{\sqrt{F_y}} = 58.1$ ∴ class 1 web

check for moment: $M_f = 120\,kN\cdot m$

W200×52:

$I_x = 52.7\times10^6\,mm^4$ $I_y = 17.8\times10^6\,mm^4$

$S_x = 512\times10^3\,mm^3$ $r_y = 51.8\,mm$

$Z_x = 569\times10^3\,mm^3$ $J = 323\times10^3\,mm^3$

$r_x = 89\,mm$ $C_w = 167\times10^9\,mm^6$

BMD (from Sframe), kN·m.

$M_u = \frac{W_2\pi}{L}\sqrt{EI_yGJ + (\frac{\pi E}{L})^2 I_y C_w}$ 13.6.a).II

$W_2 = \frac{4M_{max}}{\sqrt{M_{max}^2+4M_a^2+7M_b^2+4M_c^2}}$

$= 1.1364 \le 2.5$ ✓ok

∴ $M_u = 207.10$ MPa.

And, $M_p = \phi Z_x F_y$

$= 179.23$ MPa

∵ $M_u > 0.67M_p$,

∴ $M_r = 1.15\phi M_p[1 - \frac{0.28M_p}{M_u}]$ 13.6.a).i)

$\boxed{M_r = 140.55\ MPa} < 0.9(M_p)$

∵ $M_r > M_{max} = 125$, ✓ok for moment.

check for shear, $V_f = 70\,kN$

$V_r = \phi A_w F_s$ 13.4.1.1

∵ $\frac{h}{w} = 18.6 \le \frac{1014}{\sqrt{F_y}} = 54.2$

$F_s = 0.66F_y$ 13.4.1.1.a)

∵ $A_w = 6650\,mm^2$

∴ $V_r = 1382.5\,kN >> V_f = 70\,kN$ ✓ok for shear.

check for serviceability.

$\Delta_{max} = \frac{5wL^4}{384EI}$, $W_{snow+live} = 4.8\,kPa \times 2m$

$= 9.6\,kN/m$.

∴ $\Delta_{max} = 15.4$ mm

From table D.1, $\Delta < \frac{L}{300} = 20$ mm

∴ $\Delta_{max} < \frac{L}{300}$

∴ good for serviceability.

Brace | W200×71 @ 7000 mm, $C_f = 760$.

$A = 9100\,mm^2$

$r_y = 52.8\,mm$.

class check: $\frac{bel}{t} = \frac{\frac{206}{2}}{17.4} = 5.91 < \frac{200}{\sqrt{F_y}}$ Table 1

$\frac{h}{w} = \frac{148}{10.2} = 14.5 < \frac{670}{\sqrt{F_y}}$, ∴ ok for local buckling.

slenderness check: $\frac{kL}{r_y} = \frac{7000}{52.8} = 132.5 < 300$, and $r_x > r_y$, ∴ ok for slenderness. 10.4.2.2

$C_r = \frac{\phi A F_y}{(1+\lambda^{2n})^{\frac{1}{n}}}$ 13.3.1

$n = 1.34$.

$F_e = \frac{\pi^2 E}{(\frac{KL}{r})^2}$

$= 112.43$ MPa.

∴ $\lambda = \frac{\sqrt{F_y}}{\sqrt{F_e}}$

$\lambda = 1.7644$

$C_r = 794.6\,kN$.

∴ $C_r > C_f = 760\,kN$.

∴ ok for compression.

Check for shear & serviceability.

$V_f = 0$.

$\Delta = 0$.

∴ ok for both.

Gravity Column Check W250X73

$C_f = 1842.470\,kN$
buckling about weak axis

$n = 1.34$
$K = 1 \quad L = 3500mm$
$r_y = 64.6mm$

S16-14 CL 13.3.1

$C_r = \phi A F_y (1+\lambda^{2n})^{-\frac{1}{n}}$

$= \dfrac{0.9(9290mm^2)(350MPa)}{(1+0.721^{2.68})^{\frac{1}{1.34}}}$

$= 2256.3kN$

$F_e = \dfrac{\pi^2 E}{\left(\frac{KL}{r_y}\right)^2}$

$= \dfrac{\pi^2\, 200\,000MPa}{(54.18)^2}$

$= 672.4MPa$

$\dfrac{KL}{r_y} = \dfrac{3500}{64.6} = 54.18$

$54.18 < 200$
not too slender

$\lambda = \sqrt{\dfrac{350MPa}{672.4MPa}}$

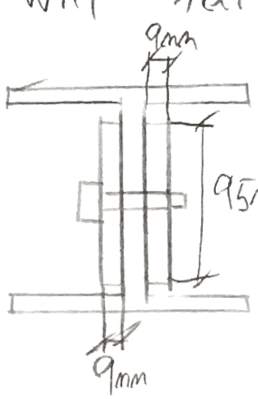
$= 0.721$

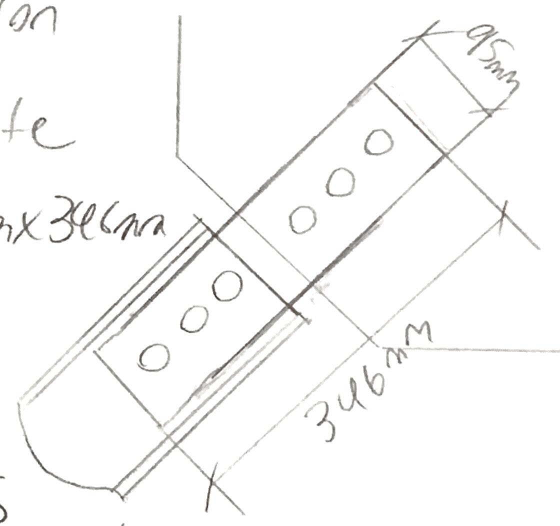
$2256.3kN > 1842.470kN$, Section is OK

Brace - Gusset plate connection

Assume only splice plate will fail

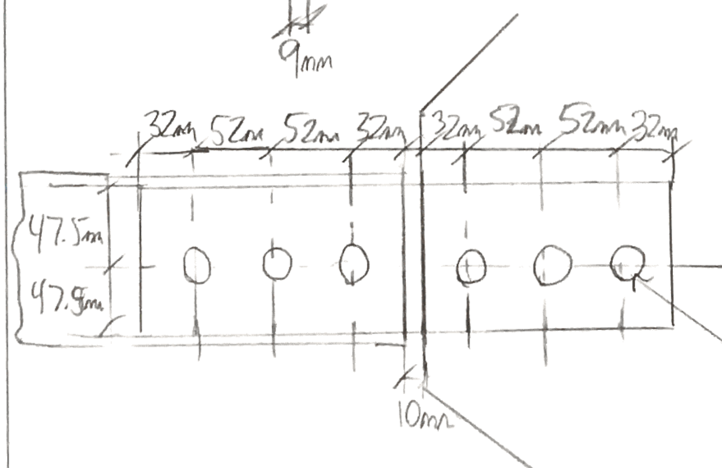
2 9mm x 95mm x 346mm plates





NTS

min pitch CL22.3.1
$2.7d \leq 52$
$51.44 \leq 52$ ✓



19.05 (3/4") diameter bolt, typ

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End distance 22.3.3, 22.3.4

28.6mm < 47.5 < 108mm ✓ edge

32mm < 32mm < 108mm ✓ end

CL13.2, CL 12.3 Net area

$T_r = 2(0.75)(95-23.05)(450)(9)$
$= 437\,kN$ ✓

CL13.2 Gross Area

$T_r = 2(0.9)(9)(95)(350)$
$= 538.7\,kN$ ✓

CL 13.11 Block shear

$V_r = 2(0.9)\left[9(95-\frac{23.05}{2})(450)+0.6(32+104)(9)(375)\right]$
$= 1020.2\,kN$ ✓

Bolt tearout

$V_r = 2(2)(0.9)(0.6)(104+32)(9)(375)$
$= 991.4\,kN$ ✓

CL 13.12.1 Bolt Bearing

$B_r = 3(0.8)(10)(19.05)(3)(450)$
$= 555.5\,kN$ ✓

Bolt shear

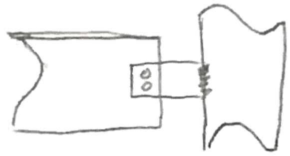
$V_r = 0.7(0.6)(0.8)(2)(2)(285)(830)$
$= 476.9\,kN$ ✓

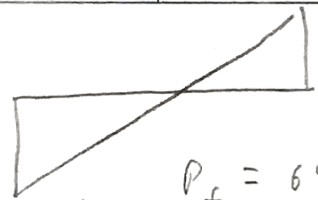
SFrame load
373.7442 kN
max tension

Assume gusset plate thickness same as web of brace

Assume punched bolt holes

Assume threads intercepted





$P_f = 69.44 \times 3 \times 0.5$ $e = 150\,mm$
$= 104.16\ kN$

Use 2 $\frac{3}{4}$" A325
$V_r = 113\ kN$ $\frac{P_f}{V_r} = 0.614$; use $b = 100$ ∴ T3-14 $\frac{P_f}{V_r} = 0.63$

$\Delta_1 = \Delta_2 = \Delta_u = 4.8\ mm$
$\tau_1 = \tau_2 = \tau_{max} = 592\ MPa$

$V_1 = V_2 = \phi_b A_b m = (0.8)(285)(592)(1)$
$= 135\ kN/bolt$

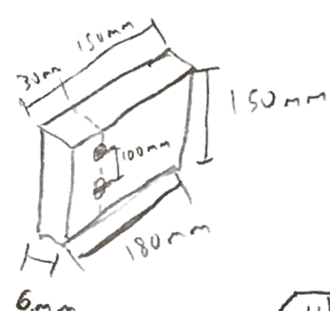
$\Sigma M_{IC} = 2(135 \times r)$
$\theta = \sin^{-1}\left(\frac{50}{r}\right)$
$\Sigma F_y = 104.16 \sin\theta = 104.16\left(\frac{50}{r}\right)$
$M_1 = \Sigma M_{IC}$ $M_2 = F_y(IC + 150)$

IC	r	F_y	M_1	M_2	equal?
20	53.85	96.71	14539	16441	x
30	58.31	89.31	15744	16076	x
35	61.03	85.33	16479	15787	x
32.5	59.63	87.34	16101	15934	x
32	59.36	87.73	16028	15468	x
31.75	59.23	87.93	15992	15981	~
31.7	59.20	87.97	15984	15985	✓

Dimension Check

$d = 19\ mm$
Cl 22.3.1
$b = 100 > 2.7(19) = 51.3$
Cl 22.3.2 and T6
use 25mm,
total height = 150mm
Cl 22.3.3
$12t = 3048 = 150$
$25 \leq 150\,mm$
Cl 22.3.4
$1.5d = 28.5 = 30\,mm$

Final dimensions

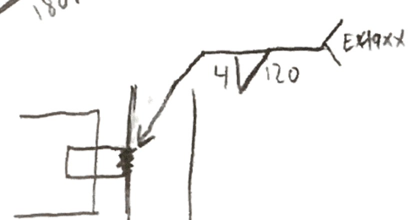


$V_r = 135\,kN$ $B_r = 3\phi_b n t d F_u$ Cl 13.12.1.2 a)
$= 455\ kN > V_r$

weld Cl 13.13.2.2
$V_r = 0.67\phi_w A_w X_u (1 + 0.5\sin^{1.5}\theta) M_w$ $M_w = 1$
$\theta = 0$

$104.16 \leq 0.67\phi_w A_w X_u$
$A_w \geq 473\ mm^2$
4mm weld, 120mm long

Dimension check
p 6-186
$t \leq 6$, $D > 3\,mm$ ✓
$D_{max} = t - 2 = 4\,mm$ ✓
4mm weld ✓

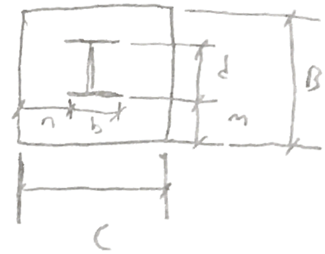


Column Base Plate P4-153

Section: W 310 x 86

$b = 254$

$d = 310$



$B_r \geq C_f$

$C_f = 1843$ kN

$B_r = 0.85\ \phi_c\ A f'_c$

$A \geq \frac{C_f}{B_r} \geq 133000\ mm^2$

$B \times C = 133000$

$B = 0.95\ d + 2m$

$C = 0.8b + 2n$ $n \approx m = x$

$A = (2x + 0.95d)(2x + 0.8b)$

$x = 59.34 = m = n$

$\boxed{B = 413.18 \quad C = 321.88}$

$t_p \geq \sqrt{\frac{2\ C_f\ (m^2)}{B\ C\ \phi\ F_y}}$

$\geq \sqrt{\frac{2(1843)(59.34)}{(133000)(0.9)(0.35)}}$

$\boxed{t_p \geq 17.6\ mm}$