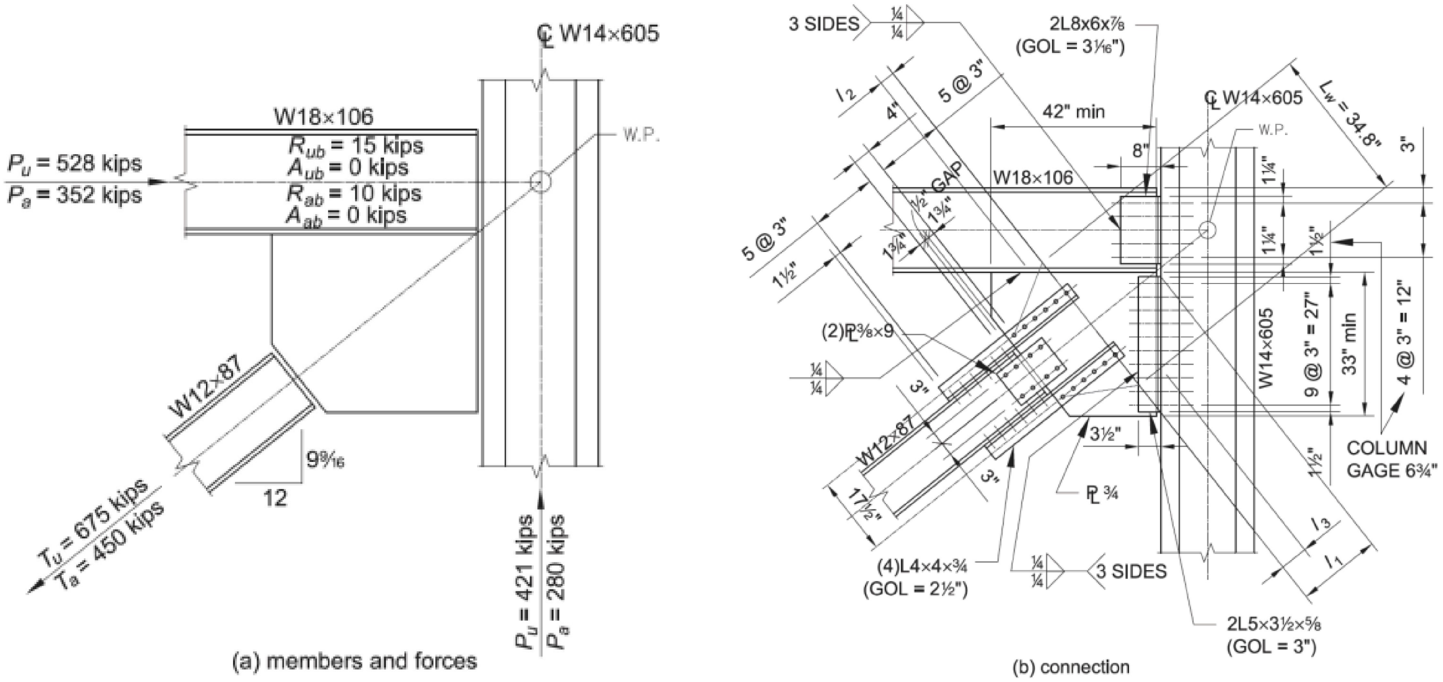
$ORIGIN := 1$

Reference to AISC 14th Edition shapes database:

$T1 :=$ AISC Shapes Database v14.1.xls

$$Row(shape) := \left| \begin{array}{l} \text{for } i \in 1 .. rows(T1) - 1 \\ \quad R \leftarrow i \text{ if } \left(T1^{\langle 2 \rangle}\right)_i = shape \\ R \end{array} \right.$$

Solve Example 3 Diagonal Bracing Connection



Loads (LRFD)

Brace axial force	$T_u := 675kip$
Beam end Reaction	$R_{u\_beam} := 15kip$
beam axial force	$P_{u\_beam} := 528kip$
Column axial force	$P_{u\_column} := 421kip$

Material Properties

Beams, Column & Brace A992	$Fy_{A992} := 50 \cdot ksi$	$Fu_{A992} := 65 \cdot ksi$
Plate and Angle A36	$Fy_{A36} := 36ksi$	$Fu_{A36} := 58ksi$
Modulus of Elasticity	$E := 29000ksi$	
weld strength	$F_{EXX} := 70ksi$	$C_1 := 1.0$
Bolt nominal stress (A325)	$F_{nt} := 90ksi$	$F_{nv} := 54ksi$

Member Properties

Brace Properties

Brace section $Brace := \text{"W12X87"}$

cross sectional area $Ag_{brace} := T1_{(Row(Brace),6)} \cdot in^2 = 25.6 \cdot in^2$

depth $d_{brace} := T1_{(Row(Brace),7)} \cdot in = 12.5 \cdot in$

web thickness $tw_{brace} := T1_{(Row(Brace),17)} \cdot in = 0.515 \cdot in$

flange width $bf_{brace} := T1_{(Row(Brace),12)} \cdot in = 12.1 \cdot in$

flange thickness $tf_{brace} := T1_{(Row(Brace),20)} \, in = 0.81 \, in$

Beam Properties

Beam section $Beam := \text{"W18X35"}$

depth of beam $d_{beam} := T1_{(Row(Beam),7)} \cdot in = 17.7 \cdot in$

width of flange $bf_{beam} := T1_{(Row(Beam),12)} \cdot in = 6.0 \cdot in$

thickness of flange $tf_{beam} := T1_{(Row(Beam),20)} \, in = 0.425 \, in$

thickness of web $tw_{beam} := T1_{(Row(Beam),17)} \cdot in = 0.3 \cdot in$

design weld depth $k\_des_{beam} := T1_{(Row(Beam),25)} \cdot in = 0.827 \cdot in$

Column Properties

$Column := \text{"W14X605"}$

depth $d_{column} := T1_{(Row(Column),7)} \cdot in = 20.9 \cdot in$

flange width $bf_{column} := T1_{(Row(Column),12)} \cdot in = 17.4 \cdot in$

flange thickness $tf_{column} := T1_{(Row(Column),20)} \, in = 4.16 \, in$

web thickness $tw_{column} := T1_{(Row(Column),17)} \cdot in = 2.6 \cdot in$

strong moment of inertia $Ix_{column} := T1_{(Row(Column),39)} \cdot in^4 = 10800 \, in^4$

Gusset Plate Properties

thickness	$t_{gusset} := 0.75in$
length	$L_{gusset} := 42in$
height	$h_{gusset} := 33in$

Bolt Properties (A325)

bolt diameter: $d_{bolt} := \frac{7}{8}in$ $\quad d'_{bolt} := d_{bolt} + \frac{1}{16}in$ $\quad d''_{bolt} := d_{bolt} + \frac{2}{16}in$

area of bolt: $A_{bolt} := \pi \cdot d_{bolt}^2 \div 4 = 0.6\,in^2$

strength reduction factor: $\Phi := 0.75$

bolt shear strength (single shear): $\Phi r_{nv} := \Phi\, F_{nv} \cdot A_{bolt} = 24.35\,kip$ EQ : J3-1

bolt tensile strength: $\Phi r_{nt} := \Phi \cdot F_{nt} \cdot A_{bolt} = 40.59\,kip$ EQ : J3-1

pitch (bolt spacing): $p := 3in$

Brace to gusset connection

recall:

$T_u = 675\,kip$

$bf_{brace} = 12.1\,in$

$tf_{brace} = 0.81\,in$

$Ag_{brace} = 25.6\,in^2$

$\Phi r_{nv} = 24.35\,kip$

force in one flange: $P_{uf} := T_u \cdot \frac{bf_{brace} \cdot tf_{brace}}{Ag_{brace}} = 258.42\,kip$

force in web: $P_{uw} := T_u - 2 \cdot P_{uf} = 158.15\,kip$

Brace Flange to Gusset Connection

number of bolts in brace flange to gusset plate rounded up to nearest even number:

$n_{bolts\_brcflng2gusset} := \frac{P_{uf}}{\Phi r_{nv}} = 10.61$

$n_{bolts\_brcflng2gusset} := Ceil(n_{bolts\_brcflng2gusset}, 2) = 12$

6 rows of 2 bolts in flange and 6 bolts total in gusset (double shear)

angle property

section: $L_1 := "L4X4X3/4"$ double angle (properties are doubled in definition)

gross area: $Ag_{L1} := 2\, T1_{(Row(L_1), 6)} \cdot in^2 = 10.88\,in \cdot in$

thickness: $t_{L1} := T1_{(Row(L_1), 22)} \cdot in = 0.75\,in$

leg length (same both legs): $L_{L1} := T1_{(Row(L_1), 15)} \cdot in = 4\,in$

centroid: $x\_bar_{L1} := T1_{(Row(L_1), 28)} \cdot in = 1.27\,in$

Tensile yielding of Angles (J4.1a)

recall:

$Ag_{L1} = 10.88\,in^2$

$p = 3\,in$

$x\_bar_{L1} = 1.27\,in$

$d''_{bolt} = 1\,in$

$t_{L1} = 0.75\,in$

$Fy_{A36} = 36\,ksi$

$Fu_{A36} = 58\,ksi$

$P_{uf} = 258.42\,kip$

strength reduction factor $\Phi := 0.90$

tensile yielding strength $\Phi R_n := \Phi \cdot Fy_{A36} \cdot Ag_{L1} = 352.51\,kip$

check capacity $if(P_{uf} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

Tensile Rupture of angles (J4.1b)

Table D3.1 (2)

$$U := 1 - \frac{x\_bar_{L1}}{p \cdot \left(\frac{n_{bolts\_brcflng2gusset}}{2} - 1\right)} = 0.915$$

net area $An_{L1} := Ag_{L1} - 2t_{L1} \cdot (d''_{bolt}) = 9.38\,in^2$

effective area $Ae_{L1} := An_{L1} \cdot U = 8.59\,in^2$

strength reduction factor $\Phi := 0.75$

tensile rupture strength $\Phi R_n := \Phi \cdot Fu_{A36} \cdot Ae_{L1} = 373.48\,kip$

check capacity $if(P_{uf} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

block shear strength (J4.3)

recall:

$n_{bolts\_brcflng2gusset} = 12$

$t_{L1} = 0.75\,in$

$p = 3\,in$

$d''_{bolt} = 1\,in$

$P_{uf} = 258.42\,kip$

block shear strength $R_n = 0.60 F_u \cdot A_{nv} + U_{bs} \cdot F_u \cdot A_{nt} \le 0.60 F_y \cdot A_{gv} + U_{bs} \cdot F_u \cdot A_{nt}$

edge distance of bolt centers $L_{ev} := 1.5in$ $L_{eh} := 1.5in$ $U_{bs} := 1.0$

net tensile area $Ant_{L1} := 2t_{L1} \cdot (L_{eh} - 0.5 \cdot d''_{bolt}) = 1.5\,in^2$

gross shear area

$$Agv_{L1} := 2t_{L1} \cdot \left[p \cdot \left(\frac{n_{bolts\_brcflng2gusset}}{2} - 1\right) + L_{ev}\right] = 24.75\,in^2$$

net shear area

$$Anv_{L1} := 2Agv_{L1} - t_{L1} \cdot \left(\frac{n_{bolts\_brcflng2gusset}}{2} - 0.5\right) \cdot d''_{bolt} = 45.37\,in^2$$

strength reduction factor $\Phi := 0.75$

$\Phi \cdot 0.60 Fu_{A36} \cdot Anv_{L1} = 1184.29\,kip$

$\Phi \cdot U_{bs} \cdot Fu_{A36} \cdot Ant_{L1} = 65.25\,kip$

$\Phi \cdot 0.60 Fy_{A36} \cdot Agv_{L1} = 400.95\,kip$

block shear strength $\Phi R_n := \Phi \cdot U_{bs} \cdot Fu_{A36} \cdot Ant_{L1} + \min(\Phi \cdot 0.60 Fy_{A36} \cdot Agv_{L1}, \Phi \cdot 0.60 Fu_{A36} \cdot Anv_{L1})$

$\Phi R_n = 466.2\,kip$

check capacity $if(P_{uf} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

Brace Web to Gusset Connection

number of bolts in brace web to gusset plate rounded up to nearest even number (double shear)

$n_{bolts\_brcweb2gusset} := \dfrac{P_{uw}}{(2)\Phi r_{nv}} = 3.25$

recall:

$P_{uw} = 158.15\,kip$

$\Phi r_{nv} = 24.35\,kip$

2 rows of 2 bolts

$n_{bolts\_brcweb2gusset} := Ceil(n_{bolts\_brcweb2gusset}, 2) = 4$

web plate dimensions

$t_{PL1} := 0.375in$ $h_{PL1} := 9in$

tensile yielding of plate (J4.1a)

gross tensile area

$Ag_{PL1} := (2) \cdot t_{PL1} \cdot h_{PL1} = 6.75\,in^2$

strength reduction factor

$\Phi := 0.90$

tensile yielding strength

$\Phi R_n := \Phi \cdot Fy_{A36} \cdot Ag_{PL1} = 218.7\,kip$

check capacity

$if(P_{uw} < \Phi R_n, "OK", "NOT OK") = "OK"$

Tensile Rupture of Plates (J4.1b)

recall:

$t_{PL1} = 0.38\,in$

$d''_{bolt} = 1\,in$

$P_{uw} = 158.15\,kip$

net area

$An_{PL1} := Ag_{PL1} - (2)t_{PL1} \cdot (2)d''_{bolt} = 5.25\,in^2$

effective area

$Ae_{PL1} := min(An_{PL1}, 0.85 \cdot Ag_{PL1}) = 5.25\,in^2$

strength reduction factor

$\Phi := 0.75$

tensile rupture strength

$\Phi R_n := \Phi \cdot Fu_{A36} \cdot Ae_{PL1} = 228.38\,kip$

check capacity

$if(P_{uw} < \Phi R_n, "OK", "NOT OK") = "OK"$

block shear strength of PL-1 (J4.3)

block shear strength

$R_n = 0.60F_u \cdot A_{nv} + U_{bs} \cdot F_u \cdot A_{nt} \le 0.60F_y \cdot A_{gv} + U_{bs} \cdot F_u \cdot A_{nt}$

edge distance of bolt centers

$L_{ev} := 1.5in$ $L_{eh} := 1.5in$ $U_{bs} := 1.0$

net tensile area

$Ant_{PL1} := (4)t_{PL1}(L_{eh} - 0.5 \cdot d''_{bolt}) = 1.5\,in^2$

gross shear area

$Agv_{PL1} := (4)t_{PL1} \cdot \left[p \cdot \left(\dfrac{n_{bolts\_brcweb2gusset}}{2} - 1\right) + L_{ev}\right] = 6.75\,in^2$

net shear area

$Anv_{PL1} := (4)Agv_{PL1} - t_{PL1} \cdot \left(\dfrac{n_{bolts\_brcweb2gusset}}{2} - 0.5\right) \cdot d''_{bolt} = 26.44\,in^2$

strength reduction factor $\Phi := 0.75$

$\Phi \cdot 0.60 Fu_{A36} \cdot Anv_{PL1} = 690.02\, kip$

$\Phi \cdot U_{bs} \cdot Fu_{A36} \cdot Ant_{PL1} = 65.25\, kip$

$\Phi \cdot 0.60 Fy_{A36} \cdot Agv_{PL1} = 109.35\, kip$

block shear strength $\Phi R_n := \Phi \cdot U_{bs} \cdot Fu_{A36} \cdot Ant_{PL1} + \min(\Phi \cdot 0.60 Fy_{A36} \cdot Agv_{PL1}, \Phi \cdot 0.60 Fu_{A36} \cdot Anv_{PL1})$

$\Phi R_n = 174.6\, kip$

check capacity if$(P_{uw} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

recall :

$tw_{brace} = 0.52\, in$

$n_{bolts\_brcweb2gusset} = 4$

$P_{uw} = 158.15\, kip$

$T_u = 675\, kip$

block shear strength of Brace (J4.3)

block shear strength $R_n = 0.60 F_u \cdot A_{nv} + U_{bs} \cdot F_u \cdot A_{nt} \le 0.60 F_y \cdot A_{gv} + U_{bs} \cdot F_u \cdot A_{nt}$

edge distance of bolt centers $L_{ev} := 1.5 in$ $L_{eh} := 3 in$ $U_{bs} := 1.0$

net tensile area $Ant_{brace1} := tw_{brace}(6 in - d''_{bolt}) = 2.57\, in^2$

gross shear area $Agv_{brace1} := (2) tw_{brace} \cdot \left[p \cdot \left(\frac{n_{bolts\_brcweb2gusset}}{2} - 1 \right) + L_{ev} \right] = 4.63\, in^2$

net shear area $Anv_{brace1} := Agv_{brace1} - (2) tw_{brace} \cdot \left(\frac{n_{bolts\_brcweb2gusset}}{2} - 0.5 \right) \cdot d''_{bolt} = 3.09\, in^2$

strength reduction factor $\Phi := 0.75$

$\Phi \cdot 0.60 Fu_{A992} \cdot Anv_{brace1} = 90.38\, kip$

$\Phi \cdot U_{bs} \cdot Fu_{A992} \cdot Ant_{brace1} = 125.53\, kip$

$\Phi \cdot 0.60 Fy_{A992} \cdot Agv_{brace1} = 104.29\, kip$

block shear strength $\Phi R_n := \Phi \cdot U_{bs} \cdot Fu_{A992} \cdot Ant_{brace1} + \min(\Phi \cdot 0.60 Fy_{A992} \cdot Agv_{brace1}, \Phi \cdot 0.60 Fu_{A992} \cdot Anv_{brace1})$

$\Phi R_n = 215.9\, kip$

check capacity if$(P_{uw} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

tensile yielding of brace (J4.1a)

strength reduction factor $\Phi := 0.90$

tensile yielding strength $\Phi R_n := \Phi \cdot Fy_{A992} \cdot Ag_{brace} = 1152\, kip$

check capacity if$(T_u < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

Tensile Rupture of brace (J4.1b)

recall :

$Ag_{brace} = 25.6\,in^2$

$tw_{brace} = 0.52\,in$

$tf_{brace} = 0.81\,in$

$d''_{bolt} = 1\,in$

$T_u = 675\,kip$

$t_{PL1} = 0.375\,in$

$t_{gusset} = 0.75\,in$

net area $An_{brace1} := Ag_{brace} - \left[tw_{brace}\cdot(2) + tf_{brace}\cdot(4)\right]d''_{bolt}$

$An_{brace1} = 21.33\,in^2$

effective area $Ae_{brace1} := An_{brace1}$

strength reduction factor $\Phi := 0.75$

tensile rupture strength $\Phi R_n := \Phi\cdot Fu_{A992}\cdot Ae_{brace1} = 1039.84\,kip$

check capacity $if(T_u < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

Gusset Plate

$t_{gusset} = 0.75\,in$ = $2\cdot t_{PL1} = 0.75\,in$

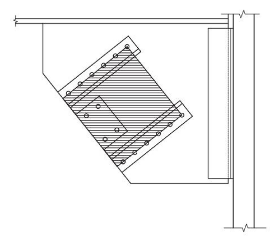


Fig. II.C-2-2. Block shear rupture area for gusset.

block shear strength of gusset (J4.3)

block shear strength $R_n = 0.60F_u\cdot A_{nv} + U_{bs}\cdot F_u\cdot A_{nt} \le 0.60F_y\cdot A_{gv} + U_{bs}\cdot F_u\cdot A_{nt}$

$U_{bs} := 1.0$

net tensile area $Ant_{gusset1} := t_{gusset}\left[d_{brace} + (2)\cdot L_{L1} - 2\cdot L_{ev} - d''_{bolt}\right] = 12.37\,in^2$

gross shear area $Agv_{gusset1} := (2)t_{gusset}\cdot\left[p\cdot\left(\frac{n_{bolts\_brcflng2gusset}}{2} - 1\right) + 1.75in\right] = 25.12\,in^2$ 1.75" edge distance

net shear area $Anv_{gusset1} := Agv_{gusset1} - (2)t_{gusset}\cdot\left(\frac{n_{bolts\_brcflng2gusset}}{2} - 0.5\right)\cdot d''_{bolt} = 16.87\,in^2$

strength reduction factor $\Phi := 0.75$

$\Phi\cdot 0.60Fu_{A36}\cdot Anv_{gusset1} = 440.44\,kip$

$\Phi\cdot U_{bs}\cdot Fu_{A36}\cdot Ant_{gusset1} = 538.31\,kip$

$\Phi\cdot 0.60Fy_{A36}\cdot Agv_{gusset1} = 407.02\,kip$

block shear strength $\Phi R_n := \Phi\cdot U_{bs}\cdot Fu_{A36}\cdot Ant_{gusset1} + \min(\Phi\cdot 0.60Fy_{A36}\cdot Agv_{gusset1}, \Phi\cdot 0.60Fu_{A36}\cdot Anv_{gusset1}$

$\Phi R_n = 945.3\,kip$

check capacity $if(T_u < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

Tensile Yielding of Whitmore section (J3.1a)

total length of whitmore section $l_w := d_{brace} + (2)\cdot L_{L1} - 2\cdot L_{ev} + 2\cdot \tan(30deg)\cdot\left[p\cdot\left(\frac{n_{bolts\_brcflng2gusset}}{2} - 1\right)\right] = 34.82\,in$

length of whitmore section in gusset $lw_{gusset} := 30.9in$ $lw_{web} := l_w - lw_{gusset} = 3.92\,in$

strength reduction factor $\Phi := 0.90$

tensile yielding strength (gusset portion) $\Phi R_{n1} := \Phi\cdot Fy_{A36}\cdot lw_{gusset}\cdot t_{gusset} = 750.87\,kip$

(web portion) $\Phi R_{n2} := \Phi\cdot Fy_{A992}\cdot lw_{web}\cdot tw_{beam} = 52.93\,kip$

tensile yielding strength $\Phi R_n := \Phi R_{n1} + \Phi R_{n2} = 803.8\,kip$

check capacity $\text{if}\left(T_u < \Phi R_n, \text{"OK"}, \text{"NOT OK"}\right) = \text{"OK"}$

recall :

$d_{brace} = 12.5\,in$

$L_{L1} = 4\,in$

$L_{ev} = 1.5\,in$

$p = 3\,in$

$n_{bolts\_brcflng2gusset} = 12$

$t_{gusset} = 0.75\,in$

$tw_{beam} = 0.3\,in$

$T_u = 675\,kip$

$2\Phi r_{nv} \div \Phi = 54.12\,kip$

bolt bearing strength (angles, brace flange, & gusset) (J3.10)

by inspection - gusset controls

edge bolt clear distance $l_{c1\_edge} := 1.75in - 0.5\cdot d'_{bolt} = 1.28\,in$ input 1.75"

interior bolt clear distance $l_{c1\_interior} := p - d'_{bolt} = 2.06\,in$

strenght reduction factor $\Phi := 0.75$

interior bolt bearing strength $\Phi r_{n\_interior} := \Phi\cdot \min\left(1.2\cdot l_{c1\_interior}\cdot t_{gusset}\cdot Fu_{A36}, 2.4\cdot d_{bolt}\cdot t_{gusset}\cdot Fu_{A36}, 2\Phi r_{nv} \div \Phi\right)$

edge bolt bearing strength $\Phi r_{n\_edge} := \Phi\cdot \min\left(1.2\cdot l_{c1\_edge}\cdot t_{gusset}\cdot Fu_{A36}, 2.4\cdot d_{bolt}\cdot t_{gusset}\cdot Fu_{A36}, 2\Phi r_{nv} \div \Phi\right)$

$\Phi r_{n\_interior} = 48.71\,kip$ $\Phi r_{n\_edge} = 48.71\,kip$

total bolt bearing strength $\Phi R_n := (1)\cdot \Phi r_{n\_edge} + \left(\frac{n_{bolts\_brcflng2gusset}}{2} - 1\right)\cdot \Phi r_{n\_interior} = 292.24\,kip$

check capacity $\text{if}\left(P_{uf} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}\right) = \text{"OK"}$

bolt bearing strength (brace web) (J3.10)

edge bolt clear distance $l_{c1\_edge} := 1.5in - 0.5\cdot d'_{bolt} = 1.03\,in$

interior bolt clear distance $l_{c1\_interior} := p - d'_{bolt} = 2.06\,in$

strenght reduction factor $\Phi := 0.75$

interior bolt bearing strength $\Phi r_{n\_interior} := \Phi\cdot \min\left(1.2\cdot l_{c1\_interior}\cdot tw_{brace}\cdot Fu_{A992}, 2.4\cdot d_{bolt}\cdot tw_{brace}\cdot Fu_{A992}, 2\Phi r_{nv} \div \Phi\right)$

edge bolt bearing strength $\Phi r_{n\_edge} := \Phi\cdot \min\left(1.2\cdot l_{c1\_edge}\cdot tw_{brace}\cdot Fu_{A992}, 2.4\cdot d_{bolt}\cdot tw_{brace}\cdot Fu_{A992}, 2\Phi r_{nv} \div \Phi\right)$

$\Phi r_{n\_interior} = 48.71\,kip$ $\Phi r_{n\_edge} = 31.07\,kip$

recall:

$P_{uw} = 158.15\,kip$

total bolt bearing strength

$\Phi R_n := (2)\cdot\Phi r_{n\_edge} + (n_{bolts\_brcweb2gusset} - 2)\cdot\Phi r_{n\_interior}$

$\Phi R_n = 159.55\,kip$

check capacity

$if(P_{uw} < \Phi R_n, "OK", "NOT OK") = "OK"$

distribution of brace forces to beam and column (AISC Chapter 13)

recall:

$d_{beam} = 17.7\,in$

$d_{column} = 20.9\,in$

$L_{gusset} = 42\,in$

$h_{gusset} = 33\,in$

$T_u = 675\,kip$

half beam depth $e_{beam} := d_{beam} \div 2 = 8.85\,in$

half column depth $e_{column} := d_{column} \div 2 = 10.45\,in$

slope of brace

used input values

$\theta_{brace} := atan\left(\dfrac{12}{9 + \dfrac{9}{16}}\right) = 51.45\cdot deg$ $\dfrac{12}{9 + \dfrac{9}{16}} = 1.25$

$e_{beam}\cdot tan(\theta_{brace}) - e_{column} = 0.66\,in$

$\alpha\_bar := \dfrac{L_{gusset}}{2} + 0.5in = 21.5\,in$

$\beta\_bar := \dfrac{h_{gusset}}{2} = 16.5\,in$ $\beta := \beta\_bar$

$\alpha - \beta\cdot tan(\theta) = e_{beam}\cdot tan(\theta) - e_{column}$ EQ: 13-1

$\alpha = e_{beam}\cdot tan(\theta) - e_{column} + \beta\cdot tan(\theta)$

$\alpha := e_{beam}\cdot tan(\theta_{brace}) - e_{column} + \beta\_bar\cdot tan(\theta_{brace}) = 21.36\,in$

$e_{additional} := \alpha - \alpha\_bar = -0.14\,in$

$r := \sqrt{(\alpha + e_{column})^2 + (\beta + e_{beam})^2} = 40.68\,in$ Eq. 13-6

required axial force on gusset to column connection $H_{column} := \dfrac{e_{column}}{r}\cdot T_u = 173.41\,kip$ Eq. 13-3

required shear force on gusset to column connection $V_{column} := \dfrac{\beta}{r}\cdot T_u = 273.8\,kip$ Eq. 13-2

required axial force on gusset to beam connection $H_{beam} := \dfrac{\alpha}{r}\cdot T_u = 354.48\,kip$ Eq. 13-5

required shear force on gusset to beam connection $V_{beam} := \dfrac{e_{beam}}{r}\cdot T_u = 146.86\,kip$ Eq. 13-4

check balance of forces $T_u\cdot sin(\theta_{brace}) - (H_{column} + H_{beam}) = -0\,kip$

section $L_2 := \text{"L5X3-1/2X5/8"}$ double angle (properties are doubled in definition)

gross area $Ag_{L2} := 2\,T1_{(Row(L_2),6)} \cdot in^2 = 9.86\,in \cdot in$

thickness $t_{L2} := T1_{(Row(L_2),22)} \cdot in = 0.625\,in$

leg length long $L_{L2} := T1_{(Row(L_2),15)} \cdot in = 5\,in$

leg length - short $h_{L2} := T1_{(Row(L_2),7)} \cdot in = 3.5\,in$

centroid $x\_bar_{L2} := T1_{(Row(L_2),28)} \cdot in = 0.95\,in$

gage of angle $GOL_2 := 3in$

number of bolts in gusset to column connection $n_{bolts\_gusset2column} := 20$

check bolt capacity (J3.7)

recall :

$H_{column} = 173.41\,kip$

$V_{column} = 273.8\,kip$

$\Phi r_{nt} = 40.59\,kip$

$A_{bolt} = 0.6\,in^2$

$F_{nt} = 90\,ksi$

$F_{nv} = 54\,ksi$

ultimate tensile force per bolt $r_{ut} := \frac{H_{column}}{n_{bolts\_gusset2column}} = 8.67\,kip$

check capacity $if(r_{ut} < \Phi r_{nt}, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

ultimate tensile force per bolt $r_{uv} := \frac{V_{column}}{n_{bolts\_gusset2column}} = 13.69\,kip$

check capacity $if(r_{uv} < \Phi r_{nv}, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

$f_{uv} := \frac{r_{uv}}{A_{bolt}} = 22.77\,ksi$

strength reduction factor $\Phi := 0.75$

modified nominal tensile stress factored to include shear stress effects

$F'_{nt} = 1.3 \cdot F_{nt} - \frac{F_{nt}}{\Phi \cdot F_{nv}} \cdot f_{rv} < F_{nt}$

$F'nt_{bolt} := \min\left(1.3 \cdot F_{nt} - \frac{F_{nt}}{\Phi \cdot F_{nv}} \cdot f_{uv}, F_{nt}\right) = 66.41\,ksi$

combined loading strength $\Phi R_n := \Phi \cdot F'nt_{bolt} \cdot A_{bolt} = 29.95\,kip$

check capacity $if(r_{ut} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

Bolt Bearing on double angle (J3.10)

bolt edge distance $l_{c1\_edge} = 1.03\,in$

strength reduction factor $\Phi := 0.75$

edge bolt bearing strength $\Phi r_{n\_edge} := \Phi \cdot min(1.2 \cdot l_{c1\_edge} \cdot t_{L2} \cdot Fu_{A36}, 2.4 \cdot d_{bolt} \cdot t_{L2} \cdot Fu_{A36})$

$\Phi r_{n\_edge} = 33.64\,kip$ > $\Phi r_{nv} = 24.35\,kip$

> $r_{uv} = 13.69\,kip$

check capacity $if(r_{uv} < \Phi r_{n\_edge}, "OK", "NOT OK") = "OK"$

since edge bolt bearing > bolt shear, and bolt shear force, no need to check

prying action on double angles (Chapter 9)

recall :
$t_{L2} = 0.63\,in$
$GOL_2 = 3\,in$
$L_{L2} = 5\,in$
$d_{bolt} = 0.88\,in$
$p = 3\,in$
$r_{ut} = 8.67\,kip$

$b_2 := GOL_2 - \frac{t_{L2}}{2} = 2.69\,in$

$a_2 := L_{L2} - GOL_2 = 2\,in$

$b'_2 := b_2 - \frac{d_{bolt}}{2} = 2.25\,in$

$a'_2 := min\left(a_2 + \frac{d_{bolt}}{2}, 1.25b_2 + \frac{d_{bolt}}{2}\right) = 2.44\,in$ EQ 9-27

$\rho_2 := \frac{b'_2}{a'_2} = 0.923$ EQ 9-26

available tension per bolt $B := \Phi r_{nt} = 40.59\,kip$

$B := 40.59kip$

$\beta_2 := \frac{1}{\rho_2} \cdot \left(\frac{B}{r_{ut}} - 1\right) = 3.99$ EQ 9-25

$\alpha'_2 := 1.0$ for $\beta > 1.0$

$\delta_2 := 1 - \frac{d'_{bolt}}{p} = 0.688$ EQ 9-24

strength reduction factor $\Phi := 0.90$

minimum thickness to neglect prying $t_{req.2} := \sqrt{\frac{4 \cdot r_{ut} \cdot b'_2}{\Phi \cdot p \cdot Fu_{A36} \cdot (1 + \delta_2 \cdot \alpha'_2)}} = 0.54\,in$ EQ 9-23

check thickness requirements $if(t_{req.2} < t_{L2}, "OK", "NOT OK") = "OK"$

weld design

recall :

$H_{column} = 173.41\,kip$

$V_{column} = 273.8\,kip$

$n_{bolts\_gusset2column} = 20$

$L_{ev} = 1.5\,in$

$p = 3\,in$

$h_{L2} = 3.5\,in$

$t_{gusset} = 0.75\,in$

force on weld

$$Pu_{column} := \sqrt{H_{column}^{2} + V_{column}^{2}} = 324.1\,kip$$

load angle on weld

$$\theta_{load.2} := atan\left(\frac{H_{column}}{V_{column}}\right) = 32.35 \cdot deg$$

side length of weld

$$l_{weld.2} := p \cdot \left(\frac{n_{bolts\_gusset2column}}{2} - 1\right) + (2) \cdot L_{ev} = 30\,in$$

bottom length of weld

$$kl_{weld.2} := h_{L2} - 0.5in = 3\,in$$

$$k_{weld.2} := \frac{kl_{weld.2}}{l_{weld.2}} = 0.1$$

$$xl_2 := \frac{(2)\frac{1}{2}kl_{weld.2}^{2}}{(2)kl_{weld.2} + l_{weld.2}} = 0.25\,in$$

$$al_{weld.2} := h_{L2} - xl_2 = 3.25\,in$$

$$a_{weld.2} := \frac{al_{weld.2}}{l_{weld.2}} = 0.108$$

Table 8-8
eccentric weld factor

$$C_{weld.2} := 2.55\,\frac{kip}{in}$$

strength reduction factpr

$$\Phi := 0.75$$

minimum weld size

$$D_2 := \frac{Pu_{column}}{\Phi \cdot C_{weld.2} \cdot C_1 \cdot (2) l_{weld.2}} = 2.82$$

minimum thickness of gusset plate

$$t_{gusset.min} := \frac{6.19\frac{kip}{in} \cdot D_2}{Fu_{A36}} = 0.301 \cdot in$$

Eq 9-3

check thickness requirements

$$if\left(t_{gusset.min} < t_{gusset}, \text{"OK"}, \text{"NOT OK"}\right) = \text{"OK"}$$

weld size

$$D_2 := max\left(ceil\left(D_2\right), 4\right) = 4$$

use 4/16 as minimum

shear yielding of angles (J4.2a)

recall:

$t_{L2} = 0.63\,in$

$l_{weld.2} = 30\,in$

$V_{column} = 273.8\,kip$

$d''_{bolt} = 1\,in$

gross shear area $Agv_{L2} := (2)\cdot t_{L2}\cdot l_{weld.2} = 37.5\,in^2$

strength reduction factor $\Phi := 1.00$

shear yielding strength $\Phi R_n := \Phi\cdot 0.60\cdot Fy_{A36}\cdot Agv_{L2} = 810\,kip$

check capacity if$(V_{column} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

shear rupture of angles (J4.2b)

net shear area $Anv_{L2} := t_{L2}\cdot(2\cdot l_{weld.2} - n_{bolts\_gusset2column}\cdot d''_{bolt}) = 25\,in^2$

strength reduction factor $\Phi := 0.75$

shear rupture strength $\Phi R_n := \Phi\cdot 0.60\cdot Fu_{A36}\cdot Anv_{L2} = 652.5\,kip$

check capacity if$(V_{column} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

block shear strength of angles (J4.3)

recall:

$t_{L2} = 0.63\,in$

$n_{bolts\_gusset2column} = 20$

$d''_{bolt} = 1\,in$

$V_{column} = 273.8\,kip$

block shear strength $R_n = 0.60F_u\cdot A_{nv} + U_{bs}\cdot F_u\cdot A_{nt} \le 0.60F_y\cdot A_{gv} + U_{bs}\cdot F_u\cdot A_{nt}$

edge distance of bolt centers $L_{ev\_L2} := 1.5in$ $L_{eh\_L2} := 2in$ $U_{bs} := 1.0$

net tensile area $Ant_{L2} := (2)t_{L2}(L_{eh\_L2} - 0.5d''_{bolt}) = 1.88\,in^2$

gross shear area $Agv_{L2} := (2)t_{L2}\cdot\left[p\cdot\left(\frac{n_{bolts\_gusset2column}}{2} - 1\right) + L_{ev\_L2}\right] = 35.63\,in^2$

net shear area $Anv_{L2} := Agv_{L2} - (2)t_{L2}\cdot\left(\frac{n_{bolts\_gusset2column}}{2} - 0.5\right)\cdot d''_{bolt} = 23.75\,in^2$

strength reduction factor $\Phi := 0.75$

$\Phi\cdot 0.60Fu_{A36}\cdot Anv_{L2} = 619.87\,kip$

$\Phi\cdot U_{bs}\cdot Fu_{A36}\cdot Ant_{L2} = 81.56\,kip$

$\Phi\cdot 0.60Fy_{A36}\cdot Agv_{L2} = 577.13\,kip$

block shear strength $\Phi R_n := \Phi\cdot U_{bs}\cdot Fu_{A36}\cdot Ant_{L2} + \min(\Phi\cdot 0.60Fy_{A36}\cdot Agv_{L2}, \Phi\cdot 0.60Fu_{A36}\cdot Anv_{L2})$

$\Phi R_n = 658.7\,kip$

check capacity if$(V_{column} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

gusset plate to beam connection

recall :

$V_{beam} = 146.86\,kip$

$H_{beam} = 354.48\,kip$

$t_{gusset} = 0.75\,in$

$L_{gusset} = 42\,in$

additional ductility factor (pg 13-11) $ductility := 1.25$

tensile yielding strength (J4.1a)

tensile stress $f_{ua\_gusset2beam} := \dfrac{V_{beam}}{t_{gusset} \cdot L_{gusset}} = 4.66\,ksi$

strength reduction factor $\Phi := 0.9$ $\Phi \cdot Fy_{A36} = 32.4\,ksi$

check capacity $if(f_{ua\_gusset2beam} < \Phi \cdot Fy_{A36}, "OK", "NOT OK") = "OK"$

shear yielding strength (J4.2a)

shear stress $f_{uv\_gusset2beam} := \dfrac{H_{beam}}{t_{gusset} \cdot L_{gusset}} = 11.25\,ksi$

strength reduction factor $\Phi := 1.00$ $\Phi \cdot 0.6Fy_{A36} = 21.6\,ksi$

check capacity $if(f_{uv\_gusset2beam} < \Phi \cdot 0.6Fy_{A36}, "OK", "NOT OK") = "OK"$

load angle $\theta_{gusset2beam} := atan\left(\dfrac{V_{beam}}{H_{beam}}\right) = 22.5 \cdot deg$

Eq J2-5
effect of load angle $\mu := 1.0 + 0.5 \cdot sin(\theta_{gusset2beam})^{1.5} = 1.12$

weld strength (Eq 8-2) $\Phi rw := \mu \cdot 1.392 \dfrac{kip}{in} = 1.56 \cdot \dfrac{kip}{in}$ per 1/16 weld size

peak stress $fu_{peak\_gusset2beam} := \left(\dfrac{t_{gusset}}{2}\right) \cdot \sqrt{f_{ua\_gusset2beam}^2 + f_{uv\_gusset2beam}^2} = 4.57 \cdot \dfrac{kip}{in}$

average stress
$$fu_{average\_gusset2beam} := \frac{\left(\dfrac{t_{gusset}}{2}\right)\left(\sqrt{f_{ua\_gusset2beam}^2 + f_{uv\_gusset2beam}^2} + \sqrt{f_{ua\_gusset2beam}^2 + f_{uv\_gusset2beam}^2}\right)}{2}$$

$fu_{average\_gusset2beam} = 4.57 \cdot \dfrac{kip}{in}$

stress on weld $fu_{weld} := max(fu_{peak\_gusset2beam}, ductility \cdot fu_{average\_gusset2beam}) = 5.71 \cdot \dfrac{kip}{in}$

minimum required weld size $D_{gusset2beam} := \dfrac{fu_{weld}}{\Phi rw} = 3.67$

actual weld size $D_{gusset2beam} := ceil(D_{gusset2beam}) = 4$

web local yielding of beam (J10.2.b)

recall :

$tw_{beam} = 0.3\,in$

$tf_{beam} = 0.43\,in$

$d_{beam} = 17.7\,in$

$k\_des_{beam} = 0.83\,in$

$L_{gusset} = 42\,in$

$V_{beam} = 146.86\,kip$

strength reduction factor $\Phi := 1.00$

web local yielding strength $\Phi R_n := \Phi \cdot Fy_{A992} \cdot tw_{beam} \cdot (2.5 \cdot k\_des_{beam} + L_{gusset})$

$\Phi R_n = 661.01\,kip$

check capacity $if(V_{beam} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

web local crippling of beam (J10.3b)

strength reduction factor $\Phi := 0.75$

web local crippling strength

$$\Phi R_n := \begin{cases} \Phi \cdot 0.40 \cdot tw_{beam}^2 \cdot \left[1 + \left(\frac{4L_{gusset}}{d_{beam}} - 0.2\right) \cdot \left(\frac{tw_{beam}}{tf_{beam}}\right)^{1.5}\right] \cdot \sqrt{\frac{E \cdot Fy_{A992} \cdot tf_{beam}}{tw_{beam}}} & \text{if } \frac{L_{gusset}}{d_{beam}} > 0.2 \\ \Phi \cdot 0.40 \cdot tw_{beam}^2 \cdot \left[1 + 3\left(\frac{L_{gusset}}{d_{beam}}\right) \cdot \left(\frac{tw_{beam}}{tf_{beam}}\right)^{1.5}\right] \cdot \sqrt{\frac{E \cdot Fy_{A992} \cdot tf_{beam}}{tw_{beam}}} & \text{otherwise} \end{cases}$$

$\Phi R_n = 251.94\,kip$

check capacity $if(V_{beam} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

beam to column connection

recall :

$R_{u\_beam} = 15\,kip$

$V_{beam} = 146.86\,kip$

$P_{u\_beam} = 528\,kip$

$H_{beam} = 354.48\,kip$

net shear in beam $Vu_{beam} := R_{u\_beam} + V_{beam} = 161.86\,kip$

net axial force in beam $Hu_{beam} := P_{u\_beam} - H_{beam} = 173.52\,kip$

section $L_3 := \text{"L8X6X7/8"}$ double angle (properties are doubled in definition)

gross area $Ag_{L3} := 2\,T1_{(Row(L_3),6)} \cdot in^2 = 23\,in \cdot in$

thickness $t_{L3} := T1_{(Row(L_3),22)} \cdot in = 0.875\,in$

leg length long $L_{L3} := T1_{(Row(L_3),15)} \cdot in = 8\,in$

leg length - short $h_{L3} := T1_{(Row(L_3),7)} \cdot in = 6\,in$

centroid $x\_bar_{L3} := T1_{(Row(L_3),28)} \cdot in = 1.6\,in$

gage of angle $GOL_3 := 3in + \frac{1}{16}in$

number of bolts in gusset to column connection $n_{bolts\_beamclip} := 10$

length of angle $Length_{L3} := 1ft + (2)1.25in$

chcek bolt shear capcity (J3.6)

recall :

$Vu_{beam} = 161.86\,kip$

$n_{bolts\_beamclip} = 10$

$\Phi r_{nv} = 24.35\,kip$

ultimate tensile force per bolt $r_{uv\_beamclip} := \frac{Vu_{beam}}{n_{bolts\_beamclip}} = 16.19\,kip$

check capacity $if(r_{uv\_beamclip} < \Phi r_{nv}, "OK", "NOT OK") = "OK"$

Bolt Bearing on double angle (J3.10)

bolt edge clear distance $l_{c3\_edge} := 1.25in - 0.5\cdot d'_{bolt} = 0.78\,in$ user input the edge distance (1.25")

strength reduction factor $\Phi := 0.75$

bolt edge bearing strength $\Phi r_{n3\_edge} := \Phi\cdot \min(1.2\cdot l_{c3\_edge}\cdot t_{L3}\cdot Fu_{A36}, 2.4\cdot d_{bolt}\cdot t_{L3}\cdot Fu_{A36})$

$\Phi r_{n3\_edge} = 35.68\,kip$ > $\Phi r_{nv} = 24.35\,kip$ bolt shear strength

check capacity $if(\Phi r_{nv} < \Phi r_{n3\_edge}, "OK", "NOT OK") = "OK"$

since edge bolt bearing > bolt shear strength, no need to check bearing

weld design table 8-8

recall :

$Hu_{beam} = 173.52\,kip$

$Vu_{beam} = 161.86\,kip$

$Length_{L3} = 14.5\,in$

$tw_{beam} = 0.3\,in$

force on weld $Pu_{clip} := \sqrt{Hu_{beam}^2 + Vu_{beam}^2} = 237.29\,kip$

force angle on weld $\theta_{clip} := atan\left(\frac{Vu_{beam}}{Hu_{beam}}\right) = 43.01\cdot deg$

length of weld side $l_{eccweld} := Length_{L3} = 14.5\,in$

length of weld bot & top $kl_{eccweld} := L_{L3} - 0.5in = 7.5\,in$ $k_{eccweld} := \frac{kl_{eccweld}}{l_{eccweld}} = 0.52$

$xl_{eccweld} := \frac{kl_{eccweld}^2}{l_{eccweld} + 2\cdot kl_{eccweld}} = 1.91\,in$

$al_{eccweld} := L_{L3} - xl_{eccweld} = 6.09\,in$ $a_{eccweld} := \frac{al_{eccweld}}{l_{eccweld}} = 0.42$

Table 8-8
eccentric weld factor $C_{clip} := 3.55kip \div in$

strength reduction factor $\Phi := 0.75$

minimum weld size $D_{clip} := \frac{Pu_{clip}}{\Phi\cdot C_{clip}\cdot C_1\cdot 2Length_{L3}} = 3.07$

minimum thickness of beam web $tw_{beam\_min} := 6.19\frac{kip}{in}\cdot D_{clip} \div Fu_{A992} = 0.29\,in$

check thickness requirements $if(tw_{beam\_min} < tw_{beam}, "OK", "NOT OK") = "OK"$

weld size $D_{clip} := ceil(D_{clip}) = 4$

shear yielding of angles (J4.2a)

recall :

$Length_{L3} = 14.5\,in$

$t_{L3} = 0.88\,in$

$n_{bolts\_beamclip} = 10$

$d''_{bolt} = 1\,in$

$Vu_{beam} = 161.86\,kip$

gross shear area $Agv_{L3} := (2) \cdot Length_{L3} \cdot t_{L3} = 25.38\,in^2$

strength reduction factor $\Phi := 1.00$

shear yielding strength $\Phi R_n := \Phi \cdot 0.6 \cdot Fy_{A36} \cdot Agv_{L3} = 548.1\,kip$

check capacity $\text{if}(Vu_{beam} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

shear rupture of angles (J4.2b)

net shear area $Anv_{L3} := Agv_{L3} - t_{L3} \cdot n_{bolts\_beamclip} \cdot d''_{bolt} = 16.63\,in^2$

strength redcuction factor $\Phi := 0.75$

shear rupture strength $\Phi R_n := \Phi \cdot 0.6 \cdot Fu_{A36} \cdot Anv_{L3} = 433.91\,kip$

check capacity $\text{if}(Vu_{beam} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

block shear strength of angles (J4.3)

recall :

$t_{L3} = 0.88\,in$

$d''_{bolt} = 1\,in$

$n_{bolts\_beamclip} = 10$

$Vu_{beam} = 161.86\,kip$

block shear strength $R_n = 0.60 F_u \cdot A_{nv} + U_{bs} \cdot F_u \cdot A_{nt} \le 0.60 F_y \cdot A_{gv} + U_{bs} \cdot F_u \cdot A_{nt}$

bolt centerline edge distance $L_{ev\_L3} := 1.25in$ $L_{eh\_L3} := 2.94in$ $U_{bs} := 1.0$

net tensile area $Ant_{L3} := (2) t_{L3} (L_{eh\_L3} - 0.5 d''_{bolt}) = 4.27\,in^2$

gross shear area $Agv_{L3} := (2) t_{L3} \cdot \left[p \cdot \left(\frac{n_{bolts\_beamclip}}{2} - 1 \right) + L_{ev\_L3} \right] = 23.19\,in^2$

net shear area $Anv_{L3} := Agv_{L3} - (2) t_{L3} \cdot \left(\frac{n_{bolts\_beamclip}}{2} - 0.5 \right) \cdot d''_{bolt} = 15.31\,in^2$

strength reduction factor $\Phi := 0.75$

$\Phi \cdot 0.60 Fu_{A36} \cdot Anv_{L3} = 399.66\,kip$

$\Phi \cdot U_{bs} \cdot Fu_{A36} \cdot Ant_{L3} = 185.74\,kip$

$\Phi \cdot 0.60 Fy_{A36} \cdot Agv_{L3} = 375.64\,kip$

block shear strength $\Phi R_n := \Phi \cdot U_{bs} \cdot Fu_{A36} \cdot Ant_{L3} + \min(\Phi \cdot 0.60 Fy_{A36} \cdot Agv_{L3}, \Phi \cdot 0.60 Fu_{A36} \cdot Anv_{L3})$

$\Phi R_n = 561.4\,kip$

check capacity $\text{if}(Vu_{beam} < \Phi R_n, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$

check gusset buckling (J4.4 & E3)

recall :

$t_{gusset} = 0.75\,in$

$lw_{gusset} = 30.9\,in$

$lw_{web} = 3.92\,in$

$tw_{beam} = 0.3\,in$

$T_u = 675\,kip$

effective length factor $K := 0.5$

whitmore cross sectional area $A_w := t_{gusset} \cdot lw_{gusset} + lw_{web} \cdot tw_{beam} \cdot \frac{Fy_{A992}}{Fy_{A36}} = 24.81\,in^2$

$l_1 := 17in$ user input guess l1 length

$\frac{KL}{r}$ $\frac{K \cdot l_1}{\sqrt{\frac{t_{gusset}^2}{12}}} = 39.26$ > 25 << $4.71 \cdot \sqrt{\frac{E}{Fy_{A36}}} = 133.68$

elastic buckling stress $F_e := \frac{\pi^2 \cdot E}{\left(\frac{K \cdot l_1}{\sqrt{t_{gusset}^2 \div 12}}\right)^2} = 185.7\,ksi$ Eq E3-4

critical stress $F_{cr} := Fy_{A36} \cdot 0.658^{\frac{Fy_{A36}}{F_e}} = 33.19\,ksi$ Eq E3-2

strength reduction factor $\Phi := 0.90$

buckling/compressive strength $\Phi R_n := \Phi \cdot F_{cr} \cdot A_w = 741.15\,kip$ Eq E3-1

check capacity $\text{if}\left(T_u < \Phi R_n, \text{"OK"}, \text{"NOT OK"}\right) = \text{"OK"}$