Osoconn

Validation Record for

VB001AM10

Double Anlge Beam-Column Vertical Bracing Connection

(March 27, 2025)

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1 Introduction

Osoconn is a free and open source connection design application. The Osoconn project is a personal project developed by Roshn Noronha for educational purposes and licensed under the MIT Open Source license. For more information visit `https://osoconn.com`.

1.1 Purpose and scope

The purpose of this document is to validate the results of the connection code VB001AM10 for the Osoconn project.

1.2 Methodology

To validate the results of the program a set of sample calculations are prepared and the results are compared with the output from the program. If the results obtained are equal within a tolerance of one percent, the validation is deemed successful.

The connection code VB001AM10 refers to the double anlge beam-column vertical bracing connection, and the design of this connection type is checked against the requirements of AISC 360-2010 [1]. The detailed calculation and a summary of the comparison with the program output is provided in section 2. The full output of the program is provided in section 3.

To minimize the chance of errors the selected validation problems tries to cover as many different options and connections configurations available in the program as possible. However, while every attempt is made to ensure the accuracy of the program, it should be noted that, not every aspect of the program can be tested,and the user shall independently verify the output of the program before using it.

References

[1] AISC. *Specification for Structural Steel Buildings*. 360. American Institute of Steel Construction, Chicago, IL, 2010.

2 Validation Calculation

2.1 Executive summary

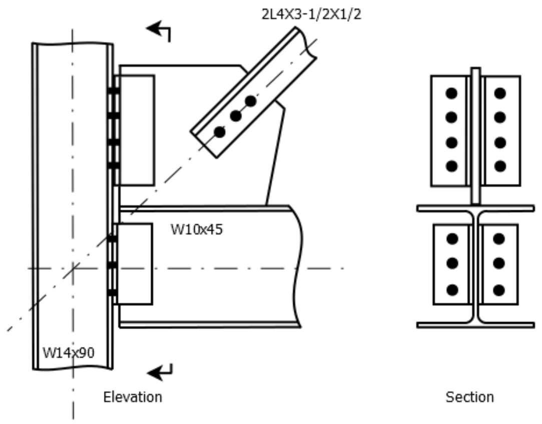
Table 1: Executive Summary

	Result
Validation problem 1	OK
Validation problem 2	OK
Validation problem 3	OK
Validation problem 4	OK
Validation problem 5	OK
Validation problem 6	OK

2.2 Validation Problem 1

Problem Statement

Design a beam column single brace connection for a double angle 2L4X3-1/2X1/2 brace with short leg back-to-back framing into the junction between a W10X45 beam and W14X90 column flange using the LRFD method. The brace has an angle of 45 degrees with the horizontal. The brace has an axial force of 35kip, and the beam has a shear force of 35kip and transfer force of 15kip. The beam, column, clip angles and plates are of grade ASTM A36. The bolts are ASTM 3125 A325 slip critical type.



Design Inputs

Material Properties

Material grade for plate	ASTM A36
Yield strength	$F_{yp} := 36\ ksi$
Tensile strength	$F_{up} := 58\ ksi$
Material grade of beam	ASTM A36
Yield strength	$F_{yb} := 36\ ksi$
Tensile strength	$F_{ub} := 58\ ksi$
Material grade of column	ASTM A36
Yield strength	$F_{yc} := 36\ ksi$
Tensile strength	$F_{uc} := 58\ ksi$
Material grade of angles	ASTM A36
Yield strength	$F_{ya} := 36\ ksi$
Tensile strength	$F_{ua} := 58\ ksi$
Material grade for weld electrode	E70XX
Tensile strength	$F_{EXX} := 70\ ksi$
Material specification for bolts	ASTM 3125 A325
Tensile strength	$F_{nt} := 90\ ksi$
Shear strength	$F_{nv} := 54\ ksi$

Young's modulus for steel	$E := 29000\ ksi$

Design Forces

Axial force in brace	$P := 35\ kip$
Shear force in beam	$SF := 35\ kip$
Transfer force in beam	$TF := 15\ kip$

Connection Geometry

Brace section	2L4X3-1/2X1/2
Thickness	$t_{br} := 0.5\ in$
Outstanding leg length	$l_{obr} := 4\ in$
Back-to-back leg length	$l_{ibr} := 3.5\ in$
Gross cross section area	$A_{br} := 7\ in^2$
Centroid of brace outstanding leg	$x'_{br} := 1.24\ in$
Brace angle with horizontal	$\theta_{br} := 45\ deg$
Beam section	W10X45
Section depth	$d_{xb} := 10.1\ in$
Flange width	$b_{fb} := 8.02\ in$
Flange thickness	$t_{fb} := 0.62\ in$
Web thickness	$t_{wb} := 0.35\ in$
Distance from outer face to fillet edge	$k_b := 1.12\ in$
Column section	W14X90
Section depth	$d_{xc} := 14\ in$
Flange width	$b_{fc} := 14.5\ in$
Flange thickness	$t_{fc} := 0.71\ in$
Web thickness	$t_{wc} := 0.44\ in$
Cross section area of column	$A_c := 26.5\ in^2$
Distance form outer face to fillet edge	$k_c := 1.31\ in$
Clip angle section	L4X3X1/2
Thickness	$t_a := 0.5\ in$
Outstanding leg length	$l_{oa} := 4\ in$
Welded leg length	$l_{ia} := 3\ in$
Gusset plate thickness	$t_g := 0.5\ in$
Gusset to beam interface length	$l_g := 20\ in$
Clip distance from beam	$d := 2\ in$
Bolt diameter	$d_b := 0.75\ in$
Bolt hole diameter	$d_{bh} := \frac{13}{16}\ in$
Slip coefficient (class A surface)	$\mu := 0.3$
Bolt pretension	$T_{pre} := 28\ kip$
Number of bolts per row on brace	$n_{br} := 3$
Number of bolts at gusset clip	$n_1 := 4$

Number of bolts at beam clip $n_2 := 3$
Bolt spacing $s := 2.25\ in$
Bolt gage on brace $g_{br} := 1.75\ in$
Bolt gage on column $g := 5.5\ in$

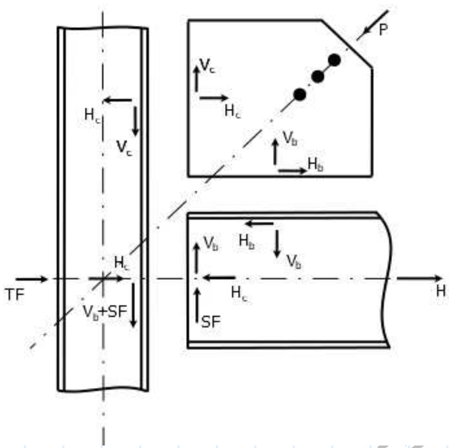
Bolt edge distance on brace $ed_1 := 1.25\ in$
Bolt edge distance on gusset $ed_2 := 1.25\ in$
Bolt edge distance on clip $ed_3 := 1.125\ in$

Gusset to beam weld thickness $w_1 := 0.25\ in$
Clip to beam weld thickness $w_2 := 0.25\ in$

Connection setback $sb := 0.5\ in$
Distance of the brace edge from the work point $loc_{br} := 16\ in$

Design Calculations

UFM forces in connection



Location of the centroid of the gusset to beam connection

$$\alpha' := 0.5 \cdot l_g \qquad \alpha' = 10\ in$$

Length of clip at gusset to column interface

$$l_{cl1} := (n_1 - 1) \cdot s + 2 \cdot ed_3 \qquad l_{cl1} = 9\ in$$

Location of the centroid of the gusset to column connection

$$\beta := d + 0.5 \cdot l_{cl1} \qquad \beta = 6.5\ in$$

Eccentricity of gusset to column connection

$$e_c := 0.5 \cdot d_{xc} \qquad e_c = 7\ in$$

Eccentricity of gusset to beam connection

$$e_b := 0.5 \cdot d_{xb} \qquad e_b = 5.05\ in$$

Dimension

$$r := \sqrt{(\alpha' + e_c)^2 + (\beta + e_b)^2} \qquad r = 20.552\ in$$

Vertical force at gusset to column interface

$$V_c := \frac{\beta}{r} \cdot P \qquad V_c = 11.069\ kip$$

Vertical force per bolt at gusset to column interface

$$V_{cb} := \frac{V_c}{2 \cdot n_1} \qquad V_{cb} = 1.384\ kip$$

Horizontal force at gusset to column interface

$$H_c := \frac{e_c}{r} \cdot P \qquad H_c = 11.921\ kip$$

Horizontal force per bolt at gusset to column interface

$$H_{cb} := \frac{H_c}{2 \cdot n_1} \qquad H_{cb} = 1.49\ kip$$

Vertical force at gusset to beam interface

$$V_b := \frac{e_b}{r} \cdot P \qquad V_b = 8.6\ kip$$

Total vertical force in beam clip connection

$$V'_b := SF + V_b \qquad V'_b = 43.6\ kip$$

Vertical force per bolt in beam clip connection

$$V'_{bb} := \frac{V'_b}{2 \cdot n_2} \qquad V'_{bb} = 7.267\ kip$$

Horizontal force at gusset to beam interface

$$H_b := \frac{\alpha'}{r} \cdot P \qquad H_b = 17.03\ kip$$

Total horizontal force in beam clip connection

$$H'_b := TF + H_c \qquad H'_b = 26.921\ kip$$

Horizontal force per bolt in beam clip connection

$$H'_{bb} := \frac{H'_b}{2 \cdot n_2} \qquad H'_{bb} = 4.487\ kip$$

Required α for no moment at gusset to beam connection

$$\alpha := e_b \cdot \tan\left(\theta_{br}\right) - e_c + \beta \cdot \tan\left(\theta_{br}\right) \qquad \alpha = 4.55\ in$$

Additional moment at gusset to beam interface

$$M_b := \mathrm{abs}\left(V_b \cdot \left(\alpha - \alpha'\right)\right) \qquad M_b = 46.87\ kip \cdot in$$

Bolt shear at brace to gusset connection

Shear per bolt

$$P_b := \frac{P}{n_{br}} \qquad V_b = 8.6\ kip$$

Nominal slip resistance of bolt

$$R_n := \mu \cdot 1.13 \cdot T_{pre} \cdot 2$$ $R_n = 18.984\ kip$

Interaction ratio in bolt shear

$$I_0 := \frac{P_b}{R_n}$$ $I_0 = 0.615$

Bolt bearing on brace check

Minimum clear distance for bearing check

$$l_{c1} := min\left(s - d_{bh}, ed_1 - 0.5 \cdot d_{bh}\right)$$ $l_{c1} = 0.021\ m$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c1} \cdot t_{br} \cdot F_{ua}, 2.4 \cdot d_b \cdot t_{br} \cdot F_{ua}\right)$$ $R_n = 29.363\ kip$

Interaction ratio in bolt bearing at brace

$$I_1 := \frac{0.5\ P_b}{0.75 \cdot R_n}$$ $I_1 = 0.265$

Bolt bearing on gusset check

Minimum clear distance for bearing on gusset

$$l_{c2} := min\left(s - d_{bh}, ed_2 - 0.5 \cdot d_{bh}\right)$$ $l_{c1} = 0.021\ m$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c2} \cdot t_g \cdot F_{up}, 2.4 \cdot d_b \cdot t_g \cdot F_{up}\right)$$ $R_n = 29.363\ kip$

Interaction ratio in bolt bearing at gusset

$$I_2 := \frac{P_b}{0.75 \cdot R_n}$$ $I_2 = 0.53$

Brace tension rupture check

Net cross section area of brace

$$A_{nbr} := A_{br} - 2 \cdot d_{bh} \cdot t_{br}$$ $A_{nbr} = 6.188\ in^2$

Length of connection

$$l_{br} := s \cdot \left(n_{br} - 1\right)$$ $l_{br} = 4.5\ in$

Shear lag factor

$$U := 1 - \frac{x'_{br}}{l_{br}}$$ $U = 0.724$

Brace strength in tension rupture

$$P_n := F_{ua} \cdot U \cdot A_{nbr}$$ $P_n = 259.985\ kip$

Interaction ratio for brace tension rupture

$$I_3 := \frac{P}{0.75 \cdot P_n}$$ $I_3 = 0.179$

Brace block shear check

Gross area in shear

$$A_{gv} := 2 \cdot \left(\left(n_{br} - 1\right) \cdot s + ed_1\right) \cdot t_{br}$$ $A_{gv} = 5.75\ in^2$

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot (n_{br} - 0.5) \cdot d_{bh} \cdot t_{br} \qquad A_{nv} = 3.719 \; in^2$$

Net area in tension

$$A_{nt} := 2 \cdot (l_{ibr} - g_{br} - 0.5 \cdot d_{bh}) \cdot t_{br} \qquad A_{nt} = 1.344 \; in^2$$

Nominal strength block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min(R_{n1}, R_{n2}) \qquad R_n = 202.138 \; kip$$

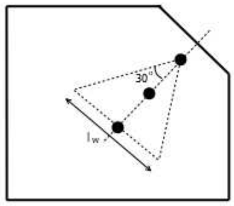
Interaction ratio in block shear

$$I_4 := \frac{P}{0.75 \cdot R_n} \qquad I_4 = 0.231$$

Gusset tension yielding check

Length of Whitmore section

$$l_w := 2 \cdot l_{br} \cdot \tan(30 \; deg) \qquad l_w = 5.196 \; in$$



Nominal strength of gusset in yielding

$$P_n := F_{yp} \cdot l_w \cdot t_g \qquad P_n = 93.531 \; kip$$

Interaction ratio in tension yielding

$$I_5 := \frac{P}{0.9 \cdot P_n} \qquad I_5 = 0.416$$

Gusset tension rupture check

Net area of gusset in tension

$$A_{ng} := (l_w - d_{bh}) \cdot t_g \qquad A_{ng} = 2.192 \; in^2$$

Nominal strength of gusset in rupture

$$P_n := F_{up} \cdot A_{ng} \qquad P_n = 127.126 \; kip$$

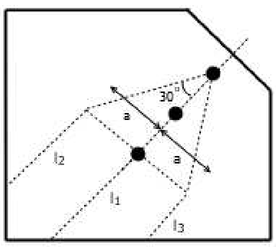
Interaction ratio in tension rupture

$$I_6 := \frac{P}{0.75 \cdot P_n} \qquad I_6 = 0.367$$

Gusset buckling check

Half the length of the Whitmore section

$$a := \frac{l_w}{2} \qquad a = 2.598 \; in$$



Distance of the first bolt to the work point

$$l_o := loc_{br} + ed_1 \qquad l_o = 17.25 \; in$$

Buckling lengths along various points on the Whitmore section

$$l_1 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})}, l_o - \frac{e_b}{\sin(\theta_{br})}\right), 0\right) \qquad l_1 = 7.351\ in$$

$$l_2 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})} - a \cdot \tan(\theta_{br}), l_o - \frac{e_b}{\sin(\theta_{br})} + a \cdot \tan(\theta_{br})\right), 0\right) \qquad l_2 = 4.752\ in$$

$$l_3 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})} + a \cdot \tan(\theta_{br}), l_o - \frac{e_b}{\sin(\theta_{br})} - a \cdot \tan(\theta_{br})\right), 0\right) \qquad l_3 = 7.51\ in$$

Average buckling length of gusset

$$l_{avg} := \frac{l_1 + l_2 + l_3}{3} \qquad l_{avg} = 6.538\ in$$

Effective length factor for gusset

$$k := 1.2$$

Moment of inertia of gusset

$$I_g := \frac{l_w \cdot t_g^{\ 3}}{12} \qquad I_g = 0.054\ in^4$$

Radius of gyration of gusset

$$r_g := \sqrt{\frac{I_g}{l_w \cdot t_g}} \qquad r_g = 0.144\ in$$

Elastic buckling stress

$$F_e := \frac{\pi^2 \cdot E}{\left(\frac{k \cdot l_{avg}}{r_g}\right)^2} \qquad F_e = 96.882\ ksi$$

Critical stress in compression

$$F_{cr1} := \left(0.658^{\frac{F_{yp}}{F_e}}\right) \cdot F_{yp}$$

$$F_{cr2} := 0.877 \cdot F_e$$

$$F_{cr} := \text{if}\left(\frac{k \cdot l_{avg}}{r_g} \le 4.71 \cdot \sqrt{\frac{E}{F_{yp}}}, F_{cr1}, F_{cr2}\right) \qquad F_{cr} = 30.815\ ksi$$

Nominal strength of gusset in compression

$$P_n := F_{cr} \cdot l_w \cdot t_g \qquad P_n = 80.059\ kip$$

Interaction ratio in compression

$$I_7 := \frac{P}{0.9 \cdot P_n} \qquad I_7 = 0.486$$

Gusset to beam weld check

Horizontal stress in weld

$$f_h := \frac{H_b}{2 \cdot l_g} \qquad f_h = 0.426\ \frac{kip}{in}$$

Vertical stress in weld

$$f_{v.max} := \frac{V_b}{2 \cdot l_g} + \frac{3 \cdot M_b}{l_g^{\ 2}} \qquad f_{v.max} = 0.567\ \frac{kip}{in}$$

Vertical stress in weld

$$f_{v.min} := \frac{V_b}{2 \cdot l_g} - \frac{3 \cdot M_b}{l_g^{\ 2}} \qquad f_{v.min} = -0.137 \ \frac{kip}{in}$$

Resultant maximum stress in weld

$$f_{max} := \sqrt{f_h^{\ 2} + f_{v.max}^{\ 2}} \qquad f_{max} = 0.709 \ \frac{kip}{in}$$

Average stress in weld

$$f_{avg} := \frac{1}{2} \cdot \left(\sqrt{f_h^{\ 2} + f_{v.max}^{\ 2}} + \sqrt{f_h^{\ 2} + f_{v.min}^{\ 2}} \right) \qquad f_{avg} = 0.578 \ \frac{kip}{in}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_1 \qquad R_n = 7.425 \ \frac{kip}{in}$$

Interaction ratio for weld check

$$I_{8} := \frac{\max\left(f_{max}, 1.25\ f_{avg}\right)}{0.75 \cdot R_n} \qquad I_{8} = 0.13$$

Gusset rupture at weld check

Minimum thickness of plate required to develop strength of weld

$$t_{min} := \frac{2 \cdot 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_1}{0.6 \cdot F_{up}} \qquad t_{min} = 0.427 \ in$$

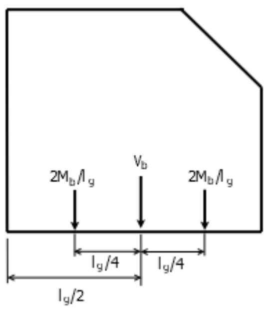
Interaction ratio in rupture

$$I_{9} := \frac{t_{min}}{t_g} \qquad I_{9} = 0.853$$

Beam web yielding check

Equivalent force at gusset to beam interface

$$N_{eq} := V_b + \frac{4 \cdot M_b}{l_g} \qquad N_{eq} = 17.974 \ kip$$



Nominal strength in web yielding

$$R_{n1} := F_{yb} \cdot t_{wb} \cdot \left(5 \cdot k_b + l_g\right)$$

$$R_{n2} := F_{yb} \cdot t_{wb} \cdot \left(2.5 \cdot k_b + l_g\right)$$

$$R_n := \text{if}\left(\alpha' > d_{xb}, R_{n1}, R_{n2}\right) \qquad R_n = 287.28 \ kip$$

nteraction ratio in web yielding

$$I_{10} := \frac{N_{eq}}{R_n} \qquad I_{10} = 0.063$$

Beam web crippling check

Nominal strength in web crippling

$$R_{n1} := 0.8 \cdot t_{wb}^{\ 2} \cdot \left(1 + 3 \cdot \frac{l_g}{d_{xb}} \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_{n2} := 0.4 \cdot t_{wb}^{\ 2} \cdot \left(1 + 3 \cdot \frac{l_g}{d_{xb}} \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_{n3} := 0.4 \cdot t_{wb}^{\;2} \cdot \left(1 + \left(\frac{4 \cdot l_g}{d_{xb}} - 0.2\right) \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_n := \text{if}\left(\alpha' < \frac{d_{xb}}{2}, R_{n1}, \text{if}\left(\frac{l_g}{d_{xb}} \le 0.2, R_{n2}, R_{n3}\right)\right) \qquad R_n = 284.851\ kip$$

Interaction ratio in web crippling

$$I_{11} := \frac{N_{eq}}{0.75 \cdot R_n} \qquad I_{11} = 0.084$$

Bolt shear at gusset to column connection

Slip resistance reduction factor

$$k_{sc} := 1 - \frac{V_{cb}}{1.13 \cdot T_{pre}} \qquad k_{sc} = 0.956$$

Nominal slip resistance of bolt

$$R_n := \mu \cdot 1.13 \cdot T_{pre} \cdot k_{sc} \qquad R_n = 9.077\ kip$$

Interaction ratio in bolt shear

$$I_{12} := \frac{V_{cb}}{R_n} \qquad I_{12} = 0.152$$

Bolt bearing at clip angle at gusset to column connection

Clear distance between bolt holes/ hole and edge

$$l_{c3} := min\left(s - d_{bh}, ed_3 - 0.5 \cdot d_{bh}\right) \qquad l_{c3} = 0.719\ in$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c3} \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_n = 25.013\ kip$$

Interaction ratio in bolt bearing

$$I_{13} := \frac{V_{cb}}{0.75\ R_n} \qquad I_{13} = 0.074$$

Bolt bearing at column flange at gusset to column connection

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{fc} \cdot F_{uc}, 2.4 \cdot d_b \cdot t_{fc} \cdot F_{uc}\right) \qquad R_n = 71.036\ kip$$

Interaction ratio in bolt bearing

$$I_{14} := \frac{V_{cb}}{0.75\ R_n} \qquad I_{14} = 0.026$$

Clip angle shear yielding at gusset to column connection

Length of gusset to column clip

$$L_1 := \left(n_1 - 1\right) \cdot s + 2\ ed_3 \qquad L_1 = 9\ in$$

Gross area in shear

$$A_{gv} := 2 \cdot L_1 \cdot t_a \qquad A_{gv} = 9\ in^2$$

Nominal strength in shear yielding

$$R_n := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_n = 194.4\ kip$$

Resultant shear in clip angle

$$S_{r1} := \sqrt{V_c^{\,2} + H_c^{\,2}} \qquad S_{r1} = 16.268\ kip$$

Interaction ratio in shear yielding

$$I_{15} := \frac{S_{r1}}{R_n} \qquad I_{15} = 0.084$$

Clip angle shear rupture at gusset to column connection

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n_1 \cdot d_{bh} \cdot t_a \qquad A_{nv} = 5.75\ in^2$$

Nominal strength in shear rupture

$$R_n := 0.6 \cdot F_{ua} \cdot A_{nv} \qquad R_n = 200.1\ kip$$

Interaction ratio in shear rupture

$$I_{16} := \frac{S_{r1}}{0.75\ R_n} \qquad I_{16} = 0.108$$

Clip angle block shear at gusset to column connection

Gross area subjected to block shear

$$A_{gv} := 2 \cdot \left(L_1 - ed_3\right) \cdot t_a \qquad A_{gv} = 7.875\ in^2$$

Net area subjected to block shear

$$A_{nv} := A_{gv} - 2 \cdot \left(n_1 - 0.5\right) \cdot d_{bh} \cdot t_a \qquad A_{nv} = 5.031\ in^2$$

Net area subjected to tension

$$A_{nt} := \left(2 \cdot l_{oa} + t_g - g - d_{bh}\right) \cdot t_a \qquad A_{nt} = 1.094\ in^2$$

Nominal strength in block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min\left(R_{n1}, R_{n2}\right) \qquad R_n = 233.538\ kip$$

Interaction ratio in block shear

$$I_{17} := \frac{V_c}{0.75\ R_n} \qquad I_{17} = 0.063$$

Bolt tension at gusset to column connection

Area of bolt

$$A_b := \frac{\pi \cdot d_b^{\,2}}{4} \qquad A_b = 0.442\ in^2$$

Nominal tensile strength

$$R_n := F_{nt} \cdot A_b \qquad R_n = 39.761\ kip$$

Interaction ratio for bolt tension

$$I_{18} := \frac{H_{cb}}{0.75\ R_n} \qquad I_{18} = 0.05$$

Bolt prying at clip angle at gusset to column connection

Available tension per bolt

$B := 0.75\ F_{nt} \cdot A_b$ $\qquad B = 29.821\ kip$

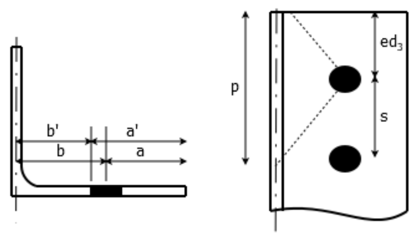
Clip dimensions for prying check

$b := 0.5 \cdot (g - t_g - t_a)$ $\qquad b = 2.25\ in$

$a := l_{oa} - b - 0.5 \cdot t_a$ $\qquad a = 1.5\ in$

$b' := b - 0.5 \cdot d_b$ $\qquad b' = 1.875\ in$

$a' := min\left(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b\right)$ $\qquad a' = 1.875\ in$



Tributary length

$p := min\left(2 \cdot b, b + ed_3, s\right)$ $\qquad p = 2.25\ in$

Ratios for prying

$\delta := 1 - \dfrac{d_{bh}}{p}$ $\qquad \delta = 0.639$

$\rho := \dfrac{b'}{a'}$ $\qquad \rho = 1$

Thickness required to develop bolt tension without prying

$t_c := \sqrt{\dfrac{4 \cdot B \cdot b'}{0.9 \cdot p \cdot F_{ua}}}$ $\qquad t_c = 1.38\ in$

$\alpha' := \dfrac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\dfrac{t_c}{t_a}\right)^2 - 1\right)$ $\qquad \alpha' = 5.179$

Proportion of tension strength available

$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\dfrac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\dfrac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right)$ $\qquad Q = 0.215$

Available tension strength with prying

$T_{av} := Q \cdot B$ $\qquad T_{av} = 6.416\ kip$

Interaction ratio in prying

$I_{19} := \dfrac{H_{cb}}{T_{av}}$ $\qquad I_{19} = 0.232$

Bolt prying at column flange at gusset to column connection

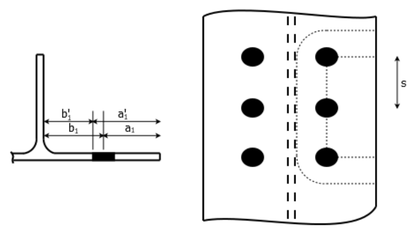
Clip dimensions for prying check

$b_1 := 0.5 \cdot (g - t_{wc})$ $\qquad b_1 = 2.53\ in$

$a_1 := min\left(0.5 \cdot (b_{fc} - g), 0.5 \cdot (2 \cdot l_{oa} + t_g - g)\right)$ $\qquad a_1 = 1.5\ in$

$b'_1 := b_1 - 0.5 \cdot d_b$ $\qquad b'_1 = 2.155\ in$

$a'_1 := min\left(a_1 + 0.5 \cdot d_b, 1.25 \cdot b_1 + 0.5 \cdot d_b\right)$ $\qquad a'_1 = 1.875\ in$



Tributary length

$$p_1 := \frac{(n_1 - 1) \cdot s + \pi \cdot b_1 + (b_{fc} - g)}{n_1} \qquad p_1 = 5.925\ in$$

Ratios for prying

$$\delta_1 := 1 - \frac{d_{bh}}{p_1} \qquad \delta_1 = 0.863$$

$$\rho_1 := \frac{b'_1}{a'_1} \qquad \rho_1 = 1.149$$

Thickness required to develop bolt tension without prying

$$t_{c1} := \sqrt{\frac{4 \cdot B \cdot b'_1}{0.9 \cdot p_1 \cdot F_{uc}}} \qquad t_{c1} = 0.912\ in$$

$$\alpha'_1 := \frac{1}{\delta_1 \cdot (1 + \rho_1)} \cdot \left(\left(\frac{t_{c1}}{t_{fc}} \right)^2 - 1 \right) \qquad \alpha'_1 = 0.35$$

Proportion of tension strength available

$$Q_1 := \text{if} \left(\alpha'_1 < 0, 1, \text{if} \left(0 \le \alpha'_1 \le 1, \left(\frac{t_{fc}}{t_{c1}} \right)^2 \cdot (1 + \delta_1 \cdot \alpha'_1), \left(\frac{t_{fc}}{t_{c1}} \right)^2 \cdot (1 + \delta_1) \right) \right) \qquad Q_1 = 0.79$$

Available tension strength with prying

$$T_{av1} := Q_1 \cdot B \qquad T_{av1} = 23.545\ kip$$

Interaction ratio in prying

$$I_{20} := \frac{H_{cb}}{T_{av1}} \qquad I_{20} = 0.063$$

Weld check at gusset to column connection

Length of horizontal run of weld

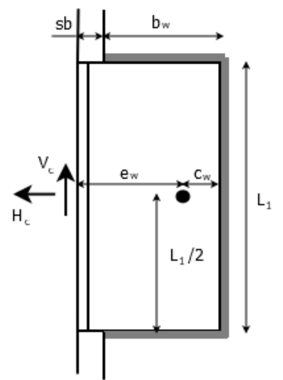
$$b_w := l_{ia} - sb \qquad b_w = 2.5\ in$$

Centroid of weld group

$$c_w := \frac{{b_w}^2}{2 \cdot b_w + L_1} \qquad c_w = 0.446\ in$$

Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 2.554\ in$$



Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L_1)^3}{12} - \frac{{b_w}^2 \cdot (b_w + L_1)^2}{2 \cdot b_w + L_1} \qquad I_w = 169.626\ in^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{H_c}{2 \cdot (2 \cdot b_w + L_1)} + \frac{V_c \cdot e_w \cdot L_1}{4 \cdot I_w} \qquad f_{wh} = 0.801\ \frac{kip}{in}$$

Vertical component of weld stress

$$f_{wv} := \frac{V_c}{2 \cdot (2 \cdot b_w + L_1)} + \frac{V_c \cdot e_w \cdot (b_w - c_w)}{2\ I_w} \qquad f_{wv} = 0.566\ \frac{kip}{in}$$

Resultant weld stress

$$f_w := \sqrt{f_{wh}^2 + f_{wv}^2} \qquad f_w = 0.981 \frac{kip}{in}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_2 \qquad R_n = 7.425 \frac{kip}{in}$$

Interaction ratio for weld check

$$I_{21} := \frac{f_w}{0.75\ R_n} \qquad I_{21} = 0.176$$

Gusset rupture at weld at gusset to column connection

Minimum web thickness to match weld strength

$$t_{g.min} := \frac{2 \cdot f_w}{0.75 \cdot 0.6 \cdot F_{up}} \qquad t_{g.min} = 0.075\ in$$

Interaction ratio in web rupture

$$I_{22} := \frac{t_{g.min}}{t_g} \qquad I_{22} = 0.15$$

Column web local yielding at gusset to column connection

Nominal strength in web local yielding

$$R_n := F_{yc} \cdot t_{wc} \cdot \left(2.5 \cdot k_c + L_1\right) \qquad R_n = 194.436\ kip$$

Interaction ratio in web local yielding

$$I_{23} := \frac{H_c}{R_n} \qquad I_{23} = 0.061$$

Column web local crippling at gusset to column connection

Nominal strength in web crippling

$$R_{n1} := 0.40 \cdot t_{wc}^2 \cdot \left(1 + 3 \cdot \frac{L_1}{d_{xc}} \cdot \left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yc} \cdot t_{fc}}{t_{wc}}}$$

$$R_{n2} := 0.40 \cdot t_{wc}^2 \cdot \left(1 + \left(\frac{4 \cdot L_1}{d_{xc}} - 0.2\right) \cdot \left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yc} \cdot t_{fc}}{t_{wc}}}$$

$$R_n := \text{if}\left(L_1 \div d_{xc} \le 0.2, R_{n1}, R_{n2}\right) \qquad R_n = 216.796\ kip$$

Interaction ratio in web crippling

$$I_{24} := \frac{H_c}{0.75\ R_n} \qquad I_{24} = 0.073$$

Bolt shear check at beam to column connection

Slip resistance reduction factor

$$k_{sc2} := 1 - \frac{H'_{bb}}{1.13 \cdot T_{pre}} \qquad k_{sc2} = 0.858$$

Nominal slip resistance of bolt

$$R_n := \mu \cdot 1.13 \cdot T_{pre} \cdot k_{sc2} \qquad R_n = 8.146\ kip$$

Interaction ratio in bolt shear

$$I_{25} := \frac{V'_{bb}}{R_n} \qquad I_{25} = 0.892$$

Bolt bearing at clip angle at beam to column connection

Clear distance between bolt holes/ hole and edge

$$l_{c3} := min\left(s - d_{bh}, ed_3 - 0.5 \cdot d_{bh}\right) \qquad l_{c3} = 0.719\ in$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c3} \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_n = 25.013\ kip$$

Interaction ratio in bolt bearing

$$I_{26} := \frac{V'_{bb}}{0.75\ R_n} \qquad I_{26} = 0.387$$

Bolt bearing at column flange at beam to column connection

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{fc} \cdot F_{uc}, 2.4 \cdot d_b \cdot t_{fc} \cdot F_{uc}\right) \qquad R_n = 71.036\ kip$$

Interaction ratio in bolt bearing

$$I_{27} := \frac{V'_{bb}}{0.75\ R_n} \qquad I_{27} = 0.136$$

Clip angle shear yielding at beam to column connection

Length of gusset to column clip

$$L_2 := \left(n_2 - 1\right) \cdot s + 2\ ed_3 \qquad L_2 = 6.75\ in$$

Gross area in shear

$$A_{gv} := 2 \cdot L_2 \cdot t_a \qquad A_{gv} = 6.75\ in^2$$

Nominal strength in shear yielding

$$R_n := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_n = 145.8\ kip$$

Resultant shear in clip angle

$$S_{r2} := \sqrt{{V'_b}^2 + {H'_b}^2} \qquad S_{r2} = 51.241\ kip$$

Interaction ratio in shear yielding

$$I_{28} := \frac{S_{r2}}{R_n} \qquad I_{28} = 0.351$$

Clip angle shear rupture at beam to column connection

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n_2 \cdot d_{bh} \cdot t_a \qquad A_{nv} = 4.313\ in^2$$

Nominal strength in shear rupture

$$R_n := 0.6 \cdot F_{ua} \cdot A_{nv} \qquad R_n = 150.075\ kip$$

Interaction ratio in shear rupture

$$I_{29} := \frac{S_{r2}}{0.75\ R_n} \qquad I_{29} = 0.455$$

Clip angle block shear at beam to column connection

Gross area subjected to block shear

$$A_{gv} := 2 \cdot (L_2 - ed_3) \cdot t_a \qquad A_{gv} = 5.625\ in^2$$

Net area subjected to block shear

$$A_{nv} := A_{gv} - 2 \cdot (n_2 - 0.5) \cdot d_{bh} \cdot t_a \qquad A_{nv} = 3.594\ in^2$$

Net area subjected to tension

$$A_{nt} := (2 \cdot l_{oa} + t_{wb} - g - d_{bh}) \cdot t_a \qquad A_{nt} = 1.019\ in^2$$

Nominal strength in block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min(R_{n1}, R_{n2}) \qquad R_n = 180.588\ kip$$

Interaction ratio in block shear

$$I_{30} := \frac{V'_b}{0.75\ R_n} \qquad I_{30} = 0.322$$

Bolt tension check at beam to column connection

Nominal tensile strength

$$R_n := F_{nt} \cdot A_b \qquad R_n = 39.761\ kip$$

Interaction ratio for bolt tension

$$I_{31} := \frac{H'_{bb}}{0.75\ R_n} \qquad I_{31} = 0.15$$

Bolt prying at clip angle at beam to column connection

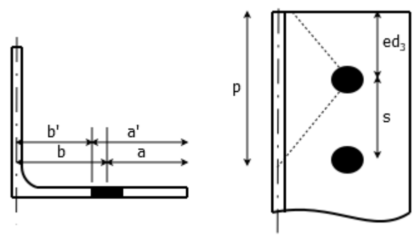
Clip dimensions for prying check

$$b := 0.5 \cdot (g - t_{wb} - t_a) \qquad b = 2.325\ in$$

$$a := l_{oa} - b - 0.5 \cdot t_a \qquad a = 1.425\ in$$

$$b' := b - 0.5 \cdot d_b \qquad b' = 1.95\ in$$

$$a' := min(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b) \qquad a' = 1.8\ in$$



Tributary length

$$p := min(2 \cdot b, b + ed_3, s) \qquad p = 2.25\ in$$

Ratios for prying

$$\delta := 1 - \frac{d_{bh}}{p} \qquad \delta = 0.639$$

$$\rho := \frac{b'}{a'} \qquad \rho = 1.083$$

Thickness required to develop bolt tension without prying

$$t_c := \sqrt{\frac{4 \cdot B \cdot b'}{0.9 \cdot p \cdot F_{ua}}} \qquad t_c = 1.407\ in$$

$$\alpha' := \frac{1}{\delta \cdot (1+\rho)} \cdot \left(\left(\frac{t_c}{t_a} \right)^2 - 1 \right) \qquad \alpha' = 5.2$$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c} \right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c} \right)^2 \cdot (1+\delta) \right) \right) \qquad Q = 0.207$$

Available tension strength with prying

$$T_{av} := Q \cdot B \qquad T_{av} = 6.169\ kip$$

Interaction ratio in prying

$$I_{32} := \frac{H'_{bb}}{T_{av}} \qquad I_{32} = 0.727$$

Bolt prying at column flange at beam to column connection

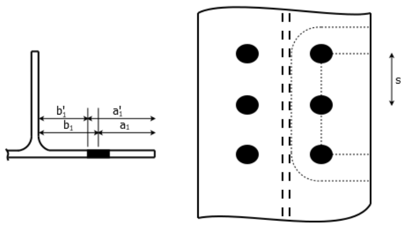
Clip dimensions for prying check

$$b_1 := 0.5 \cdot (g - t_{wc}) \qquad b_1 = 2.53\ in$$

$$a_1 := min\left(0.5 \cdot (b_{fc} - g), 0.5 \cdot (2 \cdot l_{oa} + t_{wb} - g)\right) \qquad a_1 = 1.425\ in$$

$$b'_1 := b_1 - 0.5 \cdot d_b \qquad b'_1 = 2.155\ in$$

$$a'_1 := min\left(a_1 + 0.5 \cdot d_b, 1.25 \cdot b_1 + 0.5 \cdot d_b\right) \qquad a'_1 = 1.8\ in$$



Tributary length

$$p_1 := \frac{(n_2 - 1) \cdot s + \pi \cdot b_1 + (b_{fc} - g)}{n_2} \qquad p_1 = 7.149\ in$$

Ratios for prying

$$\delta_1 := 1 - \frac{d_{bh}}{p_1} \qquad \delta_1 = 0.886$$

$$\rho_1 := \frac{b'_1}{a'_1} \qquad \rho_1 = 1.197$$

Thickness required to develop bolt tension without prying

$$t_{c1} := \sqrt{\frac{4 \cdot B \cdot b'_1}{0.9 \cdot p_1 \cdot F_{uc}}} \qquad t_{c1} = 0.83\ in$$

$$\alpha'_1 := \frac{1}{\delta_1 \cdot (1+\rho_1)} \cdot \left(\left(\frac{t_{c1}}{t_{fc}} \right)^2 - 1 \right) \qquad \alpha'_1 = 0.188$$

Proportion of tension strength available

$$Q_1 := \text{if}\left(\alpha'_1 < 0, 1, \text{if}\left(0 \le \alpha'_1 \le 1, \left(\frac{t_{fc}}{t_{c1}} \right)^2 \cdot (1 + \delta_1 \cdot \alpha'_1), \left(\frac{t_{fc}}{t_{c1}} \right)^2 \cdot (1+\delta_1) \right) \right) \qquad Q_1 = 0.854$$

Available tension strength with prying

$$T_{av1} := Q_1 \cdot B \qquad T_{av1} = 25.464\ kip$$

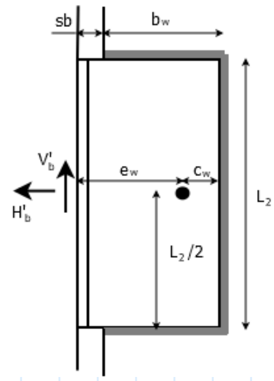
Interaction ratio in prying at column flange

$$I_{33} := \frac{H'_{bb}}{T_{av1}} \qquad I_{33} = 0.176$$

Weld check at beam to column connection

Centroid of weld group

$$c_w := \frac{b_w^{\ 2}}{2 \cdot b_w + L_2} \qquad c_w = 0.532\ in$$



Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 2.468\ in$$

Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L_2)^3}{12} - \frac{b_w^{\ 2} \cdot (b_w + L_2)^2}{2 \cdot b_w + L_2} \qquad I_w = 89.674\ in^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{H'_b}{2 \cdot (2 \cdot b_w + L_2)} + \frac{V'_b \cdot e_w \cdot L_2}{4 \cdot I_w} \qquad f_{wh} = 3.171\ \frac{kip}{in}$$

Vertical component of weld stress

$$f_{wv} := \frac{V'_b}{2 \cdot (2 \cdot b_w + L_2)} + \frac{V'_b \cdot e_w \cdot (b_w - c_w)}{2\ I_w} \qquad f_{wv} = 3.036\ \frac{kip}{in}$$

Resultant weld stress

$$f_w := \sqrt{f_{wh}^{\ 2} + f_{wv}^{\ 2}} \qquad f_w = 4.39\ \frac{kip}{in}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_2 \qquad R_n = 7.425\ \frac{kip}{in}$$

Interaction ratio for weld check

$$I_{34} := \frac{f_w}{0.75\ R_n} \qquad I_{34} = 0.788$$

Beam web rupture at weld at beam to column connection

Minimum web thickness to match weld strength

$$t_{g.min} := \frac{2 \cdot f_w}{0.75 \cdot 0.6 \cdot F_{ub}} \qquad t_{g.min} = 0.336\ in$$

Interaction ratio in web rupture

$$I_{35} := \frac{t_{g.min}}{t_{wb}} \qquad I_{35} = 0.961$$

Column web local yielding at beam to column connection

Nominal strength in web local yielding

$$R_n := F_{yc} \cdot t_{wc} \cdot (2.5 \cdot k_c + L_2) \qquad R_n = 158.796\ kip$$

Interaction ratio in web local yielding

$$I_{36} := \frac{H'_b}{R_n} \qquad I_{36} = 0.17$$

Column web local crippling at beam to column connection

Nominal strength in web crippling

$$R_{n1} := 0.40 \cdot t_{wc}^{\;2} \cdot \left(1 + 3 \cdot \frac{L_2}{d_{xc}} \cdot \left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yc} \cdot t_{fc}}{t_{wc}}}$$

$$R_{n2} := 0.40 \cdot t_{wc}^{\;2} \cdot \left(1 + \left(\frac{4 \cdot L_2}{d_{xc}} - 0.2\right) \cdot \left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yc} \cdot t_{fc}}{t_{wc}}}$$

$$R_n := \text{if}\left(L_2 \div d_{xc} \le 0.2, R_{n1}, R_{n2}\right) \qquad R_n = 185.273\ \mathit{kip}$$

Interaction ratio in web crippling

$$I_{37} := \frac{H'_b}{0.75\ R_n} \qquad I_{37} = 0.194$$

Validation Results

The calculated ratios are compared with the output of Osoconn and if it is within a tolerance of 1% the result is deemed to be OK.

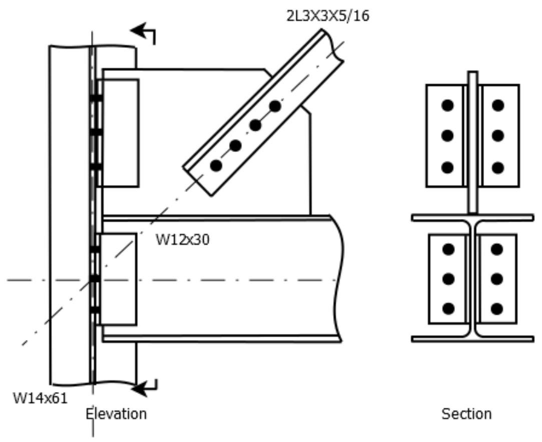
Table 2: Validation problem 1 results

	Interaction Ratio		
Check	Calculated	Osoconn	Result
Bolt shear check at brace	0.615	0.615	OK
Bolt bearing on brace	0.265	0.265	OK
Bolt bearing on gusset	0.53	0.53	OK
Brace tension rupture	0.179	0.179	OK
Brace block shear	0.231	0.231	OK
Gusset tension yielding	0.416	0.416	OK
Gusset tension rupture	0.367	0.367	OK
Gusset buckling	0.486	0.486	OK
Gusset to beam weld	0.13	0.13	OK
Gusset rupture at weld	0.853	0.853	OK
Beam web yielding	0.063	0.063	OK
Beam web crippling	0.084	0.084	OK
Bolt shear at gusset to col. conn.	0.152	0.153	OK
Bolt bearing at clip at gusset to col. conn.	0.074	0.074	OK
Bolt bearing at flange at gusset to col. conn.	0.026	0.026	OK
Clip shear yielding at gusset to col. conn.	0.084	0.084	OK
Clip shear rupture at gusset to col. conn.	0.108	0.108	OK
Clip block shear at gusset to col. conn.	0.063	0.063	OK
Bolt tension at gusset to col. conn.	0.05	0.05	OK
Bolt prying at clip at gusset to col. conn.	0.232	0.232	OK
Bolt prying at flange at gusset to col. conn.	0.063	0.063	OK
Weld check at gusset to col. conn.	0.176	0.176	OK
Gusset rupture at weld at gusset to col. conn.	0.15	0.15	OK
Web local yielding at gusset to col. conn.	0.061	0.061	OK
Web local crippling at gusset to col. conn.	0.073	0.073	OK
Bolt shear check at beam to col. conn.	0.892	0.892	OK
Bolt bearing at clip at beam to col. conn.	0.387	0.387	OK
Bolt bearing at flange at beam to col. conn.	0.136	0.136	OK
Clip shear yielding at beam to col. conn.	0.351	0.351	OK
Clip shear rupture at beam to col. conn.	0.455	0.455	OK
Clip block shear at beam to col. conn.	0.322	0.322	OK
Bolt tension check at beam to col. conn.	0.15	0.151	OK
Bolt prying at clip at beam to col. conn.	0.727	0.727	OK
Bolt prying at flange at beam to col. conn.	0.176	0.176	OK
Weld check at beam to col. conn.	0.788	0.788	OK
Beam web rupture at weld at beam to col. conn.	0.961	0.961	OK
Web local yielding at beam to col. conn.	0.17	0.17	OK
Web local crippling at beam to col. conn.	0.194	0.194	OK

2.3 Validation Problem 2

Problem Statement

Design a beam column single brace connection for a double angle 2L3X3X5/16 brace with short leg back-to-back framing into the junction between a W12X30 beam and W14X61 column web using the LRFD method. The brace has an angle of 40 degrees with the horizontal. The brace has an axial force of 45kip, and the beam has a shear force of 30kip and transfer force of 20kip. The beam and column are grade ASTM A992. Clip angles and plates are of grade ASTM A36. The bolts are ASTM 3125 A325 slip critical type.



Design Inputs

Material Properties

Material grade for plate	ASTM A36
Yield strength	$F_{yp} := 36\ ksi$
Tensile strength	$F_{up} := 58\ ksi$
Material grade of beam	ASTM A992
Yield strength	$F_{yb} := 50\ ksi$
Tensile strength	$F_{ub} := 65\ ksi$
Material grade of column	ASTM A992
Yield strength	$F_{yc} := 50\ ksi$
Tensile strength	$F_{uc} := 65\ ksi$
Material grade of angles	ASTM A36
Yield strength	$F_{ya} := 36\ ksi$
Tensile strength	$F_{ua} := 58\ ksi$
Material grade for weld electrode	E70XX
Tensile strength	$F_{EXX} := 70\ ksi$
Material specification for bolts	ASTM 3125 A325
Tensile strength	$F_{nt} := 90\ ksi$
Shear strength	$F_{nv} := 54\ ksi$

Young's modulus for steel	$E := 29000\ ksi$
Design Forces	
Axial force in brace	$P := 45\ kip$
Shear force in beam	$SF := 30\ kip$
Transfer force in beam	$TF := 20\ kip$
Connection Geometry	
Brace section	2L3X3X5/16
Thickness	$t_{br} := 0.313\ in$
Outstanding leg length	$l_{obr} := 3\ in$
Back-to-back leg length	$l_{ibr} := 3\ in$
Gross cross section area	$A_{br} := 3.56\ in^2$
Centroid of brace outstanding leg	$x'_{br} := 0.86\ in$
Brace angle with horizontal	$\theta_{br} := 40\ deg$
Beam section	W12X30
Section depth	$d_{xb} := 12.3\ in$
Flange width	$b_{fb} := 6.52\ in$
Flange thickness	$t_{fb} := 0.44\ in$
Web thickness	$t_{wb} := 0.26\ in$
Distance from outer face to fillet edge	$k_b := 0.74\ in$
Column section	W14X61
Section depth	$d_{xc} := 13.9\ in$
Flange width	$b_{fc} := 10\ in$
Flange thickness	$t_{fc} := 0.645\ in$
Web thickness	$t_{wc} := 0.375\ in$
Cross section area of column	$A_c := 17.9\ in^2$
Distance form outer face to fillet edge	$k_c := 1.24\ in$
Clip angle section	L4X3X1/2
Thickness	$t_a := 0.5\ in$
Outstanding leg length	$l_{oa} := 4\ in$
Welded leg length	$l_{ia} := 3\ in$
Gusset plate thickness	$t_g := 0.5\ in$
Gusset to beam interface length	$l_g := 16\ in$
Clip distance from beam	$d := 1.5\ in$
Bolt diameter	$d_b := 0.75\ in$
Bolt hole diameter	$d_{bh} := \frac{13}{16}\ in$
Slip coefficient (class A surface)	$\mu := 0.3$
Bolt pretension	$T_{pre} := 28\ kip$
Number of bolts per row on brace	$n_{br} := 4$
Number of bolts at gusset clip	$n_1 := 3$

Number of bolts at beam clip $n_2 := 3$

Bolt spacing $s := 3\ in$

Bolt gage on brace $g_{br} := 1.75\ in$

Bolt gage on column $g := 5.5\ in$

Bolt edge distance on brace $ed_1 := 1.25\ in$

Bolt edge distance on gusset $ed_2 := 1.25\ in$

Bolt edge distance on clip $ed_3 := 1.5\ in$

Gusset to beam weld thickness $w_1 := 0.25\ in$

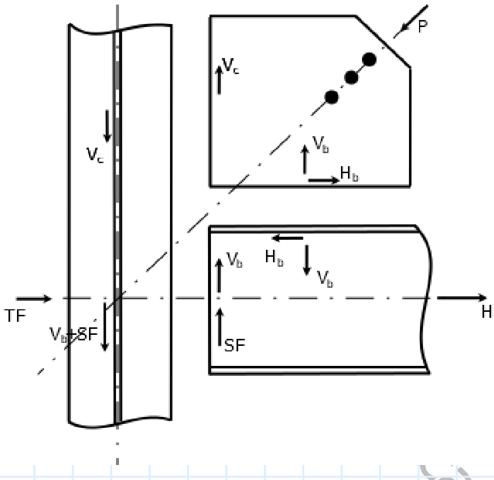
Clip to beam weld thickness $w_2 := 0.25\ in$

Connection setback $sb := 0.5\ in$

Distance of the brace edge from the work point $loc_{br} := 16\ in$

Design Calculations

UFM forces in connection



Location of the centroid of the gusset to beam connection

$\alpha' := 0.5 \cdot l_g$ $\qquad \alpha' = 8\ in$

Length of clip at gusset to column interface

$l_{cl1} := (n_1 - 1) \cdot s + 2 \cdot ed_3$ $\qquad l_{cl1} = 9\ in$

Location of the centroid of the gusset to column connection

$\beta := d + 0.5 \cdot l_{cl1}$ $\qquad \beta = 6\ in$

Eccentricity of gusset to column connection

$e_c := 0\ in$ $\qquad e_c = 0\ in$

Eccentricity of gusset to beam connection

$e_b := 0.5 \cdot d_{xb}$ $\qquad e_b = 6.15\ in$

Dimension

$r := \sqrt{(\alpha' + e_c)^2 + (\beta + e_b)^2}$ $\qquad r = 14.547\ in$

Vertical force at gusset to column interface

$$V_c := \frac{\beta}{r} \cdot P \qquad V_c = 18.56\ kip$$

Vertical force per bolt at gusset to column interface

$$V_{cb} := \frac{V_c}{2 \cdot n_1} \qquad V_{cb} = 3.093\ kip$$

Horizontal force at gusset to column interface

$$H_c := \frac{e_c}{r} \cdot P \qquad H_c = 0\ kip$$

Horizontal force per bolt at gusset to column interface

$$H_{cb} := \frac{H_c}{2 \cdot n_1} \qquad H_{cb} = 0\ kip$$

Vertical force at gusset to beam interface

$$V_b := \frac{e_b}{r} \cdot P \qquad V_b = 19.024\ kip$$

Total vertical force in beam clip connection

$$V'_b := SF + V_b \qquad V'_b = 49.024\ kip$$

Vertical force per bolt in beam clip connection

$$V'_{bb} := \frac{V'_b}{2 \cdot n_2} \qquad V'_{bb} = 8.171\ kip$$

Horizontal force at gusset to beam interface

$$H_b := \frac{\alpha'}{r} \cdot P \qquad H_b = 24.747\ kip$$

Total horizontal force in beam clip connection

$$H'_b := TF + H_c \qquad H'_b = 20\ kip$$

Horizontal force per bolt in beam clip connection

$$H'_{bb} := \frac{H'_b}{2 \cdot n_2} \qquad H'_{bb} = 3.333\ kip$$

Required α for no moment at gusset to beam connection

$$\alpha := e_b \cdot \tan\left(\theta_{br}\right) - e_c + \beta \cdot \tan\left(\theta_{br}\right) \qquad \alpha = 10.195\ in$$

Additional moment at gusset to beam interface

$$M_b := \text{abs}\left(V_b \cdot \left(\alpha - \alpha'\right)\right) \qquad M_b = 41.759\ kip \cdot in$$

Bolt shear at brace to gusset connection

Shear per bolt

$$P_b := \frac{P}{n_{br}} \qquad V_b = 19.024\ kip$$

Nominal slip resistance of bolt

$R_n := \mu \cdot 1.13 \cdot T_{pre} \cdot 2$ $\qquad R_n = 18.984\ kip$

Interaction ratio in bolt shear

$I_0 := \dfrac{P_b}{R_n}$ $\qquad I_0 = 0.593$

Bolt bearing on brace check

Minimum clear distance for bearing check

$l_{c1} := min\left(s - d_{bh}, ed_1 - 0.5 \cdot d_{bh}\right)$ $\qquad l_{c1} = 0.021\ m$

Nominal strength in bearing

$R_n := min\left(1.2 \cdot l_{c1} \cdot t_{br} \cdot F_{ua}, 2.4 \cdot d_b \cdot t_{br} \cdot F_{ua}\right)$ $\qquad R_n = 18.381\ kip$

Interaction ratio in bolt bearing at brace

$I_1 := \dfrac{0.5\ P_b}{0.75 \cdot R_n}$ $\qquad I_1 = 0.408$

Bolt bearing on gusset check

Minimum clear distance for bearing on gusset

$l_{c2} := min\left(s - d_{bh}, ed_2 - 0.5 \cdot d_{bh}\right)$ $\qquad l_{c1} = 0.021\ m$

Nominal strength in bearing

$R_n := min\left(1.2 \cdot l_{c2} \cdot t_g \cdot F_{up}, 2.4 \cdot d_b \cdot t_g \cdot F_{up}\right)$ $\qquad R_n = 29.363\ kip$

Interaction ratio in bolt bearing at gusset

$I_2 := \dfrac{P_b}{0.75 \cdot R_n}$ $\qquad I_2 = 0.511$

Brace tension rupture

Net cross section area of brace

$A_{nbr} := A_{br} - 2 \cdot d_{bh} \cdot t_{br}$ $\qquad A_{nbr} = 3.051\ in^2$

Length of connection

$l_{br} := s \cdot \left(n_{br} - 1\right)$ $\qquad l_{br} = 9\ in$

Shear lag factor

$U := 1 - \dfrac{x'_{br}}{l_{br}}$ $\qquad U = 0.904$

Brace strength in tension rupture

$P_n := F_{ua} \cdot U \cdot A_{nbr}$ $\qquad P_n = 160.068\ kip$

Interaction ratio for brace tension rupture

$I_3 := \dfrac{P}{0.75 \cdot P_n}$ $\qquad I_3 = 0.375$

Brace block shear check

Gross area in shear

$A_{gv} := 2 \cdot \left(\left(n_{br} - 1\right) \cdot s + ed_1\right) \cdot t_{br}$ $\qquad A_{gv} = 6.417\ in^2$

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot \left(n_{br} - 0.5\right) \cdot d_{bh} \cdot t_{br}$$ $A_{nv} = 4.636\ in^2$

Net area in tension

$$A_{nt} := 2 \cdot \left(l_{ibr} - g_{br} - 0.5 \cdot d_{bh}\right) \cdot t_{br}$$ $A_{nt} = 0.528\ in^2$

Nominal strength block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min\left(R_{n1}, R_{n2}\right)$$ $R_n = 169.231\ kip$

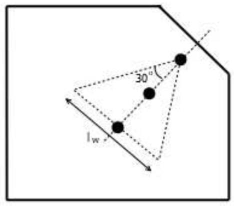
Interaction ratio in block shear

$$I_4 := \frac{P}{0.75 \cdot R_n}$$ $I_4 = 0.355$

Gusset tension yielding check

Length of Whitmore section

$$l_w := 2 \cdot l_{br} \cdot \tan(30\ deg)$$ $l_w = 10.392\ in$



Nominal strength of gusset in yielding

$$P_n := F_{yp} \cdot l_w \cdot t_g$$ $P_n = 187.061\ kip$

Interaction ratio in tension yielding

$$I_5 := \frac{P}{0.9 \cdot P_n}$$ $I_5 = 0.267$

Gusset tension rupture check

Net area of gusset in tension

$$A_{ng} := \left(l_w - d_{bh}\right) \cdot t_g$$ $A_{ng} = 4.79\ in^2$

Nominal strength of gusset in rupture

$$P_n := F_{up} \cdot A_{ng}$$ $P_n = 277.814\ kip$

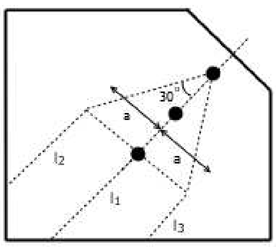
Interaction ratio in tension rupture

$$I_6 := \frac{P}{0.75 \cdot P_n}$$ $I_6 = 0.216$

Gusset buckling check

Half the length of the Whitmore section

$$a := \frac{l_w}{2}$$ $a = 5.196\ in$



Distance of the first bolt to the work point

$$l_o := loc_{br} + ed_1$$ $l_o = 17.25\ in$

Buckling lengths along various points on the Whitmore section

$$l_1 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})}, l_o - \frac{e_b}{\sin(\theta_{br})}\right), 0\right)$$ $l_1 = 7.682\ in$

$$l_2 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})} - a \cdot \tan(\theta_{br}), l_o - \frac{e_b}{\sin(\theta_{br})} + a \cdot \tan(\theta_{br})\right), 0\right)$$ $l_2 = 12.042\ in$

$$l_3 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})} + a \cdot \tan(\theta_{br}), l_o - \frac{e_b}{\sin(\theta_{br})} - a \cdot \tan(\theta_{br})\right), 0\right)$$ $l_3 = 3.322\ in$

Average buckling length of gusset

$$l_{avg} := \frac{l_1 + l_2 + l_3}{3}$$ $l_{avg} = 7.682\ in$

Effective length factor for gusset

$$k := 1.2$$

Moment of inertia of gusset

$$I_g := \frac{l_w \cdot t_g^{\ 3}}{12}$$ $I_g = 0.108\ in^4$

Radius of gyration of gusset

$$r_g := \sqrt{\frac{I_g}{l_w \cdot t_g}}$$ $r_g = 0.144\ in$

Elastic buckling stress

$$F_e := \frac{\pi^2 \cdot E}{\left(\frac{k \cdot l_{avg}}{r_g}\right)^2}$$ $F_e = 70.164\ ksi$

Critical stress in compression

$$F_{cr1} := \left(0.658^{\frac{F_{yp}}{F_e}}\right) \cdot F_{yp}$$

$$F_{cr2} := 0.877 \cdot F_e$$

$$F_{cr} := \text{if}\left(\frac{k \cdot l_{avg}}{r_g} \le 4.71 \cdot \sqrt{\frac{E}{F_{yp}}}, F_{cr1}, F_{cr2}\right)$$ $F_{cr} = 29.043\ ksi$

Nominal strength of gusset in compression

$$P_n := F_{cr} \cdot l_w \cdot t_g$$ $P_n = 150.91\ kip$

Interaction ratio in compression

$$I_7 := \frac{P}{0.9 \cdot P_n}$$ $I_7 = 0.331$

Gusset to beam weld check

Horizontal stress in weld

$$f_h := \frac{H_b}{2 \cdot l_g}$$ $f_h = 0.773\ \frac{kip}{in}$

Vertical stress in weld

$$f_{v.max} := \frac{V_b}{2 \cdot l_g} + \frac{3 \cdot M_b}{l_g^{\ 2}}$$ $f_{v.max} = 1.084\ \frac{kip}{in}$

Vertical stress in weld

$$f_{v.min} := \frac{V_b}{2 \cdot l_g} - \frac{3 \cdot M_b}{l_g^{\,2}} \qquad f_{v.min} = 0.105\ \frac{kip}{in}$$

Resultant maximum stress in weld

$$f_{max} := \sqrt{f_h^{\,2} + f_{v.max}^{\,2}} \qquad f_{max} = 1.331\ \frac{kip}{in}$$

Average stress in weld

$$f_{avg} := \frac{1}{2} \cdot \left(\sqrt{f_h^{\,2} + f_{v.max}^{\,2}} + \sqrt{f_h^{\,2} + f_{v.min}^{\,2}}\right) \qquad f_{avg} = 1.056\ \frac{kip}{in}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_1 \qquad R_n = 7.425\ \frac{kip}{in}$$

Interaction ratio for weld check

$$I_8 := \frac{\max\left(f_{max}, 1.25\ f_{avg}\right)}{0.75 \cdot R_n} \qquad I_8 = 0.239$$

Gusset rupture at weld check

Minimum thickness of plate required to develop strength of weld

$$t_{min} := \frac{2 \cdot 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_1}{0.6 \cdot F_{up}} \qquad t_{min} = 0.427\ in$$

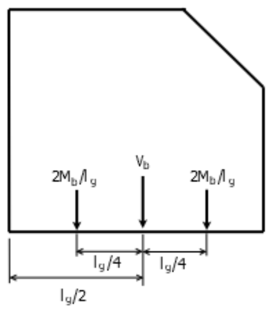
Interaction ratio in rupture

$$I_9 := \frac{t_{min}}{t_g} \qquad I_9 = 0.853$$

Beam web yielding check

Equivalent force at gusset to beam interface

$$N_{eq} := V_b + \frac{4 \cdot M_b}{l_g} \qquad N_{eq} = 29.464\ kip$$



Nominal strength in web yielding

$$R_{n1} := F_{yb} \cdot t_{wb} \cdot \left(5 \cdot k_b + l_g\right)$$

$$R_{n2} := F_{yb} \cdot t_{wb} \cdot \left(2.5 \cdot k_b + l_g\right)$$

$$R_n := \text{if}\left(\alpha' > d_{xb}, R_{n1}, R_{n2}\right) \qquad R_n = 232.05\ kip$$

nteraction ratio in web yielding

$$I_{10} := \frac{N_{eq}}{R_n} \qquad I_{10} = 0.127$$

Beam web crippling check

Nominal strength in web crippling

$$R_{n1} := 0.8 \cdot t_{wb}^{\,2} \cdot \left(1 + 3 \cdot \frac{l_g}{d_{xb}} \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_{n2} := 0.4 \cdot t_{wb}^{\,2} \cdot \left(1 + 3 \cdot \frac{l_g}{d_{xb}} \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_{n3} := 0.4 \cdot t_{wb}^{\ 2} \cdot \left(1 + \left(\frac{4 \cdot l_g}{d_{xb}} - 0.2\right) \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_n := \text{if}\left(\alpha' < \frac{d_{xb}}{2}, R_{n1}, \text{if}\left(\frac{l_g}{d_{xb}} \le 0.2, R_{n2}, R_{n3}\right)\right) \qquad R_n = 138.621\ kip$$

Interaction ratio in web crippling

$$I_{11} := \frac{N_{eq}}{0.75 \cdot R_n} \qquad I_{11} = 0.283$$

Bolt shear at gusset to column connection

Slip resistance reduction factor

$$k_{sc} := 1 - \frac{H_{cb}}{1.13 \cdot T_{pre}} \qquad k_{sc} = 1$$

Nominal slip resistance of bolt

$$R_n := \mu \cdot 1.13 \cdot T_{pre} \cdot k_{sc} \qquad R_n = 9.492\ kip$$

Interaction ratio in bolt shear

$$I_{12} := \frac{V_{cb}}{R_n} \qquad I_{12} = 0.326$$

Bolt bearing at clip angle at gusset to column connection

Clear distance between bolt holes/ hole and edge

$$l_{c3} := min\left(s - d_{bh}, ed_3 - 0.5 \cdot d_{bh}\right) \qquad l_{c3} = 1.094\ in$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c3} \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_n = 38.063\ kip$$

Interaction ratio in bolt bearing

$$I_{13} := \frac{V_{cb}}{0.75\ R_n} \qquad I_{13} = 0.108$$

Bolt bearing at column web at gusset to column connection

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{wc} \cdot F_{uc}, 2.4 \cdot d_b \cdot t_{wc} \cdot F_{uc}\right) \qquad R_n = 43.875\ kip$$

Interaction ratio in bolt bearing

$$I_{14} := \frac{V_{cb}}{0.75\ R_n} \qquad I_{14} = 0.094$$

Clip angle shear yielding at gusset to column connection

Length of gusset to column clip

$$L_1 := \left(n_1 - 1\right) \cdot s + 2\ ed_3 \qquad L_1 = 9\ in$$

Gross area in shear

$$A_{gv} := 2 \cdot L_1 \cdot t_a \qquad A_{gv} = 9\ in^2$$

Nominal strength in shear yielding

$$R_n := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_n = 194.4\ kip$$

Resultant shear in clip angle

$$S_{r1} := \sqrt{V_c^2 + H_c^2} \qquad S_{r1} = 18.56\ kip$$

Interaction ratio in shear yielding

$$I_{15} := \frac{S_{r1}}{R_n} \qquad I_{15} = 0.095$$

Clip angle shear rupture at gusset to column connection

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n_1 \cdot d_{bh} \cdot t_a \qquad A_{nv} = 6.563\ in^2$$

Nominal strength in shear rupture

$$R_n := 0.6 \cdot F_{ua} \cdot A_{nv} \qquad R_n = 228.375\ kip$$

Interaction ratio in shear rupture

$$I_{16} := \frac{S_{r1}}{0.75\ R_n} \qquad I_{16} = 0.108$$

Clip angle block shear at gusset to column connection

Gross area subjected to block shear

$$A_{gv} := 2 \cdot \left(L_1 - ed_3\right) \cdot t_a \qquad A_{gv} = 7.5\ in^2$$

Net area subjected to block shear

$$A_{nv} := A_{gv} - 2 \cdot \left(n_1 - 0.5\right) \cdot d_{bh} \cdot t_a \qquad A_{nv} = 5.469\ in^2$$

Net area subjected to tension

$$A_{nt} := \left(2 \cdot l_{oa} + t_g - g - d_{bh}\right) \cdot t_a \qquad A_{nt} = 1.094\ in^2$$

Nominal strength in block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min\left(R_{n1}, R_{n2}\right) \qquad R_n = 225.438\ kip$$

Interaction ratio in block shear

$$I_{17} := \frac{V_c}{0.75\ R_n} \qquad I_{17} = 0.11$$

Bolt tension at gusset to column connection

Area of bolt

$$A_b := \frac{\pi \cdot d_b^2}{4} \qquad A_b = 0.442\ in^2$$

Nominal tensile strength

$$R_n := F_{nt} \cdot A_b \qquad R_n = 39.761\ kip$$

Interaction ratio for bolt tension

$$I_{18} := \frac{H_{cb}}{0.75\ R_n} \qquad I_{18} = 0$$

Bolt prying at clip angle at gusset to column connection

Available tension per bolt

$B := 0.75\ F_{nt} \cdot A_b$ $\qquad B = 29.821\ kip$

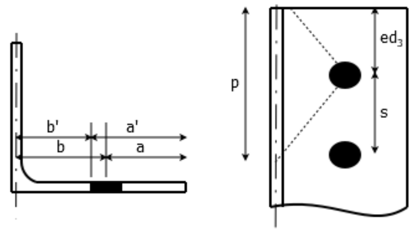
Clip dimensions for prying check

$b := 0.5 \cdot (g - t_g - t_a)$ $\qquad b = 2.25\ in$

$a := l_{oa} - b - 0.5 \cdot t_a$ $\qquad a = 1.5\ in$

$b' := b - 0.5 \cdot d_b$ $\qquad b' = 1.875\ in$

$a' := min(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b)$ $\qquad a' = 1.875\ in$



Tributary length

$p := min(2 \cdot b, b + ed_3, s)$ $\qquad p = 3\ in$

Ratios for prying

$$\delta := 1 - \frac{d_{bh}}{p} \qquad \delta = 0.729$$

$$\rho := \frac{b'}{a'} \qquad \rho = 1$$

Thickness required to develop bolt tension without prying

$$t_c := \sqrt{\frac{4 \cdot B \cdot b'}{0.9 \cdot p \cdot F_{ua}}} \qquad t_c = 1.195\ in$$

$$\alpha' := \frac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\frac{t_c}{t_a} \right)^2 - 1 \right) \qquad \alpha' = 3.232$$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c} \right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c} \right)^2 \cdot (1 + \delta) \right) \right) \qquad Q = 0.303$$

Available tension strength with prying

$T_{av} := Q \cdot B$ $\qquad T_{av} = 9.026\ kip$

Interaction ratio in prying

$$I_{19} := \frac{H_{cb}}{T_{av}} \qquad I_{19} = 0$$

Weld check at gusset to column connection

Length of horizontal run of weld

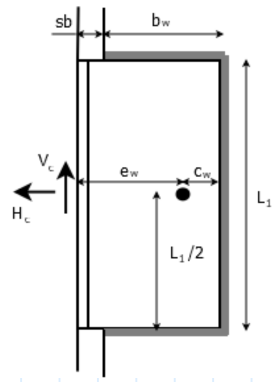
$b_w := l_{ia} - sb$ $\qquad b_w = 2.5\ in$

Centroid of weld group

$$c_w := \frac{{b_w}^2}{2 \cdot b_w + L_1} \qquad c_w = 0.446\ in$$

Eccentricity of shear force

$e_w := l_{ia} - c_w$ $\qquad e_w = 2.554\ in$



Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L_1)^3}{12} - \frac{{b_w}^2 \cdot (b_w + L_1)^2}{2 \cdot b_w + L_1} \qquad I_w = 169.626\ in^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{H_c}{2 \cdot (2 \cdot b_w + L_1)} + \frac{V_c \cdot e_w \cdot L_1}{4 \cdot I_w} \qquad f_{wh} = 0.629\ \frac{kip}{in}$$

Vertical component of weld stress

$$f_{wv} := \frac{V_c}{2 \cdot (2 \cdot b_w + L_1)} + \frac{V_c \cdot e_w \cdot (b_w - c_w)}{2\ I_w} \qquad f_{wv} = 0.95\ \frac{kip}{in}$$

Resultant weld stress

$$f_w := \sqrt{{f_{wh}}^2 + {f_{wv}}^2} \qquad f_w = 1.139\ \frac{kip}{in}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_2 \qquad R_n = 7.425\ \frac{kip}{in}$$

Interaction ratio for weld check

$$I_{20} := \frac{f_w}{0.75\ R_n} \qquad I_{20} = 0.205$$

Gusset rupture at weld at gusset to column connection

Minimum web thickness to match weld strength

$$t_{g.min} := \frac{2 \cdot f_w}{0.75 \cdot 0.6 \cdot F_{up}} \qquad t_{g.min} = 0.087\ in$$

Interaction ratio in web rupture

$$I_{21} := \frac{t_{g.min}}{t_g} \qquad I_{21} = 0.175$$

Bolt shear check at beam to column connection

Slip resistance reduction factor

$$k_{sc2} := 1 - \frac{H'_{bb}}{1.13 \cdot T_{pre}} \qquad k_{sc2} = 0.895$$

Nominal slip resistance of bolt

$$R_n := \mu \cdot 1.13 \cdot T_{pre} \cdot k_{sc2} \qquad R_n = 8.492\ kip$$

Interaction ratio in bolt shear

$$I_{22} := \frac{V'_{bb}}{R_n} \qquad I_{22} = 0.962$$

Bolt bearing at clip angle at beam to column connection

Clear distance between bolt holes/ hole and edge

$$l_{c3} := min(s - d_{bh}, ed_3 - 0.5 \cdot d_{bh}) \qquad l_{c3} = 1.094\ in$$

Nominal strength in bearing

$$R_n := min(1.2 \cdot l_{c3} \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}) \qquad R_n = 38.063\ kip$$

Interaction ratio in bolt bearing

$$I_{23} := \frac{V'_{bb}}{0.75\ R_n} \qquad I_{23} = 0.286$$

Bolt bearing at column web at beam to column connection

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{wc} \cdot F_{uc}, 2.4 \cdot d_b \cdot t_{wc} \cdot F_{uc}\right) \qquad R_n = 43.875\ \boldsymbol{kip}$$

Interaction ratio in bolt bearing

$$I_{24} := \frac{V'_{bb}}{0.75\ R_n} \qquad I_{24} = 0.248$$

Clip angle shear yielding at beam to column connection

Length of gusset to column clip

$$L_2 := \left(n_2 - 1\right) \cdot s + 2\ ed_3 \qquad L_2 = 9\ \boldsymbol{in}$$

Gross area in shear

$$A_{gv} := 2 \cdot L_2 \cdot t_a \qquad A_{gv} = 9\ \boldsymbol{in}^2$$

Nominal strength in shear yielding

$$R_n := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_n = 194.4\ \boldsymbol{kip}$$

Resultant shear in clip angle

$$S_{r2} := \sqrt{{V'_b}^2 + {H'_b}^2} \qquad S_{r2} = 52.947\ \boldsymbol{kip}$$

Interaction ratio in shear yielding

$$I_{25} := \frac{S_{r2}}{R_n} \qquad I_{25} = 0.272$$

Clip angle shear rupture at beam to column connection

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n_2 \cdot d_{bh} \cdot t_a \qquad A_{nv} = 6.563\ \boldsymbol{in}^2$$

Nominal strength in shear rupture

$$R_n := 0.6 \cdot F_{ua} \cdot A_{nv} \qquad R_n = 228.375\ \boldsymbol{kip}$$

Interaction ratio in shear rupture

$$I_{26} := \frac{S_{r2}}{0.75\ R_n} \qquad I_{26} = 0.309$$

Clip angle block shear at beam to column connection

Gross area subjected to block shear

$$A_{gv} := 2 \cdot \left(L_2 - ed_3\right) \cdot t_a \qquad A_{gv} = 7.5\ \boldsymbol{in}^2$$

Net area subjected to block shear

$$A_{nv} := A_{gv} - 2 \cdot \left(n_2 - 0.5\right) \cdot d_{bh} \cdot t_a \qquad A_{nv} = 5.469\ \boldsymbol{in}^2$$

Net area subjected to tension

$$A_{nt} := \left(2 \cdot l_{oa} + t_{wb} - g - d_{bh}\right) \cdot t_a \qquad A_{nt} = 0.974\ \boldsymbol{in}^2$$

Nominal strength in block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min\left(R_{n1}, R_{n2}\right) \qquad R_n = 218.478\ kip$$

Interaction ratio in block shear

$$I_{27} := \frac{V'_b}{0.75\ R_n} \qquad I_{27} = 0.299$$

Bolt tension check at beam to column connection

Nominal tensile strength

$$R_n := F_{nt} \cdot A_b \qquad R_n = 39.761\ kip$$

Interaction ratio for bolt tension

$$I_{28} := \frac{H'_{bb}}{0.75\ R_n} \qquad I_{28} = 0.112$$

Bolt prying at clip angle at beam to column connection

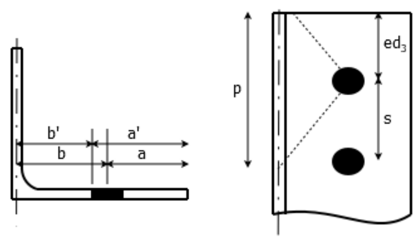
Clip dimensions for prying check

$$b := 0.5 \cdot \left(g - t_{wb} - t_a\right) \qquad b = 2.37\ in$$

$$a := l_{oa} - b - 0.5 \cdot t_a \qquad a = 1.38\ in$$

$$b' := b - 0.5 \cdot d_b \qquad b' = 1.995\ in$$

$$a' := min\left(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b\right) \qquad a' = 1.755\ in$$



Tributary length

$$p := min\left(2 \cdot b, b + ed_3, s\right) \qquad p = 3\ in$$

Ratios for prying

$$\delta := 1 - \frac{d_{bh}}{p} \qquad \delta = 0.729$$

$$\rho := \frac{b'}{a'} \qquad \rho = 1.137$$

Thickness required to develop bolt tension without prying

$$t_c := \sqrt{\frac{4 \cdot B \cdot b'}{0.9 \cdot p \cdot F_{ua}}} \qquad t_c = 1.233\ in$$

$$\alpha' := \frac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\frac{t_c}{t_a}\right)^2 - 1\right) \qquad \alpha' = 3.259$$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right) \qquad Q = 0.284$$

Available tension strength with prying

$$T_{av} := Q \cdot B \qquad T_{av} = 8.483\ kip$$

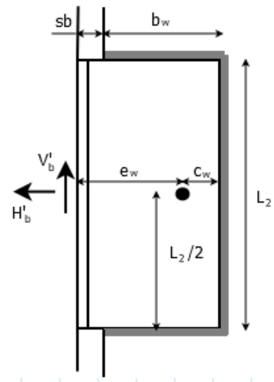
Interaction ratio in prying

$$I_{29} := \frac{H'_{bb}}{T_{av}} \qquad I_{29} = 0.393$$

Weld check at beam to column connection

Centroid of weld group

$$c_w := \frac{{b_w}^2}{2 \cdot b_w + L_2} \qquad c_w = 0.446\ in$$



Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 2.554\ in$$

Polar moment of inertia of weld group

$$I_w := \frac{\left(2 \cdot b_w + L_2\right)^3}{12} - \frac{{b_w}^2 \cdot \left(b_w + L_2\right)^2}{2 \cdot b_w + L_2} \qquad I_w = 169.626\ in^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{H'_b}{2 \cdot \left(2 \cdot b_w + L_2\right)} + \frac{V'_b \cdot e_w \cdot L_2}{4 \cdot I_w} \qquad f_{wh} = 2.375\ \frac{kip}{in}$$

Vertical component of weld stress

$$f_{wv} := \frac{V'_b}{2 \cdot \left(2 \cdot b_w + L_2\right)} + \frac{V'_b \cdot e_w \cdot \left(b_w - c_w\right)}{2\ I_w} \qquad f_{wv} = 2.509\ \frac{kip}{in}$$

Resultant weld stress

$$f_w := \sqrt{{f_{wh}}^2 + {f_{wv}}^2} \qquad f_w = 3.454\ \frac{kip}{in}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_2 \qquad R_n = 7.425\ \frac{kip}{in}$$

Interaction ratio for weld check

$$I_{30} := \frac{f_w}{0.75\ R_n} \qquad I_{30} = 0.62$$

Web rupture at weld at beam to column connection

Minimum web thickness to match weld strength

$$t_{wb.min} := \frac{2 \cdot f_w}{0.75 \cdot 0.6 \cdot F_{ub}} \qquad t_{wb.min} = 0.236\ in$$

Interaction ratio in web rupture

$$I_{31} := \frac{t_{wb.min}}{t_{wb}} \qquad I_{31} = 0.908$$

Validation Results

The calculated ratios are compared with the output of Osoconn and if it is within a tolerance of 1% the result is deemed to be OK.

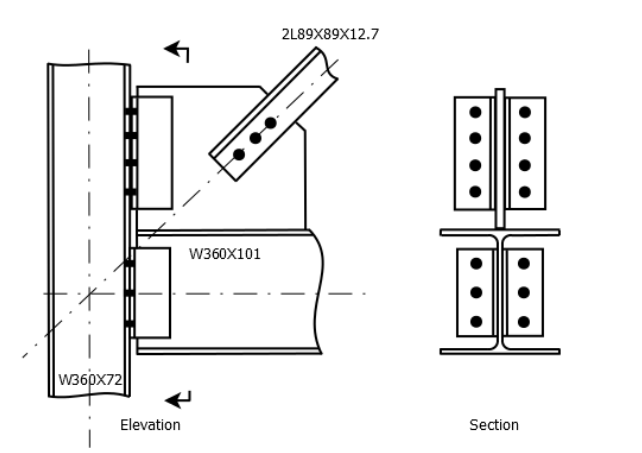
Table 3: Validation problem 2 results

	Interaction Ratio		
Check	Calculated	Osoconn	Result
Bolt shear check at brace	0.593	0.593	OK
Bolt bearing on brace check	0.408	0.408	OK
Bolt bearing on gusset	0.511	0.511	OK
Brace tension rupture	0.375	0.375	OK
Brace block shear	0.355	0.355	OK
Gusset tension yielding	0.267	0.267	OK
Gusset tension rupture	0.216	0.216	OK
Gusset buckling	0.331	0.331	OK
Gusset to beam weld	0.239	0.239	OK
Gusset rupture at weld	0.853	0.853	OK
Beam web yielding	0.127	0.127	OK
Beam web crippling	0.283	0.283	OK
Bolt shear at gusset to col. conn.	0.326	0.326	OK
Bolt bearing at clip at gusset to col. conn.	0.108	0.108	OK
Bolt bearing at web at gusset to col. conn.	0.094	0.094	OK
Clip shear yielding at gusset to col. conn.	0.095	0.095	OK
Clip shear rupture at gusset to col. conn.	0.108	0.108	OK
Clip block shear at gusset to col. conn.	0.11	0.11	OK
Bolt tension at gusset to col. conn.	0.0	0.0	OK
Bolt prying at clip at gusset to col. conn.	0.0	0.0	OK
Weld check at gusset to col. conn.	0.205	0.205	OK
Gusset rupture at weld at gusset to col. conn.	0.175	0.175	OK
Bolt shear check at beam to col. conn.	0.962	0.962	OK
Bolt bearing at clip at beam to col. conn.	0.286	0.286	OK
Bolt bearing at web at beam to col. conn.	0.248	0.248	OK
Clip shear yielding at beam to col. conn.	0.272	0.272	OK
Clip shear rupture at beam to col. conn.	0.309	0.309	OK
Clip block shear at beam to col. conn.	0.299	0.299	OK
Bolt tension check at beam to col. conn.	0.112	0.112	OK
Bolt prying at clip at beam to col. conn.	0.393	0.393	OK
Weld check at beam to col. conn.	0.62	0.62	OK
Web rupture at weld at beam to col. conn.	0.908	0.908	OK

2.4 Validation Problem 3

Problem Statement

Design a beam column single brace connection for a double angle 2L89X89X12.7 brace with short leg back-to-back framing into the junction between a W360X101 beam and W360X72 column flange using the ASD method. The brace has an angle of 55 degrees with the horizontal. The brace has an axial force of 105kN, and the beam has a shear force of 180kN and transfer force of 95kN. The beam and column are of grade ASTM A992. The clip angles and plates are of grade ASTM A36. The bolts are ASTM 3125 A490 bearing type.



Design Inputs

Material Properties

Material grade for plate	ASTM A36
Yield strength	$F_{yp} := 250\ MPa$
Tensile strength	$F_{up} := 400\ MPa$
Material grade of beam	ASTM A992
Yield strength	$F_{yb} := 345\ MPa$
Tensile strength	$F_{ub} := 450\ MPa$
Material grade of column	ASTM A992
Yield strength	$F_{yc} := 345\ MPa$
Tensile strength	$F_{uc} := 450\ MPa$
Material grade of angles	ASTM A36
Yield strength	$F_{ya} := 250\ MPa$
Tensile strength	$F_{ua} := 400\ MPa$
Material grade for weld electrode	E70XX
Tensile strength	$F_{EXX} := 482\ MPa$
Material specification for bolts	ASTM 3125 A490
Tensile strength	$F_{nt} := 780\ MPa$
Shear strength	$F_{nv} := 469\ MPa$

Young's modulus for steel	$E := 200000\ MPa$
Design Forces	
Axial force in brace	$P := 105\ kN$
Shear force in beam	$SF := 180\ kN$
Transfer force in beam	$TF := 95\ kN$
Connection Geometry	
Brace section	2L89X89X12.7
Thickness	$t_{br} := 12.7\ mm$
Outstanding leg length	$l_{obr} := 88.9\ mm$
Back-to-back leg length	$l_{ibr} := 88.9\ mm$
Gross cross section area	$A_{br} := 4190\ mm^2$
Centroid of brace outstanding leg	$x'_{br} := 26.7\ mm$
Brace angle with horizontal	$\theta_{br} := 55\ deg$
Beam section	W360X101
Section depth	$d_{xb} := 356\ mm$
Flange width	$b_{fb} := 254\ mm$
Flange thickness	$t_{fb} := 18.3\ mm$
Web thickness	$t_{wb} := 10.5\ mm$
Distance from outer face to fillet edge	$k_b := 33.3\ mm$
Column section	W360X72
Section depth	$d_{xc} := 351\ mm$
Flange width	$b_{fc} := 204\ mm$
Flange thickness	$t_{fc} := 15.1\ mm$
Web thickness	$t_{wc} := 8.64\ mm$
Cross section area of column	$A_c := 9100\ mm^2$
Distance form outer face to fillet edge	$k_c := 30.2\ mm$
Clip angle section	L102X89X12.7
Thickness	$t_a := 12.7\ mm$
Outstanding leg length	$l_{oa} := 102\ mm$
Welded leg length	$l_{ia} := 88.9\ mm$
Gusset plate thickness	$t_g := 12\ mm$
Gusset to beam interface length	$l_g := 300\ mm$
Clip distance from beam	$d := 25\ mm$
Bolt diameter	$d_b := 22\ mm$
Bolt hole diameter	$d_{bh} := 24\ mm$
Number of bolts per row on brace	$n_{br} := 3$
Number of bolts at gusset clip	$n_1 := 4$
Number of bolts at beam clip	$n_2 := 3$
Bolt spacing	$s := 70\ mm$
Bolt gage on brace	$g_{br} := 45\ mm$

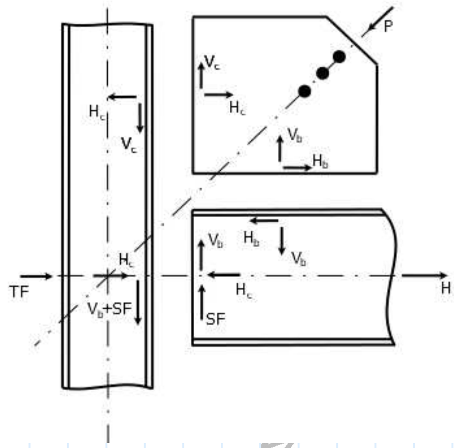
Bolt gage on column $g := 140\ mm$
Bolt edge distance on brace $ed_1 := 35\ mm$
Bolt edge distance on gusset $ed_2 := 35\ mm$
Bolt edge distance on clip $ed_3 := 35\ mm$

Gusset to beam weld thickness $w_1 := 6\ mm$
Clip to beam/gusset weld thickness $w_2 := 8\ mm$

Connection setback $sb := 12\ mm$
Distance of the brace edge from the work point $loc_{br} := 400\ mm$

Design Calculations

UFM forces in connection



Location of the centroid of the gusset to beam connection
$$\alpha' := 0.5 \cdot l_g \qquad \alpha' = 150\ mm$$

Length of clip at gusset to column interface
$$l_{cl1} := (n_1 - 1) \cdot s + 2 \cdot ed_3 \qquad l_{cl1} = 280\ mm$$

Location of the centroid of the gusset to column connection
$$\beta := d + 0.5 \cdot l_{cl1} \qquad \beta = 165\ mm$$

Eccentricity of gusset to column connection
$$e_c := 0.5 \cdot d_{xc} \qquad e_c = 175.5\ mm$$

Eccentricity of gusset to beam connection
$$e_b := 0.5 \cdot d_{xb} \qquad e_b = 178\ mm$$

Dimension
$$r := \sqrt{(\alpha' + e_c)^2 + (\beta + e_b)^2} \qquad r = 472.863\ mm$$

Vertical force at gusset to column interface
$$V_c := \frac{\beta}{r} \cdot P \qquad V_c = 36.639\ kN$$

Vertical force per bolt at gusset to column interface

$$V_{cb} := \frac{V_c}{2 \cdot n_1}$$ $V_{cb} = 4.58\ kN$

Horizontal force at gusset to column interface

$$H_c := \frac{e_c}{r} \cdot P$$ $H_c = 38.97\ kN$

Horizontal force per bolt at gusset to column interface

$$H_{cb} := \frac{H_c}{2 \cdot n_1}$$ $H_{cb} = 4.871\ kN$

Vertical force at gusset to beam interface

$$V_b := \frac{e_b}{r} \cdot P$$ $V_b = 39.525\ kN$

Total vertical force in beam clip connection

$$V'_b := SF + V_b$$ $V'_b = 219.525\ kN$

Vertical force per bolt in beam clip connection

$$V'_{bb} := \frac{V'_b}{2 \cdot n_2}$$ $V'_{bb} = 36.588\ kN$

Horizontal force at gusset to beam interface

$$H_b := \frac{\alpha'}{r} \cdot P$$ $H_b = 33.308\ kN$

Total horizontal force in beam clip connection

$$H'_b := TF + H_c$$ $H'_b = 133.97\ kN$

Horizontal force per bolt in beam clip connection

$$H'_{bb} := \frac{H'_b}{2 \cdot n_2}$$ $H'_{bb} = 22.328\ kN$

Required α for no moment at gusset to beam connection

$$\alpha := e_b \cdot \tan\left(\theta_{br}\right) - e_c + \beta \cdot \tan\left(\theta_{br}\right)$$ $\alpha = 12.376\ in$

Additional moment at gusset to beam interface

$$M_b := \text{abs}\left(V_b \cdot \left(\alpha - \alpha'\right)\right)$$ $M_b = 6.496\ kN \cdot m$

Bolt shear at brace to gusset connection

Shear per bolt

$$P_b := \frac{P}{n_{br}}$$ $P_b = 35\ kN$

Area of bolt

$$A_b := \frac{\pi \cdot {d_b}^2}{4}$$ $A_b = 380.133\ mm^2$

Nominal shear strength of bolt

$$R_n := 2 \cdot F_{nv} \cdot A_b$$ $R_n = 356.564\ kN$

Interaction ratio in bolt shear

$$I_0 := \frac{2.0\,P_b}{R_n} \qquad I_0 = 0.196$$

Bolt bearing on brace check

Minimum clear distance for bearing check

$$l_{c1} := min\left(s - d_{bh}, ed_1 - 0.5 \cdot d_{bh}\right) \qquad l_{c1} = 23\ mm$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c1} \cdot t_{br} \cdot F_{ua}, 2.4 \cdot d_b \cdot t_{br} \cdot F_{ua}\right) \qquad R_n = 140.208\ kN$$

Interaction ratio in bolt bearing at brace

$$I_1 := \frac{2.0 \cdot 0.5\,P_b}{R_n} \qquad I_1 = 0.25$$

Bolt bearing on gusset check

Minimum clear distance for bearing on gusset

$$l_{c2} := min\left(s - d_{bh}, ed_2 - 0.5 \cdot d_{bh}\right) \qquad l_{c1} = 23\ mm$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c2} \cdot t_g \cdot F_{up}, 2.4 \cdot d_b \cdot t_g \cdot F_{up}\right) \qquad R_n = 132.48\ kN$$

Interaction ratio in bolt bearing at gusset

$$I_2 := \frac{2.0\,P_b}{R_n} \qquad I_2 = 0.528$$

Brace tension rupture

Net cross section area of brace

$$A_{nbr} := A_{br} - 2 \cdot d_{bh} \cdot t_{br} \qquad A_{nbr} = 35.804\ cm^2$$

Length of connection

$$l_{br} := s \cdot \left(n_{br} - 1\right) \qquad l_{br} = 140\ mm$$

Shear lag factor

$$U := 1 - \frac{x'_{br}}{l_{br}} \qquad U = 0.809$$

Brace strength in tension rupture

$$P_n := F_{ua} \cdot U \cdot A_{nbr} \qquad P_n = 1159.027\ kN$$

Interaction ratio for brace tension rupture

$$I_3 := \frac{2.0\,P}{P_n} \qquad I_3 = 0.181$$

Brace block shear

Gross area in shear

$$A_{gv} := 2 \cdot \left(\left(n_{br} - 1\right) \cdot s + ed_1\right) \cdot t_{br} \qquad A_{gv} = 44.45\ cm^2$$

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot \left(n_{br} - 0.5\right) \cdot d_{bh} \cdot t_{br} \qquad A_{nv} = 29.21\ cm^2$$

Net area in tension

$$A_{nt} := 2 \cdot \left(l_{ibr} - g_{br} - 0.5 \cdot d_{bh}\right) \cdot t_{br} \qquad A_{nt} = 8.103\ cm^2$$

Nominal strength block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min\left(R_{n1}, R_{n2}\right) \qquad R_n = 990.854\ kN$$

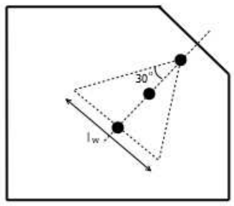
Interaction ratio in block shear

$$I_4 := \frac{2.0\ P}{R_n} \qquad I_4 = 0.212$$

Gusset tension yielding check

Length of Whitmore section

$$l_w := 2 \cdot l_{br} \cdot \tan(30\ deg) \qquad l_w = 161.658\ mm$$



Nominal strength of gusset in yielding

$$P_n := F_{yp} \cdot l_w \cdot t_g \qquad P_n = 484.974\ kN$$

Interaction ratio in tension yielding

$$I_5 := \frac{1.67\ P}{P_n} \qquad I_5 = 0.362$$

Gusset tension rupture check

Net area of gusset in tension

$$A_{ng} := \left(l_w - d_{bh}\right) \cdot t_g \qquad A_{ng} = 16.519\ cm^2$$

Nominal strength of gusset in rupture

$$P_n := F_{up} \cdot A_{ng} \qquad P_n = 660.759\ kN$$

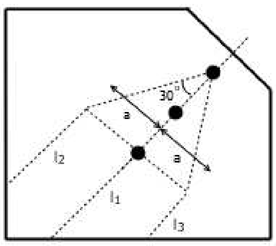
Interaction ratio in tension rupture

$$I_6 := \frac{2.0\ P}{P_n} \qquad I_6 = 0.318$$

Gusset buckling check

Half the length of the Whitmore section

$$a := \frac{l_w}{2} \qquad a = 80.829\ mm$$



Distance of the first bolt to the work point

$$l_o := loc_{br} + ed_1 \qquad l_o = 435\ mm$$

Buckling lengths along various points on the Whitmore section

$$l_1 := \max\left(min\left(l_o - \frac{e_c}{\cos\left(\theta_{br}\right)}, l_o - \frac{e_b}{\sin\left(\theta_{br}\right)}\right), 0\right) \qquad l_1 = 129.025\ mm$$

$$l_2 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})} - a \cdot \tan(\theta_{br}), l_o - \frac{e_b}{\sin(\theta_{br})} + a \cdot \tan(\theta_{br})\right), 0\right) \qquad l_2 = 13.589\ mm$$

$$l_3 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})} + a \cdot \tan(\theta_{br}), l_o - \frac{e_b}{\sin(\theta_{br})} - a \cdot \tan(\theta_{br})\right), 0\right) \qquad l_3 = 102.266\ mm$$

Average buckling length of gusset

$$l_{avg} := \frac{l_1 + l_2 + l_3}{3} \qquad l_{avg} = 81.627\ mm$$

Effective length factor for gusset

$$k := 1.2$$

Moment of inertia of gusset

$$I_g := \frac{l_w \cdot t_g^{\ 3}}{12} \qquad I_g = 2.328\ cm^4$$

Radius of gyration of gusset

$$r_g := \sqrt{\frac{I_g}{l_w \cdot t_g}} \qquad r_g = 3.464\ mm$$

Elastic buckling stress

$$F_e := \frac{\pi^2 \cdot E}{\left(\frac{k \cdot l_{avg}}{r_g}\right)^2} \qquad F_e = 2468.778\ MPa$$

Critical stress in compression

$$F_{cr1} := \left(0.658^{\frac{F_{yp}}{F_e}}\right) \cdot F_{yp}$$

$$F_{cr2} := 0.877 \cdot F_e$$

$$F_{cr} := \text{if}\left(\frac{k \cdot l_{avg}}{r_g} \le 4.71 \cdot \sqrt{\frac{E}{F_{yp}}}, F_{cr1}, F_{cr2}\right) \qquad F_{cr} = 239.625\ MPa$$

Nominal strength of gusset in compression

$$P_n := F_{cr} \cdot l_w \cdot t_g \qquad P_n = 464.848\ kN$$

Interaction ratio in compression

$$I_7 := \frac{1.67\ P}{P_n} \qquad I_7 = 0.377$$

Gusset to beam weld check

Horizontal stress in weld

$$f_h := \frac{H_b}{2 \cdot l_g} \qquad f_h = 0.056\ \frac{kN}{mm}$$

Vertical stress in weld

$$f_{v.max} := \frac{V_b}{2 \cdot l_g} + \frac{3 \cdot M_b}{l_g^{\ 2}} \qquad f_{v.max} = 0.282\ \frac{kN}{mm}$$

Vertical stress in weld

$$f_{v.min} := \frac{V_b}{2 \cdot l_g} - \frac{3 \cdot M_b}{l_g^{\ 2}}$$ $$f_{v.min} = -0.151 \ \frac{kN}{mm}$$

Resultant maximum stress in weld

$$f_{max} := \sqrt{f_h^{\ 2} + f_{v.max}^{\ 2}}$$ $$f_{max} = 0.288 \ \frac{kN}{mm}$$

Average stress in weld

$$f_{avg} := \frac{1}{2} \cdot \left(\sqrt{f_h^{\ 2} + f_{v.max}^{\ 2}} + \sqrt{f_h^{\ 2} + f_{v.min}^{\ 2}} \right)$$ $$f_{avg} = 0.224 \ \frac{kN}{mm}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_1$$ $$R_n = 1.227 \ \frac{kN}{mm}$$

Interaction ratio for weld check

$$I_8 := \frac{2.0 \ \max\left(f_{max}, 1.25 \ f_{avg}\right)}{R_n}$$ $$I_8 = 0.469$$

Gusset rupture at weld check

Minimum thickness of plate required to develop strength of weld

$$t_{min} := \frac{2 \cdot 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_1}{0.6 \cdot F_{up}}$$ $$t_{min} = 10.225 \ mm$$

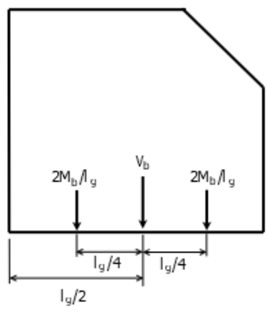
Interaction ratio in rupture

$$I_9 := \frac{t_{min}}{t_g}$$ $$I_9 = 0.852$$

Beam web yielding check

Equivalent force at gusset to beam interface

$$N_{eq} := V_b + \frac{4 \cdot M_b}{l_g}$$ $$N_{eq} = 126.141 \ kN$$



Nominal strength in web yielding

$$R_{n1} := F_{yb} \cdot t_{wb} \cdot \left(5 \cdot k_b + l_g\right)$$

$$R_{n2} := F_{yb} \cdot t_{wb} \cdot \left(2.5 \cdot k_b + l_g\right)$$

$$R_n := \text{if}\left(\frac{l_g}{4} > d_{xb}, R_{n1}, R_{n2}\right)$$ $$R_n = \left(1.388 \cdot 10^3\right) \ kN$$

nteraction ratio in web yielding

$$I_{10} := \frac{1.5 \ N_{eq}}{R_n}$$ $$I_{10} = 0.136$$

Beam web crippling check

Nominal strength in web crippling

$$R_{n1} := 0.8 \cdot t_{wb}^{\ 2} \cdot \left(1 + 3 \cdot \frac{l_g}{d_{xb}} \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_{n2} := 0.4 \cdot t_{wb}^{\ 2} \cdot \left(1 + 3 \cdot \frac{l_g}{d_{xb}} \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_{n3} := 0.4 \cdot t_{wb}^{\ 2} \cdot \left(1 + \left(\frac{4 \cdot l_g}{d_{xb}} - 0.2\right) \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_n := \text{if}\left(\frac{l_g}{4} \ge \frac{d_{xb}}{2}, R_{n1}, \text{if}\left(\frac{l_g}{d_{xb}} \le 0.2, R_{n2}, R_{n3}\right)\right) \qquad R_n = \left(1.15 \cdot 10^3\right)\ kN$$

Interaction ratio in web crippling

$$I_{11} := \frac{2.0\ N_{eq}}{R_n} \qquad I_{11} = 0.219$$

Bolt shear at gusset to column connection

Area of bolt

$$A_b := \frac{\pi \cdot d_b^{\ 2}}{4} \qquad A_b = 380.133\ mm^2$$

Nominal shear strength of bolt

$$R_n := F_{nv} \cdot A_b \qquad R_n = 178.282\ kN$$

Interaction ratio in bolt shear

$$I_{12} := \frac{2.0\ V_{cb}}{R_n} \qquad I_{12} = 0.051$$

Bolt bearing at clip angle at gusset to column connection

Clear distance between bolt holes/ hole and edge

$$l_{c3} := min\left(s - d_{bh}, ed_3 - 0.5 \cdot d_{bh}\right) \qquad l_{c3} = 23\ mm$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c3} \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_n = 140.208\ kN$$

Interaction ratio in bolt bearing

$$I_{13} := \frac{2.0\ V_{cb}}{R_n} \qquad I_{13} = 0.065$$

Bolt bearing at column flange at gusset to column connection

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{fc} \cdot F_{uc}, 2.4 \cdot d_b \cdot t_{fc} \cdot F_{uc}\right) \qquad R_n = 358.776\ kN$$

Interaction ratio in bolt bearing

$$I_{14} := \frac{2.0\ V_{cb}}{R_n} \qquad I_{14} = 0.026$$

Clip angle shear yielding at gusset to column connection

Length of gusset to column clip

$$L_1 := \left(n_1 - 1\right) \cdot s + 2\ ed_3 \qquad L_1 = 280\ mm$$

Gross area in shear

$$A_{gv} := 2 \cdot L_1 \cdot t_a \qquad A_{gv} = 71.12\ cm^2$$

Nominal strength in shear yielding

$$R_n := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_n = \left(1.067 \cdot 10^3\right)\ kN$$

Resultant shear in clip angle

$$S_{r1} := \sqrt{V_c^{\,2} + H_c^{\,2}}$$ $$S_{r1} = 53.489\ kN$$

Interaction ratio in shear yielding

$$I_{15} := \frac{1.5\ S_{r1}}{R_n}$$ $$I_{15} = 0.075$$

Clip angle shear rupture at gusset to column connection

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n_1 \cdot d_{bh} \cdot t_a$$ $$A_{nv} = 46.736\ cm^2$$

Nominal strength in shear rupture

$$R_n := 0.6 \cdot F_{ua} \cdot A_{nv}$$ $$R_n = \left(1.122 \cdot 10^3\right)\ kN$$

Interaction ratio in shear rupture

$$I_{16} := \frac{2.0\ S_{r1}}{R_n}$$ $$I_{16} = 0.095$$

Clip angle block shear at gusset to column connection

Gross area subjected to block shear

$$A_{gv} := 2 \cdot \left(L_1 - ed_3\right) \cdot t_a$$ $$A_{gv} = 62.23\ cm^2$$

Net area subjected to block shear

$$A_{nv} := A_{gv} - 2 \cdot \left(n_1 - 0.5\right) \cdot d_{bh} \cdot t_a$$ $$A_{nv} = 40.894\ cm^2$$

Net area subjected to tension

$$A_{nt} := \left(2 \cdot l_{oa} + t_g - g - d_{bh}\right) \cdot t_a$$ $$A_{nt} = 6.604\ cm^2$$

Nominal strength in block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min\left(R_{n1}, R_{n2}\right)$$ $$R_n = \left(1.198 \cdot 10^3\right)\ kN$$

Interaction ratio in block shear

$$I_{17} := \frac{2.0\ V_c}{R_n}$$ $$I_{17} = 0.061$$

Bolt tension at gusset to column connection

Required shear stress per bolt

$$f_{rv} := \frac{V_{cb}}{A_b}$$ $$f_{rv} = 12.048\ MPa$$

Modified nominal tensile strength

$$F'_{nt} := min\left(1.3 \cdot F_{nt} - \frac{F_{nt}}{0.75 \cdot F_{nv}} \cdot f_{rv}, F_{nt}\right)$$ $$F'_{nt} = 780\ MPa$$

Nominal tensile strength

$$R_n := F'_{nt} \cdot A_b$$ $$R_n = 296.504\ kN$$

Interaction ratio for bolt tension

$$I_{18} := \frac{2.0\ H_{cb}}{R_n} \qquad I_{18} = 0.033$$

Bolt prying at clip angle at gusset to column connection

Available tension per bolt

$$B := \frac{F'_{nt} \cdot A_b}{2} \qquad B = 148.252\ kN$$

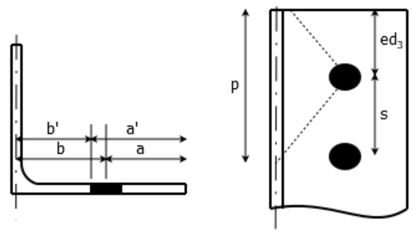
Clip dimensions for prying check

$$b := 0.5 \cdot (g - t_g - t_a) \qquad b = 57.65\ mm$$

$$a := l_{oa} - b - 0.5 \cdot t_a \qquad a = 38\ mm$$

$$b' := b - 0.5 \cdot d_b \qquad b' = 46.65\ mm$$

$$a' := min(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b) \qquad a' = 49\ mm$$



Tributary length

$$p := min(2 \cdot b, b + ed_3, s) \qquad p = 70\ mm$$

Ratios for prying

$$\delta := 1 - \frac{d_{bh}}{p} \qquad \delta = 0.657$$

$$\rho := \frac{b'}{a'} \qquad \rho = 0.952$$

Thickness required to develop bolt tension without prying

$$t_c := \sqrt{\frac{1.67 \cdot 4 \cdot B \cdot b'}{p \cdot F_{ua}}} \qquad t_c = 40.62\ mm$$

$$\alpha' := \frac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\frac{t_c}{t_a}\right)^2 - 1\right) \qquad \alpha' = 7.195$$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right) \qquad Q = 0.162$$

Available tension strength with prying

$$T_{av} := Q \cdot B \qquad T_{av} = 24.016\ kN$$

Interaction ratio in prying

$$I_{19} := \frac{H_{cb}}{T_{av}} \qquad I_{19} = 0.203$$

Bolt prying at column flange at gusset to column connection

Clip dimensions for prying check

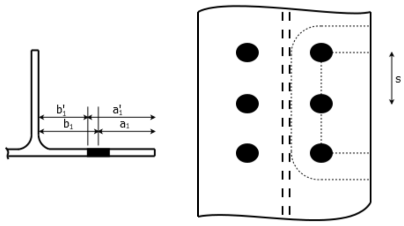
$$b_1 := 0.5 \cdot (g - t_{wc}) \qquad b_1 = 2.586\ in$$

$$a_1 := min(0.5 \cdot (b_{fc} - g), 0.5 \cdot (2 \cdot l_{oa} + t_g - g)) \qquad a_1 = 32\ mm$$

$b'_1 := b_1 - 0.5 \cdot d_b$ $\qquad b'_1 = 54.68\ mm$

$a'_1 := min\left(a_1 + 0.5 \cdot d_b, 1.25 \cdot b_1 + 0.5 \cdot d_b\right)$ $\qquad a'_1 = 43\ mm$

Tributary length



$$p_1 := \frac{\left(n_1 - 1\right) \cdot s + \pi \cdot b_1 + \left(b_{fc} - g\right)}{n_1} \qquad p_1 = 120.085\ mm$$

Ratios for prying

$$\delta_1 := 1 - \frac{d_{bh}}{p_1} \qquad \delta_1 = 0.8$$

$$\rho_1 := \frac{b'_1}{a'_1} \qquad \rho_1 = 1.272$$

Thickness required to develop bolt tension without prying

$$t_{c1} := \sqrt{\frac{1.67 \cdot 4 \cdot B \cdot b'_1}{p_1 \cdot F_{uc}}} \qquad t_{c1} = 31.656\ mm$$

$$\alpha'_1 := \frac{1}{\delta_1 \cdot \left(1 + \rho_1\right)} \cdot \left(\left(\frac{t_{c1}}{t_{fc}}\right)^2 - 1\right) \qquad \alpha'_1 = 1.868$$

Proportion of tension strength available

$$Q_1 := \mathbf{if}\left(\alpha'_1 < 0, 1, \mathbf{if}\left(0 \le \alpha'_1 \le 1, \left(\frac{t_{fc}}{t_{c1}}\right)^2 \cdot \left(1 + \delta_1 \cdot \alpha'_1\right), \left(\frac{t_{fc}}{t_{c1}}\right)^2 \cdot \left(1 + \delta_1\right)\right)\right) \qquad Q_1 = 0.41$$

Available tension strength with prying

$$T_{av1} := Q_1 \cdot B \qquad T_{av1} = 60.723\ kN$$

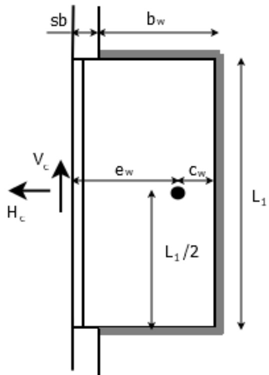
Interaction ratio in prying

$$I_{20} := \frac{H_{cb}}{T_{av1}} \qquad I_{20} = 0.08$$

Weld check at gusset to column connection

Length of horizontal run of weld

$$b_w := l_{ia} - sb \qquad b_w = 76.9\ mm$$



Centroid of weld group

$$c_w := \frac{{b_w}^2}{2 \cdot b_w + L_1} \qquad c_w = 13.632\ mm$$

Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 75.268\ mm$$

Polar moment of inertia of weld group

$$I_w := \frac{\left(2 \cdot b_w + L_1\right)^3}{12} - \frac{{b_w}^2 \cdot \left(b_w + L_1\right)^2}{2 \cdot b_w + L_1} \qquad I_w = 5066.369\ cm^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{H_c}{2 \cdot (2 \cdot b_w + L_1)} + \frac{V_c \cdot e_w \cdot L_1}{4 \cdot I_w} \qquad f_{wh} = 0.083 \ \frac{kN}{mm}$$

Vertical component of weld stress

$$f_{wv} := \frac{V_c}{2 \cdot (2 \cdot b_w + L_1)} + \frac{V_c \cdot e_w \cdot (b_w - c_w)}{2\ I_w} \qquad f_{wv} = 0.059 \ \frac{kN}{mm}$$

Resultant weld stress

$$f_w := \sqrt{{f_{wh}}^2 + {f_{wv}}^2} \qquad f_w = 0.102 \ \frac{kN}{mm}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_2 \qquad R_n = 1.636 \ \frac{kN}{mm}$$

Interaction ratio for weld check

$$I_{21} := \frac{2.0\ f_w}{R_n} \qquad I_{21} = 0.125$$

Gusset rupture at weld at gusset to column connection

Minimum web thickness to match weld strength

$$t_{g.min} := \frac{2.0 \cdot 2 \cdot f_w}{0.6 \cdot F_{up}} \qquad t_{g.min} = 1.702\ mm$$

Interaction ratio in web rupture

$$I_{22} := \frac{t_{g.min}}{t_g} \qquad I_{22} = 0.142$$

Column web local yielding at gusset to column connection

Nominal strength in web local yielding

$$R_n := F_{yc} \cdot t_{wc} \cdot (2.5 \cdot k_c + L_1) \qquad R_n = 1059.674\ kN$$

Interaction ratio in web local yielding

$$I_{23} := \frac{1.5\ H_c}{R_n} \qquad I_{23} = 0.055$$

Column web local crippling at gusset to column connection

Nominal strength in web crippling

$$R_{n1} := 0.40 \cdot {t_{wc}}^2 \cdot \left(1 + 3 \cdot \frac{L_1}{d_{xc}} \cdot \left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yc} \cdot t_{fc}}{t_{wc}}}$$

$$R_{n2} := 0.40 \cdot {t_{wc}}^2 \cdot \left(1 + \left(\frac{4 \cdot L_1}{d_{xc}} - 0.2\right) \cdot \left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yc} \cdot t_{fc}}{t_{wc}}}$$

$$R_n := \mathbf{if}\left(L_1 \div d_{xc} \le 0.2, R_{n1}, R_{n2}\right) \qquad R_n = 752.373\ kN$$

Interaction ratio in web crippling

$$I_{24} := \frac{2.0\ H_c}{R_n} \qquad I_{24} = 0.104$$

Bolt shear check at beam to column connection

Nominal shear strength of bolt

$$R_n := F_{nv} \cdot A_b \qquad R_n = 178.282\ kN$$

Interaction ratio in bolt shear

$$I_{25} := \frac{2.0\ V'_{bb}}{R_n} \qquad I_{25} = 0.41$$

Bolt bearing at clip angle at beam to column connection

Clear distance between bolt holes/ hole and edge

$$l_{c3} := min\left(s - d_{bh}, ed_3 - 0.5 \cdot d_{bh}\right) \qquad l_{c3} = 23\ mm$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c3} \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_n = 140.208\ kN$$

Interaction ratio in bolt bearing

$$I_{26} := \frac{2.0\ V'_{bb}}{R_n} \qquad I_{26} = 0.522$$

Bolt bearing at column flange at beam to column connection

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{fc} \cdot F_{uc}, 2.4 \cdot d_b \cdot t_{fc} \cdot F_{uc}\right) \qquad R_n = 358.776\ kN$$

Interaction ratio in bolt bearing

$$I_{27} := \frac{2.0\ V'_{bb}}{R_n} \qquad I_{27} = 0.204$$

Clip angle shear yielding at beam to column connection

Length of gusset to column clip

$$L_2 := \left(n_2 - 1\right) \cdot s + 2\ ed_3 \qquad L_2 = 210\ mm$$

Gross area in shear

$$A_{gv} := 2 \cdot L_2 \cdot t_a \qquad A_{gv} = 53.34\ cm^2$$

Nominal strength in shear yielding

$$R_n := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_n = 800.1\ kN$$

Resultant shear in clip angle

$$S_{r2} := \sqrt{{V'_b}^2 + {H'_b}^2} \qquad S_{r2} = 257.176\ kN$$

Interaction ratio in shear yielding

$$I_{28} := \frac{1.5\ S_{r2}}{R_n} \qquad I_{28} = 0.482$$

Clip angle shear rupture at beam to column connection

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n_2 \cdot d_{bh} \cdot t_a \qquad A_{nv} = 35.052\ cm^2$$

Nominal strength in shear rupture

$R_n := 0.6 \cdot F_{ua} \cdot A_{nv}$ $\quad R_n = 841.248\ kN$

Interaction ratio in shear rupture

$$I_{29} := \frac{2.0\ S_{r2}}{R_n} \qquad I_{29} = 0.611$$

Clip angle block shear at beam to column connection

Gross area subjected to block shear

$$A_{gv} := 2 \cdot (L_2 - ed_3) \cdot t_a \qquad A_{gv} = 44.45\ cm^2$$

Net area subjected to block shear

$$A_{nv} := A_{gv} - 2 \cdot (n_2 - 0.5) \cdot d_{bh} \cdot t_a \qquad A_{nv} = 29.21\ cm^2$$

Net area subjected to tension

$$A_{nt} := (2 \cdot l_{oa} + t_{wb} - g - d_{bh}) \cdot t_a \qquad A_{nt} = 6.414\ cm^2$$

Nominal strength in block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min(R_{n1}, R_{n2}) \qquad R_n = 923.29\ kN$$

Interaction ratio in block shear

$$I_{30} := \frac{2.0\ V'_b}{R_n} \qquad I_{30} = 0.476$$

Bolt tension check at beam to column connection

Required shear stress per bolt

$$f_{rv} := \frac{V'_{bb}}{A_b} \qquad f_{rv} = 96.249\ MPa$$

Modified nominal tensile strength

$$F'_{nt} := min\left(1.3 \cdot F_{nt} - \frac{2.0\ F_{nt}}{F_{nv}} \cdot f_{rv}, F_{nt}\right) \qquad F'_{nt} = 685.446\ MPa$$

Nominal tensile strength

$$R_n := F'_{nt} \cdot A_b \qquad R_n = 260.561\ kN$$

Interaction ratio for bolt tension

$$I_{31} := \frac{2.0\ H'_{bb}}{R_n} \qquad I_{31} = 0.171$$

Bolt prying at clip angle at beam to column connection

Available tension per bolt

$$B := \frac{F'_{nt} \cdot A_b}{2.0} \qquad B = 130.28\ kN$$

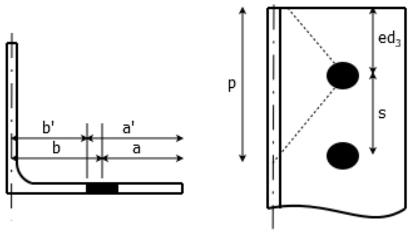
Clip dimensions for prying check

$$b := 0.5 \cdot (g - t_{wb} - t_a) \qquad b = 58.4\ mm$$

$a := l_{oa} - b - 0.5 \cdot t_a$ $\quad a = 37.25\ mm$

$b' := b - 0.5 \cdot d_b$ $\quad b' = 47.4\ mm$

$a' := min\left(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b\right)$ $\quad a' = 48.25\ mm$



Tributary length

$p := min\left(2 \cdot b, b + ed_3, s\right)$ $\quad p = 70\ mm$

Ratios for prying

$\delta := 1 - \dfrac{d_{bh}}{p}$ $\quad \delta = 0.657$

$\rho := \dfrac{b'}{a'}$ $\quad \rho = 0.982$

Thickness required to develop bolt tension without prying

$$t_c := \sqrt{\frac{1.67 \cdot 4 \cdot B \cdot b'}{p \cdot F_{ua}}} \qquad t_c = 38.383\ mm$$

$$\alpha' := \frac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\frac{t_c}{t_a}\right)^2 - 1\right) \qquad \alpha' = 6.244$$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right) \qquad Q = 0.181$$

Available tension strength with prying

$$T_{av} := Q \cdot B \qquad T_{av} = 23.636\ kN$$

Interaction ratio in prying

$$I_{32} := \frac{H'_{bb}}{T_{av}} \qquad I_{32} = 0.945$$

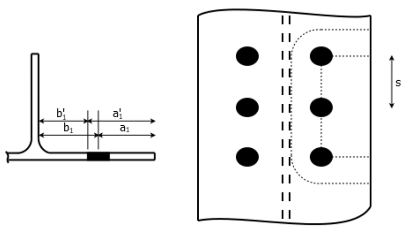
Bolt prying at column flange at beam to column connection

Clip dimensions for prying check

$b_1 := 0.5 \cdot \left(g - t_{wc}\right)$ $\quad b_1 = 65.68\ mm$

$a_1 := min\left(0.5 \cdot \left(b_{fc} - g\right), 0.5 \cdot \left(2 \cdot l_{oa} + t_{wb} - g\right)\right)$

$a_1 = 32\ mm$



$b'_1 := b_1 - 0.5 \cdot d_b$ $\quad b'_1 = 54.68\ mm$

$a'_1 := min\left(a_1 + 0.5 \cdot d_b, 1.25 \cdot b_1 + 0.5 \cdot d_b\right)$ $\quad a'_1 = 43\ mm$

Tributary length

$$p_1 := \frac{\left(n_2 - 1\right) \cdot s + \pi \cdot b_1 + \left(b_{fc} - g\right)}{n_2} \qquad p_1 = 136.78\ mm$$

Ratios for prying

$$\delta_1 := 1 - \frac{d_{bh}}{p_1} \qquad \delta_1 = 0.825$$

$$\rho_1 := \frac{b'_1}{a'_1} \qquad \rho_1 = 1.272$$

Thickness required to develop bolt tension without prying

$$t_{c1} := \sqrt{\frac{1.67 \cdot 4 \cdot B \cdot b'_1}{p_1 \cdot F_{uc}}} \qquad t_{c1} = 27.805\ mm$$

$$\alpha'_1 := \frac{1}{\delta_1 \cdot (1+\rho_1)} \cdot \left(\left(\frac{t_{c1}}{t_{fc}} \right)^2 - 1 \right) \qquad \alpha'_1 = 1.276$$

Proportion of tension strength available

$$Q_1 := \text{if}\left(\alpha'_1 < 0, 1, \text{if}\left(0 \le \alpha'_1 \le 1, \left(\frac{t_{fc}}{t_{c1}}\right)^2 \cdot (1+\delta_1 \cdot \alpha'_1), \left(\frac{t_{fc}}{t_{c1}}\right)^2 \cdot (1+\delta_1)\right)\right) \qquad Q_1 = 0.538$$

Available tension strength with prying

$$T_{av1} := Q_1 \cdot B \qquad T_{av1} = 70.103\ kN$$

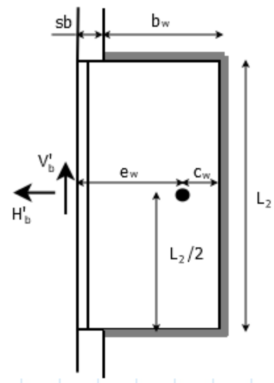
Interaction ratio in prying at column flange

$$I_{33} := \frac{H'_{bb}}{T_{av1}} \qquad I_{33} = 0.319$$

Weld check at beam to column connection

Centroid of weld group

$$c_w := \frac{{b_w}^2}{2 \cdot b_w + L_2} \qquad c_w = 16.255\ mm$$



Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 72.645\ mm$$

Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L_2)^3}{12} - \frac{{b_w}^2 \cdot (b_w + L_2)^2}{2 \cdot b_w + L_2} \qquad I_w = 2674.44\ cm^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{H'_b}{2 \cdot (2 \cdot b_w + L_2)} + \frac{V'_b \cdot e_w \cdot L_2}{4 \cdot I_w} \qquad f_{wh} = 0.497\ \frac{kN}{mm}$$

Vertical component of weld stress

$$f_{wv} := \frac{V'_b}{2 \cdot (2 \cdot b_w + L_2)} + \frac{V'_b \cdot e_w \cdot (b_w - c_w)}{2\ I_w} \qquad f_{wv} = 0.483\ \frac{kN}{mm}$$

Resultant weld stress

$$f_w := \sqrt{{f_{wh}}^2 + {f_{wv}}^2} \qquad f_w = 0.693\ \frac{kN}{mm}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_2 \qquad R_n = 1.636\ \frac{kN}{mm}$$

Interaction ratio for weld check

$$I_{34} := \frac{2.0\ f_w}{R_n} \qquad I_{34} = 0.847$$

Web rupture at weld at beam to column connection

Minimum web thickness to match weld strength

$$t_{wb.min} := \frac{2.0 \cdot 2 \cdot f_w}{0.6 \cdot F_{ub}} \qquad t_{wb.min} = 10.264\ mm$$

Interaction ratio in web rupture

$$I_{35} := \frac{t_{wb.min}}{t_{wb}} \qquad I_{35} = 0.978$$

Column web local yielding at beam to column connection

Nominal strength in web local yielding

$$R_n := F_{yc} \cdot t_{wc} \cdot \left(2.5 \cdot k_c + L_2\right) \qquad R_n = 851.018\ kN$$

Interaction ratio in web local yielding

$$I_{36} := \frac{1.5\ H'_b}{R_n} \qquad I_{36} = 0.236$$

Column web local crippling at beam to column connection

Nominal strength in web crippling

$$R_{n1} := 0.40 \cdot t_{wc}^{\ 2} \cdot \left(1 + 3 \cdot \frac{L_2}{d_{xc}} \cdot \left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yc} \cdot t_{fc}}{t_{wc}}}$$

$$R_{n2} := 0.40 \cdot t_{wc}^{\ 2} \cdot \left(1 + \left(\frac{4 \cdot L_2}{d_{xc}} - 0.2\right) \cdot \left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yc} \cdot t_{fc}}{t_{wc}}}$$

$$R_n := \text{if}\left(L_2 \div d_{xc} \le 0.2, R_{n1}, R_{n2}\right) \qquad R_n = 639.159\ kN$$

Interaction ratio in web crippling

$$I_{37} := \frac{2.0\ H'_b}{R_n} \qquad I_{37} = 0.419$$

Validation Results

The calculated ratios are compared with the output of Osoconn and if it is within a tolerance of 1% the result is deemed to be OK.

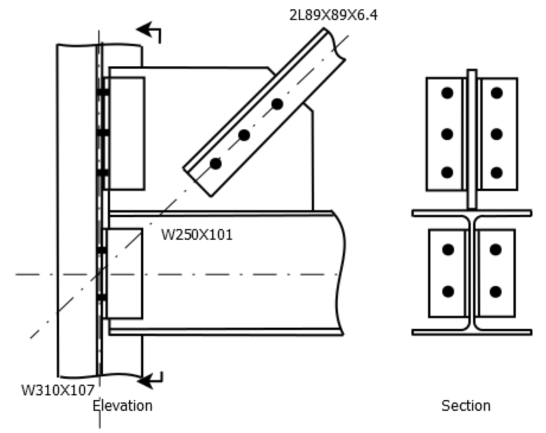
Table 4: Validation problem 3 results

	Interaction Ratio		
Check	Calculated	Osoconn	Result
Bolt shear check at brace	0.196	0.196	OK
Bolt bearing on brace check	0.25	0.25	OK
Bolt bearing on gusset	0.528	0.528	OK
Brace tension rupture	0.181	0.181	OK
Brace block shear	0.212	0.212	OK
Gusset tension yielding	0.362	0.362	OK
Gusset tension rupture	0.318	0.318	OK
Gusset buckling	0.377	0.377	OK
Gusset to beam weld	0.469	0.469	OK
Gusset rupture at weld	0.852	0.852	OK
Beam web yielding	0.136	0.136	OK
Beam web crippling	0.219	0.219	OK
Bolt shear at gusset to col. conn.	0.051	0.051	OK
Bolt bearing at clip at gusset to col. conn.	0.065	0.065	OK
Bolt bearing at flange at gusset to col. conn.	0.026	0.026	OK
Clip shear yielding at gusset to col. conn.	0.075	0.075	OK
Clip shear rupture at gusset to col. conn.	0.095	0.095	OK
Clip block shear at gusset to col. conn.	0.061	0.061	OK
Bolt tension at gusset to col. conn.	0.033	0.033	OK
Bolt prying at clip at gusset to col. conn.	0.203	0.203	OK
Bolt prying at flange at gusset to col. conn.	0.08	0.08	OK
Weld check at gusset to col. conn.	0.125	0.125	OK
Gusset rupture at weld at gusset to col. conn.	0.142	0.142	OK
Web local yielding at gusset to col. conn.	0.055	0.055	OK
Web local crippling at gusset to col. conn.	0.104	0.104	OK
Bolt shear check at beam to col. conn.	0.41	0.41	OK
Bolt bearing at clip at beam to col. conn.	0.522	0.522	OK
Bolt bearing at flange at beam to col. conn.	0.204	0.204	OK
Clip shear yielding at beam to col. conn.	0.482	0.482	OK
Clip shear rupture at beam to col. conn.	0.611	0.611	OK
Clip block shear at beam to col. conn.	0.476	0.476	OK
Bolt tension check at beam to col. conn.	0.169	0.169	OK
Bolt prying at clip at beam to col. conn.	0.945	0.945	OK
Bolt prying at flange at beam to col. conn.	0.319	0.319	OK
Weld check at beam to col. conn.	0.847	0.847	OK
Web rupture at weld at beam to col. conn.	0.978	0.978	OK
Web local yielding at beam to col. conn.	0.236	0.236	OK
Web local crippling at beam to col. conn.	0.419	0.419	OK

2.5 Validation Problem 4

Problem Statement

Design a beam column single brace connection for a double angle 2L89X89X6.4 brace with short leg back-to-back framing into the junction between a W250X80 beam and W310X107 column flange using the ASD method. The brace has an angle of 35 degrees with the horizontal. The brace has an axial force of 105kN, and the beam has a shear force of 95kN and transfer force of 80kN. The beam, column, clip angles and plates are of grade ASTM A36. The bolts are ASTM 3125 A325 bearing type.



Design Inputs

Material Properties

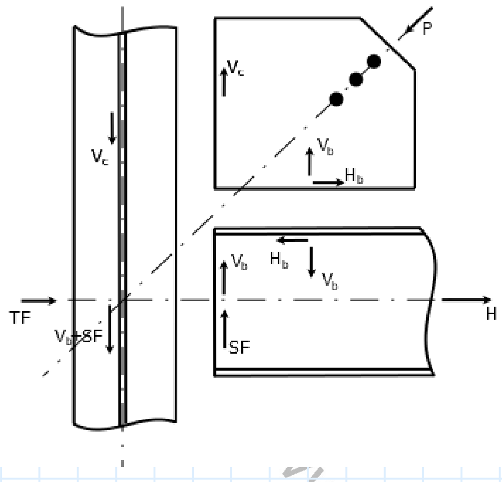
Material grade for plate	ASTM A36
Yield strength	$F_{yp} := 250\ MPa$
Tensile strength	$F_{up} := 400\ MPa$
Material grade of beam	ASTM A36
Yield strength	$F_{yb} := 250\ MPa$
Tensile strength	$F_{ub} := 400\ MPa$
Material grade of column	ASTM A36
Yield strength	$F_{yc} := 250\ MPa$
Tensile strength	$F_{uc} := 400\ MPa$
Material grade of angles	ASTM A36
Yield strength	$F_{ya} := 250\ MPa$
Tensile strength	$F_{ua} := 400\ MPa$
Material grade for weld electrode	E70XX
Tensile strength	$F_{EXX} := 482\ MPa$
Material specification for bolts	ASTM 3125 A325
Tensile strength	$F_{nt} := 620\ MPa$
Shear strength	$F_{nv} := 372\ MPa$

Young's modulus for steel	$E := 200000\ MPa$
Design Forces	
Axial force in brace	$P := 105\ kN$
Shear force in beam	$SF := 95\ kN$
Transfer force in beam	$TF := 80\ kN$
Connection Geometry	
Brace section	2L89X89X6.4
Thickness	$t_{br} := 6.35\ mm$
Outstanding leg length	$l_{obr} := 88.9\ mm$
Back-to-back leg length	$l_{ibr} := 88.9\ mm$
Gross cross section area	$A_{br} := 2190\ mm^2$
Centroid of brace outstanding leg	$x'_{br} := 24.2\ mm$
Brace angle with horizontal	$\theta_{br} := 35\ deg$
Beam section	W250X101
Section depth	$d_{xb} := 264\ mm$
Flange width	$b_{fb} := 257\ mm$
Flange thickness	$t_{fb} := 19.6\ mm$
Web thickness	$t_{wb} := 11.9\ mm$
Distance from outer face to fillet edge	$k_b := 32.3\ mm$
Column section	W310X107
Section depth	$d_{xc} := 312\ mm$
Flange width	$b_{fc} := 310\ mm$
Flange thickness	$t_{fc} := 17\ mm$
Web thickness	$t_{wc} := 10.9\ mm$
Cross section area of column	$A_c := 13600\ mm^2$
Distance form outer face to fillet edge	$k_c := 32.3\ mm$
Clip angle section	L89X76X12.7
Thickness	$t_a := 12.7\ mm$
Outstanding leg length	$l_{oa} := 88.9\ mm$
Welded leg length	$l_{ia} := 76.2\ mm$
Gusset plate thickness	$t_g := 16\ mm$
Gusset to beam interface length	$l_g := 400\ mm$
Clip distance from beam	$d := 25\ mm$
Bolt diameter	$d_b := 22\ mm$
Bolt hole diameter	$d_{bh} := 24\ mm$
Number of bolts per row on brace	$n_{br} := 3$
Number of bolts at gusset clip	$n_1 := 3$
Number of bolts at beam clip	$n_2 := 2$
Bolt spacing	$s := 70\ mm$
Bolt gage on brace	$g_{br} := 40\ mm$

Bolt gage on column	$g := 110\ mm$
Bolt edge distance on brace	$ed_1 := 30\ mm$
Bolt edge distance on gusset	$ed_2 := 30\ mm$
Bolt edge distance on clip	$ed_3 := 30\ mm$
Gusset to beam weld thickness	$w_1 := 8\ mm$
Clip to beam weld thickness	$w_2 := 8\ mm$
Connection setback	$sb := 12\ mm$
Distance of the brace edge from the work point	$loc_{br} := 400\ mm$

Design Calculations

UFM forces in connection



Location of the centroid of the gusset to beam connection

$$\alpha' := 0.5 \cdot l_g \qquad \alpha' = 200\ mm$$

Length of clip at gusset to column interface

$$l_{cl1} := (n_1 - 1) \cdot s + 2 \cdot ed_3 \qquad l_{cl1} = 200\ mm$$

Location of the centroid of the gusset to column connection

$$\beta := d + 0.5 \cdot l_{cl1} \qquad \beta = 125\ mm$$

Eccentricity of gusset to column connection

$$e_c := 0\ mm \qquad e_c = 0\ mm$$

Eccentricity of gusset to beam connection

$$e_b := 0.5 \cdot d_{xb} \qquad e_b = 132\ mm$$

Dimension

$$r := \sqrt{(\alpha' + e_c)^2 + (\beta + e_b)^2} \qquad r = 325.652\ mm$$

Vertical force at gusset to column interface

$$V_c := \frac{\beta}{r} \cdot P \qquad V_c = 40.304\ kN$$

Vertical force per bolt at gusset to column interface

$$V_{cb} := \frac{V_c}{2 \cdot n_1} \qquad V_{cb} = 6.717\ kN$$

Horizontal force at gusset to column interface

$$H_c := \frac{e_c}{r} \cdot P \qquad H_c = 0\ kN$$

Horizontal force per bolt at gusset to column interface

$$H_{cb} := \frac{H_c}{2 \cdot n_1} \qquad H_{cb} = 0\ kN$$

Vertical force at gusset to beam interface

$$V_b := \frac{e_b}{r} \cdot P \qquad V_b = 42.561\ kN$$

Total vertical force in beam clip connection

$$V'_b := SF + V_b \qquad V'_b = 137.561\ kN$$

Vertical force per bolt in beam clip connection

$$V'_{bb} := \frac{V'_b}{2 \cdot n_2} \qquad V'_{bb} = 34.39\ kN$$

Horizontal force at gusset to beam interface

$$H_b := \frac{\alpha'}{r} \cdot P \qquad H_b = 64.486\ kN$$

Total horizontal force in beam clip connection

$$H'_b := TF + H_c \qquad H'_b = 80\ kN$$

Horizontal force per bolt in beam clip connection

$$H'_{bb} := \frac{H'_b}{2 \cdot n_2} \qquad H'_{bb} = 20\ kN$$

Required α for no moment at gusset to beam connection

$$\alpha := e_b \cdot \tan\left(\theta_{br}\right) - e_c + \beta \cdot \tan\left(\theta_{br}\right) \qquad \alpha = 179.953\ mm$$

Additional moment at gusset to beam interface

$$M_b := \operatorname{abs}\left(V_b \cdot \left(\alpha - \alpha'\right)\right) \qquad M_b = 0.853\ kN \cdot m$$

Bolt shear at brace to gusset connection

Shear per bolt

$$P_b := \frac{P}{n_{br}} \qquad V_b = 42.561\ kN$$

Area of bolt

$$A_b := \frac{\pi \cdot {d_b}^2}{4} \qquad A_b = 380.133\ mm^2$$

Nominal shear strength of bolt

$$R_n := 2 \cdot F_{nv} \cdot A_b \qquad R_n = 282.819\ kN$$

Interaction ratio in bolt shear

$$I_0 := \frac{2.0\ P_b}{R_n} \qquad I_0 = 0.248$$

Bolt bearing on brace check

Minimum clear distance for bearing check

$$l_{c1} := min\left(s - d_{bh}, ed_1 - 0.5 \cdot d_{bh}\right) \qquad l_{c1} = 18\ mm$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c1} \cdot t_{br} \cdot F_{ua}, 2.4 \cdot d_b \cdot t_{br} \cdot F_{ua}\right) \qquad R_n = 54.864\ kN$$

Interaction ratio in bolt bearing at brace

$$I_1 := \frac{2.0 \cdot 0.5\ P_b}{R_n} \qquad I_1 = 0.638$$

Bolt bearing on gusset check

Minimum clear distance for bearing on gusset

$$l_{c2} := min\left(s - d_{bh}, ed_2 - 0.5 \cdot d_{bh}\right) \qquad l_{c1} = 18\ mm$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c2} \cdot t_g \cdot F_{up}, 2.4 \cdot d_b \cdot t_g \cdot F_{up}\right) \qquad R_n = 138.24\ kN$$

Interaction ratio in bolt bearing at gusset

$$I_2 := \frac{2.0\ P_b}{R_n} \qquad I_2 = 0.506$$

Tension rupture at brace to gusset connection

Net cross section area of brace

$$A_{nbr} := A_{br} - 2 \cdot d_{bh} \cdot t_{br} \qquad A_{nbr} = 18.852\ cm^2$$

Length of connection

$$l_{br} := s \cdot \left(n_{br} - 1\right) \qquad l_{br} = 140\ mm$$

Shear lag factor

$$U := 1 - \frac{x'_{br}}{l_{br}} \qquad U = 0.827$$

Brace strength in tension rupture

$$P_n := F_{ua} \cdot U \cdot A_{nbr} \qquad P_n = 623.732\ kN$$

Interaction ratio for brace tension rupture

$$I_3 := \frac{2.0\ P}{P_n} \qquad I_3 = 0.337$$

Brace block shear check

Gross area in shear

$$A_{gv} := 2 \cdot \left(\left(n_{br} - 1\right) \cdot s + ed_1\right) \cdot t_{br} \qquad A_{gv} = 21.59\ cm^2$$

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot \left(n_{br} - 0.5\right) \cdot d_{bh} \cdot t_{br} \qquad A_{nv} = 13.97\ cm^2$$

Net area in tension

$$A_{nt} := 2 \cdot (l_{ibr} - g_{br} - 0.5 \cdot d_{bh}) \cdot t_{br} \qquad A_{nt} = 4.686\ cm^2$$

Nominal strength block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min(R_{n1}, R_{n2}) \qquad R_n = 511.302\ kN$$

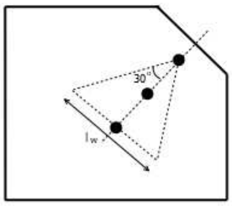
Interaction ratio in block shear

$$I_4 := \frac{2.0\ P}{R_n} \qquad I_4 = 0.411$$

Gusset tension yielding check

Length of Whitmore section

$$l_w := 2 \cdot l_{br} \cdot \tan(30\ deg) \qquad l_w = 161.658\ mm$$



Nominal strength of gusset in yielding

$$P_n := F_{yp} \cdot l_w \cdot t_g \qquad P_n = 646.632\ kN$$

Interaction ratio in tension yielding

$$I_5 := \frac{1.67\ P}{P_n} \qquad I_5 = 0.271$$

Gusset tension rupture check

Net area of gusset in tension

$$A_{ng} := (l_w - d_{bh}) \cdot t_g \qquad A_{ng} = 22.025\ cm^2$$

Nominal strength of gusset in rupture

$$P_n := F_{up} \cdot A_{ng} \qquad P_n = 881.012\ kN$$

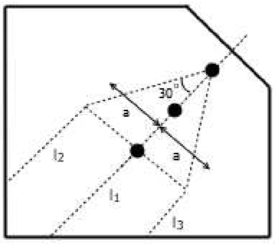
Interaction ratio in tension rupture

$$I_6 := \frac{2.0\ P}{P_n} \qquad I_6 = 0.238$$

Gusset buckling check

Half the length of the Whitmore section

$$a := \frac{l_w}{2} \qquad a = 80.829\ mm$$



Distance of the first bolt to the work point

$$l_o := loc_{br} + ed_1 \qquad l_o = 430\ mm$$

Buckling lengths along various points on the Whitmore section

$$l_1 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})}, l_o - \frac{e_b}{\sin(\theta_{br})}\right), 0\right) \qquad l_1 = 199.865\ mm$$

$$l_2 := \max\left(min\left(l_o - \frac{e_c}{\cos\left(\theta_{br}\right)} - a \cdot \tan\left(\theta_{br}\right), l_o - \frac{e_b}{\sin\left(\theta_{br}\right)} + a \cdot \tan\left(\theta_{br}\right)\right), 0\right)$$ $l_2 = 256.462\ mm$

$$l_3 := \max\left(min\left(l_o - \frac{e_c}{\cos\left(\theta_{br}\right)} + a \cdot \tan\left(\theta_{br}\right), l_o - \frac{e_b}{\sin\left(\theta_{br}\right)} - a \cdot \tan\left(\theta_{br}\right)\right), 0\right)$$ $l_3 = 143.268\ mm$

Average buckling length of gusset

$$l_{avg} := \frac{l_1 + l_2 + l_3}{3}$$ $l_{avg} = 199.865\ mm$

Effective length factor for gusset

$$k := 1.2$$

Moment of inertia of gusset

$$I_g := \frac{l_w \cdot t_g^{\ 3}}{12}$$ $I_g = 5.518\ cm^4$

Radius of gyration of gusset

$$r_g := \sqrt{\frac{I_g}{l_w \cdot t_g}}$$ $r_g = 4.619\ mm$

Elastic buckling stress

$$F_e := \frac{\pi^2 \cdot E}{\left(\frac{k \cdot l_{avg}}{r_g}\right)^2}$$ $F_e = 732.07\ MPa$

Critical stress in compression

$$F_{cr1} := \left(0.658^{\frac{F_{yp}}{F_e}}\right) \cdot F_{yp}$$

$$F_{cr2} := 0.877 \cdot F_e$$

$$F_{cr} := \mathbf{if}\left(\frac{k \cdot l_{avg}}{r_g} \le 4.71 \cdot \sqrt{\frac{E}{F_{yp}}}, F_{cr1}, F_{cr2}\right)$$ $F_{cr} = 216.703\ MPa$

Nominal strength of gusset in compression

$$P_n := F_{cr} \cdot l_w \cdot t_g$$ $P_n = 560.508\ kN$

Interaction ratio in compression

$$I_7 := \frac{1.67\ P}{P_n}$$ $I_7 = 0.313$

Gusset to beam weld check

Horizontal stress in weld

$$f_h := \frac{H_b}{2 \cdot l_g}$$ $f_h = 80.608\ \frac{kN}{m}$

Vertical stress in weld

$$f_{v.max} := \frac{V_b}{2 \cdot l_g} + \frac{3 \cdot M_b}{l_g^{\ 2}}$$ $f_{v.max} = 69.199\ \frac{kN}{m}$

Vertical stress in weld

$$f_{v.min} := \frac{V_b}{2 \cdot l_g} - \frac{3 \cdot M_b}{l_g^{\ 2}}$$ $f_{v.min} = 37.203\ \frac{kN}{m}$

Resultant maximum stress in weld

$$f_{max} := \sqrt{{f_h}^2 + {f_{v.max}}^2} \qquad f_{max} = 106.236 \ \frac{kN}{m}$$

Average stress in weld

$$f_{avg} := \frac{1}{2} \cdot \left(\sqrt{{f_h}^2 + {f_{v.max}}^2} + \sqrt{{f_h}^2 + {f_{v.min}}^2} \right) \qquad f_{avg} = 97.507 \ \frac{kN}{m}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_1 \qquad R_n = \left(1.636 \cdot 10^3\right) \ \frac{kN}{m}$$

Interaction ratio for weld check

$$I_8 := \frac{2.0 \ \max\left(f_{max}, 1.25 \ f_{avg}\right)}{R_n} \qquad I_8 = 0.149$$

Gusset rupture at weld check

Minimum thickness of plate required to develop strength of weld

$$t_{min} := \frac{2 \cdot 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_1}{0.6 \cdot F_{up}} \qquad t_{min} = 13.633 \ mm$$

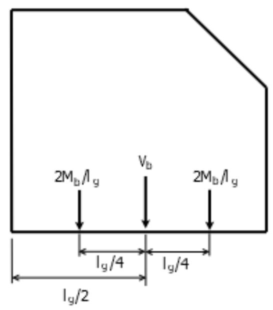
Interaction ratio in rupture

$$I_9 := \frac{t_{min}}{t_g} \qquad I_9 = 0.852$$

Beam web yielding check

Equivalent force at gusset to beam interface

$$N_{eq} := V_b + \frac{4 \cdot M_b}{l_g} \qquad N_{eq} = 51.093 \ kN$$



Nominal strength in web yielding

$$R_{n1} := F_{yb} \cdot t_{wb} \cdot \left(5 \cdot k_b + l_g\right)$$

$$R_{n2} := F_{yb} \cdot t_{wb} \cdot \left(2.5 \cdot k_b + l_g\right)$$

$$R_n := \text{if}\left(\alpha' > d_{xb}, R_{n1}, R_{n2}\right) \qquad R_n = 1430.231 \ kN$$

nteraction ratio in web yielding

$$I_{10} := \frac{1.5 \ N_{eq}}{R_n} \qquad I_{10} = 0.054$$

Beam web crippling check

Nominal strength in web crippling

$$R_{n1} := 0.8 \cdot {t_{wb}}^2 \cdot \left(1 + 3 \cdot \frac{l_g}{d_{xb}} \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_{n2} := 0.4 \cdot {t_{wb}}^2 \cdot \left(1 + 3 \cdot \frac{l_g}{d_{xb}} \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_{n3} := 0.4 \cdot {t_{wb}}^2 \cdot \left(1 + \left(\frac{4 \cdot l_g}{d_{xb}} - 0.2\right) \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_n := \text{if}\left(\alpha' < \frac{d_{xb}}{2}, R_{n1}, \text{if}\left(\frac{l_g}{d_{xb}} \le 0.2, R_{n2}, R_{n3}\right)\right) \qquad R_n = 1939.225\ kN$$

Interaction ratio in web crippling

$$I_{11} := \frac{2.0\ N_{eq}}{R_n} \qquad I_{11} = 0.053$$

Bolt shear at gusset to column connection

Area of bolt

$$A_b := \frac{\pi \cdot {d_b}^2}{4} \qquad A_b = 380.133\ mm^2$$

Nominal shear strength of bolt

$$R_n := F_{nv} \cdot A_b \qquad R_n = 141.409\ kN$$

Interaction ratio in bolt shear

$$I_{12} := \frac{2.0\ V_{cb}}{R_n} \qquad I_{12} = 0.095$$

Bolt bearing at clip angle at gusset to column connection

Clear distance between bolt holes/ hole and edge

$$l_{c3} := min\left(s - d_{bh}, ed_3 - 0.5 \cdot d_{bh}\right) \qquad l_{c3} = 18\ mm$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c3} \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_n = 109.728\ kN$$

Interaction ratio in bolt bearing

$$I_{13} := \frac{2.0\ V_{cb}}{R_n} \qquad I_{13} = 0.122$$

Bolt bearing at column web at gusset to column connection

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{wc} \cdot F_{uc}, 2.4 \cdot d_b \cdot t_{wc} \cdot F_{uc}\right) \qquad R_n = 230.208\ kN$$

Interaction ratio in bolt bearing

$$I_{14} := \frac{2.0\ V_{cb}}{R_n} \qquad I_{14} = 0.058$$

Clip angle shear yielding at gusset to column connection

Length of gusset to column clip

$$L_1 := \left(n_1 - 1\right) \cdot s + 2\ ed_3 \qquad L_1 = 200\ mm$$

Gross area in shear

$$A_{gv} := 2 \cdot L_1 \cdot t_a \qquad A_{gv} = 50.8\ cm^2$$

Nominal strength in shear yielding

$$R_n := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_n = 762\ kN$$

Resultant shear in clip angle

$$S_{r1} := \sqrt{{V_c}^2 + {H_c}^2} \qquad S_{r1} = 40.304\ kN$$

Interaction ratio in shear yielding

$$I_{15} := \frac{1.5\ S_{r1}}{R_n} \qquad I_{15} = 0.079$$

Clip angle shear rupture at gusset to column connection

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n_1 \cdot d_{bh} \cdot t_a \qquad A_{nv} = 32.512\ cm^2$$

Nominal strength in shear rupture

$$R_n := 0.6 \cdot F_{ua} \cdot A_{nv} \qquad R_n = 780.288\ kN$$

Interaction ratio in shear rupture

$$I_{16} := \frac{2.0\ S_{r1}}{R_n} \qquad I_{16} = 0.103$$

Clip angle block shear at gusset to column connection

Gross area subjected to block shear

$$A_{gv} := 2 \cdot \left(L_1 - ed_3\right) \cdot t_a \qquad A_{gv} = 43.18\ cm^2$$

Net area subjected to block shear

$$A_{nv} := A_{gv} - 2 \cdot \left(n_1 - 0.5\right) \cdot d_{bh} \cdot t_a \qquad A_{nv} = 27.94\ cm^2$$

Net area subjected to tension

$$A_{nt} := \left(2 \cdot l_{oa} + t_g - g - d_{bh}\right) \cdot t_a \qquad A_{nt} = 7.595\ cm^2$$

Nominal strength in block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min\left(R_{n1}, R_{n2}\right) \qquad R_n = 951.484\ kN$$

Interaction ratio in block shear

$$I_{17} := \frac{2.0\ V_c}{R_n} \qquad I_{17} = 0.085$$

Bolt tension at gusset to column connection

Required shear stress per bolt

$$f_{rv} := \frac{V_{cb}}{A_b} \qquad f_{rv} = 17.671\ MPa$$

Modified nominal tensile strength

$$F'_{nt} := min\left(1.3 \cdot F_{nt} - \frac{F_{nt}}{0.75 \cdot F_{nv}} \cdot f_{rv}, F_{nt}\right) \qquad F'_{nt} = 620\ MPa$$

Nominal tensile strength

$$R_n := F'_{nt} \cdot A_b \qquad R_n = 235.682\ kN$$

Interaction ratio for bolt tension

$$I_{18} := \frac{2.0\ H_{cb}}{R_n} \qquad I_{18} = 0$$

Bolt prying at clip angle at gusset to column connection

Available tension per bolt

$$B := \frac{F_{nt} \cdot A_b}{2.0} \qquad B = 117.841\ kN$$

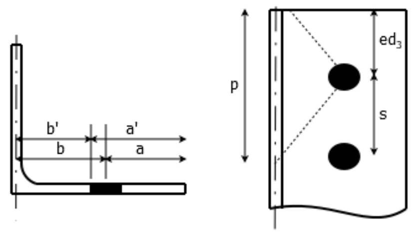
Clip dimensions for prying check

$$b := 0.5 \cdot \left(g - t_g - t_a\right) \qquad b = 40.65\ mm$$

$$a := l_{oa} - b - 0.5 \cdot t_a \qquad a = 41.9\ mm$$

$$b' := b - 0.5 \cdot d_b \qquad b' = 29.65\ mm$$

$$a' := min\left(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b\right) \qquad a' = 52.9\ mm$$



Tributary length

$$p := min\left(2 \cdot b, b + ed_3, s\right) \qquad p = 70\ mm$$

Ratios for prying

$$\delta := 1 - \frac{d_{bh}}{p} \qquad \delta = 0.657$$

$$\rho := \frac{b'}{a'} \qquad \rho = 0.56$$

Thickness required to develop bolt tension without prying

$$t_c := \sqrt{\frac{1.67 \cdot 4 \cdot B \cdot b'}{p \cdot F_{ua}}} \qquad t_c = 28.872\ mm$$

$$\alpha' := \frac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\frac{t_c}{t_a}\right)^2 - 1\right) \qquad \alpha' = 4.065$$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right) \qquad Q = 0.321$$

Available tension strength with prying

$$T_{av} := Q \cdot B \qquad T_{av} = 37.785\ kN$$

Interaction ratio in prying

$$I_{19} := \frac{H_{cb}}{T_{av}} \qquad I_{19} = 0$$

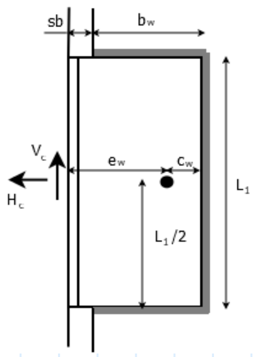
Weld check at gusset to column connection

Length of horizontal run of weld

$$b_w := l_{ia} - sb \qquad b_w = 64.2\ mm$$

Centroid of weld group

$$c_w := \frac{{b_w}^2}{2 \cdot b_w + L_1} \qquad c_w = 12.551\ mm$$



Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 63.649\ mm$$

Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L_1)^3}{12} - \frac{{b_w}^2 \cdot (b_w + L_1)^2}{2 \cdot b_w + L_1} \qquad I_w = 2075.344\ cm^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{H_c}{2 \cdot (2 \cdot b_w + L_1)} + \frac{V_c \cdot e_w \cdot L_1}{4 \cdot I_w} \qquad f_{wh} = 61.804\ \frac{kN}{m}$$

Vertical component of weld stress

$$f_{wv} := \frac{V_c}{2 \cdot (2 \cdot b_w + L_1)} + \frac{V_c \cdot e_w \cdot (b_w - c_w)}{2\ I_w} \qquad f_{wv} = 93.285\ \frac{kN}{m}$$

Resultant weld stress

$$f_w := \sqrt{{f_{wh}}^2 + {f_{wv}}^2} \qquad f_w = 111.902\ \frac{kN}{m}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_2 \qquad R_n = (1.636 \cdot 10^3)\ \frac{kN}{m}$$

Interaction ratio for weld check

$$I_{20} := \frac{2.0\ f_w}{R_n} \qquad I_{20} = 0.137$$

Gusset rupture at weld at gusset to column connection

Minimum web thickness to match weld strength

$$t_{g.min} := \frac{2.0 \cdot 2 \cdot f_w}{0.6 \cdot F_{up}} \qquad t_{g.min} = 1.865\ mm$$

Interaction ratio in web rupture

$$I_{21} := \frac{t_{g.min}}{t_g} \qquad I_{21} = 0.117$$

Bolt shear check at beam to column connection

Nominal shear strength of bolt

$$R_n := F_{nv} \cdot A_b \qquad R_n = 141.409\ kN$$

Interaction ratio in bolt shear

$$I_{22} := \frac{2.0\ V'_{bb}}{R_n} \qquad I_{22} = 0.486$$

Bolt bearing at clip angle at beam to column connection

Clear distance between bolt holes/ hole and edge

$$l_{c3} := min(s - d_{bh}, ed_3 - 0.5 \cdot d_{bh}) \qquad l_{c3} = 18\ mm$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c3} \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_n = 109.728\ kN$$

Interaction ratio in bolt bearing

$$I_{23} := \frac{2.0\ V'_{bb}}{R_n} \qquad I_{23} = 0.627$$

Bolt bearing at column web at beam to column connection

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{wc} \cdot F_{uc}, 2.4 \cdot d_b \cdot t_{wc} \cdot F_{uc}\right) \qquad R_n = 230.208\ kN$$

Interaction ratio in bolt bearing

$$I_{24} := \frac{2.0\ V'_{bb}}{R_n} \qquad I_{24} = 0.299$$

Clip angle shear yielding at beam to column connection

Length of gusset to column clip

$$L_2 := \left(n_2 - 1\right) \cdot s + 2\ ed_3 \qquad L_2 = 130\ mm$$

Gross area in shear

$$A_{gv} := 2 \cdot L_2 \cdot t_a \qquad A_{gv} = 33.02\ cm^2$$

Nominal strength in shear yielding

$$R_n := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_n = 495.3\ kN$$

Resultant shear in clip angle

$$S_{r2} := \sqrt{{V'_b}^2 + {H'_b}^2} \qquad S_{r2} = 159.132\ kN$$

Interaction ratio in shear yielding

$$I_{25} := \frac{1.5\ S_{r2}}{R_n} \qquad I_{25} = 0.482$$

Clip angle shear rupture at beam to column connection

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n_2 \cdot d_{bh} \cdot t_a \qquad A_{nv} = 20.828\ cm^2$$

Nominal strength in shear rupture

$$R_n := 0.6 \cdot F_{ua} \cdot A_{nv} \qquad R_n = 499.872\ kN$$

Interaction ratio in shear rupture

$$I_{26} := \frac{2.0\ S_{r2}}{R_n} \qquad I_{26} = 0.637$$

Clip angle block shear at beam to column connection

Gross area subjected to block shear

$$A_{gv} := 2 \cdot \left(L_2 - ed_3\right) \cdot t_a \qquad A_{gv} = 25.4\ cm^2$$

Net area subjected to block shear

$$A_{nv} := A_{gv} - 2 \cdot (n_2 - 0.5) \cdot d_{bh} \cdot t_a \qquad A_{nv} = 16.256\ cm^2$$

Net area subjected to tension

$$A_{nt} := (2 \cdot l_{oa} + t_{wb} - g - d_{bh}) \cdot t_a \qquad A_{nt} = 7.074\ cm^2$$

Nominal strength in block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min(R_{n1}, R_{n2}) \qquad R_n = 663.956\ kN$$

Interaction ratio in block shear

$$I_{27} := \frac{2.0\ V'_b}{R_n} \qquad I_{27} = 0.414$$

Bolt tension check at beam to column connection

Required shear stress per bolt

$$f_{rv} := \frac{V'_{bb}}{A_b} \qquad f_{rv} = 90.469\ MPa$$

Modified nominal tensile strength

$$F'_{nt} := min\left(1.3 \cdot F_{nt} - \frac{2.0\ F_{nt}}{F_{nv}} \cdot f_{rv}, F_{nt}\right) \qquad F'_{nt} = 504.437\ MPa$$

Nominal tensile strength

$$R_n := F'_{nt} \cdot A_b \qquad R_n = 191.753\ kN$$

Interaction ratio for bolt tension

$$I_{28} := \frac{2.0\ H'_{bb}}{R_n} \qquad I_{28} = 0.209$$

Bolt prying at clip angle at beam to column connection

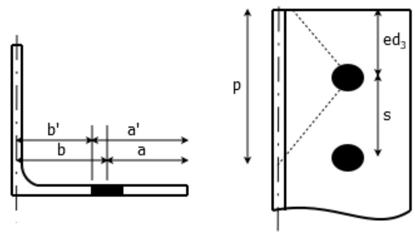
Clip dimensions for prying check

$$b := 0.5 \cdot (g - t_{wb} - t_a) \qquad b = 42.7\ mm$$

$$a := l_{oa} - b - 0.5 \cdot t_a \qquad a = 39.85\ mm$$

$$b' := b - 0.5 \cdot d_b \qquad b' = 31.7\ mm$$

$$a' := min(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b) \qquad a' = 50.85\ mm$$



Tributary length

$$p := min(2 \cdot b, b + ed_3, s) \qquad p = 70\ mm$$

Ratios for prying

$$\delta := 1 - \frac{d_{bh}}{p} \qquad \delta = 0.657$$

$$\rho := \frac{b'}{a'} \qquad \rho = 0.623$$

Thickness required to develop bolt tension without prying

$$t_c := \sqrt{\frac{1.67 \cdot 4 \cdot B \cdot b'}{p \cdot F_{ua}}} \qquad t_c = 29.853\ mm$$

$$\alpha' := \frac{1}{\delta \cdot (1+\rho)} \cdot \left(\left(\frac{t_c}{t_a}\right)^2 - 1\right) \qquad \alpha' = 4.242$$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c}\right)^2 \cdot (1+\delta \cdot \alpha'), \left(\frac{t_a}{t_c}\right)^2 \cdot (1+\delta)\right)\right) \qquad Q = 0.3$$

Available tension strength with prying

$$T_{av} := Q \cdot B \qquad T_{av} = 35.342\ kN$$

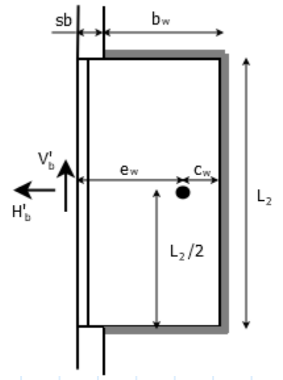
Interaction ratio in prying

$$I_{29} := \frac{H'_{bb}}{T_{av}} \qquad I_{29} = 0.566$$

Weld check at beam to column connection

Centroid of weld group

$$c_w := \frac{{b_w}^2}{2 \cdot b_w + L_2} \qquad c_w = 15.951\ mm$$



Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 60.249\ mm$$

Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L_2)^3}{12} - \frac{{b_w}^2 \cdot (b_w + L_2)^2}{2 \cdot b_w + L_2} \qquad I_w = 836.237\ cm^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{H'_b}{2 \cdot (2 \cdot b_w + L_2)} + \frac{V'_b \cdot e_w \cdot L_2}{4 \cdot I_w} \qquad f_{wh} = 476.907\ \frac{kN}{m}$$

Vertical component of weld stress

$$f_{wv} := \frac{V'_b}{2 \cdot (2 \cdot b_w + L_2)} + \frac{V'_b \cdot e_w \cdot (b_w - c_w)}{2\ I_w} \qquad f_{wv} = 505.278\ \frac{kN}{m}$$

Resultant weld stress

$$f_w := \sqrt{{f_{wh}}^2 + {f_{wv}}^2} \qquad f_w = 694.799\ \frac{kN}{m}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_2 \qquad R_n = \left(1.636 \cdot 10^3\right)\ \frac{kN}{m}$$

Interaction ratio for weld check

$$I_{30} := \frac{2.0\ f_w}{R_n} \qquad I_{30} = 0.849$$

Web rupture at weld at beam to column connection

Minimum web thickness to match weld strength

$$t_{wb.min} := \frac{2.0 \cdot 2 \cdot f_w}{0.6 \cdot F_{ub}} \qquad t_{wb.min} = 0.456\ in$$

Interaction ratio in web rupture

$$I_{31} := \frac{t_{wb.min}}{t_{wb}} \qquad I_{31} = 0.973$$

Validation Results

The calculated ratios are compared with the output of Osoconn and if it is within a tolerance of 1% the result is deemed to be OK.

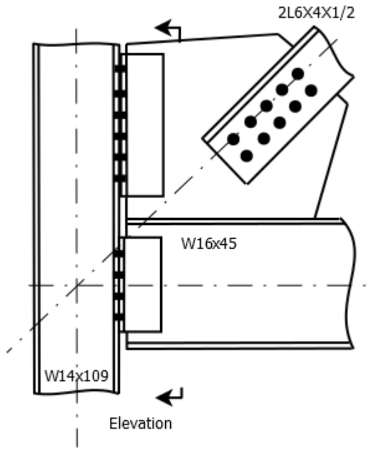
Table 5: Validation problem 4 results

	Interaction Ratio		
Check	Calculated	Osoconn	Result
Bolt shear check at brace	0.248	0.247	OK
Bolt bearing on brace check	0.638	0.638	OK
Bolt bearing on gusset	0.506	0.506	OK
Brace tension rupture	0.337	0.335	OK
Brace block shear	0.411	0.411	OK
Gusset tension yielding	0.271	0.271	OK
Gusset tension rupture	0.238	0.238	OK
Gusset buckling	0.313	0.313	OK
Gusset to beam weld	0.149	0.149	OK
Gusset rupture at weld	0.852	0.852	OK
Beam web yielding	0.054	0.054	OK
Beam web crippling	0.053	0.053	OK
Bolt shear at gusset to col. conn.	0.095	0.095	OK
Bolt bearing at clip at gusset to col. conn.	0.122	0.122	OK
Bolt bearing at web at gusset to col. conn.	0.058	0.058	OK
Clip shear yielding at gusset to col. conn.	0.079	0.079	OK
Clip shear rupture at gusset to col. conn.	0.103	0.103	OK
Clip block shear at gusset to col. conn.	0.085	0.085	OK
Bolt tension at gusset to col. conn.	0.0	0.0	OK
Bolt prying at clip at gusset to col. conn.	0.0	0.0	OK
Weld check at gusset to col. conn.	0.137	0.137	OK
Gusset rupture at weld at gusset to col. conn.	0.117	0.117	OK
Bolt shear check at beam to col. conn.	0.486	0.486	OK
Bolt bearing at clip at beam to col. conn.	0.627	0.627	OK
Bolt bearing at web at beam to col. conn.	0.299	0.299	OK
Clip shear yielding at beam to col. conn.	0.482	0.482	OK
Clip shear rupture at beam to col. conn.	0.637	0.637	OK
Clip block shear at beam to col. conn.	0.414	0.414	OK
Bolt tension check at beam to col. conn.	0.209	0.209	OK
Bolt prying at clip at beam to col. conn.	0.566	0.566	OK
Weld check at beam to col. conn.	0.849	0.85	OK
Web rupture at weld at beam to col. conn.	0.973	0.973	OK

2.6 Validation Problem 5

Problem Statement

Design a beam column single brace connection for a double angle 2L6X4X1/2 brace with long leg back-to-back framing into the junction between a W16X45 beam and W14X109 column flange using the LRFD method. The brace has an angle of 50 degrees with the horizontal. The brace has an axial force of 141kip, and the beam has a shear force of 40kip and transfer force of 30kip. The beam and column are ASTM A992. The clip angles and plates are of grade ASTM A36. The bolts are ASTM 3125 A325 slip critical type.



Design Inputs

Material Properties

Material grade for plate	ASTM A36
Yield strength	$F_{yp} := 36\ ksi$
Tensile strength	$F_{up} := 58\ ksi$
Material grade of beam	ASTM A992
Yield strength	$F_{yb} := 50\ ksi$
Tensile strength	$F_{ub} := 65\ ksi$
Material grade of column	ASTM A992
Yield strength	$F_{yc} := 50\ ksi$
Tensile strength	$F_{uc} := 65\ ksi$
Material grade of angles	ASTM A36
Yield strength	$F_{ya} := 36\ ksi$
Tensile strength	$F_{ua} := 58\ ksi$
Material grade for weld electrode	E70XX
Tensile strength	$F_{EXX} := 70\ ksi$
Material specification for bolts	ASTM 3125 A325
Tensile strength	$F_{nt} := 90\ ksi$
Shear strength	$F_{nv} := 54\ ksi$

Young's modulus for steel	$E := 29000\ ksi$
Design Forces	
Axial force in brace	$P := 141\ kip$
Shear force in beam	$SF := 40\ kip$
Transfer force in beam	$TF := 30\ kip$
Connection Geometry	
Brace section	2L6X4X1/2
Thickness	$t_{br} := 0.5\ in$
Outstanding leg length	$l_{obr} := 4\ in$
Back-to-back leg length	$l_{ibr} := 6\ in$
Gross cross section area	$A_{br} := 9.5\ in^2$
Centroid of brace outstanding leg	$x'_{br} := 0.981\ in$
Brace angle with horizontal	$\theta_{br} := 50\ deg$
Beam section	W16X45
Section depth	$d_{xb} := 16.1\ in$
Flange width	$b_{fb} := 7.04\ in$
Flange thickness	$t_{fb} := 0.565\ in$
Web thickness	$t_{wb} := 0.345\ in$
Distance from outer face to fillet edge	$k_b := 0.967\ in$
Column section	W14X109
Section depth	$d_{xc} := 14.3\ in$
Flange width	$b_{fc} := 14.6\ in$
Flange thickness	$t_{fc} := 0.86\ in$
Web thickness	$t_{wc} := 0.525\ in$
Cross section area of column	$A_c := 32\ in^2$
Distance form outer face to fillet edge	$k_c := 1.46\ in$
Clip angle section	L4X3X1/2
Thickness	$t_a := 0.5\ in$
Outstanding leg length	$l_{oa} := 4\ in$
Welded leg length	$l_{ia} := 3\ in$
Gusset plate thickness	$t_g := 0.75\ in$
Gusset to beam interface length	$l_g := 25\ in$
Clip distance from beam	$d := 1\ in$
Bolt diameter	$d_b := 0.75\ in$
Bolt hole diameter	$d_{bh} := \frac{13}{16}\ in$
Slip coefficient (class B surface)	$\mu := 0.5$
Bolt pretension	$T_{pre} := 28\ kip$
Number of bolts per row on brace	$n_{br} := 5$
Number of bolts at gusset clip	$n_1 := 6$

Number of bolts at beam clip $n_2 := 4$
Bolt spacing $s := 3\ in$
Bolt row spacing $s_r := 2.5\ in$
Bolt gage on brace $g_{br} := 1.75\ in$
Bolt gage on column $g := 5.0\ in$

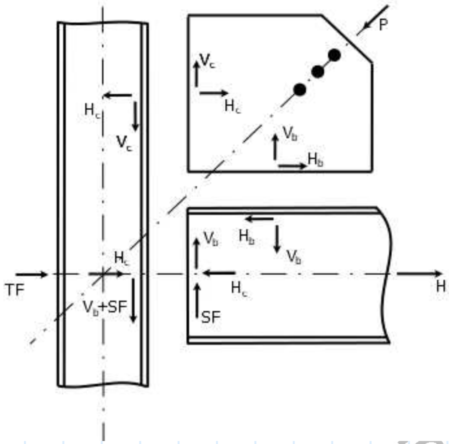
Bolt edge distance on brace $ed_1 := 1.25\ in$
Bolt edge distance on gusset $ed_2 := 1.25\ in$
Bolt edge distance on clip $ed_3 := 1.5\ in$

Gusset to beam weld thickness $w_1 := 0.313\ in$
Clip to beam weld thickness $w_2 := 0.25\ in$

Connection setback $sb := 0.5\ in$
Distance of the brace edge from the work point $loc_{br} := 20\ in$

Design Calculations

UFM forces in connection



Location of the centroid of the gusset to beam connection

$$\alpha' := 0.5 \cdot l_g \qquad \alpha' = 12.5\ in$$

Length of clip at gusset to column interface

$$l_{cl1} := (n_1 - 1) \cdot s + 2 \cdot ed_3 \qquad l_{cl1} = 18\ in$$

Location of the centroid of the gusset to column connection

$$\beta := d + 0.5 \cdot l_{cl1} \qquad \beta = 10\ in$$

Eccentricity of gusset to column connection

$$e_c := 0.5 \cdot d_{xc} \qquad e_c = 7.15\ in$$

Eccentricity of gusset to beam connection

$$e_b := 0.5 \cdot d_{xb} \qquad e_b = 8.05\ in$$

Dimension

$$r := \sqrt{(\alpha' + e_c)^2 + (\beta + e_b)^2} \qquad r = 26.682\ in$$

Vertical force at gusset to column interface

$V_c := \frac{\beta}{r} \cdot P$ $\quad V_c = 52.845\ kip$

Vertical force per bolt at gusset to column interface

$V_{cb} := \frac{V_c}{2 \cdot n_1}$ $\quad V_{cb} = 4.404\ kip$

Horizontal force at gusset to column interface

$H_c := \frac{e_c}{r} \cdot P$ $\quad H_c = 37.784\ kip$

Horizontal force per bolt at gusset to column interface

$H_{cb} := \frac{H_c}{2 \cdot n_1}$ $\quad H_{cb} = 3.149\ kip$

Vertical force at gusset to beam interface

$V_b := \frac{e_b}{r} \cdot P$ $\quad V_b = 42.54\ kip$

Total vertical force in beam clip connection

$V'_b := SF + V_b$ $\quad V'_b = 82.54\ kip$

Vertical force per bolt in beam clip connection

$V'_{bb} := \frac{V'_b}{2 \cdot n_2}$ $\quad V'_{bb} = 10.318\ kip$

Horizontal force at gusset to beam interface

$H_b := \frac{\alpha'}{r} \cdot P$ $\quad H_b = 66.056\ kip$

Total horizontal force in beam clip connection

$H'_b := TF + H_c$ $\quad H'_b = 67.784\ kip$

Horizontal force per bolt in beam clip connection

$H'_{bb} := \frac{H'_b}{2 \cdot n_2}$ $\quad H'_{bb} = 8.473\ kip$

Required α for no moment at gusset to beam connection

$\alpha := e_b \cdot \tan(\theta_{br}) - e_c + \beta \cdot \tan(\theta_{br})$ $\quad \alpha = 14.361\ in$

Additional moment at gusset to beam interface

$M_b := \text{abs}(V_b \cdot (\alpha - \alpha'))$ $\quad M_b = 79.173\ kip \cdot in$

Bolt shear at brace to gusset connection

Shear per bolt

$P_b := \frac{P}{2 \cdot n_{br}}$ $\quad P_b = 14.1\ kip$

Nominal slip resistance of bolt

$$R_n := \mu \cdot 1.13 \cdot T_{pre} \cdot 2 \qquad R_n = 31.64\ kip$$

Interaction ratio in bolt shear

$$I_0 := \frac{P_b}{R_n} \qquad I_0 = 0.446$$

Bolt bearing on brace check

Minimum clear distance for bearing check

$$l_{c1} := min\left(s - d_{bh}, ed_1 - 0.5 \cdot d_{bh}\right) \qquad l_{c1} = 0.021\ m$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c1} \cdot t_{br} \cdot F_{ua}, 2.4 \cdot d_b \cdot t_{br} \cdot F_{ua}\right) \qquad R_n = 29.363\ kip$$

Interaction ratio in bolt bearing at brace

$$I_1 := \frac{0.5\ P_b}{0.75 \cdot R_n} \qquad I_1 = 0.32$$

Bolt bearing on gusset check

Minimum clear distance for bearing on gusset

$$l_{c2} := min\left(s - d_{bh}, ed_2 - 0.5 \cdot d_{bh}\right) \qquad l_{c1} = 0.021\ m$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c2} \cdot t_g \cdot F_{up}, 2.4 \cdot d_b \cdot t_g \cdot F_{up}\right) \qquad R_n = 44.044\ kip$$

Interaction ratio in bolt bearing at gusset

$$I_2 := \frac{P_b}{0.75 \cdot R_n} \qquad I_2 = 0.427$$

Tension rupture at brace to gusset connection

Net cross section area of brace

$$A_{nbr} := A_{br} - 4\ d_{bh} \cdot t_{br} \qquad A_{nbr} = 7.875\ in^2$$

Length of connection

$$l_{br} := s \cdot \left(n_{br} - 1\right) \qquad l_{br} = 12\ in$$

Shear lag factor

$$U := 1 - \frac{x'_{br}}{l_{br}} \qquad U = 0.918$$

Brace strength in tension rupture

$$P_n := F_{ua} \cdot U \cdot A_{nbr} \qquad P_n = 419.411\ kip$$

Interaction ratio for brace tension rupture

$$I_3 := \frac{P}{0.75 \cdot P_n} \qquad I_3 = 0.448$$

Brace block shear check

Gross area in shear

$$A_{gv} := 2 \cdot \left(\left(n_{br} - 1\right) \cdot s + ed_1\right) \cdot t_{br} \qquad A_{gv} = 13.25\ in^2$$

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot (n_{br} - 0.5) \cdot d_{bh} \cdot t_{br} \qquad A_{nv} = 9.594\ in^2$$

Net area in tension

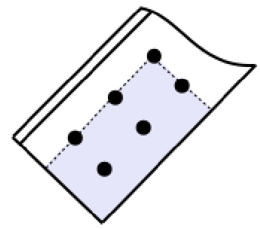
$$A_{nt} := 2 \cdot (l_{ibr} - g_{br} - 1.5 \cdot d_{bh}) \cdot t_{br} \qquad A_{nt} = 3.031\ in^2$$

Nominal strength block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min(R_{n1}, R_{n2}) \qquad R_n = 462.013\ kip$$



Interaction ratio in block shear

$$I_4 := \frac{P}{0.75 \cdot R_n} \qquad I_4 = 0.407$$

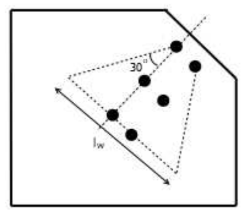
Gusset tension yielding check

Length of Whitmore section

$$l_w := 2 \cdot l_{br} \cdot \tan(30\ deg) + s_r \qquad l_w = 16.356\ in$$

Nominal strength of gusset in yielding

$$P_n := F_{yp} \cdot l_w \cdot t_g \qquad P_n = 441.623\ kip$$



Interaction ratio in tension yielding

$$I_5 := \frac{P}{0.9 \cdot P_n} \qquad I_5 = 0.355$$

Gusset tension rupture check

Net area of gusset in tension

$$A_{ng} := (l_w - 2 \cdot d_{bh}) \cdot t_g \qquad A_{ng} = 11.049\ in^2$$

Nominal strength of gusset in rupture

$$P_n := F_{up} \cdot A_{ng} \qquad P_n = 640.816\ kip$$

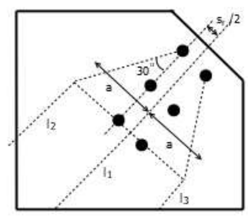
Interaction ratio in tension rupture

$$I_6 := \frac{P}{0.75 \cdot P_n} \qquad I_6 = 0.293$$

Gusset buckling check

Half the length of the Whitmore section

$$a := \frac{l_w}{2} \qquad a = 8.178\ in$$



Distance of the first bolt to the work point

$$l_o := loc_{br} + ed_1 \qquad l_o = 21.25\ in$$

Buckling lengths along various points on the Whitmore section

$$l_1 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})}, l_o - \frac{e_b}{\sin(\theta_{br})}\right), 0\right) \qquad l_1 = 10.127\ in$$

$$l_2 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})} - a \cdot \tan(\theta_{br}), l_o - \frac{e_b}{\sin(\theta_{br})} + a \cdot \tan(\theta_{br})\right), 0\right) \qquad l_2 = 0.38\ in$$

$$l_3 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})} + a \cdot \tan(\theta_{br}), l_o - \frac{e_b}{\sin(\theta_{br})} - a \cdot \tan(\theta_{br})\right), 0\right) \qquad l_3 = 0.995\ in$$

Average buckling length of gusset

$$l_{avg} := \frac{l_1 + l_2 + l_3}{3} \qquad l_{avg} = 3.834\ in$$

Effective length factor for gusset

$$k := 1.2$$

Moment of inertia of gusset

$$I_g := \frac{l_w \cdot t_g^{\ 3}}{12} \qquad I_g = 0.575\ in^4$$

Radius of gyration of gusset

$$r_g := \sqrt{\frac{I_g}{l_w \cdot t_g}} \qquad r_g = 0.217\ in$$

Elastic buckling stress

$$F_e := \frac{\pi^2 \cdot E}{\left(\frac{k \cdot l_{avg}}{r_g}\right)^2} \qquad F_e = 633.85\ ksi$$

Critical stress in compression

$$F_{cr1} := \left(0.658^{\frac{F_{yp}}{F_e}}\right) \cdot F_{yp}$$

$$F_{cr2} := 0.877 \cdot F_e$$

$$F_{cr} := \text{if}\left(\frac{k \cdot l_{avg}}{r_g} \le 4.71 \cdot \sqrt{\frac{E}{F_{yp}}}, F_{cr1}, F_{cr2}\right) \qquad F_{cr} = 35.154\ ksi$$

Nominal strength of gusset in compression

$$P_n := F_{cr} \cdot l_w \cdot t_g \qquad P_n = 431.249\ kip$$

Interaction ratio in compression

$$I_7 := \frac{P}{0.9 \cdot P_n} \qquad I_7 = 0.363$$

Gusset block shear check

Gross area in shear

$$A_{gv} := 2\ \left(\left(n_{br} - 1\right) \cdot s + ed_2\right) \cdot t_g \qquad A_{gv} = 19.875\ in^2$$

Net area in shear

$$A_{nv} := A_{gv} - \left(2 \cdot n_{br} - 1\right) \cdot d_{bh} \cdot t_g \qquad A_{nv} = 14.391\ in^2$$

Net area in tension

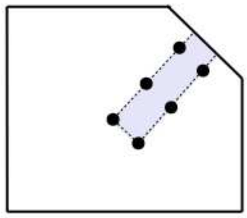
$$A_{nt} := (s_r - d_{bh}) \cdot t_g \qquad A_{nt} = 1.266\ in^2$$

Nominal strength block shear

$$R_{n1} := 0.6 \cdot F_{up} \cdot A_{nv} + F_{up} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{yp} \cdot A_{gv} + F_{up} \cdot A_{nt}$$

$$R_n := min(R_{n1}, R_{n2}) \qquad R_n = 502.706\ kip$$



Interaction ratio in block shear

$$I_8 := \frac{P}{0.75 \cdot R_n} \qquad I_8 = 0.374$$

Gusset to beam weld check

Horizontal stress in weld

$$f_h := \frac{H_b}{2 \cdot l_g} \qquad f_h = 1.321\ \frac{kip}{in}$$

Vertical stress in weld

$$f_{v.max} := \frac{V_b}{2 \cdot l_g} + \frac{3 \cdot M_b}{{l_g}^2} \qquad f_{v.max} = 1.231\ \frac{kip}{in}$$

Vertical stress in weld

$$f_{v.min} := \frac{V_b}{2 \cdot l_g} - \frac{3 \cdot M_b}{{l_g}^2} \qquad f_{v.min} = 0.471\ \frac{kip}{in}$$

Resultant maximum stress in weld

$$f_{max} := \sqrt{{f_h}^2 + {f_{v.max}}^2} \qquad f_{max} = 1.806\ \frac{kip}{in}$$

Average stress in weld

$$f_{avg} := \frac{1}{2} \cdot \left(\sqrt{{f_h}^2 + {f_{v.max}}^2} + \sqrt{{f_h}^2 + {f_{v.min}}^2}\right) \qquad f_{avg} = 1.604\ \frac{kip}{in}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_1 \qquad R_n = 9.296\ \frac{kip}{in}$$

Interaction ratio for weld check

$$I_9 := \frac{\max(f_{max}, 1.25\ f_{avg})}{0.75 \cdot R_n} \qquad I_9 = 0.288$$

Gusset rupture at weld check

Minimum thickness of plate required to develop strength of weld

$$t_{min} := \frac{2 \cdot 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_1}{0.6 \cdot F_{up}} \qquad t_{min} = 0.534\ in$$

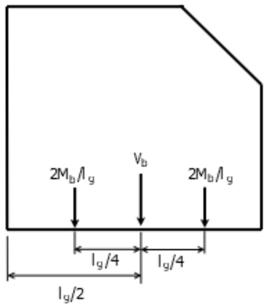
Interaction ratio in rupture

$$I_{10} := \frac{t_{min}}{t_g} \qquad I_{10} = 0.712$$

Beam web yielding check

Equivalent force at gusset to beam interface

$$N_{eq} := V_b + \frac{4 \cdot M_b}{l_g} \qquad N_{eq} = 55.208\ kip$$



Nominal strength in web yielding

$$R_{n1} := F_{yb} \cdot t_{wb} \cdot (5 \cdot k_b + l_g)$$

$$R_{n2} := F_{yb} \cdot t_{wb} \cdot (2.5 \cdot k_b + l_g)$$

$$R_n := \text{if}\left(\alpha' > d_{xb}, R_{n1}, R_{n2}\right) \qquad R_n = 472.952\ kip$$

nteraction ratio in web yielding

$$I_{11} := \frac{N_{eq}}{R_n} \qquad I_{11} = 0.117$$

Beam web crippling check

Nominal strength in web crippling

$$R_{n1} := 0.8 \cdot t_{wb}^{2} \cdot \left(1 + 3 \cdot \frac{l_g}{d_{xb}} \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_{n2} := 0.4 \cdot t_{wb}^{2} \cdot \left(1 + 3 \cdot \frac{l_g}{d_{xb}} \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_{n3} := 0.4 \cdot t_{wb}^{2} \cdot \left(1 + \left(\frac{4 \cdot l_g}{d_{xb}} - 0.2\right) \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_n := \text{if}\left(\alpha' < \frac{d_{xb}}{2}, R_{n1}, \text{if}\left(\frac{l_g}{d_{xb}} \le 0.2, R_{n2}, R_{n3}\right)\right) \qquad R_n = 283.799\ kip$$

Interaction ratio in web crippling

$$I_{12} := \frac{N_{eq}}{0.75 \cdot R_n} \qquad I_{12} = 0.259$$

Bolt shear at gusset to column connection

Slip resistance reduction factor

$$k_{sc} := 1 - \frac{H_{cb}}{1.13 \cdot T_{pre}} \qquad k_{sc} = 0.9$$

Nominal slip resistance of bolt

$$R_n := \mu \cdot 1.13 \cdot T_{pre} \cdot k_{sc} \qquad R_n = 14.246\ kip$$

Interaction ratio in bolt shear

$$I_{13} := \frac{V_{cb}}{R_n} \qquad I_{13} = 0.309$$

Bolt bearing at clip angle at gusset to column connection

Clear distance between bolt holes/ hole and edge

$$l_{c3} := min\left(s - d_{bh}, ed_3 - 0.5 \cdot d_{bh}\right) \qquad l_{c3} = 1.094\ in$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c3} \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_n = 38.063\ kip$$

Interaction ratio in bolt bearing

$$I_{14} := \frac{V_{cb}}{0.75\ R_n} \qquad I_{14} = 0.154$$

Bolt bearing at column flange at gusset to column connection

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{fc} \cdot F_{uc}, 2.4 \cdot d_b \cdot t_{fc} \cdot F_{uc}\right) \qquad R_n = 100.62\ kip$$

Interaction ratio in bolt bearing

$$I_{15} := \frac{V_{cb}}{0.75\ R_n} \qquad I_{15} = 0.058$$

Clip angle shear yielding at gusset to column connection

Length of gusset to column clip

$$L_1 := \left(n_1 - 1\right) \cdot s + 2\ ed_3 \qquad L_1 = 18\ in$$

Gross area in shear

$$A_{gv} := 2 \cdot L_1 \cdot t_a \qquad A_{gv} = 18\ in^2$$

Nominal strength in shear yielding

$$R_n := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_n = 388.8\ kip$$

Resultant shear in clip angle

$$S_{r1} := \sqrt{V_c^{\ 2} + H_c^{\ 2}} \qquad S_{r1} = 64.963\ kip$$

Interaction ratio in shear yielding

$$I_{16} := \frac{S_{r1}}{R_n} \qquad I_{16} = 0.167$$

Clip angle shear rupture at gusset to column connection

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n_1 \cdot d_{bh} \cdot t_a \qquad A_{nv} = 13.125\ in^2$$

Nominal strength in shear rupture

$$R_n := 0.6 \cdot F_{ua} \cdot A_{nv} \qquad R_n = 456.75\ kip$$

Interaction ratio in shear rupture

$$I_{17} := \frac{S_{r1}}{0.75\ R_n} \qquad I_{17} = 0.19$$

Clip angle block shear at gusset to column connection

Gross area subjected to block shear

$$A_{gv} := 2 \cdot \left(L_1 - ed_3\right) \cdot t_a \qquad A_{gv} = 16.5\ in^2$$

Net area subjected to block shear

$$A_{nv} := A_{gv} - 2 \cdot \left(n_1 - 0.5\right) \cdot d_{bh} \cdot t_a \qquad A_{nv} = 12.031\ in^2$$

Net area subjected to tension

$A_{nt} := (2 \cdot l_{oa} + t_g - g - d_{bh}) \cdot t_a$ $\qquad A_{nt} = 1.469\ in^2$

Nominal strength in block shear

$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$

$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$

$R_n := min(R_{n1}, R_{n2})$ $\qquad R_n = 441.588\ kip$

Interaction ratio in block shear

$I_{18} := \dfrac{V_c}{0.75\ R_n}$ $\qquad I_{18} = 0.16$

Bolt tension at gusset to column connection

Area of bolt

$A_b := \dfrac{\pi \cdot {d_b}^2}{4}$ $\qquad A_b = 0.442\ in^2$

Nominal tensile strength

$R_n := F_{nt} \cdot A_b$ $\qquad R_n = 39.761\ kip$

Interaction ratio for bolt tension

$I_{19} := \dfrac{H_{cb}}{0.75\ R_n}$ $\qquad I_{19} = 0.106$

Bolt prying at clip angle at gusset to column connection

Available tension per bolt

$B := 0.75\ F_{nt} \cdot A_b$ $\qquad B = 29.821\ kip$

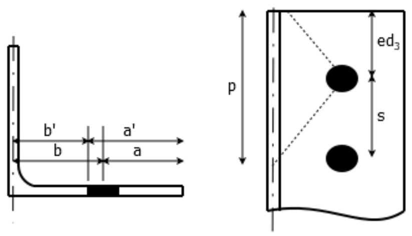
Clip dimensions for prying check

$b := 0.5 \cdot (g - t_g - t_a)$ $\qquad b = 1.875\ in$

$a := l_{oa} - b - 0.5 \cdot t_a$ $\qquad a = 1.875\ in$

$b' := b - 0.5 \cdot d_b$ $\qquad b' = 1.5\ in$

$a' := min(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b)$ $\qquad a' = 2.25\ in$



Tributary length

$p := min(2 \cdot b, b + ed_3, s)$ $\qquad p = 3\ in$

Ratios for prying

$\delta := 1 - \dfrac{d_{bh}}{p}$ $\qquad \delta = 0.729$

$\rho := \dfrac{b'}{a'}$ $\qquad \rho = 0.667$

Thickness required to develop bolt tension without prying

$t_c := \sqrt{\dfrac{4 \cdot B \cdot b'}{0.9 \cdot p \cdot F_{ua}}}$ $\qquad t_c = 1.069\ in$

$$\alpha' := \frac{1}{\delta \cdot (1+\rho)} \cdot \left(\left(\frac{t_c}{t_a} \right)^2 - 1 \right) \qquad \alpha' = 2.938$$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c} \right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c} \right)^2 \cdot (1+\delta) \right) \right) \qquad Q = 0.378$$

Available tension strength with prying

$$T_{av} := Q \cdot B \qquad T_{av} = 11.283\ kip$$

Interaction ratio in prying

$$I_{20} := \frac{H_{cb}}{T_{av}} \qquad I_{20} = 0.279$$

Bolt prying at column flange at gusset to column connection

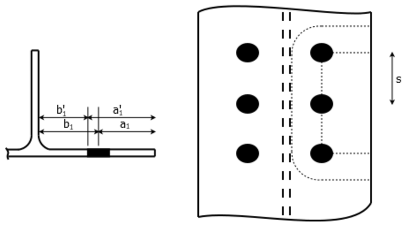
Clip dimensions for prying check

$$b_1 := 0.5 \cdot (g - t_{wc}) \qquad b_1 = 2.238\ in$$

$$a_1 := min\left(0.5 \cdot (b_{fc} - g), 0.5 \cdot (2 \cdot l_{oa} + t_g - g)\right) \qquad a_1 = 1.875\ in$$

$$b'_1 := b_1 - 0.5 \cdot d_b \qquad b'_1 = 1.863\ in$$

$$a'_1 := min\left(a_1 + 0.5 \cdot d_b, 1.25 \cdot b_1 + 0.5 \cdot d_b\right) \qquad a'_1 = 2.25\ in$$



Tributary length

$$p_1 := \frac{(n_1 - 1) \cdot s + \pi \cdot b_1 + (b_{fc} - g)}{n_1} \qquad p_1 = 5.272\ in$$

Ratios for prying

$$\delta_1 := 1 - \frac{d_{bh}}{p_1} \qquad \delta_1 = 0.846$$

$$\rho_1 := \frac{b'_1}{a'_1} \qquad \rho_1 = 0.828$$

Thickness required to develop bolt tension without prying

$$t_{c1} := \sqrt{\frac{4 \cdot B \cdot b'_1}{0.9 \cdot p_1 \cdot F_{uc}}} \qquad t_{c1} = 0.849\ in$$

$$\alpha'_1 := \frac{1}{\delta_1 \cdot (1+\rho_1)} \cdot \left(\left(\frac{t_{c1}}{t_{fc}} \right)^2 - 1 \right) \qquad \alpha'_1 = -0.017$$

Proportion of tension strength available

$$Q_1 := \text{if}\left(\alpha'_1 < 0, 1, \text{if}\left(0 \le \alpha'_1 \le 1, \left(\frac{t_{fc}}{t_{c1}} \right)^2 \cdot (1 + \delta_1 \cdot \alpha'_1), \left(\frac{t_{fc}}{t_{c1}} \right)^2 \cdot (1+\delta_1) \right) \right) \qquad Q_1 = 1$$

Available tension strength with prying

$$T_{av1} := Q_1 \cdot B \qquad T_{av1} = 29.821\ kip$$

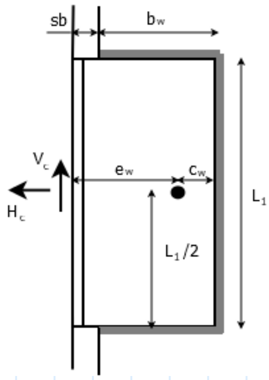
Interaction ratio in prying

$$I_{21} := \frac{H_{cb}}{T_{av1}} \qquad I_{21} = 0.106$$

Weld check at gusset to column connection

Length of horizontal run of weld

$$b_w := l_{ia} - sb \qquad b_w = 2.5\ in$$



Centroid of weld group

$$c_w := \frac{b_w^{\ 2}}{2 \cdot b_w + L_1} \qquad c_w = 0.272\ in$$

Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 2.728\ in$$

Polar moment of inertia of weld group

$$I_w := \frac{\left(2 \cdot b_w + L_1\right)^3}{12} - \frac{b_w^{\ 2} \cdot \left(b_w + L_1\right)^2}{2 \cdot b_w + L_1} \qquad I_w = 899.718\ in^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{H_c}{2 \cdot \left(2 \cdot b_w + L_1\right)} + \frac{V_c \cdot e_w \cdot L_1}{4 \cdot I_w} \qquad f_{wh} = 1.542\ \frac{kip}{in}$$

Vertical component of weld stress

$$f_{wv} := \frac{V_c}{2 \cdot \left(2 \cdot b_w + L_1\right)} + \frac{V_c \cdot e_w \cdot \left(b_w - c_w\right)}{2\ I_w} \qquad f_{wv} = 1.327\ \frac{kip}{in}$$

Resultant weld stress

$$f_w := \sqrt{f_{wh}^{\ 2} + f_{wv}^{\ 2}} \qquad f_w = 2.035\ \frac{kip}{in}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_2 \qquad R_n = 7.425\ \frac{kip}{in}$$

Interaction ratio for weld check

$$I_{22} := \frac{f_w}{0.75\ R_n} \qquad I_{22} = 0.365$$

Gusset rupture at weld at gusset to column connection

Minimum web thickness to match weld strength

$$t_{g.min} := \frac{2 \cdot f_w}{0.75 \cdot 0.6 \cdot F_{up}} \qquad t_{g.min} = 0.156\ in$$

Interaction ratio in web rupture

$$I_{23} := \frac{t_{g.min}}{t_g} \qquad I_{23} = 0.208$$

Column web local yielding at gusset to column connection

Nominal strength in web local yielding

$$R_n := F_{yc} \cdot t_{wc} \cdot \left(2.5 \cdot k_c + L_1\right) \qquad R_n = 568.313\ kip$$

Interaction ratio in web local yielding

$$I_{24} := \frac{H_c}{R_n} \qquad I_{24} = 0.066$$

Column web local crippling at gusset to column connection

Nominal strength in web crippling

$$R_{n1} := 0.40 \cdot t_{wc}^{\ 2} \cdot \left(1 + 3 \cdot \frac{L_1}{d_{xc}} \cdot \left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yc} \cdot t_{fc}}{t_{wc}}}$$

$$R_{n2} := 0.40 \cdot t_{wc}^{\ 2} \cdot \left(1 + \left(\frac{4 \cdot L_1}{d_{xc}} - 0.2\right) \cdot \left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yc} \cdot t_{fc}}{t_{wc}}}$$

$$R_n := \mathrm{if}\left(L_1 \div d_{xc} \le 0.2, R_{n1}, R_{n2}\right) \qquad R_n = 561.762\ kip$$

Interaction ratio in web crippling

$$I_{25} := \frac{H_c}{0.75\ R_n} \qquad I_{25} = 0.09$$

Bolt shear check at beam to column connection

Slip resistance reduction factor

$$k_{sc2} := 1 - \frac{H'_{bb}}{1.13 \cdot T_{pre}} \qquad k_{sc2} = 0.732$$

Nominal slip resistance of bolt

$$R_n := \mu \cdot 1.13 \cdot T_{pre} \cdot k_{sc2} \qquad R_n = 11.583\ kip$$

Interaction ratio in bolt shear

$$I_{26} := \frac{V'_{bb}}{R_n} \qquad I_{26} = 0.891$$

Bolt bearing at clip angle at beam to column connection

Clear distance between bolt holes/ hole and edge

$$l_{c3} := min\left(s - d_{bh}, ed_3 - 0.5 \cdot d_{bh}\right) \qquad l_{c3} = 1.094\ in$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c3} \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_n = 38.063\ kip$$

Interaction ratio in bolt bearing

$$I_{27} := \frac{V'_{bb}}{0.75\ R_n} \qquad I_{27} = 0.361$$

Bolt bearing at column flange at beam to column connection

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{fc} \cdot F_{uc}, 2.4 \cdot d_b \cdot t_{fc} \cdot F_{uc}\right) \qquad R_n = 100.62\ kip$$

Interaction ratio in bolt bearing

$$I_{28} := \frac{V'_{bb}}{0.75\ R_n} \qquad I_{28} = 0.137$$

Clip angle shear yielding at beam to column connection

Length of gusset to column clip

$$L_2 := \left(n_2 - 1\right) \cdot s + 2\ ed_3 \qquad L_2 = 12\ in$$

Gross area in shear

$$A_{gv} := 2 \cdot L_2 \cdot t_a \qquad A_{gv} = 12 \ in^2$$

Nominal strength in shear yielding

$$R_n := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_n = 259.2 \ kip$$

Resultant shear in clip angle

$$S_{r2} := \sqrt{{V'_b}^2 + {H'_b}^2} \qquad S_{r2} = 106.806 \ kip$$

Interaction ratio in shear yielding

$$I_{29} := \frac{S_{r2}}{R_n} \qquad I_{29} = 0.412$$

Clip angle shear rupture at beam to column connection

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n_2 \cdot d_{bh} \cdot t_a \qquad A_{nv} = 8.75 \ in^2$$

Nominal strength in shear rupture

$$R_n := 0.6 \cdot F_{ua} \cdot A_{nv} \qquad R_n = 304.5 \ kip$$

Interaction ratio in shear rupture

$$I_{30} := \frac{S_{r2}}{0.75 \ R_n} \qquad I_{30} = 0.468$$

Clip angle block shear at beam to column connection

Gross area subjected to block shear

$$A_{gv} := 2 \cdot \left(L_2 - ed_3\right) \cdot t_a \qquad A_{gv} = 10.5 \ in^2$$

Net area subjected to block shear

$$A_{nv} := A_{gv} - 2 \cdot \left(n_2 - 0.5\right) \cdot d_{bh} \cdot t_a \qquad A_{nv} = 7.656 \ in^2$$

Net area subjected to tension

$$A_{nt} := \left(2 \cdot l_{oa} + t_{wb} - g - d_{bh}\right) \cdot t_a \qquad A_{nt} = 1.266 \ in^2$$

Nominal strength in block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min\left(R_{n1}, R_{n2}\right) \qquad R_n = 300.243 \ kip$$

Interaction ratio in block shear

$$I_{31} := \frac{V'_b}{0.75 \ R_n} \qquad I_{31} = 0.367$$

Bolt tension check at beam to column connection

Nominal tensile strength

$$R_n := F_{nt} \cdot A_b \qquad R_n = 39.761 \ kip$$

Interaction ratio for bolt tension

$$I_{32} := \frac{H'_{bb}}{0.75\ R_n}$$ $I_{32} = 0.284$

Bolt prying at clip angle at beam to column connection

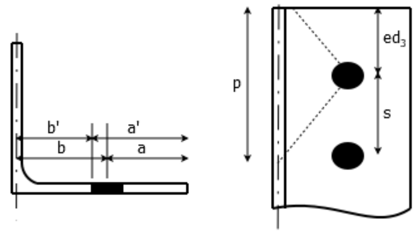
Clip dimensions for prying check

$b := 0.5 \cdot (g - t_{wb} - t_a)$ $b = 2.078\ in$

$a := l_{oa} - b - 0.5 \cdot t_a$ $a = 1.673\ in$

$b' := b - 0.5 \cdot d_b$ $b' = 1.703\ in$

$a' := min(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b)$ $a' = 2.048\ in$



Tributary length

$$p := min(2 \cdot b, b + ed_3, s)$$ $p = 3\ in$

Ratios for prying

$$\delta := 1 - \frac{d_{bh}}{p}$$ $\delta = 0.729$

$$\rho := \frac{b'}{a'}$$ $\rho = 0.832$

Thickness required to develop bolt tension without prying

$$t_c := \sqrt{\frac{4 \cdot B \cdot b'}{0.9 \cdot p \cdot F_{ua}}}$$ $t_c = 1.139\ in$

$$\alpha' := \frac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\frac{t_c}{t_a}\right)^2 - 1\right)$$ $\alpha' = 3.135$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right)$$ $Q = 0.333$

Available tension strength with prying

$$T_{av} := Q \cdot B$$ $T_{av} = 9.941\ kip$

Interaction ratio in prying

$$I_{33} := \frac{H'_{bb}}{T_{av}}$$ $I_{33} = 0.852$

Bolt prying at column flange at beam to column connection

Clip dimensions for prying check

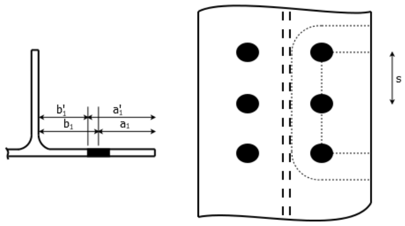
$$b_1 := 0.5 \cdot (g - t_{wc})$$ $b_1 = 2.238\ in$

$$a_1 := min(0.5 \cdot (b_{fc} - g), 0.5 \cdot (2 \cdot l_{oa} + t_{wb} - g))$$ $a_1 = 1.673\ in$

$$b'_1 := b_1 - 0.5 \cdot d_b$$ $b'_1 = 1.863\ in$

$a'_1 := min\left(a_1 + 0.5 \cdot d_b, 1.25 \cdot b_1 + 0.5 \cdot d_b\right)$ $a'_1 = 2.048\ in$

Tributary length



$$p_1 := \frac{(n_2 - 1) \cdot s + \pi \cdot b_1 + (b_{fc} - g)}{n_2}$$ $p_1 = 6.407\ in$

Ratios for prying

$$\delta_1 := 1 - \frac{d_{bh}}{p_1}$$ $\delta_1 = 0.873$

$$\rho_1 := \frac{b'_1}{a'_1}$$ $\rho_1 = 0.91$

Thickness required to develop bolt tension without prying

$$t_{c1} := \sqrt{\frac{4 \cdot B \cdot b'_1}{0.9 \cdot p_1 \cdot F_{uc}}}$$ $t_{c1} = 0.77\ in$

$$\alpha'_1 := \frac{1}{\delta_1 \cdot (1 + \rho_1)} \cdot \left(\left(\frac{t_{c1}}{t_{fc}}\right)^2 - 1\right)$$ $\alpha'_1 = -0.119$

Proportion of tension strength available

$$Q_1 := \text{if}\left(\alpha'_1 < 0, 1, \text{if}\left(0 \le \alpha'_1 \le 1, \left(\frac{t_{fc}}{t_{c1}}\right)^2 \cdot \left(1 + \delta_1 \cdot \alpha'_1\right), \left(\frac{t_{fc}}{t_{c1}}\right)^2 \cdot \left(1 + \delta_1\right)\right)\right)$$ $Q_1 = 1$

Available tension strength with prying

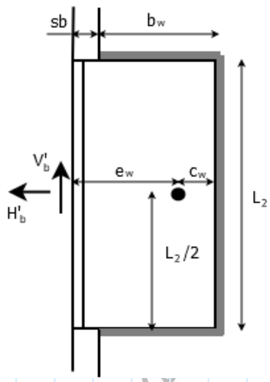
$$T_{av1} := Q_1 \cdot B$$ $T_{av1} = 29.821\ kip$

Interaction ratio in prying at column flange

$$I_{34} := \frac{H'_{bb}}{T_{av1}}$$ $I_{34} = 0.284$

Weld check at beam to column connection

Centroid of weld group



$$c_w := \frac{b_w^2}{2 \cdot b_w + L_2}$$ $c_w = 0.368\ in$

Eccentricity of shear force

$$e_w := l_{ia} - c_w$$ $e_w = 2.632\ in$

Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L_2)^3}{12} - \frac{b_w^2 \cdot (b_w + L_2)^2}{2 \cdot b_w + L_2}$$ $I_w = 332.119\ in^3$

Horizontal component of weld stress

$$f_{wh} := \frac{H'_b}{2 \cdot (2 \cdot b_w + L_2)} + \frac{V'_b \cdot e_w \cdot L_2}{4 \cdot I_w}$$ $f_{wh} = 3.956\ \frac{kip}{in}$

Vertical component of weld stress

$$f_{wv} := \frac{V'_b}{2 \cdot (2 \cdot b_w + L_2)} + \frac{V'_b \cdot e_w \cdot (b_w - c_w)}{2\ I_w}$$ $$f_{wv} = 3.125\ \frac{kip}{in}$$

Resultant weld stress

$$f_w := \sqrt{f_{wh}^{\ 2} + f_{wv}^{\ 2}}$$ $$f_w = 5.042\ \frac{kip}{in}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_2$$ $$R_n = 7.425\ \frac{kip}{in}$$

Interaction ratio for weld check

$$I_{35} := \frac{f_w}{0.75\ R_n}$$ $$I_{35} = 0.905$$

Beam web rupture at weld at beam to column connection

Minimum web thickness to match weld strength

$$t_{g.min} := \frac{2 \cdot f_w}{0.75 \cdot 0.6 \cdot F_{ub}}$$ $$t_{g.min} = 0.345\ in$$

Interaction ratio in web rupture

$$I_{36} := \frac{t_{g.min}}{t_{wb}}$$ $$I_{36} = 0.999$$

Column web local yielding at beam to column connection

Nominal strength in web local yielding

$$R_n := F_{yc} \cdot t_{wc} \cdot (2.5 \cdot k_c + L_2)$$ $$R_n = 410.813\ kip$$

Interaction ratio in web local yielding

$$I_{37} := \frac{H'_b}{R_n}$$ $$I_{37} = 0.165$$

Column web local crippling at beam to column connection

Nominal strength in web crippling

$$R_{n1} := 0.40 \cdot t_{wc}^{\ 2} \cdot \left(1 + 3 \cdot \frac{L_2}{d_{xc}} \cdot \left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yc} \cdot t_{fc}}{t_{wc}}}$$

$$R_{n2} := 0.40 \cdot t_{wc}^{\ 2} \cdot \left(1 + \left(\frac{4 \cdot L_2}{d_{xc}} - 0.2\right) \cdot \left(\frac{t_{wc}}{t_{fc}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yc} \cdot t_{fc}}{t_{wc}}}$$

$$R_n := \text{if}\left(L_2 \div d_{xc} \le 0.2, R_{n1}, R_{n2}\right)$$ $$R_n = 425.744\ kip$$

Interaction ratio in web crippling

$$I_{38} := \frac{H'_b}{0.75\ R_n}$$ $$I_{38} = 0.212$$

Validation Results

The calculated ratios are compared with the output of Osoconn and if it is within a tolerance of 1% the result is deemed to be OK.

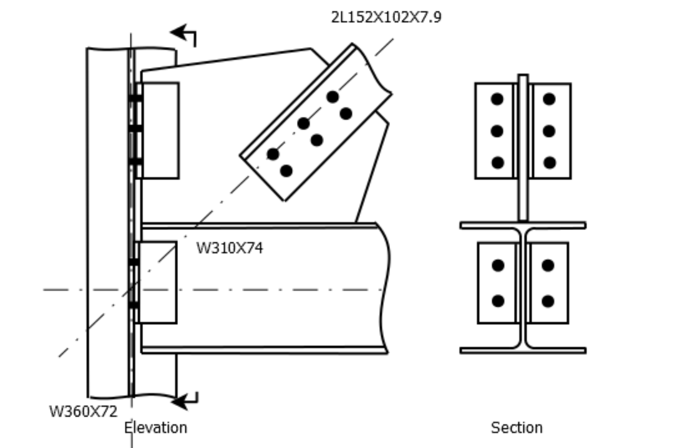
Table 6: Validation problem 5 results

	Interaction Ratio		
Check	Calculated	Osoconn	Result
Bolt shear check at brace	0.446	0.446	OK
Bolt bearing on brace check	0.32	0.32	OK
Bolt bearing on gusset	0.427	0.427	OK
Brace tension rupture	0.448	0.448	OK
Brace block shear	0.407	0.407	OK
Gusset tension yielding	0.355	0.355	OK
Gusset tension rupture	0.293	0.293	OK
Gusset buckling	0.363	0.363	OK
Gusset block shear	0.374	0.374	OK
Gusset to beam weld	0.288	0.288	OK
Gusset rupture at weld	0.712	0.712	OK
Beam web yielding	0.117	0.117	OK
Beam web crippling	0.259	0.259	OK
Bolt shear at gusset to col. conn.	0.309	0.309	OK
Bolt bearing at clip at gusset to col. conn.	0.154	0.154	OK
Bolt bearing at flange at gusset to col. conn.	0.058	0.058	OK
Clip shear yielding at gusset to col. conn.	0.167	0.167	OK
Clip shear rupture at gusset to col. conn.	0.19	0.19	OK
Clip block shear at gusset to col. conn.	0.16	0.16	OK
Bolt tension at gusset to col. conn.	0.106	0.106	OK
Bolt prying at clip at gusset to col. conn.	0.279	0.279	OK
Bolt prying at flange at gusset to col. conn.	0.106	0.106	OK
Weld check at gusset to col. conn.	0.365	0.365	OK
Gusset rupture at weld at gusset to col. conn.	0.208	0.208	OK
Web local yielding at gusset to col. conn.	0.066	0.066	OK
Web local crippling at gusset to col. conn.	0.09	0.09	OK
Bolt shear check at beam to col. conn.	0.891	0.891	OK
Bolt bearing at clip at beam to col. conn.	0.361	0.361	OK
Bolt bearing at flange at beam to col. conn.	0.137	0.137	OK
Clip shear yielding at beam to col. conn.	0.412	0.412	OK
Clip shear rupture at beam to col. conn.	0.468	0.468	OK
Clip block shear at beam to col. conn.	0.367	0.367	OK
Bolt tension check at beam to col. conn.	0.284	0.284	OK
Bolt prying at clip at beam to col. conn.	0.852	0.852	OK
Bolt prying at flange at beam to col. conn.	0.284	0.284	OK
Weld check at beam to col. conn.	0.905	0.906	OK
Beam web rupture at weld at beam to col. conn.	0.999	0.999	OK
Web local yielding at beam to col. conn.	0.165	0.165	OK
Web local crippling at beam to col. conn.	0.212	0.212	OK

2.7 Validation Problem 6

Problem Statement

Design a beam column single brace connection for a double angle 2L152X102X7.9 brace with long leg back-to-back framing into the junction between a W310X74 beam and W360X72 column flange using the ASD method. The brace has an angle of 35 degrees with the horizontal. The brace has an axial force of 125kN, and the beam has a shear force of 45kN and transfer force of 70kN. The beam, column, clip angles and plates are of grade ASTM A36. The bolts are ASTM 3125 A325 bearing type.



Design Inputs

Material Properties

Material grade for plate	ASTM A36
Yield strength	$F_{yp} := 250\ MPa$
Tensile strength	$F_{up} := 400\ MPa$
Material grade of beam	ASTM A36
Yield strength	$F_{yb} := 250\ MPa$
Tensile strength	$F_{ub} := 400\ MPa$
Material grade of column	ASTM A36
Yield strength	$F_{yc} := 250\ MPa$
Tensile strength	$F_{uc} := 400\ MPa$
Material grade of angles	ASTM A36
Yield strength	$F_{ya} := 250\ MPa$
Tensile strength	$F_{ua} := 400\ MPa$
Material grade for weld electrode	E70XX
Tensile strength	$F_{EXX} := 482\ MPa$
Material specification for bolts	ASTM 3125 A325
Tensile strength	$F_{nt} := 620\ MPa$
Shear strength	$F_{nv} := 372\ MPa$

Young's modulus for steel	$E := 200000\ MPa$

Design Forces

Axial force in brace	$P := 125\ kN$
Shear force in beam	$SF := 45\ kN$
Transfer force in beam	$TF := 70\ kN$

Connection Geometry

Brace section	2L152X102X7.9
Thickness	$t_{br} := 7.94\ mm$
Outstanding leg length	$l_{obr} := 102\ mm$
Back-to-back leg length	$l_{ibr} := 152\ mm$
Gross cross section area	$A_{br} := 3900\ mm^2$
Centroid of brace outstanding leg	$x'_{br} := 23.1\ mm$
Brace angle with horizontal	$\theta_{br} := 35\ deg$
Beam section	W310X74
Section depth	$d_{xb} := 310\ mm$
Flange width	$b_{fb} := 205\ mm$
Flange thickness	$t_{fb} := 16.3\ mm$
Web thickness	$t_{wb} := 9.4\ mm$
Distance from outer face to fillet edge	$k_b := 29\ mm$
Column section	W360X72
Section depth	$d_{xc} := 351\ mm$
Flange width	$b_{fc} := 204\ mm$
Flange thickness	$t_{fc} := 15.1\ mm$
Web thickness	$t_{wc} := 8.64\ mm$
Cross section area of column	$A_c := 9100\ mm^2$
Distance form outer face to fillet edge	$k_c := 30.2\ mm$
Clip angle section	L89X76X12.7
Thickness	$t_a := 12.7\ mm$
Outstanding leg length	$l_{oa} := 88.9\ mm$
Welded leg length	$l_{ia} := 76.2\ mm$
Gusset plate thickness	$t_g := 16\ mm$
Gusset to beam interface length	$l_g := 400\ mm$
Clip distance from beam	$d := 25\ mm$
Bolt diameter	$d_b := 22\ mm$
Bolt hole diameter	$d_{bh} := 24\ mm$
Number of bolts per row on brace	$n_{br} := 3$
Number of bolts at gusset clip	$n_1 := 3$
Number of bolts at beam clip	$n_2 := 2$
Bolt spacing	$s := 70\ mm$
Bolt row spacing	$s_r := 60\ mm$

Bolt gage on brace $g_{br} := 45\ mm$

Bolt gage on column $g := 100\ mm$

Bolt edge distance on brace $ed_1 := 30\ mm$

Bolt edge distance on gusset $ed_2 := 30\ mm$

Bolt edge distance on clip $ed_3 := 30\ mm$

Gusset to beam weld thickness $w_1 := 8\ mm$

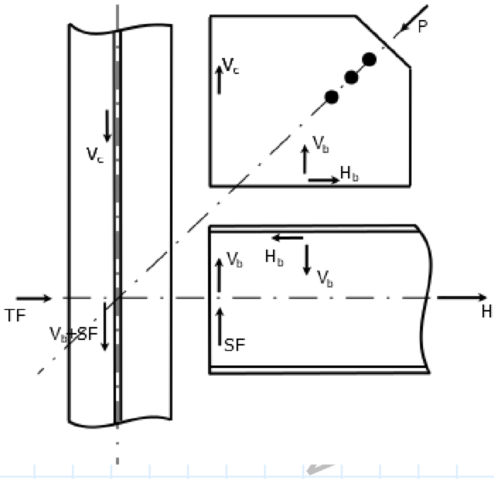
Clip to beam weld thickness $w_2 := 6\ mm$

Connection setback $sb := 12\ mm$

Distance of the brace edge from the work point $loc_{br} := 400\ mm$

Design Calculations

UFM forces in connection



Location of the centroid of the gusset to beam connection

$\alpha' := 0.5 \cdot l_g$ $\alpha' = 200\ mm$

Length of clip at gusset to column interface

$l_{cl1} := (n_1 - 1) \cdot s + 2 \cdot ed_3$ $l_{cl1} = 200\ mm$

Location of the centroid of the gusset to column connection

$\beta := d + 0.5 \cdot l_{cl1}$ $\beta = 125\ mm$

Eccentricity of gusset to column connection

$e_c := 0\ mm$ $e_c = 0\ mm$

Eccentricity of gusset to beam connection

$e_b := 0.5 \cdot d_{xb}$ $e_b = 155\ mm$

Dimension

$r := \sqrt{(\alpha' + e_c)^2 + (\beta + e_b)^2}$ $r = 344.093\ mm$

Vertical force at gusset to column interface

$V_c := \frac{\beta}{r} \cdot P$ $V_c = 45.409\ kN$

Vertical force per bolt at gusset to column interface

$$V_{cb} := \frac{V_c}{2 \cdot n_1}$$ $V_{cb} = 7.568\ kN$

Horizontal force at gusset to column interface

$$H_c := \frac{e_c}{r} \cdot P$$ $H_c = 0\ kN$

Horizontal force per bolt at gusset to column interface

$$H_{cb} := \frac{H_c}{2 \cdot n_1}$$ $H_{cb} = 0\ kN$

Vertical force at gusset to beam interface

$$V_b := \frac{e_b}{r} \cdot P$$ $V_b = 56.307\ kN$

Total vertical force in beam clip connection

$$V'_b := SF + V_b$$ $V'_b = 101.307\ kN$

Vertical force per bolt in beam clip connection

$$V'_{bb} := \frac{V'_b}{2 \cdot n_2}$$ $V'_{bb} = 25.327\ kN$

Horizontal force at gusset to beam interface

$$H_b := \frac{\alpha'}{r} \cdot P$$ $H_b = 72.655\ kN$

Total horizontal force in beam clip connection

$$H'_b := TF + H_c$$ $H'_b = 70\ kN$

Horizontal force per bolt in beam clip connection

$$H'_{bb} := \frac{H'_b}{2 \cdot n_2}$$ $H'_{bb} = 17.5\ kN$

Required α for no moment at gusset to beam connection

$$\alpha := e_b \cdot \tan\left(\theta_{br}\right) - e_c + \beta \cdot \tan\left(\theta_{br}\right)$$ $\alpha = 196.058\ mm$

Additional moment at gusset to beam interface

$$M_b := \text{abs}\left(V_b \cdot \left(\alpha - \alpha'\right)\right)$$ $M_b = 0.222\ kN \cdot m$

Bolt shear at brace to gusset connection

Shear per bolt

$$P_b := \frac{P}{2 \cdot n_{br}}$$ $P_b = 20.833\ kN$

Area of bolt

$$A_b := \frac{\pi \cdot {d_b}^2}{4}$$ $A_b = 380.133\ mm^2$

Nominal shear strength of bolt

$$R_n := 2 \cdot F_{nv} \cdot A_b$$ $R_n = 282.819\ kN$

Interaction ratio in bolt shear

$$I_0 := \frac{2.0\ P_b}{R_n} \qquad I_0 = 0.147$$

Bolt bearing on brace check

Minimum clear distance for bearing check

$$l_{c1} := min\left(s - d_{bh}, ed_1 - 0.5 \cdot d_{bh}\right) \qquad l_{c1} = 18\ mm$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c1} \cdot t_{br} \cdot F_{ua}, 2.4 \cdot d_b \cdot t_{br} \cdot F_{ua}\right) \qquad R_n = 68.602\ kN$$

Interaction ratio in bolt bearing at brace

$$I_1 := \frac{2.0 \cdot 0.5\ P_b}{R_n} \qquad I_1 = 0.304$$

Bolt bearing on gusset check

Minimum clear distance for bearing on gusset

$$l_{c2} := min\left(s - d_{bh}, ed_2 - 0.5 \cdot d_{bh}\right) \qquad l_{c1} = 18\ mm$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c2} \cdot t_g \cdot F_{up}, 2.4 \cdot d_b \cdot t_g \cdot F_{up}\right) \qquad R_n = 138.24\ kN$$

Interaction ratio in bolt bearing at gusset

$$I_2 := \frac{2.0\ P_b}{R_n} \qquad I_2 = 0.301$$

Tension rupture at brace to gusset connection

Net cross section area of brace

$$A_{nbr} := A_{br} - 4 \cdot d_{bh} \cdot t_{br} \qquad A_{nbr} = 31.378\ cm^2$$

Length of connection

$$l_{br} := s \cdot \left(n_{br} - 1\right) \qquad l_{br} = 140\ mm$$

Shear lag factor

$$U := 1 - \frac{x'_{br}}{l_{br}} \qquad U = 0.835$$

Brace strength in tension rupture

$$P_n := F_{ua} \cdot U \cdot A_{nbr} \qquad P_n = 1048.012\ kN$$

Interaction ratio for brace tension rupture

$$I_3 := \frac{2.0\ P}{P_n} \qquad I_3 = 0.239$$

Brace block shear check

Gross area in shear

$$A_{gv} := 2 \cdot \left(\left(n_{br} - 1\right) \cdot s + ed_1\right) \cdot t_{br} \qquad A_{gv} = 26.996\ cm^2$$

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot \left(n_{br} - 0.5\right) \cdot d_{bh} \cdot t_{br} \qquad A_{nv} = 17.468\ cm^2$$

Net area in tension

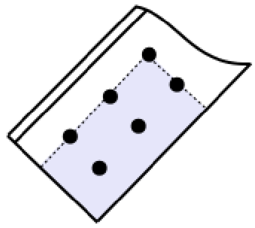
$$A_{nt} := 2 \cdot (l_{ibr} - g_{br} - 1.5 \cdot d_{bh}) \cdot t_{br} \qquad A_{nt} = 11.275\ cm^2$$

Nominal strength block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min(R_{n1}, R_{n2}) \qquad R_n = 855.932\ kN$$



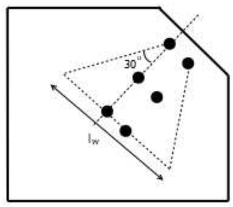
Interaction ratio in block shear

$$I_4 := \frac{2.0\ P}{R_n} \qquad I_4 = 0.292$$

Gusset tension yielding check

Length of Whitmore section

$$l_w := 2 \cdot l_{br} \cdot \tan(30\ deg) + s_r \qquad l_w = 221.658\ mm$$



Nominal strength of gusset in yielding

$$P_n := F_{yp} \cdot l_w \cdot t_g \qquad P_n = 886.632\ kN$$

Interaction ratio in tension yielding

$$I_5 := \frac{1.67\ P}{P_n} \qquad I_5 = 0.235$$

Gusset tension rupture check

Net area of gusset in tension

$$A_{ng} := (l_w - 2 \cdot d_{bh}) \cdot t_g \qquad A_{ng} = 27.785\ cm^2$$

Nominal strength of gusset in rupture

$$P_n := F_{up} \cdot A_{ng} \qquad P_n = 1111.412\ kN$$

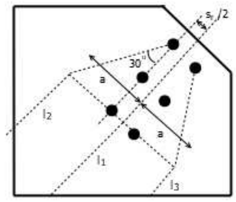
Interaction ratio in tension rupture

$$I_6 := \frac{2.0\ P}{P_n} \qquad I_6 = 0.225$$

Gusset buckling check

Half the length of the Whitmore section

$$a := \frac{l_w}{2} \qquad a = 110.829\ mm$$



Distance of the first bolt to the work point

$$l_o := loc_{br} + ed_1 \qquad l_o = 430\ mm$$

Buckling lengths along various points on the Whitmore section

$$l_1 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})}, l_o - \frac{e_b}{\sin(\theta_{br})}\right), 0\right) \qquad l_1 = 159.766\ mm$$

$$l_2 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})} - a \cdot \tan(\theta_{br}), l_o - \frac{e_b}{\sin(\theta_{br})} + a \cdot \tan(\theta_{br})\right), 0\right) \qquad l_2 = 237.369\ mm$$

$$l_3 := \max\left(min\left(l_o - \frac{e_c}{\cos(\theta_{br})} + a \cdot \tan(\theta_{br}), l_o - \frac{e_b}{\sin(\theta_{br})} - a \cdot \tan(\theta_{br})\right), 0\right) \qquad l_3 = 82.162\ mm$$

Average buckling length of gusset

$$l_{avg} := \frac{l_1 + l_2 + l_3}{3} \qquad l_{avg} = 159.766\ mm$$

Effective length factor for gusset

$$k := 1.2$$

Moment of inertia of gusset

$$I_g := \frac{l_w \cdot t_g^{\ 3}}{12} \qquad I_g = 7.566\ cm^4$$

Radius of gyration of gusset

$$r_g := \sqrt{\frac{I_g}{l_w \cdot t_g}} \qquad r_g = 4.619\ mm$$

Elastic buckling stress

$$F_e := \frac{\pi^2 \cdot E}{\left(\frac{k \cdot l_{avg}}{r_g}\right)^2} \qquad F_e = 1145.668\ MPa$$

Critical stress in compression

$$F_{cr1} := \left(0.658^{\frac{F_{yp}}{F_e}}\right) \cdot F_{yp}$$

$$F_{cr2} := 0.877 \cdot F_e$$

$$F_{cr} := \text{if}\left(\frac{k \cdot l_{avg}}{r_g} \le 4.71 \cdot \sqrt{\frac{E}{F_{yp}}}, F_{cr1}, F_{cr2}\right) \qquad F_{cr} = 228.178\ MPa$$

Nominal strength of gusset in compression

$$P_n := F_{cr} \cdot l_w \cdot t_g \qquad P_n = 809.241\ kN$$

Interaction ratio in compression

$$I_7 := \frac{1.67\ P}{P_n} \qquad I_7 = 0.258$$

Gusset block shear check

Gross area in shear

$$A_{gv} := 2\ \left(\left(n_{br} - 1\right) \cdot s + ed_2\right) \cdot t_g \qquad A_{gv} = 54.4\ cm^2$$

Net area in shear

$$A_{nv} := A_{gv} - \left(2 \cdot n_{br} - 1\right) \cdot d_{bh} \cdot t_g \qquad A_{nv} = 35.2\ cm^2$$

Net area in tension

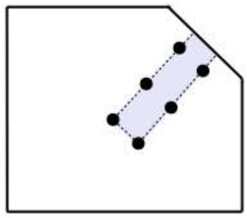
$$A_{nt} := \left(s_r - d_{bh}\right) \cdot t_g \qquad A_{nt} = 5.76\ cm^2$$

Nominal strength block shear

$$R_{n1} := 0.6 \cdot F_{up} \cdot A_{nv} + F_{up} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{yp} \cdot A_{gv} + F_{up} \cdot A_{nt}$$

$$R_n := min\left(R_{n1}, R_{n2}\right) \qquad R_n = 1046.4\ kN$$



Interaction ratio in block shear

$$I_8 := \frac{2.0\ P}{R_n} \qquad I_8 = 0.239$$

Gusset to beam weld check

Horizontal stress in weld

$$f_h := \frac{H_b}{2 \cdot l_g} \qquad f_h = 90.818\ \frac{kN}{m}$$

Vertical stress in weld

$$f_{v.max} := \frac{V_b}{2 \cdot l_g} + \frac{3 \cdot M_b}{{l_g}^2} \qquad f_{v.max} = 74.546\ \frac{kN}{m}$$

Vertical stress in weld

$$f_{v.min} := \frac{V_b}{2 \cdot l_g} - \frac{3 \cdot M_b}{{l_g}^2} \qquad f_{v.min} = 66.223\ \frac{kN}{m}$$

Resultant maximum stress in weld

$$f_{max} := \sqrt{{f_h}^2 + {f_{v.max}}^2} \qquad f_{max} = 117.495\ \frac{kN}{m}$$

Average stress in weld

$$f_{avg} := \frac{1}{2} \cdot \left(\sqrt{{f_h}^2 + {f_{v.max}}^2} + \sqrt{{f_h}^2 + {f_{v.min}}^2}\right) \qquad f_{avg} = 114.947\ \frac{kN}{m}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_1 \qquad R_n = \left(1.636 \cdot 10^3\right)\ \frac{kN}{m}$$

Interaction ratio for weld check

$$I_9 := \frac{2.0\ \max\left(f_{max}, 1.25\ f_{avg}\right)}{R_n} \qquad I_9 = 0.176$$

Gusset rupture at weld check

Minimum thickness of plate required to develop strength of weld

$$t_{min} := \frac{2 \cdot 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_1}{0.6 \cdot F_{up}} \qquad t_{min} = 13.633\ mm$$

Interaction ratio in rupture

$$I_{10} := \frac{t_{min}}{t_g} \qquad I_{10} = 0.852$$

Beam web yielding check

Equivalent force at gusset to beam interface

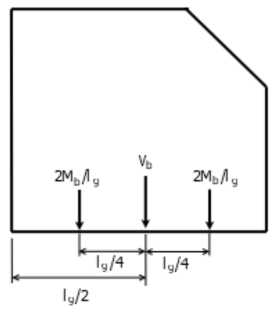
$$N_{eq} := V_b + \frac{4 \cdot M_b}{l_g} \qquad N_{eq} = 58.527\ kN$$

Nominal strength in web yielding

$$R_{n1} := F_{yb} \cdot t_{wb} \cdot \left(5 \cdot k_b + l_g\right)$$

$$R_{n2} := F_{yb} \cdot t_{wb} \cdot \left(2.5 \cdot k_b + l_g\right)$$

$$R_n := \text{if}\left(\alpha' > d_{xb}, R_{n1}, R_{n2}\right) \qquad R_n = 1110.375\ kN$$



nteraction ratio in web yielding

$$I_{11} := \frac{1.5\ N_{eq}}{R_n} \qquad I_{11} = 0.079$$

Beam web crippling check

Nominal strength in web crippling

$$R_{n1} := 0.8 \cdot t_{wb}^{\ 2} \cdot \left(1 + 3 \cdot \frac{l_g}{d_{xb}} \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_{n2} := 0.4 \cdot t_{wb}^{\ 2} \cdot \left(1 + 3 \cdot \frac{l_g}{d_{xb}} \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_{n3} := 0.4 \cdot t_{wb}^{\ 2} \cdot \left(1 + \left(\frac{4 \cdot l_g}{d_{xb}} - 0.2\right) \cdot \left(\frac{t_{wb}}{t_{fb}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{yb} \cdot t_{fb}}{t_{wb}}}$$

$$R_n := \text{if}\left(\alpha' < \frac{d_{xb}}{2}, R_{n1}, \text{if}\left(\frac{l_g}{d_{xb}} \le 0.2, R_{n2}, R_{n3}\right)\right) \qquad R_n = 1044.151\ kN$$

Interaction ratio in web crippling

$$I_{12} := \frac{2.0\ N_{eq}}{R_n} \qquad I_{12} = 0.112$$

Bolt shear at gusset to column connection

Area of bolt

$$A_b := \frac{\pi \cdot d_b^{\ 2}}{4} \qquad A_b = 380.133\ mm^2$$

Nominal shear strength of bolt

$$R_n := F_{nv} \cdot A_b \qquad R_n = 141.409\ kN$$

Interaction ratio in bolt shear

$$I_{13} := \frac{2.0\ V_{cb}}{R_n} \qquad I_{13} = 0.107$$

Bolt bearing at clip angle at gusset to column connection

Clear distance between bolt holes/ hole and edge

$$l_{c3} := min\left(s - d_{bh}, ed_3 - 0.5 \cdot d_{bh}\right) \qquad l_{c3} = 18\ mm$$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c3} \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_n = 109.728\ kN$$

Interaction ratio in bolt bearing

$$I_{14} := \frac{2.0\ V_{cb}}{R_n}$$ $I_{14} = 0.138$

Bolt bearing at column web at gusset to column connection

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot (s - d_{bh}) \cdot t_{wc} \cdot F_{uc}, 2.4 \cdot d_b \cdot t_{wc} \cdot F_{uc}\right)$$ $R_n = 182.477\ kN$

Interaction ratio in bolt bearing

$$I_{15} := \frac{2.0\ V_{cb}}{R_n}$$ $I_{15} = 0.083$

Clip angle shear yielding at gusset to column connection

Length of gusset to column clip

$$L_1 := (n_1 - 1) \cdot s + 2\ ed_3$$ $L_1 = 200\ mm$

Gross area in shear

$$A_{gv} := 2 \cdot L_1 \cdot t_a$$ $A_{gv} = 50.8\ cm^2$

Nominal strength in shear yielding

$$R_n := 0.6 \cdot F_{ya} \cdot A_{gv}$$ $R_n = 762\ kN$

Resultant shear in clip angle

$$S_{r1} := \sqrt{V_c^2 + H_c^2}$$ $S_{r1} = 45.409\ kN$

Interaction ratio in shear yielding

$$I_{16} := \frac{1.5\ S_{r1}}{R_n}$$ $I_{16} = 0.089$

Clip angle shear rupture at gusset to column connection

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n_1 \cdot d_{bh} \cdot t_a$$ $A_{nv} = 32.512\ cm^2$

Nominal strength in shear rupture

$$R_n := 0.6 \cdot F_{ua} \cdot A_{nv}$$ $R_n = 780.288\ kN$

Interaction ratio in shear rupture

$$I_{17} := \frac{2.0\ S_{r1}}{R_n}$$ $I_{17} = 0.116$

Clip angle block shear at gusset to column connection

Gross area subjected to block shear

$$A_{gv} := 2 \cdot (L_1 - ed_3) \cdot t_a$$ $A_{gv} = 43.18\ cm^2$

Net area subjected to block shear

$$A_{nv} := A_{gv} - 2 \cdot (n_1 - 0.5) \cdot d_{bh} \cdot t_a$$ $A_{nv} = 27.94\ cm^2$

Net area subjected to tension

$$A_{nt} := (2 \cdot l_{oa} + t_g - g - d_{bh}) \cdot t_a$$ $A_{nt} = 8.865\ cm^2$

Nominal strength in block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min\left(R_{n1}, R_{n2}\right) \qquad R_n = 1002.284\ kN$$

Interaction ratio in block shear

$$I_{18} := \frac{2.0\ V_c}{R_n} \qquad I_{18} = 0.091$$

Bolt tension at gusset to column connection

Required shear stress per bolt

$$f_{rv} := \frac{V_{cb}}{A_b} \qquad f_{rv} = 19.909\ MPa$$

Modified nominal tensile strength

$$F'_{nt} := min\left(1.3 \cdot F_{nt} - \frac{F_{nt}}{0.75 \cdot F_{nv}} \cdot f_{rv}, F_{nt}\right) \qquad F'_{nt} = 620\ MPa$$

Nominal tensile strength

$$R_n := F'_{nt} \cdot A_b \qquad R_n = 235.682\ kN$$

Interaction ratio for bolt tension

$$I_{19} := \frac{2.0\ H_{cb}}{R_n} \qquad I_{19} = 0$$

Bolt prying at clip angle at gusset to column connection

Available tension per bolt

$$B := \frac{F_{nt} \cdot A_b}{2.0} \qquad B = 117.841\ kN$$

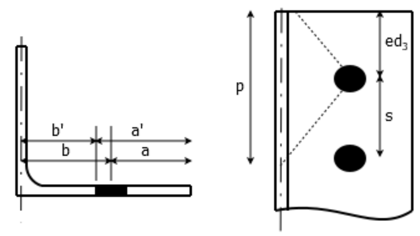
Clip dimensions for prying check

$$b := 0.5 \cdot \left(g - t_g - t_a\right) \qquad b = 35.65\ mm$$

$$a := l_{oa} - b - 0.5 \cdot t_a \qquad a = 46.9\ mm$$

$$b' := b - 0.5 \cdot d_b \qquad b' = 24.65\ mm$$

$$a' := min\left(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b\right) \qquad a' = 55.563\ mm$$



Tributary length

$$p := min\left(2 \cdot b, b + ed_3, s\right) \qquad p = 65.65\ mm$$

Ratios for prying

$$\delta := 1 - \frac{d_{bh}}{p} \qquad \delta = 0.634$$

$$\rho := \frac{b'}{a'} \qquad \rho = 0.444$$

Thickness required to develop bolt tension without prying

$$t_c := \sqrt{\frac{1.67 \cdot 4 \cdot B \cdot b'}{p \cdot F_{ua}}} \qquad t_c = 27.183\ mm$$

$$\alpha' := \frac{1}{\delta \cdot (1+\rho)} \cdot \left(\left(\frac{t_c}{t_a} \right)^2 - 1 \right) \qquad \alpha' = 3.91$$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c} \right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c} \right)^2 \cdot (1+\delta) \right) \right) \qquad Q = 0.357$$

Available tension strength with prying

$$T_{av} := Q \cdot B \qquad T_{av} = 42.041\ kN$$

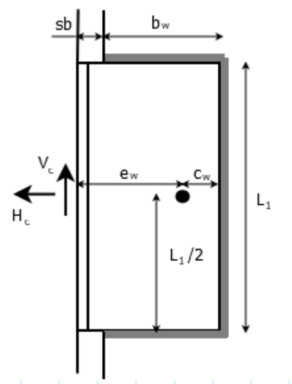
Interaction ratio in prying

$$I_{20} := \frac{H_{cb}}{T_{av}} \qquad I_{20} = 0$$

Weld check at gusset to column connection

Length of horizontal run of weld

$$b_w := l_{ia} - sb \qquad b_w = 64.2\ mm$$



Centroid of weld group

$$c_w := \frac{{b_w}^2}{2 \cdot b_w + L_1} \qquad c_w = 12.551\ mm$$

Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 63.649\ mm$$

Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L_1)^3}{12} - \frac{{b_w}^2 \cdot (b_w + L_1)^2}{2 \cdot b_w + L_1} \qquad I_w = 2075.344\ cm^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{H_c}{2 \cdot (2 \cdot b_w + L_1)} + \frac{V_c \cdot e_w \cdot L_1}{4 \cdot I_w} \qquad f_{wh} = 69.633\ \frac{kN}{m}$$

Vertical component of weld stress

$$f_{wv} := \frac{V_c}{2 \cdot (2 \cdot b_w + L_1)} + \frac{V_c \cdot e_w \cdot (b_w - c_w)}{2\ I_w} \qquad f_{wv} = 105.102\ \frac{kN}{m}$$

Resultant weld stress

$$f_w := \sqrt{{f_{wh}}^2 + {f_{wv}}^2} \qquad f_w = 126.077\ \frac{kN}{m}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_2 \qquad R_n = \left(1.227 \cdot 10^3\right)\ \frac{kN}{m}$$

Interaction ratio for weld check

$$I_{21} := \frac{2.0\ f_w}{R_n}$$ $I_{21} = 0.206$

Gusset rupture at weld at gusset to column connection

Minimum web thickness to match weld strength

$$t_{g.min} := \frac{2.0 \cdot 2 \cdot f_w}{0.6 \cdot F_{up}}$$ $t_{g.min} = 2.101\ mm$

Interaction ratio in web rupture

$$I_{22} := \frac{t_{g.min}}{t_g}$$ $I_{22} = 0.131$

Bolt shear check at beam to column connection

Nominal shear strength of bolt

$$R_n := F_{nv} \cdot A_b$$ $R_n = 141.409\ kN$

Interaction ratio in bolt shear

$$I_{23} := \frac{2.0\ V'_{bb}}{R_n}$$ $I_{23} = 0.358$

Bolt bearing at clip angle at beam to column connection

Clear distance between bolt holes/ hole and edge

$$l_{c3} := min\left(s - d_{bh}, ed_3 - 0.5 \cdot d_{bh}\right)$$ $l_{c3} = 18\ mm$

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot l_{c3} \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right)$$ $R_n = 109.728\ kN$

Interaction ratio in bolt bearing

$$I_{24} := \frac{2.0\ V'_{bb}}{R_n}$$ $I_{24} = 0.462$

Bolt bearing at column web at beam to column connection

Nominal strength in bearing

$$R_n := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{wc} \cdot F_{uc}, 2.4 \cdot d_b \cdot t_{wc} \cdot F_{uc}\right)$$ $R_n = 182.477\ kN$

Interaction ratio in bolt bearing

$$I_{25} := \frac{2.0\ V'_{bb}}{R_n}$$ $I_{25} = 0.278$

Clip angle shear yielding at beam to column connection

Length of gusset to column clip

$$L_2 := \left(n_2 - 1\right) \cdot s + 2\ ed_3$$ $L_2 = 130\ mm$

Gross area in shear

$$A_{gv} := 2 \cdot L_2 \cdot t_a$$ $A_{gv} = 33.02\ cm^2$

Nominal strength in shear yielding

$$R_n := 0.6 \cdot F_{ya} \cdot A_{gv}$$ $R_n = 495.3\ kN$

Resultant shear in clip angle

$$S_{r2} := \sqrt{V'_b{}^2 + H'_b{}^2} \qquad S_{r2} = 123.139\ kN$$

Interaction ratio in shear yielding

$$I_{26} := \frac{1.5\ S_{r2}}{R_n} \qquad I_{26} = 0.373$$

Clip angle shear rupture at beam to column connection

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n_2 \cdot d_{bh} \cdot t_a \qquad A_{nv} = 20.828\ cm^2$$

Nominal strength in shear rupture

$$R_n := 0.6 \cdot F_{ua} \cdot A_{nv} \qquad R_n = 499.872\ kN$$

Interaction ratio in shear rupture

$$I_{27} := \frac{2.0\ S_{r2}}{R_n} \qquad I_{27} = 0.493$$

Clip angle block shear at beam to column connection

Gross area subjected to block shear

$$A_{gv} := 2 \cdot \left(L_2 - ed_3\right) \cdot t_a \qquad A_{gv} = 25.4\ cm^2$$

Net area subjected to block shear

$$A_{nv} := A_{gv} - 2 \cdot \left(n_2 - 0.5\right) \cdot d_{bh} \cdot t_a \qquad A_{nv} = 16.256\ cm^2$$

Net area subjected to tension

$$A_{nt} := \left(2 \cdot l_{oa} + t_{wb} - g - d_{bh}\right) \cdot t_a \qquad A_{nt} = 8.026\ cm^2$$

Nominal strength in block shear

$$R_{n1} := 0.6 \cdot F_{ua} \cdot A_{nv} + F_{ua} \cdot A_{nt}$$

$$R_{n2} := 0.6 \cdot F_{ya} \cdot A_{gv} + F_{ua} \cdot A_{nt}$$

$$R_n := min\left(R_{n1}, R_{n2}\right) \qquad R_n = 702.056\ kN$$

Interaction ratio in block shear

$$I_{28} := \frac{2.0\ V'_b}{R_n} \qquad I_{28} = 0.289$$

Bolt tension check at beam to column connection

Required shear stress per bolt

$$f_{rv} := \frac{V'_{bb}}{A_b} \qquad f_{rv} = 66.626\ MPa$$

Modified nominal tensile strength

$$F'_{nt} := min\left(1.3 \cdot F_{nt} - \frac{2.0\ F_{nt}}{F_{nv}} \cdot f_{rv}, F_{nt}\right) \qquad F'_{nt} = 583.912\ MPa$$

Nominal tensile strength

$$R_n := F'_{nt} \cdot A_b \qquad R_n = 221.964\ kN$$

Interaction ratio for bolt tension

$$I_{29} := \frac{2.0\ H'_{bb}}{R_n} \qquad I_{29} = 0.158$$

Bolt prying at clip angle at beam to column connection

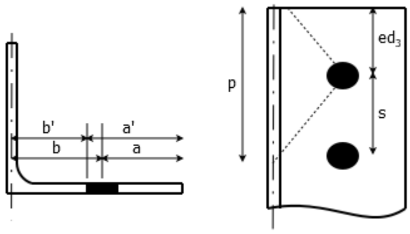
Clip dimensions for prying check

$$b := 0.5 \cdot (g - t_{wb} - t_a) \qquad b = 38.95\ mm$$

$$a := l_{oa} - b - 0.5 \cdot t_a \qquad a = 43.6\ mm$$

$$b' := b - 0.5 \cdot d_b \qquad b' = 27.95\ mm$$

$$a' := min(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b) \qquad a' = 54.6\ mm$$



Tributary length

$$p := min(2 \cdot b, b + ed_3, s) \qquad p = 68.95\ mm$$

Ratios for prying

$$\delta := 1 - \frac{d_{bh}}{p} \qquad \delta = 0.652$$

$$\rho := \frac{b'}{a'} \qquad \rho = 0.512$$

Thickness required to develop bolt tension without prying

$$t_c := \sqrt{\frac{1.67 \cdot 4 \cdot B \cdot b'}{p \cdot F_{ua}}} \qquad t_c = 28.244\ mm$$

$$\alpha' := \frac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\frac{t_c}{t_a} \right)^2 - 1 \right) \qquad \alpha' = 4.003$$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right) \qquad Q = 0.334$$

Available tension strength with prying

$$T_{av} := Q \cdot B \qquad T_{av} = 39.358\ kN$$

Interaction ratio in prying

$$I_{30} := \frac{H'_{bb}}{T_{av}} \qquad I_{30} = 0.445$$

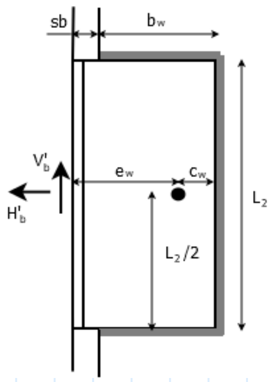
Weld check at beam to column connection

Centroid of weld group

$$c_w := \frac{{b_w}^2}{2 \cdot b_w + L_2} \qquad c_w = 15.951\ mm$$

Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 60.249\ mm$$



Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L_2)^3}{12} - \frac{{b_w}^2 \cdot (b_w + L_2)^2}{2 \cdot b_w + L_2} \qquad I_w = 836.237\ cm^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{H'_b}{2 \cdot (2 \cdot b_w + L_2)} + \frac{V'_b \cdot e_w \cdot L_2}{4 \cdot I_w} \qquad f_{wh} = 372.667\ \frac{kN}{m}$$

Vertical component of weld stress

$$f_{wv} := \frac{V'_b}{2 \cdot (2 \cdot b_w + L_2)} + \frac{V'_b \cdot e_w \cdot (b_w - c_w)}{2\ I_w} \qquad f_{wv} = 372.115\ \frac{kN}{m}$$

Resultant weld stress

$$f_w := \sqrt{{f_{wh}}^2 + {f_{wv}}^2} \qquad f_w = 526.641\ \frac{kN}{m}$$

Nominal weld strength

$$R_n := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w_2 \qquad R_n = \left(1.227 \cdot 10^3\right)\ \frac{kN}{m}$$

Interaction ratio for weld check

$$I_{31} := \frac{2.0\ f_w}{R_n} \qquad I_{31} = 0.858$$

Web rupture at weld at beam to column connection

Minimum web thickness to match weld strength

$$t_{wb.min} := \frac{2.0 \cdot 2 \cdot f_w}{0.6 \cdot F_{ub}} \qquad t_{wb.min} = 0.346\ in$$

Interaction ratio in web rupture

$$I_{32} := \frac{t_{wb.min}}{t_{wb}} \qquad I_{32} = 0.934$$

Validation Results

The calculated ratios are compared with the output of Osoconn and if it is within a tolerance of 1% the result is deemed to be OK.

Table 7: Validation problem 6 results

	Interaction Ratio		
Check	Calculated	Osoconn	Result
Bolt shear check at brace	0.147	0.147	OK
Bolt bearing on brace check	0.304	0.304	OK
Bolt bearing on gusset	0.301	0.301	OK
Brace tension rupture	0.239	0.239	OK
Brace block shear	0.292	0.292	OK
Gusset tension yielding	0.235	0.235	OK
Gusset tension rupture	0.225	0.225	OK
Gusset buckling	0.258	0.258	OK
Gusset block shear	0.239	0.239	OK
Gusset to beam weld	0.176	0.176	OK
Gusset rupture at weld	0.852	0.852	OK
Beam web yielding	0.079	0.079	OK
Beam web crippling	0.112	0.112	OK
Bolt shear at gusset to col. conn.	0.107	0.107	OK
Bolt bearing at clip at gusset to col. conn.	0.138	0.138	OK
Bolt bearing at web at gusset to col. conn.	0.083	0.083	OK
Clip shear yielding at gusset to col. conn.	0.089	0.089	OK
Clip shear rupture at gusset to col. conn.	0.116	0.116	OK
Clip block shear at gusset to col. conn.	0.091	0.091	OK
Bolt tension at gusset to col. conn.	0.0	0.0	OK
Bolt prying at clip at gusset to col. conn.	0.0	0.0	OK
Weld check at gusset to col. conn.	0.206	0.206	OK
Gusset rupture at weld at gusset to col. conn.	0.131	0.131	OK
Bolt shear check at beam to col. conn.	0.358	0.358	OK
Bolt bearing at clip at beam to col. conn.	0.462	0.462	OK
Bolt bearing at web at beam to col. conn.	0.278	0.278	OK
Clip shear yielding at beam to col. conn.	0.373	0.373	OK
Clip shear rupture at beam to col. conn.	0.493	0.493	OK
Clip block shear at beam to col. conn.	0.289	0.289	OK
Bolt tension check at beam to col. conn.	0.158	0.158	OK
Bolt prying at clip at beam to col. conn.	0.445	0.445	OK
Weld check at beam to col. conn.	0.858	0.859	OK
Web rupture at weld at beam to col. conn.	0.934	0.934	OK

3 Osoconn Output

3.1 Validation problem 1

```
Osoconn v1.1
Connection code : VB001AM10
Connection ID : VB001_1
-----------------------------------------------------------------------+----------------------
Design Summary                                                         |
-----------------------------------------------------------------------+----------------------
   Connection is OK                                                    |
   Maximum interaction ratio                                           | 0.961
-----------------------------------------------------------------------+----------------------
Design Input                                                           |
-----------------------------------------------------------------------+----------------------
   Design method                                                       | LRFD
   Brace axial force (P)                                               | 35.000 kip
   Shear force in beam (Rb)                                            | 35.000 kip
   Transfer force in connection (Tf)                                   | 15.000 kip
                                                                       |
   Angle steel grade                                                   | ASTM A36
   Yield strength of angle section                                     | 36.000 ksi
   Tensile strength of angle section                                   | 58.000 ksi
                                                                       |
   Beam steel grade                                                    | ASTM A36
   Yield strength of beam section                                      | 36.000 ksi
   Tensile strength of beam section                                    | 58.000 ksi
                                                                       |
   Column steel grade                                                  | ASTM A36
   Yield strength of column section                                    | 36.000 ksi
   Tensile strength of column section                                  | 58.000 ksi
                                                                       |
   Plate steel grade                                                   | ASTM A36
   Yield strength of plate                                             | 36.000 ksi
   Tensile strength of plate                                           | 58.000 ksi
                                                                       |
   Bolt grade                                                          | ASTM A325
   Bolt type                                                           | Friction
   Bolt diameter                                                       | 0.750 in
   Bolt gage                                                           | 5.500 in
   Bolt spacing                                                        | 2.250 in
   Bolt edge distance to brace edge                                    | 1.250 in
   Bolt edge distance to gusset edge                                   | 1.250 in
   Bolt edge distance to clip angle edge                               | 1.125 in
                                                                       |
   Weld electrode                                                      | E70
   Weld tensile strength                                               | 70.000 ksi
                                                                       |
   Brace section                                                       | L4X3-1/2X1/2
   Brace angle with beam                                               | 45.000 deg
   Gusset plate thickness (tg)                                         | 0.500 in
   Gusset to beam weld thickness                                       | 0.250 in
   Gusset length at connection to beam                                 | 20.000 in
```

```
   Number of bolts per row at brace (nb)                                    | 3
   Number of bolt rows at brace                                             | 1
   Clip angle section                                                       | L4X3X1/2
   Number of bolts at beam to column connection (n1)                        | 3
   Number of bolts at gusset to column connection (n2)                      | 4
   Weld thickness at clip angle                                             | 0.250 in
   Beam section property                                                    | W10X45
      Depth                                                                 | 10.100 in
      Flange width                                                          | 8.020 in
      Web thickness                                                         | 0.350 in
      Flange thickness                                                      | 0.620 in
   Column section property                                                  | W14X90
      Depth                                                                 | 14.000 in
      Flange width                                                          | 14.500 in
      Web thickness                                                         | 0.440 in
      Flange thickness                                                      | 0.710 in
------------------------------------------------------------------------+---------------------
Design Calculation                                                      |
------------------------------------------------------------------------+---------------------
                                                                        |
Bolt shear check at brace:                                              |
   Shear per bolt (Pb)                                                  | 11.667 kip
   Nominal bolt shear strength (Rn)                                     | 18.984 kip
   LRFD factor in bolt slip (phi)                                       | 1.000
   Allowable strength of bolt in shear                                  |
      [Ra=Rn*phi]                                                       | 18.984 kip
   Interaction ratio for bolt shear                                     |
      [Pb/Ra]                                                           | 0.615
                                                                        |
Bolt bearing at brace check:                                            |
   Nominal strength of bolt bearing at brace (Rn)                       | 29.362 kip
   LRFD factor in bolt bearing (phi)                                    | 0.750
   Allowable strength of bolt bearing at brace                          |
      [Ra=Rn*phi]                                                       | 22.022 kip
   Interaction ratio for bolt bearing at brace                          |
      [Pb/2*Ra]                                                         | 0.265
                                                                        |
Bolt bearing at gusset check:                                           |
   Nominal strength in bolt bearing at gusset (Rn)                      | 29.362 kip
   LRFD factor in bolt bearing (phi)                                    | 0.750
   Allowable strength of bolt bearing at gusset                         |
      [Ra=Rn*phi]                                                       | 22.022 kip
   Interaction ratio for bolt bearing at gusset                         |
      [Pb/Ra]                                                           | 0.530
                                                                        |
Brace rupture check:                                                    |
   Net cross-section area of brace (An)                                 | 6.188 in^2
   Shear lag factor (U)                                                 | 0.724
   Effective cross-section area for tension rupture                     |
      [Ae=U*An]                                                         | 4.482 in^2
   Nominal strength of brace in tension rupture (Pn)                    | 259.985 kip
   LRFD factor in tension rupture (phi)                                 | 0.750
   Allowable strength of brace in tension rupture                       |
```

```
      [Pa=Pn*phi]                                                  | 194.989 kip
   Interaction ratio in brace rupture                              |
      [P/Pa]                                                       | 0.179
                                                                   |
Block shear at brace check:                                        |
   Gross area in shear                                             | 5.750 in^2
   Net area in shear                                               | 3.719 in^2
   Net area in tension                                             | 1.344 in^2
   Nominal strength in block shear at brace (Rn)                   | 202.137 kip
   LRFD factor in block shear (phi)                                | 0.750
   Allowable strength in block shear at brace                      |
      [Ra=Rn*phi]                                                  | 151.603 kip
   Interaction ratio in block shear at brace                       |
      [P/Ra]                                                       | 0.231
                                                                   |
Gusset tension yielding check:                                     |
   Length of Whitmore section                                      | 5.196 in
   Gross area of gusset in tension                                 | 2.598 in^2
   Nominal strength of gusset in tension yielding (Pn)             | 93.531 kip
   LRFD factor in tension yielding (phi)                           | 0.900
   Allowable strength of gusset in tension yielding                |
      [Pa=Pn*phi]                                                  | 84.178 kip
   Interaction ratio in tension yielding of gusset                 |
      [P/Pa]                                                       | 0.416
                                                                   |
Gusset tension rupture check:                                      |
   Net area of gusset in tension                                   | 2.192 in^2
   Nominal strength of gusset in tension rupture (Pn)              | 127.126 kip
   LRFD factor in tension rupture (phi)                            | 0.750
   Allowable strength of gusset in tension rupture                 |
      [Pa=Pn*phi]                                                  | 95.344 kip
   Interaction ratio in tension rupture of gusset                  |
      [P/Pa]                                                       | 0.367
                                                                   |
Gusset compression buckling check:                                 |
   Buckling lenght at connection centerline (l1)                   | 7.351 in
   Buckling lenght at top most point of whitmore section (l2)      | 4.752 in
   Buckling length at bottom most point of whitmore section (l3)   | 7.510 in
   Average buckling length of gusset plate                         |
      [lb=(l1+l2+l3)/3]                                            | 6.538 in
   Nominal strength of gusset plate in compression (Pn)            | 80.060 kip
   LRFD factor in compression (phi)                                | 0.900
   Allowable strength of gusset in compression                     |
      [Pa=Pn*phi]                                                  | 72.054 kip
   Interaction ratio in compression of gusset                      |
      [P/Pa]                                                       | 0.486
                                                                   |
UFM forces at gusset interface                                     |
------------------------------                                     |
   Horizontal force at gusset to column interface (Hc)             | 11.921 kip
   Vertical force at gusset to column interface (Vc)               | 11.069 kip
   Horizontal force at gusset to beam interface (Hb)               | 17.030 kip
   Vertical force at gusset to beam interface (Vb)                 | 8.600 kip
```

```
   Moment at gusset to beam interface (Mb)                    | 46.870 kip in
                                                              |
Gusset to beam connection checks                              |
--------------------------------                              |
                                                              |
Gusset to beam weld check:                                    |
   Required strength of weld (fw)                             | 0.722 kip/in
   Nominal strength of weld (fn)                              | 7.423 kip/in
   LRFD factor for weld strength (phi)                        | 0.750
   Allowable strength of weld                                 |
      [fa=fn*phi]                                             | 5.568 kip/in
   Interaction ratio for weld                                 |
      [fw/fa]                                                 | 0.130
                                                              |
Rupture of gusset at weld check:                              |
   Minimum thickness of plate required for rupture (tg‘)      | 0.427 in
   Interaction ratio for gusset rupture at weld               |
      [tg‘/tg]                                                | 0.853
                                                              |
Beam web yielding check:                                      |
   Nominal strength in web yielding (Rn)                      | 287.280 kip
   LRFD factor in web yielding (phi)                          | 1.000
   Allowable strength in web yielding                         |
      [Ra=Rn*phi]                                             | 287.280 kip
   Interaction ratio for web yielding                         |
      [(Vb+4*Mb/lg)/Ra]                                       | 0.063
                                                              |
Beam web crippling check:                                     |
   Nominal strength of beam in web crippling (Rn)             | 284.851 kip
   LRFD factor for web crippling (phi)                        | 0.750
   Allowable strength of beam in web crippling                |
      [Ra=Rn*phi]                                             | 213.638 kip
   Interaction ratio in web crippling                         |
      [(Vb+4*Mb/lg)/Ra]                                       | 0.084
                                                              |
Gusset to column connection checks                            |
----------------------------------                            |
   Tension per bolt (without prying)                          |
      [T2=Hc/(2*n2)]                                          | 1.490 kip
   Shear force per bolt                                       |
      [R2=Vc/(2*n2)]                                          | 1.384 kip
                                                              |
Bolt shear check:                                             |
   Nominal strength of bolt in shear (Rn)                     | 9.045 kip
   LRFD factor in bolt slip (phi)                             | 1.000
   Allowable strength of bolt in shear                        |
      [Ra=Rn*phi]                                             | 9.045 kip
   Interaction ratio in bolt shear                            |
      [R2/Ra]                                                 | 0.153
                                                              |
Bolt bearing at clip angle check:                             |
   Nominal strength in bolt bearing at clip angle (Rn)        | 25.012 kip
   LRFD factor in bolt bearing (phi)                          | 0.750
```

```
   Allowable strength in bolt bearing at clip angle                  |
      [Ra=Rn*phi]                                                     | 18.759 kip
   Interaction ratio in bolt bearing at clip angle                   |
      [R2/Ra]                                                         | 0.074
                                                                      |
Bolt bearing at column check:                                         |
   Nominal strength in bolt bearing at column (Rn)                   | 71.035 kip
   LRFD factor in bolt bearing (phi)                                 | 0.750
   Allowable strength in bolt bearing at column                      |
      [Ra=Rn*phi]                                                     | 53.277 kip
   Interaction ratio in bolt bearing at column                       |
      [R2/Ra]                                                         | 0.026
                                                                      |
Clip angle shear yielding check:                                      |
   Nominal shear yieldind strength of clip angle (Rn)                | 194.400 kip
   LRFD factor in shear yielding (phi)                               | 1.000
   Allowable shear yield strength of clip angle                      |
      [Ra=Rn*phi]                                                     | 194.400 kip
   Interaction ratio in clip shear yielding                          |
      [sqrt(Hc^2+Vc^2)/Ra]                                            | 0.084
                                                                      |
Clip angle shear rupture check:                                       |
   Nominal shear rupture strength of clip angle (Rn)                 | 200.100 kip
   LRFD factor in shear rupture (phi)                                | 0.750
   Allowable shear rupture strength of clip angle                    |
      [Ra=Rn*phi]                                                     | 150.075 kip
   Interaction ratio in clip shear rupture                           |
      [sqrt(Hc^2+Vc^2)/Ra]                                            | 0.108
                                                                      |
Block shear at clip angle check:                                      |
   Gross area in shear                                               | 7.875 in^2
   Net area in shear                                                 | 5.031 in^2
   Net area in tension                                               | 1.094 in^2
   Nominal strength in block shear at clip angle (Rn)                | 233.537 kip
   LRFD factor in block shear (phi)                                  | 0.750
   Allowable strength in block shear at clip angle                   |
      [Ra=Rn*phi]                                                     | 175.153 kip
   Interaction ratio in block shear at clip angle                    |
      [Vc/Ra]                                                         | 0.063
                                                                      |
Bolt tension check (without prying):                                  |
   Nominal strength of bolt in tension (Rn)                          | 39.741 kip
   LRFD factor in bolt tension (phi)                                 | 0.750
   Allowable strength of bolt in tension                             |
      [B=Rn*phi]                                                      | 29.805 kip
   Interaction ratio in bolt tension                                 |
      [T2/B]                                                          | 0.050
                                                                      |
Clip angle prying action check:                                       |
   Bolt strength reduction factor due to clip prying (Q)             | 0.215
   Interaction ratio in clip prying                                  |
      [T2/(Q*B)]                                                      | 0.232
                                                                      |
```

```
Column flange prying action check:                                      |
   Bolt strength reduction factor due to column flange prying (Q)       | 0.790
   Interaction ratio in column flange prying                            |
      [T2/(Q*B)]                                                        | 0.063
                                                                        |
Weld check:                                                             |
   Polar moment of inertia of weld group                                | 169.626 in^3
   Maximum stress in weld (fw)                                          | 0.981 kip/in
   Nominal strength of weld (fn)                                        | 7.423 kip/in
   LRFD factor for weld strength (phi)                                  | 0.750
   Allowable strength of weld                                           |
      [fa=fn*phi]                                                       | 5.568 kip/in
   Interaction ratio in weld strength                                   |
      [fw/fa]                                                           | 0.176
                                                                        |
Gusset rupture at weld check:                                           |
   Nominal strength of gusset in rupture at weld (fn)                   | 17.400 kip/in
   LRFD factor for rupture (phi)                                        | 0.750
   Allowable strength of gusset in rupture at weld                      |
      [fa=fn*phi]                                                       | 13.050 kip/in
   Interaction ratio in gusset rupture at weld                          |
      [2*fw/fa]                                                         | 0.150
                                                                        |
Column web yielding check:                                              |
   Nominal strength of column web yielding (Rn)                         | 194.436 kip
   LRFD factor in web yielding (phi)                                    | 1.000
   Allowable strength of column in web yielding                         |
      [Ra=Rn*phi]                                                       | 194.436 kip
   Interaction ratio in column web yielding                             |
      [Hc/Ra]                                                           | 0.061
                                                                        |
Column web crippling check:                                             |
   Nominal strength of column in web crippling (Rn)                     | 216.796 kip
   LRFD factor in web crippling (phi)                                   | 0.750
   Allowable strength of column in web crippling                        |
      [Ra=Rn*phi]                                                       | 162.597 kip
   Interaction ratio in column web crippling                            |
      [Hc/Ra]                                                           | 0.073
                                                                        |
Beam to column connection checks                                        |
--------------------------------                                        |
   Tension per bolt (without prying)                                    |
      [T1=(Tf+Hc)/(2*n1)]                                               | 4.487 kip
   Shear force per bolt                                                 |
      [R1=(Rb+Vb)/(2*n1)]                                               | 7.267 kip
                                                                        |
Bolt shear check:                                                       |
   Nominal strength of bolt in shear (Rn)                               | 8.146 N
   LRFD factor in bolt slip (phi)                                       | 1.000
   Allowable strength of bolt in shear                                  |
      [Ra=Rn*phi]                                                       | 8.146 kip
   Interaction ratio in bolt shear                                      |
      [R1/Ra]                                                           | 0.892
```

```
                                                                        |
Bolt bearing at clip angle check:                                       |
   Nominal strength in bolt bearing at clip angle (Rn)                  | 25.012 kip
   LRFD factor in bolt bearing (phi)                                    | 0.750
   Allowable strength in bolt bearing at clip angle                     |
      [Ra=Rn*phi]                                                       | 18.759 kip
   Interaction ratio in bolt bearing at clip angle                      |
      [R1/Ra]                                                           | 0.387
                                                                        |
Bolt bearing at column check:                                           |
   Nominal strength in bolt bearing at column (Rn)                      | 71.035 kip
   LRFD factor in bolt bearing (phi)                                    | 0.750
   Allowable strength in bolt bearing at column                         |
      [Ra=Rn*phi]                                                       | 53.277 kip
   Interaction ratio in bolt bearing at column                          |
      [R1/Ra]                                                           | 0.136
                                                                        |
Clip angle shear yielding check:                                        |
   Nominal shear yieldind strength of clip angle (Rn)                   | 145.800 kip
   LRFD factor in shear yielding (phi)                                  | 1.000
   Allowable shear yield strength of clip angle                         |
      [Ra=Rn*phi]                                                       | 145.800 kip
   Interaction ratio in clip shear yielding                             |
      [sqrt((Hc+Tf)^2+(Vb+Rb)^2)/Ra]                                    | 0.351
                                                                        |
Clip angle shear rupture check:                                         |
   Nominal shear rupture strength of clip angle (Rn)                    | 150.075 kip
   LRFD factor in shear rupture (phi)                                   | 0.750
   Allowable shear rupture strength of clip angle                       |
      [Ra=Rn*phi]                                                       | 112.556 kip
   Interaction ratio in clip shear rupture                              |
      [sqrt((Hc+Tf)^2+(Vb+Rb)^2)/Ra]                                    | 0.455
                                                                        |
Block shear at clip angle check:                                        |
   Gross area in shear                                                  | 5.625 in^2
   Net area in shear                                                    | 3.594 in^2
   Net area in tension                                                  | 1.019 in^2
   Nominal strength in block shear at clip angle (Rn)                   | 180.587 kip
   LRFD factor in block shear (phi)                                     | 0.750
   Allowable strength in block shear at clip angle                      |
      [Ra=Rn*phi]                                                       | 135.441 kip
   Interaction ratio in block shear at clip angle                       |
      [(Rb+Vb)/Ra]                                                      | 0.322
                                                                        |
Bolt tension check (without prying):                                    |
   Nominal strength of bolt in tension (Rn)                             | 39.741 kip
   LRFD factor in bolt tension (phi)                                    | 0.750
   Allowable strength of bolt in tension                                |
      [B=Rn*phi]                                                        | 29.805 kip
   Interaction ratio in bolt tension                                    |
      [T1/B]                                                            | 0.151
                                                                        |
Clip angle prying action check:                                         |
```

```
   Bolt strength reduction factor due to clip prying (Q)                 | 0.207
   Interaction ratio in clip prying                                      |
      [T1/(Q*B)]                                                         | 0.727
                                                                         |
Column flange prying action check:                                       |
   Bolt strength reduction factor due to column flange prying (Q)        | 0.854
   Interaction ratio in column flange prying                             |
      [T1/(Q*B)]                                                         | 0.176
                                                                         |
Weld check:                                                              |
   Polar moment of inertia of weld group                                 | 89.674 in^3
   Maximum stress in weld (fw)                                           | 4.390 kip/in
   Nominal strength of weld (fn)                                         | 7.423 kip/in
   LRFD factor for weld strength (phi)                                   | 0.750
   Allowable strength of weld                                            |
      [fa=fn*phi]                                                        | 5.568 kip/in
   Interaction ratio in weld strength                                    |
      [fw/fa]                                                            | 0.788
                                                                         |
Beam rupture at weld check:                                              |
   Nominal strength of beam web in rupture at weld (fn)                  | 12.180 kip/in
   LRFD factor for rupture (phi)                                         | 0.750
   Allowable strength of beam web in rupture at weld                     |
      [fa=fn*phi]                                                        | 9.135 kip/in
   Interaction ratio in rupture of beam web at weld                      |
      [2*fw/fa]                                                          | 0.961
                                                                         |
Column web yielding check:                                               |
   Nominal strength of column web yielding (Rn)                          | 158.796 kip
   LRFD factor in web yielding (phi)                                     | 1.000
   Allowable strength of column in web yielding                          |
      [Ra=Rn*phi]                                                        | 158.796 kip
   Interaction ratio in column web yielding                              |
      [(Hc+Tf)/Ra]                                                       | 0.170
                                                                         |
Column web crippling check:                                              |
   Nominal strength of column in web crippling (Rn)                      | 185.273 kip
   LRFD factor in web crippling (phi)                                    | 0.750
   Allowable strength of column in web crippling                         |
      [Ra=Rn*phi]                                                        | 138.955 kip
   Interaction ratio in column web crippling                             |
      [(Hc+Tf)/Ra]                                                       | 0.194
```

3.2 Validation problem 2

```
Osoconn v1.1
Connection code : VB001AM10
Connection ID : VB001_2
-------------------------------------------------------------------------+--------------------
Design Summary                                                           |
-------------------------------------------------------------------------+--------------------
   Connection is OK                                                      |
   Maximum interaction ratio                                             | 0.962
```

```
--------------------------------------------------------------------------+--------------------
Design Input                                                              |
--------------------------------------------------------------------------+--------------------
   Design method                                                          | LRFD
   Brace axial force (P)                                                  | 45.000 kip
   Shear force in beam (Rb)                                               | 30.000 kip
   Transfer force in connection (Tf)                                      | 20.000 kip
                                                                          |
   Angle steel grade                                                      | ASTM A36
   Yield strength of angle section                                        | 36.000 ksi
   Tensile strength of angle section                                      | 58.000 ksi
                                                                          |
   Beam steel grade                                                       | ASTM A992
   Yield strength of beam section                                         | 50.000 ksi
   Tensile strength of beam section                                       | 65.000 ksi
                                                                          |
   Column steel grade                                                     | ASTM A992
   Yield strength of column section                                       | 50.000 ksi
   Tensile strength of column section                                     | 65.000 ksi
                                                                          |
   Plate steel grade                                                      | ASTM A36
   Yield strength of plate                                                | 36.000 ksi
   Tensile strength of plate                                              | 58.000 ksi
                                                                          |
   Bolt grade                                                             | ASTM A325
   Bolt type                                                              | Friction
   Bolt diameter                                                          | 0.750 in
   Bolt gage                                                              | 5.500 in
   Bolt spacing                                                           | 3.000 in
   Bolt edge distance to brace edge                                       | 1.250 in
   Bolt edge distance to gusset edge                                      | 1.250 in
   Bolt edge distance to clip angle edge                                  | 1.500 in
                                                                          |
   Weld electrode                                                         | E70
   Weld tensile strength                                                  | 70.000 ksi
                                                                          |
   Brace section                                                          | L3X3X5/16
   Brace angle with beam                                                  | 40.000 deg
   Gusset plate thickness (tg)                                            | 0.500 in
   Gusset to beam weld thickness                                          | 0.250 in
   Gusset length at connection to beam                                    | 16.000 in
   Number of bolts per row at brace (nb)                                  | 4
   Number of bolt rows at brace                                           | 1
   Clip angle section                                                     | L4X3X1/2
   Number of bolts at beam to column connection (n1)                      | 3
   Number of bolts at gusset to column connection (n2)                    | 3
   Weld thickness at clip angle                                           | 0.250 in
   Beam section property                                                  | W12X30
      Depth                                                               | 12.300 in
      Flange width                                                        | 6.520 in
      Web thickness                                                       | 0.260 in
      Flange thickness                                                    | 0.440 in
   Column section property                                                | W14X61
```

```
      Depth                                                                 | 13.900 in
      Flange width                                                          | 10.000 in
      Web thickness                                                         | 0.375 in
      Flange thickness                                                      | 0.645 in
----------------------------------------------------------------------------+---------------------
Design Calculation                                                          |
----------------------------------------------------------------------------+---------------------
                                                                            |
Bolt shear check at brace:                                                  |
   Shear per bolt (Pb)                                                      | 11.250 kip
   Nominal bolt shear strength (Rn)                                         | 18.984 kip
   LRFD factor in bolt slip (phi)                                           | 1.000
   Allowable strength of bolt in shear                                      |
      [Ra=Rn*phi]                                                           | 18.984 kip
   Interaction ratio for bolt shear                                         |
      [Pb/Ra]                                                               | 0.593
                                                                            |
Bolt bearing at brace check:                                                |
   Nominal strength of bolt bearing at brace (Rn)                           | 18.381 kip
   LRFD factor in bolt bearing (phi)                                        | 0.750
   Allowable strength of bolt bearing at brace                              |
      [Ra=Rn*phi]                                                           | 13.786 kip
   Interaction ratio for bolt bearing at brace                              |
      [Pb/2*Ra]                                                             | 0.408
                                                                            |
Bolt bearing at gusset check:                                               |
   Nominal strength in bolt bearing at gusset (Rn)                          | 29.362 kip
   LRFD factor in bolt bearing (phi)                                        | 0.750
   Allowable strength of bolt bearing at gusset                             |
      [Ra=Rn*phi]                                                           | 22.022 kip
   Interaction ratio for bolt bearing at gusset                             |
      [Pb/Ra]                                                               | 0.511
                                                                            |
Brace rupture check:                                                        |
   Net cross-section area of brace (An)                                     | 3.051 in^2
   Shear lag factor (U)                                                     | 0.904
   Effective cross-section area for tension rupture                         |
      [Ae=U*An]                                                             | 2.760 in^2
   Nominal strength of brace in tension rupture (Pn)                        | 160.068 kip
   LRFD factor in tension rupture (phi)                                     | 0.750
   Allowable strength of brace in tension rupture                           |
      [Pa=Pn*phi]                                                           | 120.051 kip
   Interaction ratio in brace rupture                                       |
      [P/Pa]                                                                | 0.375
                                                                            |
Block shear at brace check:                                                 |
   Gross area in shear                                                      | 6.417 in^2
   Net area in shear                                                        | 4.636 in^2
   Net area in tension                                                      | 0.528 in^2
   Nominal strength in block shear at brace (Rn)                            | 169.231 kip
   LRFD factor in block shear (phi)                                         | 0.750
   Allowable strength in block shear at brace                               |
      [Ra=Rn*phi]                                                           | 126.923 kip
```

```
   Interaction ratio in block shear at brace                          |
      [P/Ra]                                                          | 0.355
                                                                      |
Gusset tension yielding check:                                        |
   Length of Whitmore section                                         | 10.392 in
   Gross area of gusset in tension                                    | 5.196 in^2
   Nominal strength of gusset in tension yielding (Pn)                | 187.061 kip
   LRFD factor in tension yielding (phi)                              | 0.900
   Allowable strength of gusset in tension yielding                   |
      [Pa=Pn*phi]                                                     | 168.355 kip
   Interaction ratio in tension yielding of gusset                    |
      [P/Pa]                                                          | 0.267
                                                                      |
Gusset tension rupture check:                                         |
   Net area of gusset in tension                                      | 4.790 in^2
   Nominal strength of gusset in tension rupture (Pn)                 | 277.814 kip
   LRFD factor in tension rupture (phi)                               | 0.750
   Allowable strength of gusset in tension rupture                    |
      [Pa=Pn*phi]                                                     | 208.361 kip
   Interaction ratio in tension rupture of gusset                     |
      [P/Pa]                                                          | 0.216
                                                                      |
Gusset compression buckling check:                                    |
   Buckling lenght at connection centerline (l1)                      | 7.682 in
   Buckling lenght at top most point of whitmore section (l2)         | 12.042 in
   Buckling length at bottom most point of whitmore section (l3)      | 3.322 in
   Average buckling length of gusset plate                            |
      [lb=(l1+l2+l3)/3]                                               | 7.682 in
   Nominal strength of gusset plate in compression (Pn)               | 150.912 kip
   LRFD factor in compression (phi)                                   | 0.900
   Allowable strength of gusset in compression                        |
      [Pa=Pn*phi]                                                     | 135.821 kip
   Interaction ratio in compression of gusset                         |
      [P/Pa]                                                          | 0.331
                                                                      |
UFM forces at gusset interface                                        |
------------------------------                                        |
   Horizontal force at gusset to column interface (Hc)                | 0.000 kip
   Vertical force at gusset to column interface (Vc)                  | 18.560 kip
   Horizontal force at gusset to beam interface (Hb)                  | 24.747 kip
   Vertical force at gusset to beam interface (Vb)                    | 19.024 kip
   Moment at gusset to beam interface (Mb)                            | 41.759 kip in
                                                                      |
Gusset to beam connection checks                                      |
--------------------------------                                      |
                                                                      |
Gusset to beam weld check:                                            |
   Required strength of weld (fw)                                     | 1.331 kip/in
   Nominal strength of weld (fn)                                      | 7.423 kip/in
   LRFD factor for weld strength (phi)                                | 0.750
   Allowable strength of weld                                         |
      [fa=fn*phi]                                                     | 5.568 kip/in
   Interaction ratio for weld                                         |
```

```
      [fw/fa]                                                           | 0.239
                                                                        |
Rupture of gusset at weld check:                                        |
   Minimum thickness of plate required for rupture (tg‘)                | 0.427 in
   Interaction ratio for gusset rupture at weld                         |
      [tg‘/tg]                                                          | 0.853
                                                                        |
Beam web yielding check:                                                |
   Nominal strength in web yielding (Rn)                                | 232.050 kip
   LRFD factor in web yielding (phi)                                    | 1.000
   Allowable strength in web yielding                                   |
      [Ra=Rn*phi]                                                       | 232.050 kip
   Interaction ratio for web yielding                                   |
      [(Vb+4*Mb/lg)/Ra]                                                 | 0.127
                                                                        |
Beam web crippling check:                                               |
   Nominal strength of beam in web crippling (Rn)                       | 138.621 kip
   LRFD factor for web crippling (phi)                                  | 0.750
   Allowable strength of beam in web crippling                          |
      [Ra=Rn*phi]                                                       | 103.966 kip
   Interaction ratio in web crippling                                   |
      [(Vb+4*Mb/lg)/Ra]                                                 | 0.283
                                                                        |
Gusset to column connection checks                                      |
----------------------------------                                      |
   Tension per bolt (without prying)                                    |
      [T2=Hc/(2*n2)]                                                    | 0.000 kip
   Shear force per bolt                                                 |
      [R2=Vc/(2*n2)]                                                    | 3.093 kip
                                                                        |
Bolt shear check:                                                       |
   Nominal strength of bolt in shear (Rn)                               | 9.492 kip
   LRFD factor in bolt slip (phi)                                       | 1.000
   Allowable strength of bolt in shear                                  |
      [Ra=Rn*phi]                                                       | 9.492 kip
   Interaction ratio in bolt shear                                      |
      [R2/Ra]                                                           | 0.326
                                                                        |
Bolt bearing at clip angle check:                                       |
   Nominal strength in bolt bearing at clip angle (Rn)                  | 38.062 kip
   LRFD factor in bolt bearing (phi)                                    | 0.750
   Allowable strength in bolt bearing at clip angle                     |
      [Ra=Rn*phi]                                                       | 28.547 kip
   Interaction ratio in bolt bearing at clip angle                      |
      [R2/Ra]                                                           | 0.108
                                                                        |
Bolt bearing at column check:                                           |
   Nominal strength in bolt bearing at column (Rn)                      | 43.875 kip
   LRFD factor in bolt bearing (phi)                                    | 0.750
   Allowable strength in bolt bearing at column                         |
      [Ra=Rn*phi]                                                       | 32.906 kip
   Interaction ratio in bolt bearing at column                          |
      [R2/Ra]                                                           | 0.094
```

```
                                                                         |
Clip angle shear yielding check:                                         |
   Nominal shear yieldind strength of clip angle (Rn)                    | 194.400 kip
   LRFD factor in shear yielding (phi)                                   | 1.000
   Allowable shear yield strength of clip angle                          |
      [Ra=Rn*phi]                                                        | 194.400 kip
   Interaction ratio in clip shear yielding                              |
      [sqrt(Hc^2+Vc^2)/Ra]                                               | 0.095
                                                                         |
Clip angle shear rupture check:                                          |
   Nominal shear rupture strength of clip angle (Rn)                     | 228.375 kip
   LRFD factor in shear rupture (phi)                                    | 0.750
   Allowable shear rupture strength of clip angle                        |
      [Ra=Rn*phi]                                                        | 171.281 kip
   Interaction ratio in clip shear rupture                               |
      [sqrt(Hc^2+Vc^2)/Ra]                                               | 0.108
                                                                         |
Block shear at clip angle check:                                         |
   Gross area in shear                                                   | 7.500 in^2
   Net area in shear                                                     | 5.469 in^2
   Net area in tension                                                   | 1.094 in^2
   Nominal strength in block shear at clip angle (Rn)                    | 225.437 kip
   LRFD factor in block shear (phi)                                      | 0.750
   Allowable strength in block shear at clip angle                       |
      [Ra=Rn*phi]                                                        | 169.078 kip
   Interaction ratio in block shear at clip angle                        |
      [Vc/Ra]                                                            | 0.110
                                                                         |
Bolt tension check (without prying):                                     |
   Nominal strength of bolt in tension (Rn)                              | 39.741 kip
   LRFD factor in bolt tension (phi)                                     | 0.750
   Allowable strength of bolt in tension                                 |
      [B=Rn*phi]                                                         | 29.805 kip
   Interaction ratio in bolt tension                                     |
      [T2/B]                                                             | 0.000
                                                                         |
Clip angle prying action check:                                          |
   Bolt strength reduction factor due to clip prying (Q)                 | 0.303
   Interaction ratio in clip prying                                      |
      [T2/(Q*B)]                                                         | 0.000
                                                                         |
Weld check:                                                              |
   Polar moment of inertia of weld group                                 | 169.626 in^3
   Maximum stress in weld (fw)                                           | 1.139 kip/in
   Nominal strength of weld (fn)                                         | 7.423 kip/in
   LRFD factor for weld strength (phi)                                   | 0.750
   Allowable strength of weld                                            |
      [fa=fn*phi]                                                        | 5.568 kip/in
   Interaction ratio in weld strength                                    |
      [fw/fa]                                                            | 0.205
                                                                         |
Gusset rupture at weld check:                                            |
   Nominal strength of gusset in rupture at weld (fn)                    | 17.400 kip/in
```

```
   LRFD factor for rupture (phi)                                        | 0.750
   Allowable strength of gusset in rupture at weld                      |
      [fa=fn*phi]                                                       | 13.050 kip/in
   Interaction ratio in gusset rupture at weld                          |
      [2*fw/fa]                                                         | 0.175
                                                                        |
Beam to column connection checks                                        |
--------------------------------                                        |
   Tension per bolt (without prying)                                    |
      [T1=(Tf+Hc)/(2*n1)]                                               | 3.333 kip
   Shear force per bolt                                                 |
      [R1=(Rb+Vb)/(2*n1)]                                               | 8.171 kip
                                                                        |
Bolt shear check:                                                       |
   Nominal strength of bolt in shear (Rn)                               | 8.492 N
   LRFD factor in bolt slip (phi)                                       | 1.000
   Allowable strength of bolt in shear                                  |
      [Ra=Rn*phi]                                                       | 8.492 kip
   Interaction ratio in bolt shear                                      |
      [R1/Ra]                                                           | 0.962
                                                                        |
Bolt bearing at clip angle check:                                       |
   Nominal strength in bolt bearing at clip angle (Rn)                  | 38.062 kip
   LRFD factor in bolt bearing (phi)                                    | 0.750
   Allowable strength in bolt bearing at clip angle                     |
      [Ra=Rn*phi]                                                       | 28.547 kip
   Interaction ratio in bolt bearing at clip angle                      |
      [R1/Ra]                                                           | 0.286
                                                                        |
Bolt bearing at column check:                                           |
   Nominal strength in bolt bearing at column (Rn)                      | 43.875 kip
   LRFD factor in bolt bearing (phi)                                    | 0.750
   Allowable strength in bolt bearing at column                         |
      [Ra=Rn*phi]                                                       | 32.906 kip
   Interaction ratio in bolt bearing at column                          |
      [R1/Ra]                                                           | 0.248
                                                                        |
Clip angle shear yielding check:                                        |
   Nominal shear yieldind strength of clip angle (Rn)                   | 194.400 kip
   LRFD factor in shear yielding (phi)                                  | 1.000
   Allowable shear yield strength of clip angle                         |
      [Ra=Rn*phi]                                                       | 194.400 kip
   Interaction ratio in clip shear yielding                             |
      [sqrt((Hc+Tf)^2+(Vb+Rb)^2)/Ra]                                    | 0.272
                                                                        |
Clip angle shear rupture check:                                         |
   Nominal shear rupture strength of clip angle (Rn)                    | 228.375 kip
   LRFD factor in shear rupture (phi)                                   | 0.750
   Allowable shear rupture strength of clip angle                       |
      [Ra=Rn*phi]                                                       | 171.281 kip
   Interaction ratio in clip shear rupture                              |
      [sqrt((Hc+Tf)^2+(Vb+Rb)^2)/Ra]                                    | 0.309
                                                                        |
```

```
Block shear at clip angle check:                                        |
   Gross area in shear                                                  | 7.500 in^2
   Net area in shear                                                    | 5.469 in^2
   Net area in tension                                                  | 0.974 in^2
   Nominal strength in block shear at clip angle (Rn)                   | 218.477 kip
   LRFD factor in block shear (phi)                                     | 0.750
   Allowable strength in block shear at clip angle                      |
      [Ra=Rn*phi]                                                       | 163.858 kip
   Interaction ratio in block shear at clip angle                       |
      [(Rb+Vb)/Ra]                                                      | 0.299
                                                                        |
Bolt tension check (without prying):                                    |
   Nominal strength of bolt in tension (Rn)                             | 39.741 kip
   LRFD factor in bolt tension (phi)                                    | 0.750
   Allowable strength of bolt in tension                                |
      [B=Rn*phi]                                                        | 29.805 kip
   Interaction ratio in bolt tension                                    |
      [T1/B]                                                            | 0.112
                                                                        |
Clip angle prying action check:                                         |
   Bolt strength reduction factor due to clip prying (Q)                | 0.285
   Interaction ratio in clip prying                                     |
      [T1/(Q*B)]                                                        | 0.393
                                                                        |
Weld check:                                                             |
   Polar moment of inertia of weld group                                | 169.626 in^3
   Maximum stress in weld (fw)                                          | 3.454 kip/in
   Nominal strength of weld (fn)                                        | 7.423 kip/in
   LRFD factor for weld strength (phi)                                  | 0.750
   Allowable strength of weld                                           |
      [fa=fn*phi]                                                       | 5.568 kip/in
   Interaction ratio in weld strength                                   |
      [fw/fa]                                                           | 0.620
                                                                        |
Beam rupture at weld check:                                             |
   Nominal strength of beam web in rupture at weld (fn)                 | 10.140 kip/in
   LRFD factor for rupture (phi)                                        | 0.750
   Allowable strength of beam web in rupture at weld                    |
      [fa=fn*phi]                                                       | 7.605 kip/in
   Interaction ratio in rupture of beam web at weld                     |
      [2*fw/fa]                                                         | 0.908
```

3.3 Validation problem 3

```
Osoconn v1.1
Connection code : VB001AM10
Connection ID : VB001_3
------------------------------------------------------------------------+--------------------
Design Summary                                                          |
------------------------------------------------------------------------+--------------------
   Connection is OK                                                     |
   Maximum interaction ratio                                            | 0.978
------------------------------------------------------------------------+--------------------
```

```
Design Input                                                         |
---------------------------------------------------------------------+--------------------
   Design method                                                     | ASD
   Brace axial force (P)                                             | 105000.000 N
   Shear force in beam (Rb)                                          | 180000.000 N
   Transfer force in connection (Tf)                                 | 95000.000 N
                                                                     |
   Angle steel grade                                                 | ASTM A36
   Yield strength of angle section                                   | 250.000 MPa
   Tensile strength of angle section                                 | 400.000 MPa
                                                                     |
   Beam steel grade                                                  | ASTM A992
   Yield strength of beam section                                    | 345.000 MPa
   Tensile strength of beam section                                  | 450.000 MPa
                                                                     |
   Column steel grade                                                | ASTM A992
   Yield strength of column section                                  | 345.000 MPa
   Tensile strength of column section                                | 450.000 MPa
                                                                     |
   Plate steel grade                                                 | ASTM A36
   Yield strength of plate                                           | 250.000 MPa
   Tensile strength of plate                                         | 400.000 MPa
                                                                     |
   Bolt grade                                                        | ASTM A490
   Bolt type                                                         | Bearing
   Bolt thread in shear plane                                        | Yes
   Bolt diameter                                                     | 22.000 mm
   Bolt gage                                                         | 140.000 mm
   Bolt spacing                                                      | 70.000 mm
   Bolt edge distance to brace edge                                  | 35.000 mm
   Bolt edge distance to gusset edge                                 | 35.000 mm
   Bolt edge distance to clip angle edge                             | 35.000 mm
                                                                     |
   Weld electrode                                                    | E70
   Weld tensile strength                                             | 482.000 MPa
                                                                     |
   Brace section                                                     | L89X89X12.7
   Brace angle with beam                                             | 55.000 deg
   Gusset plate thickness (tg)                                       | 12.000 mm
   Gusset to beam weld thickness                                     | 6.000 mm
   Gusset length at connection to beam                               | 300.000 mm
   Number of bolts per row at brace (nb)                             | 3
   Number of bolt rows at brace                                      | 1
   Clip angle section                                                | L102X89X12.7
   Number of bolts at beam to column connection (n1)                 | 3
   Number of bolts at gusset to column connection (n2)               | 4
   Weld thickness at clip angle                                      | 8.000 mm
   Beam section property                                             | W360X101
      Depth                                                          | 356.000 mm
      Flange width                                                   | 254.000 mm
      Web thickness                                                  | 10.500 mm
      Flange thickness                                               | 18.300 mm
   Column section property                                           | W360X72
```

```
      Depth                                                         | 351.000 mm
      Flange width                                                  | 204.000 mm
      Web thickness                                                 | 8.640 mm
      Flange thickness                                              | 15.100 mm
--------------------------------------------------------------------+---------------------
Design Calculation                                                  |
--------------------------------------------------------------------+---------------------
                                                                    |
Bolt shear check at brace:                                          |
   Shear per bolt (Pb)                                              | 35000.000 N
   Nominal bolt shear strength (Rn)                                 | 356610.716 N
   ASD factor in bolt shear (omega)                                 | 2.000
   Allowable strength of bolt in shear                              |
      [Ra=Rn/omega]                                                 | 178305.358 N
   Interaction ratio for bolt shear                                 |
      [Pb/Ra]                                                       | 0.196
                                                                    |
Bolt bearing at brace check:                                        |
   Nominal strength of bolt bearing at brace (Rn)                   | 140208.000 N
   ASD factor in bolt bearing (omega)                               | 2.000
   Allowable strength of bolt bearing at brace                      |
      [Ra=Rn/omega]                                                 | 70104.000 N
   Interaction ratio for bolt bearing at brace                      |
      [Pb/2*Ra]                                                     | 0.250
                                                                    |
Bolt bearing at gusset check:                                       |
   Nominal strength in bolt bearing at gusset (Rn)                  | 132480.000 N
   ASD factor in bolt bearing (omega)                               | 2.000
   Allowable strength of bolt bearing at gusset                     |
      [Ra=Rn/omega]                                                 | 66240.000 N
   Interaction ratio for bolt bearing at gusset                     |
      [Pb/Ra]                                                       | 0.528
                                                                    |
Brace rupture check:                                                |
   Net cross-section area of brace (An)                             | 3590.400 mm^2
   Shear lag factor (U)                                             | 0.809
   Effective cross-section area for tension rupture                 |
      [Ae=U*An]                                                     | 2905.659 mm^2
   Nominal strength of brace in tension rupture (Pn)                | 1162263.771 N
   ASD factor in tension rupture (omega)                            | 2.000
   Allowable strength of brace in tension rupture                   |
      [Pa=Pn/omega]                                                 | 581131.886 N
   Interaction ratio in brace rupture                               |
      [P/Pa]                                                        | 0.181
                                                                    |
Block shear at brace check:                                         |
   Gross area in shear                                              | 4445.000 mm^2
   Net area in shear                                                | 2921.000 mm^2
   Net area in tension                                              | 810.260 mm^2
   Nominal strength in block shear at brace (Rn)                    | 990854.000 N
   ASD factor in bolt bearing (omega)                               | 2.000
   Allowable strength in block shear at brace                       |
      [Ra=Rn/omega]                                                 | 495427.000 N
```

```
   Interaction ratio in block shear at brace                               |
      [P/Ra]                                                               | 0.212
                                                                           |
Gusset tension yielding check:                                             |
   Length of Whitmore section                                              | 161.658 mm
   Gross area of gusset in tension                                         | 1939.897 mm^2
   Nominal strength of gusset in tension yielding (Pn)                     | 484974.226 N
   ASD factor in tension yielding (omega)                                  | 1.670
   Allowable strength of gusset in tension yielding                        |
      [Ra=Rn/omega]                                                        | 290403.728 N
   Interaction ratio in tension yielding of gusset                         |
      [P/Pa]                                                               | 0.362
                                                                           |
Gusset tension rupture check:                                              |
   Net area of gusset in tension                                           | 1651.897 mm^2
   Nominal strength of gusset in tension rupture (Pn)                      | 660758.762 N
   ASD factor in tension rupture (omega)                                   | 2.000
   Allowable strength of gusset in tension rupture                         |
      [Ra=Rn/omega]                                                        | 330379.381 N
   Interaction ratio in tension rupture of gusset                          |
      [P/Pa]                                                               | 0.318
                                                                           |
Gusset compression buckling check:                                         |
   Buckling lenght at connection centerline (l1)                           | 129.025 mm
   Buckling lenght at top most point of whitmore section (l2)              | 13.589 mm
   Buckling length at bottom most point of whitmore section (l3)           | 102.266 mm
   Average buckling length of gusset plate                                 |
      [lb=(l1+l2+l3)/3]                                                    | 81.627 mm
   Nominal strength of gusset plate in compression (Pn)                    | 464849.583 N
   ASD factor in compression (omega)                                       | 1.670
   Allowable strength of gusset in compression                             |
      [Pa=Pn/omega]                                                        | 278353.044 N
   Interaction ratio in compression of gusset                              |
      [P/Pa]                                                               | 0.377
                                                                           |
UFM forces at gusset interface                                             |
------------------------------                                             |
   Horizontal force at gusset to column interface (Hc)                     | 38970.076 N
   Vertical force at gusset to column interface (Vc)                       | 36638.533 N
   Horizontal force at gusset to beam interface (Hb)                       | 33307.757 N
   Vertical force at gusset to beam interface (Vb)                         | 39525.205 N
   Moment at gusset to beam interface (Mb)                                 | 6496155.817 N mm
                                                                           |
Gusset to beam connection checks                                           |
--------------------------------                                           |
                                                                           |
Gusset to beam weld check:                                                 |
   Required strength of weld (fw)                                          | 287.818 N/mm
   Nominal strength of weld (fn)                                           | 1226.786 N/mm
   ASD factor for weld strength (omega)                                    | 2.000
   Allowable strength of weld                                              |
      [fa=fn/omega]                                                        | 613.393 N/mm
   Interaction ratio for weld                                              |
```

```
      [fw/fa]                                                      | 0.469
                                                                   |
Rupture of gusset at weld check:                                   |
   Minimum thickness of plate required for rupture (tg‘)           | 10.223 mm
   Interaction ratio for gusset rupture at weld                    |
      [tg‘/tg]                                                     | 0.852
                                                                   |
Beam web yielding check:                                           |
   Nominal strength in web yielding (Rn)                           | 1388323.125 N
   ASD factor in web yielding (omega)                              | 1.500
   Allowable strength in web yielding                              |
      [Ra=Rn/omega]                                                | 925548.750 N
   Interaction ratio for web yielding                              |
      [(Vb+4*Mb/lg)/Ra]                                            | 0.136
                                                                   |
Beam web crippling check:                                          |
   Nominal strength of beam in web crippling (Rn)                  | 1150059.805 N
   ASD factor for web crippling (omega)                            | 2.000
   Allowable strength of beam in web crippling                     |
      [Ra=Rn/omega]                                                | 575029.903 N
   Interaction ratio in web crippling                              |
      [(Vb+4*Mb/lg)/Ra]                                            | 0.219
                                                                   |
Gusset to column connection checks                                 |
----------------------------------                                 |
   Tension per bolt (without prying)                               |
      [T2=Hc/(2*n2)]                                               | 4871.259 N
   Shear force per bolt                                            |
      [R2=Vc/(2*n2)]                                               | 4579.817 N
                                                                   |
Bolt shear check:                                                  |
   Nominal strength of bolt in shear (Rn)                          | 178305.358 N
   ASD factor in bolt shear (omega)                                | 2.000
   Allowable strength of bolt in shear                             |
      [Ra=Rn/omega]                                                | 89152.679 N
   Interaction ratio in bolt shear                                 |
      [R2/Ra]                                                      | 0.051
                                                                   |
Bolt bearing at clip angle check:                                  |
   Nominal strength in bolt bearing at clip angle (Rn)             | 140208.000 N
   ASD factor in bolt bearing (omega)                              | 0.750
   Allowable strength in bolt bearing at clip angle                |
      [Ra=Rn/omega]                                                | 70104.000 N
   Interaction ratio in bolt bearing at clip angle                 |
      [R2/Ra]                                                      | 0.065
                                                                   |
Bolt bearing at column check:                                      |
   Nominal strength in bolt bearing at column (Rn)                 | 358776.000 N
   ASD factor in bolt bearing (omega)                              | 2.000
   Allowable strength in bolt bearing at column                    |
      [Ra=Rn/omega]                                                | 179388.000 N
   Interaction ratio in bolt bearing at column                     |
      [R2/Ra]                                                      | 0.026
```

```
                                                                        |
Clip angle shear yielding check:                                        |
   Nominal shear yieldind strength of clip angle (Rn)                   | 1066800.000 N
   ASD factor in shear yielding (omega)                                 | 1.500
   Allowable shear yield strength of clip angle                         |
      [Ra=Rn/omega]                                                     | 711200.000 N
   Interaction ratio in clip shear yielding                             |
      [sqrt(Hc^2+Vc^2)/Ra]                                              | 0.075
                                                                        |
Clip angle shear rupture check:                                         |
   Nominal shear rupture strength of clip angle (Rn)                    | 1121664.000 N
   ASD factor in shear yielding (omega)                                 | 2.000
   Allowable shear rupture strength of clip angle                       |
      [Ra=Rn/omega]                                                     | 560832.000 N
   Interaction ratio in clip shear rupture                              |
      [sqrt(Hc^2+Vc^2)/Ra]                                              | 0.095
                                                                        |
Block shear at clip angle check:                                        |
   Gross area in shear                                                  | 6223.000 mm^2
   Net area in shear                                                    | 4089.400 mm^2
   Net area in tension                                                  | 660.400 mm^2
   Nominal strength in block shear at clip angle (Rn)                   | 1197610.000 N
   ASD factor in bolt bearing (omega)                                   | 2.000
   Allowable strength in block shear at clip angle                      |
      [Ra=Rn/omega]                                                     | 598805.000 N
   Interaction ratio in block shear at clip angle                       |
      [Vc/Ra]                                                           | 0.061
                                                                        |
Bolt tension check (without prying):                                    |
   Nominal strength of bolt in tension (Rn)                             | 296353.200 N
   ASD factor in bolt tension (omega)                                   | 2.000
   Allowable strength of bolt in tension                                |
      [B=Rn/omega]                                                      | 148176.600 N
   Interaction ratio in bolt tension                                    |
      [T2/B]                                                            | 0.033
                                                                        |
Clip angle prying action check:                                         |
   Bolt strength reduction factor due to clip prying (Q)                | 0.162
   Interaction ratio in clip prying                                     |
      [T2/(Q*B)]                                                        | 0.203
                                                                        |
Column flange prying action check:                                      |
   Bolt strength reduction factor due to column flange prying (Q)       | 0.410
   Interaction ratio in column flange prying                            |
      [T2/(Q*B)]                                                        | 0.080
                                                                        |
Weld check:                                                             |
   Polar moment of inertia of weld group                                | 5066369.415 mm^3
   Maximum stress in weld (fw)                                          | 102.109 N/mm
   Nominal strength of weld (fn)                                        | 1635.715 N/mm
   ASD factor for weld strength (omega)                                 | 2.000
   Allowable strength of weld                                           |
      [fa=fn/omega]                                                     | 817.858 N/mm
```

```
   Interaction ratio in weld strength                                   |
      [fw/fa]                                                           | 0.125
                                                                        |
Gusset rupture at weld check:                                           |
   Nominal strength of gusset in rupture at weld (fn)                   | 2880.000 N/mm
   ASD factor for rupture (omega)                                       | 2.000
   Allowable strength of gusset in rupture at weld                      |
      [fa=fn/omega]                                                     | 1440.000 N/mm
   Interaction ratio in gusset rupture at weld                          |
      [2*fw/fa]                                                         | 0.142
                                                                        |
Column web yielding check:                                              |
   Nominal strength of column web yielding (Rn)                         | 1059674.400 N
   ASD factor in web yielding (omega)                                   | 1.500
   Allowable strength of column in web yielding                         |
      [Ra=Rn/omega]                                                     | 706449.600 N
   Interaction ratio in column web yielding                             |
      [Hc/Ra]                                                           | 0.055
                                                                        |
Column web crippling check:                                             |
   Nominal strength of column in web crippling (Rn)                     | 752372.905 N
   ASD factor in web crippling (omega)                                  | 2.000
   Allowable strength of column in web crippling                        |
      [Ra=Rn/omega]                                                     | 376186.453 N
   Interaction ratio in column web crippling                            |
      [Hc/Ra]                                                           | 0.104
                                                                        |
Beam to column connection checks                                        |
--------------------------------                                        |
   Tension per bolt (without prying)                                    |
      [T1=(Tf+Hc)/(2*n1)]                                               | 22328.346 N
   Shear force per bolt                                                 |
      [R1=(Rb+Vb)/(2*n1)]                                               | 36587.534 N
                                                                        |
Bolt shear check:                                                       |
   Nominal strength of bolt in shear (Rn)                               | 178305.358 N
   ASD factor in bolt shear (omega)                                     | 2.000
   Allowable strength of bolt in shear                                  |
      [Ra=Rn/omega]                                                     | 89152.679 N
   Interaction ratio in bolt shear                                      |
      [R1/Ra]                                                           | 0.410
                                                                        |
Bolt bearing at clip angle check:                                       |
   Nominal strength in bolt bearing at clip angle (Rn)                  | 140208.000 N
   ASD factor in bolt bearing (omega)                                   | 0.750
   Allowable strength in bolt bearing at clip angle                     |
      [Ra=Rn/omega]                                                     | 70104.000 N
   Interaction ratio in bolt bearing at clip angle                      |
      [R1/Ra]                                                           | 0.522
                                                                        |
Bolt bearing at column check:                                           |
   Nominal strength in bolt bearing at column (Rn)                      | 358776.000 N
   ASD factor in bolt bearing (omega)                                   | 2.000
```

```
   Allowable strength in bolt bearing at column                      |
      [Ra=Rn/omega]                                                  | 179388.000 N
   Interaction ratio in bolt bearing at column                       |
      [R1/Ra]                                                        | 0.204
                                                                     |
Clip angle shear yielding check:                                     |
   Nominal shear yieldind strength of clip angle (Rn)                | 800100.000 N
   ASD factor in shear yielding (omega)                              | 1.500
   Allowable shear yield strength of clip angle                      |
      [Ra=Rn/omega]                                                  | 533400.000 N
   Interaction ratio in clip shear yielding                          |
      [sqrt((Hc+Tf)^2+(Vb+Rb)^2)/Ra]                                 | 0.482
                                                                     |
Clip angle shear rupture check:                                      |
   Nominal shear rupture strength of clip angle (Rn)                 | 841248.000 N
   ASD factor in shear yielding (omega)                              | 2.000
   Allowable shear rupture strength of clip angle                    |
      [Ra=Rn/omega]                                                  | 420624.000 N
   Interaction ratio in clip shear rupture                           |
      [sqrt((Hc+Tf)^2+(Vb+Rb)^2)/Ra]                                 | 0.611
                                                                     |
Block shear at clip angle check:                                     |
   Gross area in shear                                               | 4445.000 mm^2
   Net area in shear                                                 | 2921.000 mm^2
   Net area in tension                                               | 641.350 mm^2
   Nominal strength in block shear at clip angle (Rn)                | 923290.000 N
   ASD factor in bolt bearing (omega)                                | 2.000
   Allowable strength in block shear at clip angle                   |
      [Ra=Rn/omega]                                                  | 461645.000 N
   Interaction ratio in block shear at clip angle                    |
      [(Rb+Vb)/Ra]                                                   | 0.476
                                                                     |
Bolt tension check (without prying):                                 |
   Nominal strength of bolt in tension (Rn)                          | 263560.752 N
   ASD factor in bolt tension (omega)                                | 2.000
   Allowable strength of bolt in tension                             |
      [B=Rn/omega]                                                   | 131780.376 N
   Interaction ratio in bolt tension                                 |
      [T1/B]                                                         | 0.169
                                                                     |
Clip angle prying action check:                                      |
   Bolt strength reduction factor due to clip prying (Q)             | 0.179
   Interaction ratio in clip prying                                  |
      [T1/(Q*B)]                                                     | 0.945
                                                                     |
Column flange prying action check:                                   |
   Bolt strength reduction factor due to column flange prying (Q)    | 0.532
   Interaction ratio in column flange prying                         |
      [T1/(Q*B)]                                                     | 0.319
                                                                     |
Weld check:                                                          |
   Polar moment of inertia of weld group                             | 2674439.676 mm^3
   Maximum stress in weld (fw)                                       | 692.829 N/mm
```

```
   Nominal strength of weld (fn)                                        | 1635.715 N/mm
   ASD factor for weld strength (omega)                                 | 2.000
   Allowable strength of weld                                           |
      [fa=fn/omega]                                                     | 817.858 N/mm
   Interaction ratio in weld strength                                   |
      [fw/fa]                                                           | 0.847
                                                                        |
Beam rupture at weld check:                                             |
   Nominal strength of beam web in rupture at weld (fn)                 | 2835.000 N/mm
   ASD factor for rupture (omega)                                       | 2.000
   Allowable strength of beam web in rupture at weld                    |
      [fa=fn/omega]                                                     | 1417.500 N/mm
   Interaction ratio in rupture of beam web at weld                     |
      [2*fw/fa]                                                         | 0.978
                                                                        |
Column web yielding check:                                              |
   Nominal strength of column web yielding (Rn)                         | 851018.400 N
   ASD factor in web yielding (omega)                                   | 1.500
   Allowable strength of column in web yielding                         |
      [Ra=Rn/omega]                                                     | 567345.600 N
   Interaction ratio in column web yielding                             |
      [(Hc+Tf)/Ra]                                                      | 0.236
                                                                        |
Column web crippling check:                                             |
   Nominal strength of column in web crippling (Rn)                     | 639159.011 N
   ASD factor in web crippling (omega)                                  | 2.000
   Allowable strength of column in web crippling                        |
      [Ra=Rn/omega]                                                     | 319579.505 N
   Interaction ratio in column web crippling                            |
      [(Hc+Tf)/Ra]                                                      | 0.419
```

3.4 Validation problem 4

```
Osoconn v1.1
Connection code : VB001AM10
Connection ID : VB001_4
------------------------------------------------------------------------+---------------------
Design Summary                                                          |
------------------------------------------------------------------------+---------------------
   Connection is OK                                                     |
   Maximum interaction ratio                                            | 0.973
------------------------------------------------------------------------+---------------------
Design Input                                                            |
------------------------------------------------------------------------+---------------------
   Design method                                                        | ASD
   Brace axial force (P)                                                | 105000.000 N
   Shear force in beam (Rb)                                             | 95000.000 N
   Transfer force in connection (Tf)                                    | 80000.000 N
                                                                        |
   Angle steel grade                                                    | ASTM A36
   Yield strength of angle section                                      | 250.000 MPa
   Tensile strength of angle section                                    | 400.000 MPa
                                                                        |
```

```
   Beam steel grade                                                        | ASTM A36
   Yield strength of beam section                                          | 250.000 MPa
   Tensile strength of beam section                                        | 400.000 MPa
                                                                           |
   Column steel grade                                                      | ASTM A36
   Yield strength of column section                                        | 250.000 MPa
   Tensile strength of column section                                      | 400.000 MPa
                                                                           |
   Plate steel grade                                                       | ASTM A36
   Yield strength of plate                                                 | 250.000 MPa
   Tensile strength of plate                                               | 400.000 MPa
                                                                           |
   Bolt grade                                                              | ASTM A325
   Bolt type                                                               | Bearing
   Bolt thread in shear plane                                              | Yes
   Bolt diameter                                                           | 22.000 mm
   Bolt gage                                                               | 110.000 mm
   Bolt spacing                                                            | 70.000 mm
   Bolt edge distance to brace edge                                        | 30.000 mm
   Bolt edge distance to gusset edge                                       | 30.000 mm
   Bolt edge distance to clip angle edge                                   | 30.000 mm
                                                                           |
   Weld electrode                                                          | E70
   Weld tensile strength                                                   | 482.000 MPa
                                                                           |
   Brace section                                                           | L89X89X6.4
   Brace angle with beam                                                   | 35.000 deg
   Gusset plate thickness (tg)                                             | 16.000 mm
   Gusset to beam weld thickness                                           | 8.000 mm
   Gusset length at connection to beam                                     | 400.000 mm
   Number of bolts per row at brace (nb)                                   | 3
   Number of bolt rows at brace                                            | 1
   Clip angle section                                                      | L89X76X12.7
   Number of bolts at beam to column connection (n1)                       | 2
   Number of bolts at gusset to column connection (n2)                     | 3
   Weld thickness at clip angle                                            | 8.000 mm
   Beam section property                                                   | W250X101
      Depth                                                                | 264.000 mm
      Flange width                                                         | 257.000 mm
      Web thickness                                                        | 11.900 mm
      Flange thickness                                                     | 19.600 mm
   Column section property                                                 | W310X107
      Depth                                                                | 312.000 mm
      Flange width                                                         | 305.000 mm
      Web thickness                                                        | 10.900 mm
      Flange thickness                                                     | 17.000 mm
---------------------------------------------------------------------------+---------------------
Design Calculation                                                         |
---------------------------------------------------------------------------+---------------------
                                                                           |
Bolt shear check at brace:                                                 |
   Shear per bolt (Pb)                                                     | 35000.000 N
   Nominal bolt shear strength (Rn)                                        | 282855.408 N
```

```
   ASD factor in bolt shear (omega)                                   | 2.000
   Allowable strength of bolt in shear                                |
      [Ra=Rn/omega]                                                   | 141427.704 N
   Interaction ratio for bolt shear                                   |
      [Pb/Ra]                                                         | 0.247
                                                                      |
Bolt bearing at brace check:                                          |
   Nominal strength of bolt bearing at brace (Rn)                     | 54864.000 N
   ASD factor in bolt bearing (omega)                                 | 2.000
   Allowable strength of bolt bearing at brace                        |
      [Ra=Rn/omega]                                                   | 27432.000 N
   Interaction ratio for bolt bearing at brace                        |
      [Pb/2*Ra]                                                       | 0.638
                                                                      |
Bolt bearing at gusset check:                                         |
   Nominal strength in bolt bearing at gusset (Rn)                    | 138240.000 N
   ASD factor in bolt bearing (omega)                                 | 2.000
   Allowable strength of bolt bearing at gusset                       |
      [Ra=Rn/omega]                                                   | 69120.000 N
   Interaction ratio for bolt bearing at gusset                       |
      [Pb/Ra]                                                         | 0.506
                                                                      |
Brace rupture check:                                                  |
   Net cross-section area of brace (An)                               | 1895.200 mm^2
   Shear lag factor (U)                                               | 0.827
   Effective cross-section area for tension rupture                   |
      [Ae=U*An]                                                       | 1567.601 mm^2
   Nominal strength of brace in tension rupture (Pn)                  | 627040.457 N
   ASD factor in tension rupture (omega)                              | 2.000
   Allowable strength of brace in tension rupture                     |
      [Pa=Pn/omega]                                                   | 313520.229 N
   Interaction ratio in brace rupture                                 |
      [P/Pa]                                                          | 0.335
                                                                      |
Block shear at brace check:                                           |
   Gross area in shear                                                | 2159.000 mm^2
   Net area in shear                                                  | 1397.000 mm^2
   Net area in tension                                                | 468.630 mm^2
   Nominal strength in block shear at brace (Rn)                      | 511302.000 N
   ASD factor in bolt bearing (omega)                                 | 2.000
   Allowable strength in block shear at brace                         |
      [Ra=Rn/omega]                                                   | 255651.000 N
   Interaction ratio in block shear at brace                          |
      [P/Ra]                                                          | 0.411
                                                                      |
Gusset tension yielding check:                                        |
   Length of Whitmore section                                         | 161.658 mm
   Gross area of gusset in tension                                    | 2586.529 mm^2
   Nominal strength of gusset in tension yielding (Pn)                | 646632.301 N
   ASD factor in tension yielding (omega)                             | 1.670
   Allowable strength of gusset in tension yielding                   |
      [Ra=Rn/omega]                                                   | 387204.971 N
   Interaction ratio in tension yielding of gusset                    |
```

```
      [P/Pa]                                                           | 0.271
                                                                       |
Gusset tension rupture check:                                          |
   Net area of gusset in tension                                       | 2202.529 mm^2
   Nominal strength of gusset in tension rupture (Pn)                  | 881011.682 N
   ASD factor in tension rupture (omega)                               | 2.000
   Allowable strength of gusset in tension rupture                     |
      [Ra=Rn/omega]                                                    | 440505.841 N
   Interaction ratio in tension rupture of gusset                      |
      [P/Pa]                                                           | 0.238
                                                                       |
Gusset compression buckling check:                                     |
   Buckling lenght at connection centerline (l1)                       | 199.865 mm
   Buckling lenght at top most point of whitmore section (l2)          | 256.462 mm
   Buckling length at bottom most point of whitmore section (l3)       | 143.268 mm
   Average buckling length of gusset plate                             |
      [lb=(l1+l2+l3)/3]                                                | 199.865 mm
   Nominal strength of gusset plate in compression (Pn)                | 560512.909 N
   ASD factor in compression (omega)                                   | 1.670
   Allowable strength of gusset in compression                         |
      [Pa=Pn/omega]                                                    | 335636.472 N
   Interaction ratio in compression of gusset                          |
      [P/Pa]                                                           | 0.313
                                                                       |
UFM forces at gusset interface                                         |
------------------------------                                         |
   Horizontal force at gusset to column interface (Hc)                 | 0.000 N
   Vertical force at gusset to column interface (Vc)                   | 40303.803 N
   Horizontal force at gusset to beam interface (Hb)                   | 64486.084 N
   Vertical force at gusset to beam interface (Vb)                     | 42560.816 N
   Moment at gusset to beam interface (Mb)                             | 853202.313 N mm
                                                                       |
Gusset to beam connection checks                                       |
--------------------------------                                       |
                                                                       |
Gusset to beam weld check:                                             |
   Required strength of weld (fw)                                      | 121.884 N/mm
   Nominal strength of weld (fn)                                       | 1635.715 N/mm
   ASD factor for weld strength (omega)                                | 2.000
   Allowable strength of weld                                          |
      [fa=fn/omega]                                                    | 817.858 N/mm
   Interaction ratio for weld                                          |
      [fw/fa]                                                          | 0.149
                                                                       |
Rupture of gusset at weld check:                                       |
   Minimum thickness of plate required for rupture (tg‘)               | 13.631 mm
   Interaction ratio for gusset rupture at weld                        |
      [tg‘/tg]                                                         | 0.852
                                                                       |
Beam web yielding check:                                               |
   Nominal strength in web yielding (Rn)                               | 1430231.250 N
   ASD factor in web yielding (omega)                                  | 1.500
   Allowable strength in web yielding                                  |
```

```
      [Ra=Rn/omega]                                                    | 953487.500 N
   Interaction ratio for web yielding                                  |
      [(Vb+4*Mb/lg)/Ra]                                                | 0.054
                                                                       |
Beam web crippling check:                                              |
   Nominal strength of beam in web crippling (Rn)                      | 1939224.512 N
   ASD factor for web crippling (omega)                                | 2.000
   Allowable strength of beam in web crippling                         |
      [Ra=Rn/omega]                                                    | 969612.256 N
   Interaction ratio in web crippling                                  |
      [(Vb+4*Mb/lg)/Ra]                                                | 0.053
                                                                       |
Gusset to column connection checks                                     |
----------------------------------                                     |
   Tension per bolt (without prying)                                   |
      [T2=Hc/(2*n2)]                                                   | 0.000 N
   Shear force per bolt                                                |
      [R2=Vc/(2*n2)]                                                   | 6717.300 N
                                                                       |
Bolt shear check:                                                      |
   Nominal strength of bolt in shear (Rn)                              | 141427.704 N
   ASD factor in bolt shear (omega)                                    | 2.000
   Allowable strength of bolt in shear                                 |
      [Ra=Rn/omega]                                                    | 70713.852 N
   Interaction ratio in bolt shear                                     |
      [R2/Ra]                                                          | 0.095
                                                                       |
Bolt bearing at clip angle check:                                      |
   Nominal strength in bolt bearing at clip angle (Rn)                 | 109728.000 N
   ASD factor in bolt bearing (omega)                                  | 0.750
   Allowable strength in bolt bearing at clip angle                    |
      [Ra=Rn/omega]                                                    | 54864.000 N
   Interaction ratio in bolt bearing at clip angle                     |
      [R2/Ra]                                                          | 0.122
                                                                       |
Bolt bearing at column check:                                          |
   Nominal strength in bolt bearing at column (Rn)                     | 230208.000 N
   ASD factor in bolt bearing (omega)                                  | 2.000
   Allowable strength in bolt bearing at column                        |
      [Ra=Rn/omega]                                                    | 115104.000 N
   Interaction ratio in bolt bearing at column                         |
      [R2/Ra]                                                          | 0.058
                                                                       |
Clip angle shear yielding check:                                       |
   Nominal shear yieldind strength of clip angle (Rn)                  | 762000.000 N
   ASD factor in shear yielding (omega)                                | 1.500
   Allowable shear yield strength of clip angle                        |
      [Ra=Rn/omega]                                                    | 508000.000 N
   Interaction ratio in clip shear yielding                            |
      [sqrt(Hc^2+Vc^2)/Ra]                                             | 0.079
                                                                       |
Clip angle shear rupture check:                                        |
   Nominal shear rupture strength of clip angle (Rn)                   | 780288.000 N
```

```
   ASD factor in shear yielding (omega)                            | 2.000
   Allowable shear rupture strength of clip angle                  |
      [Ra=Rn/omega]                                                | 390144.000 N
   Interaction ratio in clip shear rupture                         |
      [sqrt(Hc^2+Vc^2)/Ra]                                         | 0.103
                                                                   |
Block shear at clip angle check:                                   |
   Gross area in shear                                             | 4318.000 mm^2
   Net area in shear                                               | 2794.000 mm^2
   Net area in tension                                             | 759.460 mm^2
   Nominal strength in block shear at clip angle (Rn)              | 951484.000 N
   ASD factor in bolt bearing (omega)                              | 2.000
   Allowable strength in block shear at clip angle                 |
      [Ra=Rn/omega]                                                | 475742.000 N
   Interaction ratio in block shear at clip angle                  |
      [Vc/Ra]                                                      | 0.085
                                                                   |
Bolt tension check (without prying):                               |
   Nominal strength of bolt in tension (Rn)                        | 235562.800 N
   ASD factor in bolt tension (omega)                              | 2.000
   Allowable strength of bolt in tension                           |
      [B=Rn/omega]                                                 | 117781.400 N
   Interaction ratio in bolt tension                               |
      [T2/B]                                                       | 0.000
                                                                   |
Clip angle prying action check:                                    |
   Bolt strength reduction factor due to clip prying (Q)           | 0.321
   Interaction ratio in clip prying                                |
      [T2/(Q*B)]                                                   | 0.000
                                                                   |
Weld check:                                                        |
   Polar moment of inertia of weld group                           | 2075343.516 mm^3
   Maximum stress in weld (fw)                                     | 111.902 N/mm
   Nominal strength of weld (fn)                                   | 1635.715 N/mm
   ASD factor for weld strength (omega)                            | 2.000
   Allowable strength of weld                                      |
      [fa=fn/omega]                                                | 817.858 N/mm
   Interaction ratio in weld strength                              |
      [fw/fa]                                                      | 0.137
                                                                   |
Gusset rupture at weld check:                                      |
   Nominal strength of gusset in rupture at weld (fn)              | 3840.000 N/mm
   ASD factor for rupture (omega)                                  | 2.000
   Allowable strength of gusset in rupture at weld                 |
      [fa=fn/omega]                                                | 1920.000 N/mm
   Interaction ratio in gusset rupture at weld                     |
      [2*fw/fa]                                                    | 0.117
                                                                   |
Beam to column connection checks                                   |
--------------------------------                                   |
   Tension per bolt (without prying)                               |
      [T1=(Tf+Hc)/(2*n1)]                                          | 20000.000 N
   Shear force per bolt                                            |
```

```
      [R1=(Rb+Vb)/(2*n1)]                                               | 34390.204 N
                                                                        |
Bolt shear check:                                                       |
   Nominal strength of bolt in shear (Rn)                               | 141427.704 N
   ASD factor in bolt shear (omega)                                     | 2.000
   Allowable strength of bolt in shear                                  |
      [Ra=Rn/omega]                                                     | 70713.852 N
   Interaction ratio in bolt shear                                      |
      [R1/Ra]                                                           | 0.486
                                                                        |
Bolt bearing at clip angle check:                                       |
   Nominal strength in bolt bearing at clip angle (Rn)                  | 109728.000 N
   ASD factor in bolt bearing (omega)                                   | 0.750
   Allowable strength in bolt bearing at clip angle                     |
      [Ra=Rn/omega]                                                     | 54864.000 N
   Interaction ratio in bolt bearing at clip angle                      |
      [R1/Ra]                                                           | 0.627
                                                                        |
Bolt bearing at column check:                                           |
   Nominal strength in bolt bearing at column (Rn)                      | 230208.000 N
   ASD factor in bolt bearing (omega)                                   | 2.000
   Allowable strength in bolt bearing at column                         |
      [Ra=Rn/omega]                                                     | 115104.000 N
   Interaction ratio in bolt bearing at column                          |
      [R1/Ra]                                                           | 0.299
                                                                        |
Clip angle shear yielding check:                                        |
   Nominal shear yieldind strength of clip angle (Rn)                   | 495300.000 N
   ASD factor in shear yielding (omega)                                 | 1.500
   Allowable shear yield strength of clip angle                         |
      [Ra=Rn/omega]                                                     | 330200.000 N
   Interaction ratio in clip shear yielding                             |
      [sqrt((Hc+Tf)^2+(Vb+Rb)^2)/Ra]                                    | 0.482
                                                                        |
Clip angle shear rupture check:                                         |
   Nominal shear rupture strength of clip angle (Rn)                    | 499872.000 N
   ASD factor in shear yielding (omega)                                 | 2.000
   Allowable shear rupture strength of clip angle                       |
      [Ra=Rn/omega]                                                     | 249936.000 N
   Interaction ratio in clip shear rupture                              |
      [sqrt((Hc+Tf)^2+(Vb+Rb)^2)/Ra]                                    | 0.637
                                                                        |
Block shear at clip angle check:                                        |
   Gross area in shear                                                  | 2540.000 mm^2
   Net area in shear                                                    | 1625.600 mm^2
   Net area in tension                                                  | 707.390 mm^2
   Nominal strength in block shear at clip angle (Rn)                   | 663956.000 N
   ASD factor in bolt bearing (omega)                                   | 2.000
   Allowable strength in block shear at clip angle                      |
      [Ra=Rn/omega]                                                     | 331978.000 N
   Interaction ratio in block shear at clip angle                       |
      [(Rb+Vb)/Ra]                                                      | 0.414
                                                                        |
```

```
Bolt tension check (without prying):                                    |
   Nominal strength of bolt in tension (Rn)                             | 191597.627 N
   ASD factor in bolt tension (omega)                                   | 2.000
   Allowable strength of bolt in tension                                |
      [B=Rn/omega]                                                      | 95798.814 N
   Interaction ratio in bolt tension                                    |
      [T1/B]                                                            | 0.209
                                                                        |
Clip angle prying action check:                                         |
   Bolt strength reduction factor due to clip prying (Q)                | 0.369
   Interaction ratio in clip prying                                     |
      [T1/(Q*B)]                                                        | 0.566
                                                                        |
Weld check:                                                             |
   Polar moment of inertia of weld group                                | 836236.815 mm^3
   Maximum stress in weld (fw)                                          | 694.799 N/mm
   Nominal strength of weld (fn)                                        | 1635.715 N/mm
   ASD factor for weld strength (omega)                                 | 2.000
   Allowable strength of weld                                           |
      [fa=fn/omega]                                                     | 817.858 N/mm
   Interaction ratio in weld strength                                   |
      [fw/fa]                                                           | 0.850
                                                                        |
Beam rupture at weld check:                                             |
   Nominal strength of beam web in rupture at weld (fn)                 | 2856.000 N/mm
   ASD factor for rupture (omega)                                       | 2.000
   Allowable strength of beam web in rupture at weld                    |
      [fa=fn/omega]                                                     | 1428.000 N/mm
   Interaction ratio in rupture of beam web at weld                     |
      [2*fw/fa]                                                         | 0.973
```

3.5 Validation problem 5

```
Osoconn v1.1
Connection code : VB001AM10
Connection ID : VB001_5
------------------------------------------------------------------------+--------------------
Design Summary                                                          |
------------------------------------------------------------------------+--------------------
   Connection is OK                                                     |
   Maximum interaction ratio                                            | 0.999
------------------------------------------------------------------------+--------------------
Design Input                                                            |
------------------------------------------------------------------------+--------------------
   Design method                                                        | LRFD
   Brace axial force (P)                                                | 141.000 kip
   Shear force in beam (Rb)                                             | 40.000 kip
   Transfer force in connection (Tf)                                    | 30.000 kip
                                                                        |
   Angle steel grade                                                    | ASTM A36
   Yield strength of angle section                                      | 36.000 ksi
   Tensile strength of angle section                                    | 58.000 ksi
                                                                        |
```

```
   Beam steel grade                                                        | ASTM A992
   Yield strength of beam section                                          | 50.000 ksi
   Tensile strength of beam section                                        | 65.000 ksi
                                                                           |
   Column steel grade                                                      | ASTM A992
   Yield strength of column section                                        | 50.000 ksi
   Tensile strength of column section                                      | 65.000 ksi
                                                                           |
   Plate steel grade                                                       | ASTM A36
   Yield strength of plate                                                 | 36.000 ksi
   Tensile strength of plate                                               | 58.000 ksi
                                                                           |
   Bolt grade                                                              | ASTM A325
   Bolt type                                                               | Friction
   Bolt diameter                                                           | 0.750 in
   Bolt gage                                                               | 5.000 in
   Bolt spacing                                                            | 3.000 in
   Bolt edge distance to brace edge                                        | 1.250 in
   Bolt edge distance to gusset edge                                       | 1.250 in
   Bolt edge distance to clip angle edge                                   | 1.500 in
                                                                           |
   Weld electrode                                                          | E70
   Weld tensile strength                                                   | 70.000 ksi
                                                                           |
   Brace section                                                           | L6X4X1/2
   Brace angle with beam                                                   | 50.000 deg
   Gusset plate thickness (tg)                                             | 0.750 in
   Gusset to beam weld thickness                                           | 0.313 in
   Gusset length at connection to beam                                     | 25.000 in
   Number of bolts per row at brace (nb)                                   | 5
   Number of bolt rows at brace                                            | 2
   Clip angle section                                                      | L4X3X1/2
   Number of bolts at beam to column connection (n1)                       | 4
   Number of bolts at gusset to column connection (n2)                     | 6
   Weld thickness at clip angle                                            | 0.250 in
   Beam section property                                                   | W16X45
      Depth                                                                | 16.100 in
      Flange width                                                         | 7.040 in
      Web thickness                                                        | 0.345 in
      Flange thickness                                                     | 0.565 in
   Column section property                                                 | W14X109
      Depth                                                                | 14.300 in
      Flange width                                                         | 14.600 in
      Web thickness                                                        | 0.525 in
      Flange thickness                                                     | 0.860 in
------------------------------------------------------------------------+--------------------
Design Calculation                                                      |
------------------------------------------------------------------------+--------------------
                                                                        |
Bolt shear check at brace:                                              |
   Shear per bolt (Pb)                                                  | 14.100 kip
   Nominal bolt shear strength (Rn)                                     | 31.640 kip
   LRFD factor in bolt slip (phi)                                       | 1.000
```

```
   Allowable strength of bolt in shear                                |
      [Ra=Rn*phi]                                                     | 31.640 kip
   Interaction ratio for bolt shear                                   |
      [Pb/Ra]                                                         | 0.446
                                                                      |
Bolt bearing at brace check:                                          |
   Nominal strength of bolt bearing at brace (Rn)                     | 29.362 kip
   LRFD factor in bolt bearing (phi)                                  | 0.750
   Allowable strength of bolt bearing at brace                        |
      [Ra=Rn*phi]                                                     | 22.022 kip
   Interaction ratio for bolt bearing at brace                        |
      [Pb/2*Ra]                                                       | 0.320
                                                                      |
Bolt bearing at gusset check:                                         |
   Nominal strength in bolt bearing at gusset (Rn)                    | 44.044 kip
   LRFD factor in bolt bearing (phi)                                  | 0.750
   Allowable strength of bolt bearing at gusset                       |
      [Ra=Rn*phi]                                                     | 33.033 kip
   Interaction ratio for bolt bearing at gusset                       |
      [Pb/Ra]                                                         | 0.427
                                                                      |
Brace rupture check:                                                  |
   Net cross-section area of brace (An)                               | 7.875 in^2
   Shear lag factor (U)                                               | 0.918
   Effective cross-section area for tension rupture                   |
      [Ae=U*An]                                                       | 7.231 in^2
   Nominal strength of brace in tension rupture (Pn)                  | 419.411 kip
   LRFD factor in tension rupture (phi)                               | 0.750
   Allowable strength of brace in tension rupture                     |
      [Pa=Pn*phi]                                                     | 314.558 kip
   Interaction ratio in brace rupture                                 |
      [P/Pa]                                                          | 0.448
                                                                      |
Block shear at brace check:                                           |
   Gross area in shear                                                | 13.250 in^2
   Net area in shear                                                  | 9.594 in^2
   Net area in tension                                                | 3.031 in^2
   Nominal strength in block shear at brace (Rn)                      | 462.012 kip
   LRFD factor in block shear (phi)                                   | 0.750
   Allowable strength in block shear at brace                         |
      [Ra=Rn*phi]                                                     | 346.509 kip
   Interaction ratio in block shear at brace                          |
      [P/Ra]                                                          | 0.407
                                                                      |
Gusset tension yielding check:                                        |
   Length of Whitmore section                                         | 16.356 in
   Gross area of gusset in tension                                    | 12.267 in^2
   Nominal strength of gusset in tension yielding (Pn)                | 441.623 kip
   LRFD factor in tension yielding (phi)                              | 0.900
   Allowable strength of gusset in tension yielding                   |
      [Pa=Pn*phi]                                                     | 397.461 kip
   Interaction ratio in tension yielding of gusset                    |
      [P/Pa]                                                          | 0.355
```

```
                                                                        |
Gusset tension rupture check:                                           |
   Net area of gusset in tension                                        | 11.049 in^2
   Nominal strength of gusset in tension rupture (Pn)                   | 640.816 kip
   LRFD factor in tension rupture (phi)                                 | 0.750
   Allowable strength of gusset in tension rupture                      |
      [Pa=Pn*phi]                                                       | 480.612 kip
   Interaction ratio in tension rupture of gusset                       |
      [P/Pa]                                                            | 0.293
                                                                        |
Gusset compression buckling check:                                      |
   Buckling lenght at connection centerline (l1)                        | 10.127 in
   Buckling lenght at top most point of whitmore section (l2)           | 0.380 in
   Buckling length at bottom most point of whitmore section (l3)        | 0.995 in
   Average buckling length of gusset plate                              |
      [lb=(l1+l2+l3)/3]                                                 | 3.834 in
   Nominal strength of gusset plate in compression (Pn)                 | 431.249 kip
   LRFD factor in compression (phi)                                     | 0.900
   Allowable strength of gusset in compression                          |
      [Pa=Pn*phi]                                                       | 388.124 kip
   Interaction ratio in compression of gusset                           |
      [P/Pa]                                                            | 0.363
                                                                        |
Block shear at gusset check:                                            |
   Gross area in shear                                                  | 19.875 in^2
   Net area in shear                                                    | 14.391 in^2
   Net area in tension                                                  | 1.266 in^2
   Nominal strength in block shear at brace (Rn)                        | 502.706 kip
   LRFD factor in block shear (phi)                                     | 0.750
   Allowable strength in block shear at brace                           |
      [Ra=Rn*phi]                                                       | 377.030 kip
   Interaction ratio in block shear at brace                            |
      [P/Ra]                                                            | 0.374
                                                                        |
UFM forces at gusset interface                                          |
------------------------------                                          |
   Horizontal force at gusset to column interface (Hc)                  | 37.784 kip
   Vertical force at gusset to column interface (Vc)                    | 52.845 kip
   Horizontal force at gusset to beam interface (Hb)                    | 66.056 kip
   Vertical force at gusset to beam interface (Vb)                      | 42.540 kip
   Moment at gusset to beam interface (Mb)                              | 79.173 kip in
                                                                        |
Gusset to beam connection checks                                        |
--------------------------------                                        |
                                                                        |
Gusset to beam weld check:                                              |
   Required strength of weld (fw)                                       | 2.005 kip/in
   Nominal strength of weld (fn)                                        | 9.294 kip/in
   LRFD factor for weld strength (phi)                                  | 0.750
   Allowable strength of weld                                           |
      [fa=fn*phi]                                                       | 6.971 kip/in
   Interaction ratio for weld                                           |
      [fw/fa]                                                           | 0.288
```

```
                                                                               |
Rupture of gusset at weld check:                                               |
   Minimum thickness of plate required for rupture (tg')                       | 0.534 in
   Interaction ratio for gusset rupture at weld                                |
      [tg'/tg]                                                                 | 0.712
                                                                               |
Beam web yielding check:                                                       |
   Nominal strength in web yielding (Rn)                                       | 472.952 kip
   LRFD factor in web yielding (phi)                                           | 1.000
   Allowable strength in web yielding                                          |
      [Ra=Rn*phi]                                                              | 472.952 kip
   Interaction ratio for web yielding                                          |
      [(Vb+4*Mb/lg)/Ra]                                                        | 0.117
                                                                               |
Beam web crippling check:                                                      |
   Nominal strength of beam in web crippling (Rn)                              | 283.799 kip
   LRFD factor for web crippling (phi)                                         | 0.750
   Allowable strength of beam in web crippling                                 |
      [Ra=Rn*phi]                                                              | 212.849 kip
   Interaction ratio in web crippling                                          |
      [(Vb+4*Mb/lg)/Ra]                                                        | 0.259
                                                                               |
Gusset to column connection checks                                             |
----------------------------------                                             |
   Tension per bolt (without prying)                                           |
      [T2=Hc/(2*n2)]                                                           | 3.149 kip
   Shear force per bolt                                                        |
      [R2=Vc/(2*n2)]                                                           | 4.404 kip
                                                                               |
Bolt shear check:                                                              |
   Nominal strength of bolt in shear (Rn)                                      | 14.246 kip
   LRFD factor in bolt slip (phi)                                              | 1.000
   Allowable strength of bolt in shear                                         |
      [Ra=Rn*phi]                                                              | 14.246 kip
   Interaction ratio in bolt shear                                             |
      [R2/Ra]                                                                  | 0.309
                                                                               |
Bolt bearing at clip angle check:                                              |
   Nominal strength in bolt bearing at clip angle (Rn)                         | 38.062 kip
   LRFD factor in bolt bearing (phi)                                           | 0.750
   Allowable strength in bolt bearing at clip angle                            |
      [Ra=Rn*phi]                                                              | 28.547 kip
   Interaction ratio in bolt bearing at clip angle                             |
      [R2/Ra]                                                                  | 0.154
                                                                               |
Bolt bearing at column check:                                                  |
   Nominal strength in bolt bearing at column (Rn)                             | 100.620 kip
   LRFD factor in bolt bearing (phi)                                           | 0.750
   Allowable strength in bolt bearing at column                                |
      [Ra=Rn*phi]                                                              | 75.465 kip
   Interaction ratio in bolt bearing at column                                 |
      [R2/Ra]                                                                  | 0.058
                                                                               |
```

```
Clip angle shear yielding check:                                           |
   Nominal shear yieldind strength of clip angle (Rn)                      | 388.800 kip
   LRFD factor in shear yielding (phi)                                     | 1.000
   Allowable shear yield strength of clip angle                            |
      [Ra=Rn*phi]                                                          | 388.800 kip
   Interaction ratio in clip shear yielding                                |
      [sqrt(Hc^2+Vc^2)/Ra]                                                 | 0.167
                                                                           |
Clip angle shear rupture check:                                            |
   Nominal shear rupture strength of clip angle (Rn)                       | 456.750 kip
   LRFD factor in shear rupture (phi)                                      | 0.750
   Allowable shear rupture strength of clip angle                          |
      [Ra=Rn*phi]                                                          | 342.562 kip
   Interaction ratio in clip shear rupture                                 |
      [sqrt(Hc^2+Vc^2)/Ra]                                                 | 0.190
                                                                           |
Block shear at clip angle check:                                           |
   Gross area in shear                                                     | 16.500 in^2
   Net area in shear                                                       | 12.031 in^2
   Net area in tension                                                     | 1.469 in^2
   Nominal strength in block shear at clip angle (Rn)                      | 441.587 kip
   LRFD factor in block shear (phi)                                        | 0.750
   Allowable strength in block shear at clip angle                         |
      [Ra=Rn*phi]                                                          | 331.191 kip
   Interaction ratio in block shear at clip angle                          |
      [Vc/Ra]                                                              | 0.160
                                                                           |
Bolt tension check (without prying):                                       |
   Nominal strength of bolt in tension (Rn)                                | 39.741 kip
   LRFD factor in bolt tension (phi)                                       | 0.750
   Allowable strength of bolt in tension                                   |
      [B=Rn*phi]                                                           | 29.805 kip
   Interaction ratio in bolt tension                                       |
      [T2/B]                                                               | 0.106
                                                                           |
Clip angle prying action check:                                            |
   Bolt strength reduction factor due to clip prying (Q)                   | 0.379
   Interaction ratio in clip prying                                        |
      [T2/(Q*B)]                                                           | 0.279
                                                                           |
Column flange prying action check:                                         |
   Bolt strength reduction factor due to column flange prying (Q)          | 1.000
   Interaction ratio in column flange prying                               |
      [T2/(Q*B)]                                                           | 0.106
                                                                           |
Weld check:                                                                |
   Polar moment of inertia of weld group                                   | 899.718 in^3
   Maximum stress in weld (fw)                                             | 2.035 kip/in
   Nominal strength of weld (fn)                                           | 7.423 kip/in
   LRFD factor for weld strength (phi)                                     | 0.750
   Allowable strength of weld                                              |
      [fa=fn*phi]                                                          | 5.568 kip/in
   Interaction ratio in weld strength                                      |
```

```
      [fw/fa]                                                          | 0.365
                                                                       |
Gusset rupture at weld check:                                          |
   Nominal strength of gusset in rupture at weld (fn)                  | 26.100 kip/in
   LRFD factor for rupture (phi)                                       | 0.750
   Allowable strength of gusset in rupture at weld                     |
      [fa=fn*phi]                                                      | 19.575 kip/in
   Interaction ratio in gusset rupture at weld                         |
      [2*fw/fa]                                                        | 0.208
                                                                       |
Column web yielding check:                                             |
   Nominal strength of column web yielding (Rn)                        | 568.312 kip
   LRFD factor in web yielding (phi)                                   | 1.000
   Allowable strength of column in web yielding                        |
      [Ra=Rn*phi]                                                      | 568.312 kip
   Interaction ratio in column web yielding                            |
      [Hc/Ra]                                                          | 0.066
                                                                       |
Column web crippling check:                                            |
   Nominal strength of column in web crippling (Rn)                    | 561.762 kip
   LRFD factor in web crippling (phi)                                  | 0.750
   Allowable strength of column in web crippling                       |
      [Ra=Rn*phi]                                                      | 421.322 kip
   Interaction ratio in column web crippling                           |
      [Hc/Ra]                                                          | 0.090
                                                                       |
Beam to column connection checks                                       |
--------------------------------                                       |
   Tension per bolt (without prying)                                   |
      [T1=(Tf+Hc)/(2*n1)]                                              | 8.473 kip
   Shear force per bolt                                                |
      [R1=(Rb+Vb)/(2*n1)]                                              | 10.318 kip
                                                                       |
Bolt shear check:                                                      |
   Nominal strength of bolt in shear (Rn)                              | 11.583 N
   LRFD factor in bolt slip (phi)                                      | 1.000
   Allowable strength of bolt in shear                                 |
      [Ra=Rn*phi]                                                      | 11.583 kip
   Interaction ratio in bolt shear                                     |
      [R1/Ra]                                                          | 0.891
                                                                       |
Bolt bearing at clip angle check:                                      |
   Nominal strength in bolt bearing at clip angle (Rn)                 | 38.062 kip
   LRFD factor in bolt bearing (phi)                                   | 0.750
   Allowable strength in bolt bearing at clip angle                    |
      [Ra=Rn*phi]                                                      | 28.547 kip
   Interaction ratio in bolt bearing at clip angle                     |
      [R1/Ra]                                                          | 0.361
                                                                       |
Bolt bearing at column check:                                          |
   Nominal strength in bolt bearing at column (Rn)                     | 100.620 kip
   LRFD factor in bolt bearing (phi)                                   | 0.750
   Allowable strength in bolt bearing at column                        |
```

```
      [Ra=Rn*phi]                                                     | 75.465 kip
   Interaction ratio in bolt bearing at column                        |
      [R1/Ra]                                                         | 0.137
                                                                      |
Clip angle shear yielding check:                                      |
   Nominal shear yieldind strength of clip angle (Rn)                 | 259.200 kip
   LRFD factor in shear yielding (phi)                                | 1.000
   Allowable shear yield strength of clip angle                       |
      [Ra=Rn*phi]                                                     | 259.200 kip
   Interaction ratio in clip shear yielding                           |
      [sqrt((Hc+Tf)^2+(Vb+Rb)^2)/Ra]                                  | 0.412
                                                                      |
Clip angle shear rupture check:                                       |
   Nominal shear rupture strength of clip angle (Rn)                  | 304.500 kip
   LRFD factor in shear rupture (phi)                                 | 0.750
   Allowable shear rupture strength of clip angle                     |
      [Ra=Rn*phi]                                                     | 228.375 kip
   Interaction ratio in clip shear rupture                            |
      [sqrt((Hc+Tf)^2+(Vb+Rb)^2)/Ra]                                  | 0.468
                                                                      |
Block shear at clip angle check:                                      |
   Gross area in shear                                                | 10.500 in^2
   Net area in shear                                                  | 7.656 in^2
   Net area in tension                                                | 1.266 in^2
   Nominal strength in block shear at clip angle (Rn)                 | 300.243 kip
   LRFD factor in block shear (phi)                                   | 0.750
   Allowable strength in block shear at clip angle                    |
      [Ra=Rn*phi]                                                     | 225.182 kip
   Interaction ratio in block shear at clip angle                     |
      [(Rb+Vb)/Ra]                                                    | 0.367
                                                                      |
Bolt tension check (without prying):                                  |
   Nominal strength of bolt in tension (Rn)                           | 39.741 kip
   LRFD factor in bolt tension (phi)                                  | 0.750
   Allowable strength of bolt in tension                              |
      [B=Rn*phi]                                                      | 29.805 kip
   Interaction ratio in bolt tension                                  |
      [T1/B]                                                          | 0.284
                                                                      |
Clip angle prying action check:                                       |
   Bolt strength reduction factor due to clip prying (Q)              | 0.334
   Interaction ratio in clip prying                                   |
      [T1/(Q*B)]                                                      | 0.852
                                                                      |
Column flange prying action check:                                    |
   Bolt strength reduction factor due to column flange prying (Q)     | 1.000
   Interaction ratio in column flange prying                          |
      [T1/(Q*B)]                                                      | 0.284
                                                                      |
Weld check:                                                           |
   Polar moment of inertia of weld group                              | 332.119 in^3
   Maximum stress in weld (fw)                                        | 5.042 kip/in
   Nominal strength of weld (fn)                                      | 7.423 kip/in
```

```
   LRFD factor for weld strength (phi)                                    | 0.750
   Allowable strength of weld                                             |
      [fa=fn*phi]                                                         | 5.568 kip/in
   Interaction ratio in weld strength                                     |
      [fw/fa]                                                             | 0.906
                                                                          |
Beam rupture at weld check:                                               |
   Nominal strength of beam web in rupture at weld (fn)                   | 13.455 kip/in
   LRFD factor for rupture (phi)                                          | 0.750
   Allowable strength of beam web in rupture at weld                      |
      [fa=fn*phi]                                                         | 10.091 kip/in
   Interaction ratio in rupture of beam web at weld                       |
      [2*fw/fa]                                                           | 0.999
                                                                          |
Column web yielding check:                                                |
   Nominal strength of column web yielding (Rn)                           | 410.812 kip
   LRFD factor in web yielding (phi)                                      | 1.000
   Allowable strength of column in web yielding                           |
      [Ra=Rn*phi]                                                         | 410.812 kip
   Interaction ratio in column web yielding                               |
      [(Hc+Tf)/Ra]                                                        | 0.165
                                                                          |
Column web crippling check:                                               |
   Nominal strength of column in web crippling (Rn)                       | 425.744 kip
   LRFD factor in web crippling (phi)                                     | 0.750
   Allowable strength of column in web crippling                          |
      [Ra=Rn*phi]                                                         | 319.308 kip
   Interaction ratio in column web crippling                              |
      [(Hc+Tf)/Ra]                                                        | 0.212
```

3.6 Validation problem 6

```
Osoconn v1.1
Connection code : VB001AM10
Connection ID : VB001_6
--------------------------------------------------------------------------+---------------------
Design Summary                                                            |
--------------------------------------------------------------------------+---------------------
   Connection is OK                                                       |
   Maximum interaction ratio                                              | 0.934
--------------------------------------------------------------------------+---------------------
Design Input                                                              |
--------------------------------------------------------------------------+---------------------
   Design method                                                          | ASD
   Brace axial force (P)                                                  | 125000.000 N
   Shear force in beam (Rb)                                               | 45000.000 N
   Transfer force in connection (Tf)                                      | 70000.000 N
                                                                          |
   Angle steel grade                                                      | ASTM A36
   Yield strength of angle section                                        | 250.000 MPa
   Tensile strength of angle section                                      | 400.000 MPa
                                                                          |
   Beam steel grade                                                       | ASTM A36
```

```
   Yield strength of beam section                                        | 250.000 MPa
   Tensile strength of beam section                                      | 400.000 MPa
                                                                         |
   Column steel grade                                                    | ASTM A36
   Yield strength of column section                                      | 250.000 MPa
   Tensile strength of column section                                    | 400.000 MPa
                                                                         |
   Plate steel grade                                                     | ASTM A36
   Yield strength of plate                                               | 250.000 MPa
   Tensile strength of plate                                             | 400.000 MPa
                                                                         |
   Bolt grade                                                            | ASTM A325
   Bolt type                                                             | Bearing
   Bolt thread in shear plane                                            | Yes
   Bolt diameter                                                         | 22.000 mm
   Bolt gage                                                             | 100.000 mm
   Bolt spacing                                                          | 70.000 mm
   Bolt edge distance to brace edge                                      | 30.000 mm
   Bolt edge distance to gusset edge                                     | 30.000 mm
   Bolt edge distance to clip angle edge                                 | 30.000 mm
                                                                         |
   Weld electrode                                                        | E70
   Weld tensile strength                                                 | 482.000 MPa
                                                                         |
   Brace section                                                         | L152X102X7.9
   Brace angle with beam                                                 | 35.000 deg
   Gusset plate thickness (tg)                                           | 16.000 mm
   Gusset to beam weld thickness                                         | 8.000 mm
   Gusset length at connection to beam                                   | 400.000 mm
   Number of bolts per row at brace (nb)                                 | 3
   Number of bolt rows at brace                                          | 2
   Clip angle section                                                    | L89X76X12.7
   Number of bolts at beam to column connection (n1)                     | 2
   Number of bolts at gusset to column connection (n2)                   | 3
   Weld thickness at clip angle                                          | 6.000 mm
   Beam section property                                                 | W310X74
      Depth                                                              | 310.000 mm
      Flange width                                                       | 205.000 mm
      Web thickness                                                      | 9.400 mm
      Flange thickness                                                   | 16.300 mm
   Column section property                                               | W360X72
      Depth                                                              | 351.000 mm
      Flange width                                                       | 204.000 mm
      Web thickness                                                      | 8.640 mm
      Flange thickness                                                   | 15.100 mm
-------------------------------------------------------------------------+--------------------
Design Calculation                                                       |
-------------------------------------------------------------------------+--------------------
                                                                         |
Bolt shear check at brace:                                               |
   Shear per bolt (Pb)                                                   | 20833.333 N
   Nominal bolt shear strength (Rn)                                      | 282855.408 N
   ASD factor in bolt shear (omega)                                      | 2.000
```

```
   Allowable strength of bolt in shear                            |
      [Ra=Rn/omega]                                               | 141427.704 N
   Interaction ratio for bolt shear                               |
      [Pb/Ra]                                                     | 0.147
                                                                  |
Bolt bearing at brace check:                                      |
   Nominal strength of bolt bearing at brace (Rn)                 | 68601.600 N
   ASD factor in bolt bearing (omega)                             | 2.000
   Allowable strength of bolt bearing at brace                    |
      [Ra=Rn/omega]                                               | 34300.800 N
   Interaction ratio for bolt bearing at brace                    |
      [Pb/2*Ra]                                                   | 0.304
                                                                  |
Bolt bearing at gusset check:                                     |
   Nominal strength in bolt bearing at gusset (Rn)                | 138240.000 N
   ASD factor in bolt bearing (omega)                             | 2.000
   Allowable strength of bolt bearing at gusset                   |
      [Ra=Rn/omega]                                               | 69120.000 N
   Interaction ratio for bolt bearing at gusset                   |
      [Pb/Ra]                                                     | 0.301
                                                                  |
Brace rupture check:                                              |
   Net cross-section area of brace (An)                           | 3137.760 mm^2
   Shear lag factor (U)                                           | 0.835
   Effective cross-section area for tension rupture               |
      [Ae=U*An]                                                   | 2620.030 mm^2
   Nominal strength of brace in tension rupture (Pn)              | 1048011.840 N
   ASD factor in tension rupture (omega)                          | 2.000
   Allowable strength of brace in tension rupture                 |
      [Pa=Pn/omega]                                               | 524005.920 N
   Interaction ratio in brace rupture                             |
      [P/Pa]                                                      | 0.239
                                                                  |
Block shear at brace check:                                       |
   Gross area in shear                                            | 2699.600 mm^2
   Net area in shear                                              | 1746.800 mm^2
   Net area in tension                                            | 1127.480 mm^2
   Nominal strength in block shear at brace (Rn)                  | 855932.000 N
   ASD factor in bolt bearing (omega)                             | 2.000
   Allowable strength in block shear at brace                     |
      [Ra=Rn/omega]                                               | 427966.000 N
   Interaction ratio in block shear at brace                      |
      [P/Ra]                                                      | 0.292
                                                                  |
Gusset tension yielding check:                                    |
   Length of Whitmore section                                     | 221.658 mm
   Gross area of gusset in tension                                | 3546.529 mm^2
   Nominal strength of gusset in tension yielding (Pn)            | 886632.301 N
   ASD factor in tension yielding (omega)                         | 1.670
   Allowable strength of gusset in tension yielding               |
      [Ra=Rn/omega]                                               | 530917.546 N
   Interaction ratio in tension yielding of gusset                |
      [P/Pa]                                                      | 0.235
```

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                                                                         |
Gusset tension rupture check:                                            |
   Net area of gusset in tension                                         | 2778.529 mm^2
   Nominal strength of gusset in tension rupture (Pn)                    | 1111411.682 N
   ASD factor in tension rupture (omega)                                 | 2.000
   Allowable strength of gusset in tension rupture                       |
      [Ra=Rn/omega]                                                      | 555705.841 N
   Interaction ratio in tension rupture of gusset                        |
      [P/Pa]                                                             | 0.225
                                                                         |
Gusset compression buckling check:                                       |
   Buckling lenght at connection centerline (l1)                         | 159.766 mm
   Buckling lenght at top most point of whitmore section (l2)            | 237.369 mm
   Buckling length at bottom most point of whitmore section (l3)         | 82.162 mm
   Average buckling length of gusset plate                               |
      [lb=(l1+l2+l3)/3]                                                  | 159.766 mm
   Nominal strength of gusset plate in compression (Pn)                  | 809245.575 N
   ASD factor in compression (omega)                                     | 1.670
   Allowable strength of gusset in compression                           |
      [Pa=Pn/omega]                                                      | 484578.188 N
   Interaction ratio in compression of gusset                            |
      [P/Pa]                                                             | 0.258
                                                                         |
Block shear at gusset check:                                             |
   Gross area in shear                                                   | 5440.000 mm^2
   Net area in shear                                                     | 3520.000 mm^2
   Net area in tension                                                   | 576.000 mm^2
   Nominal strength in block shear at brace (Rn)                         | 1046400.000 N
   ASD factor in bolt bearing (omega)                                    | 2.000
   Allowable strength in block shear at brace                            |
      [Ra=Rn/omega]                                                      | 523200.000 N
   Interaction ratio in block shear at brace                             |
      [P/Ra]                                                             | 0.239
                                                                         |
UFM forces at gusset interface                                           |
------------------------------                                           |
   Horizontal force at gusset to column interface (Hc)                   | 0.000 N
   Vertical force at gusset to column interface (Vc)                     | 45409.234 N
   Horizontal force at gusset to beam interface (Hb)                     | 72654.774 N
   Vertical force at gusset to beam interface (Vb)                       | 56307.450 N
   Moment at gusset to beam interface (Mb)                               | 221957.735 N mm
                                                                         |
Gusset to beam connection checks                                         |
--------------------------------                                         |
                                                                         |
Gusset to beam weld check:                                               |
   Required strength of weld (fw)                                        | 143.684 N/mm
   Nominal strength of weld (fn)                                         | 1635.715 N/mm
   ASD factor for weld strength (omega)                                  | 2.000
   Allowable strength of weld                                            |
      [fa=fn/omega]                                                      | 817.858 N/mm
   Interaction ratio for weld                                            |
      [fw/fa]                                                            | 0.176
```

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                                                                      |
Rupture of gusset at weld check:                                      |
   Minimum thickness of plate required for rupture (tg‘)              | 13.631 mm
   Interaction ratio for gusset rupture at weld                       |
      [tg‘/tg]                                                        | 0.852
                                                                      |
Beam web yielding check:                                              |
   Nominal strength in web yielding (Rn)                              | 1110375.000 N
   ASD factor in web yielding (omega)                                 | 1.500
   Allowable strength in web yielding                                 |
      [Ra=Rn/omega]                                                   | 740250.000 N
   Interaction ratio for web yielding                                 |
      [(Vb+4*Mb/lg)/Ra]                                               | 0.079
                                                                      |
Beam web crippling check:                                             |
   Nominal strength of beam in web crippling (Rn)                     | 1044150.692 N
   ASD factor for web crippling (omega)                               | 2.000
   Allowable strength of beam in web crippling                        |
      [Ra=Rn/omega]                                                   | 522075.346 N
   Interaction ratio in web crippling                                 |
      [(Vb+4*Mb/lg)/Ra]                                               | 0.112
                                                                      |
Gusset to column connection checks                                    |
----------------------------------                                    |
   Tension per bolt (without prying)                                  |
      [T2=Hc/(2*n2)]                                                  | 0.000 N
   Shear force per bolt                                               |
      [R2=Vc/(2*n2)]                                                  | 7568.206 N
                                                                      |
Bolt shear check:                                                     |
   Nominal strength of bolt in shear (Rn)                             | 141427.704 N
   ASD factor in bolt shear (omega)                                   | 2.000
   Allowable strength of bolt in shear                                |
      [Ra=Rn/omega]                                                   | 70713.852 N
   Interaction ratio in bolt shear                                    |
      [R2/Ra]                                                         | 0.107
                                                                      |
Bolt bearing at clip angle check:                                     |
   Nominal strength in bolt bearing at clip angle (Rn)                | 109728.000 N
   ASD factor in bolt bearing (omega)                                 | 0.750
   Allowable strength in bolt bearing at clip angle                   |
      [Ra=Rn/omega]                                                   | 54864.000 N
   Interaction ratio in bolt bearing at clip angle                    |
      [R2/Ra]                                                         | 0.138
                                                                      |
Bolt bearing at column check:                                         |
   Nominal strength in bolt bearing at column (Rn)                    | 182476.800 N
   ASD factor in bolt bearing (omega)                                 | 2.000
   Allowable strength in bolt bearing at column                       |
      [Ra=Rn/omega]                                                   | 91238.400 N
   Interaction ratio in bolt bearing at column                        |
      [R2/Ra]                                                         | 0.083
                                                                      |
```

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Clip angle shear yielding check:                                    |
   Nominal shear yieldind strength of clip angle (Rn)               | 762000.000 N
   ASD factor in shear yielding (omega)                             | 1.500
   Allowable shear yield strength of clip angle                     |
      [Ra=Rn/omega]                                                 | 508000.000 N
   Interaction ratio in clip shear yielding                         |
      [sqrt(Hc^2+Vc^2)/Ra]                                          | 0.089
                                                                    |
Clip angle shear rupture check:                                     |
   Nominal shear rupture strength of clip angle (Rn)                | 780288.000 N
   ASD factor in shear yielding (omega)                             | 2.000
   Allowable shear rupture strength of clip angle                   |
      [Ra=Rn/omega]                                                 | 390144.000 N
   Interaction ratio in clip shear rupture                          |
      [sqrt(Hc^2+Vc^2)/Ra]                                          | 0.116
                                                                    |
Block shear at clip angle check:                                    |
   Gross area in shear                                              | 4318.000 mm^2
   Net area in shear                                                | 2794.000 mm^2
   Net area in tension                                              | 886.460 mm^2
   Nominal strength in block shear at clip angle (Rn)               | 1002284.000 N
   ASD factor in bolt bearing (omega)                               | 2.000
   Allowable strength in block shear at clip angle                  |
      [Ra=Rn/omega]                                                 | 501142.000 N
   Interaction ratio in block shear at clip angle                   |
      [Vc/Ra]                                                       | 0.091
                                                                    |
Bolt tension check (without prying):                                |
   Nominal strength of bolt in tension (Rn)                         | 235562.800 N
   ASD factor in bolt tension (omega)                               | 2.000
   Allowable strength of bolt in tension                            |
      [B=Rn/omega]                                                  | 117781.400 N
   Interaction ratio in bolt tension                                |
      [T2/B]                                                        | 0.000
                                                                    |
Clip angle prying action check:                                     |
   Bolt strength reduction factor due to clip prying (Q)            | 0.357
   Interaction ratio in clip prying                                 |
      [T2/(Q*B)]                                                    | 0.000
                                                                    |
Weld check:                                                         |
   Polar moment of inertia of weld group                            | 2075343.516 mm^3
   Maximum stress in weld (fw)                                      | 126.077 N/mm
   Nominal strength of weld (fn)                                    | 1226.786 N/mm
   ASD factor for weld strength (omega)                             | 2.000
   Allowable strength of weld                                       |
      [fa=fn/omega]                                                 | 613.393 N/mm
   Interaction ratio in weld strength                               |
      [fw/fa]                                                       | 0.206
                                                                    |
Gusset rupture at weld check:                                       |
   Nominal strength of gusset in rupture at weld (fn)               | 3840.000 N/mm
   ASD factor for rupture (omega)                                   | 2.000
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   Allowable strength of gusset in rupture at weld                 |
      [fa=fn/omega]                                                 | 1920.000 N/mm
   Interaction ratio in gusset rupture at weld                     |
      [2*fw/fa]                                                     | 0.131
                                                                    |
Beam to column connection checks                                    |
--------------------------------                                    |
   Tension per bolt (without prying)                                |
      [T1=(Tf+Hc)/(2*n1)]                                           | 17500.000 N
   Shear force per bolt                                             |
      [R1=(Rb+Vb)/(2*n1)]                                           | 25326.863 N
                                                                    |
Bolt shear check:                                                   |
   Nominal strength of bolt in shear (Rn)                           | 141427.704 N
   ASD factor in bolt shear (omega)                                 | 2.000
   Allowable strength of bolt in shear                              |
      [Ra=Rn/omega]                                                 | 70713.852 N
   Interaction ratio in bolt shear                                  |
      [R1/Ra]                                                       | 0.358
                                                                    |
Bolt bearing at clip angle check:                                   |
   Nominal strength in bolt bearing at clip angle (Rn)              | 109728.000 N
   ASD factor in bolt bearing (omega)                               | 0.750
   Allowable strength in bolt bearing at clip angle                 |
      [Ra=Rn/omega]                                                 | 54864.000 N
   Interaction ratio in bolt bearing at clip angle                  |
      [R1/Ra]                                                       | 0.462
                                                                    |
Bolt bearing at column check:                                       |
   Nominal strength in bolt bearing at column (Rn)                  | 182476.800 N
   ASD factor in bolt bearing (omega)                               | 2.000
   Allowable strength in bolt bearing at column                     |
      [Ra=Rn/omega]                                                 | 91238.400 N
   Interaction ratio in bolt bearing at column                      |
      [R1/Ra]                                                       | 0.278
                                                                    |
Clip angle shear yielding check:                                    |
   Nominal shear yieldind strength of clip angle (Rn)               | 495300.000 N
   ASD factor in shear yielding (omega)                             | 1.500
   Allowable shear yield strength of clip angle                     |
      [Ra=Rn/omega]                                                 | 330200.000 N
   Interaction ratio in clip shear yielding                         |
      [sqrt((Hc+Tf)^2+(Vb+Rb)^2)/Ra]                                | 0.373
                                                                    |
Clip angle shear rupture check:                                     |
   Nominal shear rupture strength of clip angle (Rn)                | 499872.000 N
   ASD factor in shear yielding (omega)                             | 2.000
   Allowable shear rupture strength of clip angle                   |
      [Ra=Rn/omega]                                                 | 249936.000 N
   Interaction ratio in clip shear rupture                          |
      [sqrt((Hc+Tf)^2+(Vb+Rb)^2)/Ra]                                | 0.493
                                                                    |
Block shear at clip angle check:                                    |
```

```
   Gross area in shear                                               | 2540.000 mm^2
   Net area in shear                                                 | 1625.600 mm^2
   Net area in tension                                               | 802.640 mm^2
   Nominal strength in block shear at clip angle (Rn)                | 702056.000 N
   ASD factor in bolt bearing (omega)                                | 2.000
   Allowable strength in block shear at clip angle                   |
      [Ra=Rn/omega]                                                  | 351028.000 N
   Interaction ratio in block shear at clip angle                    |
      [(Rb+Vb)/Ra]                                                   | 0.289
                                                                     |
Bolt tension check (without prying):                                 |
   Nominal strength of bolt in tension (Rn)                          | 221808.765 N
   ASD factor in bolt tension (omega)                                | 2.000
   Allowable strength of bolt in tension                             |
      [B=Rn/omega]                                                   | 110904.382 N
   Interaction ratio in bolt tension                                 |
      [T1/B]                                                         | 0.158
                                                                     |
Clip angle prying action check:                                      |
   Bolt strength reduction factor due to clip prying (Q)             | 0.355
   Interaction ratio in clip prying                                  |
      [T1/(Q*B)]                                                     | 0.445
                                                                     |
Weld check:                                                          |
   Polar moment of inertia of weld group                             | 836236.815 mm^3
   Maximum stress in weld (fw)                                       | 526.641 N/mm
   Nominal strength of weld (fn)                                     | 1226.786 N/mm
   ASD factor for weld strength (omega)                              | 2.000
   Allowable strength of weld                                        |
      [fa=fn/omega]                                                  | 613.393 N/mm
   Interaction ratio in weld strength                                |
      [fw/fa]                                                        | 0.859
                                                                     |
Beam rupture at weld check:                                          |
   Nominal strength of beam web in rupture at weld (fn)              | 2256.000 N/mm
   ASD factor for rupture (omega)                                    | 2.000
   Allowable strength of beam web in rupture at weld                 |
      [fa=fn/omega]                                                  | 1128.000 N/mm
   Interaction ratio in rupture of beam web at weld                  |
      [2*fw/fa]                                                      | 0.934
```