Osoconn

Validation Record for

SC001AM10

Shop-Welded, Field-Bolted Clip Angle Shear 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 SC001AM10 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 SC001AM10 refers to the shop-welded, field-bolted clip angle shear 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

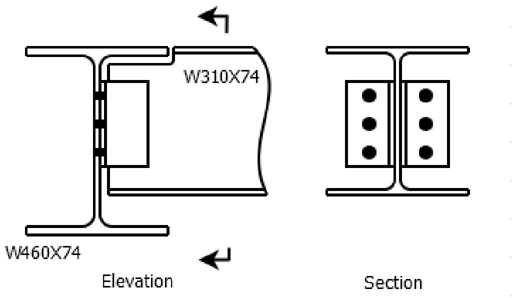
Table 1: Executive Summary

	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 shop-welded field-bolted clip angle shear connection for a W310X74 beam framing into the web of a W460X74 beam using the LRFD method. The connection has to be designed for a shear force of 200kN and a transfer force of 15kN. The beams have a grade of ASTM A36 while the bolts are ASTM 3125 A325 bearing type bolts.



Design Inputs

Material Properties

Material grade for angles — ASTM A36

Yield strength $F_{ya} := 250\ MPa$

Tensile strength $F_{ua} := 400\ MPa$

Material grade of beam — ASTM A36

Yield strength $F_{yb} := 250\ MPa$

Tensile strength $F_{ub} := 400\ MPa$

Material grade of supporting member — ASTM A36

Yield strength $F_{ys} := 250\ MPa$

Tensile strength $F_{us} := 400\ MPa$

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 $E := 200000\ MPa$

Poisson's ratio $v := 0.3$

Design Forces

Shear force in connection $SF := 200000\ N$

Transfer force in connection $TF := 15000\ N$

Geometry

Beam section — W310X74

Section depth $d_{xb} := 310\ mm$

Flange width $b_{fb} := 205\ mm$

Flange thickness $t_{fb} := 16.3\ mm$

Web thickness $t_{wb} := 9.4\ mm$

Supporting member section	W460X74
Section depth	$d_{sc} := 457\ mm$
Flange width	$b_{fs} := 191\ mm$
Flange thickness	$t_{fs} := 14.5\ mm$
Web thickness	$t_{ws} := 9.02\ mm$
Clip angle section	L102X76X9.5
Thickness	$t_a := 9.5\ mm$
Outstanding leg length	$l_{oa} := 102\ mm$
Welded leg length	$l_{ia} := 76.2\ mm$
Cope length	$c_l := 100\ mm$
Top cope depth	$c_{dt} := 35\ mm$
Bolt diameter	$d_b := 22\ mm$
Bolt hole diameter	$d_{bh} := 24\ mm$
Number of bolts	$n := 3$
Bolt spacing	$s := 70\ mm$
Bolt gage	$g := 90\ mm$
Weld thickness	$w := 6\ mm$
Clip angle length	$L := 210\ mm$
Clip angle offset from beam top	$o := 47\ mm$
Connection setback	$sb := 12\ mm$

Design Calculations

Bolt shear check

Shear per bolt

$$SF_b := \frac{SF}{2 \cdot n} \qquad SF_b = 33.333\ kN$$

Area of bolt

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

Nominal shear strength of bolt

$$R_{n.bv} := F_{nv} \cdot A_b \qquad R_{n.bv} = 141.409\ kN$$

Interaction ratio in bolt shear

$$I_0 := \frac{SF_b}{0.75 \cdot R_{n.bv}} \qquad I_0 = 0.314$$

Bolt tension check

Tension per bolt

$$TF_b := \frac{TF}{2 \cdot n} \qquad TF_b = 2.5\ kN$$

Required shear stress per bolt

$$f_{rv} := \frac{SF_b}{A_b} \qquad f_{rv} = 87.689\ MPa$$

Modified nominal tensile strength

$$F'_{nt} := min\left(1.3 \cdot F_{nt} - \frac{F_{nt}}{0.75 \cdot F_{nv}} \cdot f_{rv}, F_{nt}\right) \qquad F'_{nt} = 611.136\ MPa$$

Nominal tensile strength

$$R_{n.bt} := F'_{nt} \cdot A_b \qquad R_{n.bt} = 232.313\ kN$$

Interaction ratio for bolt tension

$$I_1 := \frac{TF_b}{0.75 \cdot R_{n.bt}} \qquad I_1 = 0.014$$

Bolt bearing at clip angle

Edge distance from bolt centre

$$ed := \frac{L - (n-1) \cdot s}{2} \qquad ed = 35\ mm$$

Clear distance between bolt holes/ hole and edge

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

Nominal strength in bearing

$$R_{n.bc} := min\left(1.2 \cdot l_c \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_{n.bc} = 104.88\ kN$$

Interaction ratio in bolt bearing

$$I_2 := \frac{SF_b}{0.75 \cdot R_{n.bc}} \qquad I_2 = 0.424$$

Bolt bearing at beam web

Nominal strength in bearing

$$R_{n.bw} := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{ws} \cdot F_{us}, 2.4 \cdot d_b \cdot t_{ws} \cdot F_{us}\right) \qquad R_{n.bw} = 190.502\ kN$$

Interaction ratio in bolt bearing

$$I_3 := \frac{SF_b}{0.75 \cdot R_{n.bw}} \qquad I_3 = 0.233$$

Clip angle shear yielding strength

Gross area in shear

$$A_{gv} := 2 \cdot L \cdot t_a \qquad A_{gv} = 3990\ mm^2$$

Nominal strength in shear yielding

$$R_{ny} := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_{ny} = 598.5\ kN$$

Resultant shear in clip angle

$$S_r := \sqrt{TF^2 + SF^2} \qquad S_r = 200.562\ kN$$

Interaction ratio in shear yielding

$$I_4 := \frac{S_r}{R_{ny}} \qquad I_4 = 0.335$$

Clip angle shear rupture strength

Net area in shear

$A_{nv} := A_{gv} - 2 \cdot n \cdot d_{bh} \cdot t_a$ $\quad A_{nv} = 2622\ mm^2$

Nominal strength in shear rupture

$R_{nr} := 0.6 \cdot F_{ua} \cdot A_{nv}$ $\quad R_{nr} = 629.28\ kN$

Interaction ratio in shear rupture

$I_5 := \dfrac{S_r}{0.75 \cdot R_{nr}}$ $\quad I_5 = 0.425$

Clip angle block shear check

Gross area subjected to block shear

$A_{gvb} := 2 \cdot (L - ed) \cdot t_a$ $\quad A_{gvb} = 3325\ mm^2$

Net area subjected to block shear

$A_{nvb} := A_{gvb} - 2 \cdot (n - 0.5) \cdot d_{bh} \cdot t_a$ $\quad A_{nvb} = 2185\ mm^2$

Net area subjected to tension

$A_{ntb} := 0.5 \cdot (2 \cdot l_{oa} + t_{wb} - g - d_{bh}) \cdot t_a$ $\quad A_{ntb} = 472.15\ mm^2$

Nominal strength in block shear

$R_{nbs1} := 0.6 \cdot F_{ua} \cdot A_{nvb} + F_{ua} \cdot A_{ntb}$

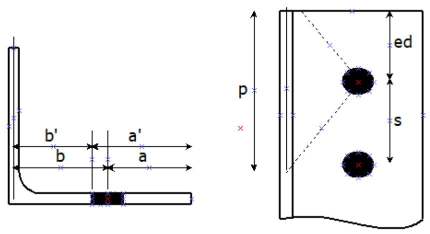
$R_{nbs2} := 0.6 \cdot F_{ya} \cdot A_{gvb} + F_{ua} \cdot A_{ntb}$

$R_{nbs} := min(R_{nbs1}, R_{nbs2})$ $\quad R_{nbs} = 687.61\ kN$

Interaction ratio in block shear

$I_6 := \dfrac{SF}{0.75 \cdot R_{nbs}}$ $\quad I_6 = 0.388$

Bolt prying check



Available tension per bolt

$B := 0.75 \cdot F'_{nt} \cdot A_b$ $\quad B = 174.235\ kN$

Clip dimensions for prying check

$b := 0.5 \cdot (g - t_{wb} - t_a)$ $\quad b = 35.55\ mm$

$a := l_{oa} - b - 0.5 \cdot t_a$ $\quad a = 61.7\ mm$

$b' := b - 0.5 \cdot d_b$ $b' = 24.55\ mm$

$a' := min\left(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b\right)$ $a' = 55.438\ mm$

Tributary length

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

Ratios for prying

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

$\rho := \frac{b'}{a'}$ $\rho = 0.443$

Thickness required to develop bolt tension without prying

$t_c := \sqrt{\frac{4 \cdot B \cdot b'}{0.9 \cdot p \cdot F_{ua}}}$ $t_c = 26.057\ mm$

$\alpha' := \frac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\frac{t_c}{t_a}\right)^2 - 1\right)$ $\alpha' = 6.88$

Proportion of tension strength available

$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right)$ $Q = 0.22$

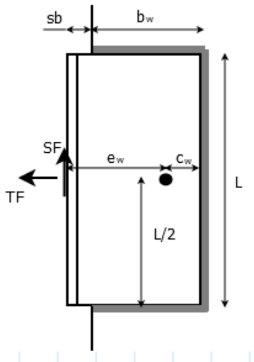
Available tension strength with prying

$T_{av} := Q \cdot B$ $T_{av} = 38.379\ kN$

Interaction ratio in prying

$I_7 := \frac{TF_b}{T_{av}}$ $I_7 = 0.065$

Weld check



Length of horizontal run of weld

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

Centroid of weld group

$c_w := \frac{{b_w}^2}{2 \cdot b_w + L}$ $c_w = 12.18\ mm$

Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 64.02\ mm$$

Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L)^3}{12} - \frac{{b_w}^2 \cdot (b_w + L)^2}{2 \cdot b_w + L} \qquad I_w = 2313.565\ cm^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{TF}{2 \cdot (2 \cdot b_w + L)} + \frac{SF \cdot e_w \cdot L}{4 \cdot I_w} \qquad f_{wh} = 312.716\ \frac{N}{mm}$$

Vertical component of weld stress

$$f_{wv} := \frac{SF}{2 \cdot (2 \cdot b_w + L)} + \frac{SF \cdot e_w \cdot (b_w - c_w)}{2\ I_w} \qquad f_{wv} = 439.457\ \frac{N}{mm}$$

Resultant weld stress

$$f_w := \sqrt{{f_{wh}}^2 + {f_{wv}}^2} \qquad f_w = 539.364\ \frac{N}{mm}$$

Nominal weld strength

$$R_{nw} := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w \qquad R_{nw} = 1226.972\ \frac{N}{mm}$$

Interaction ratio for weld check

$$I_8 := \frac{f_w}{0.75 \cdot R_{nw}} \qquad I_8 = 0.586$$

Beam web rupture at weld check

Minimum web thickness to match weld strength

$$t_{wb.min} := \frac{2 \cdot f_w}{0.75 \cdot 0.6 \cdot F_{ub}} \qquad t_{wb.min} = 5.993\ mm$$

Interaction ratio in web rupture

$$I_9 := \frac{t_{wb.min}}{t_{wb}} \qquad I_9 = 0.638$$

Beam cope flexure check

Plate buckling adjustment factor

$$f := \text{if}\left(\frac{c_l}{d_{xb}} \le 1.0, \frac{2 \cdot c_l}{d_{xb}}, 1 + \frac{c_l}{d_{xb}}\right) \qquad f = 0.645$$

Reduced beam depth

$$h_o := d_{xb} - c_{dt} \qquad h_o = 275\ mm$$

Plate buckling coefficient

$$k := \text{if}\left(\frac{c_l}{h_o} \le 1.0, 2.2 \cdot \left(\frac{h_o}{c_l}\right)^{1.65}, \frac{2.2 \cdot h_o}{c_l}\right) \qquad k = 11.677$$

Flexural buckling stress for coped section

$$F_{cr} := min\left(\frac{\pi^2 \cdot E}{12 \cdot (1 - v^2)} \cdot \left(\frac{t_{wb}}{h_o}\right) \cdot f \cdot k, F_{yb}\right) \qquad F_{cr} = 250\ MPa$$

Area of the beam flange

$A_f := t_{fb} \cdot b_{fb}$ $A_f = 3341.5\ mm^2$

Area of the beam web

$A_w := (h_o - t_{fb}) \cdot t_{wb}$ $A_w = 2431.78\ mm^2$

Distance of CG of flange from beam bottom

$x_f := 0.5 \cdot t_{fb}$ $x_f = 8.15\ mm$

Distance of CG of web from beam bottom

$x_w := 0.5 \cdot (h_o - t_{fb}) + t_{fb}$ $x_w = 145.65\ mm$

Centroid of the coped section

$$x_c := \frac{A_f \cdot x_f + A_w \cdot x_w}{A_f + A_w}$$ $x_c = 66.067\ mm$

Moment of inertia of the flange about its CG

$$I_{xf} := \frac{b_{fb} \cdot t_{fb}^{\ 3}}{12}$$ $I_{xf} = 7.398\ cm^4$

Moment of inertia of the web about its CG

$$I_{xw} := \frac{t_{wb} \cdot (h_o - t_{fb})^3}{12}$$ $I_{xw} = 1356.238\ cm^4$

Moment of inertia of the coped section

$I_{xc} := I_{xf} + A_f \cdot (x_c - x_f)^2 + I_{xw} + A_w \cdot (x_c - x_w)^2$ $I_{xc} = 4024.659\ cm^4$

Section modulus of the coped section

$$S_{xc} := \frac{I_{xc}}{h_o - x_c}$$ $S_{xc} = 192.629\ cm^3$

Nominal strength of coped section in flexure

$M_n := F_{cr} \cdot S_{xc}$ $M_n = 48.157\ kN \cdot m$

Moments in coped section due to shear force

$M_{SF} := SF \cdot (c_l + sb)$ $M_{SF} = 22.4\ kN \cdot m$

Eccentricity of applied transfer force from centroid of cope

$e_c := \text{abs}(d_{xb} - x_c - o - 0.5\ L)$ $e_c = 91.933\ mm$

Moment in coped section due to transfer force

$M_{TF} := TF \cdot e_c$ $M_{TF} = 1.379\ kN \cdot m$

Interaction ratio in cope flexure

$$I_{10} := \frac{M_{SF} + M_{TF}}{0.9 \cdot M_n}$$ $I_{10} = 0.549$

Beam cope axial check

Gross area of coped section

$$A_c := A_f + A_w \qquad A_c = 5773.28\ mm^2$$

Minor axis moment of inertia of coped sections

$$I_{yc} := \frac{(h_o - t_{fb}) \cdot t_{wb}^3}{12} + \frac{t_{fb} \cdot b_{fb}^3}{12} \qquad I_{yc} = 1172.012\ cm^4$$

Radius of gyration of coped section

$$r_c := \sqrt{\frac{min(I_{xc}, I_{yc})}{A_c}} \qquad r_c = 45.056\ mm$$

Slenderness ratio of coped section

$$KLr := \frac{c_l + sb}{r_c} \qquad KLr = 2.486$$

Elastic buckling stress

$$F_e := \frac{\pi^2 \cdot E}{KLr^2} \qquad F_e = 319450.108\ MPa$$

Critical buckling stress

$$F_{crc} := \text{if}\left(KLr \le 4.71 \cdot \sqrt{\frac{E}{F_{yb}}}, 0.658^{\frac{F_{yb}}{F_e}} \cdot F_{yb}, 0.877 \cdot F_e\right) \qquad F_{crc} = 249.918\ MPa$$

Nominal compressive strength of coped section

$$P_{nc} := F_{crc} \cdot A_c \qquad P_{nc} = 1442.847\ kN$$

Interaction ratio in compression

$$I_{11} := \frac{TF}{0.9 \cdot P_{nc}} \qquad I_{11} = 0.012$$

Beam cope shear check

Gross area of the coped section in shear

$$A_{cv} := h_o \cdot t_{wb} \qquad A_{cv} = 2585\ mm^2$$

Nominal shear strength of coped section

$$V_n := 0.6 \cdot F_{yb} \cdot A_{cv} \qquad V_n = 387.75\ kN$$

Interaction ratio in shear

$$I_{12} := \frac{SF}{V_n} \qquad I_{12} = 0.516$$

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.

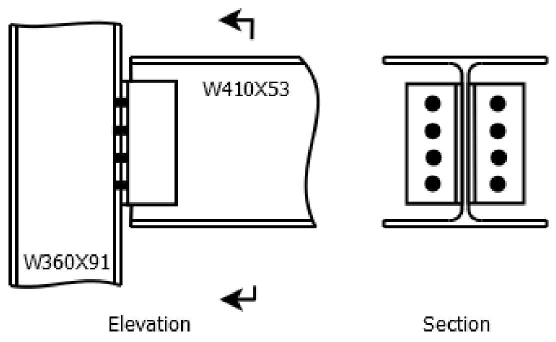
Table 2: Validation problem 1 results

	Interaction Ratio		
Check	Calculated	Osoconn	Result
Bolt shear check	0.314	0.314	OK
Bolt tension check	0.014	0.014	OK
Bolt bearing at clip angle	0.424	0.422	OK
Bolt bearing at beam web	0.233	0.233	OK
Clip angle shear yielding strength	0.335	0.334	OK
Clip angle shear rupture strength	0.425	0.424	OK
Clip angle block shear check	0.388	0.387	OK
Bolt prying check	0.065	0.065	OK
Weld check	0.586	0.586	OK
Beam web rupture at weld check	0.638	0.638	OK
Beam cope flexure check	0.549	0.549	OK
Beam cope axial check	0.012	0.012	OK
Beam cope shear check	0.516	0.516	OK

2.3 Validation Problem 2

Problem Statement

Design a shop-welded field-bolted clip angle shear connection for a W410X53 beam framing into the flange of a W360X91 column using the LRFD method. The connection has to be designed for a shear force of 160kN and a transfer force of 120kN. The beam and clip are of grade of ASTM A36 while the column is ASTM A992. The bolts used are ASTM 3125 A325 bearing type bolts.



Design Inputs

Material Properties

Material grade for angles	ASTM A36
Yield strength	$F_{ya} := 250\ MPa$
Tensile strength	$F_{ua} := 400\ MPa$
Material grade of beam	ASTM A36
Yield strength	$F_{yb} := 250\ MPa$
Tensile strength	$F_{ub} := 400\ MPa$
Material grade of supporting member	ASTM A992
Yield strength	$F_{ys} := 345\ MPa$
Tensile strength	$F_{us} := 450\ MPa$
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	$E := 200000\ MPa$
Poisson's ratio	$v := 0.3$

Design Forces

Shear force in connection	$SF := 160000\ N$
Transfer force in connection	$TF := 120000\ N$

Geometry

Beam section — W410X53

Section depth — $d_{xb} := 404\ mm$

Flange width — $b_{fb} := 178\ mm$

Flange thickness — $t_{fb} := 10.9\ mm$

Web thickness — $t_{wb} := 7.49\ mm$

Supporting member section — W360X91

Section depth — $d_{xs} := 353\ mm$

Flange width — $b_{fs} := 254\ mm$

Flange thickness — $t_{fs} := 16.4\ mm$

Web thickness — $t_{ws} := 9.53\ mm$

Fillet area dimension — $k_s := 31.5\ mm$

Clip angle section — L127X76X9.5

Thickness — $t_a := 9.5\ mm$

Outstanding leg length — $l_{oa} := 127\ mm$

Welded leg length — $l_{ia} := 76.2\ mm$

Bolt diameter — $d_b := 22\ mm$

Bolt hole diameter — $d_{bh} := 24\ mm$

Number of bolts — $n := 4$

Bolt spacing — $s := 70\ mm$

Bolt gage — $g := 140\ mm$

Weld thickness — $w := 6\ mm$

Clip angle length — $L := 270\ mm$

Clip angle offset from beam top — $o := 37\ mm$

Connection setback — $sb := 12\ mm$

Design Calculations

Bolt shear check

Shear per bolt

$$SF_b := \frac{SF}{2 \cdot n} \qquad SF_b = 20\ kN$$

Area of bolt

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

Nominal shear strength of bolt

$$R_{n.bv} := F_{nv} \cdot A_b \qquad R_{n.bv} = 141.409\ kN$$

Interaction ratio in bolt shear

$$I_0 := \frac{SF_b}{0.75 \cdot R_{n.bv}} \qquad I_0 = 0.189$$

Bolt tension check

Tension per bolt

$$TF_b := \frac{TF}{2 \cdot n} \qquad TF_b = 15\ kN$$

Required shear stress per bolt

$$f_{rv} := \frac{SF_b}{A_b} \qquad f_{rv} = 52.613\ MPa$$

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

$$R_{n.bt} := F'_{nt} \cdot A_b \qquad R_{n.bt} = 235.682\ kN$$

Interaction ratio for bolt tension

$$I_1 := \frac{TF_b}{0.75 \cdot R_{n.bt}} \qquad I_1 = 0.085$$

Bolt bearing at clip angle

Edge distance from bolt centre

$$ed := \frac{L - (n-1) \cdot s}{2} \qquad ed = 30\ mm$$

Clear distance between bolt holes/ hole and edge

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

Nominal strength in bearing

$$R_{n.bc} := min\left(1.2 \cdot l_c \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_{n.bc} = 82.08\ kN$$

Interaction ratio in bolt bearing

$$I_2 := \frac{SF_b}{0.75 \cdot R_{n.bc}} \qquad I_2 = 0.325$$

Bolt bearing at column flange

Nominal strength in bearing

$$R_{n.bf} := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{fs} \cdot F_{us}, 2.4 \cdot d_b \cdot t_{fs} \cdot F_{us}\right) \qquad R_{n.bf} = 389.664\ kN$$

Interaction ratio in bolt bearing

$$I_3 := \frac{SF_b}{0.75 \cdot R_{n.bf}} \qquad I_3 = 0.068$$

Clip angle shear yielding strength

Gross area in shear

$$A_{gv} := 2 \cdot L \cdot t_a \qquad A_{gv} = 5130\ mm^2$$

Nominal strength in shear yielding

$$R_{ny} := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_{ny} = 769.5\ kN$$

Resultant shear in clip angle

$$S_r := \sqrt{TF^2 + SF^2} \qquad S_r = 200\ kN$$

Interaction ratio in shear yielding

$$I_4 := \frac{S_r}{R_{ny}}$$ $I_4 = 0.26$

Clip angle shear rupture strength

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n \cdot d_{bh} \cdot t_a$$ $A_{nv} = 3306\ mm^2$

Nominal strength in shear rupture

$$R_{nr} := 0.6 \cdot F_{ua} \cdot A_{nv}$$ $R_{nr} = 793.44\ kN$

Interaction ratio in shear rupture

$$I_5 := \frac{S_r}{0.75 \cdot R_{nr}}$$ $I_5 = 0.336$

Clip angle block shear check

Gross area subjected to block shear

$$A_{gvb} := 2 \cdot (L - ed) \cdot t_a$$ $A_{gvb} = 4560\ mm^2$

Net area subjected to block shear

$$A_{nvb} := A_{gvb} - 2 \cdot (n - 0.5) \cdot d_{bh} \cdot t_a$$ $A_{nvb} = 2964\ mm^2$

Net area subjected to tension

$$A_{ntb} := 0.5 \cdot (2 \cdot l_{oa} + t_{wb} - g - d_{bh}) \cdot t_a$$ $A_{ntb} = 463.078\ mm^2$

Nominal strength in block shear

$$R_{nbs1} := 0.6 \cdot F_{ua} \cdot A_{nvb} + F_{ua} \cdot A_{ntb}$$

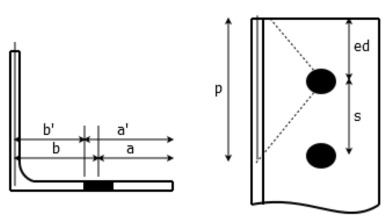
$$R_{nbs2} := 0.6 \cdot F_{ya} \cdot A_{gvb} + F_{ua} \cdot A_{ntb}$$

$$R_{nbs} := min(R_{nbs1}, R_{nbs2})$$ $R_{nbs} = 869.231\ kN$

Interaction ratio in block shear

$$I_6 := \frac{SF}{0.75 \cdot R_{nbs}}$$ $I_6 = 0.245$

Bolt prying at clip angle check



Available tension per bolt

$$B := 0.75 \cdot F'_{nt} \cdot A_b$$ $B = 176.762\ kN$

Clip dimensions for prying check

$$b := 0.5 \cdot (g - t_{wb} - t_a) \qquad b = 61.505\ mm$$

$$a := l_{oa} - b - 0.5 \cdot t_a \qquad a = 60.745\ mm$$

$$b' := b - 0.5 \cdot d_b \qquad b' = 50.505\ mm$$

$$a' := min\left(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b\right) \qquad a' = 71.745\ mm$$

Tributary length

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

Ratios for prying

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

$$\rho := \frac{b'}{a'} \qquad \rho = 0.704$$

Thickness required to develop bolt tension without prying

$$t_c := \sqrt{\frac{4 \cdot B \cdot b'}{0.9 \cdot p \cdot F_{ua}}} \qquad t_c = 37.644\ mm$$

$$\alpha' := \frac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\frac{t_c}{t_a}\right)^2 - 1\right) \qquad \alpha' = 13.129$$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right) \qquad Q = 0.106$$

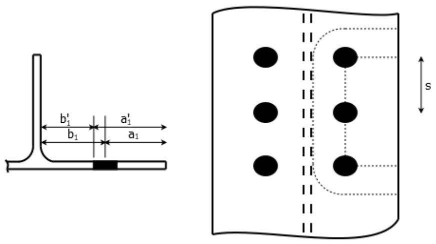
Available tension strength with prying

$$T_{av} := Q \cdot B \qquad T_{av} = 18.656\ kN$$

Interaction ratio in prying

$$I_7 := \frac{TF_b}{T_{av}} \qquad I_7 = 0.804$$

Bolt prying at column flange



Clip dimensions for prying check

$b_1 := 0.5 \cdot (g - t_{ws})$ $b_1 = 65.235\ mm$

$a_1 := min(0.5 \cdot (b_{fs} - g), 0.5 \cdot (2 \cdot l_{oa} + t_{wb} - g))$ $a_1 = 57\ mm$

$b'_1 := b_1 - 0.5 \cdot d_b$ $b'_1 = 54.235\ mm$

$a'_1 := min(a_1 + 0.5 \cdot d_b, 1.25 \cdot b_1 + 0.5 \cdot d_b)$ $a'_1 = 68\ mm$

Tributary length

$$p_1 := \frac{(n-1) \cdot s + \pi \cdot b_1 + (b_{fs} - g)}{n}$$ $p_1 = 132.235\ mm$

Ratios for prying

$$\delta_1 := 1 - \frac{d_{bh}}{p_1}$$ $\delta_1 = 0.819$

$$\rho_1 := \frac{b'_1}{a'_1}$$ $\rho_1 = 0.798$

Thickness required to develop bolt tension without prying

$$t_{c1} := \sqrt{\frac{4 \cdot B \cdot b'_1}{0.9 \cdot p_1 \cdot F_{us}}}$$ $t_{c1} = 26.759\ mm$

$$\alpha'_1 := \frac{1}{\delta_1 \cdot (1 + \rho_1)} \cdot \left(\left(\frac{t_{c1}}{t_{fs}} \right)^2 - 1 \right)$$ $\alpha'_1 = 1.13$

Proportion of tension strength available

$$Q_1 := \text{if}\left(\alpha'_1 < 0, 1, \text{if}\left(0 \le \alpha'_1 \le 1, \left(\frac{t_{fs}}{t_{c1}}\right)^2 \cdot (1 + \delta_1 \cdot \alpha'_1), \left(\frac{t_{fs}}{t_{c1}}\right)^2 \cdot (1 + \delta_1)\right)\right)$$ $Q_1 = 0.683$

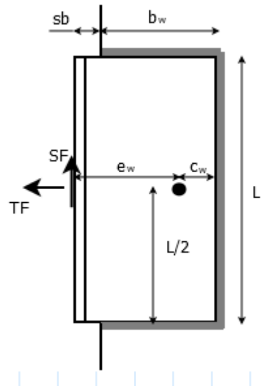
Available tension strength with prying

$T_{av1} := Q_1 \cdot B$ $T_{av1} = 120.744\ kN$

Interaction ratio in prying

$$I_8 := \frac{TF_b}{T_{av1}}$$ $I_8 = 0.124$

Weld check



Length of horizontal run of weld

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

Centroid of weld group

$$c_w := \frac{{b_w}^2}{2 \cdot b_w + L} \qquad c_w = 10.345\ mm$$

Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 65.855\ mm$$

Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L)^3}{12} - \frac{{b_w}^2 \cdot (b_w + L)^2}{2 \cdot b_w + L} \qquad I_w = 4114.106\ cm^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{TF}{2 \cdot (2 \cdot b_w + L)} + \frac{SF \cdot e_w \cdot L}{4 \cdot I_w} \qquad f_{wh} = 323.478\ \frac{N}{mm}$$

Vertical component of weld stress

$$f_{wv} := \frac{SF}{2 \cdot (2 \cdot b_w + L)} + \frac{SF \cdot e_w \cdot (b_w - c_w)}{2\ I_w} \qquad f_{wv} = 269.767\ \frac{N}{mm}$$

Resultant weld stress

$$f_w := \sqrt{{f_{wh}}^2 + {f_{wv}}^2} \qquad f_w = 421.204\ \frac{N}{mm}$$

Nominal weld strength

$$R_{nw} := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w \qquad R_{nw} = 1226.972\ \frac{N}{mm}$$

Interaction ratio for weld check

$$I_9 := \frac{f_w}{0.75 \cdot R_{nw}} \qquad I_9 = 0.458$$

Beam web rupture at weld check

Minimum web thickness to match weld strength

$$t_{wb.min} := \frac{2 \cdot f_w}{0.75 \cdot 0.6 \cdot F_{ub}} \qquad t_{wb.min} = 4.68\ mm$$

Interaction ratio in web rupture

$$I_{10} := \frac{t_{wb.min}}{t_{wb}} \qquad I_{10} = 0.625$$

Column web local yielding check

Nominal strength in web local yielding

$$R_{nwy} := F_{ys} \cdot t_{ws} \cdot (2.5 \cdot k_s + L) \qquad R_{nwy} = 1146.638\ kN$$

Interaction ratio in web local yielding

$$I_{11} := \frac{TF}{1.0 \cdot R_{nwy}} \qquad I_{11} = 0.105$$

Column web local crippling

Nominal strength in web crippling

$$R_{nwc1} := 0.40 \cdot t_{ws}^{\ 2} \cdot \left(1 + 3 \cdot \frac{L}{d_{xs}} \cdot \left(\frac{t_{ws}}{t_{fs}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{ys} \cdot t_{fs}}{t_{ws}}}$$

$$R_{nwc2} := 0.40 \cdot t_{ws}^{\ 2} \cdot \left(1 + \left(\frac{4 \cdot L}{d_{xs}} - 0.2\right) \cdot \left(\frac{t_{ws}}{t_{fs}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{ys} \cdot t_{fs}}{t_{ws}}}$$

$$R_{nwc} := \text{if}\left(\frac{L}{d_{xs}} \le 0.2, R_{nwc1}, R_{nwc2}\right) \qquad R_{nwc} = 897.291\ kN$$

Interaction ratio in web crippling

$$I_{12} := \frac{TF}{0.75 \cdot R_{nwc}} \qquad I_{12} = 0.178$$

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.

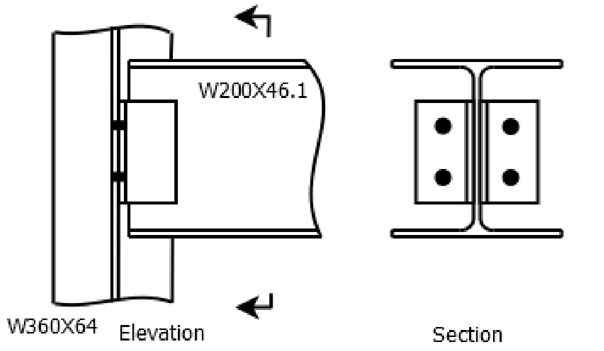
Table 3: Validation problem 2 results

	Interaction Ratio		
Check	Calculated	Osoconn	Result
Bolt shear check	0.189	0.189	OK
Bolt tension check	0.085	0.085	OK
Bolt bearing at clip angle	0.325	0.324	OK
Bolt bearing at column flange	0.068	0.068	OK
Clip angle shear yielding strength	0.26	0.259	OK
Clip angle shear rupture strength	0.336	0.335	OK
Clip angle block shear check	0.245	0.245	OK
Bolt prying at clip angle check	0.804	0.799	OK
Bolt prying at column flange	0.124	0.124	OK
Weld check	0.458	0.458	OK
Beam web rupture at weld check	0.625	0.625	OK
Column web local yielding check	0.105	0.105	OK
Column web local crippling	0.178	0.178	OK

2.4 Validation Problem 3

Problem Statement

Design a shop-welded field-bolted clip angle shear connection for a W200X46.1 beam framing into the web of a W360X64 column using the LRFD method. The connection has to be designed for a shear force of 20kN and a transfer force of 15kN. The beam and the column is of grade ASTM A992. The clip angle is ASTM A36. The bolts used are ASTM 3125 A325 bearing type bolts.



Design Inputs

Material Properties

Material grade for angles	ASTM A36
Yield strength	$F_{ya} := 250\ MPa$
Tensile strength	$F_{ua} := 400\ MPa$
Material grade of beam	ASTM A992
Yield strength	$F_{yb} := 345\ MPa$
Tensile strength	$F_{ub} := 450\ MPa$
Material grade of supporting member	ASTM A992
Yield strength	$F_{ys} := 345\ MPa$
Tensile strength	$F_{us} := 450\ MPa$
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	$E := 200000\ MPa$
Poisson's ratio	$\upsilon := 0.3$

Design Forces

Shear force in connection	$SF := 20000\ N$
Transfer force in connection	$TF := 15000\ N$

Geometry

Beam section — W200X46.1

Section depth — $d_{xb} := 203\ mm$

Flange width — $b_{fb} := 203\ mm$

Flange thickness — $t_{fb} := 11\ mm$

Web thickness — $t_{wb} := 7.24\ mm$

Supporting member section — W360X64

Section depth — $d_{xs} := 348\ mm$

Flange width — $b_{fs} := 203\ mm$

Flange thickness — $t_{fs} := 13.5\ mm$

Web thickness — $t_{ws} := 7.75\ mm$

Fillet area dimension — $k_s := 28.4\ mm$

Clip angle section — L89X76X6.4

Thickness — $t_a := 6.4\ mm$

Outstanding leg length — $l_{oa} := 88.9\ mm$

Welded leg length — $l_{ia} := 76.2\ mm$

Bolt diameter — $d_b := 20\ mm$

Bolt hole diameter — $d_{bh} := 22\ mm$

Number of bolts — $n := 2$

Bolt spacing — $s := 60\ mm$

Bolt gage — $g := 90\ mm$

Weld thickness — $w := 4\ mm$

Clip angle length — $L := 120\ mm$

Clip angle offset from beam top — $o := 37\ mm$

Connection setback — $sb := 12\ mm$

Design Calculations

Bolt shear check

Shear per bolt

$$SF_b := \frac{SF}{2 \cdot n} \qquad SF_b = 5\ kN$$

Area of bolt

$$A_b := \frac{\pi \cdot {d_b}^2}{4} \qquad A_b = 314.159\ mm^2$$

Nominal shear strength of bolt

$$R_{n.bv} := F_{nv} \cdot A_b \qquad R_{n.bv} = 116.867\ kN$$

Interaction ratio in bolt shear

$$I_0 := \frac{SF_b}{0.75 \cdot R_{n.bv}} \qquad I_0 = 0.057$$

Bolt tension check

Tension per bolt

$$TF_b := \frac{TF}{2 \cdot n} \qquad TF_b = 3.75\ kN$$

Required shear stress per bolt

$$f_{rv} := \frac{SF_b}{A_b}$$ $$f_{rv} = 15.915\ MPa$$

Modified nominal tensile strength

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

Nominal tensile strength

$$R_{n.bt} := F'_{nt} \cdot A_b$$ $$R_{n.bt} = 194.779\ kN$$

Interaction ratio for bolt tension

$$I_1 := \frac{TF_b}{0.75 \cdot R_{n.bt}}$$ $$I_1 = 0.026$$

Bolt bearing at clip angle

Edge distance from bolt centre

$$ed := \frac{L - (n-1) \cdot s}{2}$$ $$ed = 30\ mm$$

Clear distance between bolt holes/ hole and edge

$$l_c := min\left(s - d_{bh}, ed - 0.5 \cdot d_{bh}\right)$$ $$l_c = 19\ mm$$

Nominal strength in bearing

$$R_{n.bc} := min\left(1.2 \cdot l_c \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right)$$ $$R_{n.bc} = 58.368\ kN$$

Interaction ratio in bolt bearing

$$I_2 := \frac{SF_b}{0.75 \cdot R_{n.bc}}$$ $$I_2 = 0.114$$

Bolt bearing at column web

Nominal strength in bearing

$$R_{n.bw} := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{ws} \cdot F_{us}, 2.4 \cdot d_b \cdot t_{ws} \cdot F_{us}\right)$$ $$R_{n.bw} = 159.03\ kN$$

Interaction ratio in bolt bearing

$$I_3 := \frac{SF_b}{0.75 \cdot R_{n.bw}}$$ $$I_3 = 0.042$$

Clip angle shear yielding strength

Gross area in shear

$$A_{gv} := 2 \cdot L \cdot t_a$$ $$A_{gv} = 1536\ mm^2$$

Nominal strength in shear yielding

$$R_{ny} := 0.6 \cdot F_{ya} \cdot A_{gv}$$ $$R_{ny} = 230.4\ kN$$

Resultant shear in clip angle

$$S_r := \sqrt{TF^2 + SF^2}$$ $$S_r = 25\ kN$$

Interaction ratio in shear yielding

$I_4 := \frac{S_r}{R_{ny}}$ $\qquad I_4 = 0.109$

Clip angle shear rupture strength

Net area in shear

$A_{nv} := A_{gv} - 2 \cdot n \cdot d_{bh} \cdot t_a$ $\qquad A_{nv} = 972.8\ mm^2$

Nominal strength in shear rupture

$R_{nr} := 0.6 \cdot F_{ua} \cdot A_{nv}$ $\qquad R_{nr} = 233.472\ kN$

Interaction ratio in shear rupture

$I_5 := \frac{S_r}{0.75 \cdot R_{nr}}$ $\qquad I_5 = 0.143$

Clip angle block shear check

Gross area subjected to block shear

$A_{gvb} := 2 \cdot (L - ed) \cdot t_a$ $\qquad A_{gvb} = 1152\ mm^2$

Net area subjected to block shear

$A_{nvb} := A_{gvb} - 2 \cdot (n - 0.5) \cdot d_{bh} \cdot t_a$ $\qquad A_{nvb} = 729.6\ mm^2$

Net area subjected to tension

$A_{ntb} := 0.5 \cdot (2 \cdot l_{oa} + t_{wb} - g - d_{bh}) \cdot t_a$ $\qquad A_{ntb} = 233.728\ mm^2$

Nominal strength in block shear

$R_{nbs1} := 0.6 \cdot F_{ua} \cdot A_{nvb} + F_{ua} \cdot A_{ntb}$

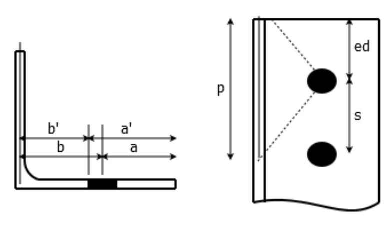
$R_{nbs2} := 0.6 \cdot F_{ya} \cdot A_{gvb} + F_{ua} \cdot A_{ntb}$

$R_{nbs} := min(R_{nbs1}, R_{nbs2})$ $\qquad R_{nbs} = 266.291\ kN$

Interaction ratio in block shear

$I_6 := \frac{SF}{0.75 \cdot R_{nbs}}$ $\qquad I_6 = 0.1$

Bolt prying at clip angle check



Available tension per bolt

$B := 0.75 \cdot F'_{nt} \cdot A_b$ $\qquad B = 146.084\ kN$

Clip dimensions for prying check

$b := 0.5 \cdot (g - t_{wb} - t_a)$ $\qquad b = 38.18\ mm$

$a := l_{oa} - b - 0.5 \cdot t_a$ $\quad a = 47.52\ mm$

$b' := b - 0.5 \cdot d_b$ $\quad b' = 28.18\ mm$

$a' := min\left(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b\right)$ $\quad a' = 57.52\ mm$

Tributary length

$p := min\left(2 \cdot b, b + ed, s\right)$ $\quad p = 60\ mm$

Ratios for prying

$\delta := 1 - \dfrac{d_{bh}}{p}$ $\quad \delta = 0.633$

$\rho := \dfrac{b'}{a'}$ $\quad \rho = 0.49$

Thickness required to develop bolt tension without prying

$t_c := \sqrt{\dfrac{4 \cdot B \cdot b'}{0.9 \cdot p \cdot F_{ua}}}$ $\quad t_c = 27.611\ mm$

$\alpha' := \dfrac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\dfrac{t_c}{t_a}\right)^2 - 1\right)$ $\quad \alpha' = 18.664$

Proportion of tension strength available

$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\dfrac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\dfrac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right)$ $\quad Q = 0.088$

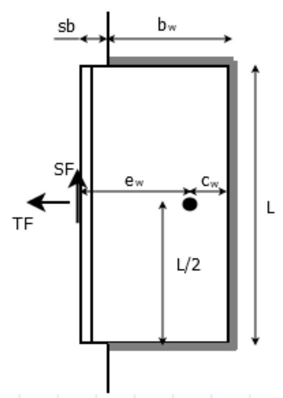
Available tension strength with prying

$T_{av} := Q \cdot B$ $\quad T_{av} = 12.82\ kN$

Interaction ratio in prying

$I_7 := \dfrac{TF_b}{T_{av}}$ $\quad I_7 = 0.293$

Weld check



Length of horizontal run of weld

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

Centroid of weld group

$$c_w := \frac{b_w^2}{2 \cdot b_w + L}$$ $c_w = 16.593\ mm$

Eccentricity of shear force

$$e_w := l_{ia} - c_w$$ $e_w = 59.607\ mm$

Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L)^3}{12} - \frac{b_w^2 \cdot (b_w + L)^2}{2 \cdot b_w + L}$$ $I_w = 714.257\ cm^3$

Horizontal component of weld stress

$$f_{wh} := \frac{TF}{2 \cdot (2 \cdot b_w + L)} + \frac{SF \cdot e_w \cdot L}{4 \cdot I_w}$$ $f_{wh} = 80.265\ \frac{N}{mm}$

Vertical component of weld stress

$$f_{wv} := \frac{SF}{2 \cdot (2 \cdot b_w + L)} + \frac{SF \cdot e_w \cdot (b_w - c_w)}{2\ I_w}$$ $f_{wv} = 79.988\ \frac{N}{mm}$

Resultant weld stress

$$f_w := \sqrt{f_{wh}^2 + f_{wv}^2}$$ $f_w = 113.316\ \frac{N}{mm}$

Nominal weld strength

$$R_{nw} := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w$$ $R_{nw} = 817.981\ \frac{N}{mm}$

Interaction ratio for weld check

$$I_8 := \frac{f_w}{0.75 \cdot R_{nw}}$$ $I_8 = 0.185$

Beam web rupture at weld check

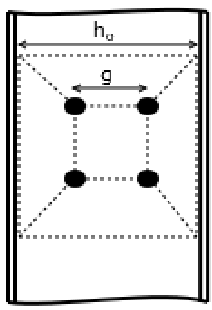
Minimum web thickness to match weld strength

$$t_{wb.min} := \frac{2 \cdot f_w}{0.75 \cdot 0.6 \cdot F_{ub}}$$ $t_{wb.min} = 1.119\ mm$

Interaction ratio in web rupture

$$I_9 := \frac{t_{wb.min}}{t_{wb}}$$ $I_9 = 0.155$

Column web yielding check



Flange to flange height of column web

$$h_o := d_{cs} - 2\ t_{fc}$$ $h_o = 321\ mm$

Nominal strength of web in yielding

$$P_{nwb} := 2 \cdot F_{ys} \cdot t_{ws}^{2} \cdot \left(\sqrt{\frac{2 \cdot h_o}{h_o - g} + \frac{(n-1) \cdot s}{2 \cdot (h_o - g)}} \right) \qquad P_{nwb} = 70.686 \ kN$$

Interaction ratio for web yielding

$$I_{10} := \frac{TF}{0.9 \cdot P_{nwb}} \qquad I_{10} = 0.236$$

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.

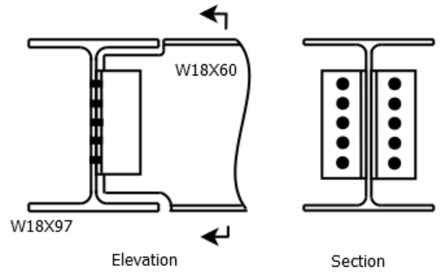
Table 4: Validation problem 3 results

Check	Interaction Ratio		Result
	Calculated	Osoconn	
Bolt shear check	0.057	0.057	OK
Bolt tension check	0.026	0.026	OK
Bolt bearing at clip angle	0.114	0.115	OK
Bolt bearing at column web	0.042	0.042	OK
Clip angle shear yielding strength	0.109	0.109	OK
Clip angle shear rupture strength	0.143	0.144	OK
Clip angle block shear check	0.1	0.101	OK
Bolt prying at clip angle check	0.293	0.297	OK
Weld check	0.185	0.185	OK
Beam web rupture at weld check	0.155	0.155	OK
Column web yielding check	0.236	0.237	OK

2.5 Validation Problem 4

Problem Statement

Design a shop-welded field-bolted clip angle shear connection for a W18X60 beam framing into the web of a W18X97 beam using the ASD method. The connection has to be designed for a shear force of 40kip and a transfer force of 45kip. The angles, beam and column have a grade of ASTM A36 while the bolts are ASTM 3125 A490 slip critical type bolts.



Design Inputs

Material Properties

Material grade for angles — ASTM A36

Yield strength — $F_{ya} := 36\ ksi$

Tensile strength — $F_{ua} := 58\ ksi$

Material grade of beam — ASTM A36

Yield strength — $F_{yb} := 36\ ksi$

Tensile strength — $F_{ub} := 58\ ksi$

Material grade of supporting member — ASTM A36

Yield strength — $F_{ys} := 36\ ksi$

Tensile strength — $F_{us} := 58\ ksi$

Material grade for weld electrode — E70XX

Tensile strength — $F_{EXX} := 70\ ksi$

Material specification for bolts — ASTM 3125 A490

Tensile strength — $F_{nt} := 113\ ksi$

Shear strength — $F_{nv} := 68\ ksi$

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

Poisson's ratio — $v := 0.3$

Design Forces

Shear force in connection — $SF := 40\ kip$

Transfer force in connection — $TF := 45\ kip$

Geometry

Beam section — W18X60

Section depth — $d_{xb} := 18.2\ in$

Flange width — $b_{fb} := 7.56\ in$

Flange thickness — $t_{fb} := 0.695\ in$

Web thickness — $t_{wb} := 0.415\ in$

Supporting member section | W18X97
Section depth | $d_{sc} := 18.6\ in$
Flange width | $b_{fs} := 11.1\ in$
Flange thickness | $t_{fs} := 0.87\ in$
Web thickness | $t_{ws} := 0.535\ in$

Clip angle section | L4X3X1/2
Thickness | $t_a := 0.5\ in$
Outstanding leg length | $l_{oa} := 4\ in$
Welded leg length | $l_{ia} := 3\ in$

Is the beam coped? | YES
Cope length | $c_l := 6\ in$
Top cope depth | $c_{dt} := 1.5\ in$
Bottom cope depth | $c_{db} := 1.5\ in$

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 | $T_{pre} := 35\ kip$

Number of bolts | $n := 5$
Bolt spacing | $s := 2.5\ in$
Bolt gage | $g := 5.5\ in$

Weld thickness | $w := 0.25\ in$
Clip angle length | $L := 13\ in$
Clip angle offset from beam top | $o := 2\ in$
Connection setback | $sb := 0.5\ in$

Design Calculations

Bolt tension check

Tension per bolt

$$TF_b := \frac{TF}{2 \cdot n} \qquad TF_b = 4.5\ kip$$

Area of bolt

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

Nominal tensile strength

$$R_{n.bt} := F_{nt} \cdot A_b \qquad R_{n.bt} = 49.922\ kip$$

Interaction ratio for bolt tension

$$I_1 := \frac{2.0\ TF_b}{R_{n.bt}} \qquad I_1 = 0.18$$

Bolt shear check

Shear per bolt

$$SF_b := \frac{SF}{2 \cdot n}$$ $SF_b = 4\ kip$

Slip resistance reduction factor

$$k_{sc} := 1 - \frac{1.5 \cdot TF_b}{1.13 \cdot T_{pre}}$$ $k_{sc} = 0.829$

Nominal slip resistance of bolt

$$R_{nbv} := \mu \cdot 1.13 \cdot T_{pre} \cdot k_{sc}$$ $R_{nbv} = 9.84\ kip$

Interaction ratio in bolt shear

$$I_0 := \frac{1.5 \cdot SF_b}{R_{nbv}}$$ $I_0 = 0.61$

Bolt bearing at clip angle

Edge distance from bolt centre

$$ed := \frac{L - (n-1) \cdot s}{2}$$ $ed = 1.5\ in$

Clear distance between bolt holes/ hole and edge

$$l_c := min\left(s - d_{bh}, ed - 0.5 \cdot d_{bh}\right)$$ $l_c = 1.094\ in$

Nominal strength in bearing

$$R_{n.bc} := min\left(1.2 \cdot l_c \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right)$$ $R_{n.bc} = 38.063\ kip$

Interaction ratio in bolt bearing

$$I_2 := \frac{2.0\ SF_b}{R_{n.bc}}$$ $I_2 = 0.21$

Bolt bearing at beam web

Nominal strength in bearing

$$R_{n.bw} := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{ws} \cdot F_{us}, 2.4 \cdot d_b \cdot t_{ws} \cdot F_{us}\right)$$ $R_{n.bw} = 55.854\ kip$

Interaction ratio in bolt bearing

$$I_3 := \frac{2.0\ SF_b}{R_{n.bw}}$$ $I_3 = 0.143$

Clip angle shear yielding strength

Gross area in shear

$$A_{gv} := 2 \cdot L \cdot t_a$$ $A_{gv} = 13\ in^2$

Nominal strength in shear yielding

$$R_{ny} := 0.6 \cdot F_{ya} \cdot A_{gv}$$ $R_{ny} = 280.8\ kip$

Resultant shear in clip angle

$$S_r := \sqrt{TF^2 + SF^2}$$ $S_r = 60.208\ kip$

Interaction ratio in shear yielding

$$I_4 := \frac{1.5\ S_r}{R_{ny}}$$ $I_4 = 0.322$

Clip angle shear rupture strength

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n \cdot d_{bh} \cdot t_a$$ $A_{nv} = 8.938\ in^2$

Nominal strength in shear rupture

$$R_{nr} := 0.6 \cdot F_{ua} \cdot A_{nv}$$ $R_{nr} = 311.025\ kip$

Interaction ratio in shear rupture

$$I_5 := \frac{2.0\ S_r}{R_{nr}}$$ $I_5 = 0.387$

Clip angle block shear check

Gross area subjected to block shear

$$A_{gvb} := 2 \cdot (L - ed) \cdot t_a$$ $A_{gvb} = 11.5\ in^2$

Net area subjected to block shear

$$A_{nvb} := A_{gvb} - 2 \cdot (n - 0.5) \cdot d_{bh} \cdot t_a$$ $A_{nvb} = 7.844\ in^2$

Net area subjected to tension

$$A_{ntb} := 0.5 \cdot (2 \cdot l_{oa} + t_{wb} - g - d_{bh}) \cdot t_a$$ $A_{ntb} = 0.526\ in^2$

Nominal strength in block shear

$$R_{nbs1} := 0.6 \cdot F_{ua} \cdot A_{nvb} + F_{ua} \cdot A_{ntb}$$

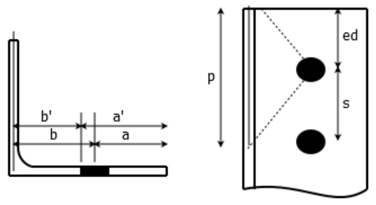
$$R_{nbs2} := 0.6 \cdot F_{ya} \cdot A_{gvb} + F_{ua} \cdot A_{ntb}$$

$$R_{nbs} := min(R_{nbs1}, R_{nbs2})$$ $R_{nbs} = 278.886\ kip$

Interaction ratio in block shear

$$I_6 := \frac{2.0\ SF}{R_{nbs}}$$ $I_6 = 0.287$

Bolt prying check



Available tension per bolt

$$B := \frac{F_{nt} \cdot A_b}{2.0}$$ $B = 24.961\ kip$

Clip dimensions for prying check

$b := 0.5 \cdot (g - t_{wb} - t_a)$ $b = 2.293\ in$

$a := l_{oa} - b - 0.5 \cdot t_a$ $a = 1.458\ in$

$b' := b - 0.5 \cdot d_b$ $b' = 1.918\ in$

$a' := min(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b)$ $a' = 1.833\ in$

Tributary length

$p := min(2 \cdot b, b + ed, s)$ $p = 2.5\ in$

Ratios for prying

$\delta := 1 - \frac{d_{bh}}{p}$ $\delta = 0.675$

$\rho := \frac{b'}{a'}$ $\rho = 1.046$

Thickness required to develop bolt tension without prying

$t_c := \sqrt{\frac{1.67 \cdot 4 \cdot B \cdot b'}{p \cdot F_{ua}}}$ $t_c = 1.485\ in$

$\alpha' := \frac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\frac{t_c}{t_a}\right)^2 - 1\right)$ $\alpha' = 5.661$

Proportion of tension strength available

$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right)$ $Q = 0.19$

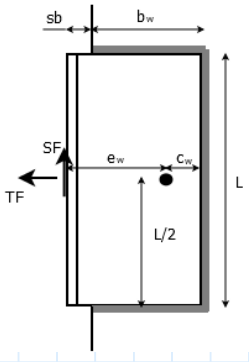
Available tension strength with prying

$T_{av} := Q \cdot B$ $T_{av} = 4.74\ kip$

Interaction ratio in prying

$I_7 := \frac{TF_b}{T_{av}}$ $I_7 = 0.949$

Weld check



Length of horizontal run of weld

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

Centroid of weld group

$$c_w := \frac{b_w^{\,2}}{2 \cdot b_w + L}$$ $c_w = 0.347\ in$

Eccentricity of shear force

$$e_w := l_{ia} - c_w$$ $e_w = 2.653\ in$

Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L)^3}{12} - \frac{b_w^{\,2} \cdot (b_w + L)^2}{2 \cdot b_w + L}$$ $I_w = 402.58\ in^3$

Horizontal component of weld stress

$$f_{wh} := \frac{TF}{2 \cdot (2 \cdot b_w + L)} + \frac{SF \cdot e_w \cdot L}{4 \cdot I_w}$$ $f_{wh} = 2.107\ \frac{kip}{in}$

Vertical component of weld stress

$$f_{wv} := \frac{SF}{2 \cdot (2 \cdot b_w + L)} + \frac{SF \cdot e_w \cdot (b_w - c_w)}{2\ I_w}$$ $f_{wv} = 1.395\ \frac{kip}{in}$

Resultant weld stress

$$f_w := \sqrt{f_{wh}^{\,2} + f_{wv}^{\,2}}$$ $f_w = 2.527\ \frac{kip}{in}$

Nominal weld strength

$$R_{nw} := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w$$ $R_{nw} = 7.425\ \frac{kip}{in}$

Interaction ratio for weld check

$$I_{8} := \frac{2.0\ f_w}{R_{nw}}$$ $I_{8} = 0.681$

Beam web rupture at weld check

Minimum web thickness to match weld strength

$$t_{wb.min} := \frac{2.0 \cdot 2 \cdot f_w}{0.6 \cdot F_{ub}}$$ $t_{wb.min} = 0.29\ in$

Interaction ratio in web rupture

$$I_{9} := \frac{t_{wb.min}}{t_{wb}}$$ $I_{9} = 0.7$

Beam cope flexure check

Reduced beam depth

$$h_o := d_{xb} - c_{dt} - c_{db}$$ $h_o = 15.2\ in$

Flexural buckling stress for coped section

$$F_{cr} := min\left(0.62 \cdot \pi \cdot E \cdot \frac{t_{wb}^{\,2}}{c_l \cdot h_o} \cdot \left(3.5 - 7.5 \cdot \frac{c_{dt}}{d_{xb}}\right), F_{yb}\right)$$ $F_{cr} = 36\ ksi$

Moment of inertia of the coped section

$$I_{xc} := \frac{t_{wb} \cdot h_o^{\,3}}{12}$$ $I_{xc} = 121.45\ in^4$

Section modulus of the coped section

$$S_{xc} := \frac{I_{xc}}{0.5\ h_o}$$ $S_{xc} = 15.98\ in^3$

Nominal strength of coped section in flexure

$$M_n := F_{cr} \cdot S_{xc}$$ $M_n = 575.29\ kip \cdot in$

Moments in coped section due to shear force

$$M_{SF} := SF \cdot (c_l + sb)$$ $M_{SF} = 260\ kip \cdot in$

Eccentricity of applied transfer force from centroid of cope

$$e_c := \text{abs}(0.5\ h_o + c_{dt} - o - 0.5\ L)$$ $e_c = 0.6\ in$

Moment in coped section due to transfer force

$$M_{TF} := TF \cdot e_c$$ $M_{TF} = 27\ kip \cdot in$

Interaction ratio in cope flexure

$$I_{10} := \frac{1.67\ (M_{SF} + M_{TF})}{M_n}$$ $I_{10} = 0.833$

Beam cope axial check

Gross area of coped section

$$A_c := h_o \cdot t_{wb}$$ $A_c = 6.308\ in^2$

Minor axis moment of inertia of coped sections

$$I_{yc} := \frac{h_o \cdot t_{wb}^{\ 3}}{12}$$ $I_{yc} = 0.091\ in^4$

Radius of gyration of coped section

$$r_c := \sqrt{\frac{min(I_{xc}, I_{yc})}{A_c}}$$ $r_c = 0.12\ in$

Slenderness ratio of coped section

$$KLr := \frac{c_l + sb}{r_c}$$ $KLr = 54.257$

Elastic buckling stress

$$F_e := \frac{\pi^2 \cdot E}{KLr^2}$$ $F_e = 97.227\ ksi$

Critical buckling stress

$$F_{crc} := \text{if}\left(KLr \le 4.71 \cdot \sqrt{\frac{E}{F_{yb}}}, 0.658^{\frac{F_{yb}}{F_e}} \cdot F_{yb}, 0.877 \cdot F_e\right)$$ $F_{crc} = 30.832\ ksi$

Nominal compressive strength of coped section

$$P_{nc} := F_{crc} \cdot A_c$$ $P_{nc} = 194.486\ kip$

Interaction ratio in compression

$$I_{11} := \frac{1.67\ TF}{P_{nc}}$$ $I_{11} = 0.386$

Beam cope shear check

Gross area of the coped section in shear

$$A_{cv} := h_o \cdot t_{wb}$$ $A_{cv} = 6.308\ in^2$

Nominal shear strength of coped section

$$V_n := 0.6 \cdot F_{yb} \cdot A_{cv}$$ $V_n = 136.253\ kip$

Interaction ratio in shear

$$I_{12} := \frac{1.5\ SF}{V_n}$$ $I_{12} = 0.44$

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.

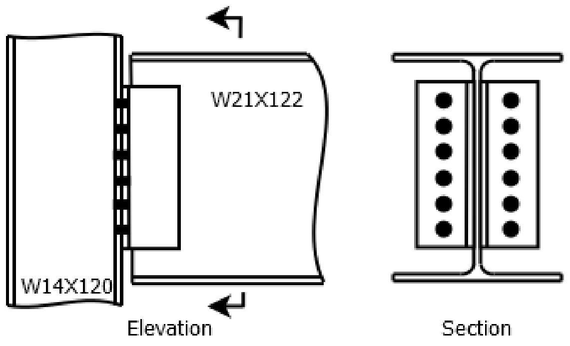
Table 5: Validation problem 4 results

	Interaction Ratio		
Check	Calculated	Osoconn	Result
Bolt shear check	0.61	0.61	OK
Bolt tension check	0.18	0.18	OK
Bolt bearing at clip angle	0.21	0.21	OK
Bolt bearing at beam web	0.143	0.143	OK
Clip angle shear yielding strength	0.322	0.322	OK
Clip angle shear rupture strength	0.387	0.387	OK
Clip angle block shear check	0.287	0.287	OK
Bolt prying check	0.949	0.949	OK
Weld check	0.681	0.681	OK
Beam web rupture at weld check	0.7	0.7	OK
Beam cope flexure check	0.833	0.833	OK
Beam cope axial check	0.386	0.386	OK
Beam cope shear check	0.44	0.44	OK

2.6 Validation Problem 5

Problem Statement

Design a shop-welded field-bolted clip angle shear connection for a W21X122 beam framing into the flange of a W14X120 column using the ASD method. The connection has to be designed for a shear force of 65kip and a transfer force of 50kip. The clip angle is of grade of ASTM A36 while the beam and column are ASTM A992. The bolts used are ASTM 3125 A325 slip critical bolts.



Design Inputs

Material Properties

Material grade for angles	ASTM A36
Yield strength	$F_{ya} := 36\ ksi$
Tensile strength	$F_{ua} := 58\ ksi$
Material grade of beam	ASTM A992
Yield strength	$F_{yb} := 50\ ksi$
Tensile strength	$F_{ub} := 65\ ksi$
Material grade of supporting member	ASTM A992
Yield strength	$F_{ys} := 50\ ksi$
Tensile strength	$F_{us} := 65\ ksi$
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	$E := 29000\ ksi$
Poisson's ratio	$v := 0.3$

Design Forces

Shear force in connection	$SF := 65\ kip$
Transfer force in connection	$TF := 50\ kip$

Geometry

Beam section	W21X122
Section depth	$d_{xb} := 21.7\ in$
Flange width	$b_{fb} := 12.4\ in$
Flange thickness	$t_{fb} := 0.96\ in$
Web thickness	$t_{wb} := 0.6\ in$
Supporting member section	W14X120
Section depth	$d_{xs} := 14.5\ in$
Flange width	$b_{fs} := 14.7\ in$
Flange thickness	$t_{fs} := 0.94\ in$
Web thickness	$t_{ws} := 0.59\ in$
Fillet area dimension	$k_s := 1.54\ in$
Clip angle section	L4X3-1/2X1/2
Thickness	$t_a := 0.5\ in$
Outstanding leg length	$l_{oa} := 4\ in$
Welded leg length	$l_{ia} := 3.5\ in$
Bolt diameter	$d_b := \frac{7}{8}\ in$
Bolt hole diameter	$d_{bh} := \frac{15}{16}\ in$
Slip coefficient (class A surface)	$\mu := 0.3$
Bolt pretension	$T_{pre} := 39\ kip$
Number of bolts	$n := 6$
Bolt spacing	$s := 2.625\ in$
Bolt gage	$g := 5.5\ in$
Weld thickness	$w := \frac{5}{16}\ in$
Clip angle length	$L := 15.75\ in$
Clip angle offset from beam top	$o := 2.75\ in$
Connection setback	$sb := 0.5\ in$

Design Calculations

Bolt tension check

Tension per bolt

$$TF_b := \frac{TF}{2 \cdot n} \qquad TF_b = 4.167\ kip$$

Area of bolt

$$A_b := \frac{\pi \cdot {d_b}^2}{4} \qquad A_b = 0.601\ in^2$$

Nominal tensile strength

$$R_{n.bt} := F_{nt} \cdot A_b \qquad R_{n.bt} = 54.119\ kip$$

Interaction ratio for bolt tension

$$I_1 := \frac{2.0\ TF_b}{R_{n.bt}}$$ $I_1 = 0.154$

Bolt shear check

Shear per bolt

$$SF_b := \frac{SF}{2 \cdot n}$$ $SF_b = 5.417\ kip$

Slip resistance reduction factor

$$k_{sc} := 1 - \frac{1.5 \cdot TF_b}{1.13 \cdot T_{pre}}$$ $k_{sc} = 0.858$

Nominal slip resistance of bolt

$$R_{nbv} := \mu \cdot 1.13 \cdot T_{pre} \cdot k_{sc}$$ $R_{nbv} = 11.346\ kip$

Interaction ratio in bolt shear

$$I_0 := \frac{1.5 \cdot SF_b}{R_{nbv}}$$ $I_0 = 0.716$

Bolt bearing at clip angle

Edge distance from bolt centre

$$ed := \frac{L - (n-1) \cdot s}{2}$$ $ed = 1.313\ in$

Clear distance between bolt holes/ hole and edge

$$l_c := min\left(s - d_{bh}, ed - 0.5 \cdot d_{bh}\right)$$ $l_c = 0.844\ in$

Nominal strength in bearing

$$R_{n.bc} := min\left(1.2 \cdot l_c \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right)$$ $R_{n.bc} = 29.363\ kip$

Interaction ratio in bolt bearing

$$I_2 := \frac{2.0\ SF_b}{R_{n.bc}}$$ $I_2 = 0.369$

Bolt bearing at column flange

Nominal strength in bearing

$$R_{n.bf} := min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{fs} \cdot F_{us}, 2.4 \cdot d_b \cdot t_{fs} \cdot F_{us}\right)$$ $R_{n.bf} = 123.728\ kip$

Interaction ratio in bolt bearing

$$I_3 := \frac{2.0\ SF_b}{R_{n.bf}}$$ $I_3 = 0.088$

Clip angle shear yielding strength

Gross area in shear

$$A_{gv} := 2 \cdot L \cdot t_a$$ $A_{gv} = 15.75\ in^2$

Nominal strength in shear yielding

$$R_{ny} := 0.6 \cdot F_{ya} \cdot A_{gv}$$ $R_{ny} = 340.2\ kip$

Resultant shear in clip angle

$$S_r := \sqrt{TF^2 + SF^2}$$ $S_r = 82.006\ kip$

Interaction ratio in shear yielding

$$I_4 := \frac{1.5\ S_r}{R_{ny}}$$ $I_4 = 0.362$

Clip angle shear rupture strength

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n \cdot d_{bh} \cdot t_a$$ $A_{nv} = 10.125\ in^2$

Nominal strength in shear rupture

$$R_{nr} := 0.6 \cdot F_{ua} \cdot A_{nv}$$ $R_{nr} = 352.35\ kip$

Interaction ratio in shear rupture

$$I_5 := \frac{2.0\ S_r}{R_{nr}}$$ $I_5 = 0.465$

Clip angle block shear check

Gross area subjected to block shear

$$A_{gvb} := 2 \cdot (L - ed) \cdot t_a$$ $A_{gvb} = 14.438\ in^2$

Net area subjected to block shear

$$A_{nvb} := A_{gvb} - 2 \cdot (n - 0.5) \cdot d_{bh} \cdot t_a$$ $A_{nvb} = 9.281\ in^2$

Net area subjected to tension

$$A_{ntb} := 0.5 \cdot \left(2 \cdot l_{oa} + t_{wb} - g - d_{bh}\right) \cdot t_a$$ $A_{ntb} = 0.541\ in^2$

Nominal strength in block shear

$$R_{nbs1} := 0.6 \cdot F_{ua} \cdot A_{nvb} + F_{ua} \cdot A_{ntb}$$

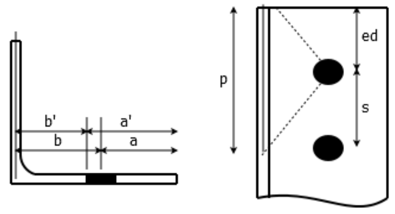
$$R_{nbs2} := 0.6 \cdot F_{ya} \cdot A_{gvb} + F_{ua} \cdot A_{ntb}$$

$$R_{nbs} := min\left(R_{nbs1}, R_{nbs2}\right)$$ $R_{nbs} = 343.206\ kip$

Interaction ratio in block shear

$$I_6 := \frac{2.0\ SF}{R_{nbs}}$$ $I_6 = 0.379$

Bolt prying at clip angle check



Available tension per bolt

$$B := \frac{F_{nt} \cdot A_b}{2.0}$$ $B = 27.059\ kip$

Clip dimensions for prying check

$$b := 0.5 \cdot (g - t_{wb} - t_a)$$ $b = 2.2\ in$

$$a := l_{oa} - b - 0.5 \cdot t_a$$ $a = 1.55\ in$

$$b' := b - 0.5 \cdot d_b$$ $b' = 1.763\ in$

$$a' := min\left(a + 0.5 \cdot d_b, 1.25 \cdot b + 0.5 \cdot d_b\right)$$ $a' = 1.988\ in$

Tributary length

$$p := min(2 \cdot b, b + ed, s)$$ $p = 2.625\ in$

Ratios for prying

$$\delta := 1 - \frac{d_{bh}}{p}$$ $\delta = 0.643$

$$\rho := \frac{b'}{a'}$$ $\rho = 0.887$

Thickness required to develop bolt tension without prying

$$t_c := \sqrt{\frac{1.67 \cdot 4 \cdot B \cdot b'}{p \cdot F_{ua}}}$$ $t_c = 1.447\ in$

$$\alpha' := \frac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\frac{t_c}{t_a}\right)^2 - 1\right)$$ $\alpha' = 6.076$

Proportion of tension strength available

$$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\frac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right)$$ $Q = 0.196$

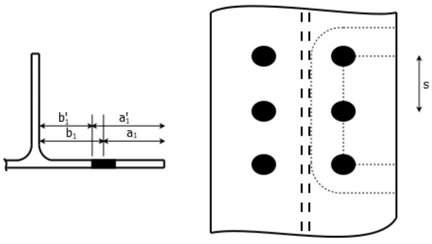
Available tension strength with prying

$$T_{av} := Q \cdot B$$ $T_{av} = 5.311\ kip$

Interaction ratio in prying

$$I_7 := \frac{TF_b}{T_{av}}$$ $I_7 = 0.785$

Bolt prying at column flange



Clip dimensions for prying check

$b_1 := 0.5 \cdot (g - t_{ws})$ $\quad b_1 = 2.455\ in$

$a_1 := min\left(0.5 \cdot (b_{fs} - g), 0.5 \cdot (2 \cdot l_{oa} + t_{wb} - g)\right)$ $\quad a_1 = 1.55\ in$

$b'_1 := b_1 - 0.5 \cdot d_b$ $\quad b'_1 = 2.018\ in$

$a'_1 := min\left(a_1 + 0.5 \cdot d_b, 1.25 \cdot b_1 + 0.5 \cdot d_b\right)$ $\quad a'_1 = 1.988\ in$

Tributary length

$p_1 := \dfrac{(n-1) \cdot s + \pi \cdot b_1 + (b_{fs} - g)}{n}$ $\quad p_1 = 5.006\ in$

Ratios for prying

$\delta_1 := 1 - \dfrac{d_{bh}}{p_1}$ $\quad \delta_1 = 0.813$

$\rho_1 := \dfrac{b'_1}{a'_1}$ $\quad \rho_1 = 1.015$

Thickness required to develop bolt tension without prying

$t_{c1} := \sqrt{\dfrac{1.67 \cdot 4 \cdot B \cdot b'_1}{p_1 \cdot F_{us}}}$ $\quad t_{c1} = 1.059\ in$

$\alpha'_1 := \dfrac{1}{\delta_1 \cdot (1 + \rho_1)} \cdot \left(\left(\dfrac{t_{c1}}{t_{fs}}\right)^2 - 1\right)$ $\quad \alpha'_1 = 0.164$

Proportion of tension strength available

$Q_1 := \text{if}\left(\alpha'_1 < 0, 1, \text{if}\left(0 \le \alpha'_1 \le 1, \left(\dfrac{t_{fs}}{t_{c1}}\right)^2 \cdot (1 + \delta_1 \cdot \alpha'_1), \left(\dfrac{t_{fs}}{t_{c1}}\right)^2 \cdot (1 + \delta_1)\right)\right)$ $\quad Q_1 = 0.893$

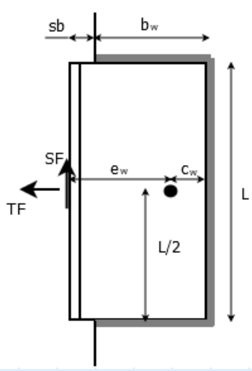
Available tension strength with prying

$T_{av1} := Q_1 \cdot B$ $\quad T_{av1} = 24.176\ kip$

Interaction ratio in prying

$I_8 := \dfrac{TF_b}{T_{av1}}$ $\quad I_8 = 0.172$

Weld check



Length of horizontal run of weld

$b_w := l_{ia} - sb$ $\quad b_w = 3\ in$

Centroid of weld group

$$c_w := \frac{b_w^{\,2}}{2 \cdot b_w + L} \qquad c_w = 0.414\ in$$

Eccentricity of shear force

$$e_w := l_{ia} - c_w \qquad e_w = 3.086\ in$$

Polar moment of inertia of weld group

$$I_w := \frac{(2 \cdot b_w + L)^3}{12} - \frac{b_w^{\,2} \cdot (b_w + L)^2}{2 \cdot b_w + L} \qquad I_w = 711.952\ in^3$$

Horizontal component of weld stress

$$f_{wh} := \frac{TF}{2 \cdot (2 \cdot b_w + L)} + \frac{SF \cdot e_w \cdot L}{4 \cdot I_w} \qquad f_{wh} = 2.259\ \frac{kip}{in}$$

Vertical component of weld stress

$$f_{wv} := \frac{SF}{2 \cdot (2 \cdot b_w + L)} + \frac{SF \cdot e_w \cdot (b_w - c_w)}{2\ I_w} \qquad f_{wv} = 1.859\ \frac{kip}{in}$$

Resultant weld stress

$$f_w := \sqrt{f_{wh}^{\,2} + f_{wv}^{\,2}} \qquad f_w = 2.925\ \frac{kip}{in}$$

Nominal weld strength

$$R_{nw} := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w \qquad R_{nw} = 9.281\ \frac{kip}{in}$$

Interaction ratio for weld check

$$I_9 := \frac{2.0\ f_w}{R_{nw}} \qquad I_9 = 0.63$$

Beam web rupture at weld check

Minimum web thickness to match weld strength

$$t_{wb.min} := \frac{2.0 \cdot 2 \cdot f_w}{0.6 \cdot F_{ub}} \qquad t_{wb.min} = 0.3\ in$$

Interaction ratio in web rupture

$$I_{10} := \frac{t_{wb.min}}{t_{wb}} \qquad I_{10} = 0.5$$

Column web local yielding check

Nominal strength in web local yielding

$$R_{nwy} := F_{ys} \cdot t_{ws} \cdot (2.5 \cdot k_s + L) \qquad R_{nwy} = 578.2\ kip$$

Interaction ratio in web local yielding

$$I_{11} := \frac{1.5\ TF}{R_{nwy}} \qquad I_{11} = 0.13$$

Column web local crippling

Nominal strength in web crippling

$$R_{nwc1} := 0.40 \cdot t_{ws}{}^2 \cdot \left(1 + 3 \cdot \frac{L}{d_{xs}} \cdot \left(\frac{t_{ws}}{t_{fs}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{ys} \cdot t_{fs}}{t_{ws}}}$$

$$R_{nwc2} := 0.40 \cdot t_{ws}{}^2 \cdot \left(1 + \left(\frac{4 \cdot L}{d_{xs}} - 0.2\right) \cdot \left(\frac{t_{ws}}{t_{fs}}\right)^{1.5}\right) \cdot \sqrt{\frac{E \cdot F_{ys} \cdot t_{fs}}{t_{ws}}}$$

$$R_{nwc} := \mathbf{if}\left(\frac{L}{d_{xs}} \le 0.2, R_{nwc1}, R_{nwc2}\right) \qquad R_{nwc} = 647.827\ \boldsymbol{kip}$$

Interaction ratio in web crippling

$$I_{12} := \frac{2.0\ TF}{R_{nwc}} \qquad I_{12} = 0.154$$

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.

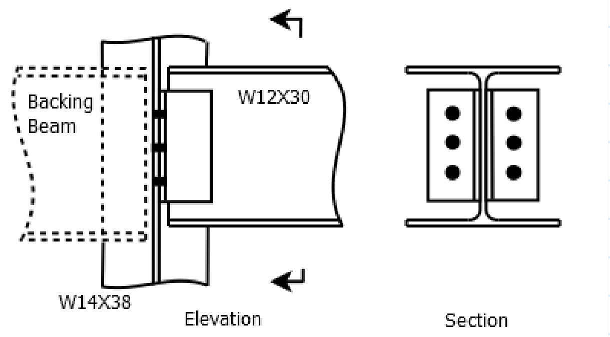
Table 6: Validation problem 5 results

Check	Interaction Ratio		Result
	Calculated	Osoconn	
Bolt shear check	0.716	0.716	OK
Bolt tension check	0.154	0.154	OK
Bolt bearing at clip angle	0.369	0.369	OK
Bolt bearing at column flange	0.088	0.088	OK
Clip angle shear yielding strength	0.362	0.362	OK
Clip angle shear rupture strength	0.465	0.465	OK
Clip angle block shear check	0.379	0.379	OK
Bolt prying at clip angle check	0.785	0.785	OK
Bolt prying at column flange	0.172	0.172	OK
Weld check	0.63	0.629	OK
Beam web rupture at weld check	0.5	0.5	OK
Column web local yielding check	0.13	0.13	OK
Column web local crippling	0.154	0.154	OK

2.7 Validation Problem 6

Problem Statement

Design a shop-welded field-bolted clip angle shear connection for a W12X30 beam framing into the web of a W14X38 column using the ASD method. The connection has to be designed for a shear force of 22kip and a transfer force of 12kip. The beam, column and clip angle are ASTM A36. The bolts used are ASTM 3125 A490 slip critical bolts. A backing beam is present.



Design Inputs

Material Properties

Material grade for angles — ASTM A36

Yield strength — $F_{ya} := 36\ ksi$

Tensile strength — $F_{ua} := 58\ ksi$

Material grade of beam — ASTM A36

Yield strength — $F_{yb} := 36\ ksi$

Tensile strength — $F_{ub} := 58\ ksi$

Material grade of supporting member — ASTM A36

Yield strength — $F_{ys} := 36\ ksi$

Tensile strength — $F_{us} := 58\ ksi$

Material grade for weld electrode — E70XX

Tensile strength — $F_{EXX} := 70\ ksi$

Material specification for bolts — ASTM 3125 A490

Tensile strength — $F_{nt} := 113\ ksi$

Shear strength — $F_{nv} := 68\ ksi$

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

Design Forces

Shear force in connection — $SF := 22\ kip$

Transfer force in connection — $TF := 12\ kip$

Geometry

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	$t_{wb} := 0.26\ in$
Supporting member section	W14X38
Section depth	$d_{xs} := 14.1\ in$
Flange width	$b_{fs} := 6.77\ in$
Flange thickness	$t_{fs} := 0.515\ in$
Web thickness	$t_{ws} := 0.31\ in$
Fillet area dimension	$k_s := 0.915\ in$
Clip angle section	L3X3X5/16
Thickness	$t_a := 0.313\ in$
Outstanding leg length	$l_{oa} := 3\ in$
Welded leg length	$l_{ia} := 3\ in$
Bolt diameter	$d_b := \frac{3}{4}\ in$
Bolt hole diameter	$d_{bh} := \frac{13}{16}\ in$
Slip coefficient (class A surface)	$\mu := 0.3$
Bolt pretension	$T_{pre} := 35\ kip$
Number of bolts	$n := 3$
Bolt spacing	$s := 2.25\ in$
Bolt gage	$g := 3.5\ in$
Weld thickness	$w := 0.25\ in$
Clip angle length	$L := 6.75\ in$
Clip angle offset from beam top	$o := 1.5\ in$
Connection setback	$sb := 0.5\ in$

Design Calculations

Bolt tension check

Tension per bolt

$$TF_b := \frac{TF}{2 \cdot n} \qquad TF_b = 2\ kip$$

Area of bolt

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

Nominal tensile strength

$$R_{n.bt} := F_{nt} \cdot A_b \qquad R_{n.bt} = 49.922\ kip$$

Interaction ratio for bolt tension

$$I_1 := \frac{2.0\ TF_b}{R_{n.bt}} \qquad I_1 = 0.08$$

Bolt shear check

Shear per bolt

$$SF_b := \frac{SF}{2 \cdot n} \qquad SF_b = 3.667\ kip$$

Slip resistance reduction factor

$$k_{sc} := 1 - \frac{1.5 \cdot TF_b}{1.13 \cdot T_{pre}} \qquad k_{sc} = 0.924$$

Nominal slip resistance of bolt

$$R_{nbv} := \mu \cdot 1.13 \cdot T_{pre} \cdot k_{sc} \qquad R_{nbv} = 10.965\ kip$$

Interaction ratio in bolt shear

$$I_0 := \frac{1.5 \cdot SF_b}{R_{nbv}} \qquad I_0 = 0.502$$

Bolt bearing at clip angle

Edge distance from bolt centre

$$ed := \frac{L - (n-1) \cdot s}{2} \qquad ed = 1.125\ in$$

Clear distance between bolt holes/ hole and edge

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

Nominal strength in bearing

$$R_{n.bc} := min\left(1.2 \cdot l_c \cdot t_a \cdot F_{ua}, 2.4 \cdot d_b \cdot t_a \cdot F_{ua}\right) \qquad R_{n.bc} = 15.658\ kip$$

Interaction ratio in bolt bearing

$$I_2 := \frac{2.0\ SF_b}{R_{n.bc}} \qquad I_2 = 0.468$$

Bolt bearing at column web

Nominal strength in bearing

$$R_{n.bw} := 0.5\ min\left(1.2 \cdot \left(s - d_{bh}\right) \cdot t_{ws} \cdot F_{us}, 2.4 \cdot d_b \cdot t_{ws} \cdot F_{us}\right) \qquad R_{n.bw} = 15.508\ kip$$

Interaction ratio in bolt bearing

$$I_3 := \frac{2.0\ SF_b}{R_{n.bw}} \qquad I_3 = 0.473$$

Clip angle shear yielding strength

Gross area in shear

$$A_{gv} := 2 \cdot L \cdot t_a \qquad A_{gv} = 4.226\ in^2$$

Nominal strength in shear yielding

$$R_{ny} := 0.6 \cdot F_{ya} \cdot A_{gv} \qquad R_{ny} = 91.271\ kip$$

Resultant shear in clip angle

$$S_r := \sqrt{TF^2 + SF^2} \qquad S_r = 25.06\ kip$$

Interaction ratio in shear yielding

$$I_4 := \frac{1.5\ S_r}{R_{ny}}$$ $$I_4 = 0.412$$

Clip angle shear rupture strength

Net area in shear

$$A_{nv} := A_{gv} - 2 \cdot n \cdot d_{bh} \cdot t_a$$ $$A_{nv} = 2.7\ in^2$$

Nominal strength in shear rupture

$$R_{nr} := 0.6 \cdot F_{ua} \cdot A_{nv}$$ $$R_{nr} = 93.947\ kip$$

Interaction ratio in shear rupture

$$I_5 := \frac{2.0\ S_r}{R_{nr}}$$ $$I_5 = 0.533$$

Clip angle block shear check

Gross area subjected to block shear

$$A_{gvb} := 2 \cdot (L - ed) \cdot t_a$$ $$A_{gvb} = 3.521\ in^2$$

Net area subjected to block shear

$$A_{nvb} := A_{gvb} - 2 \cdot (n - 0.5) \cdot d_{bh} \cdot t_a$$ $$A_{nvb} = 2.25\ in^2$$

Net area subjected to tension

$$A_{ntb} := 0.5 \cdot \left(2 \cdot l_{oa} + t_{wb} - g - d_{bh}\right) \cdot t_a$$ $$A_{ntb} = 0.305\ in^2$$

Nominal strength in block shear

$$R_{nbs1} := 0.6 \cdot F_{ua} \cdot A_{nvb} + F_{ua} \cdot A_{ntb}$$

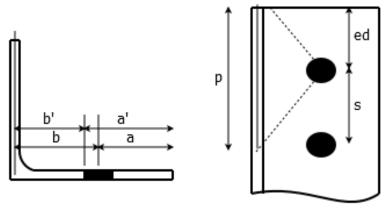
$$R_{nbs2} := 0.6 \cdot F_{ya} \cdot A_{gvb} + F_{ua} \cdot A_{ntb}$$

$$R_{nbs} := min\left(R_{nbs1}, R_{nbs2}\right)$$ $$R_{nbs} = 93.736\ kip$$

Interaction ratio in block shear

$$I_6 := \frac{2.0\ SF}{R_{nbs}}$$ $$I_6 = 0.469$$

Bolt prying at clip angle check



Available tension per bolt

$$B := \frac{F_{nt} \cdot A_b}{2.0}$$ $$B = 24.961\ kip$$

Clip dimensions for prying check

$b := 0.5 \cdot (g - t_{wb} - t_a)$ $\qquad b = 1.464\ in$

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

$b' := b - 0.5 \cdot d_b$ $\qquad b' = 1.089\ in$

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

Tributary length

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

Ratios for prying

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

$\rho := \dfrac{b'}{a'}$ $\qquad \rho = 0.62$

Thickness required to develop bolt tension without prying

$t_c := \sqrt{\dfrac{1.67 \cdot 4 \cdot B \cdot b'}{p \cdot F_{ua}}}$ $\qquad t_c = 1.179\ in$

$\alpha' := \dfrac{1}{\delta \cdot (1 + \rho)} \cdot \left(\left(\dfrac{t_c}{t_a}\right)^2 - 1\right)$ $\qquad \alpha' = 12.748$

Proportion of tension strength available

$Q := \text{if}\left(\alpha' < 0, 1, \text{if}\left(0 \le \alpha' \le 1, \left(\dfrac{t_a}{t_c}\right)^2 \cdot (1 + \delta \cdot \alpha'), \left(\dfrac{t_a}{t_c}\right)^2 \cdot (1 + \delta)\right)\right)$ $\qquad Q = 0.115$

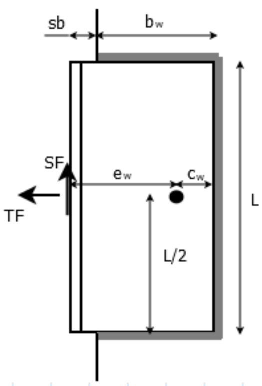
Available tension strength with prying

$T_{av} := Q \cdot B$ $\qquad T_{av} = 2.882\ kip$

Interaction ratio in prying

$I_7 := \dfrac{TF_b}{T_{av}}$ $\qquad I_7 = 0.694$

Weld check



Length of horizontal run of weld

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

Centroid of weld group

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

Eccentricity of shear force

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

Polar moment of inertia of weld group

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

Horizontal component of weld stress

$f_{wh} := \frac{TF}{2 \cdot (2 \cdot b_w + L)} + \frac{SF \cdot e_w \cdot L}{4 \cdot I_w}$ $\qquad f_{wh} = 1.532\ \frac{kip}{in}$

Vertical component of weld stress

$f_{wv} := \frac{SF}{2 \cdot (2 \cdot b_w + L)} + \frac{SF \cdot e_w \cdot (b_w - c_w)}{2\ I_w}$ $\qquad f_{wv} = 1.532\ \frac{kip}{in}$

Resultant weld stress

$f_w := \sqrt{f_{wh}^{\ 2} + f_{wv}^{\ 2}}$ $\qquad f_w = 2.167\ \frac{kip}{in}$

Nominal weld strength

$R_{nw} := 0.6 \cdot F_{EXX} \cdot \frac{\sqrt{2}}{2} \cdot w$ $\qquad R_{nw} = 7.425\ \frac{kip}{in}$

Interaction ratio for weld check

$I_8 := \frac{2.0\ f_w}{R_{nw}}$ $\qquad I_8 = 0.584$

Beam web rupture at weld check

Minimum web thickness to match weld strength

$t_{wb.min} := \frac{2.0 \cdot 2 \cdot f_w}{0.6 \cdot F_{ub}}$ $\qquad t_{wb.min} = 0.249\ in$

Interaction ratio in web rupture

$I_9 := \frac{t_{wb.min}}{t_{wb}}$ $\qquad I_9 = 0.958$

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	0.502	0.502	OK
Bolt tension check	0.08	0.08	OK
Bolt bearing at clip angle	0.468	0.468	OK
Bolt bearing at column web	0.473	0.473	OK
Clip angle shear yielding strength	0.412	0.412	OK
Clip angle shear rupture strength	0.533	0.533	OK
Clip angle block shear check	0.469	0.469	OK
Bolt prying at clip angle check	0.694	0.694	OK
Weld check	0.584	0.584	OK
Beam web rupture at weld check	0.958	0.958	OK

3 Osoconn Output

3.1 Validation problem 1

```
Osoconn v1.1
Connection code : SC001AM10
Connection ID : SC001_1
-----------------------------------------------------------------------+---------------------
Design Summary                                                         |
-----------------------------------------------------------------------+---------------------
   Connection is OK                                                    |
   Maximum utility ratio for connection                                | 0.638
-----------------------------------------------------------------------+---------------------
Design Inputs                                                          |
-----------------------------------------------------------------------+---------------------
   Design method                                                       | LRFD
   Young's modulus of elasticity                                       | 200000.000 MPa
   Poisson's ratio                                                     | 0.300
                                                                       |
Connection forces:                                                     |
   Transfer force (TF)                                                 | 15000.000 N
   Shear force (SF)                                                    | 200000.000 N
                                                                       |
Bolt Details:                                                          |
   Bolt Diameter                                                       | 22.000 mm
   Number of bolts per clip angle (n)                                  | 3.000
   Bolt Gage                                                           | 90.000 mm
   Bolt Spacing                                                        | 70.000 mm
   Nominal tensile capacity of bolt                                    | 620.000 MPa
   Nominal shear capacity of bolt                                      | 372.000 MPa
                                                                       |
Weld Details:                                                          |
   Weld thickness                                                      | 6.000 mm
   Weld tensile strength                                               | 482.000 MPa
                                                                       |
Clip angle dimensions:                                                 |
   Clip angle  size (li x lo x ta)                                     | 76.2x102x9.53 mm
   Clip angle length                                                   | 210.000 mm
   Yield strength of clip angle                                        | 250.000 MPa
   Tensile strenght of clip angle                                      | 400.000 MPa
                                                                       |
Connecting beam properties:                                            |
   Section size                                                        | W310X74
      Depth                                                            | 310.000 mm
      Flange width                                                     | 205.000 mm
      Flange thickness                                                 | 16.300 mm
      Web thickness (tw)                                               | 9.400 mm
   Yield strength of beam                                              | 250.000 MPa
   Tensile strength of beam                                            | 400.000 MPa
   Beam setback from connection member (s)                             | 12.000 mm
   Top cope depth                                                      | 35.000 mm
   Bottom cope depth                                                   | 0.000 mm
   Cope length (c)                                                     | 100.000 mm
```

```
                                                                       |
Supporting member properties:                                          |
   Support type                                                        | Beam Web
   Section size                                                        | W460X74
      Depth                                                            | 457.000 mm
      Flange width                                                     | 191.000 mm
      Flange thickness                                                 | 14.500 mm
      Web thickness                                                    | 9.020 mm
   Yield strength of support                                           | 250.000 MPa
   Tensile strength of support                                         | 400.000 MPa
-----------------------------------------------------------------------+--------------------
Design Calculations                                                    |
-----------------------------------------------------------------------+--------------------
                                                                       |
Bolt Shear Check:                                                      |
   Shear per bolt                                                      |
      [Vb=SF/(2*n)]                                                    | 33333.333 N
   Nominal shear strength of bolt (Rn)                                 | 141427.704 N
   LRFD factor in bolt shear (phi)                                     | 0.750
   Allowable shear strength of bolt                                    |
      [Ra=phi*Rn]                                                      | 106070.778 N
   Interaction ratio in bolt shear                                     |
      [Vb/Ra]                                                          | 0.314
                                                                       |
Bolt Tension Check (without prying:                                    |
   Tension per bolt without prying                                     |
      [Tb=TF/(2*n)]                                                    | 2500.000 N
   Nominal bolt strength in tension (Rn)                               | 232157.566 N
   LRFD factor in bolt tension (phi)                                   | 0.750
   Allowable bolt strength in tension                                  |
      [B=phi*Rn]                                                       | 174118.174 N
   Interaction ratio in bolt tension                                   |
      [Tb/B]                                                           | 0.014
                                                                       |
Bolt Bearing at Clip Angle Check:                                      |
   Nominal strength in bearing at clip angle (Rn)                      | 105211.200 N
   LRFD factor in bolt bearing (phi)                                   | 0.750
   Allowable strength in bearing at clip angle                         |
      [Ra=phi*Rn]                                                      | 78908.400 N
   Interaction ratio in bearing at clip angle                          |
      [Vb/Ra]                                                          | 0.422
                                                                       |
Bolt Bearing at Support Check:                                         |
   Nominal strength in bearing at support (Rn)                         | 190502.400 N
   LRFD factor in bolt bearing (phi)                                   | 0.750
   Allowable strength in bearing at support                            |
      [Ra=phi*Rn]                                                      | 142876.800 N
   Strength reduction factor to account for backing beam (r)           | 1.000
   Interaction ratio in bearing at support                             |
      [Vb/(Ra*r)]                                                      | 0.233
                                                                       |
Clip Angle Shear Yielding Check:                                       |
   Shear in clip angle                                                 |
```

```
      [Va=sqrt(TF^2+SF^2)/2]                                            | 100280.856 N
   Nominal shear yeilding strength of clip angle (Rn)                   | 300195.000 N
   LRFD factor for shear yielding (phi)                                 | 1.000
   Allowable shear yielding strength of clip angle                      |
      [Ra=phi*Rn]                                                       | 300195.000 N
   Interaction ratio in shear yielding                                  |
      [Va/Ra]                                                           | 0.334
                                                                        |
Clip Angle Shear Rupture Check:                                         |
   Nominal shear rupture strength of clip angle (Rn)                    | 315633.600 N
   LRFD factor for shear rupture (phi)                                  | 0.750
   Shear rupture strength of clip angle                                 |
      [Ra=phi*Rn]                                                       | 236725.200 N
   Interaction ratio in shear rupture                                   |
      [Va/Ra]                                                           | 0.424
                                                                        |
Clip Angle Block Shear Check:                                           |
   Nominal block shear strength of clip angle (Rn)                      | 689781.400 N
   LRFD factor for block shear (phi)                                    | 0.750
   Block shear strength of clip angle                                   |
      [Ra=phi*Rn]                                                       | 517336.050 N
   Interaction ratio in block shear                                     |
      [SF/Ra]                                                           | 0.387
                                                                        |
Clip angle prying action check:                                         |
   Bolt strength reduction factor due to clip prying (Q)                | 0.222
   Interaction ratio in clip prying                                     |
      [Tb/(Q*B)]                                                        | 0.065
                                                                        |
Weld Check:                                                             |
   Maximum stress in weld group (fw)                                    | 539.364 N/mm
   Nominal strength of weld (Rn)                                        | 1226.786 N/mm
   LRFD factor for weld (phi)                                           | 0.750
   Allowable weld strength                                              |
      [Ra=phi*Rn]                                                       | 920.090 N/mm
   Interaction ratio for weld                                           |
      [fw/Ra]                                                           | 0.586
                                                                        |
Web Rupture at Weld Check:                                              |
   Minimum thickness of web at weld (tw‘)                               | 5.993 mm
   Interaction ratio in rupture at weld                                 |
      [tw‘/tw]                                                          | 0.638
                                                                        |
Beam Cope Flexure Check:                                                |
   Eccetricity of applied transfer force from centroid of cope (e)      | 91.933 mm
   Bending moment in coped section                                      |
      [M=SF*(s+c)+TF*e]                                                 | 23778998.398 N mm
   Section modulus of coped section about major axis (Sx)               | 192628.943 mm^3
   Critical stress in coped section (Fcr)                               | 250.000 MPa
   Nominal flexural strength of coped section                           |
      [Mn=Fcr*Sx]                                                       | 48157235.874 N mm
   LRFD factor in flexure (phi)                                         | 0.900
   Allowable flexural strength of coped section                         |
```

```
      [Ma=phi*Mn]                                                        | 43341512.287 N mm
   Interaction ratio in coped section flexure                            |
      [M/Ma]                                                             | 0.549
                                                                         |
Beam Cope Compression Check:                                             |
   Cross section area of coped section (Ac)                              | 5773.280 mm^2
   Critical compressive stress in coped section (fcr)                    | 249.918 MPa
   Nominal strength of coped section in compression (Pn)                 |
      [Pn=fcr*Ac]                                                        | 1442847.310 N
   LRFD factor in compression (phi)                                      | 0.900
   Allowable compression strength of coped section                       |
      [Pa=phi*Pn]                                                        | 1298562.579 N
   Interaction ratio in coped section compression                        |
      [TF/Pa]                                                            | 0.012
                                                                         |
Beam Cope Shear Check:                                                   |
   Nominal strength of cope in shear (Rn)                                | 387750.000 N
   LRFD factor in shear yeilding (phi)                                   | 1.000
   Allowable shear strength of coped section                             |
      [Ra=phi*Rn]                                                        | 387750.000 N
   Interaction ratio in coped section shear                              |
      [SF/Ra]                                                            | 0.516
```

3.2 Validation problem 2

```
Osoconn v1.1
Connection code : SC001AM10
Connection ID : SC001_2
-------------------------------------------------------------------------+---------------------
Design Summary                                                           |
-------------------------------------------------------------------------+---------------------
   Connection is OK                                                      |
   Maximum utility ratio for connection                                  | 0.799
-------------------------------------------------------------------------+---------------------
Design Inputs                                                            |
-------------------------------------------------------------------------+---------------------
   Design method                                                         | LRFD
   Young's modulus of elasticity                                         | 200000.000 MPa
   Poisson's ratio                                                       | 0.300
                                                                         |
Connection forces:                                                       |
   Transfer force (TF)                                                   | 120000.000 N
   Shear force (SF)                                                      | 160000.000 N
                                                                         |
Bolt Details:                                                            |
   Bolt Diameter                                                         | 22.000 mm
   Number of bolts per clip angle (n)                                    | 4.000
   Bolt Gage                                                             | 140.000 mm
   Bolt Spacing                                                          | 70.000 mm
   Nominal tensile capacity of bolt                                      | 620.000 MPa
   Nominal shear capacity of bolt                                        | 372.000 MPa
                                                                         |
Weld Details:                                                            |
```

```
   Weld thickness                                                      | 6.000 mm
   Weld tensile strength                                               | 482.000 MPa
                                                                       |
Clip angle dimensions:                                                 |
   Clip angle  size (li x lo x ta)                                     | 76.2x127x9.53 mm
   Clip angle length                                                   | 270.000 mm
   Yield strength of clip angle                                        | 250.000 MPa
   Tensile strenght of clip angle                                      | 400.000 MPa
                                                                       |
Connecting beam properties:                                            |
   Section size                                                        | W410X53
      Depth                                                            | 404.000 mm
      Flange width                                                     | 178.000 mm
      Flange thickness                                                 | 10.900 mm
      Web thickness (tw)                                               | 7.490 mm
   Yield strength of beam                                              | 250.000 MPa
   Tensile strength of beam                                            | 400.000 MPa
   Beam setback from connection member (s)                             | 12.000 mm
                                                                       |
Supporting member properties:                                          |
   Support type                                                        | Column Flange
   Section size                                                        | W360X91
      Depth                                                            | 353.000 mm
      Flange width                                                     | 254.000 mm
      Flange thickness                                                 | 16.400 mm
      Web thickness                                                    | 9.530 mm
   Yield strength of support                                           | 345.000 MPa
   Tensile strength of support                                         | 450.000 MPa
-----------------------------------------------------------------------+---------------------
Design Calculations                                                    |
-----------------------------------------------------------------------+---------------------
                                                                       |
Bolt Shear Check:                                                      |
   Shear per bolt                                                      |
      [Vb=SF/(2*n)]                                                    | 20000.000 N
   Nominal shear strength of bolt (Rn)                                 | 141427.704 N
   LRFD factor in bolt shear (phi)                                     | 0.750
   Allowable shear strength of bolt                                    |
      [Ra=phi*Rn]                                                      | 106070.778 N
   Interaction ratio in bolt shear                                     |
      [Vb/Ra]                                                          | 0.189
                                                                       |
Bolt Tension Check (without prying:                                    |
   Tension per bolt without prying                                     |
      [Tb=TF/(2*n)]                                                    | 15000.000 N
   Nominal bolt strength in tension (Rn)                               | 235562.800 N
   LRFD factor in bolt tension (phi)                                   | 0.750
   Allowable bolt strength in tension                                  |
      [B=phi*Rn]                                                       | 176672.100 N
   Interaction ratio in bolt tension                                   |
      [Tb/B]                                                           | 0.085
                                                                       |
Bolt Bearing at Clip Angle Check:                                      |
```

```
   Nominal strength in bearing at clip angle (Rn)                    | 82339.200 N
   LRFD factor in bolt bearing (phi)                                 | 0.750
   Allowable strength in bearing at clip angle                       |
      [Ra=phi*Rn]                                                    | 61754.400 N
   Interaction ratio in bearing at clip angle                        |
      [Vb/Ra]                                                        | 0.324
                                                                     |
Bolt Bearing at Support Check:                                       |
   Nominal strength in bearing at support (Rn)                       | 389664.000 N
   LRFD factor in bolt bearing (phi)                                 | 0.750
   Allowable strength in bearing at support                          |
      [Ra=phi*Rn]                                                    | 292248.000 N
   Strength reduction factor to account for backing beam (r)         | 1.000
   Interaction ratio in bearing at support                           |
      [Vb/(Ra*r)]                                                    | 0.068
                                                                     |
Clip Angle Shear Yielding Check:                                     |
   Shear in clip angle                                               |
      [Va=sqrt(TF^2+SF^2)/2]                                         | 100000.000 N
   Nominal shear yeilding strength of clip angle (Rn)                | 385965.000 N
   LRFD factor for shear yielding (phi)                              | 1.000
   Allowable shear yielding strength of clip angle                   |
      [Ra=phi*Rn]                                                    | 385965.000 N
   Interaction ratio in shear yielding                               |
      [Va/Ra]                                                        | 0.259
                                                                     |
Clip Angle Shear Rupture Check:                                      |
   Nominal shear rupture strength of clip angle (Rn)                 | 397972.800 N
   LRFD factor for shear rupture (phi)                               | 0.750
   Shear rupture strength of clip angle                              |
      [Ra=phi*Rn]                                                    | 298479.600 N
   Interaction ratio in shear rupture                                |
      [Va/Ra]                                                        | 0.335
                                                                     |
Clip Angle Block Shear Check:                                        |
   Nominal block shear strength of clip angle (Rn)                   | 871975.940 N
   LRFD factor for block shear (phi)                                 | 0.750
   Block shear strength of clip angle                                |
      [Ra=phi*Rn]                                                    | 653981.955 N
   Interaction ratio in block shear                                  |
      [SF/Ra]                                                        | 0.245
                                                                     |
Clip angle prying action check:                                      |
   Bolt strength reduction factor due to clip prying (Q)             | 0.106
   Interaction ratio in clip prying                                  |
      [Tb/(Q*B)]                                                     | 0.799
                                                                     |
Column flange prying action check:                                   |
   Bolt strength reduction factor due to column flange prying (Q)    | 0.683
   Interaction ratio in column flange prying                         |
      [Tb/(Q*B)]                                                     | 0.124
                                                                     |
Weld Check:                                                          |
```

```
   Maximum stress in weld group (fw)                                        | 421.204 N/mm
   Nominal strength of weld (Rn)                                            | 1226.786 N/mm
   LRFD factor for weld (phi)                                               | 0.750
   Allowable weld strength                                                  |
      [Ra=phi*Rn]                                                           | 920.090 N/mm
   Interaction ratio for weld                                               |
      [fw/Ra]                                                               | 0.458
                                                                            |
Web Rupture at Weld Check:                                                  |
   Minimum thickness of web at weld (tw‘)                                   | 4.680 mm
   Interaction ratio in rupture at weld                                     |
      [tw‘/tw]                                                              | 0.625
                                                                            |
Column web yielding check:                                                  |
   Nominal strength of column web yielding (Rn)                             | 1146637.688 N
   LRFD factor in web yielding (phi)                                        | 1.000
   Allowable strength of column in web yielding                             |
      [Ra=Rn*phi]                                                           | 1146637.688 N
   Interaction ratio in column web yielding                                 |
      [TF/Ra]                                                               | 0.105
                                                                            |
Column web crippling check:                                                 |
   Nominal strength of column in web crippling (Rn)                         | 897291.132 N
   LRFD factor in web crippling (phi)                                       | 0.750
   Allowable strength of column in web crippling                            |
      [Ra=Rn*phi]                                                           | 672968.349 N
   Interaction ratio in column web crippling                                |
      [TF/Ra]                                                               | 0.178
```

3.3 Validation problem 3

```
Osoconn v1.1
Connection code : SC001AM10
Connection ID : SC001_3
----------------------------------------------------------------------------+---------------------
Design Summary                                                              |
----------------------------------------------------------------------------+---------------------
   Connection is OK                                                         |
   Maximum utility ratio for connection                                     | 0.297
----------------------------------------------------------------------------+---------------------
Design Inputs                                                               |
----------------------------------------------------------------------------+---------------------
   Design method                                                            | LRFD
   Young’s modulus of elasticity                                            | 200000.000 MPa
   Poisson’s ratio                                                          | 0.300
                                                                            |
Connection forces:                                                          |
   Transfer force (TF)                                                      | 15000.000 N
   Shear force (SF)                                                         | 20000.000 N
                                                                            |
Bolt Details:                                                               |
   Bolt Diameter                                                            | 20.000 mm
   Number of bolts per clip angle (n)                                       | 2.000
```

```
   Bolt Gage                                                          | 90.000 mm
   Bolt Spacing                                                       | 60.000 mm
   Nominal tensile capacity of bolt                                   | 620.000 MPa
   Nominal shear capacity of bolt                                     | 372.000 MPa
                                                                      |
Weld Details:                                                         |
   Weld thickness                                                     | 4.000 mm
   Weld tensile strength                                              | 482.000 MPa
                                                                      |
Clip angle dimensions:                                                |
   Clip angle  size (li x lo x ta)                                    | 76.2x88.9x6.35 mm
   Clip angle length                                                  | 120.000 mm
   Yield strength of clip angle                                       | 250.000 MPa
   Tensile strenght of clip angle                                     | 400.000 MPa
                                                                      |
Connecting beam properties:                                           |
   Section size                                                       | W200X46.1
      Depth                                                           | 203.000 mm
      Flange width                                                    | 203.000 mm
      Flange thickness                                                | 11.000 mm
      Web thickness (tw)                                              | 7.240 mm
   Yield strength of beam                                             | 345.000 MPa
   Tensile strength of beam                                           | 450.000 MPa
   Beam setback from connection member (s)                            | 12.000 mm
                                                                      |
Supporting member properties:                                         |
   Support type                                                       | Column Web
   Section size                                                       | W360X64
      Depth                                                           | 348.000 mm
      Flange width                                                    | 203.000 mm
      Flange thickness                                                | 13.500 mm
      Web thickness                                                   | 7.750 mm
   Yield strength of support                                          | 345.000 MPa
   Tensile strength of support                                        | 450.000 MPa
----------------------------------------------------------------------+--------------------
Design Calculations                                                   |
----------------------------------------------------------------------+--------------------
                                                                      |
Bolt Shear Check:                                                     |
   Shear per bolt                                                     |
      [Vb=SF/(2*n)]                                                   | 5000.000 N
   Nominal shear strength of bolt (Rn)                                | 116882.400 N
   LRFD factor in bolt shear (phi)                                    | 0.750
   Allowable shear strength of bolt                                   |
      [Ra=phi*Rn]                                                     | 87661.800 N
   Interaction ratio in bolt shear                                    |
      [Vb/Ra]                                                         | 0.057
                                                                      |
Bolt Tension Check (without prying:                                   |
   Tension per bolt without prying                                    |
      [Tb=TF/(2*n)]                                                   | 3750.000 N
   Nominal bolt strength in tension (Rn)                              | 194680.000 N
   LRFD factor in bolt tension (phi)                                  | 0.750
```

```
   Allowable bolt strength in tension                                |
      [B=phi*Rn]                                                     | 146010.000 N
   Interaction ratio in bolt tension                                 |
      [Tb/B]                                                         | 0.026
                                                                     |
Bolt Bearing at Clip Angle Check:                                    |
   Nominal strength in bearing at clip angle (Rn)                    | 57912.000 N
   LRFD factor in bolt bearing (phi)                                 | 0.750
   Allowable strength in bearing at clip angle                       |
      [Ra=phi*Rn]                                                    | 43434.000 N
   Interaction ratio in bearing at clip angle                        |
      [Vb/Ra]                                                        | 0.115
                                                                     |
Bolt Bearing at Support Check:                                       |
   Nominal strength in bearing at support (Rn)                       | 159030.000 N
   LRFD factor in bolt bearing (phi)                                 | 0.750
   Allowable strength in bearing at support                          |
      [Ra=phi*Rn]                                                    | 119272.500 N
   Strength reduction factor to account for backing beam (r)         | 1.000
   Interaction ratio in bearing at support                           |
      [Vb/(Ra*r)]                                                    | 0.042
                                                                     |
Clip Angle Shear Yielding Check:                                     |
   Shear in clip angle                                               |
      [Va=sqrt(TF^2+SF^2)/2]                                         | 12500.000 N
   Nominal shear yeilding strength of clip angle (Rn)                | 114300.000 N
   LRFD factor for shear yielding (phi)                              | 1.000
   Allowable shear yielding strength of clip angle                   |
      [Ra=phi*Rn]                                                    | 114300.000 N
   Interaction ratio in shear yielding                               |
      [Va/Ra]                                                        | 0.109
                                                                     |
Clip Angle Shear Rupture Check:                                      |
   Nominal shear rupture strength of clip angle (Rn)                 | 115824.000 N
   LRFD factor for shear rupture (phi)                               | 0.750
   Shear rupture strength of clip angle                              |
      [Ra=phi*Rn]                                                    | 86868.000 N
   Interaction ratio in shear rupture                                |
      [Va/Ra]                                                        | 0.144
                                                                     |
Clip Angle Block Shear Check:                                        |
   Nominal block shear strength of clip angle (Rn)                   | 264210.800 N
   LRFD factor for block shear (phi)                                 | 0.750
   Block shear strength of clip angle                                |
      [Ra=phi*Rn]                                                    | 198158.100 N
   Interaction ratio in block shear                                  |
      [SF/Ra]                                                        | 0.101
                                                                     |
Clip angle prying action check:                                      |
   Bolt strength reduction factor due to clip prying (Q)             | 0.086
   Interaction ratio in clip prying                                  |
      [Tb/(Q*B)]                                                     | 0.297
                                                                     |
```

```
Weld Check:                                                                 |
   Maximum stress in weld group (fw)                                        | 113.316 N/mm
   Nominal strength of weld (Rn)                                            | 817.858 N/mm
   LRFD factor for weld (phi)                                               | 0.750
   Allowable weld strength                                                  |
      [Ra=phi*Rn]                                                           | 613.393 N/mm
   Interaction ratio for weld                                               |
      [fw/Ra]                                                               | 0.185
                                                                            |
Web Rupture at Weld Check:                                                  |
   Minimum thickness of web at weld (tw‘)                                   | 1.119 mm
   Interaction ratio in rupture at weld                                     |
      [tw‘/tw]                                                              | 0.155
                                                                            |
Column web flexure yielding check:                                          |
   Nominal strength of column in web flexure yielding (Rn)                  | 70427.911 N
   LRFD factor in flexure (phi)                                             | 0.900
   Allowable strength of column in web flexure yielding                     |
      [Ra=Rn*phi]                                                           | 63385.120 N
   Interaction ratio in column web flexure yielding                         |
      [TF/Ra]                                                               | 0.237
```

3.4 Validation problem 4

```
Osoconn v1.1
Connection code : SC001AM10
Connection ID : SC001_4
----------------------------------------------------------------------------+---------------------
Design Summary                                                              |
----------------------------------------------------------------------------+---------------------
   Connection is OK                                                         |
   Maximum utility ratio for connection                                     | 0.949
----------------------------------------------------------------------------+---------------------
Design Inputs                                                               |
----------------------------------------------------------------------------+---------------------
   Design method                                                            | ASD
   Young’s modulus of elasticity                                            | 29000.000 ksi
   Poisson’s ratio                                                          | 0.300
                                                                            |
Connection forces:                                                          |
   Transfer force (TF)                                                      | 45.000 kip
   Shear force (SF)                                                         | 40.000 kip
                                                                            |
Bolt Details:                                                               |
   Bolt Diameter                                                            | 0.750 in
   Number of bolts per clip angle (n)                                       | 5.000
   Bolt Gage                                                                | 5.500 in
   Bolt Spacing                                                             | 2.500 in
   Nominal tensile capacity of bolt                                         | 113.000 ksi
   Nominal shear capacity of bolt                                           | 68.000 ksi
                                                                            |
Weld Details:                                                               |
   Weld thickness                                                           | 0.250 in
```

```
   Weld tensile strength                                              | 70.000 ksi
                                                                      |
Clip angle dimensions:                                                |
   Clip angle  size (li x lo x ta)                                    | 3x4x0.5 in
   Clip angle length                                                  | 13.000 in
   Yield strength of clip angle                                       | 36.000 ksi
   Tensile strenght of clip angle                                     | 58.000 ksi
                                                                      |
Connecting beam properties:                                           |
   Section size                                                       | W18X60
      Depth                                                           | 18.200 in
      Flange width                                                    | 7.560 in
      Flange thickness                                                | 0.695 in
      Web thickness (tw)                                              | 0.415 in
   Yield strength of beam                                             | 36.000 ksi
   Tensile strength of beam                                           | 58.000 ksi
   Beam setback from connection member (s)                            | 0.500 in
   Top cope depth                                                     | 1.500 in
   Bottom cope depth                                                  | 1.500 in
   Cope length (c)                                                    | 6.000 in
                                                                      |
Supporting member properties:                                         |
   Support type                                                       | Beam Web
   Section size                                                       | W18X97
      Depth                                                           | 18.600 in
      Flange width                                                    | 11.100 in
      Flange thickness                                                | 0.870 in
      Web thickness                                                   | 0.535 in
   Yield strength of support                                          | 36.000 ksi
   Tensile strength of support                                        | 58.000 ksi
----------------------------------------------------------------------+---------------------
Design Calculations                                                   |
----------------------------------------------------------------------+---------------------
                                                                      |
Bolt Shear Check:                                                     |
   Shear per bolt                                                     |
      [Vb=SF/(2*n)]                                                   | 4.000 kip
   Nominal shear strength of bolt (Rn)                                | 9.840 kip
   ASD factor in bolt shear (omega)                                   | 1.500
   Allowable shear strength of bolt                                   |
      [Ra=Rn/omega]                                                   | 6.560 kip
   Interaction ratio in bolt shear                                    |
      [Vb/Ra]                                                         | 0.610
                                                                      |
Bolt Tension Check (without prying:                                   |
   Tension per bolt without prying                                    |
      [Tb=TF/(2*n)]                                                   | 4.500 kip
   Nominal bolt strength in tension (Rn)                              | 49.897 kip
   ASD factor in bolt tension (omega)                                 | 2.000
   Allowable bolt strength in tension                                 |
      [B=Rn/omega]                                                    | 24.948 kip
   Interaction ratio in bolt tension                                  |
      [Tb/B]                                                          | 0.180
```

```
                                                                      |
Bolt Bearing at Clip Angle Check:                                     |
   Nominal strength in bearing at clip angle (Rn)                     | 38.062 kip
   ASD factor in bolt bearing (omega)                                 | 2.000
   Allowable strength in bearing at clip angle                        |
      [Ra=Rn/omega]                                                   | 19.031 kip
   Interaction ratio in bearing at clip angle                         |
      [Vb/Ra]                                                         | 0.210
                                                                      |
Bolt Bearing at Support Check:                                        |
   Nominal strength in bearing at support (Rn)                        | 55.854 kip
   ASD factor in bolt bearing (omega)                                 | 2.000
   Allowable strength in bearing at support                           |
      [Ra=Rn/omega]                                                   | 27.927 kip
   Strength reduction factor to account for backing beam (r)          | 1.000
   Interaction ratio in bearing at support                            |
      [Vb/(Ra*r)]                                                     | 0.143
                                                                      |
Clip Angle Shear Yielding Check:                                      |
   Shear in clip angle                                                |
      [Va=sqrt(TF^2+SF^2)/2]                                          | 30.104 kip
   Nominal shear yeilding strength of clip angle (Rn)                 | 140.400 kip
   ASD factor for shear yielding (omega)                              | 1.500
   Allowable shear yielding strength of clip angle                    |
      [Ra=Rn/omega]                                                   | 93.600 kip
   Interaction ratio in shear yielding                                |
      [Va/Ra]                                                         | 0.322
                                                                      |
Clip Angle Shear Rupture Check:                                       |
   Nominal shear rupture strength of clip angle (Rn)                  | 155.512 kip
   ASD factor for shear rupture (omega)                               | 2.000
   Shear rupture strength of clip angle                               |
      [Ra=Rn/omega]                                                   | 77.756 kip
   Interaction ratio in shear rupture                                 |
      [Va/Ra]                                                         | 0.387
                                                                      |
Clip Angle Block Shear Check:                                         |
   Nominal block shear strength of clip angle (Rn)                    | 278.886 kip
   ASD factor for block shear (omega)                                 | 2.000
   Block shear strength of clip angle                                 |
      [Ra=Rn/omega]                                                   | 139.443 kip
   Interaction ratio in block shear                                   |
      [SF/Ra]                                                         | 0.287
                                                                      |
Clip angle prying action check:                                       |
   Bolt strength reduction factor due to clip prying (Q)              | 0.190
   Interaction ratio in clip prying                                   |
      [Tb/(Q*B)]                                                      | 0.949
                                                                      |
Weld Check:                                                           |
   Maximum stress in weld group (fw)                                  | 2.527 kip/in
   Nominal strength of weld (Rn)                                      | 7.423 kip/in
   ASD factor for weld (omega)                                        | 2.000
```

```
   Allowable weld strength                                                 |
      [Ra=Rn/omega]                                                        | 3.712 kip/in
   Interaction ratio for weld                                              |
      [fw/Ra]                                                              | 0.681
                                                                           |
Web Rupture at Weld Check:                                                 |
   Minimum thickness of web at weld (tw‘)                                  | 0.290 in
   Interaction ratio in rupture at weld                                    |
      [tw‘/tw]                                                             | 0.700
                                                                           |
Beam Cope Flexure Check:                                                   |
   Eccetricity of applied transfer force from centroid of cope (e)        | 0.600 in
   Bending moment in coped section                                         |
      [M=SF*(s+c)+TF*e]                                                    | 287.000 kip in
   Section modulus of coped section about major axis (Sx)                  | 15.980 in^3
   Critical stress in coped section (Fcr)                                  | 36.000 ksi
   Nominal flexural strength of coped section                              |
      [Mn=Fcr*Sx]                                                          | 575.290 kip in
   ASD factor in flexure (omega)                                           | 1.670
   Allowable flexural strength of coped section                            |
      [Ma=Mn/omega]                                                        | 344.485 kip in
   Interaction ratio in coped section flexure                              |
      [M/Ma]                                                               | 0.833
                                                                           |
Beam Cope Compression Check:                                               |
   Cross section area of coped section (Ac)                                | 6.308 in^2
   Critical compressive stress in coped section (fcr)                      | 30.832 ksi
   Nominal strength of coped section in compression (Pn)                   |
      [Pn=fcr*Ac]                                                          | 194.486 kip
   ASD factor in compression (omega)                                       | 1.670
   Allowable compression strength of coped section                         |
      [Pa=Pn/omega]                                                        | 116.459 kip
   Interaction ratio in coped section compression                          |
      [TF/Pa]                                                              | 0.386
                                                                           |
Beam Cope Shear Check:                                                     |
   Nominal strength of cope in shear (Rn)                                  | 136.253 kip
   ASD factor in shear (omega)                                             | 1.500
   Allowable shear strength of coped section                               |
      [Ra=Rn/omega]                                                        | 90.835 kip
   Interaction ratio in coped section shear                                |
      [SF/Ra]                                                              | 0.440
```

3.5 Validation problem 5

```
Osoconn v1.1
Connection code : SC001AM10
Connection ID : SC001_5
---------------------------------------------------------------------------+---------------------
Design Summary                                                             |
---------------------------------------------------------------------------+---------------------
   Connection is OK                                                        |
   Maximum utility ratio for connection                                    | 0.785
```

```
-----------------------------------------------------------------------+---------------------
Design Inputs                                                          |
-----------------------------------------------------------------------+---------------------
   Design method                                                       | ASD
   Young's modulus of elasticity                                       | 29000.000 ksi
   Poisson's ratio                                                     | 0.300
                                                                       |
Connection forces:                                                     |
   Transfer force (TF)                                                 | 50.000 kip
   Shear force (SF)                                                    | 65.000 kip
                                                                       |
Bolt Details:                                                          |
   Bolt Diameter                                                       | 0.875 in
   Number of bolts per clip angle (n)                                  | 6.000
   Bolt Gage                                                           | 5.500 in
   Bolt Spacing                                                        | 2.625 in
   Nominal tensile capacity of bolt                                    | 90.000 ksi
   Nominal shear capacity of bolt                                      | 54.000 ksi
                                                                       |
Weld Details:                                                          |
   Weld thickness                                                      | 0.313 in
   Weld tensile strength                                               | 70.000 ksi
                                                                       |
Clip angle dimensions:                                                 |
   Clip angle  size (li x lo x ta)                                     | 3.5x4x0.5 in
   Clip angle length                                                   | 15.750 in
   Yield strength of clip angle                                        | 36.000 ksi
   Tensile strenght of clip angle                                      | 58.000 ksi
                                                                       |
Connecting beam properties:                                            |
   Section size                                                        | W21X122
      Depth                                                            | 21.700 in
      Flange width                                                     | 12.400 in
      Flange thickness                                                 | 0.960 in
      Web thickness (tw)                                               | 0.600 in
   Yield strength of beam                                              | 50.000 ksi
   Tensile strength of beam                                            | 65.000 ksi
   Beam setback from connection member (s)                             | 0.500 in
                                                                       |
Supporting member properties:                                          |
   Support type                                                        | Column Flange
   Section size                                                        | W14X120
      Depth                                                            | 14.500 in
      Flange width                                                     | 14.700 in
      Flange thickness                                                 | 0.940 in
      Web thickness                                                    | 0.590 in
   Yield strength of support                                           | 50.000 ksi
   Tensile strength of support                                         | 65.000 ksi
-----------------------------------------------------------------------+---------------------
Design Calculations                                                    |
-----------------------------------------------------------------------+---------------------
                                                                       |
Bolt Shear Check:                                                      |
```

```
   Shear per bolt                                                        |
      [Vb=SF/(2*n)]                                                      | 5.417 kip
   Nominal shear strength of bolt (Rn)                                   | 11.346 kip
   ASD factor in bolt shear (omega)                                      | 1.500
   Allowable shear strength of bolt                                      |
      [Ra=Rn/omega]                                                      | 7.564 kip
   Interaction ratio in bolt shear                                       |
      [Vb/Ra]                                                            | 0.716
                                                                         |
Bolt Tension Check (without prying:                                      |
   Tension per bolt without prying                                       |
      [Tb=TF/(2*n)]                                                      | 4.167 kip
   Nominal bolt strength in tension (Rn)                                 | 54.091 kip
   ASD factor in bolt tension (omega)                                    | 2.000
   Allowable bolt strength in tension                                    |
      [B=Rn/omega]                                                       | 27.046 kip
   Interaction ratio in bolt tension                                     |
      [Tb/B]                                                             | 0.154
                                                                         |
Bolt Bearing at Clip Angle Check:                                        |
   Nominal strength in bearing at clip angle (Rn)                        | 29.362 kip
   ASD factor in bolt bearing (omega)                                    | 2.000
   Allowable strength in bearing at clip angle                           |
      [Ra=Rn/omega]                                                      | 14.681 kip
   Interaction ratio in bearing at clip angle                            |
      [Vb/Ra]                                                            | 0.369
                                                                         |
Bolt Bearing at Support Check:                                           |
   Nominal strength in bearing at support (Rn)                           | 123.727 kip
   ASD factor in bolt bearing (omega)                                    | 2.000
   Allowable strength in bearing at support                              |
      [Ra=Rn/omega]                                                      | 61.864 kip
   Strength reduction factor to account for backing beam (r)             | 1.000
   Interaction ratio in bearing at support                               |
      [Vb/(Ra*r)]                                                        | 0.088
                                                                         |
Clip Angle Shear Yielding Check:                                         |
   Shear in clip angle                                                   |
      [Va=sqrt(TF^2+SF^2)/2]                                             | 41.003 kip
   Nominal shear yeilding strength of clip angle (Rn)                    | 170.100 kip
   ASD factor for shear yielding (omega)                                 | 1.500
   Allowable shear yielding strength of clip angle                       |
      [Ra=Rn/omega]                                                      | 113.400 kip
   Interaction ratio in shear yielding                                   |
      [Va/Ra]                                                            | 0.362
                                                                         |
Clip Angle Shear Rupture Check:                                          |
   Nominal shear rupture strength of clip angle (Rn)                     | 176.175 kip
   ASD factor for shear rupture (omega)                                  | 2.000
   Shear rupture strength of clip angle                                  |
      [Ra=Rn/omega]                                                      | 88.087 kip
   Interaction ratio in shear rupture                                    |
      [Va/Ra]                                                            | 0.465
```

```
                                                                           |
Clip Angle Block Shear Check:                                              |
   Nominal block shear strength of clip angle (Rn)                         | 343.206 kip
   ASD factor for block shear (omega)                                      | 2.000
   Block shear strength of clip angle                                      |
      [Ra=Rn/omega]                                                        | 171.603 kip
   Interaction ratio in block shear                                        |
      [SF/Ra]                                                              | 0.379
                                                                           |
Clip angle prying action check:                                            |
   Bolt strength reduction factor due to clip prying (Q)                   | 0.196
   Interaction ratio in clip prying                                        |
      [Tb/(Q*B)]                                                           | 0.785
                                                                           |
Column flange prying action check:                                         |
   Bolt strength reduction factor due to column flange prying (Q)          | 0.894
   Interaction ratio in column flange prying                               |
      [Tb/(Q*B)]                                                           | 0.172
                                                                           |
Weld Check:                                                                |
   Maximum stress in weld group (fw)                                       | 2.925 kip/in
   Nominal strength of weld (Rn)                                           | 9.294 kip/in
   ASD factor for weld (omega)                                             | 2.000
   Allowable weld strength                                                 |
      [Ra=Rn/omega]                                                        | 4.647 kip/in
   Interaction ratio for weld                                              |
      [fw/Ra]                                                              | 0.629
                                                                           |
Web Rupture at Weld Check:                                                 |
   Minimum thickness of web at weld (tw‘)                                  | 0.300 in
   Interaction ratio in rupture at weld                                    |
      [tw‘/tw]                                                             | 0.500
                                                                           |
Column web yielding check:                                                 |
   Nominal strength of column web yielding (Rn)                            | 578.200 kip
   ASD factor in web yielding (omega)                                      | 1.500
   Allowable strength of column in web yielding                            |
      [Ra=Rn/omega]                                                        | 385.467 kip
   Interaction ratio in column web yielding                                |
      [TF/Ra]                                                              | 0.130
                                                                           |
Column web crippling check:                                                |
   Nominal strength of column in web crippling (Rn)                        | 647.827 kip
   ASD factor in web crippling (omega)                                     | 2.000
   Allowable strength of column in web crippling                           |
      [Ra=Rn/omega]                                                        | 323.914 kip
   Interaction ratio in column web crippling                               |
      [TF/Ra]                                                              | 0.154
```

3.6 Validation problem 6

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Osoconn v1.1
Connection code : SC001AM10
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Connection ID : SC001_6
-----------------------------------------------------------------------+-------------------
Design Summary                                                         |
-----------------------------------------------------------------------+-------------------
   Connection is OK                                                    |
   Maximum utility ratio for connection                                | 0.958
-----------------------------------------------------------------------+-------------------
Design Inputs                                                          |
-----------------------------------------------------------------------+-------------------
   Design method                                                       | ASD
   Young's modulus of elasticity                                       | 29000.000 ksi
   Poisson's ratio                                                     | 0.300
                                                                       |
Connection forces:                                                     |
   Transfer force (TF)                                                 | 12.000 kip
   Shear force (SF)                                                    | 22.000 kip
                                                                       |
Bolt Details:                                                          |
   Bolt Diameter                                                       | 0.750 in
   Number of bolts per clip angle (n)                                  | 3.000
   Bolt Gage                                                           | 3.500 in
   Bolt Spacing                                                        | 2.250 in
   Nominal tensile capacity of bolt                                    | 113.000 ksi
   Nominal shear capacity of bolt                                      | 68.000 ksi
                                                                       |
Weld Details:                                                          |
   Weld thickness                                                      | 0.250 in
   Weld tensile strength                                               | 70.000 ksi
                                                                       |
Clip angle dimensions:                                                 |
   Clip angle  size (li x lo x ta)                                     | 3x3x0.313 in
   Clip angle length                                                   | 6.750 in
   Yield strength of clip angle                                        | 36.000 ksi
   Tensile strenght of clip angle                                      | 58.000 ksi
                                                                       |
Connecting beam properties:                                            |
   Section size                                                        | W12X30
      Depth                                                            | 12.300 in
      Flange width                                                     | 6.520 in
      Flange thickness                                                 | 0.440 in
      Web thickness (tw)                                               | 0.260 in
   Yield strength of beam                                              | 36.000 ksi
   Tensile strength of beam                                            | 58.000 ksi
   Beam setback from connection member (s)                             | 0.500 in
                                                                       |
Supporting member properties:                                          |
   Support type                                                        | Column Web
   Section size                                                        | W14X38
      Depth                                                            | 14.100 in
      Flange width                                                     | 6.770 in
      Flange thickness                                                 | 0.515 in
      Web thickness                                                    | 0.310 in
   Yield strength of support                                           | 36.000 ksi
```

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   Tensile strength of support                                            | 58.000 ksi
--------------------------------------------------------------------------+---------------------
Design Calculations                                                       |
--------------------------------------------------------------------------+---------------------
                                                                          |
Bolt Shear Check:                                                         |
   Shear per bolt                                                         |
      [Vb=SF/(2*n)]                                                       | 3.667 kip
   Nominal shear strength of bolt (Rn)                                    | 10.965 kip
   ASD factor in bolt shear (omega)                                       | 1.500
   Allowable shear strength of bolt                                       |
      [Ra=Rn/omega]                                                       | 7.310 kip
   Interaction ratio in bolt shear                                        |
      [Vb/Ra]                                                             | 0.502
                                                                          |
Bolt Tension Check (without prying:                                       |
   Tension per bolt without prying                                        |
      [Tb=TF/(2*n)]                                                       | 2.000 kip
   Nominal bolt strength in tension (Rn)                                  | 49.897 kip
   ASD factor in bolt tension (omega)                                     | 2.000
   Allowable bolt strength in tension                                     |
      [B=Rn/omega]                                                        | 24.948 kip
   Interaction ratio in bolt tension                                      |
      [Tb/B]                                                              | 0.080
                                                                          |
Bolt Bearing at Clip Angle Check:                                         |
   Nominal strength in bearing at clip angle (Rn)                         | 15.658 kip
   ASD factor in bolt bearing (omega)                                     | 2.000
   Allowable strength in bearing at clip angle                            |
      [Ra=Rn/omega]                                                       | 7.829 kip
   Interaction ratio in bearing at clip angle                             |
      [Vb/Ra]                                                             | 0.468
                                                                          |
Bolt Bearing at Support Check:                                            |
   Nominal strength in bearing at support (Rn)                            | 31.015 kip
   ASD factor in bolt bearing (omega)                                     | 2.000
   Allowable strength in bearing at support                               |
      [Ra=Rn/omega]                                                       | 15.508 kip
   Strength reduction factor to account for backing beam (r)              | 0.500
   Interaction ratio in bearing at support                                |
      [Vb/(Ra*r)]                                                         | 0.473
                                                                          |
Clip Angle Shear Yielding Check:                                          |
   Shear in clip angle                                                    |
      [Va=sqrt(TF^2+SF^2)/2]                                              | 12.530 kip
   Nominal shear yeilding strength of clip angle (Rn)                     | 45.635 kip
   ASD factor for shear yielding (omega)                                  | 1.500
   Allowable shear yielding strength of clip angle                        |
      [Ra=Rn/omega]                                                       | 30.424 kip
   Interaction ratio in shear yielding                                    |
      [Va/Ra]                                                             | 0.412
                                                                          |
Clip Angle Shear Rupture Check:                                           |
```

```
   Nominal shear rupture strength of clip angle (Rn)                | 46.973 kip
   ASD factor for shear rupture (omega)                             | 2.000
   Shear rupture strength of clip angle                             |
      [Ra=Rn/omega]                                                 | 23.487 kip
   Interaction ratio in shear rupture                               |
      [Va/Ra]                                                       | 0.533
                                                                    |
Clip Angle Block Shear Check:                                       |
   Nominal block shear strength of clip angle (Rn)                  | 93.736 kip
   ASD factor for block shear (omega)                               | 2.000
   Block shear strength of clip angle                               |
      [Ra=Rn/omega]                                                 | 46.868 kip
   Interaction ratio in block shear                                 |
      [SF/Ra]                                                       | 0.469
                                                                    |
Clip angle prying action check:                                     |
   Bolt strength reduction factor due to clip prying (Q)            | 0.116
   Interaction ratio in clip prying                                 |
      [Tb/(Q*B)]                                                    | 0.694
                                                                    |
Weld Check:                                                         |
   Maximum stress in weld group (fw)                                | 2.167 kip/in
   Nominal strength of weld (Rn)                                    | 7.423 kip/in
   ASD factor for weld (omega)                                      | 2.000
   Allowable weld strength                                          |
      [Ra=Rn/omega]                                                 | 3.712 kip/in
   Interaction ratio for weld                                       |
      [fw/Ra]                                                       | 0.584
                                                                    |
Web Rupture at Weld Check:                                          |
   Minimum thickness of web at weld (tw‘)                           | 0.249 in
   Interaction ratio in rupture at weld                             |
      [tw‘/tw]                                                      | 0.958
```