Verification example – End plate shear connection

Type of connection: Pinned end plate beam-column connection

Unit system: Metric

Designed acc. to: CSA S14-16

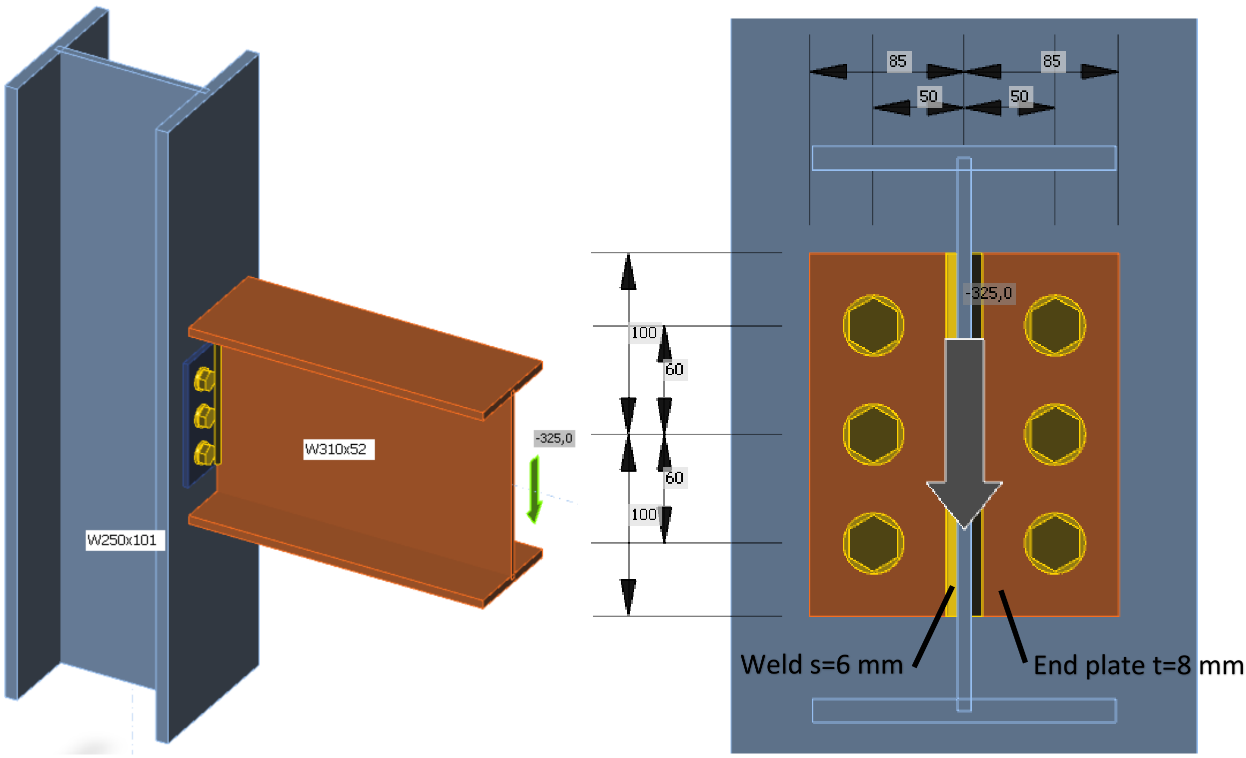
Investigated: Bolts, welds, base material,

Plate Materials: Steel grade 350W,

Bolts: 5/8, grade A325

Welds: leg size *s* = 6 mm, electrode E49XX

Geometry:



Applied forces:

N = 0 kN

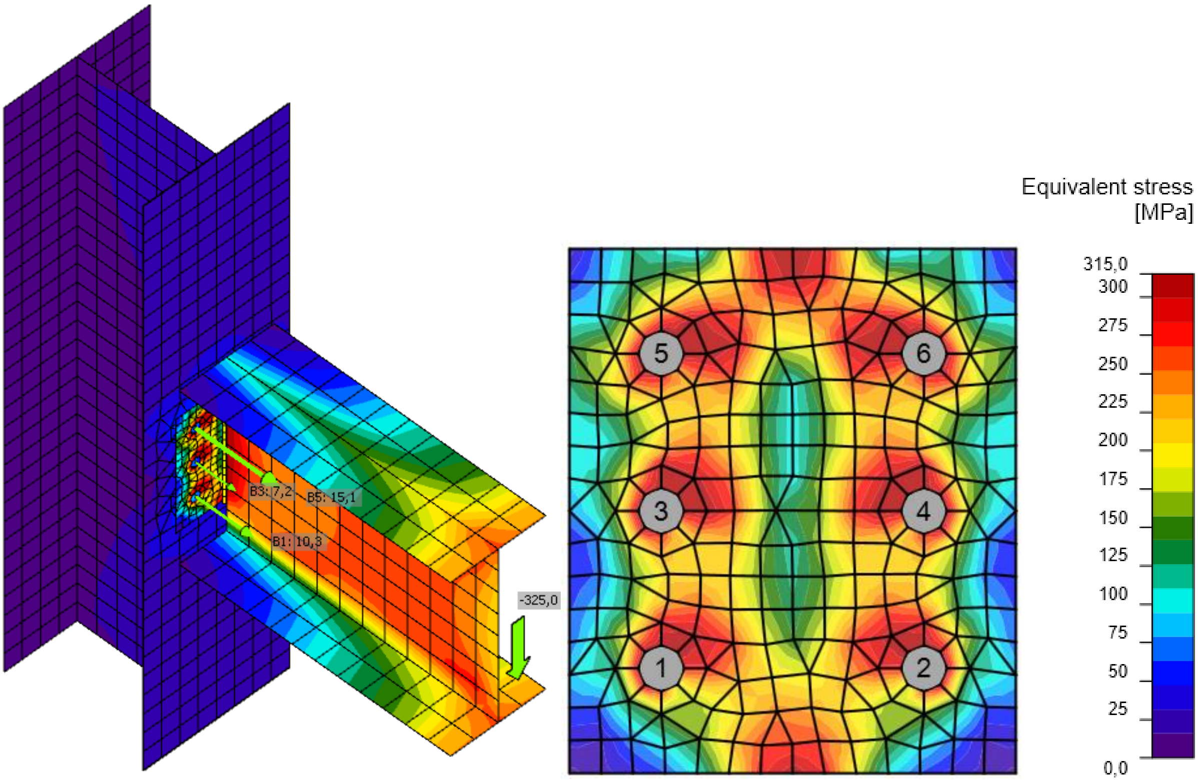
V = 325 kN

M = 0 kNm

Procedure:

Bolts are considered to be only in shear. IDEA StatiCa takes into account the tension force in bolts caused by eccentricity. However, tension force does not determine the design in this example. The check for combined tension/shear needs to be verified and is performed by IDEA StatiCa. Threads are intercepted by the shear plane. Fillet welds are loaded parallel to the force. Hole tear-out and shear block resistance of the end plate is checked.

IDEA StatiCa Connection



Check of members and steel plates for extreme load effect

	Status	Item	Th [mm]	Loads	σ,Ed [MPa]	ε,Pl [%]
	✓	W250x101-bfl 1	20	LE1	158,7	0,0
	✓	W250x101-tfl 1	20	LE1	12,6	0,0
	✓	W250x101-w 1	12	LE1	33,7	0,0
	✓	W310x52-bfl 1	13	LE1	257,1	0,0
	✓	W310x52-tfl 1	13	LE1	257,1	0,0
	✓	W310x52-w 1	8	LE1	311,3	0,3
>	✓	EP1	8	LE1	315,7	0,3

Design data

	Material	Fy [MPa]	ε,lim [%]
>	350W	350,0	5,0

Check of bolts for extreme load effect

		Status	Item	Loads	Tf [kN]	Vf [kN]	Br [kN]	Utt [%]	Uts [%]	Utts [%]
>	+	✓	B1	LE1	10,3	54,3	137,2	10,6	99,0	99,0
	+	✓	B2	LE1	10,3	54,3	137,2	10,5	99,0	99,0
	+	✓	B3	LE1	7,2	54,5	137,2	7,4	99,4	99,3
	+	✓	B4	LE1	7,3	54,5	137,2	7,4	99,4	99,3
	+	✓	B5	LE1	15,1	53,7	137,2	15,5	97,9	98,2
	+	✓	B6	LE1	15,2	53,7	137,2	15,5	97,9	98,2

Design data

	Item	Tr [kN]	Vr [kN]
>	5/8 A325 - 1	98,0	54,9

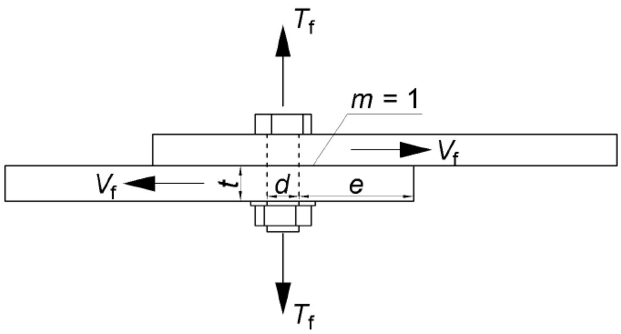
Check of welds for extreme load effect (Plastic redistribution)

		Status	Item	Edge	Th [mm]	Ls [mm]	L [mm]	Lc [mm]	Loads	Fw [kN]	Vr [kN]	Ut [%]
>	+	✓	EP1	W310x52-w 1	◢4,2◣	◢6,0◣	199	12	LE1	12,8	12,8	99,8
	+	✓			◢4,2◣	◢6,0◣	199	12	LE1	12,8	12,8	99,8

Manual assessment

IDEA StatiCa Connection CISC Verification Example

Bolt assessment



Material of steel: $F_y := 350\ \text{MPa}$

$F_u := 450\ \text{MPa}$

Material of bolts: $F_{ub} := 825\ \text{MPa}$

Bolt diameter: $d := 15.875\ \text{mm}$

Cross-sectional area of a bolt based on its nominal diameter: $A_b := \pi \cdot \frac{d^2}{4}$

$A_b = 198\ \text{mm}^2$

Resistance factor for structural steel: $\phi := 0.9$

Resistance factor for bolts: $\phi_b := 0.8$

Resistance factor for tear-out: $\phi_u := 0.75$

Geometrical parameters:

- End plate thickness: $t := 6\ \text{mm}$
- Edge distance: $e := 40\ \text{mm}$
- Pitch: $p := 60\ \text{mm}$

Number of shear planes:	$m := 1$
Number of bolts:	$n := 6$
Shear strength of a bolt:	$V_r := 0.7 \cdot 0.6 \cdot \phi_b \cdot m \cdot A_b \cdot F_{ub} = 54.9\ \text{kN}$
Design shear force:	$V_f := 329.4\ \text{kN}$
Utilization for 6 bolts:	$\frac{V_f}{n \cdot V_r} = 100\%$
Resistance factor for bearing of bolts on steel:	$\phi_{br} := 0.8$
Bearing strength in a regular bolt hole:	$B_r := 3 \cdot \phi_{br} \cdot t \cdot d \cdot F_u = 102.9\ \text{kN}$
Gross area in shear:	$A_{gv} := 2 \cdot t \cdot e = 480\ \text{mm}^2$
Hole tear-out:	$T_r := \phi_u \cdot 0.6 \cdot A_{gv} \cdot \frac{(F_y + F_u)}{2} = 86.4\ \text{kN}$
Gross area in shear:	$A_{gv} := 2 \cdot t \cdot (2 \cdot e + 2 \cdot p) = 2400\ \text{mm}^2$
Shear block:	$T_r := \phi_u \cdot 0.6 \cdot A_{gv} \cdot \frac{(F_y + F_u)}{2} = 432\ \text{kN}$
Net area in tension:	$A_n := t \cdot (2 \cdot e - (d + 2\ \text{mm})) = 373\ \text{mm}^2$ $\qquad U_t := 1$
Gross area in shear:	$A_{gv} := 2 \cdot t \cdot (e + 2 \cdot p) = 1920\ \text{mm}^2$
Tension and shear block:	$T_r := \phi_u \cdot \left(U_t \cdot A_n \cdot F_u + 0.6 \cdot A_{gv} \cdot \frac{(F_y + F_u)}{2}\right) = 471\ \text{kN}$

Weld assessment

Material:	$X_u := 490\ \text{MPa}$
Resistance factor for welds:	$\phi_w := 0.67$
Geometrical parameters:	
Leg size:	$s := 6\ \text{mm}$
Weld length:	$L_w := 2 \cdot e + 2 \cdot p - 2 \cdot s = 188\ \text{mm}$
Weld orientation:	$\theta := 0\ °$
Longitudinal weld area:	$A_{wl} := 2 \cdot L_w \cdot \frac{\sqrt{2}}{2} \cdot s = 1595\ \text{mm}^2$
Strength reduction factor for multi-orientation fillet welds:	$M_w := 1$
Lungitudinal weld:	$V_r := 0.67 \cdot \phi_w \cdot A_{wl} \cdot X_u \cdot \left(1 + 0.5 \cdot \sin(\theta)^{1.5}\right) \cdot M_w = 350.9\ \text{kN}$
Utilization for weld:	$\frac{V_f}{V_r} = 94\%$

Shear block nor hole tear-out is a decisive failure mode. IDEA StatiCa Connection shows 0.3% yielding of the end plate which still gives sufficient reserve.

Comparison:

The results of both IDEA StatiCa Connection design and manual computation according to CSA 16-14 give similar values: Bolt check: IDEA suggests existence of small tensile forces due to deformation of a plate, which are generally neglected in manual calculations. These tensile forces have little effect on the overall resistance. The resistance in IDEA is 325 kN and in manual assessment 329 kN (1% difference. Welds in IDEA are slightly conservative, they fail at shear force 325 kN and according to manual assessment they should transfer 346 kN. The difference is 6 %. Strength of the end plate was checked and it was found as sufficient both in manual calculation and software check.