Verification example – Splice connection of I-beam flanges

Type of connection: Splice connections of flanges of I-beam

Unit system: Metric

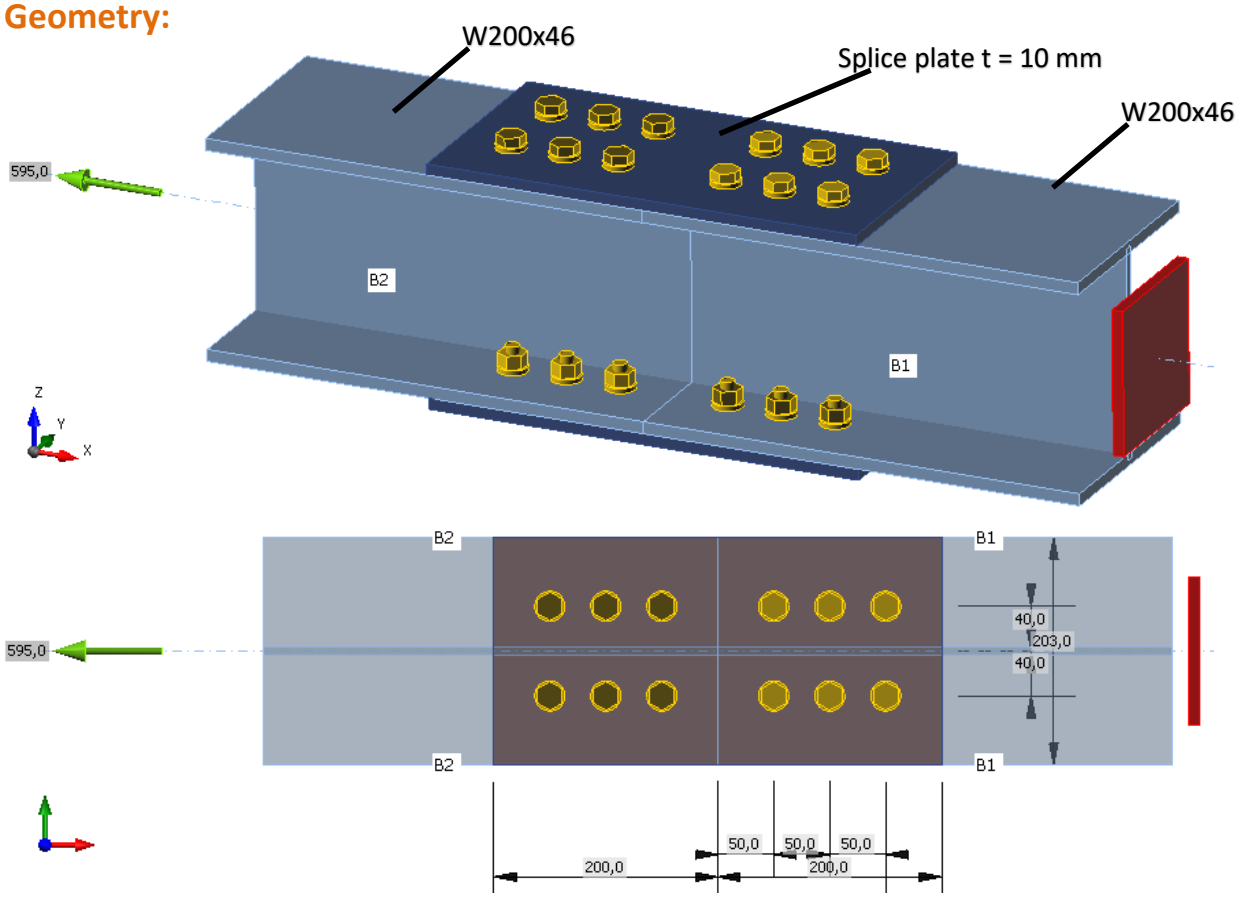
Designed acc. to: CSA S14-16

Investigated: Bolts, base material,

Plate Materials: Steel grade 350W,

Bolts: 1/2, grade A325

Geometry:



Applied forces:

N = 595 kN

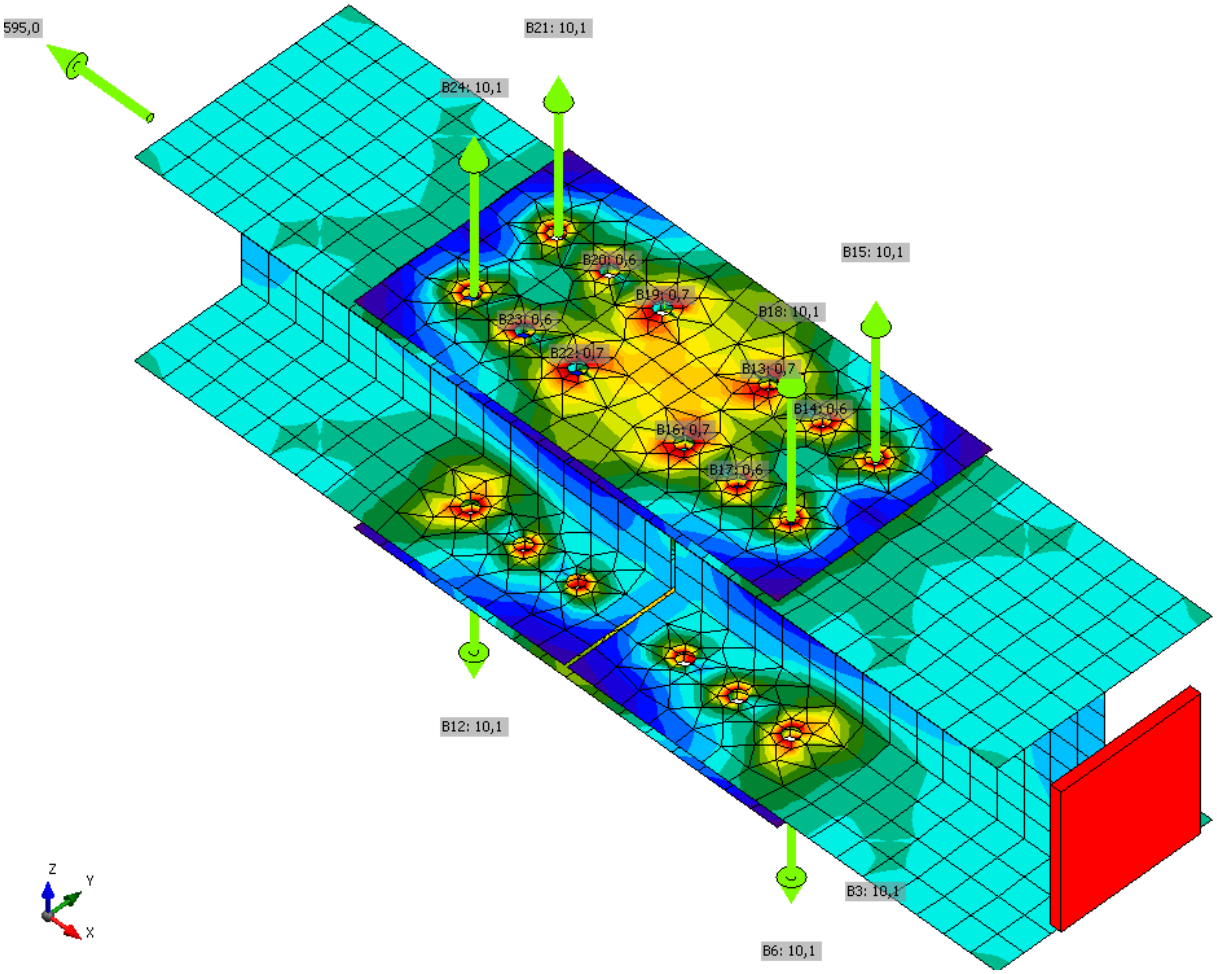
V = 0 kN

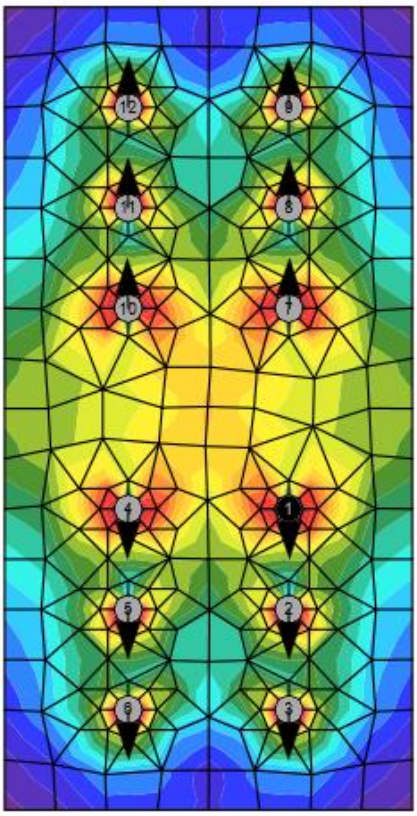
M = 0 kNm

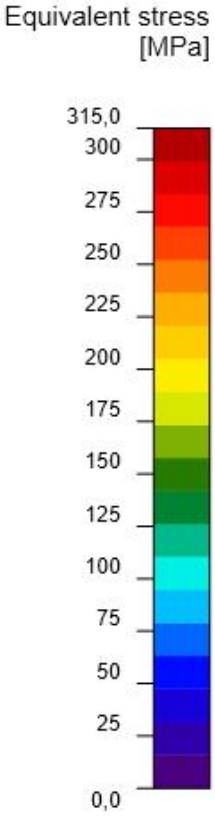
Procedure:

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. The check for combined tension/shear needs to be verified and is performed by IDEA StatiCa. Threads are excluded from the shear plane.

IDEA StatiCa Connection







Check of bolts for extreme load effect

		Status	Item	Loads	Tf [kN]	Vf [kN]	Br [kN]	Utt [%]	Uts [%]	Utts [%]
>	+	✓	B1	LE1	0,7	50,1	137,2	1,2	99,9	99,8
	+	✓	B2	LE1	0,6	49,6	137,2	0,9	98,9	97,8
	+	✓	B3	LE1	10,0	49,0	137,2	15,9	97,7	98,1
	+	✓	B4	LE1	0,7	50,1	137,2	1,1	99,9	99,8
	+	✓	B5	LE1	0,6	49,6	137,2	0,9	98,9	97,8
	+	✓	B6	LE1	10,0	49,0	137,2	15,9	97,7	98,1
	+	✓	B7	LE1	0,7	50,1	137,2	1,1	99,9	99,8
	+	✓	B8	LE1	0,6	49,6	137,2	0,9	98,9	97,8
	+	✓	B9	LE1	10,0	49,0	137,2	15,9	97,7	98,1
	+	✓	B10	LE1	0,7	50,1	137,2	1,2	99,9	99,8
	+	✓	B11	LE1	0,6	49,6	137,2	0,9	98,9	97,8
	+	✓	B12	LE1	10,0	49,0	137,2	15,9	97,7	98,1
	+	✓	B13	LE1	0,7	50,1	137,2	1,2	99,9	99,8
	+	✓	B14	LE1	0,6	49,6	137,2	0,9	98,9	97,8
	+	✓	B15	LE1	10,0	49,0	137,2	15,9	97,7	98,1
	+	✓	B16	LE1	0,7	50,1	137,2	1,1	99,9	99,8
	+	✓	B17	LE1	0,6	49,6	137,2	0,9	98,9	97,8
	+	✓	B18	LE1	10,0	49,0	137,2	15,9	97,7	98,1
	+	✓	B19	LE1	0,7	50,1	137,2	1,1	99,9	99,8
	+	✓	B20	LE1	0,6	49,6	137,2	0,9	98,9	97,8
	+	✓	B21	LE1	10,0	49,0	137,2	15,9	97,7	98,1
	+	✓	B22	LE1	0,7	50,1	137,2	1,2	99,9	99,8
	+	✓	B23	LE1	0,6	49,6	137,2	0,9	98,9	97,8
	+	✓	B24	LE1	10,0	49,0	137,2	15,9	97,7	98,1

Design data

	Item	Tr [kN]	Vr [kN]
>	1/2 A325 - 1	62,7	50,2

IDEA StatiCa Connection CISC Verification Example

Bolted Connection

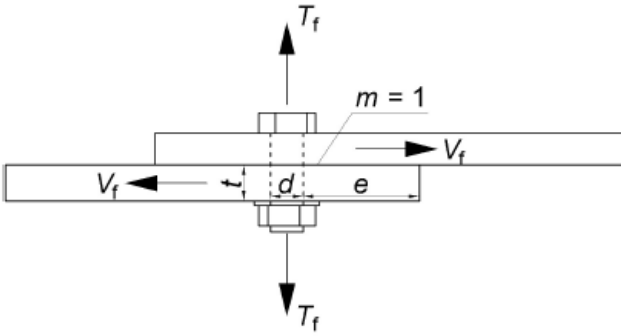
Material of steel: $F_y := 350\ \text{MPa}$
$F_u := 450\ \text{MPa}$

Material of bolts: $F_{ub} := 830\ \text{MPa}$

Bolt diameter: $d := 12.7\ \text{mm}$

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

$A_b = 127\ \text{mm}^2$



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: $e := 50\ \text{mm}$
$t := 10\ \text{mm}$

Tensile strength of a bolt: $T_r := 0.75 \cdot \phi_b \cdot A_b \cdot F_{ub} = 63.1\ \text{kN}$

Number of shear planes: $m := 1$

Shear strength of a bolt: $V_r := 0.6 \cdot \phi_b \cdot m \cdot A_b \cdot F_{ub} = 50.5\ \text{kN}$

Design tensile force: $T_f := 0\ \text{kN}$

Design shear force: $V_f := 50.5\ \text{kN}$

Combined tension and shear: $\left(\frac{T_f}{T_r}\right)^2 + \left(\frac{V_f}{V_r}\right)^2 = 100\%$

Resistance factor for bearing of bolts on steel: $\phi_{br} := 0.8$

Bearing strength in a regular bolt hole: $B_r := 3 \cdot \phi_{br} \cdot t \cdot d \cdot F_u = 137.2\ \text{kN}$

Gross area in shear: $A_{gv} := 2 \cdot t \cdot e = 1000\ \text{mm}^2$

Hole tear-out: $T_r := \phi_u \cdot 0.6 \cdot A_{gv} \cdot \frac{(F_y + F_u)}{2} = 180\ \text{kN}$

Total of 12 bolts can transfer $N = 50.5 \cdot 12 = 606\ \text{kN}$ which is nearly identical to 595 kN as determined by IDEA StatiCa Connection (2% difference).

IDEA StatiCa Connection CISC Verification Example

Tension and shear block: $U_t := 1$

Net area in tension: $A_n := t \cdot (80 - 14.7)\ \text{mm} = 653\ \text{mm}^2$

Gross area in shear: $A_{gv} := 2 \cdot t \cdot e = 1000\ \text{mm}^2$

For 2 bolts: $T_r := \phi_u \cdot \left(U_t \cdot A_n \cdot F_u + 0.6 \cdot A_{gv} \cdot \frac{\langle F_y + F_u \rangle}{2} \right) = 400\ \text{kN}$

Gross area in shear: $A_{gv} := 4 \cdot t \cdot e = 2000\ \text{mm}^2$

For 2 bolts: $T_r := \phi_u \cdot \left(0.6 \cdot A_{gv} \cdot \frac{\langle F_y + F_u \rangle}{2} \right) = 360\ \text{kN}$

Net area in tension: $A_n := t \cdot (80 - 14.7)\ \text{mm} = 653\ \text{mm}^2$

Gross area in shear: $A_{gv} := 4 \cdot t \cdot e = 2000\ \text{mm}^2$

For 4 bolts: $T_r := \phi_u \cdot \left(U_t \cdot A_n \cdot F_u + 0.6 \cdot A_{gv} \cdot \frac{\langle F_y + F_u \rangle}{2} \right) = 580\ \text{kN}$

Net area in tension: $A_n := t \cdot (80 - 14.7)\ \text{mm} = 653\ \text{mm}^2$

Gross area in shear: $A_{gv} := 6 \cdot t \cdot e = 3000\ \text{mm}^2$

For 6 bolts: $T_r := \phi_u \cdot \left(U_t \cdot A_n \cdot F_u + 0.6 \cdot A_{gv} \cdot \frac{\langle F_y + F_u \rangle}{2} \right) = 760\ \text{kN}$

Net area in tension: $A_n := t \cdot (200 - 2 \cdot 14.7)\ \text{mm} = 1706\ \text{mm}^2$

For 6 bolts: $T_r := \phi_u \cdot A_n \cdot F_u = 576\ \text{kN}$

Gross area in tension: $A_g := t \cdot 200\ \text{mm} = 2000\ \text{mm}^2$

Gross section yielding: $T_r := \phi \cdot A_g \cdot F_y = 630\ \text{kN}$

Shear block, tension and shear block, tension block nor gross section yielding is a decisive failure mode. IDEA StatiCa Connection shows sufficient reserve as well as can be seen on figures with von Mises stress distribution.

Comparison:

The results of both IDEA StatiCa Connection design and manual computation according to CSA 16-14 gives nearly identical values: Bolt check: Both results give the same values. 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. Strength of the plates was checked and it was found as sufficient both in manual calculation and software check.