Verification example – Bolts in combined tension and shear

Type of connection: Bolts in combined tension and shear

Unit system: Metric

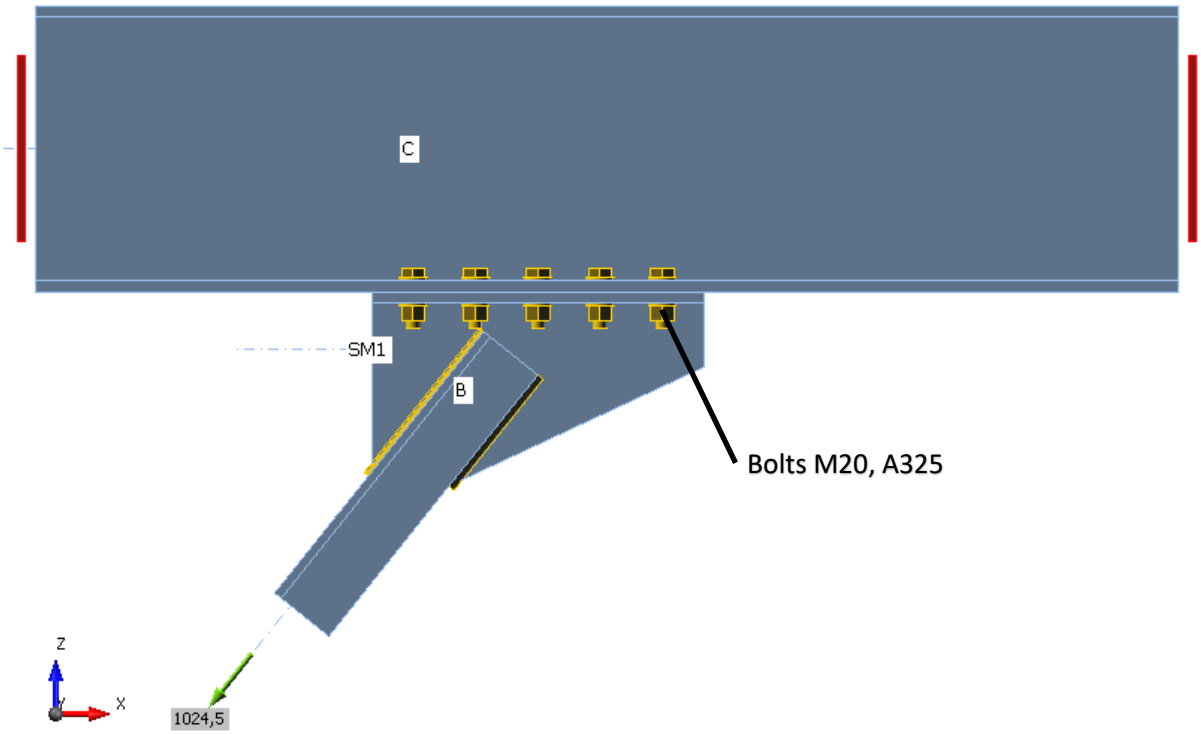
Designed acc. to: CSA S14-16

Investigated: Bolts

Plate Materials: Steel grade 350W

Bolts: M20, grade A325

Geometry:



Applied forces:

N = 1024,5 kN

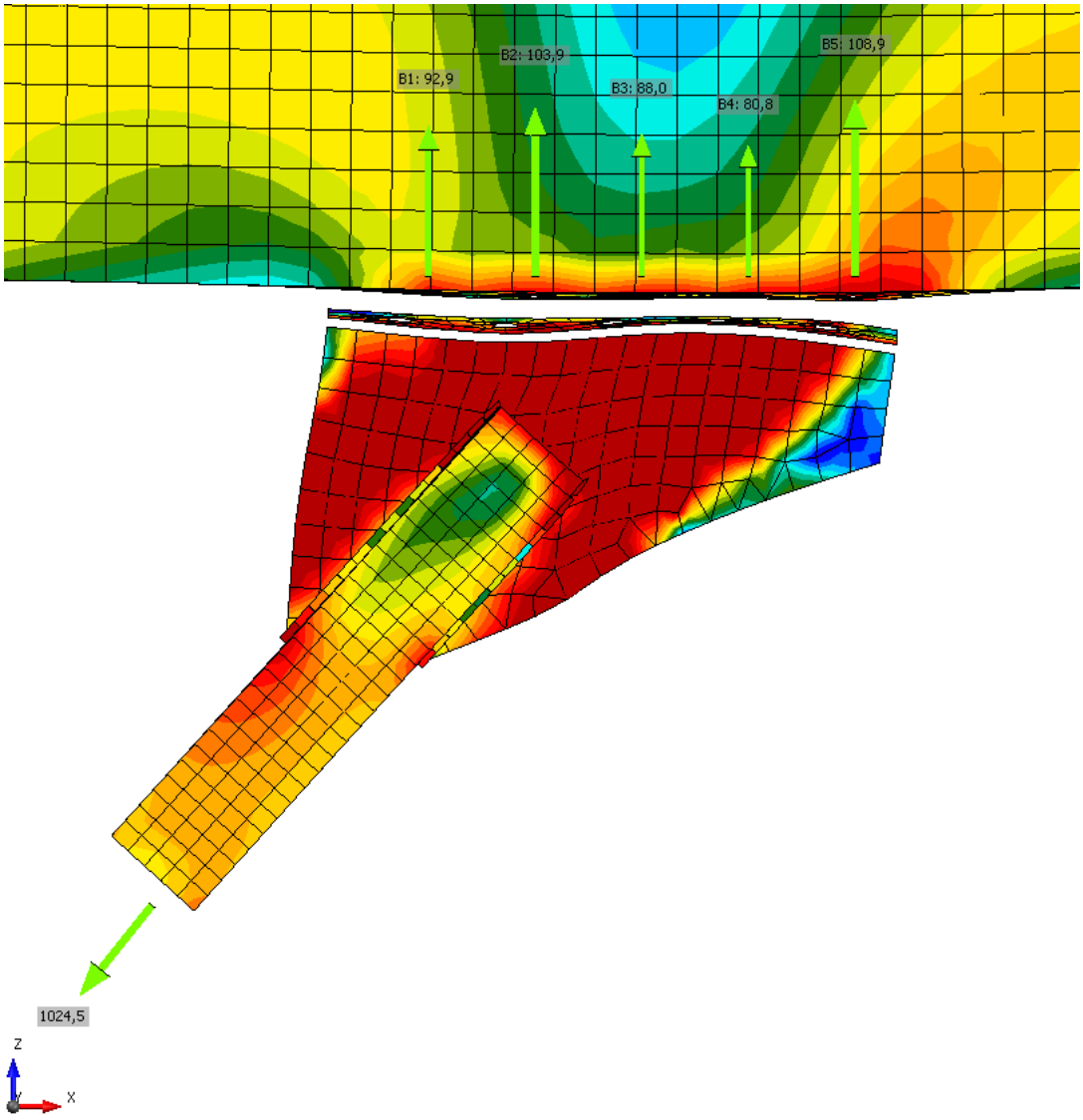
V = 0 kN

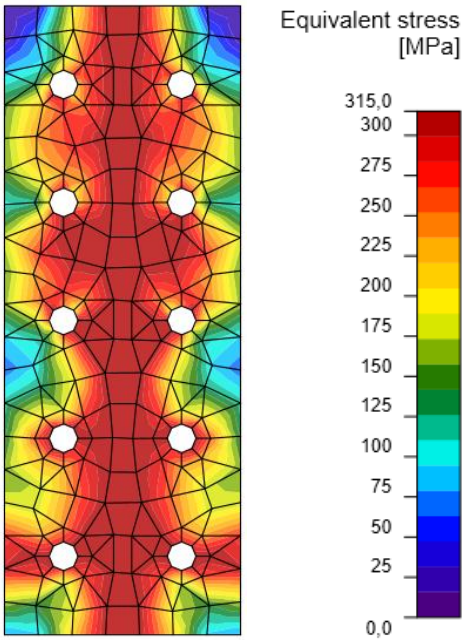
M = 0 kNm

Procedure:

The example was taken from CISC Handbook of Steel Construction. Regular bolts M20, steel grade A325 (shear force transfer by bearing) are used. It is assumed that bolt threads are not intercepted by the shear plane.

IDEA StatiCa Connection





Check of bolts for extreme load effect

		Item	Loads	Tf [kN]	Vf [kN]	Utt [%]	Uts [%]	Utts [%]	Status
>	⊞	B1	LE1	92,9	63,6	59,4	50,8	61,1	✓
	⊞	B2	LE1	103,9	58,6	66,4	46,9	66,1	✓
	⊞	B3	LE1	88,0	68,6	56,3	54,8	61,8	✓
	⊞	B4	LE1	80,8	72,8	51,7	58,2	60,6	✓
	⊞	B5	LE1	108,9	56,7	69,6	45,4	69,0	✓
	⊞	B6	LE1	92,9	63,6	59,4	50,8	61,1	✓
	⊞	B7	LE1	104,0	58,6	66,5	46,8	66,1	✓
	⊞	B8	LE1	88,1	68,6	56,3	54,8	61,8	✓
	⊞	B9	LE1	80,8	72,8	51,7	58,2	60,6	✓
	⊞	B10	LE1	108,9	56,7	69,6	45,4	69,0	✓

Design data

	Item	Tr [kN]	Vr [kN]	Br [kN]
>	20 A325M - 1	156,4	125,1	345,6

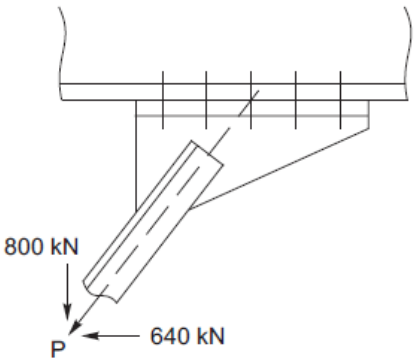
Although the bolts have still sufficient reserve in load resistance, the plates yield significantly and the forces in bolts vary. The average tension load in bolt is 95 kN and average shear load in bolt is 64 kN.

Manual assessment

The example was taken from CISC Handbook of Steel Construction, 8th edition, 2003.

Example

Given: A bracing connection for an inclined factored load P, with a tension component T_f of 800 kN and a shear component V_f of 640 kN, uses a tee section cut from a W410x74. Check the number of M20, A325M bolts required, assuming G40.21 350W steel with a 90 mm gauge on the tee flange and a 90 mm bolt pitch.



Solution:

Shear-tension ratio is $X = 640 / 800 = 0.80$.

From Table 3-8, permitted V_f = 88.8 kN and permitted T_f = 111 kN per bolt.

Therefore, number of bolts required = 640 / 88.8 or 800 / 111 = 7.21 ≈ 8.

Although only 8 bolts are required, try 10 bolts because of prying action. Check the effects of prying action on the bolt tension, and the connection capacity (see page 3-19).

Applied factored tensile load per bolt is 800 / 10 = 80 kN = P_f.

For W410x74, t = 16.0 mm, w = 9.7 mm, and flange width = 180 mm.

b = (90 - 9.7) / 2 = 40.2; b' = 40.2 - 10 = 30.2 mm; 1.25 b = 50.3

a = (180 - 90) / 2 = 45.0 < 1.25 b; a' = 45.0 + 10 = 55.0

$K = (4 \times 30.2 \times 10^3) / (0.9 \times 90 \times 350) = 4.26$ (Eqn. 1)

$\delta = 1 - 22/90 = 0.756$ (Eqn. 2)

In Eqn. 4, use bolt load at failure, T_f = 111 kN rather than T_r.

$$\alpha = \left(\frac{4.26 \times 111}{16.0^2} - 1\right) \times \frac{55.0}{0.756(55.0 + 30.2)} = 0.723 \quad \delta\alpha = 0.547 \qquad \text{(Eqn. 4)}$$

Connection capacity = $(16.0^2 / 4.26)(1.547)10 = 930$ kN > 800 — OK (Eqn. 5)

To find actual bolt load (including prying):

$$\alpha = \left(\frac{4.26 \times 80}{16.0^2} - 1\right) \times \frac{1}{0.756} = 0.438 \text{ (for applied load): } \delta\alpha = 0.331 \qquad \text{(Eqn. 6)}$$

$$T_f \approx 80\left[1 + \left(\frac{30.2}{55.0} \times \frac{0.331}{1.331}\right)\right] = 90.9 \text{ kN} < 111 \text{ kN} \quad \text{— OK} \qquad \text{(Eqn. 7)}$$

3-12 CISC Handbook of Steel Construction

Comparison:

The results of both IDEA StatiCa Connection design and manual computation according to CISC Handbook of Steel Construction gives similar values: the tension force in bolt including prying forces in manual assessment is 90.9 kN and in IDEA, the average tension load in bolt is 95 kN. The shear load in manual assessment is 64 kN, which is the same value as the average in IDEA. Due to the deformation of plates, the force distribution in bolts is slightly uneven. The most loaded bolt determines the resistance of the connection and therefore, the assessment in IDEA is conservative.