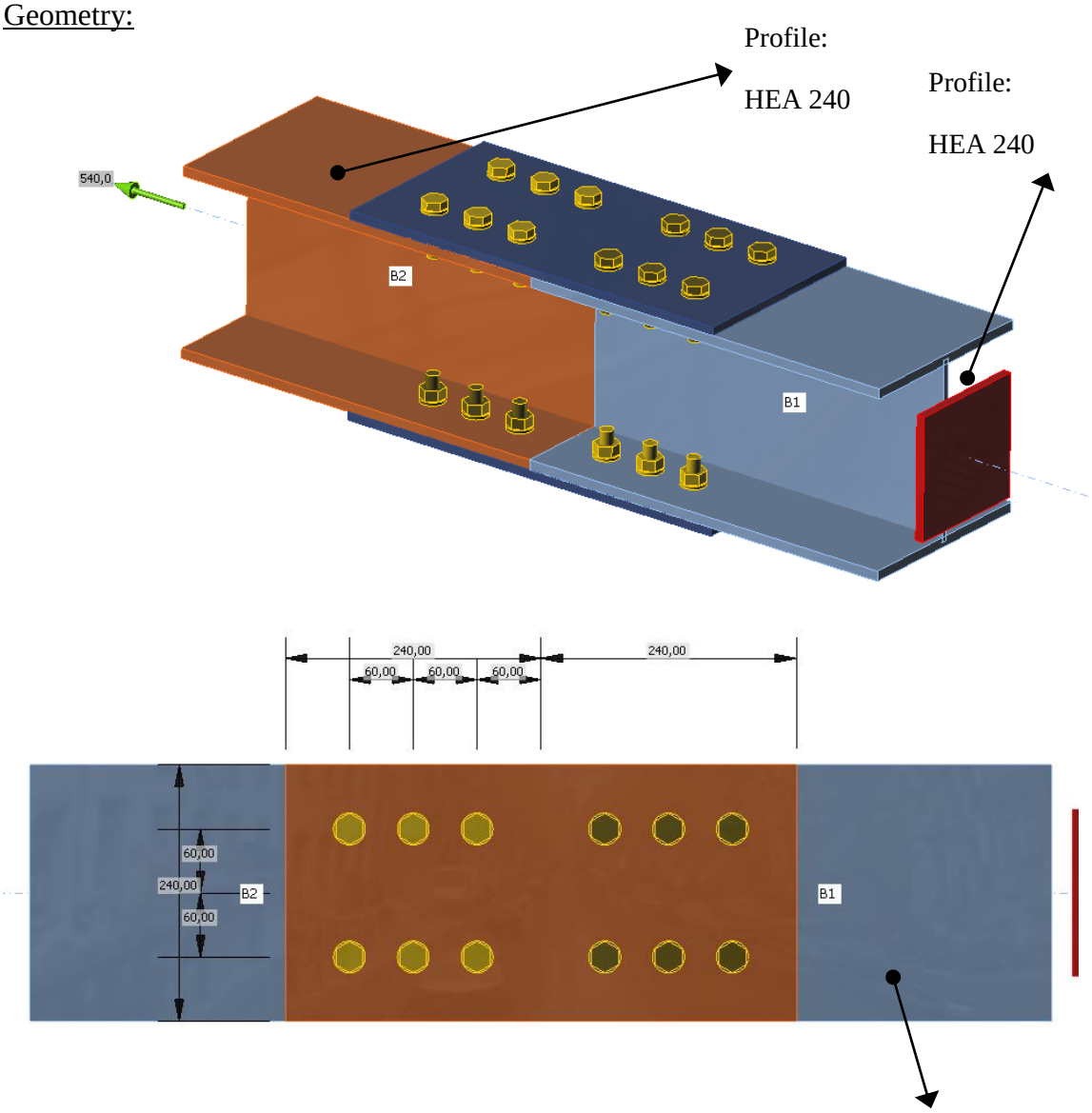
Verification example Splice connections of I-beam flanges

Type of connection:	Splice connections of flanges of I-beam
Unit system:	Metric
Designed acc. to:	AISC 360-10
Investigated:	Bolts, Plate
Materials:	Steel A36, Bolts A490M

Geometry:



Bolts:

M16 – A490M

Spacing of bolts
60mm

Splice plate thickness:

t_p = 10 mm

Applied forces:

V = 0 kN

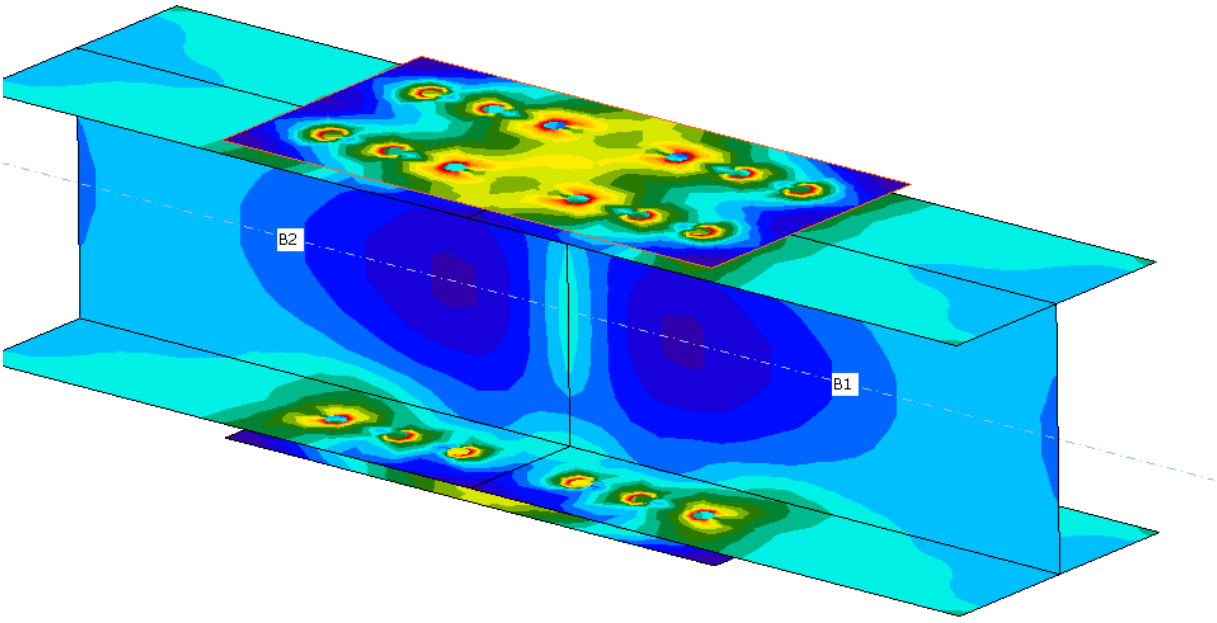
N = 540 kN

M = 0 kNm

Procedure:

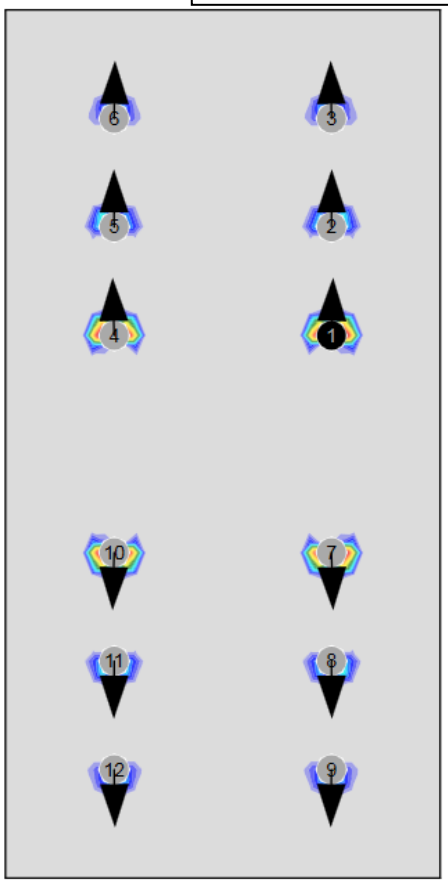
Bolts are considered to be only in shear (in threaded parts). IDEA StatiCa takes into account the tension force in bolts caused by eccentricity. However, tension force does not determine the design. The check for combined tension/shear needs to be verified and is performed by IDEA StatiCa.

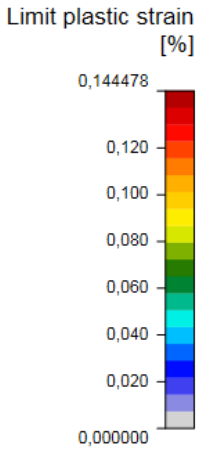
IDEA StatiCa Connection – results



Von Mieses stress

Plastic strain ratio + Direction of resultants in bolts





Check of bolts and anchors for extreme load effect

	Item	Loads	Ft [kN]	V [kN]	Utt [%]	Uts [%]	Utts [%]	Status
>	B1	LE1	0,987	45,424	0,8	65,9	1,3	✓
	B2	LE1	0,926	44,71	0,8	64,9	1,2	✓
	B3	LE1	9,889	44,891	8,4	65,2	13,0	✓
	B4	LE1	0,892	45,412	0,8	65,9	1,2	✓
	B5	LE1	0,915	44,708	0,8	64,9	1,2	✓
	B6	LE1	9,942	44,899	8,5	65,2	13,0	✓
	B7	LE1	1,037	45,431	0,9	65,9	1,4	✓
	B8	LE1	0,817	44,725	0,7	64,9	1,1	✓
	B9	LE1	10,116	44,877	8,6	65,1	13,3	✓
	B10	LE1	1,078	45,424	0,9	65,9	1,4	✓
	B11	LE1	0,766	44,716	0,7	64,9	1,0	✓
	B12	LE1	10,103	44,872	8,6	65,1	13,2	✓
	B13	LE1	0,987	45,424	0,8	65,9	1,3	✓
	B14	LE1	0,926	44,71	0,8	64,9	1,2	✓
	B15	LE1	9,889	44,891	8,4	65,2	13,0	✓
	B16	LE1	0,892	45,413	0,8	65,9	1,2	✓
	B17	LE1	0,915	44,708	0,8	64,9	1,2	✓
	B18	LE1	9,942	44,899	8,5	65,2	13,0	✓
	B19	LE1	1,037	45,431	0,9	65,9	1,4	✓
	B20	LE1	0,817	44,725	0,7	64,9	1,1	✓
	B21	LE1	10,116	44,878	8,6	65,1	13,3	✓
	B22	LE1	1,078	45,424	0,9	65,9	1,4	✓
	B23	LE1	0,766	44,717	0,7	64,9	1,0	✓
	B24	LE1	10,103	44,872	8,6	65,1	13,2	✓

The shear force in one bolt is app. **Fv = 45 kN**

The ultimate shear strength of M16 – A490M is **ϕFnv = 69 kN**

The unit check: 45/69 = **0.65 = 65%**

The forces in bolts are almost linearly distributed.

AISC 360-10 and Steel construction manual – results

Splice Plate connection (AISC)

Tension force N_{Ed} = **270** kN

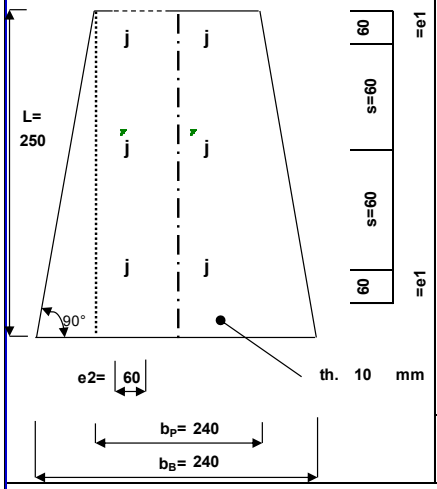


Plate:

plate thickness d_1 =	10	mm
plate width b_P =	240	mm
length of plate L=	250	mm
pl. width at base b_B =	240	mm
number of bolts n =	3	pieces/ 1 angle
bolt spacing s =	60	mm
e1 =	60	mm
e2 =	60	mm
g=	10	mm

6 x M 16 Class A490M

Plate and beam steel: A36

f_y =	250	MPa
f_u =	400	MPa
Φ_b =	0,9	
$\Phi_b f_y$ =	225	MPa
Φ =	0,75	
E=	200	GPa
d_0 =	18	mm
A =	201	mm^2
A_S =	157	mm^2

Shear strength per 1 bolt:
F_{nv} = 92 kN
acc. Table J3.2
in threaded part of bolts

utilization of connection: **65,3%** **OK**

Bolt shear capacity

acc. AISC 360-10 - J3.6

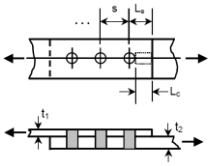
$n \Phi F_{nv}$ = 413 kN

Unit Check: $N_{Ed} / n \Phi F_{nv}$ = **0,65** **OK**

Bearing capacity

Per 1 angle (Deformation at bolt hole at service load is a consideration - J3.10 - a-i)

Tension force acts in straight line, change of force direction due to eccentricity is neglected, for calculation N_{Ed} is taken.



$d_{B0} = d_0 + 2$ mm = 20 mm (+2mm acc. B4.3b)

minimal thickness of connected plates:

t= 10 mm

At edge:					Between holes:				
$L_c = e_1 - d_{B0}/2$ =	50 mm				$L_c = s - d_{B0}$ =	40 mm			
$R_n = 1{,}2 L_c f_u t$ =	240 kN	<	2,4 d t f_u=	154 kN	$R_n = 1{,}2 L_c f_u t$ =	192 kN	<	2,4 d t f_u=	154 kN
R_n=	154 kN				R_n=	154 kN			
ΦR_n=	115 kN	>	N_{Ed}/n=	45 **0,39 OK**	ΦR_n=	115 kN			
					(n-1)ΦR_n=	230 kN	(in total between holes)		

N_{ed}= 135 < $\Sigma \Phi R_n$= 346 kN **0,39 OK**

Block shear rupture

U_{bs}= 1,0 **0,45** **OK as whole** *acc. AISC 360-10 - J4.3*

A = area; n = net; g = gross; t = tension; v = shear

Gusset plate block shear (as shown on picture)

1st bolts N_{Ed}=	90 kN	**1st bolts** N_{Ed}=	45 kN	**1st bolts** N_{Ed}=	90 kN
$A_{g(side)}$=	750 mm^2	$A_{g(side)}$=	750 mm^2	$A_{g(side)}$=	750 mm^2
$A_{n(side)}$=	650 mm^2	$A_{n(side)}$=	650 mm^2	$A_{n(side)}$=	650 mm^2
A_{nt}=	700 mm^2	A_{nt}=	650 mm^2	A_{nt}=	2000 mm^2
A_{gt}=	900 mm^2	A_{gt}=	750 mm^2	A_{gt}=	2400 mm^2
A_{nv}=	1000 mm^2	A_{nv}=	500 mm^2	A_{nv}=	0 mm^2
A_{gv}=	1200 mm^2	A_{gv}=	600 mm^2	A_{gv}=	0 mm^2
R_n=	460 kN	R_n=	350 kN	R_n=	800 kN
ΦR_n=	345 kN	ΦR_n=	263 kN	ΦR_n=	600 kN
Unit Check:	**0,26 OK**	Unit Check:	**0,17 OK**	Unit Check:	**0,15 OK**

Last bolts N_{Ed}=	270 kN	**Last bolts** N_{Ed}=	135 kN	**Last bolts** N_{Ed}=	270 kN
$A_{g(side)}$=	750 mm^2	$A_{g(side)}$=	750 mm^2	$A_{g(side)}$=	750 mm^2
$A_{n(side)}$=	650 mm^2	$A_{n(side)}$=	650 mm^2	$A_{n(side)}$=	650 mm^2
A_{nt}=	700 mm^2	A_{nt}=	650 mm^2	A_{nt}=	2000 mm^2
A_{gt}=	900 mm^2	A_{gt}=	750 mm^2	A_{gt}=	2400 mm^2
A_{nv}=	2600 mm^2	A_{nv}=	1300 mm^2	A_{nv}=	0 mm^2
A_{gv}=	3600 mm^2	A_{gv}=	1800 mm^2	A_{gv}=	0 mm^2
R_n=	820 kN	R_n=	530 kN	R_n=	800 kN
ΦR_n=	615 kN	ΦR_n=	398 kN	ΦR_n=	600 kN
Unit Check:	**0,44 OK**	Unit Check:	**0,34 OK**	Unit Check:	**0,45 OK**

The resulting shear force in one bolt is: **Fnv =** N / 6 bolts = 270/6 = 45 **kN**

The unit check: **65%**

Combined tension and shear:

Bolt B3 is investigated (see IDEA StatiCa table with results)

Fv= 44.9 kN

Ft= 9.9 kN

$$F'_{nt} = 1.3F_{nt} - \frac{F_{nt}}{\phi F_{nv}} f_{rv} \le F_{nt} \quad \text{(LRFD)} \qquad \text{(J3-3a)}$$

For M16 A490M:

Fnt= 157 kN

Fnv= 92 kN

A= 201.1 mm^2

frv= 44.9 kN

F'nt= 1.3 x 157 – 157 x 44.9/(0.75 x 92) = 101.9 kN

The unit check: Ft/ϕF'nt = 9.9/(0,75 x 101.9) = **13%**

Check of bolts and anchors for extreme load effect

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	B2	LE1	0,926	44,71	0,8	64,9	1,2	✓
	B3	LE1	9,889	44,891	8,4	65,2	13,0	✓

The results fully correspond to each other.

Utts (unit check for combination shear/tension):

Utts= 13%

Comparison:

The results of both IDEA StatiCa design and manual computation according to AISC 360-10 gives comparable values:

Bolt check: Both results give the same values. The check of combination of shear/tension gives the same results as well.

Plate check: Block rupture determines the plate check. Von Mises stress shows that block rupture across the splice plate is possible and could determine the design in manual check.

However, according the IDEA StatiCa, there is still a reserve in plastic strain limit.