Verification example Cap plate connection of CHS profile

Type of connection:	Cap plate connection of CHS profile
Unit system:	Metric
Designed acc. to:	AISC 360-10
Investigated:	Bolts, Plates, Welds
Materials:	Steel A36, Bolts A490M, Weld E70XX

Geometry:

Profile:

HEA 200

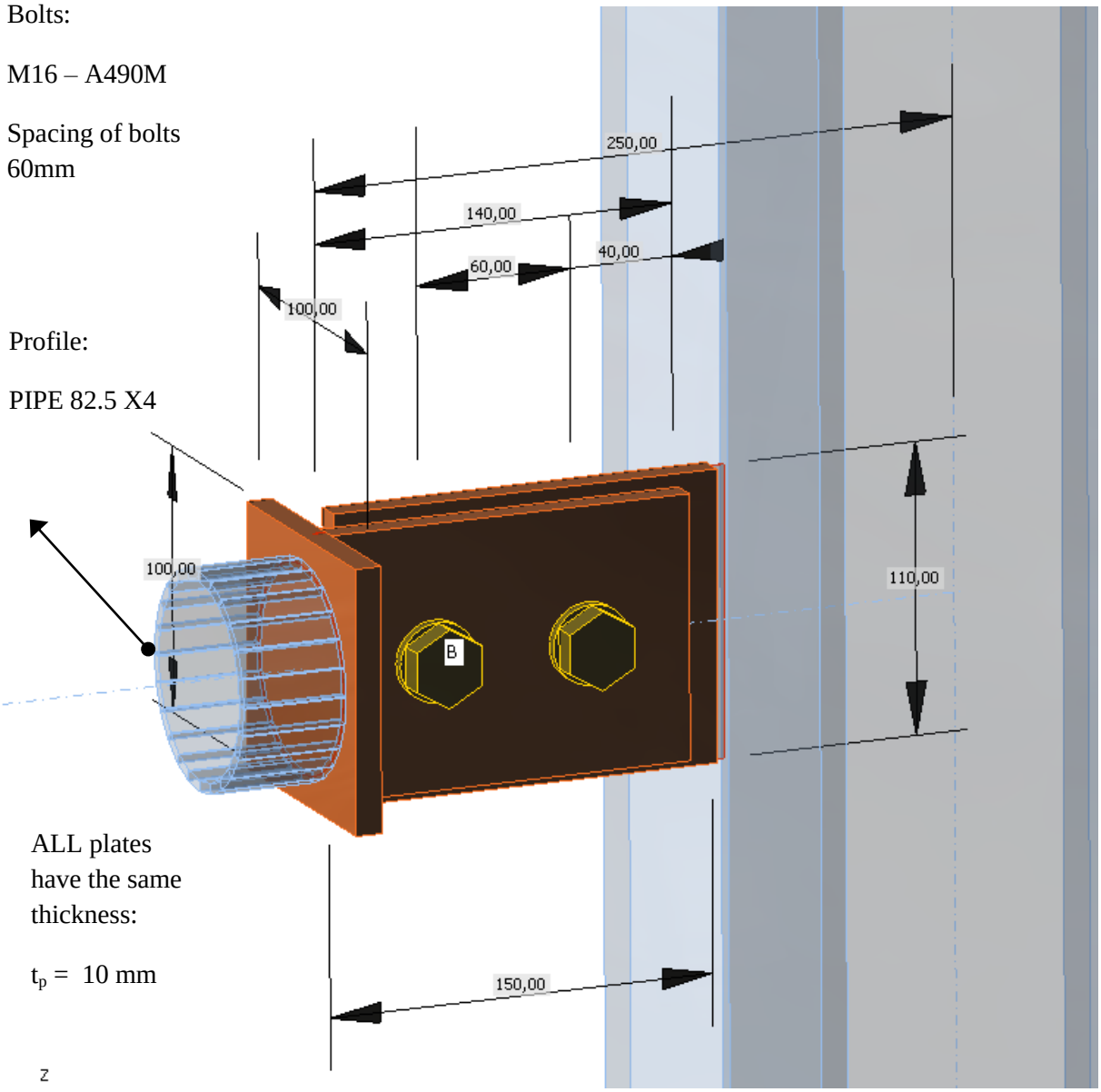
Bolts:

M16 – A490M

Spacing of bolts
60mm

Profile:

PIPE 82.5 X4



ALL plates
have the same
thickness:

t_p = 10 mm

Applied forces:

V = 0 kN

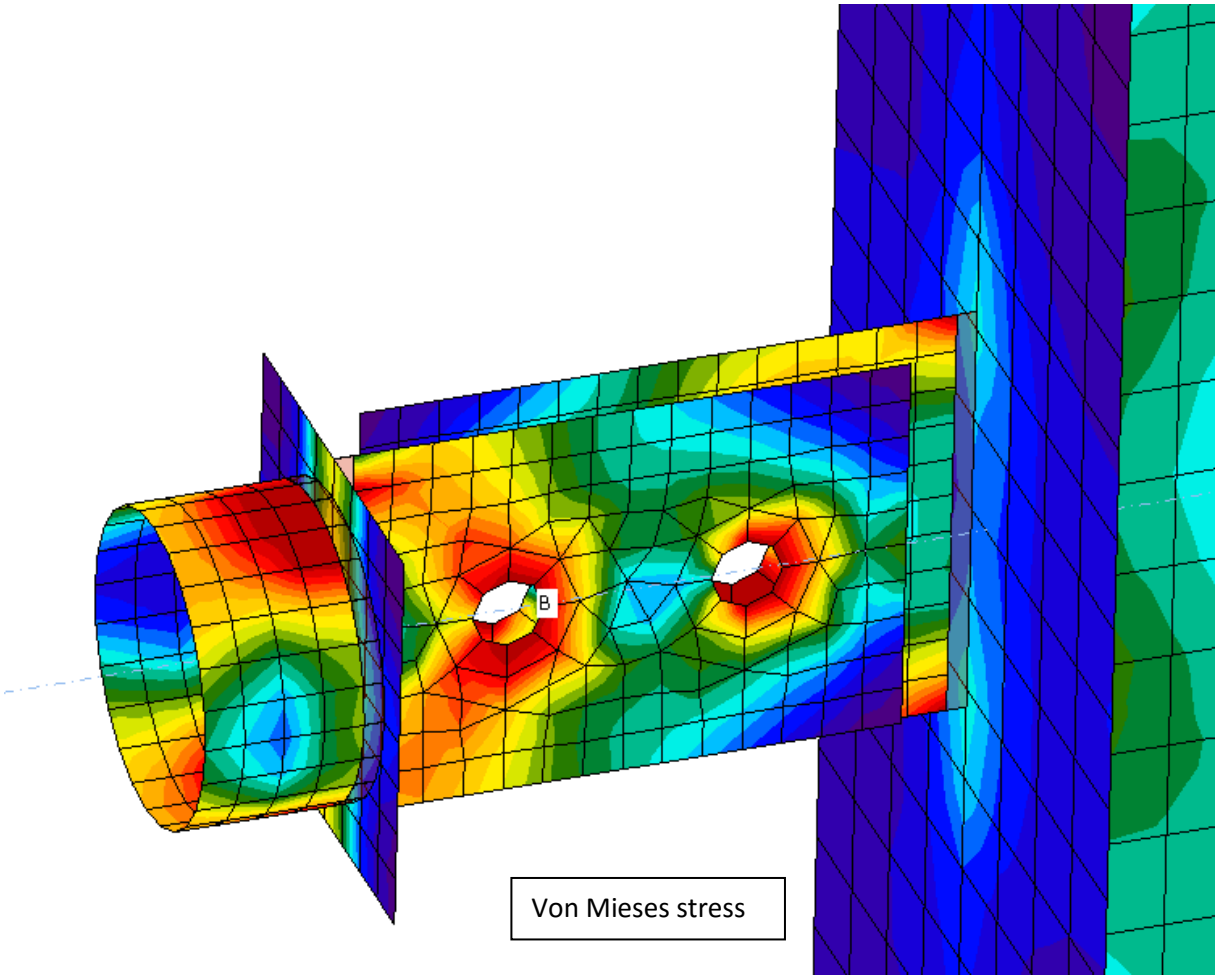
N = 110 kN

M = 0 kNm

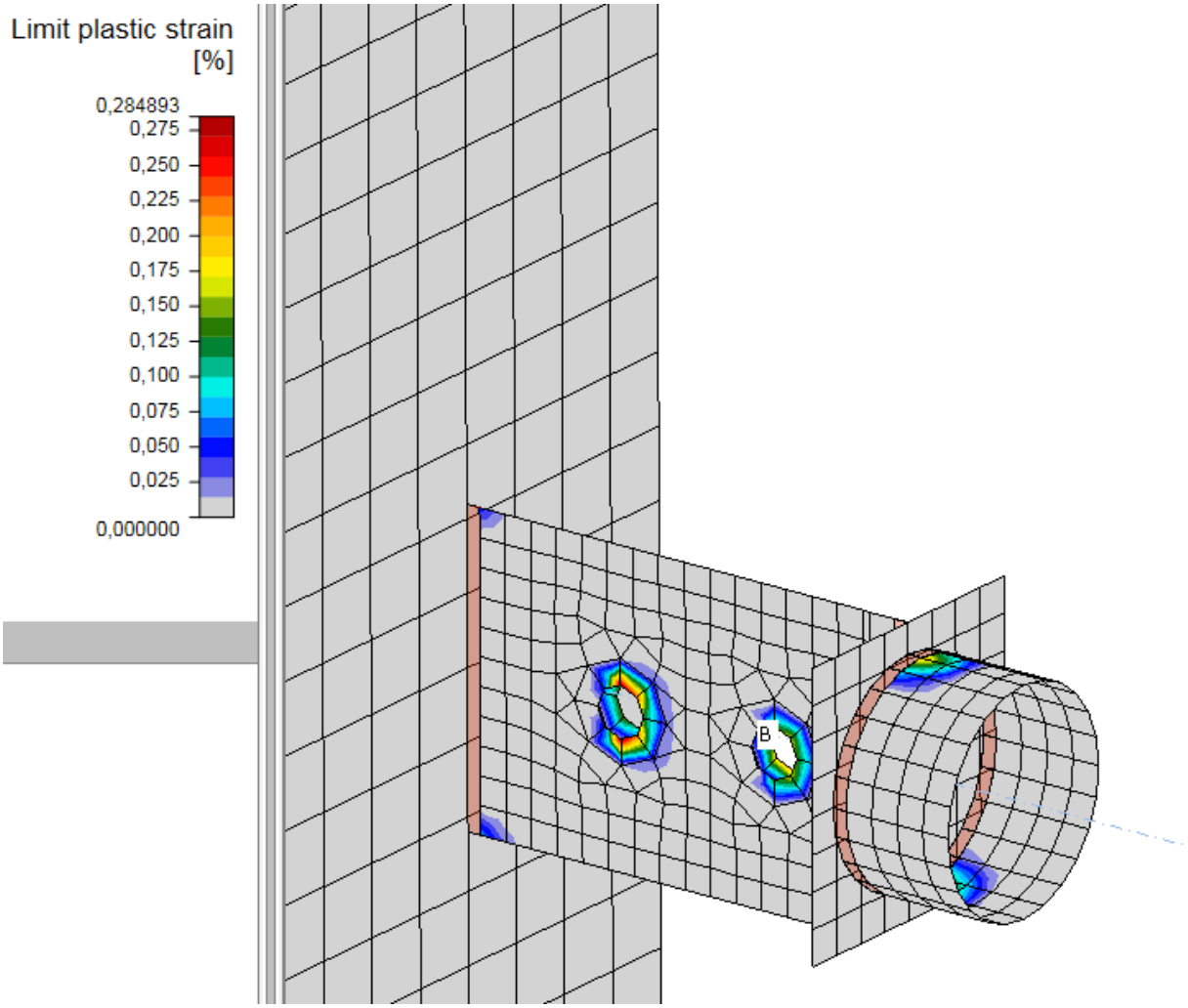
Procedure:

Bolts are considered to be only in shear (in threaded parts). IDEA StatiCa takes into account the tension force in bolts caused by eccentricity. This interaction however doesn't determine the design.

IDEA StatiCa Connection – results



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	13,664	55,192	11,6	80,1	23,3	✓
	B2	LE1	11,482	54,808	9,8	79,6	19,4	✓

Welds results:

Check of welds for extreme load effect

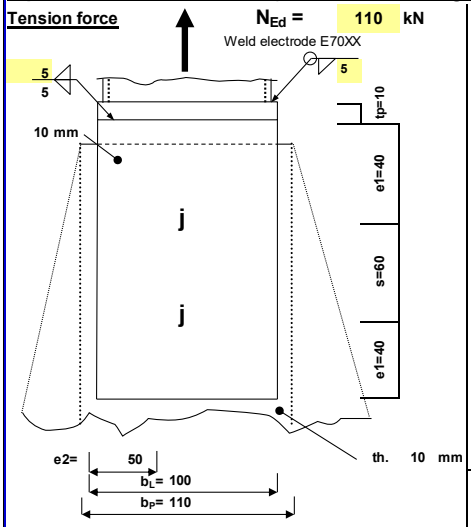
	Item	Edge	Ls [mm]	L[mm]	Type	Loads	Load[kN]	φRn[kN]	Ut [%]	Status
>	C-bfl 1	CPL1a	5,0	110,0	Double fillet	LE1	110,28	168,82	65,3	✓
	CPL1b	CPL1c	5,0	100,0	Double fillet	LE1	110,28	153,47	71,9	✓
	CPL1b	B-1	3,5	245,9	Fillet	LE1	107,67	191,33	56,3	✓

AISC 360-10 and Steel construction manual – results

Pipe - End Tee Connection (AISC 360-10- Design Guide 24)

Tension force N_{Ed} = **110** kN

Weld electrode E70XX



Gusset Plate:

plate thickness d_1 =	10	mm
plate width b_P =	110	mm
Number of plates:	Single plate	

Stem plate: PL100/ 10

Cap: t_P = 10 mm

- width as stem plate

Bolts:

number of columns m =	1	
number of row r =	2	
bolt spacing s =	60	mm
e1 =	40	mm
e2 =	50	mm
s2 =	0	mm
number of bolts n =	2	pcs

2 x 16 Class A490M

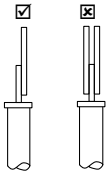


Plate and beam steel: A36

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

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

Utilization of connection: 79,8% OK
Buckling of gusset plate/stem: 0,0% OK
Cap plate connection: 91,7% OK
Welds: 79,5% OK

Bolt shear capacity

acc. AISC 360-10 - J3.6 ***Bolts are in single shear***

$n \Phi F_{nv}$ = 138 kN

Unit Check: $N_{Ed} / n \Phi F_{nv}$ = **0,80** **OK**

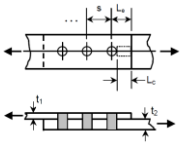
Bearing capacity

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

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

minimal thickness of connected plates:

t= 10 mm Thickness of pipe plate t=10mm is decisive.

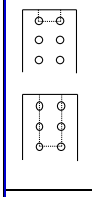


At edge:						Between holes:					
$L_c = e_1 - d_{B0}/2$ =	30 mm					$L_c = s - d_{B0}$ =	40 mm				
$R_n = 1{,}2 L_c f_u t$ =	144 kN	<	2,4 d t f_u=	154 kN		$R_n = 1{,}2 L_c f_u t$ =	192 kN	<	2,4 d t f_u=	154 kN	
R_n=	144 kN					R_n=	154 kN				
ΦR_n=	108 kN	<	N_{Ed}/n=	55 kN	0,51 OK	ΦR_n=	115 kN				
						$(r-1)\Phi R_n$=	115 kN	(in total between holes)			

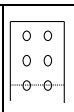
N_{ed}= 110 < $\Sigma \Phi R_n$= 223 kN **0,49** **OK**

Block shear rupture

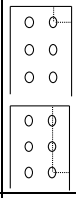
Ubs = 1,0 **0,47** **OK as whole** *acc. AISC 360-10 - J4.3* **Thickness of pipe plate t=10mm is decisive.**



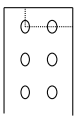
	1st row	Last row
A_{nt}=		
A_{gt}=		
A_{nv}=		
A_{gv}=		
R_n=		
ΦR_n=		
N_{Ed}=		
UC:		



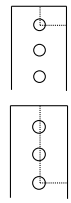
	Last row
A_{nt}=	
A_{gt}=	
A_{nv}=	
A_{gv}=	
R_n=	
ΦR_n=	
N_{Ed}=	
UC:	



	1st row	Last row
A_{nt}=		
A_{gt}=		
A_{nv}=		
A_{gv}=		
R_n=		
ΦR_n=		
N_{Ed}=		
UC:		



	1st row	Last row
A_{nt}=		800mm2
A_{gt}=		1000mm2
A_{nv}=		0mm2
A_{gv}=		0mm2
R_n=		320 kN
ΦR_n=		240 kN
N_{Ed}=		110 kN
UC:		0,46



	1st row	Last row
A_{nt}=	400mm2	400mm2
A_{gt}=	500mm2	500mm2
A_{nv}=	300mm2	700mm2
A_{gv}=	400mm2	1000mm2
R_n=	220 kN	310 kN
ΦR_n=	165 kN	233 kN
N_{Ed}=	55 kN	110 kN
UC:	0,33	0,47

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

Cap plate connection

acc. AISC 360-10 - K2 - Table K1.1

Welds are taken as E70XX electrode

D= 82,5 mm t= 4 mm

Length of connection (weld/slot):

Φ= 1,00

R_n= 120 kN must be less $f_y A$= 247 kN

ΦR_n= 120 kN > N_{Ed}= 110 kN **0,92** **OK**

Weld: Cap - pipe

$A_w = \min(2w/2^{0.5}(5t_p + l_b); \pi Dw/2^{0.5})$ = 424 mm^2

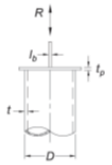
ΦR_n= 0,75* 0,6* 0,483 *1,5 * Aw= 138 kN **OK**

Weld: Stem - cap

$A_w = 2w/2^{0.5} b_L$ = 707 mm^2

ΦRn= 231 kN **OK**

Cap Plate Connections



Limit State: Local Yielding of HSS Axial Load

$$R_n = 2F_y t(5t_p + l_b) \le F_y A \quad \text{(K1-4)}$$

$\phi = 1.00$ (LRFD) $\Omega = 1.50$ (ASD)

Welds as whole: **0,80**

Plate tensile yielding/rupture

acc. AISC 360-10 - J4.1 **Thickness of stem plate t=10mm is decisive.**

Whitmore's section: w= 69 mm

$A_{w,g}$= 693 mm^2

$A_{w,net}$= 493 mm^2 < $0{,}85 A_{w,g}$= 589 mm^2

Tensile yielding: R_n= 173 kN ϕR_n= 156 kN UC: **0,71**

Tensile rupture: R_n= 197 kN ϕR_n= 148 kN UC: **0,74**

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. (Unit check about 80%)

Plate check: Local Yielding of HSS determines the connection. Von Mises stress shows stress concentration in the same area. Results are justified.

Weld: In general, the weld check gives different values for IDEA StatiCa and standard approach. However, the approach given in AISC360-10 is very approximate.

Cap-pipe: Acc. standard approach the unit check is 110kN/138kN = 0.791. IDEA StatiCa gives the value 0.563

Stem-cap: Acc. standard approach the unit check is 110kN/231kN = 0.476. IDEA StatiCa gives the value 0.719