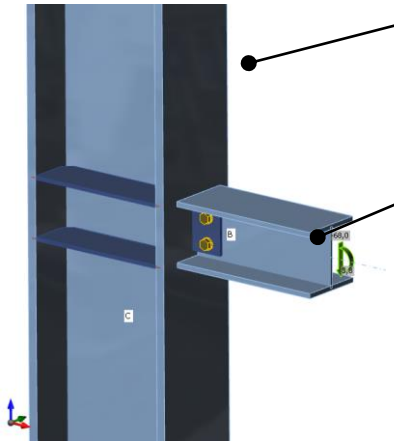
Verification example Single plate shear

Type of connection:	Single plate shear connection
Unit system:	Metric
Designed acc. to:	AISC 360-10
Investigated:	Bolts, Shear plate, Welds
Materials:	Steel A36, Bolts A490M

Geometry:

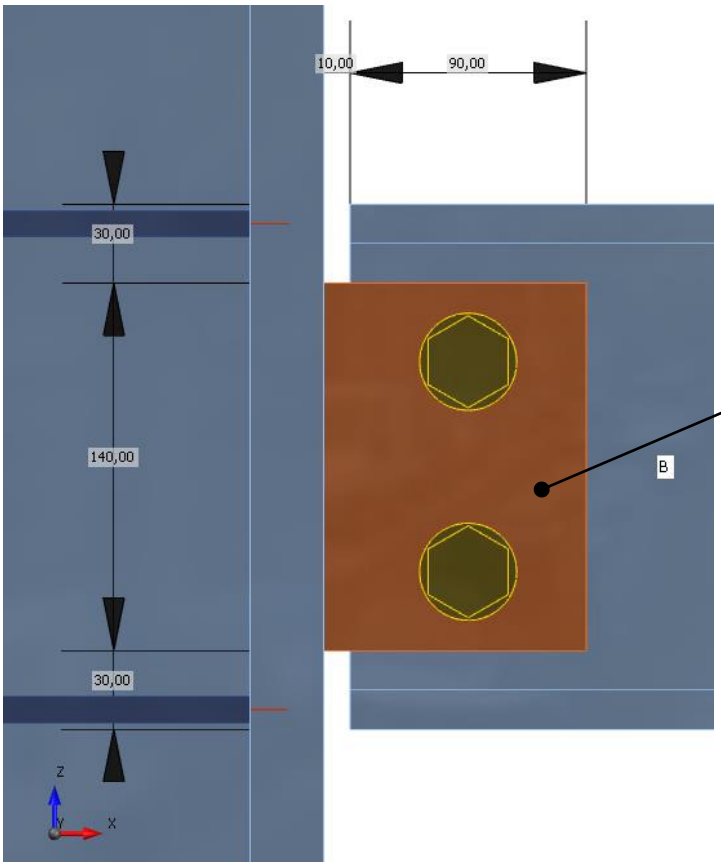


Profile:

HEB 500

Profile:

HEB 200



Shear plate thickness:

t_p = 10 mm

Bolts:

M20 – A490M

Spacing of bolts 80mm

Applied forces:

V = 68 kN

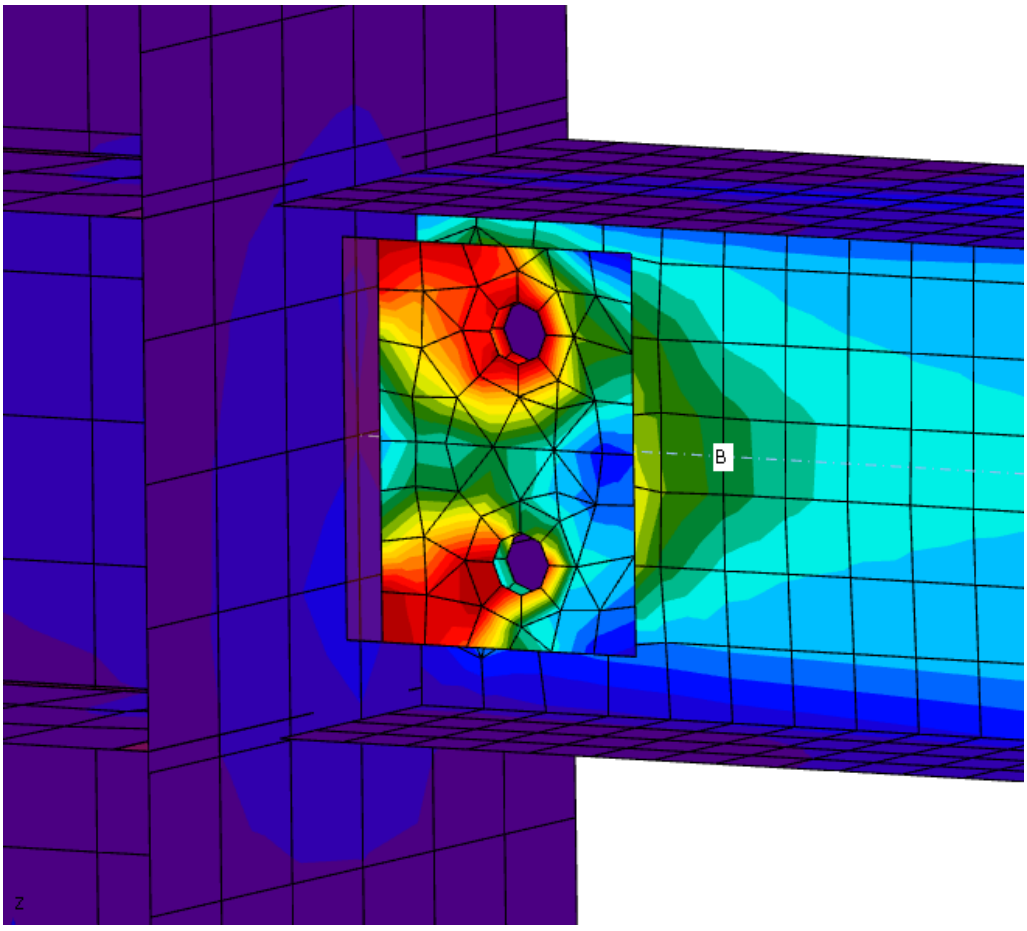
N = 0 kN

M = 3.8 kNm (this moment is caused by eccentricity of center of gravity of bolt group M = 68 kN x 0,055m; The shear force V must be set in the center of gravity of bolt group but such configuration doesn't give a correct moment at column wall; Therefore additional moment must be added.)

Procedure:

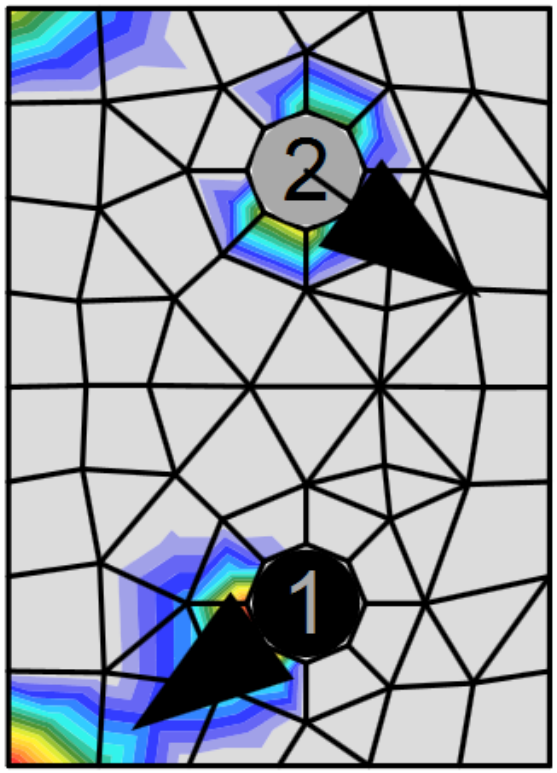
Instantaneous center of rotation method is used for computing the bolt coefficient C – Crawford and Kulak algorithm is used. The AISC Steel construction manual (2006 printing) - table 8-4 gives values for weld verification.

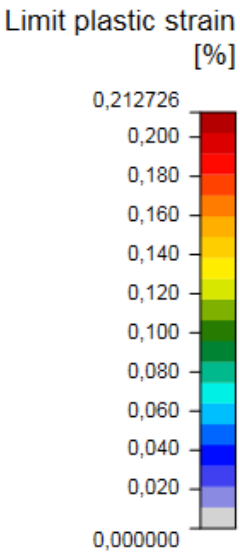
IDEA StatiCa Connection – results



Von Mieses stress

Plastic strain ratio + Direction of resultants in bolts





X = -0,01 Z = 0,00

Summary | Analysis | Plates | Bolts/Anchors | Welds

Check of bolts and anchors for extreme load effect

	Item	Loads	Ft [kN]	V [kN]	Utt [%]	Uts [%]	Utts [%]	Status
>	B1	LE1	2,785	57,953	1,5	53,8	2,5	✓
	B2	LE1	8,950	57,86	4,9	53,8	8,0	✓

The shear force in one bolt is **Fv = 58 kN**

The ultimate shear strength of M20 – A490M is **Fnv = 108 kN** *acc. Table J3-2 and Eq. J3-1*

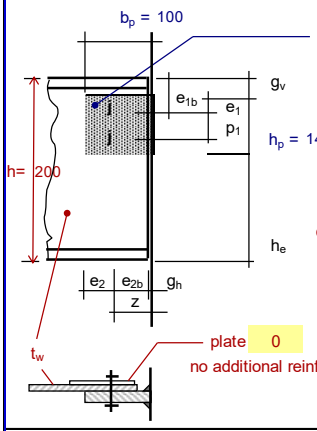
The unit check: 58/108 = **0.54 = 54%**

AISC 360-10 and Steel construction manual – results

1) Bolt check without check of bearing strength at holes

Simple shear plate connection

Plate and beam steel: A36



fin plate thickness d =	10	mm	
number of bolts n =	2	pieces	
bolt spacing p_1 =	80	mm	
e1 =	30	mm	
e2 = e2b =	45	mm	
g_v =	30	mm	
g_h =	10	mm	
cross-section height h =	200	mm	
web thickness t_w =	9	mm	
plate width b_P =	100	mm	
plate height h_P =	140	mm	
e_{1b} =	60	mm	
h_e =	30	mm	
z =	55,0	mm	

plate 0

no additional reinforcing

Plates: f_y = 250 MPa

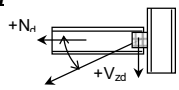
f_u = 400 MPa

Φ_b = 0,9

Φ = 0,75

Utilization as wt 0,54 OK

Design load



Tension force N_d = ***0,0*** *kN*

Shear force V_{zd} = ***68,0*** *kN*

R_d = 68,0 kN β = 90,0 °

Bolt design - resistance check

d_{B0}= 24 mm (d_b+2mm)

C - coefficient of eccentrically loaded bolts

M 20 Class A490M F_{nt}= 245 kN tension force per 1 bolt

Shear plane in thread? Yes fy= 780 F_{nv}= 144 kN shear force per 1 bolt and shear plane in thread

Bolt coefficient C= 1,176 (computed using VBA algorithm based on ICR method - Crawford, Kulak)

Shear strength:

ΦF_{nv}= 108 kN

ΦR_b= C x min ΦF_{nv}= 127 kN > 68 kN 0,54 OK

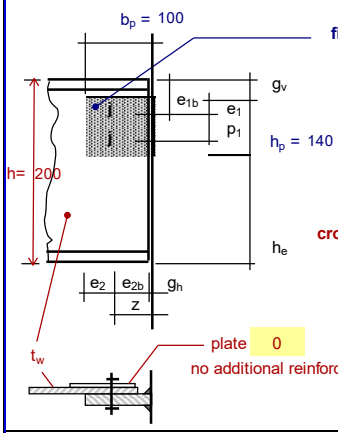
The resulting shear force in one bolt is: **Fv** = V / C = 68 kN / 1,176 = **58 kN**

The unit check: **54%**

2) Check of bearing strength at holes

Simple shear plate connection

Plate and beam steel: A36



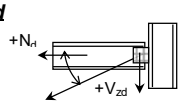
fin plate thickness d =	**10**	**mm**
number of bolts n =	**2**	**pieces**
bolt spacing p_1 =	**80**	**mm**
e1 =	**30**	**mm**
e2 = e2b =	**45**	**mm**
g_v =	**30**	**mm**
g_h =	**10**	**mm**
cross-section height h =	**200**	**mm**
web thickness t_w =	**9**	**mm**
plate width b_P =	**100**	**mm**
plate height h_P =	**140**	**mm**
e_{1b} =	**60**	**mm**
h_e =	**30**	**mm**
z =	**55,0**	**mm**

plate 0
no additional reinforcing

Plates: f_y = 250 MPa
f_u = 400 MPa
Φ_b = 0,9
Φ = 0,75

Utilization: **0,99 OK**

Design load



Tension force N_d = ***0,0*** *kN*
Shear force V_{zd} = ***68,0*** *kN*

R_d = 68,0 kN *β = 90,0 °*

Bolt design - resistance check

d_{B0}= 24 mm (d_b+2mm)

C - coefficient of eccentrically loaded bolts

M 20 **Class A490M** F_{nt}= 245 kN tension force per 1 bolt

Shear plane in thread? Yes fy= 780 F_{nv}= 144 kN shear force per 1 bolt and shear plane in thread

Bolt coefficient C= 1,176 (computed using VBA algorithm based on ICR method - Crawford, Kulak)

Shear strength:
ΦF_{nv}= 108 kN

Clear distance Lc to edge of plate:
L_c= 18 mm

$\Phi r_{brg,1} = \Phi\ 1{,}2\ L_c\ d\ F_u$ = 58 kN thickness is taken as minimum of beam web or fin plate

$\Phi r_{brg,max} = \Phi\ 2{,}4\ d_b\ d\ F_u$ = 130 kN

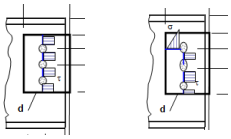
Φr_{brg} = min r_{brg} = 58 kN

ΦR_b = C x min (Φr_{brg};ΦF_{nv})= 69 kN > 68 kN **0,99 OK**

Plate check

U_{bs}= 1,0

Case 1 Case 2



For V - direction of force:

Case 1

A_{gv}= 1400 mm^2 ΦR_n=0,90 x 0,6$F_y A_{gv}$= 189 kN

A_{nv}= 920 mm^2 ΦR_n=0,75 x 0,6$F_u A_{nv}$= 166 kN

Unit check: **0,41 OK**

Case 2

A_{gv}= 1100 mm^2 R_n=0,6$F_u A_{nv}$ + $U_{bs} F_u A_{nt}$= 310 kN > R_n=0,6$F_y A_{gv}$ + $U_{bs} F_u A_n$ 297 kN

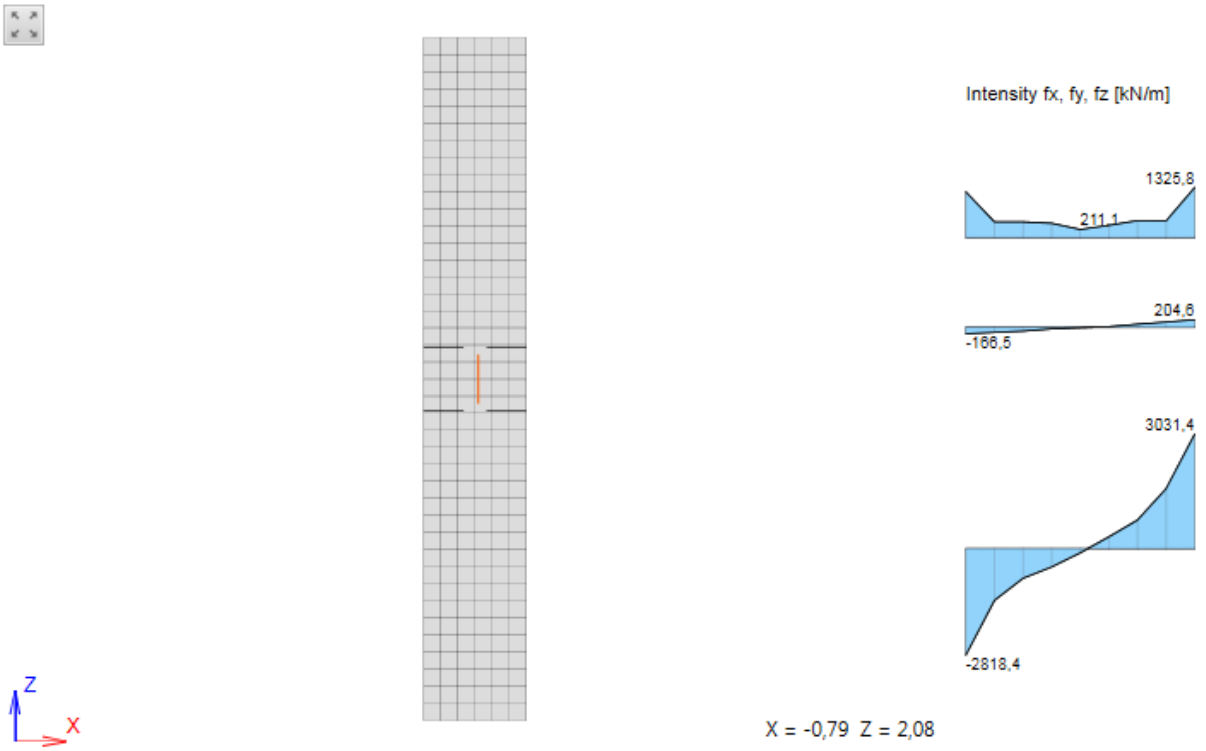
A_{nv}= 740 mm^2 R_n= 297 kN

A_{gt}= 450 mm^2 ΦR_n= 223 kN

A_{nt}= 330 mm^2

Unit check: **0,31 OK**

Weld design – IDEA StatiCa



Summary | Analysis | Plates | Bolts/Anchors | Welds

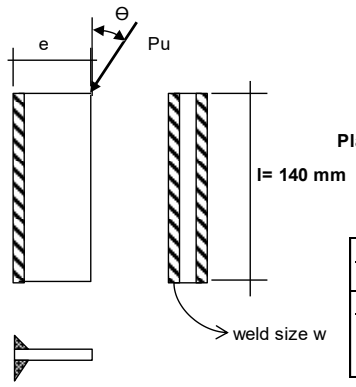
Check of welds for extreme load effect

	Item	Edge	Th [mm]	L[mm]	Type	Loads	Load[kN]	φRn[kN]	Ut [%]	Status
	C-bfl 1	STIFF1a	5,0	115,7	Fillet	LE1	4,03	188,54	2,1	✓
	C-w 1	STIFF1a	5,0	390,0	Fillet	LE1	1,58	172,65	0,9	✓
	C-tfl 1	STIFF1a	5,0	115,7	Fillet	LE1	1,14	188,13	0,6	✓
	C-bfl 1	STIFF1b	5,0	115,8	Fillet	LE1	10,60	188,54	5,6	✓
	C-w 1	STIFF1b	5,0	390,0	Fillet	LE1	7,01	318,90	2,2	✓
	C-tfl 1	STIFF1b	5,0	115,8	Fillet	LE1	1,82	188,38	1,0	✓
	C-bfl 1	STIFF1c	5,0	115,7	Fillet	LE1	4,20	188,54	2,2	✓
	C-w 1	STIFF1c	5,0	390,0	Fillet	LE1	1,91	162,94	1,2	✓
	C-tfl 1	STIFF1c	5,0	115,7	Fillet	LE1	1,20	188,18	0,6	✓
	C-bfl 1	STIFF1d	5,0	115,8	Fillet	LE1	10,98	188,54	5,8	✓
	C-w 1	STIFF1d	5,0	390,0	Fillet	LE1	6,87	311,36	2,2	✓
	C-tfl 1	STIFF1d	5,0	115,8	Fillet	LE1	1,99	188,41	1,1	✓
>	C-bfl 1	FP1	5,0	140,0	Double fillet	LE1	80,07	174,16	46,0	✓

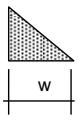
Item c-bfl shows the results of weld of shear plate, thickness 5.0mm is the throat of weld. Unit check is 46%.

Weld design – AISC – Steel construction manual

Eccentrically loaded weld group - AISC Steel construction manual - table 8-4



weld size w =	7	mm	= 0,27577164	Weld:
Length l=	140	mm	= 5,46 in.	
eccentricity e=	55	mm	= 2,145 in.	
angle Θ=	0	°		
Plate thickness t=	10	mm		
a=	0,393			
D=	4,41			
C=	2,691			



Electrode E70XX

C_1= 1,000

Φ = 0,75

Reduction at elevated temperature: 1,00 (no reduction)

Design load Pu

Load Pu = ***68,0*** *kN*

Design of weld

$R_n = CC_1Dl$ =	64,8 kips	=	288,3 kN
ΦR_n =	48,6 kips	=	216,2 kN

Results: 0,31 O.K.

Comparison:

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

Bolt check: Both results give exactly the same values.

Plate check: Bearing strength at bolt holes determines the plate check. The same result is given by the FEM computation. However, according the IDEA StatiCa, there is still a reserve in plastic strain limit.

Weld: IDEA StatiCa can design the welds using 3 possible methods. The least conservative values were taken into account – average stress in welds. This method gives a unit ratio of 46%. The design according to AISC Steel construction manual – table 8-4 – Eccentrically loaded weld group is less conservative (31%) than IDEA StatiCa, but both results are reasonable and gives good values.