STEEL CONNECTIONS FOR INDUSTRIAL STRUCTURES

MARCH 2026

IDEA StatiCa®

Calculate yesterday's estimates

AGENDA

IDEA StatiCa intro

Industrial case studies:

1. A-frame substation connections: Knuckle joint
2. Pipe racks connections: Multi-member joints
3. Anchored Pipe supports

Finite element analysis for Connection design

Q&A Session

COMMON INDUSTRIES

- Architectural, High Rise, and Buildings
- Industrial, Plant, & Data Center
- Infrastructure & Transportation
- Construction & Erection

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Calculate yesterday's estimates

Connection

Member

Detail

Checkbot

Architectural, High Rise, and Buildings

Industrial, Plant, & Data Center

Infrastructure & Transportation

Construction & Erection

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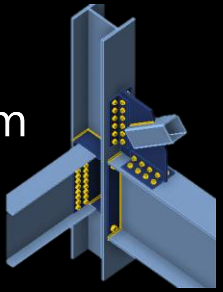
Calculate yesterday's estimates

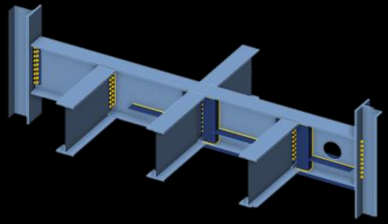
Connection

Design all steel connections from standard to complex joints



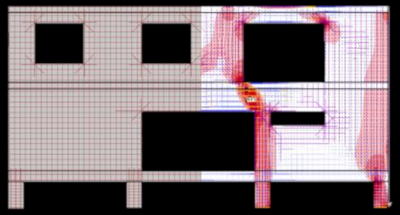
Member

Critical Beam and column design



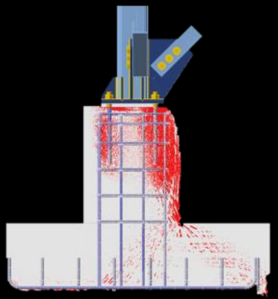
Detail

Replace STM when designing:
Transfer beams
Shear walls
Corbels
Walking columns



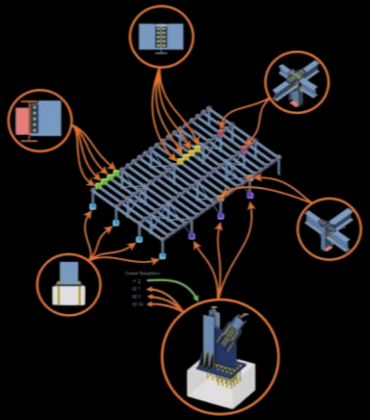
Connection + Detail

Complete base plate workflow including steel and concrete reinforcement design to avoid concrete breakout



Checkbot

Integration of 3rd party apps analysis models or BIM models with IDEA StatiCa applications



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SUBSTATION STRUCTURES
(KNUCKLE JOINT)

SANDMAN Structural Engineers 100% EMPLOYEE OWNED

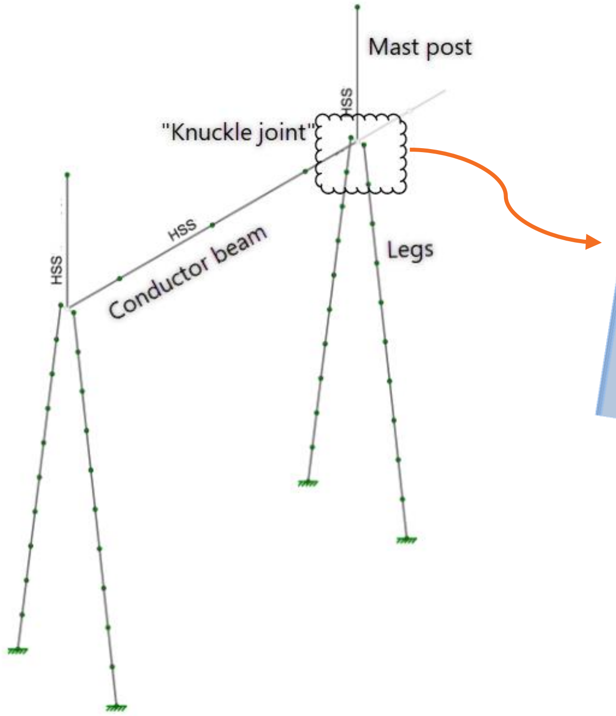
Challenges:

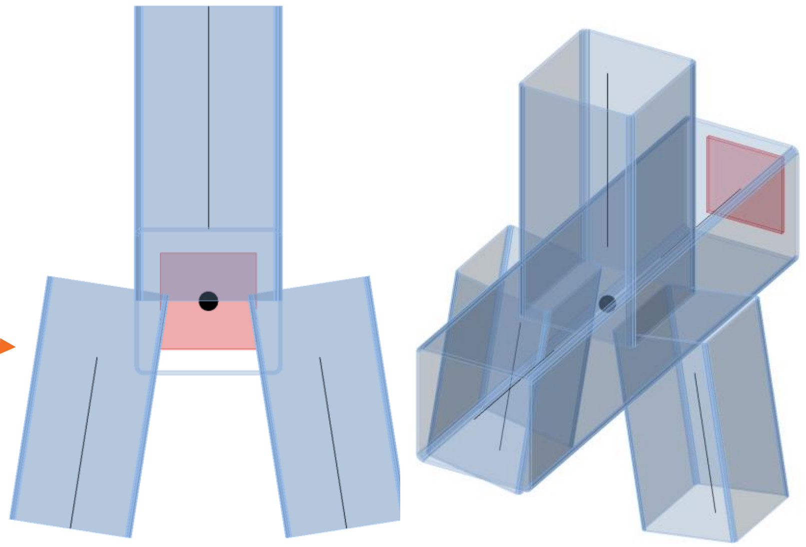
- HSS members connections
- 3D Joints/Multiple members
- Atypical/unique geometry
- Torsion load in some members

*"Unique connections **don't easily fit** the **typical analysis** methods prescribed by AISC."*

Read the article here

SUBSTATION STRUCTURES (A-FRAME)

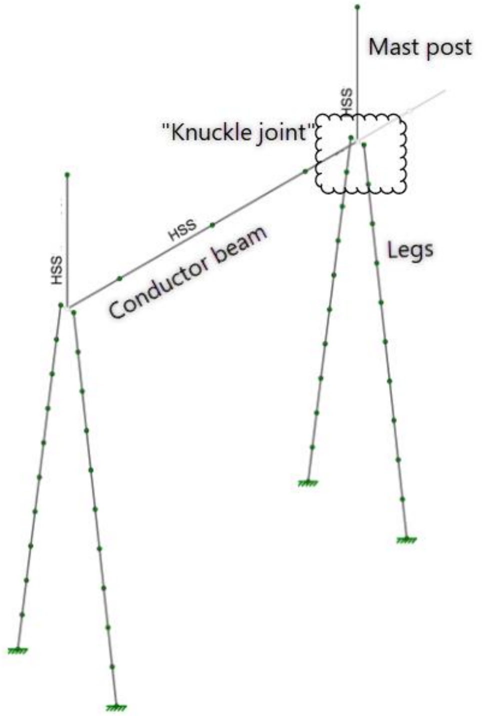




Geometry only model – IDEA StatiCa

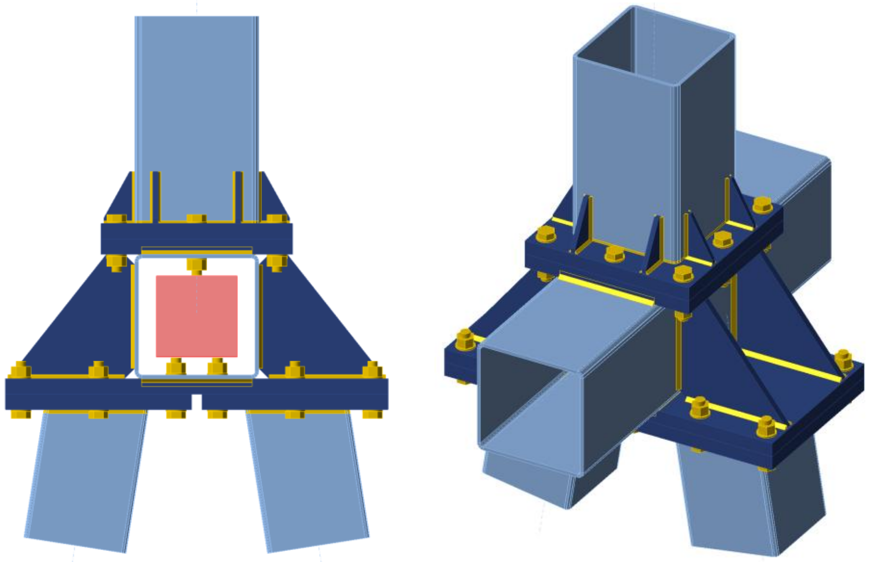
Analytical model

SUBSTATION STRUCTURES (A-FRAME)



Analytical model

Connection model in
IDEA StatiCa



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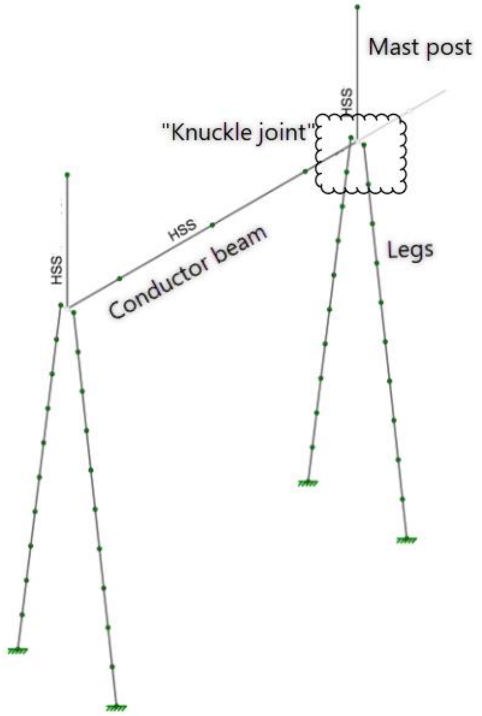
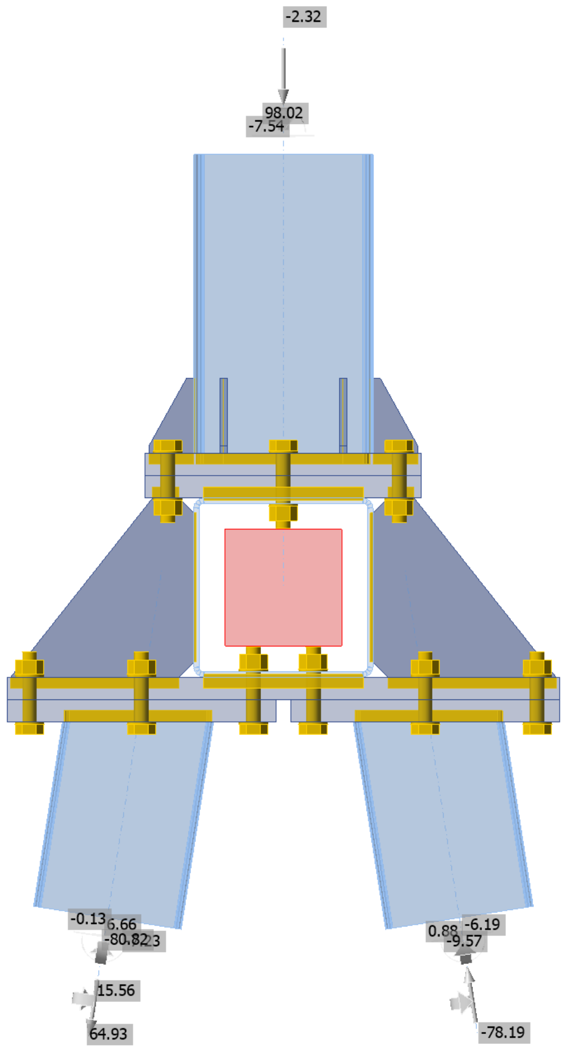
SUBSTATION STRUCTURES (A-FRAME)

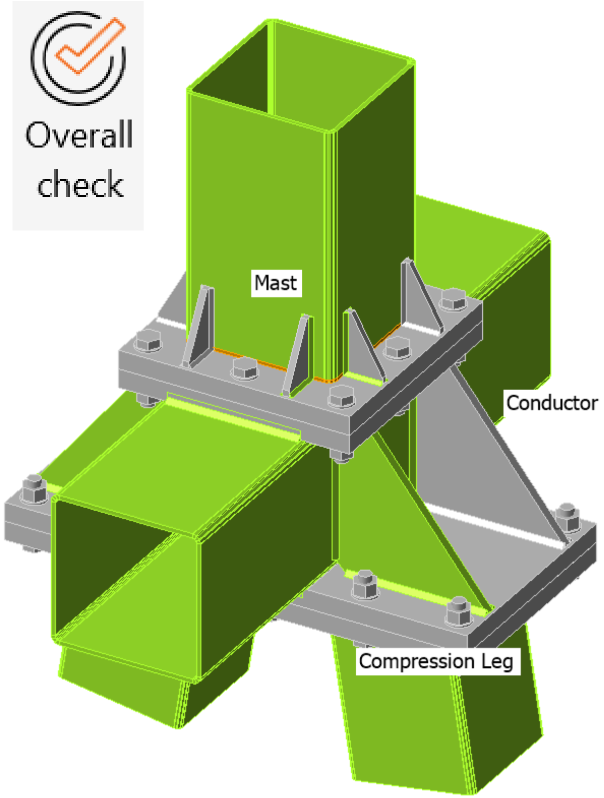


Analytical model

Loading – end reactions on members

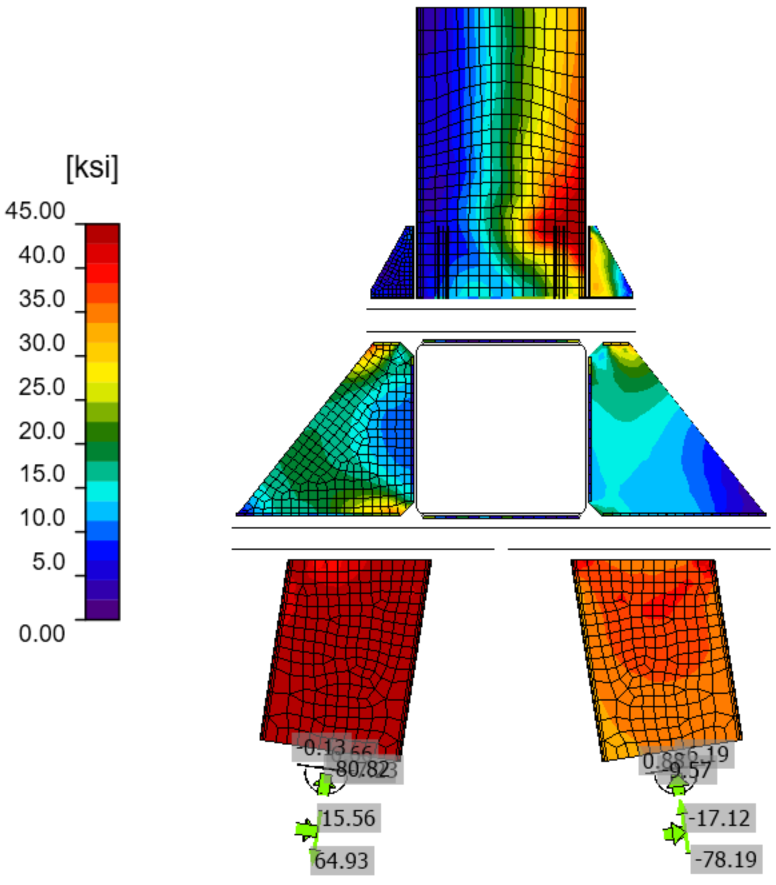


SUBSTATION STRUCTURES (A-FRAME)



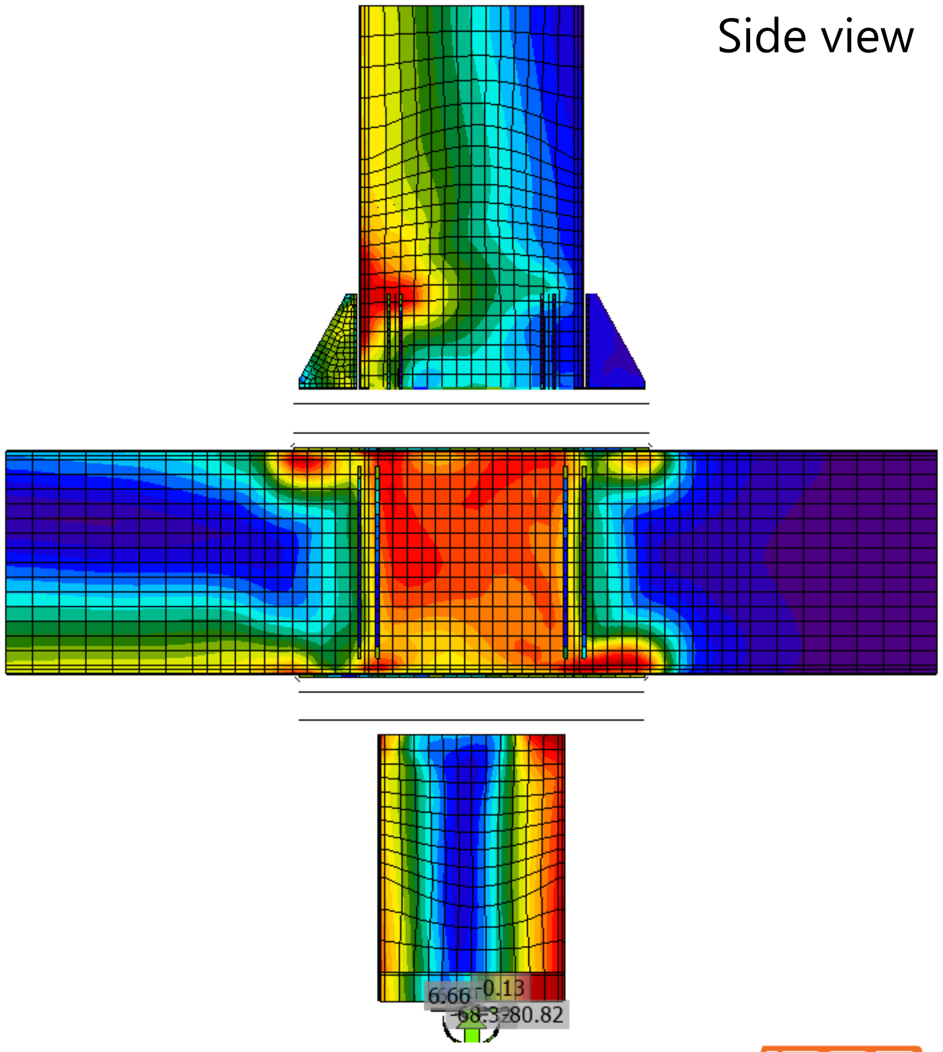
- Utilization ratio < 60%
- Utilization ratio > 60%
- Utilization ratio > 95%
- Utilization ratio > 100%

SUBSTATION STRUCTURES (A-FRAME)

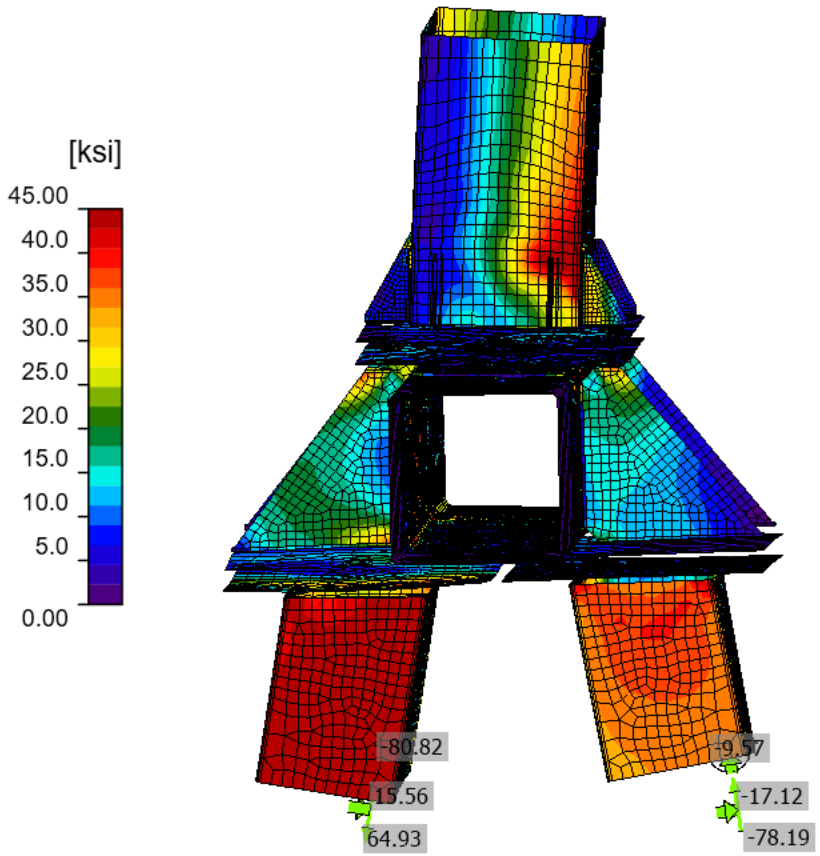


Front view

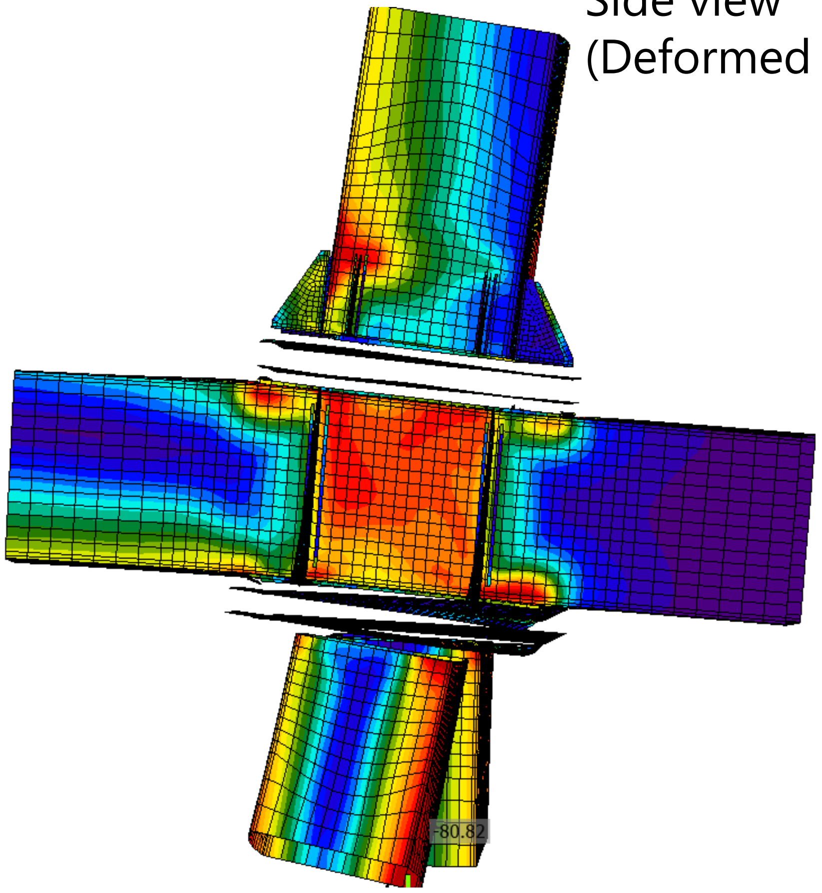
Side view



SUBSTATION STRUCTURES (A-FRAME)



Front view
(Deformed shape)



Side view
(Deformed shape)

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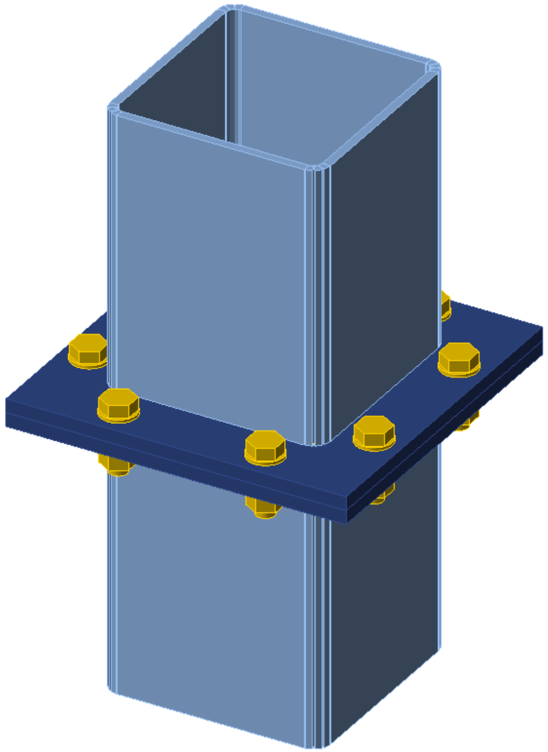
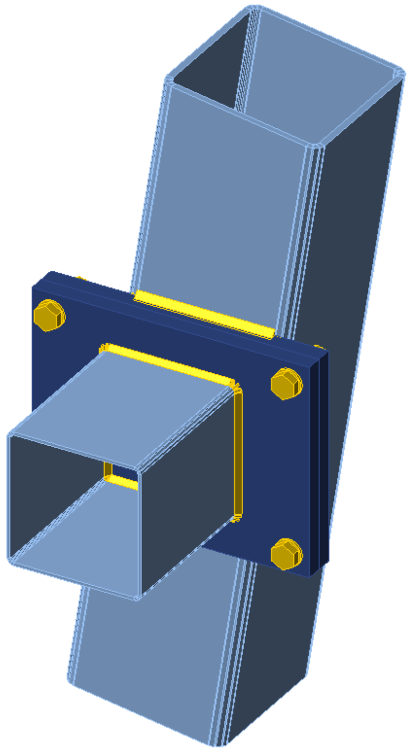
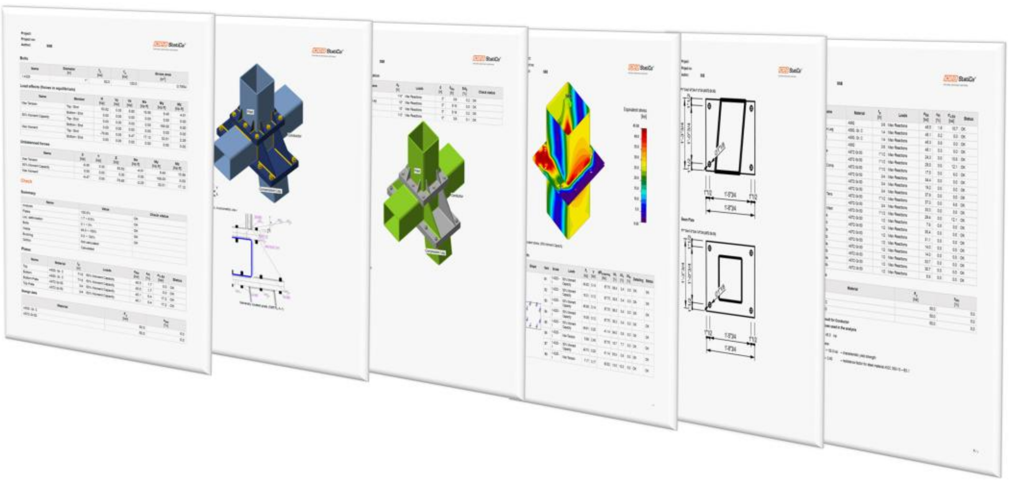
SUBSTATION STRUCTURES (A-FRAME)



Column splice



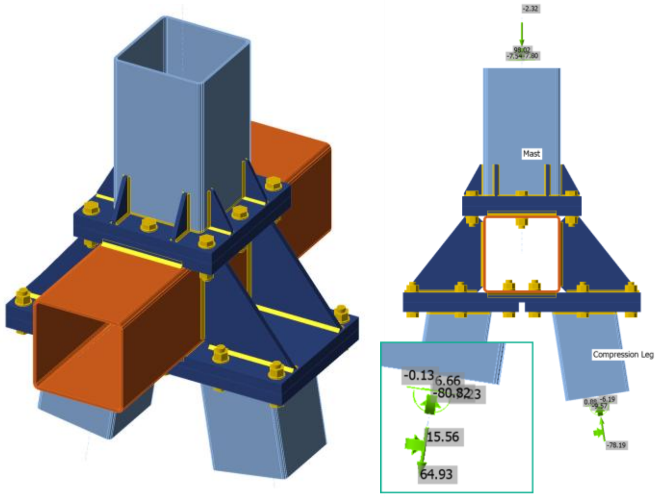
End plate to sloped leg

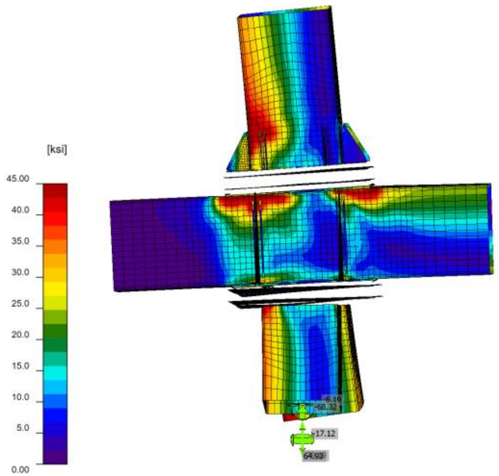


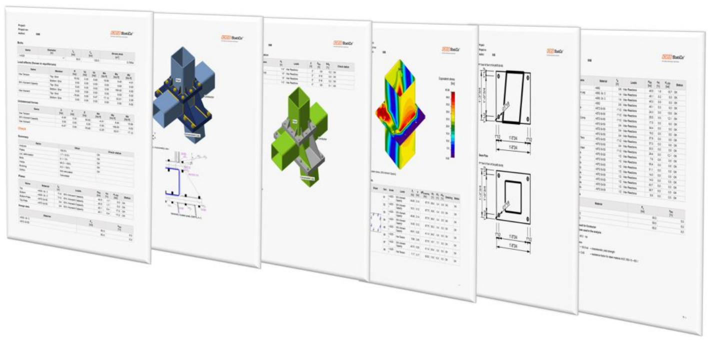
Consistent report across the project

SUBSTATION AND TRANSMISSION STRUCTURES

Results







3D Joint modeling

Multiple loads: axial, moments and **torsion**

Clear load path

Stress Hot spots

Consistent deliverables for all the connections across the project

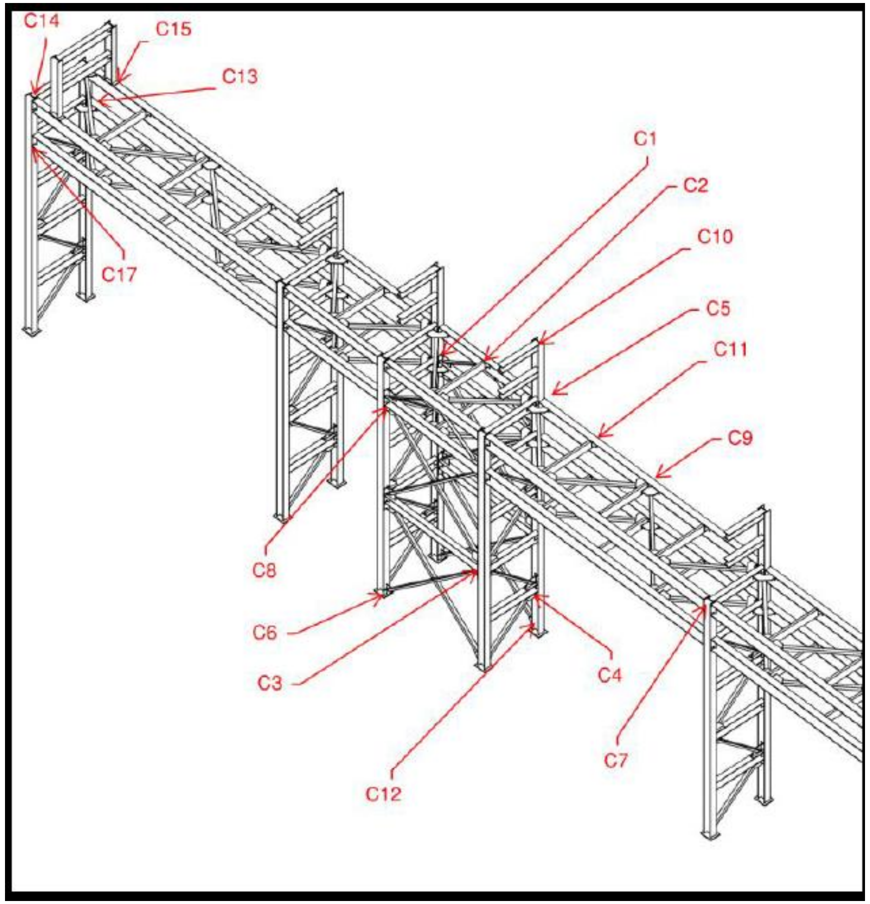
PIPE RACKS

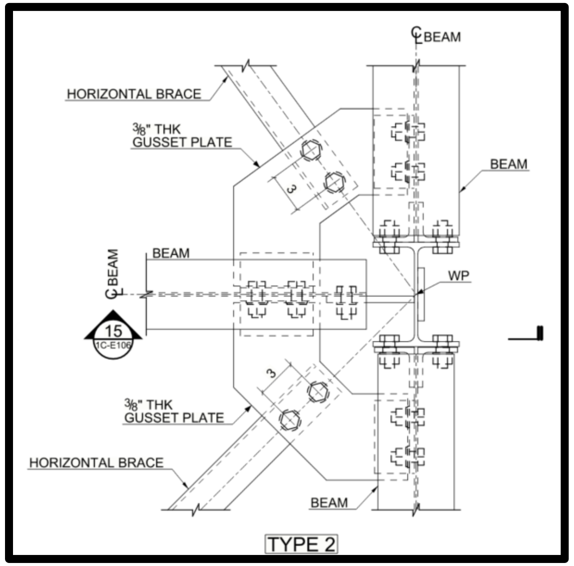
Challenges:

- Joints with multiple members and tight clearances
- Horizontal and vertical bracings (Gusset plates)
- Repetitive connections
- Coordination between teams (EoR, connection designer and fabricator)

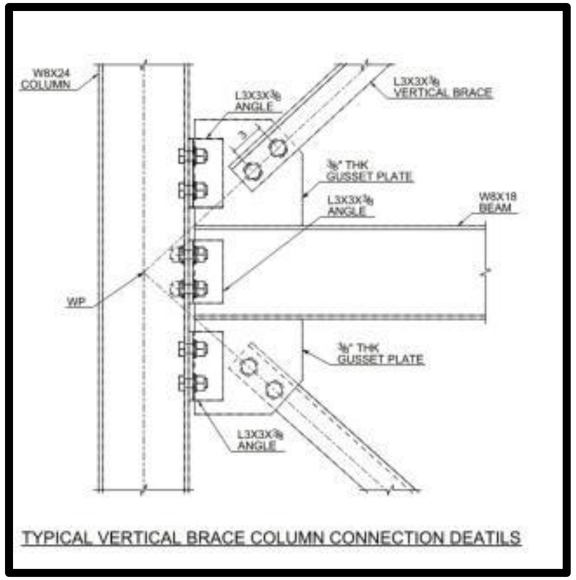
*"In this project there was a lot of **pretty tight spacing**. The member sizes weren't very large, and we had a little bit of an **accessibility issue**."*

Read the article here

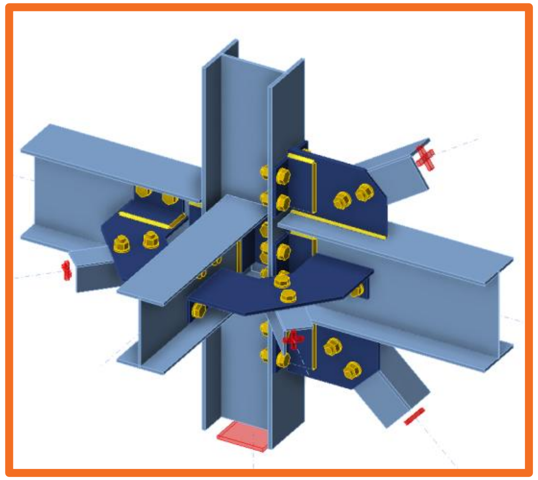


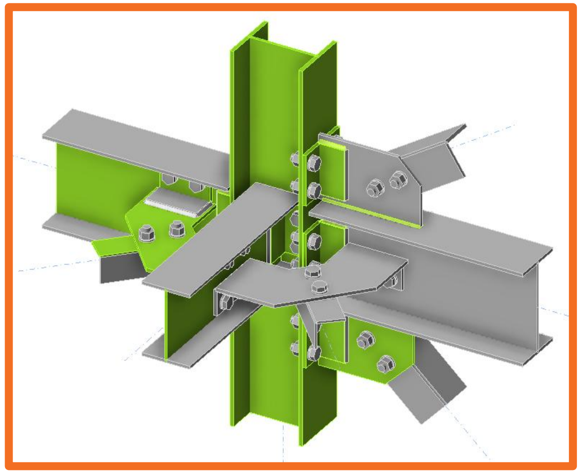


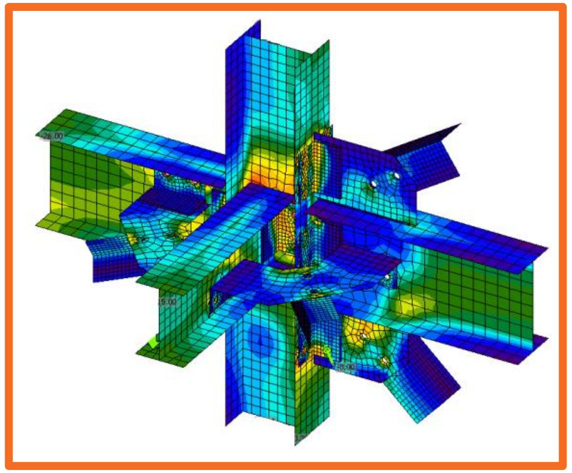
BEAM
HORIZONTAL BRACE
3/8" THK GUSSET PLATE
BEAM
BEAM
WP
BEAM
15
1C-E106
3/8" THK GUSSET PLATE
HORIZONTAL BRACE
BEAM
TYPE 2



W8X24 COLUMN
L3X3X3/8 ANGLE
L3X3X3/8 VERTICAL BRACE
3/8" THK GUSSET PLATE
L3X3X3/8 ANGLE
W8X18 BEAM
WP
3/8" THK GUSSET PLATE
L3X3X3/8 ANGLE
TYPICAL VERTICAL BRACE COLUMN CONNECTION DEATILS

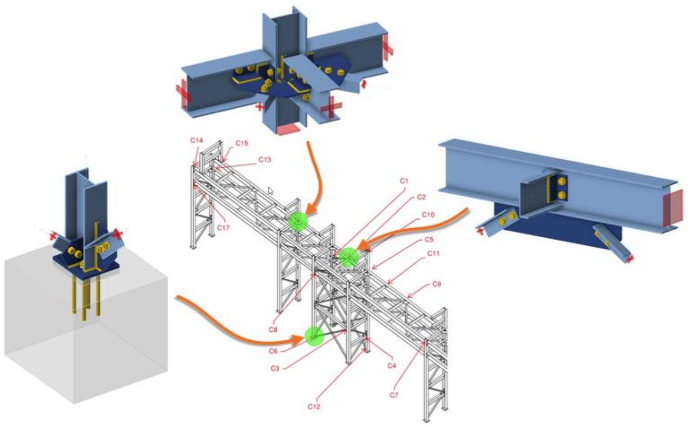


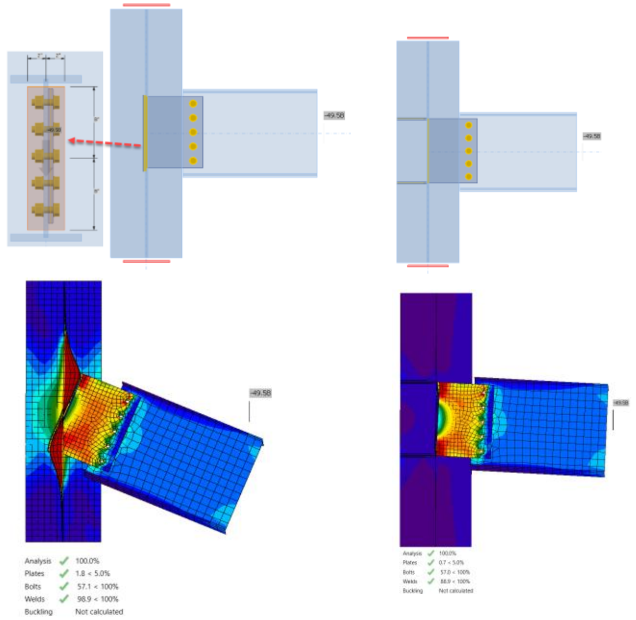


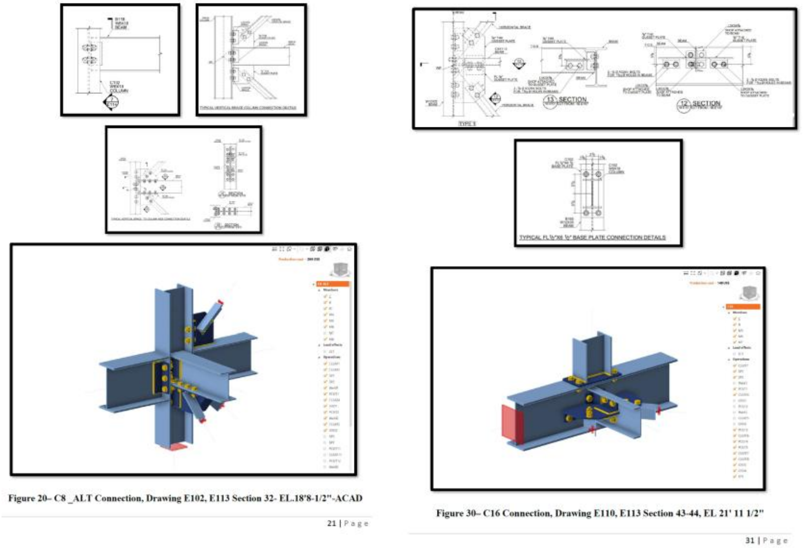


PIPE RACKS

Results







All connections across **800ft** rack designed **50% faster!**

Clear communication with the **fabricator** using:

Force flow contours

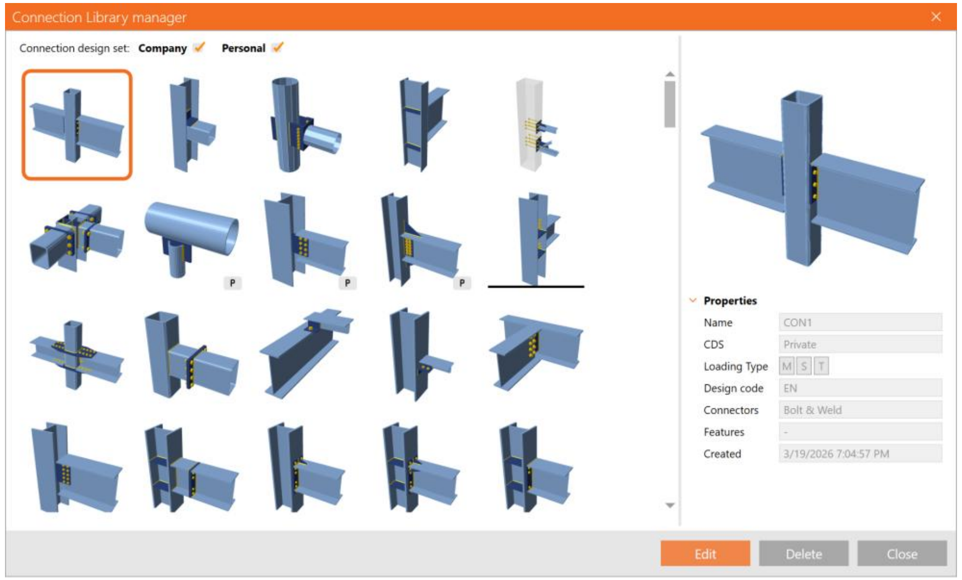
Annotated 3D models

EoR **accepted** the package on the **first submission**

PRO TIP: RE-USE MODELS FROM CONNECTION LIBRARY

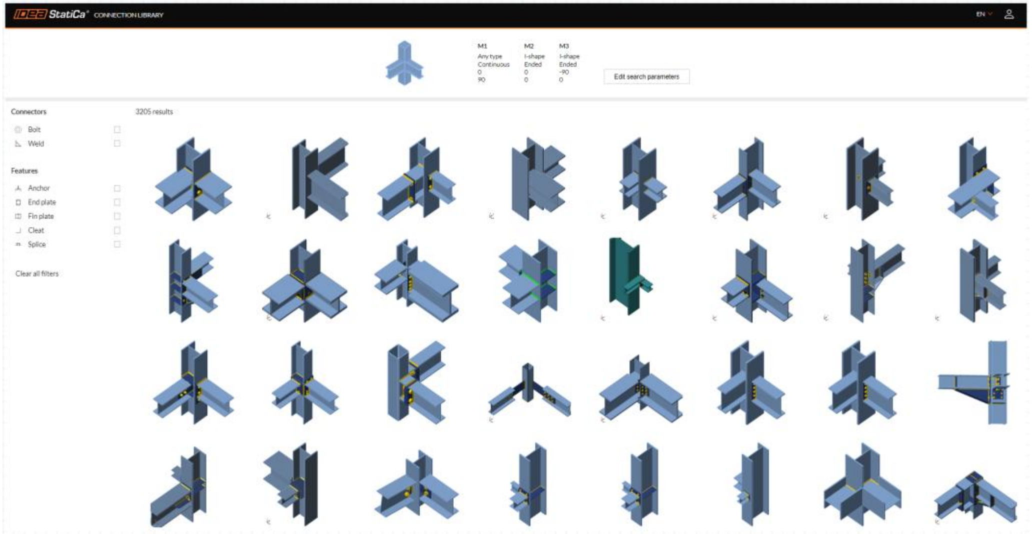
Desktop Connection library

Build personalized library within the desktop app



Web connection library

Largest detail library with +1mill connection files



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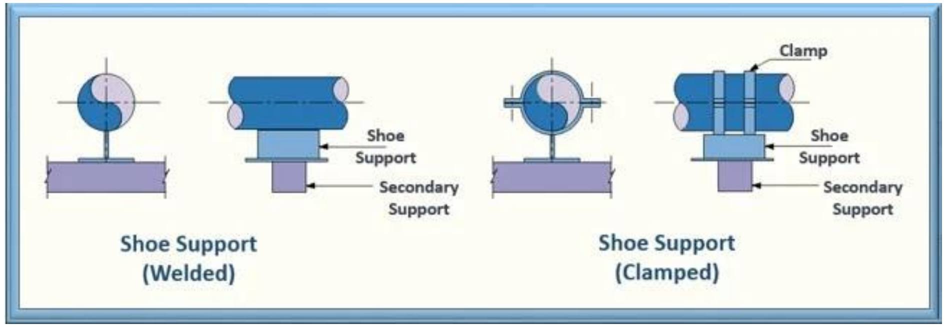
ANCHORED PIPE SUPPORTS

Challenges:

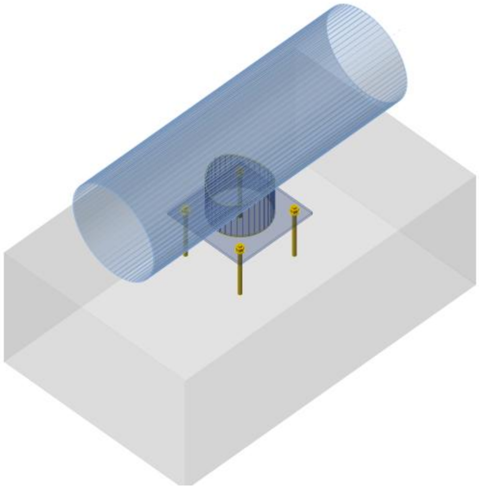
- Large pipe sections and curved pipe sections
- Custom base plate geometry
- Unconventional anchor layout
- Post-installed anchors
- Multiple stiffeners required

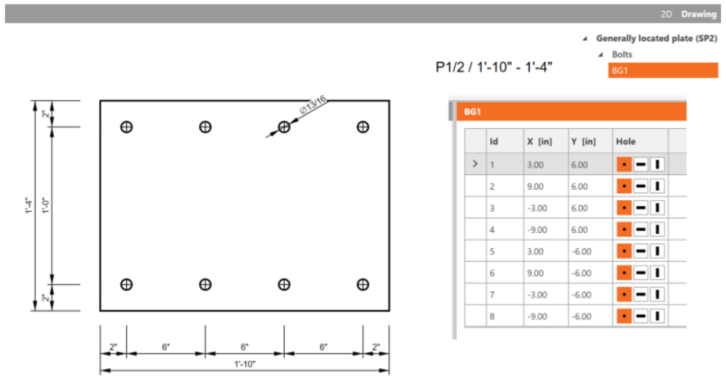
Sample project here



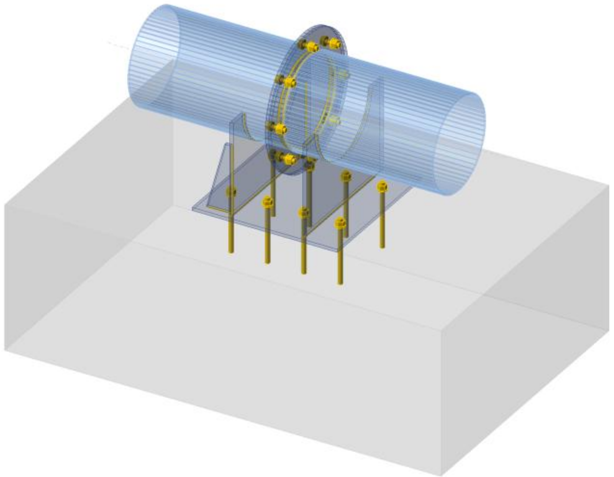
PIPE SUPPORTS

Results:





Id	X [in]	Y [in]	Hole
1	3.00	6.00	
2	9.00	6.00	
3	-3.00	6.00	
4	-9.00	6.00	
5	3.00	-6.00	
6	9.00	-6.00	
7	-3.00	-6.00	
8	-9.00	-6.00	



Rolled and **custom** cross section database available

Custom base plate
Flexible anchor layout

Post-installed anchors

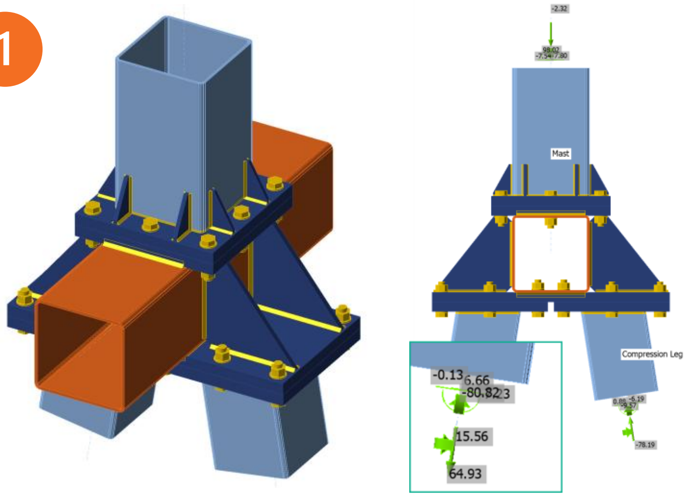
Stiffener operation

Automated operations to locate reinforcement plates in any location

SUMMARY AND RESULTS

Industrial Structures

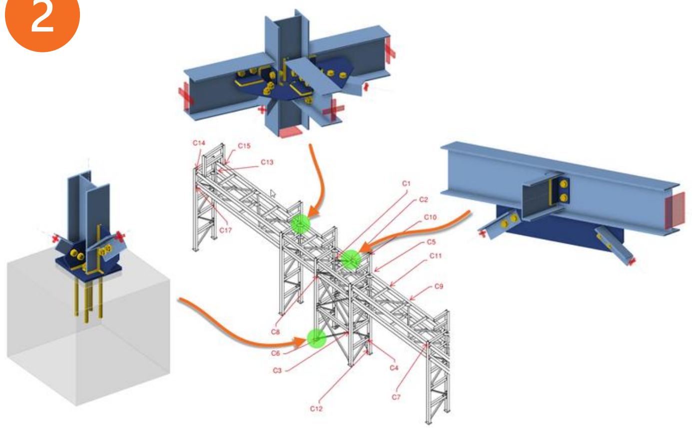
1



Substation A-frame:

Unique HSS Connection design

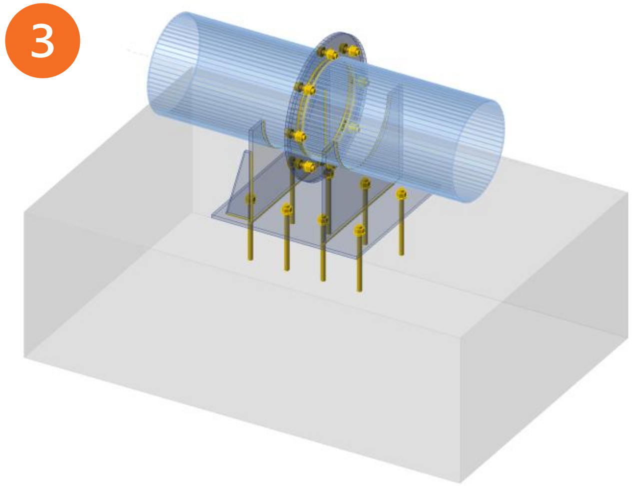
2



Pipe rack:

Quick project delivery

3

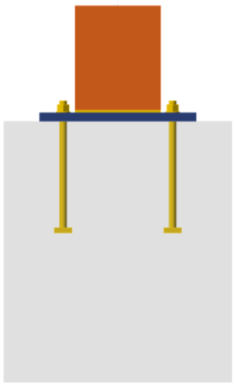


Anchored pipe support:

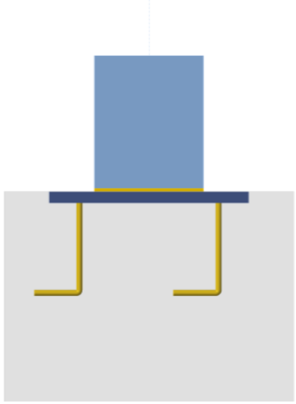
Flexible modeling

ANCHOR DESIGN

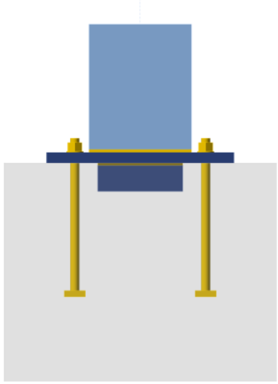
Cast in place



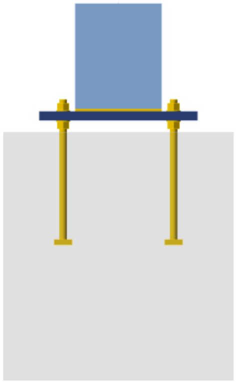
Anchors with washer plates



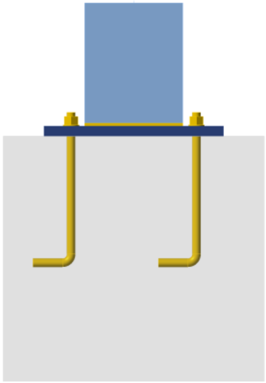
Embedded plate with welded reinforcement



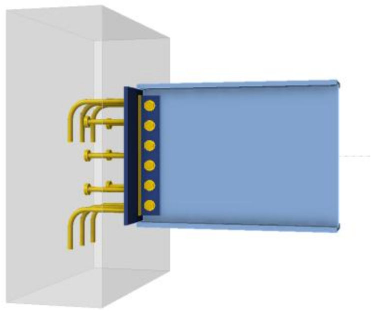
Shear lug



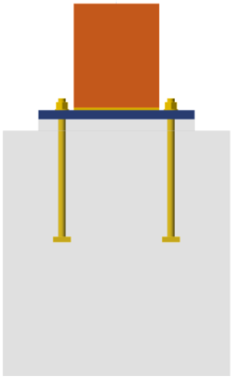
Gap



Hooked anchors

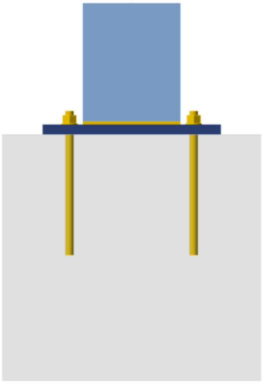


Embedded plate w/headed studs and welded rebar



Mortar joint/grout

Post installed



Adhesive anchors

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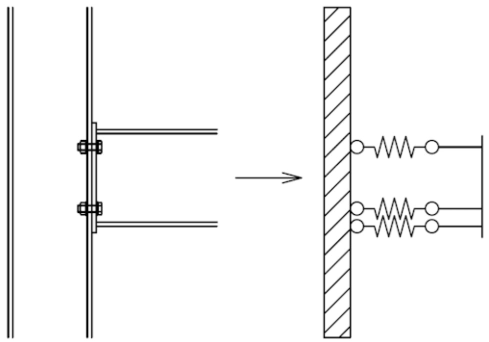
STEEL CONNECTION DESIGN USING FEA

CBFEM is a synergy of the Component Method and Finite Element analysis.

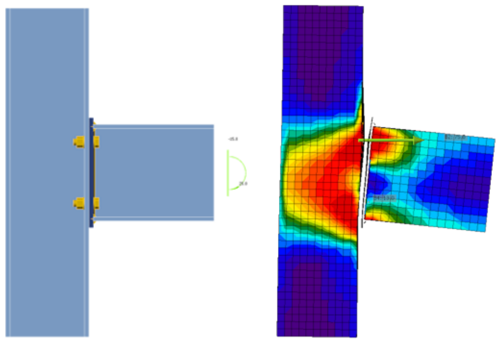
The check itself consists of two steps:

1. Forces in each component of the joint are calculated using FEA
2. Each component (bolts, welds, anchors) is checked using the code equations

COMPONENT METHOD



CBFEM MODEL

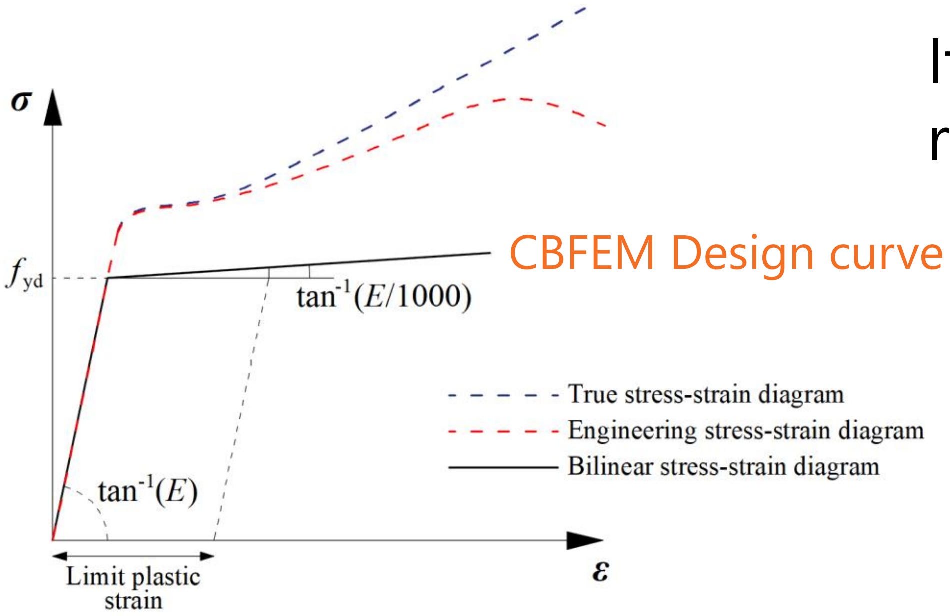


STEEL MATERIAL MODEL FOR PLATES

The material behavior is based on the von Mises yield criterion

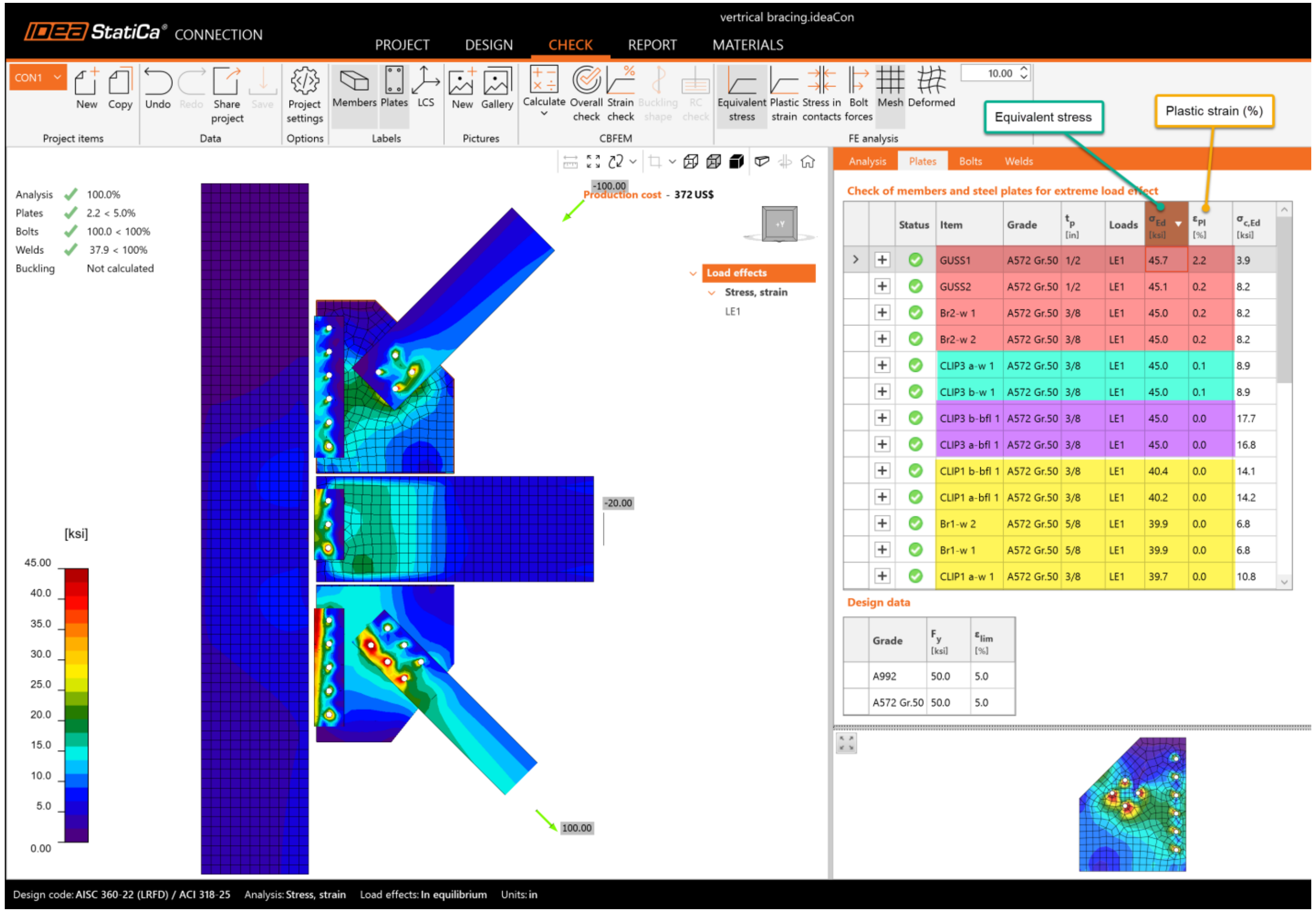
It is assumed to be elastic before reaching the design yield strength, f_{yd}.

Design yield stress
(LRFD) fy*0.9
(ASD) fy/1.67

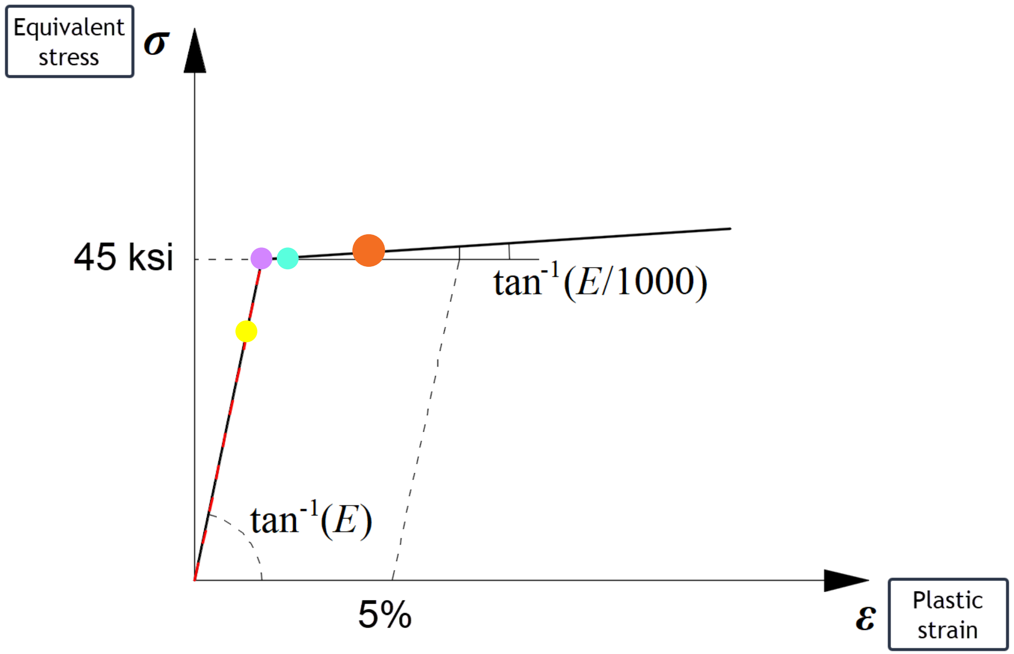


5%

EQUIVALENT STRESS

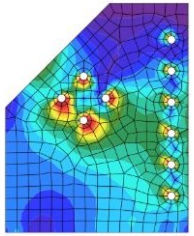


Design yield strength (LRFD) = 50 ksi *0.9 = 45 ksi

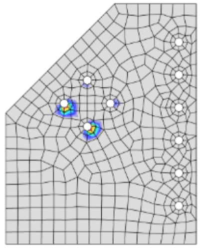


CBFEM CODE CHECKS OF STEEL CONNECTION COMPONENTS

Plates: Material properties are checked, design limit is based on plastic strain



Equivalent stresses



Plastic strain

Check of members and steel plates for extreme load effect

	Status	Item	Grade	t_p [in]	Loads	σ_{Ed} [ksi]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [ksi]
−	✓	GUSS1	A572 Gr.50	1/2	LE1	45.7	2.2	3.9

Design values used in the analysis

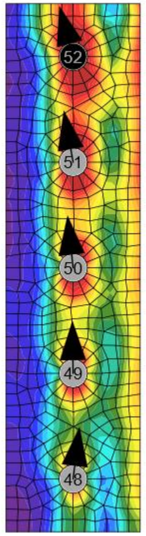
$\phi F_y =$ 45.0 ksi

Where:

$F_y = 50.0$ ksi – characteristic yield strength

$\phi = 0.90$ – resistance factor for steel material AISC 360-22 – B3.1

Bolts and anchors



Tension resistance check (AISC 360-22 – J3-1)

$\phi R_n = \phi \cdot F_{nt} \cdot A_b =$ 29.79 kip ≥ $F_t =$ 9.31 kip

Where:

$F_{nt} = 89.9$ ksi – nominal tensile stress AISC 360-22 – Table J3.2

$A_b = 0.4418$ in^2 – gross bolt cross-sectional area

$\phi = 0.75$ – resistance factor

Shear resistance check (AISC 360-22 – J3-1)

$\phi R_n = \phi \cdot F_{nv} \cdot A_b =$ 17.88 kip ≥ $V =$ 5.97 kip

Where:

$F_{nv} = 54.0$ ksi – nominal shear stress AISC 360-22 – Table J3.2

$A_b = 0.4418$ in^2 – gross bolt cross-sectional area

$\phi = 0.75$ – resistance factor

Bearing resistance check (AISC 360-22 – J3-6)

$R_n = 1.20 \cdot l_c \cdot t \cdot F_u \le 2.40 \cdot d \cdot t \cdot F_u$

$\phi R_n =$ 25.21 kip ≥ $V =$ 5.97 kip

Where:

$l_c = $ 1"1/8 in – clear distance, in the direction of the force, between the edge hole or edge of the material

$t = 3/8$ in – thickness of the plate

$d = 3/4$ in – diameter of a bolt

$F_u = 65.0$ ksi – specified minimum tensile strength of the connected material

$\phi = 0.75$ – resistance factor for bearing at bolt holes

Interaction of tension and shear check (AISC 360-22 – J3-3)

$\phi R_n = \phi \cdot F'_{nt} \cdot A_b =$ 28.78 kip ≥ $F_t =$ 9.31 kip

Where:

$F'_{nt} = 86.9$ ksi – nominal tensile stress modified to include the effects of shea

- $F'_{nt} = 1.3 \cdot F_{nt} - \frac{f_{rv} \cdot F_{nt}}{\phi \cdot F_{nv}} \le F_{nt}$, where:
  - $F_{nt} =$ 89.9 ksi – nominal tensile stress AISC 360-22 – Table J:
  - $F_{nv} =$ 54.0 ksi – nominal shear stress AISC 360-22 – Table J3
  - $f_{rv} =$ 13.5 ksi – required shear stress using LRFD or ASD loa of the fastener shall be equal or exceed the required shear stres
  - $\phi =$ 0.75 – resistance factor for tension and shear combinatior

$A_b = 0.4418$ in^2 – gross bolt cross-sectional area

Welds

Check of welds for extreme load effect

		Status	Item	Edge	Xu	t_w [in]	w [in]	L [in]	L_c [in]	Loads	F_n [kip]	ϕRn [kip]	Ut [%]	Ut_c [%]	Detailing
	+	✓	BP1	W14X90-tfl 1	E70xx	◢ 5/16 ◣	◢ 7/16 ◣	1'-2"1/2	1"3/16	L1T+S+M	16.87	17.02	99.1	99.1	✓
	+	✓			E70xx	◢ 5/16 ◣	◢ 7/16 ◣	1'-2"1/2	1"3/16	L1T+S+M	16.38	16.94	96.6	96.6	✓
	−	✓			E70xx	◢ 5/16 ◣	◢ 7/16 ◣	1'-2"1/2	1"3/16	L2 C+S+M	13.46	16.83	80.0	69.5	✓

Weld resistance check (AISC 360-22 – J2-4)

$\phi R_n = \phi \cdot F_{nw} \cdot A_{we} =$ 16.83 kip ≥ $F_n =$ 13.46 kip

Where:

$F_{nw} = 60.1$ ksi – nominal stress of weld material:

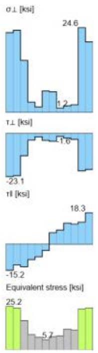
- $F_{nw} = 0.6 \cdot F_{EXX} \cdot (1 + 0.5 \cdot sin^{1.5}\theta)$, where:
  - $F_{EXX} =$ 70.0 ksi – electrode classification number, i.e. minimum specified tensile strength
  - $\theta =$ 65.1° – angle of loading measured from the weld longitudinal axis

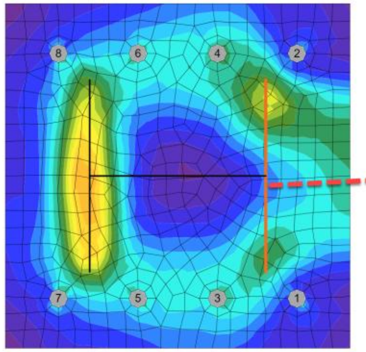
$A_{we} = 0.3732$ in^2 – effective area of weld critical element

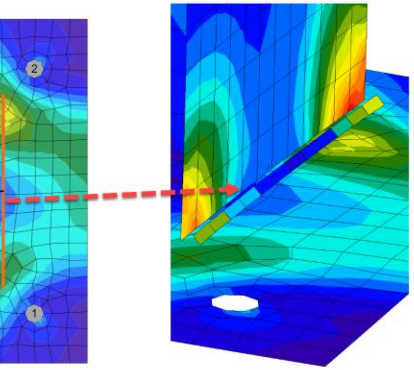
$\phi = 0.75$ – resistance factor for welded connections

Design data

	Material	F_{exx} [ksi]
	E70xx	70.0







STEEL COMPONENTS AISC CODE CHECKS

Project:
Project no:
Author:

IDEA StatiCa
Calculate yesterday's estimates

Check

Summary

Name	Value	Check status
Analysis	100.0%	OK
Plates	2.2 < 5.0%	OK
Bolts	98.2 < 100%	OK
Welds	87.6 < 100%	OK
Buckling	Not calculated	

Plates

Name	Material	t_p [in]	Loads	σ_{Ed} [ksi]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [ksi]	Status
C-bfl 1	A992	1/2	LE1	45.6	2.2	9.4	OK
C-tfl 1	A992	1/2	LE1	45.0	0.1	0.0	OK
C-w 1	A992	5/16	LE1	45.2	0.6	0.0	OK
B-bfl 1	A992	7/16	LE1	41.5	0.0	0.0	OK
B-tfl 1	A992	7/16	LE1	33.6	0.0	0.0	OK
B-w 1	A992	5/16	LE1	38.3	0.0	0.0	OK
EP1	A572 Gr.50	3/4	LE1	45.0	0.2	22.7	OK
STIFF1a	A572 Gr.50	7/16	LE1	36.3	0.0	0.0	OK
STIFF1b	A572 Gr.50	7/16	LE1	36.7	0.0	0.0	OK
STIFF1c	A572 Gr.50	7/16	LE1	45.0	0.1	0.0	OK
STIFF1d	A572 Gr.50	7/16	LE1	45.0	0.1	0.0	OK

Design data

Material	F_y [ksi]	ε_{lim} [%]
A992	50.0	5.0
A572 Gr.50	50.0	5.0

Detailed result for C-bfl 1

Design values used in the analysis

$\phi F_y =$ 45.0 ksi

Where:

$F_y = 50.0$ ksi – characteristic yield strength

$\phi = 0.90$ – resistance factor for steel material AISC 360-22 – B3.1

Plates

Detailed result for B2

Tension resistance check (AISC 360-22 – J3-1)

$\phi R_n = \phi \cdot F_{nt} \cdot A_b =$ 29.79 kip ≥ $F_t =$ 29.27 kip

Where:

$F_{nt} = 89.9$ ksi – nominal tensile stress AISC 360-22 – Table J3.2

$A_b = 0.4418$ in^2 – gross bolt cross-sectional area

$\phi = 0.75$ – resistance factor

Shear resistance check (AISC 360-22 – J3-1)

$\phi R_n = \phi \cdot F_{nv} \cdot A_b =$ 17.88 kip ≥ $V =$ 2.43 kip

Where:

$F_{nv} = 54.0$ ksi – nominal shear stress AISC 360-22 – Table J3.2

$A_b = 0.4418$ in^2 – gross bolt cross-sectional area

$\phi = 0.75$ – resistance factor

Bearing resistance check (AISC 360-22 – J3-6)

$R_n = 1.20 \cdot l_c \cdot t \cdot F_u \quad \leq \quad 2.40 \cdot d \cdot t \cdot F_u$

$\phi R_n =$ 45.63 kip ≥ $V =$ 2.43 kip

Where:

$l_c = 5"13/16$ in – clear distance, in the direction of the force, between the edge of the hole and the edge of the adjacent hole or edge of the material

$t = 1/2$ in – thickness of the plate

$d = 3/4$ in – diameter of a bolt

$F_u = 65.0$ ksi – specified minimum tensile strength of the connected material

$\phi = 0.75$ – resistance factor for bearing at bolt holes

Interaction of tension and shear check (AISC 360-22 – J3-2)

The required stress, in either shear or tension, is less than or equal to 30% of the corresponding available stress and the effects of combined stresses need not to be investigated.

Bolts

Welds

Item	Edge	Xu	t_w [in]	w [in]	L [in]	L_c [in]	Loads	F_n [kip]	ϕR_n [kip]	Ut [%]	Ut_c [%]	Detailing	Status
EP1	B-bfl 1	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	6"	1"	LE1	7.51	9.25	81.2	75.8	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	6"	1"	LE1	8.11	9.26	87.6	87.6	OK	OK
EP1	B-tfl 1	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	6"	1"	LE1	6.84	9.10	75.1	51.7	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	6"	1"	LE1	6.32	8.51	74.2	52.0	OK	OK
EP1	B-w 1	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	1'-5"3/16	15/16	LE1	6.07	7.10	85.5	84.2	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	1'-5"3/16	15/16	LE1	6.07	7.10	85.5	84.2	OK	OK
C-bfl 1	STIFF1a	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	7.21	9.83	73.3	50.9	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	7.75	9.89	78.4	66.6	OK	OK
C-w 1	STIFF1a	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	9"7/16	1"1/16	LE1	3.46	7.14	48.5	29.4	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	9"7/16	1"1/16	LE1	2.85	8.49	33.6	18.0	OK	OK
C-tfl 1	STIFF1a	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	4.19	9.63	43.5	20.9	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	1.82	7.46	24.4	10.3	OK	OK
C-bfl 1	STIFF1b	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	7.74	9.89	78.3	66.3	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	7.15	9.81	72.9	50.6	OK	OK
C-w 1	STIFF1b	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	9"7/16	1"1/16	LE1	2.84	8.49	33.5	17.9	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	9"7/16	1"1/16	LE1	3.45	7.14	48.3	29.2	OK	OK
C-tfl 1	STIFF1b	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	1.81	7.48	24.2	10.2	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	4.18	9.63	43.4	20.8	OK	OK
C-bfl 1	STIFF1c	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	3.84	9.29	41.4	20.1	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	7.45	9.72	76.7	61.0	OK	OK
C-w 1	STIFF1c	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	9"7/16	1"1/16	LE1	2.53	9.29	27.3	13.8	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	9"7/16	1"1/16	LE1	2.65	9.69	27.4	11.9	OK	OK
C-tfl 1	STIFF1c	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	0.66	7.73	8.5	0.0	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	1.02	8.90	11.4	0.0	OK	OK
C-bfl 1	STIFF1d	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	7.44	9.72	76.6	60.8	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	3.96	9.40	42.1	20.7	OK	OK
C-w 1	STIFF1d	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	9"7/16	1"1/16	LE1	2.63	9.69	27.1	11.6	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	9"7/16	1"1/16	LE1	2.46	9.32	26.4	13.6	OK	OK
C-tfl 1	STIFF1d	E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	1.00	8.91	11.2	0.0	OK	OK
		E70xx	◢ 3/16 ◣	◢ 1/4 ◣	2"1/8	1"1/16	LE1	0.67	7.92	8.4	0.0	OK	OK

Design data

Material	F_{exx} [ksi]
E70xx	70.0

Detailed result for EP1 / B-bfl 1

Weld resistance check (AISC 360-22 – J2-4)

$\phi R_n = \phi \cdot F_{nw} \cdot A_{we} =$ 9.26 kip ≥ $F_n =$ 8.11 kip

Where:

$F_{nw} = 63.0$ ksi – nominal stress of weld material:

- $F_{nw} = 0.6 \cdot F_{EXX} \cdot (1 + 0.5 \cdot sin^{1.5}\theta)$, where:
  - $F_{EXX} =$ 70.0 ksi – electrode classification number, i.e. minimum specified tensile strength
  - $\theta =$ 88.3° – angle of loading measured from the weld longitudinal axis

$A_{we} = 0.1961$ in^2 – effective area of weld critical element

$\phi = 0.75$ – resistance factor for welded connections

Welds

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Concrete pullout resistance (ACI 318-25 – 17.6.3)

$\phi N_{pn} = \phi \cdot \psi_a \cdot \psi_{c,P} \cdot N_p =$ 174.11 kip ≥ $N_f =$ 71.11 kip

Where:

$\phi = 0.70$ – resistance factor

$\psi_a = 1.00$ – Strength modification factor ψa for anchors in tension

$\psi_{c,P} = 1.00$ – modification factor for concrete condition

$N_p = 248.73$ kip – basic concrete pullout strength for headed anchor:

- $N_{pr} = 8 \cdot A_{brg} \cdot f'_c$, where:
  - $A_{brg} =$ 7.7728 in^2 – bearing area of the head of stud or anchor bolt
  - $f'_c =$ 4.0 ksi – concrete compressive strength

Concrete sideface blowout resistance (ACI 318-25 – 17.6.4)

$\phi N_{sb} = r_c \cdot \phi \cdot N_{sbg} =$ 97.51 kip ≥ $N_f =$ 71.11 kip

Where:

$r_c = 0.51$ – reduction factor for anchor close to an edge or multiple anchors with small spacing:

- $r_c = \min(\frac{1+\frac{c_{a2}}{c_{a1}}}{4}, \frac{1+\frac{s}{6 \cdot c_{a1}}}{2}),\ 0.5 \le r_c \le 1$, where:
  - $c_{a1} =$ 9"3/4 in – shorter distance from an anchor to an edge
  - $c_{a2} =$ 10" in – longer distance from an anchor to an edge
  - $s =$ 6" in – spacing between anchors

$\phi N_{sbg} = 192.55$ kip – concrete side-face blowout strength of headed anchor in tension:

- $\phi N_{sb} = \phi \cdot \psi_a \cdot 160.0 \cdot c_{a1} \cdot \sqrt{A_{bgr}} \cdot \sqrt{f'_c}$, where:
  - $\phi =$ 0.70 – resistance factor
  - $\psi_a =$ 1.00 – Strength modification factor ψa for anchors in tension
  - $A_{bgr} =$ 7.7728 in^2 – bearing area of the head of stud or anchor bolt
  - $f'_c =$ 4.0 ksi – concrete compressive strength

Shear resistance (ACI 318-25 – 17.7.1)

$\phi V_{sa} = \phi \cdot 0.6 \cdot A_{se,V} \cdot f_{uta} =$ 47.14 kip ≥ $V =$ 5.31 kip

Where:

$\phi = 0.65$ – resistance factor

$A_{se,V} = 0.9690$ in^2 – tensile stress area

$f_{uta} = 124.7$ ksi – specified tensile strength of anchor steel:

- $f_{uta} = \min(125\ \text{ksi}, 1.9 \cdot f_{ya},\ f_u)$, where:
  - $f_{ya} =$ 105.0 ksi – specified yield strength of anchor steel
  - $f_u =$ 125.0 ksi – specified ultimate strength of anchor steel

Anchors

Concrete breakout resistance of anchor in tension (ACI 318-25 – 17.6.2)

The check is performed for group of anchors that form common tension breakout cone: A5, A6, A7, A8

$\phi N_{cbg} = \phi \cdot \frac{A_{Nc}}{A_{Nc0}} \cdot \psi_a \cdot \psi_{ec,N} \cdot \psi_{ed,N} \cdot \psi_{c,N} \cdot \psi_{cm,N} \cdot N_b =$ 41.89 kip < $N_{fg} =$ 211.63 kip

Where:

$N_{fg} = 211.63$ kip – sum of tension forces of anchors with common concrete breakout cone area

$\phi = 0.70$ – resistance factor

$A_{Nc} = 1044.0356$ in^2 – concrete breakout cone area for group of anchors

$A_{Nc0} = 400.0000$ in^2 – concrete breakout cone area for single anchor not influenced by edges

$\psi_a = 1.00$ – Strength modification factor ψa for anchors in tension

$\psi_{ec,N} = 0.89$ – modification factor for eccentrically loaded group of anchors

- $\psi_{ec,N} = \psi_{ecx,N} \cdot \psi_{ecy,N}$, where:
  - $\psi_{ecx,N} = \frac{1}{1+\frac{2 \cdot e_{x,N}}{3 \cdot h_{ef}}} =$ 0.97 – modification factor that depends on eccentricity in x-direction
  - $e_{x,N} =$ 5/16 in – tension load eccentricity in x-direction
  - $\psi_{ecy,N} = \frac{1}{1+\frac{2 \cdot e_{y,N}}{3 \cdot h_{ef}}} =$ 0.91 – modification factor that depends on eccentricity in y-direction
  - $e_{y,N} =$ 15/16 in – tension load eccentricity in y-direction
  - $h_{ef} = \min(h_{emb}, \max(\frac{c_{a,max}}{1.5}, \frac{s}{3})) =$ 6"11/16 in – depth of embedment, where:
    - $h_{emb} =$ 1'-6" in – embedment depth
    - $c_{a,max} =$ 10" in – maximum distance from the anchor to one of the three closest edges
    - $s =$ 1'-6"1/2 in – maximum spacing between anchors

$\psi_{ed,N} = 0.99$ – modification factor for edge distance:

- $\psi_{ed,N} = \min(0.7 + \frac{0.3 \cdot c_{a,min}}{1.5 \cdot h_{ef}}, 1)$, where:
  - $c_{a,min} =$ 9"3/4 in – minimum distance from the anchor to the edge
  - $h_{ef} =$ 6"11/16 in – depth of embedment

$\psi_{c,N} = 1.00$ – modification factor for concrete conditions

$\psi_{cm,N} = 1.00$ – breakout compression field factor

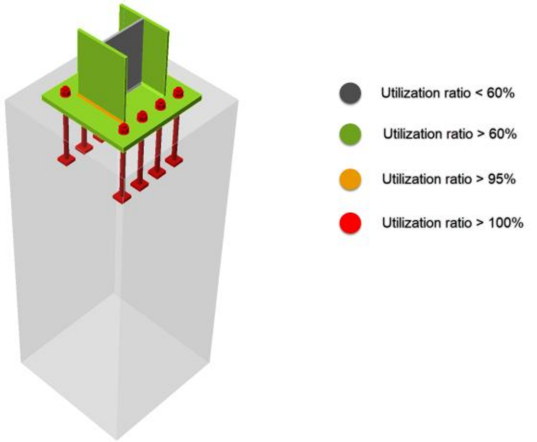
- $\psi_{cm,N} = 1.0$, one of the following criteria is met:
  - $c_{a,min} < 1.5 \cdot h_{ef}$
  - $\frac{N}{C} < 0.8$
  - $\frac{z}{h_{ef}} \ge 1.5$

$N_b = 26.01$ kip – basic concrete breakout strength of a single anchor in tension:

- $N_b = k_c \cdot \lambda_a \cdot \sqrt{f'_c} \cdot h_{ef}^{1.5}$, where:
  - $k_c =$ 24.0 – coefficient taking into account the installation process
  - $\lambda_a =$ 1.00 – modification factor for lightweight concrete
  - $f'_c =$ 4.0 ksi – concrete compressive strength
  - $h_{ef} =$ 6"11/16 in – depth of embedment

Concrete breakout

Overall check traffic light system



Overall check, L1T+S+M

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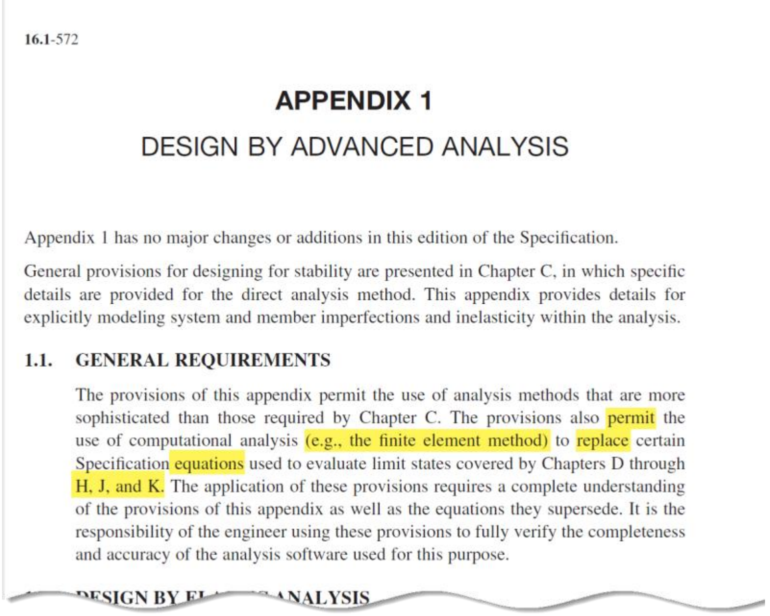
Does AISC allow the use of FEA in Connection Design?

Short answer: YES!

Long answer: AISC references



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APPENDIX 1

DESIGN BY ADVANCED ANALYSIS

Appendix 1 has no major changes or additions in this edition of the Specification.

General provisions for designing for stability are presented in Chapter C, in which specific details are provided for the direct analysis method. This appendix provides details for explicitly modeling system and member imperfections and inelasticity within the analysis.

1.1. GENERAL REQUIREMENTS

The provisions of this appendix permit the use of analysis methods that are more sophisticated than those required by Chapter C. The provisions also permit the use of computational analysis (e.g., the finite element method) to replace certain Specification equations used to evaluate limit states covered by Chapters D through H, J, and K. The application of these provisions requires a complete understanding of the provisions of this appendix as well as the equations they supersede. It is the responsibility of the engineer using these provisions to fully verify the completeness and accuracy of the analysis software used for this purpose.

DESIGN BY EL[illegible] ANALYSIS

- ✓ AISC Spec Comm. Appendix 1
- ✓ AISC Spec Commentary Ch. B, F, J, K
- ✓ AISC Design Guide 1 – Appendix D
- ✓ AISC Design Guide 24 – Chapter 2.13

Verification studies

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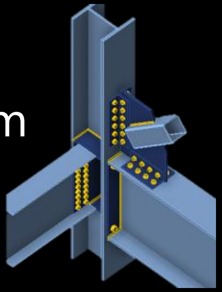
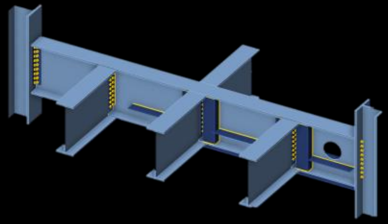
Connection

Design all steel connections from standard to complex joints



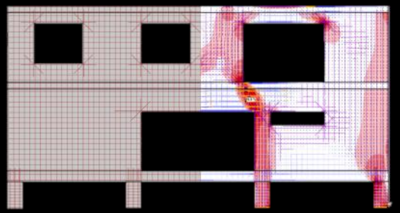
Member

Critical Beam and column design



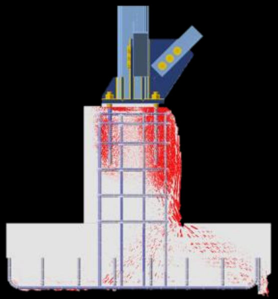
Detail

Replace STM when designing:
Transfer beams
Shear walls
Corbels
Walking columns



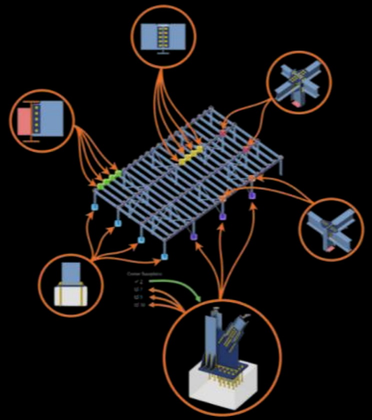
Connection + Detail

Complete base plate workflow including steel and concrete reinforcement design to avoid concrete breakout



Checkbot

Integration of 3rd party apps analysis models or BIM models with IDEA StatiCa applications



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