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SPECIAL CONCENTRIC BRACED FRAME CONNECTIONS

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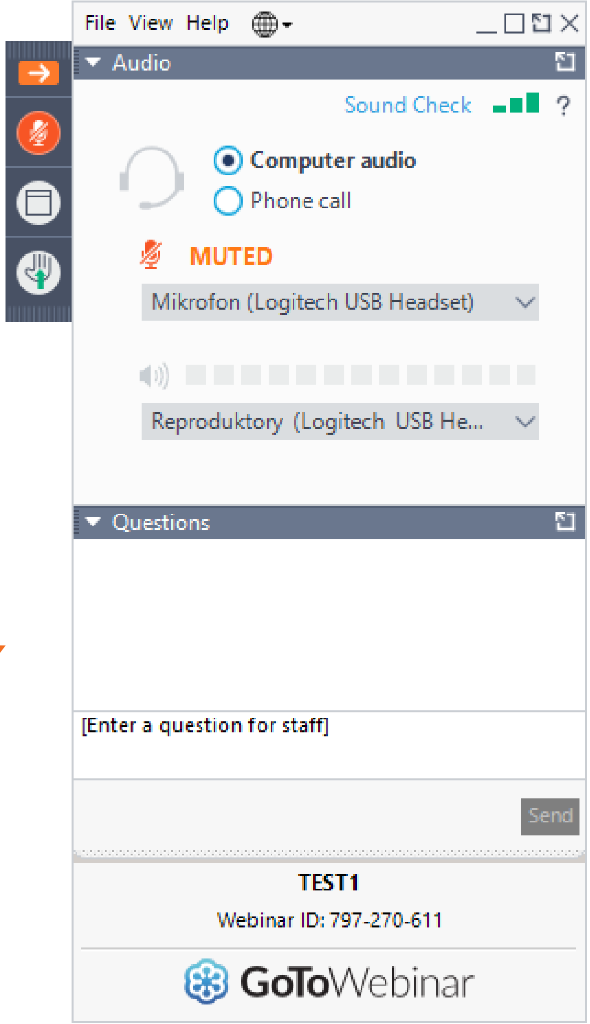
QUESTIONS

HANDOUT AVAILABLE



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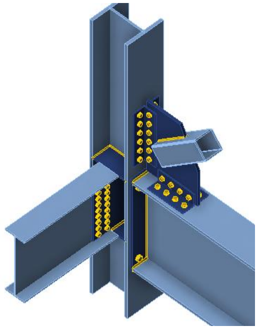
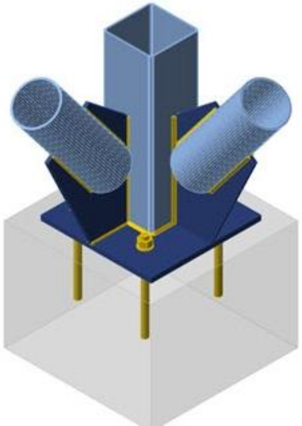
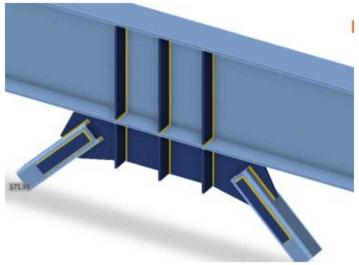
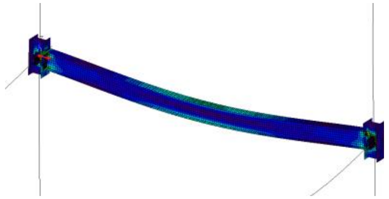
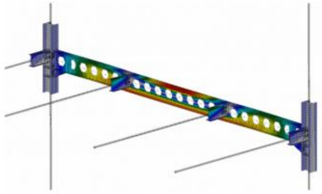
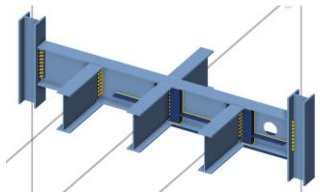
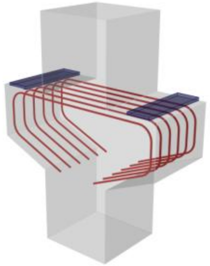
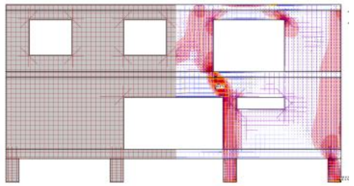
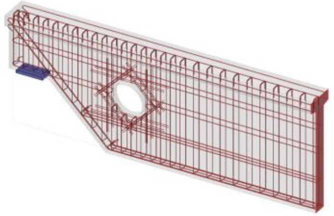
Connection
Steel

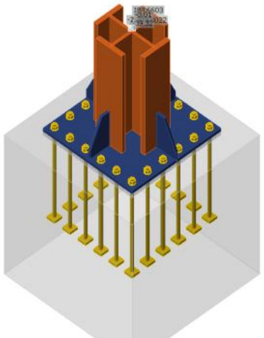
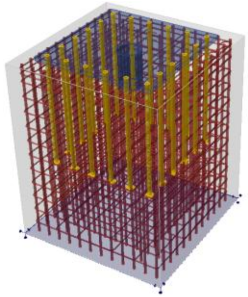
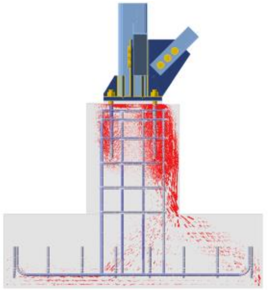
Member
Steel

Detail
Concrete

Connection + Detail
Steel + Concrete

AGENDA

Intro

AISC 341 braced frame systems

SCBF connection design in IDEA StatiCa – live demo

Verification studies

Q&A

FRIENDLY REMINDER

This is a summary of the requirements and details for SCBF connections, we encourage you to always review the actual standards and examples in the AISC 341 and Seismic Design Manual

IDEA StatiCa is a tool that should be used in tandem with AISC seismic provisions

Use your engineering judgement and experience

AISC 341 – SEISMIC FORCE-RESISTING SYSTEMS (SFRS)

Moment frame	• OMF, IMF, SMF, STMF, OCCS, SCCS
Braced frame and shear walls	• OCBF, **SCBF**, EBF, SPSW
Composite moment frame	• C-OMF, C-IMF, C-SMF, C-PRMF
Composite braced frame and shear wall	• C-OBF, C-SCBF, C-EBF, C-OSW, C-SSW, C-PSW/CE, C-PSW/CF, CC-PSW/CF

POLL

SCBF – SPECIAL CONCENTRICALLY BRACED FRAME

AISC Chapter F2.1 – The design is meant to provide significant inelastic deformation capacity primarily through **brace buckling in compression and yielding of the brace in tension**

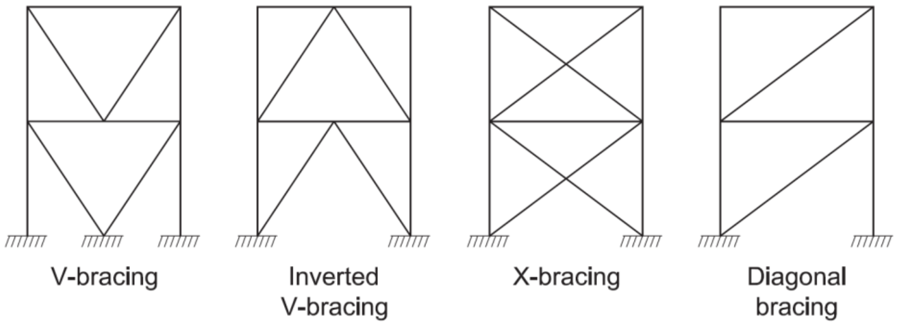


Fig. C-F2.1. Examples of concentric bracing configurations.

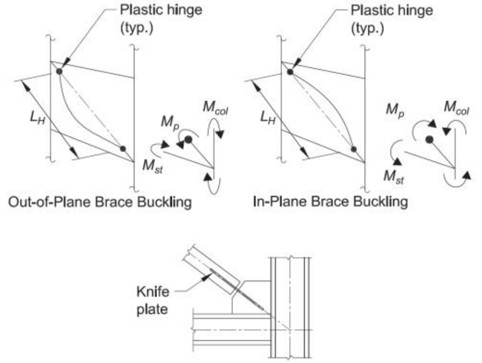


Fig. C-F2.6. Forces induced by buckling of the braces.

SCBF CONNECTIONS

Beam to column connections

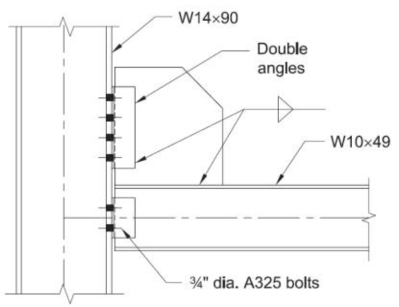


Fig. C-F2.15. Beam-to-column connection that allows rotation (Stoakes and Fahnestock, 2010).

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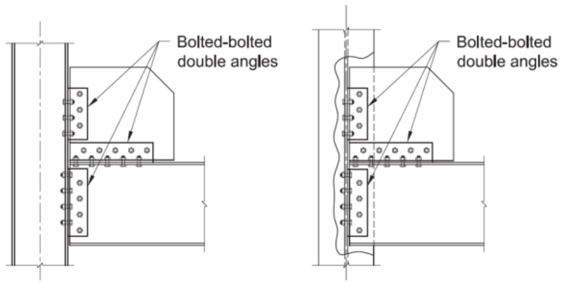

(a) All-bolted unstiffened gusset connection to column flange

(b) All-bolted gusset connection to column web

Fig. C-F2.16. All-bolted beam-to-column connection that allows rotation (McManus et al., 2013).

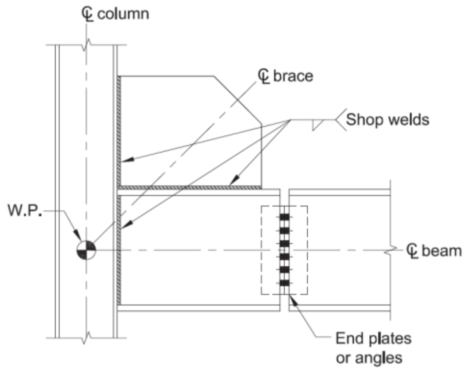

Fig. C-F2.17. Beam-to-column connection that allows rotation (Thornton and Muir, 2008).

Brace connections

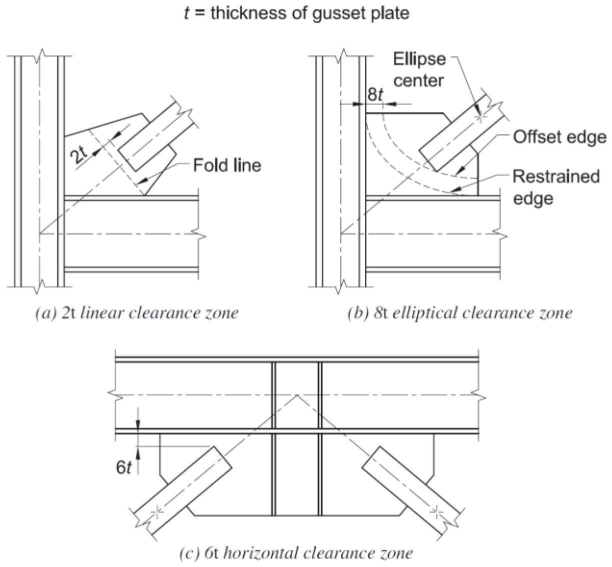

Fig. C-F2.18. Brace-to-gusset plate requirement for buckling out-of-plane bracing system.

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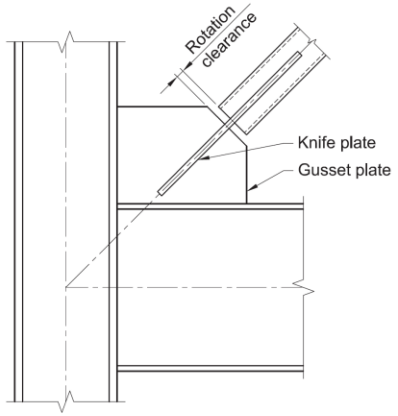

Fig. C-F2.20. Gusset designed for in-plane rotation (Tsai et al., 2013).

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SCBF CONNECTION DESIGN OPTIONS

F2.6b Beam to column connections:

a) **Simple** connections= 0.025 rad

b) **Designed to resists the moment** lesser from 1.1 times the beam or column flexural strength

c) **OMF Fully restrained** Connection

F2.6c Brace connection – accommodation of brace buckling

a) Connections with sufficient flexural resistance such that the end rotation due to brace flexural buckling occurs in the **brace itself**

b) Gusset detailed such that the end rotation **occurs in the connection without loss of strength**

GUSSET DETAILED TO DEFORM

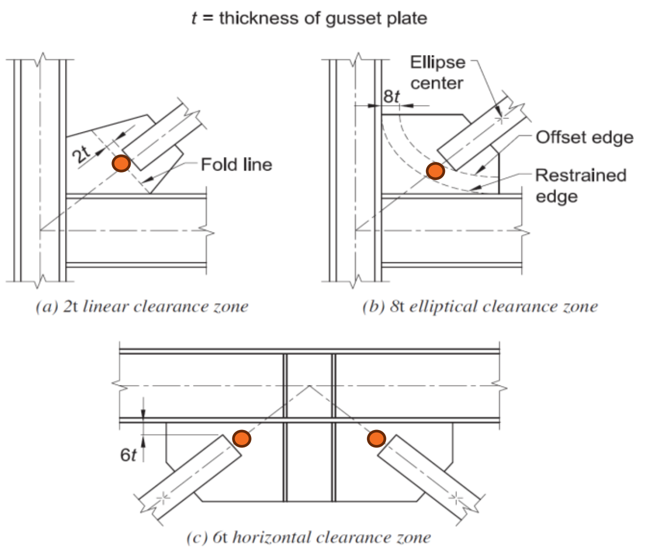

Fig. C-F2.18. Brace-to-gusset plate requirement for buckling out-of-plane bracing system.

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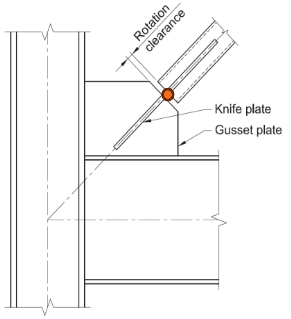

Fig. C-F2.20. Gusset designed for in-plane rotation (Tsai et al., 2013).

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Brace connection

a) Connections with sufficient flexural resistance such that the end rotation due to brace flexural buckling occurs in the brace itself

b) Gusset detailed such that the end rotation occurs in the connection without loss of strength

POLL

AISC DESIGN MANUAL SCBF EXAMPLES

Example	Method of Complying with AISC *Seismic Provisions* Section F2.6b	Method of Complying with AISC *Seismic Provisions* Section F2.6c.3
5.3.10	Detailed to provide rotation per Section F2.6b(a)	Linear hinge zone
5.3.11	Detailed as FR connection per Section F2.6b(c)	Elliptical hinge zone
5.3.12	Designed to resist moments per Section F2.6b(b)	Hinge plate for in-plane brace buckling

Examples 5.3.1 through 5.3.7 address analysis and SCBF member design issues. Examples 5.3.8 and 5.3.9 address brace-to-beam connection design. Example 5.3.13 determines the required forces for a column that is common to intersecting SCBF and SMF systems.

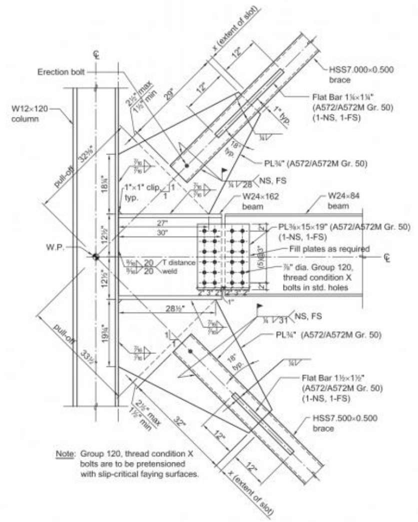
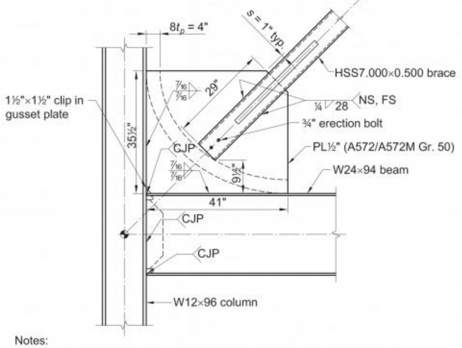


Fig. 5-50. Geometry and completed design for Example 5.3.10.



Notes:
Welds of web and doubler/shear plate to column flange are demand critical.

Fig. 5-62. Rectangular gusset plate with $8t_p$ elliptical brace offset addressed in Example 5.3.11.

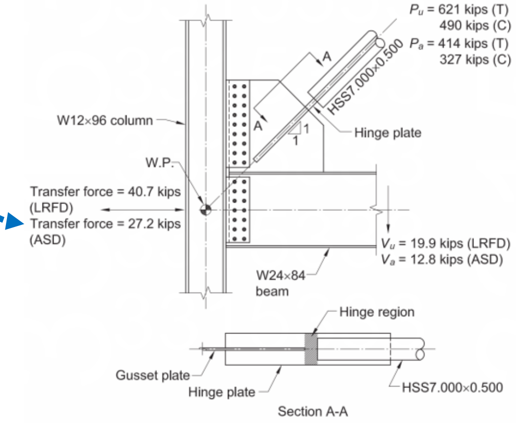


Fig. 5-67. Brace connection to be designed for Example 5.3.12.

EXAMPLES – AISC SEISMIC DESIGN MANUAL 4TH ED.

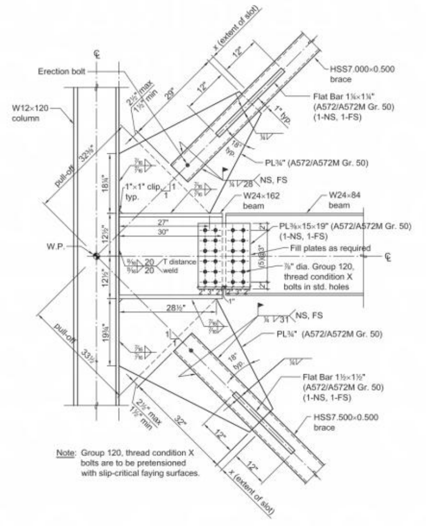


Fig. 5-50. Geometry and completed design for Example 5.3.10.

5.3.10 SCBF Brace-to-Beam/Column Connection Design

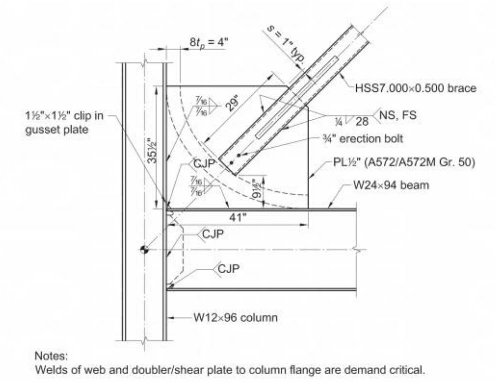


Fig. 5-62. Rectangular gusset plate with 8t_p elliptical brace offset addressed in Example 5.3.11.

5.3.11 SCBF Brace-to-Beam/Column Connection Design with Elliptical Clearance and Fixed Beam-to-Column Connection

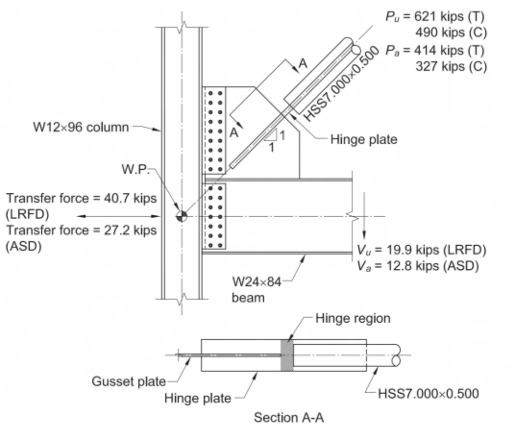
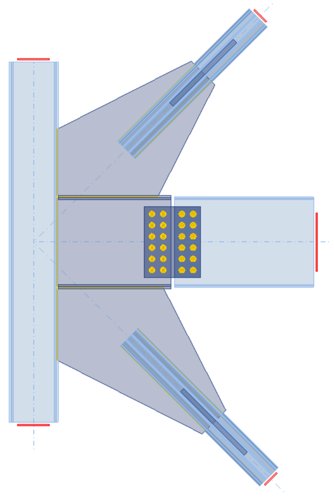


Fig. 5-67. Brace connection to be designed for Example 5.3.12.

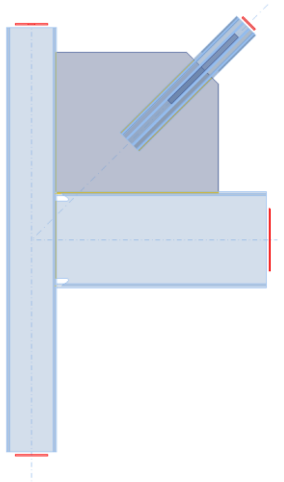
5.3.12 SCBF Brace-to-Beam/Column Connection Design—In-Plane Brace Buckling

EXAMPLES – AISC SEISMIC DESIGN MANUAL 4TH ED.

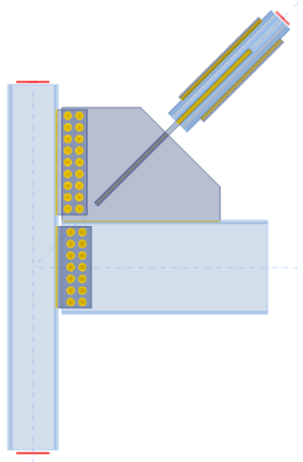


5.3.10 SCBF Brace-to-Beam/Column Connection Design

Modeling from scratch



5.3.11 SCBF Brace-to-Beam/Column Connection Design with Elliptical Clearance and Fixed Beam-to-Column Connection

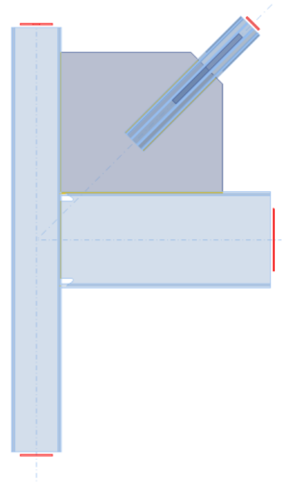


5.3.12 SCBF Brace-to-Beam/Column Connection Design—In-Plane Brace Buckling

Modeling from scratch

EXAMPLES – AISC SEISMIC DESIGN MANUAL 4TH ED.

LIVE DEMO



5.3.11 SCBF Brace-to-Beam/Column Connection Design with Elliptical Clearance and Fixed Beam-to-Column Connection

DESIGN PROCESS FOR EXAMPLE 5.3.11

1. **Select** cross sections for bracing members – AISC
2. Calculate **required strength** for the **bracing members** (from the seismic analysis and capacity-limited strength) – AISC
3. Calculate the initial **gusset geometry** (gusset plate basic geometry depending on the method to use linear hinge, elliptical hinge, out of plane bracing) – AISC
4. Calculate the initial gusset plate **thickness** using the code formula as starting point – AISC
5. Select the type of connection for the beam to column (simple, fully restrained, OMF) – AISC
6. Set up the **model** in IDEA StatiCa
7. Design (stress/strain) the beam to column connection using gravity loads and run a **stiffness analysis** to verify the classification (simple or fully restrained)
8. Select **Capacity design**, Input the loads for the bracing from point 1 and balance them, select the dissipative members.
9. Run 1st iteration – **check the connection** for instance: member failing for the tension case, weld brace to gusset
10. Run 2nd 3, 4 … iterations – Modify the design as needed and run until the connection **passes all the checks**
11. Finally run a **buckling analysis** to prove the buckling happens in the gusset plate

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1. SCBF BRACE DESIGN (AISC)

V_L = 3.00 kips

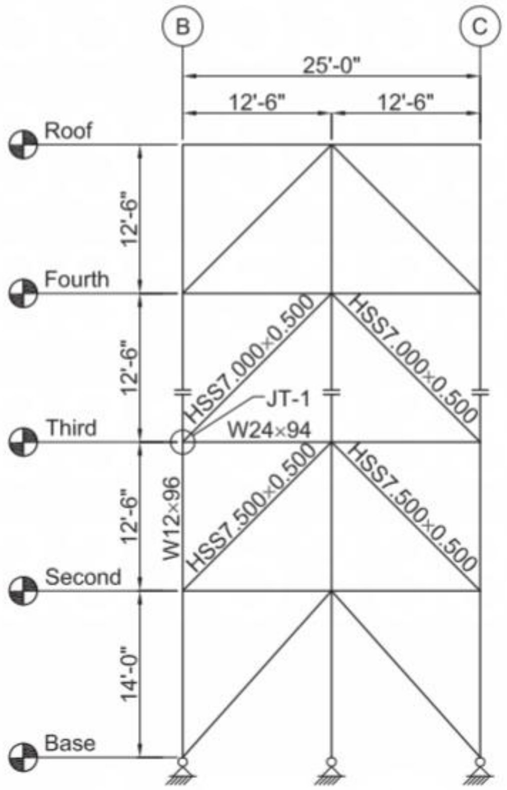

Fig. 5-61. Frame elevation.

2. CALCULATION OF BRACE REQUIRED STENGHT (AISC)

$d = 12.7$ in. $t_w = 0.550$ in. $b_f = 12.2$ in. $t_f = 0.900$ in.
$k_{des} = 1.50$ in.

Required Strength

For the HSS7.000×0.500 brace above the beam, according to AISC *Seismic Provisions* Section F2.3(a), the seismic load effect with overstrength is determined from the expected strengths of the brace in compression and in tension. The expected strengths of the brace are determined as follows.

From AISC *Seismic Provisions* Section F2.3, Table A3.2, and previous examples:

The required tensile strength due to seismic loading is

LRFD	ASD
$P_u = 621$ kips	$P_a = 414$ kips

The required compressive strength due to seismic loading is

LRFD	ASD
$P_u = 490$ kips	$P_a = 327$ kips

The required compressive strength based on post-buckling strength is

LRFD	ASD
$P_u = 147$ kips	$P_a = 98.0$ kips

For the HSS7.500×0.500 brace below the beam, the connection of the brace below the beam is not designed as part of this example for Joint JT-1, but the brace member size is important when considering the analysis provisions of AISC *Seismic Provisions* Section F2.3.

The required tensile strength due to seismic loading is

LRFD	ASD
$P_u = 670$ kips	$P_a = 447$ kips

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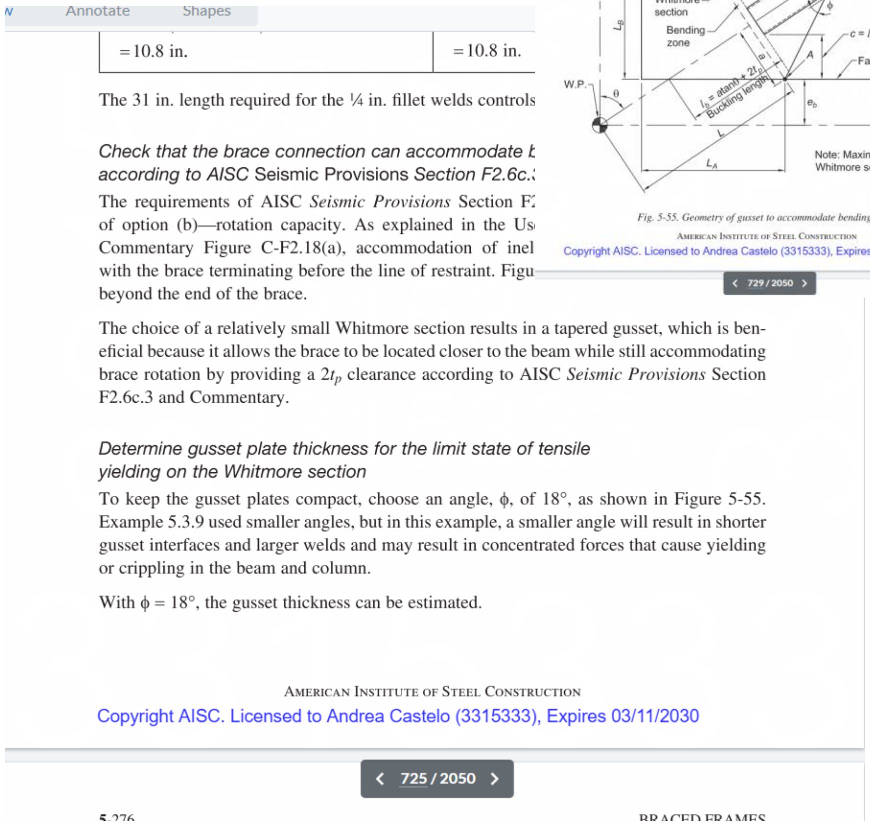
3. GUSSET GEOMETRY (AISC)

Linear clearance


Annotate Shapes

= 10.8 in.	= 10.8 in.

The 31 in. length required for the ¼ in. fillet welds controls

Check that the brace connection can accommodate b… according to AISC Seismic Provisions Section F2.6c.…

The requirements of AISC *Seismic Provisions* Section F… of option (b)—rotation capacity. As explained in the Us… Commentary Figure C-F2.18(a), accommodation of inel… with the brace terminating before the line of restraint. Figu… beyond the end of the brace.

The choice of a relatively small Whitmore section results in a tapered gusset, which is beneficial because it allows the brace to be located closer to the beam while still accommodating brace rotation by providing a $2t_p$ clearance according to AISC *Seismic Provisions* Section F2.6c.3 and Commentary.

Determine gusset plate thickness for the limit state of tensile yielding on the Whitmore section

To keep the gusset plates compact, choose an angle, ϕ, of 18°, as shown in Figure 5-55. Example 5.3.9 used smaller angles, but in this example, a smaller angle will result in shorter gusset interfaces and larger welds and may result in concentrated forces that cause yielding or crippling in the beam and column.

With ϕ = 18°, the gusset thickness can be estimated.

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5-276 BRACED FRAMES

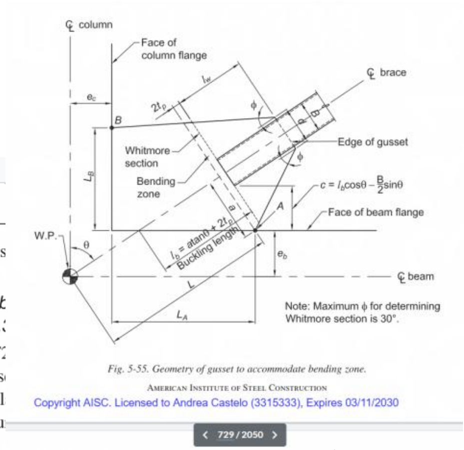

Fig. 5-55. Geometry of gusset to accommodate bending zone.

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Elliptical clearance

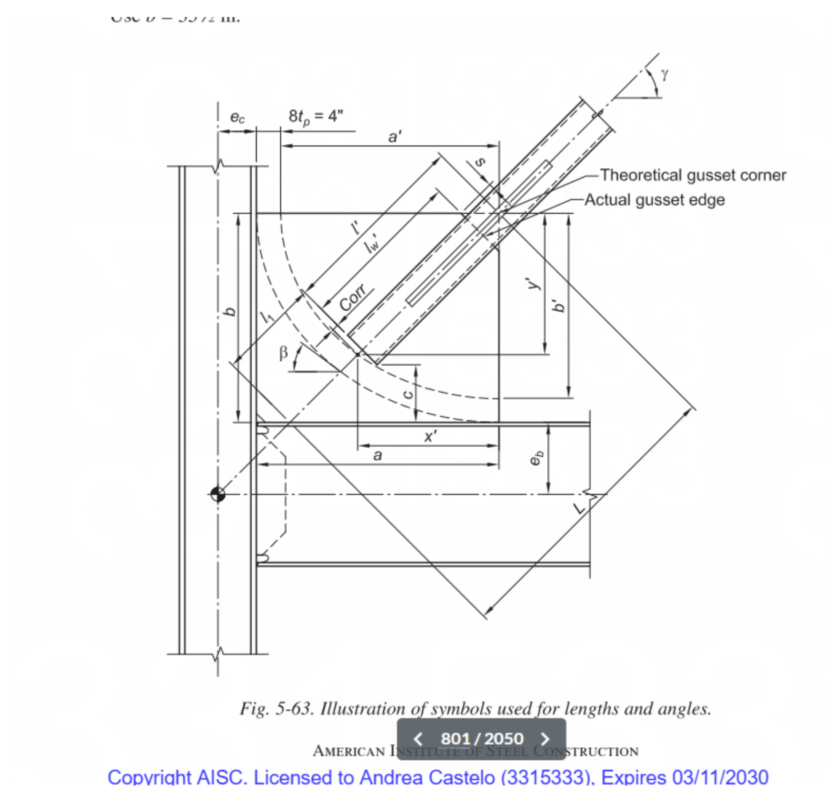

Fig. 5-63. Illustration of symbols used for lengths and angles.

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4. GUSSET PLATE THICKNESS (AISC)

Annotate Shapes

Check required gusset plate thickness based on the limit state of tensile yielding

Tension yielding is checked on a section of the gusset plate commonly referred to as the Whitmore section. This section is explained in AISC *Manual* Part 9 (Figure 9-1) and in Thornton and Lini (2011). The width of the Whitmore section is determined based on a 30° spread.

$$w_p = 2l_w \tan 30° + D$$
$$= 2(28 \text{ in.})\tan 30° + 7.000 \text{ in.}$$
$$= 39.3 \text{ in.}$$

From AISC *Specification* Equation J4-1, the available tensile yielding strength is

LRFD	ASD
$\phi R_n = \phi F_y A_g$ Setting this equal to the required tensile strength of the brace connection, and with $A_g = t_p w_p$, the gusset plate thickness is $t_p = \dfrac{P_u}{\phi F_y w_p}$ $= \dfrac{621 \text{ kips}}{0.90(50 \text{ ksi})(39.3 \text{ in.})}$ $= 0.351$ in.	$\dfrac{R_n}{\Omega} = \dfrac{F_y A_g}{\Omega}$ Setting this equal to the required tensile strength of the brace connection, and with $A_g = t_p w_p$, the gusset plate thickness is $t_p = \dfrac{\Omega P_a}{F_y w_p}$ $= \dfrac{1.67(414 \text{ kips})}{(50 \text{ ksi})(39.3 \text{ in.})}$ $= 0.352$ in.

Try a ½-in.-thick gusset plate.

This calculation does not include any reduction considering that the Whitmore width extends into the web of the column or beam. If the Whitmore width enters into a beam or column web that is substantially thinner than the gusset, there is a potential for web local yielding.

In the configuration selected, the Whitmore width does not intrude into the beam or column web. This can be demonstrated by a geometric evaluation.

Determine geometry of the gusset plate

The determination of the location of the end of the brace shown in the following is based on the methodology described in [obscured] the equations in the following are updated from the reference. The location may also be determined from Kotulka (2007).

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5. SELECTION OF BEAM TO COLUMN CONNECTION TYPE (AISC)

(2) There is no net tension under load combinations including the overstrength seismic load.

(c) Welds at beam-to-column connections conforming to Section F2.6b(c)

6b. Beam-to-Column Connections

Where a brace or gusset plate connects to both members at a beam-to-column connection, the connection shall satisfy one of the following requirements:

(a) The connection assembly shall be a simple connection meeting the requirements of *Specification* Section B3.4a, where the required rotation is taken to be 0.025 rad.

(b) The connection assembly shall be designed to resist a moment equal to the lesser of the following:

(1) A moment corresponding to the expected beam flexural strength, R_yM_p, multiplied by 1.1 and divided by α_s,

where

R_y = ratio of the expected yield stress to the specified minimum yield stress of the beam, F_y

(2) A moment corresponding to the sum of the expected column flexural strengths, $\Sigma(R_yF_yZ)$, multiplied by 1.1 and divided by α_s,

where

R_y = ratio of the expected yield stress to specified minimum yield stress of the column, F_y

Z = plastic section modulus of the column, in.^{3} (mm^3)

This moment shall be considered in combination with the required strength of the brace connection and beam connection, including the diaphragm collector forces determined using the overstrength seismic load.

(c) The beam-to-column connection shall meet the requirements of Section E1.6b(c).

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IDEA StatiCa DESIGN PROCESS

- Set up the **model** in IDEA StatiCa
- Design (stress/strain) the beam to column connection using gravity loads and run a **stiffness analysis** to verify the classification (simple or fully restrained)
- Select **Capacity design**, Input the loads for the bracing from point 1 and balance them, select the dissipative members.
- Run 1st iteration – **check the connection** for instance: member failing for the tension case, weld brace to gusset
- Run 2nd 3, 4 … iterations – Modify the design as needed and run until the connection **passes all the checks**
- Finally run a **buckling analysis** to prove the buckling happens in the gusset plate

AISC 341	IDEA StatiCa
Design connection elements for expected strength	Capacity design
Design beam to column connection to accommodate demands corresponding to large drifts	Stiffness analysis
Gusset design: Linear and elliptical hinge zone, hinge plate	Advanced operations to model special gusset geometry, parametric design
Design the brace end condition to maintain its integrity as the brace buckles	Buckling analysis

AISC 341	IDEA StatiCa
Design connection elements for expected strength	Capacity design
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Gusset design: Linear and elliptical hinge zone, hinge plate	Advanced operations to model special gusset geometry, parametric design
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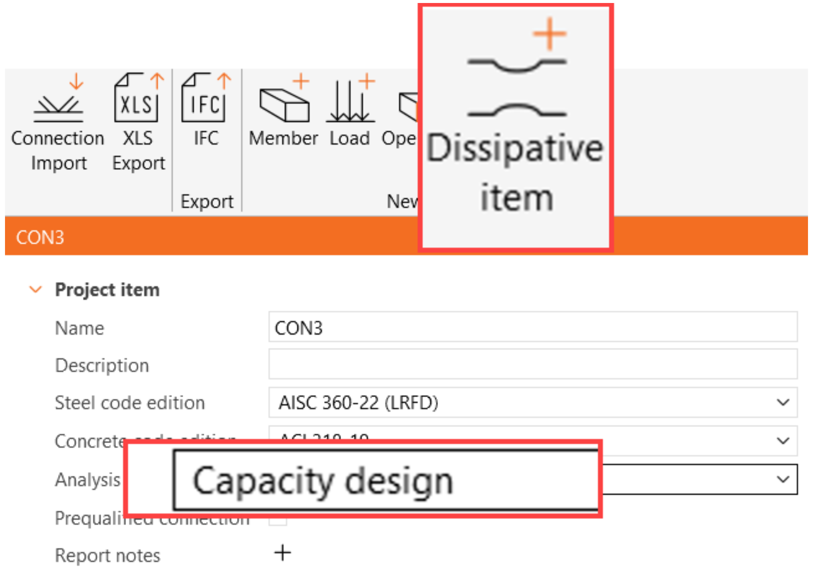

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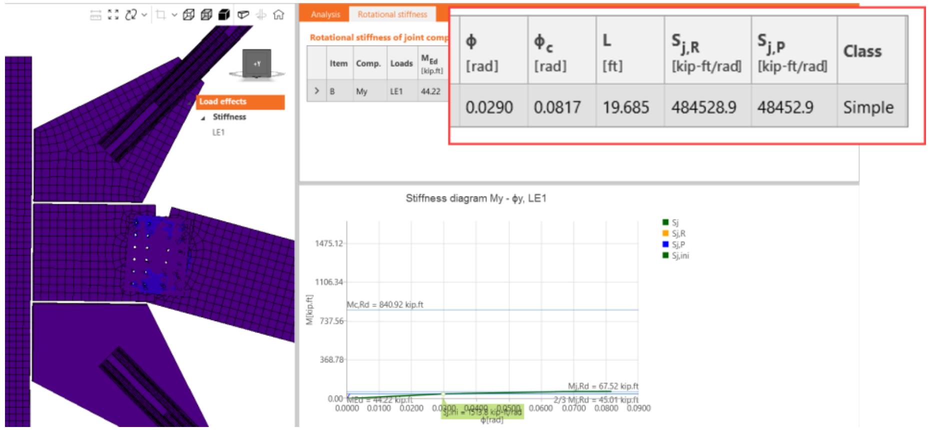

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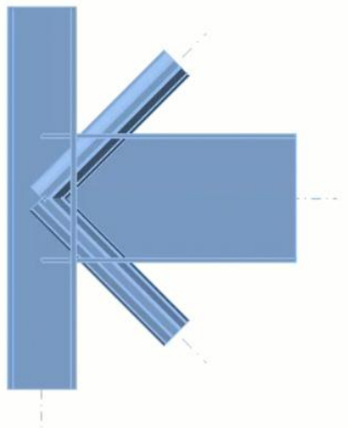

AISC 341

IDEA StatiCa

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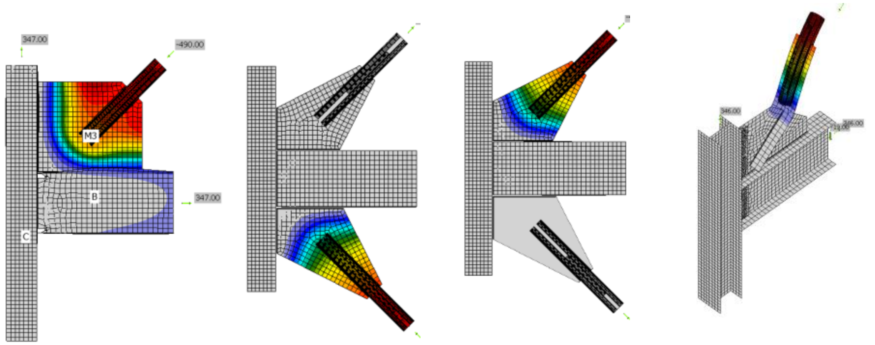
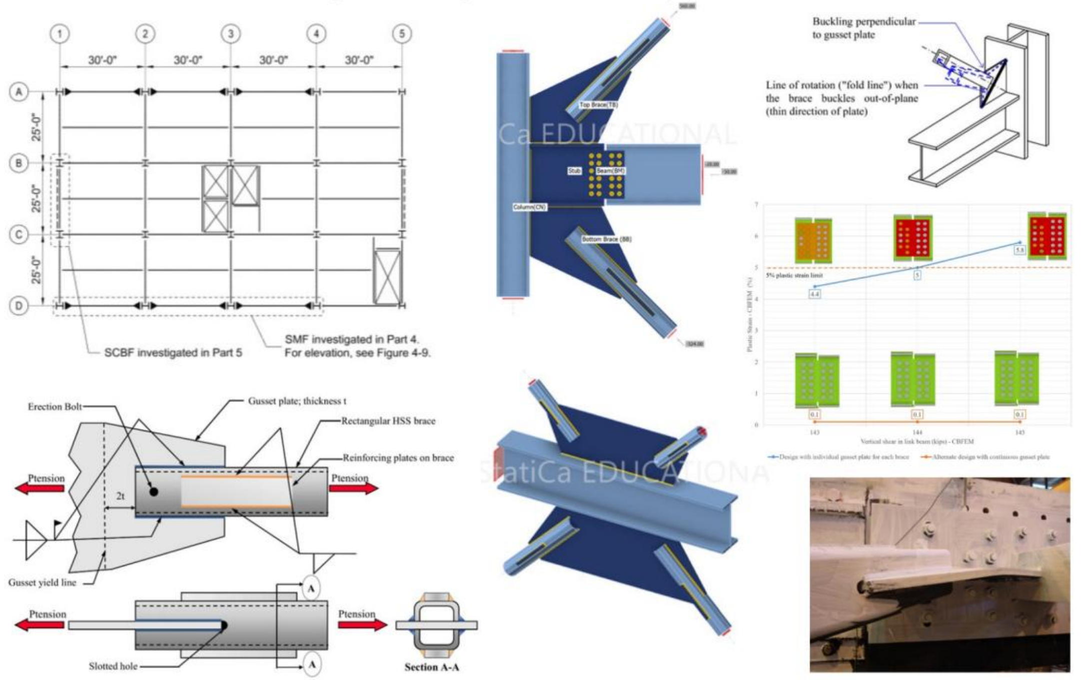


SCBF VERIFICATION STUDIES COMING SOON

Evaluation of CBFEM for bracing connections in three storey building with Special Concentrically Braced System (SCBF) as per AISC 360 and 341



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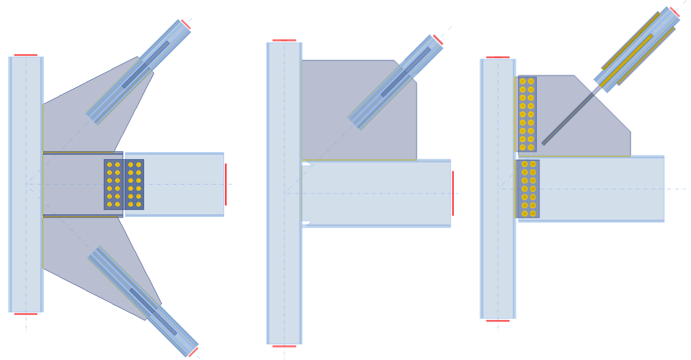
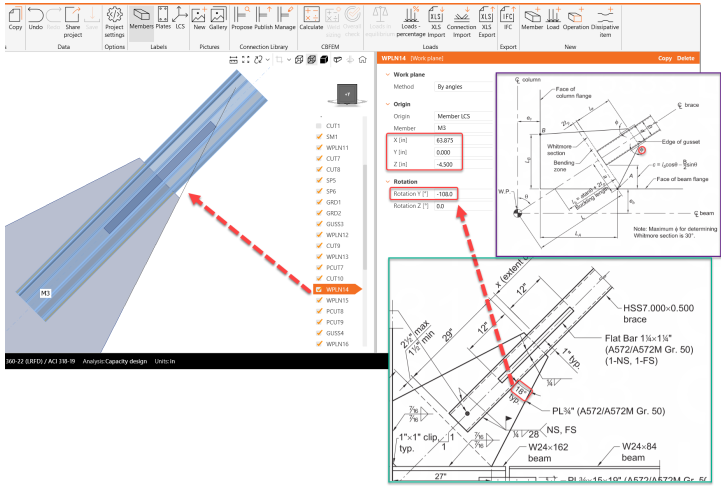
Authors

- **Mustafa Mahamid, PhD,** Research Associate Professor, Civil Engineering, University of Illinois at Chicago
- **Satyam Bhosale**, Project Engineer at Southern Steel Engineers, LLC (USA), and Former M.S. Student at the University of Illinois at Chicago

Q&A





[Trial version for 14 days]

[Download the sample models]

[Reach out for a demo]

UPCOMING EVENTS 2025

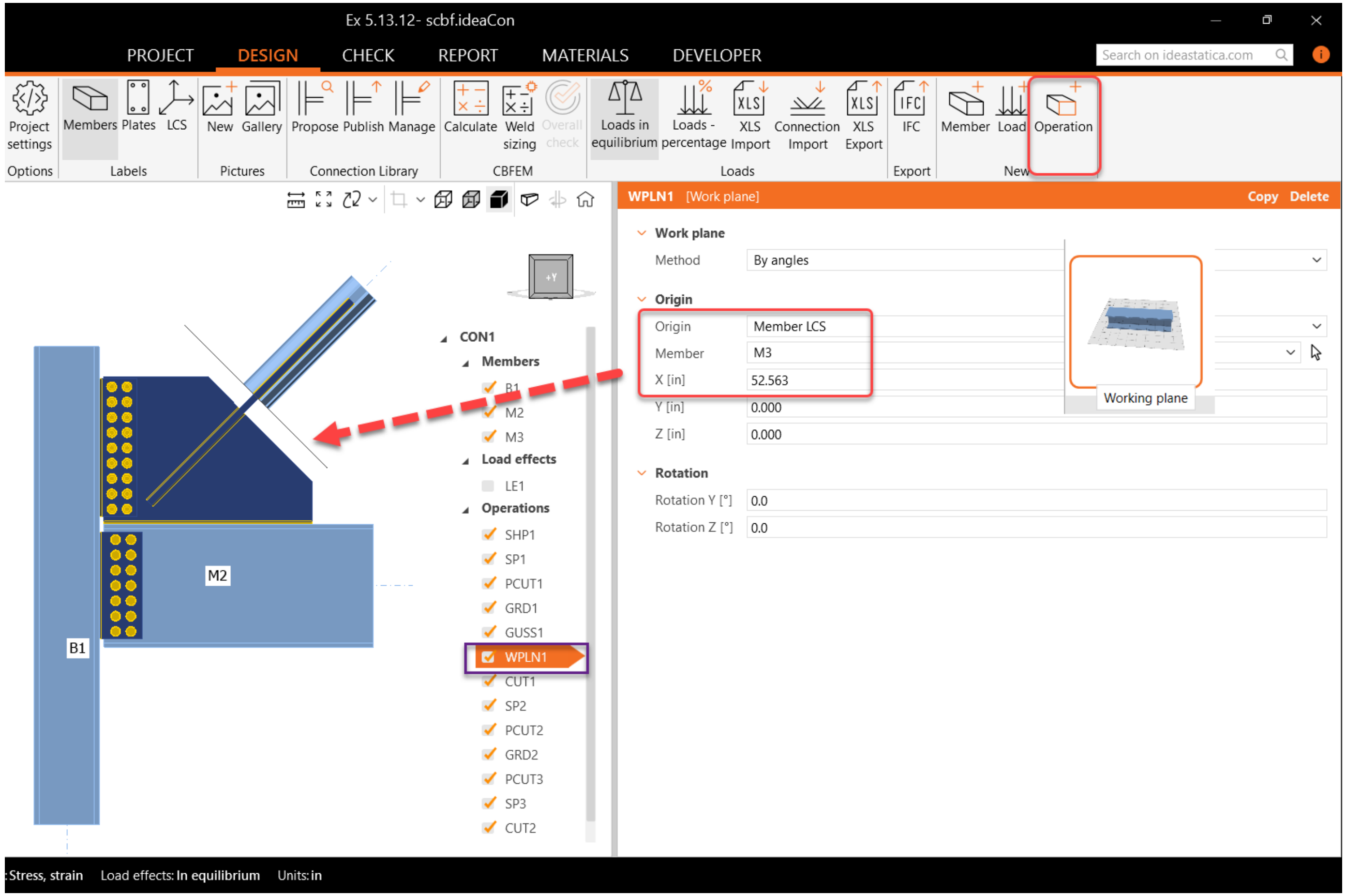
Sept 3-5	SEA of California, San Diego
Sept 17	SEA of Ohio, Columbus
Sept 18	SEA of North Carolina, Raleigh
Sept 24	NCSEA Webinar - *Integration for base plate design and anchor reinforcement*
Sept 25-26	SEA of North West, Spokane, WA
Oct 14-17	NCSEA Structural Engineering Summit, New York
Oct 15-16	Build Forward Conference / SDS2 Summit, Omaha, NE
Oct 26-29	ACI Concrete Convention Fall 2025, Baltimore, MD
Oct 28-29	2025 HSS Summit (Steel Tube Institute), Dallas, TX

APPENDIX

Tips for modeling SCBF Connections in IDEA StatiCa

WORKING PLANES FROM MEMBER LOCAL AXIS

The working plane operation help us to pull off the member from the node



GUSSET PLATE TAPERED DESIGN

Working planes from the member local axis

Use angle rotations

Later use a plate cut to form the tapered gusset plate

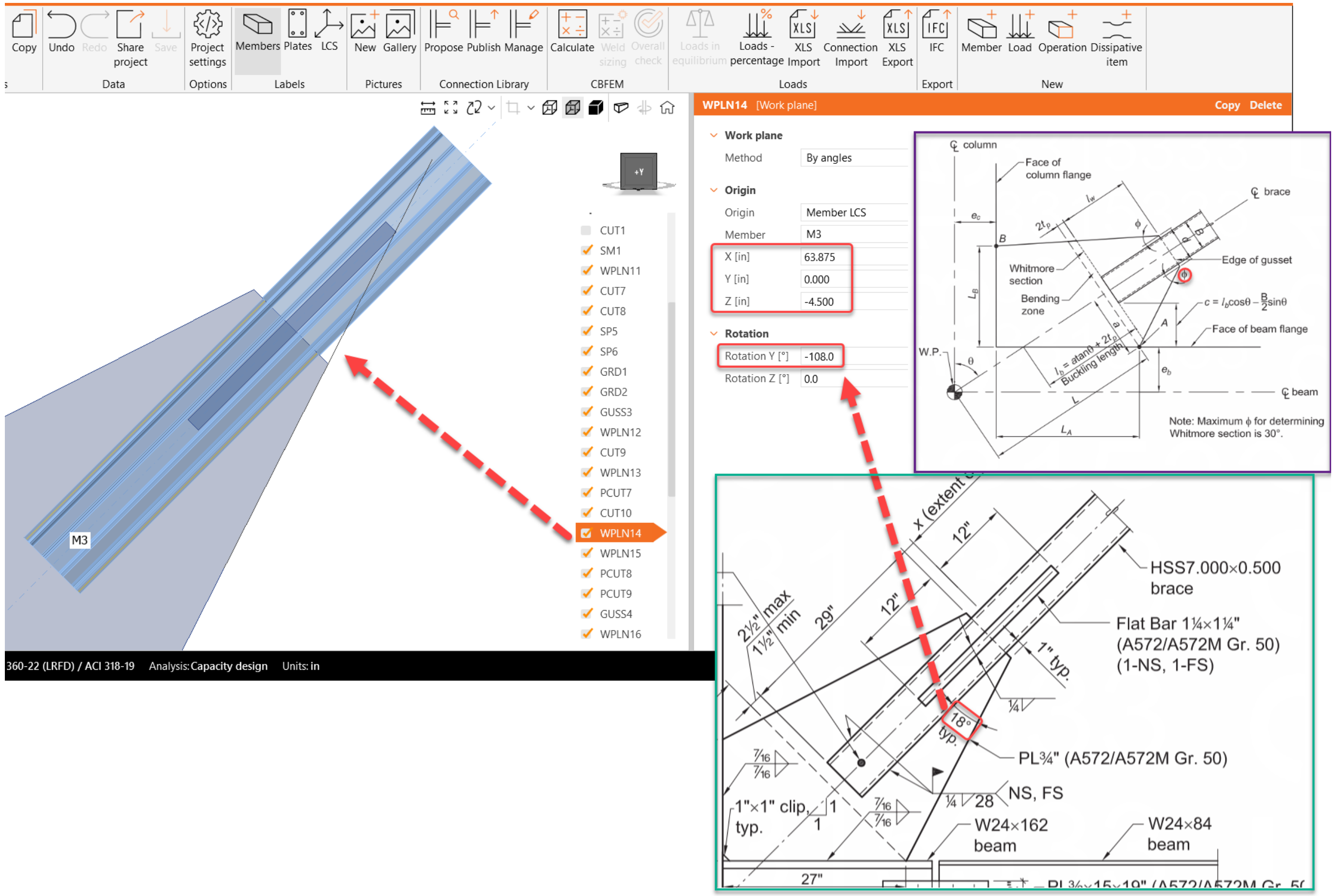
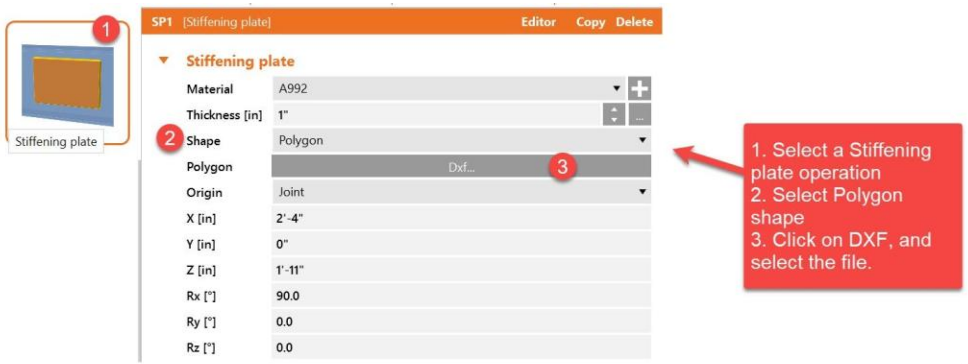
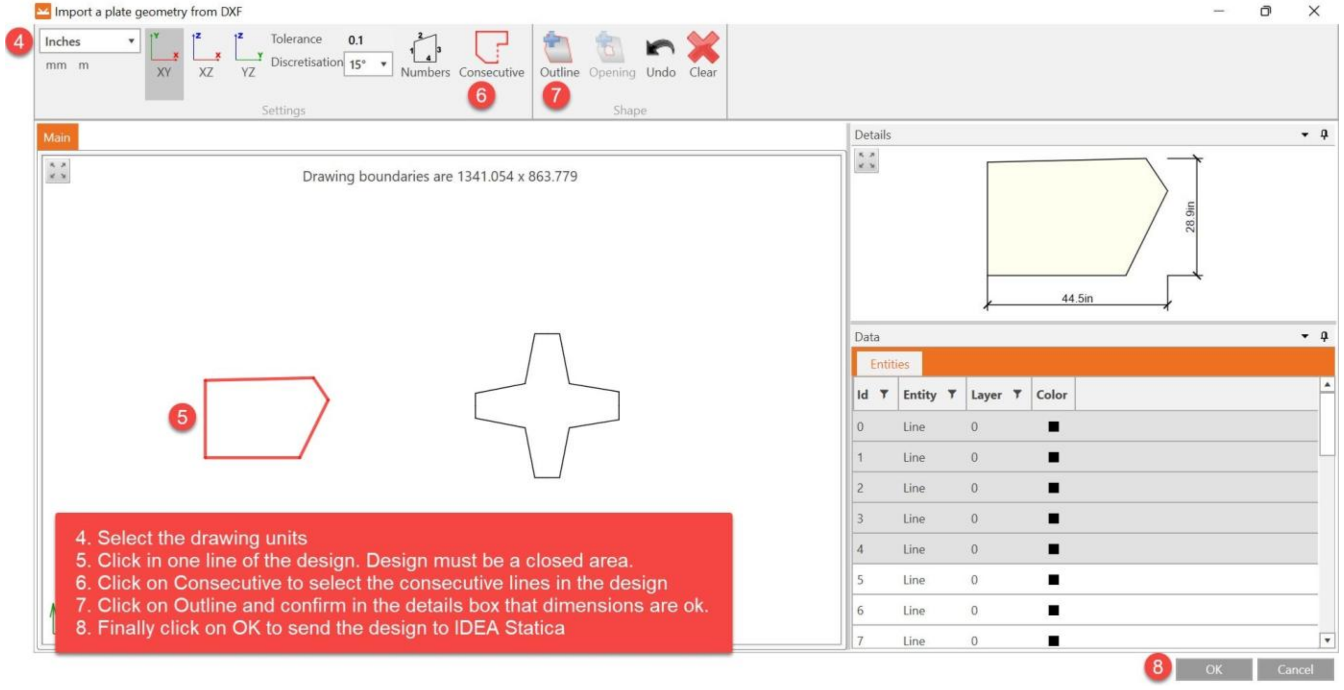


PLATE SHAPE IMPORT FROM A CAD FILE

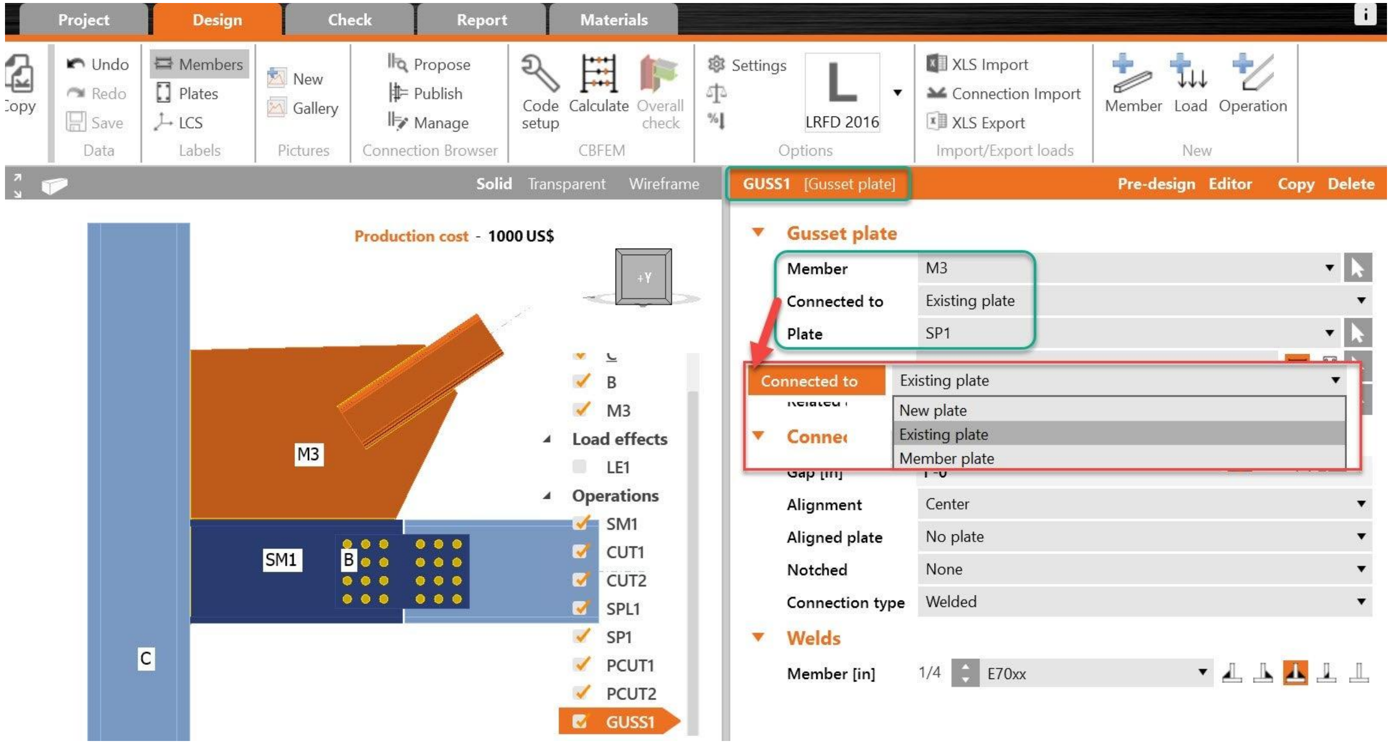
Import a DXF drawing with a specific plate design and use it for the gusset plate





GUSSET PLATE OPERATION: EXISTING PLATE

When using a gusset plate operation, the operation itself can create a new plate, but if there is the case that the plate is already in the model, the option of the **existing plate** in the model.



STIFFNESS ANALYSIS IN IDEA STATICA
STEP BY STEP

Tutorial

1. Perform Stress/strain analysis first, to ensure correct modeling

2. Copy the connection and change the analysis type to Stiffness analysis

3. Select the analyzed member, only one member in the joint can be analyzed

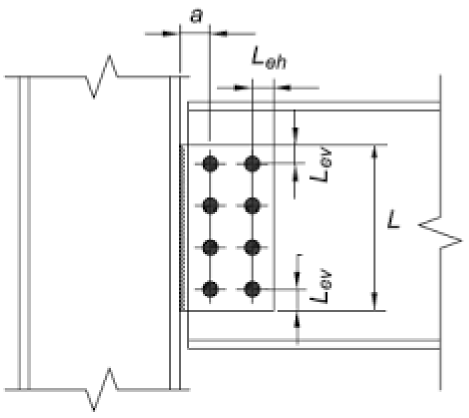
4. Input moment force/axial force, depending what value of stiffness is needed. It is recommended to input only one force in the analyzed member

5. Calculate and review results

IDEA StatiCa®

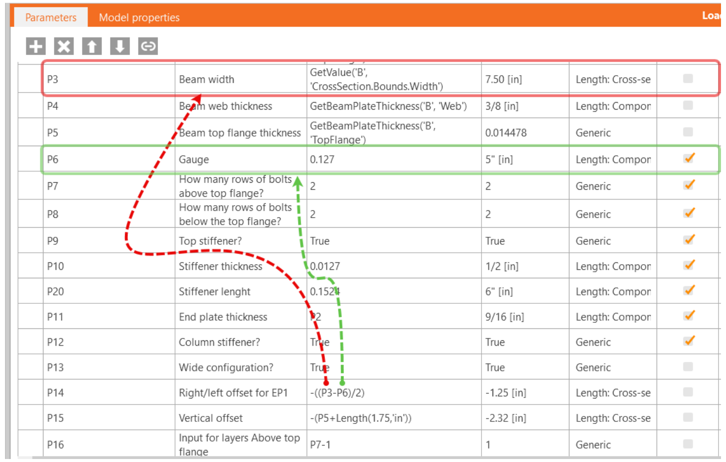
PARAMETRIC TEMPLATES

[Tutorial: Parametric design in IDEA StatiCa Connection - Flush moment end plate connections]

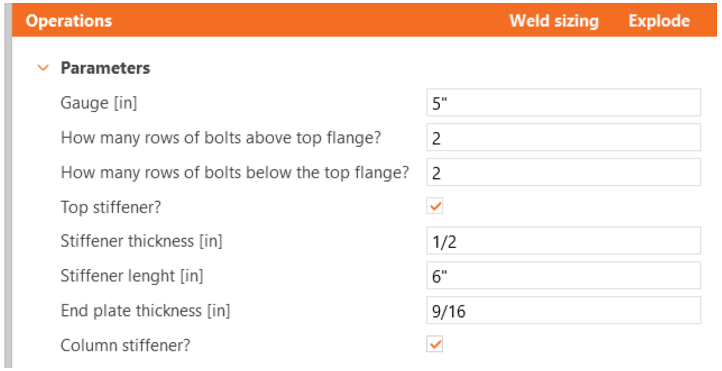


Custom company connections

Common company details



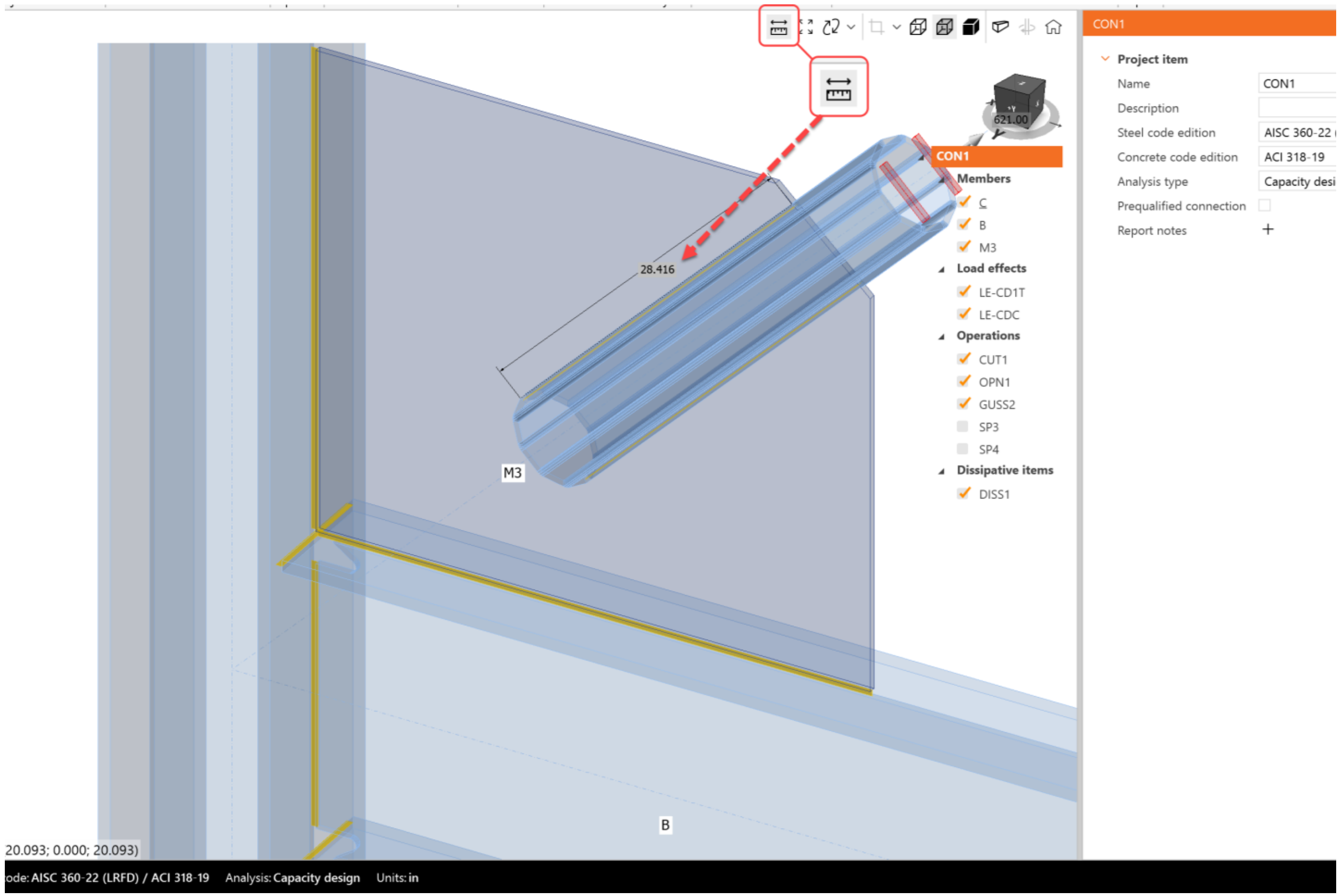
Smart templates



Avoid learning curve for simple connections

MEASURE TOOL

Use the measure tool to get distances between points, edges and surfaces



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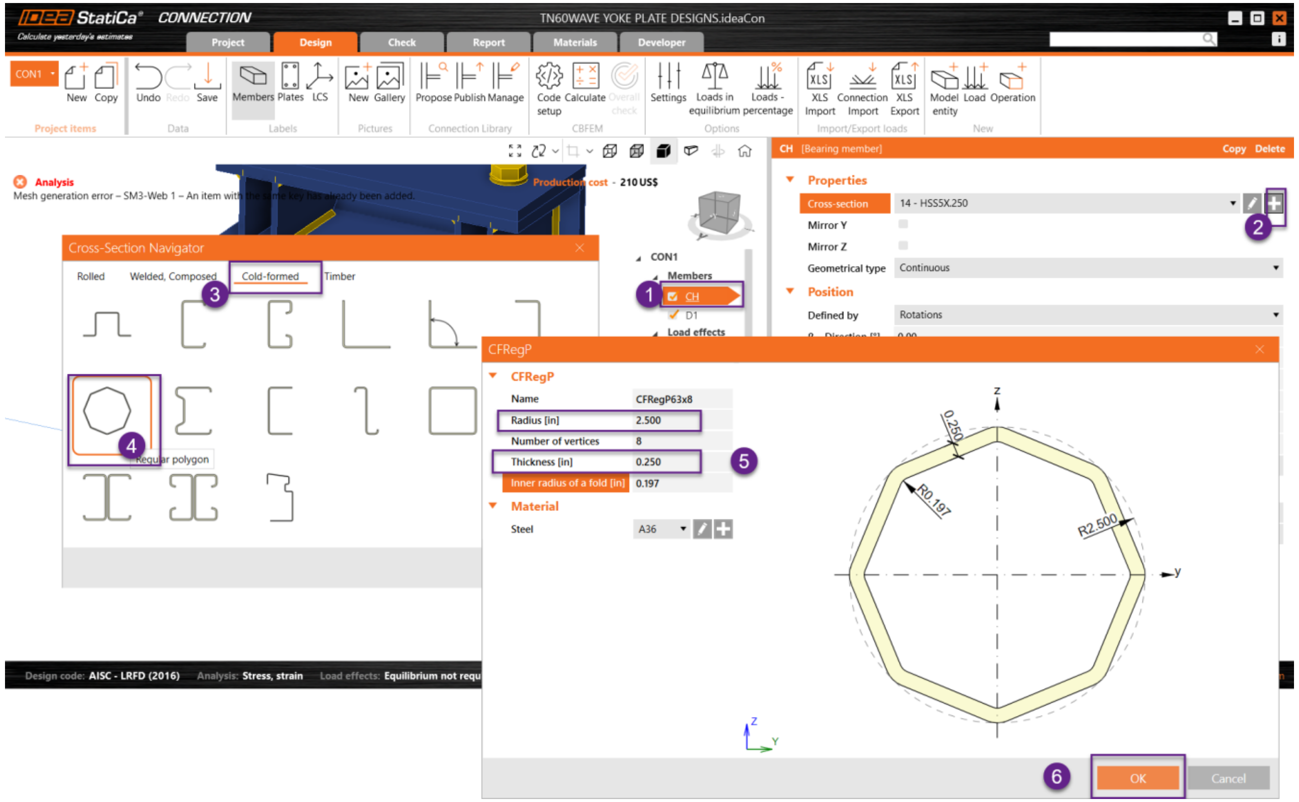
USE OF POLYGON SHAPE TO REINFORCE THE MEMBER

When using HSS sections, the members are break out in vertical thin plate strips.

However, you cannot place HSS reinforcement in those stips. The workaround is to use a hollow section polygon under the cold-formed database. With that type of section, the plates are workable.

Note: Make sure you input the correct design thickness



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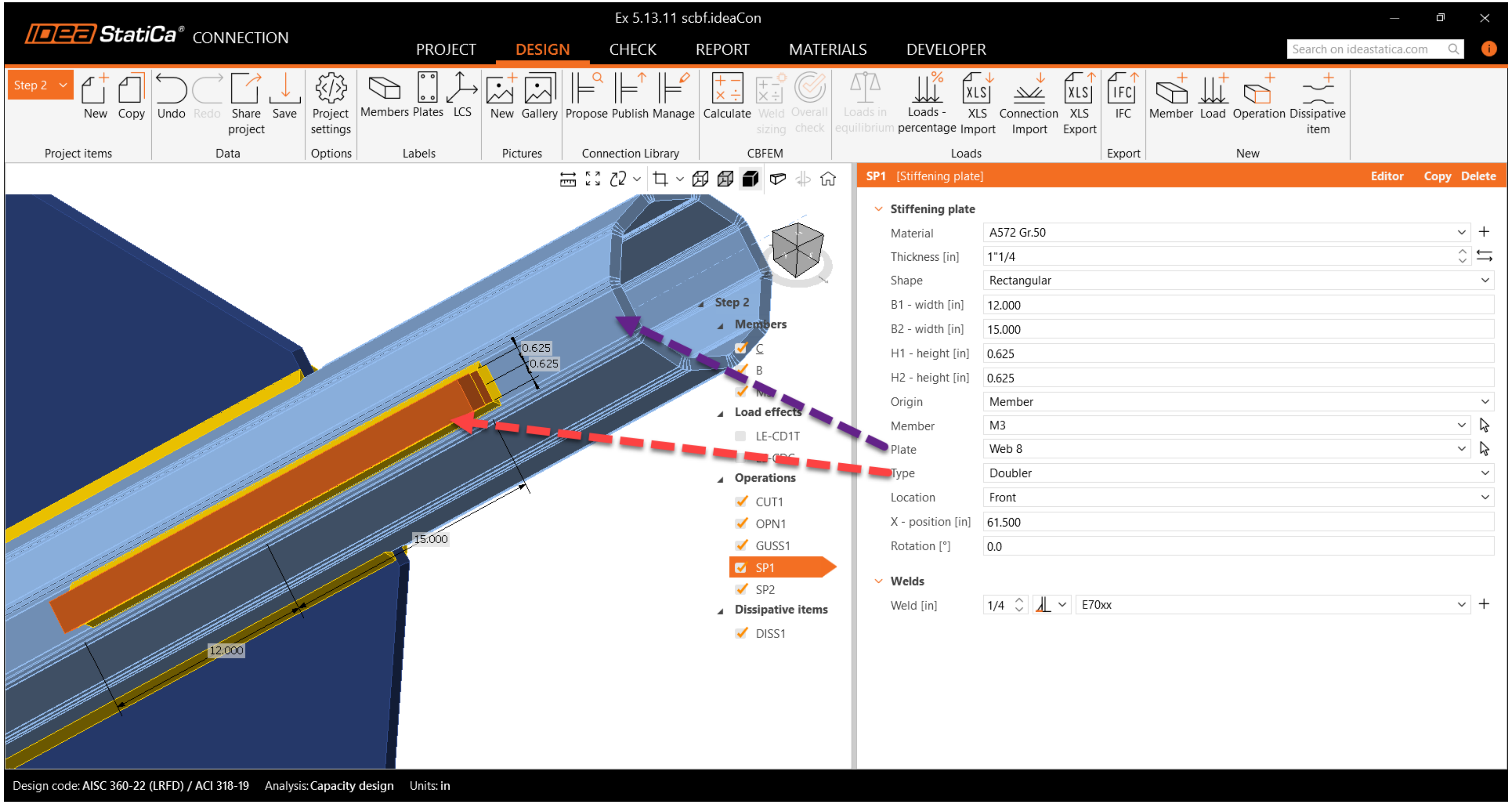
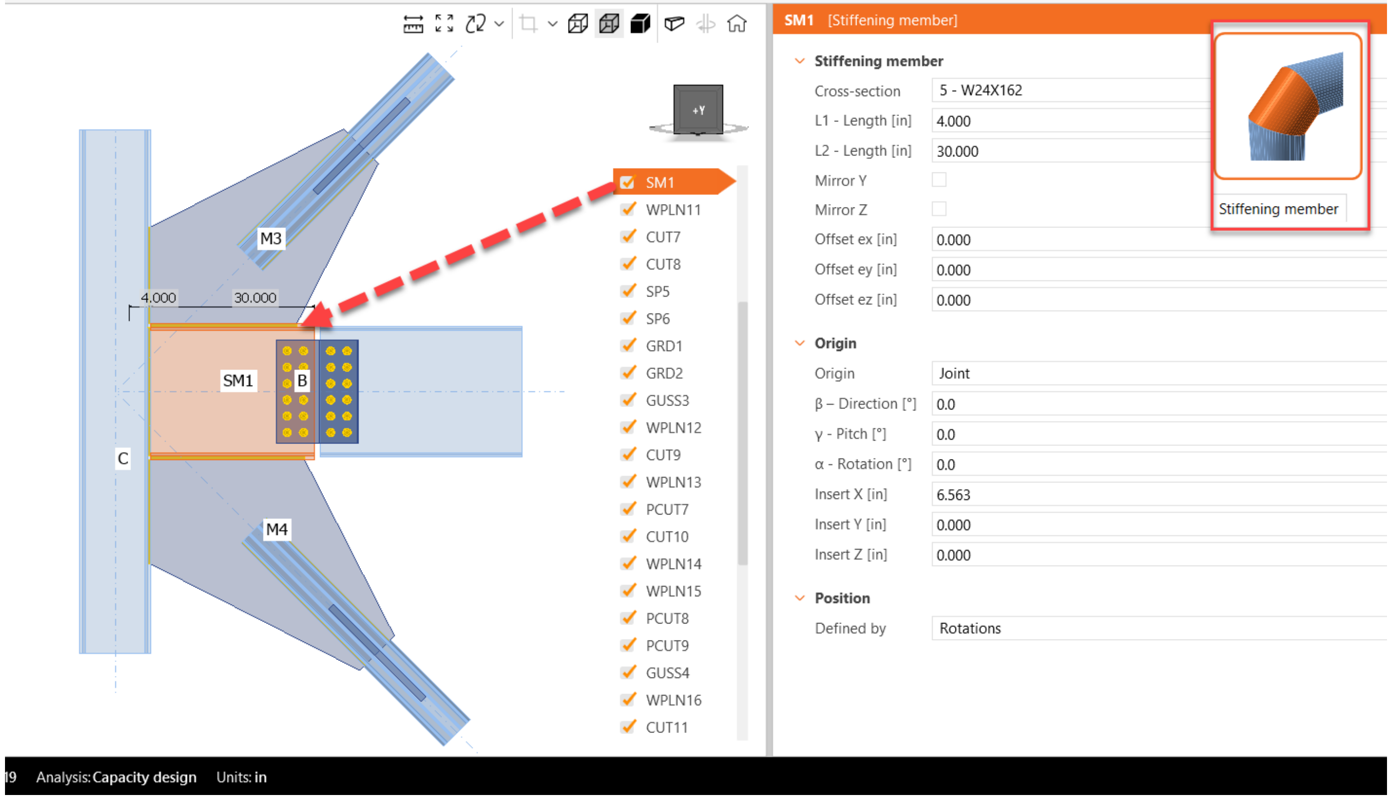
REINFORCING PLATE: STIFFENING PLATE AS A DOUBLER

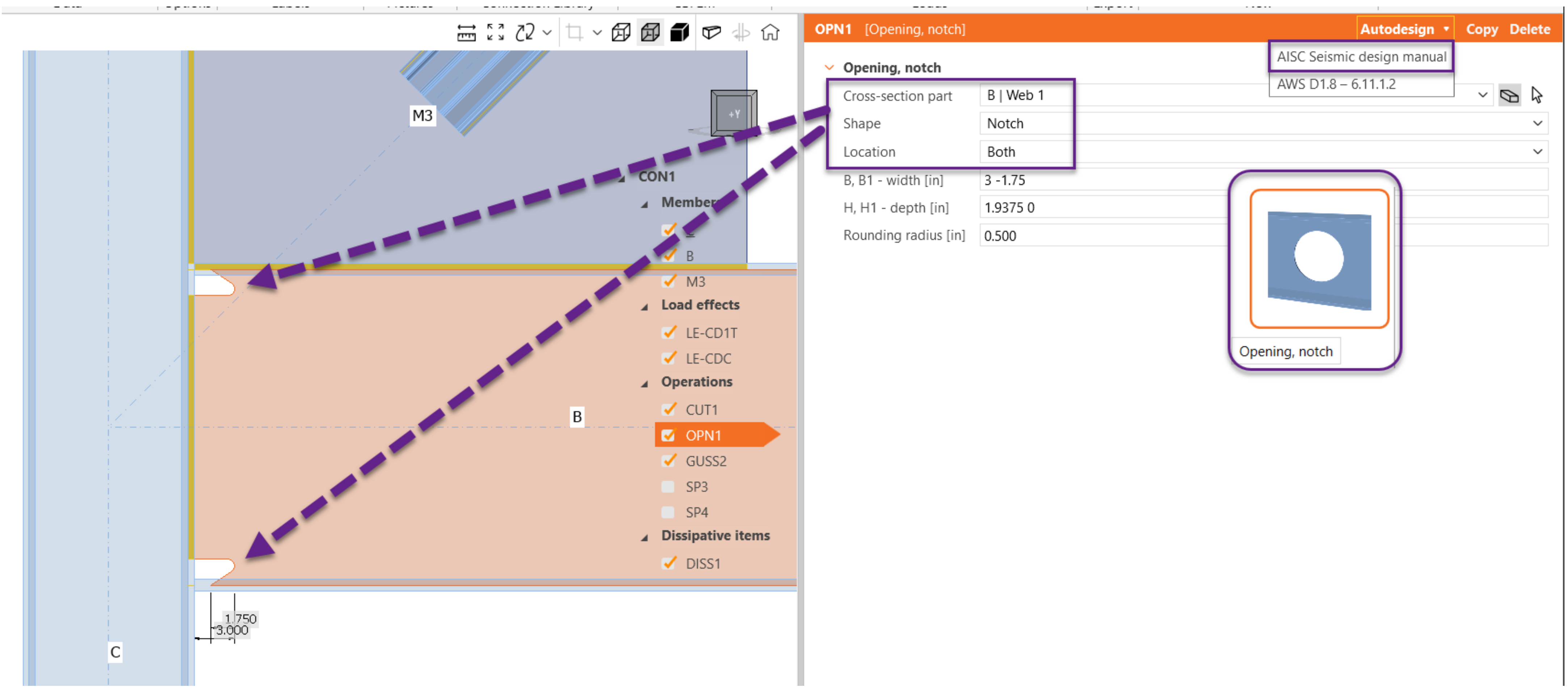


STIFFENING MEMBER FOR SHEAR CONNECTION OUT OF THE JOINT

A stiffening member is an operation that helps to add a member in the model to be part of the connection. One of the keys to using a stiffening member is that you can not directly apply load to it. This operation helps in the next examples:



BEAM NOTCH AUTO DESIGN: AISC



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BUCKLING ANALYSIS IN IDEA STATICA

https://www.ideastatica.com/webinars/linear-buckling-analysis-for-steel-connection-design

1. Design the connection

- Run regular stress/strain analysis and verify you comply with all the code checks

2. Run Buckling analysis

- Go to Check tab>Calculate>Buckling

3. Analyze results and decide

- Review the mode shapes and buckling load factors
- Compare against recommended factors
- Higher than recommended factor?

4. Re-iterate until Buckling is OK

- If the connecting elements are under the recommended factors, use your engineering judgement to decide the solution

IDEA StatiCa®

BUCKLING ANALYSIS SUMMARY

IDEA StatiCa connection uses linear buckling analysis to provide a buckling factor only and recommended limit factors are provided

The recommended limit factors ensure the non-slender design of connection plates

Buckling analysis in IDEA StatiCa is a tool

It doesn’t provide pass/fail result

Use your engineering judgement and experience to decide the design solution

Before running the analysis, make sure loads and the connection design is OK