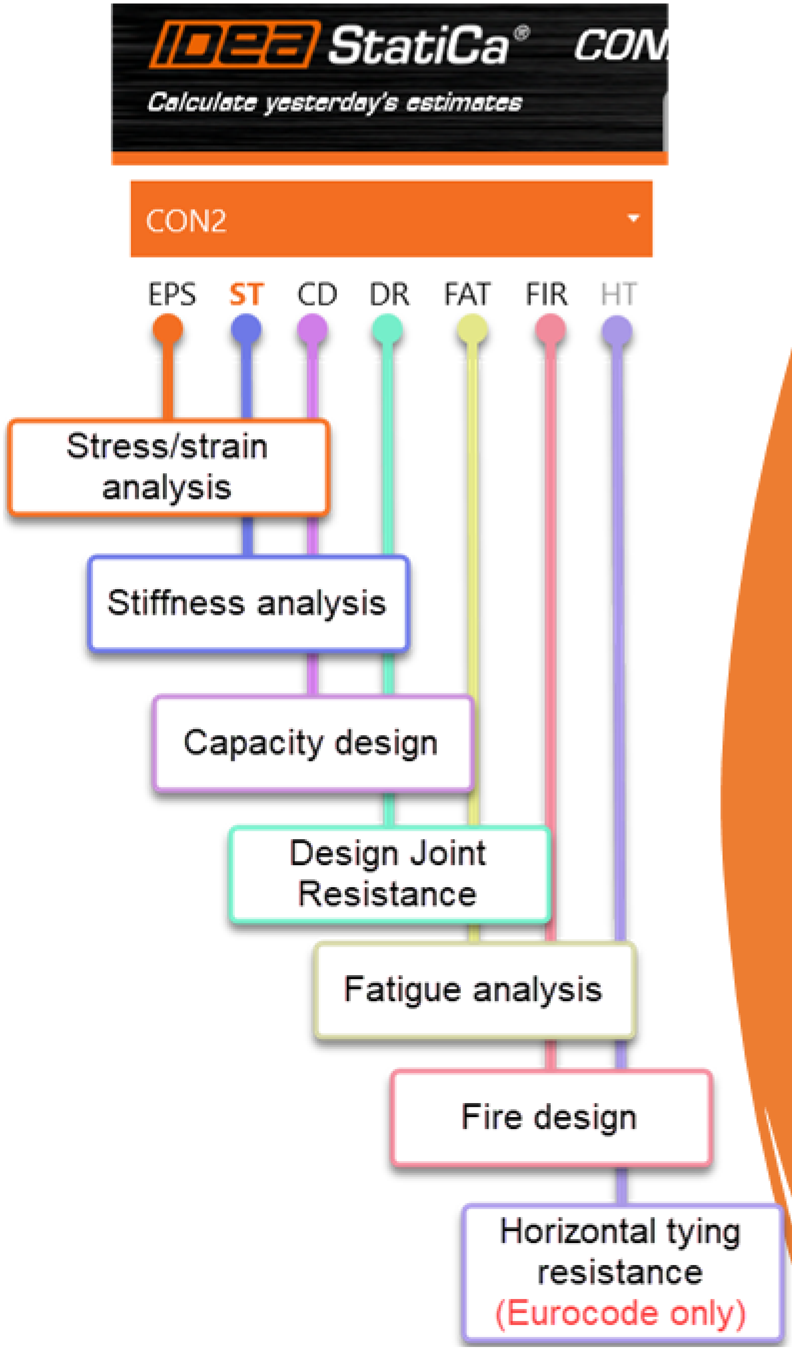


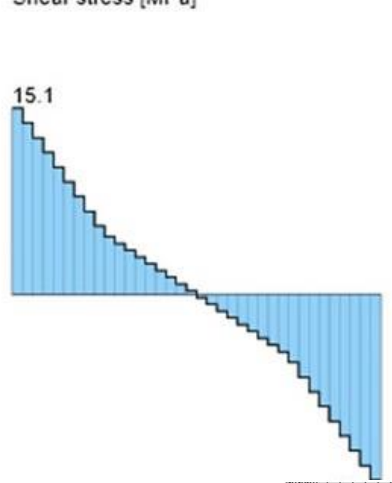
Analysis types for Steel Connection Design

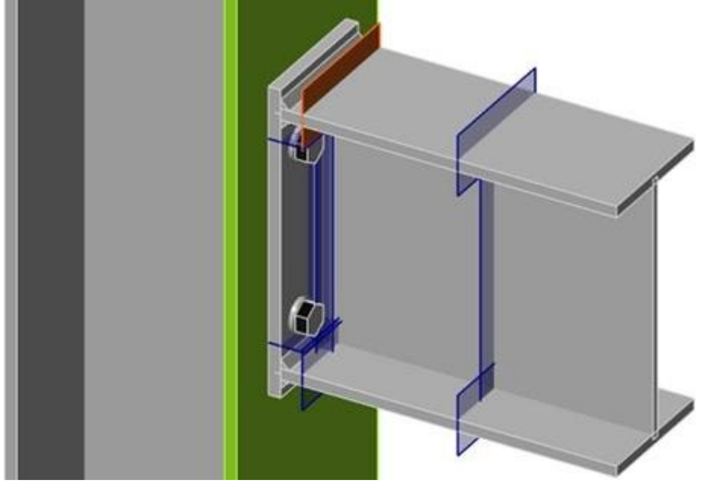
November 30th

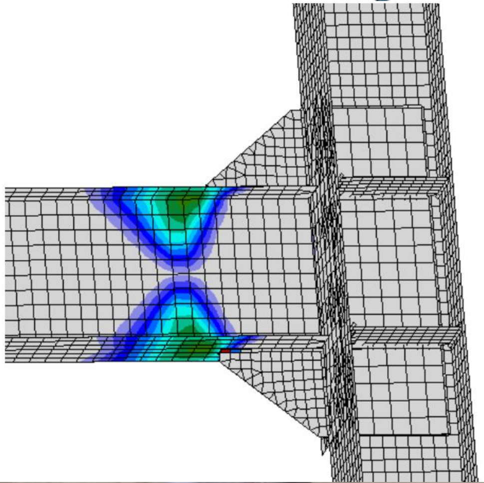
12:00 pm EST

Agenda

- Buckling analysis
- Design resistance
- Stiffness analysis
- Capacity design
- Fatigue analysis
- Fire design
- [Horizontal Tying resistance](#)

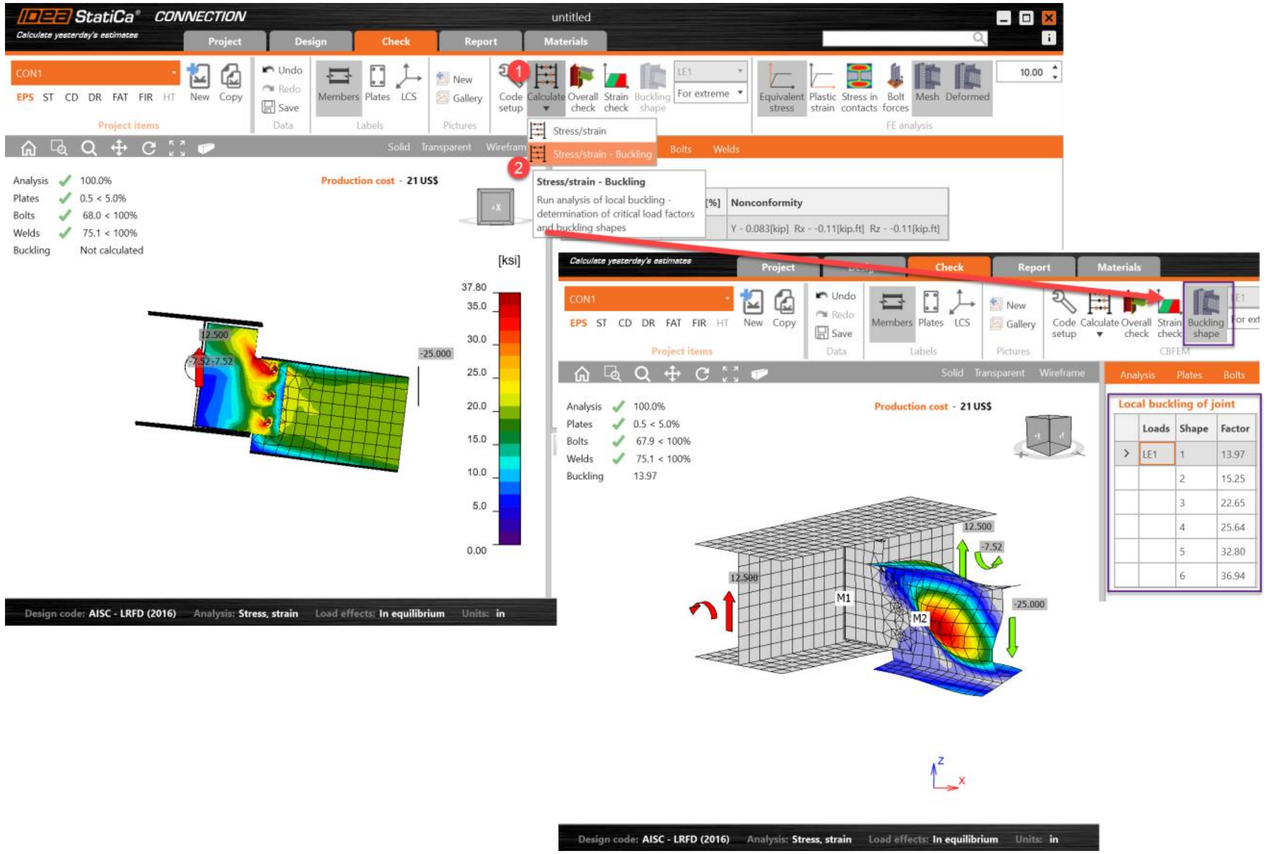






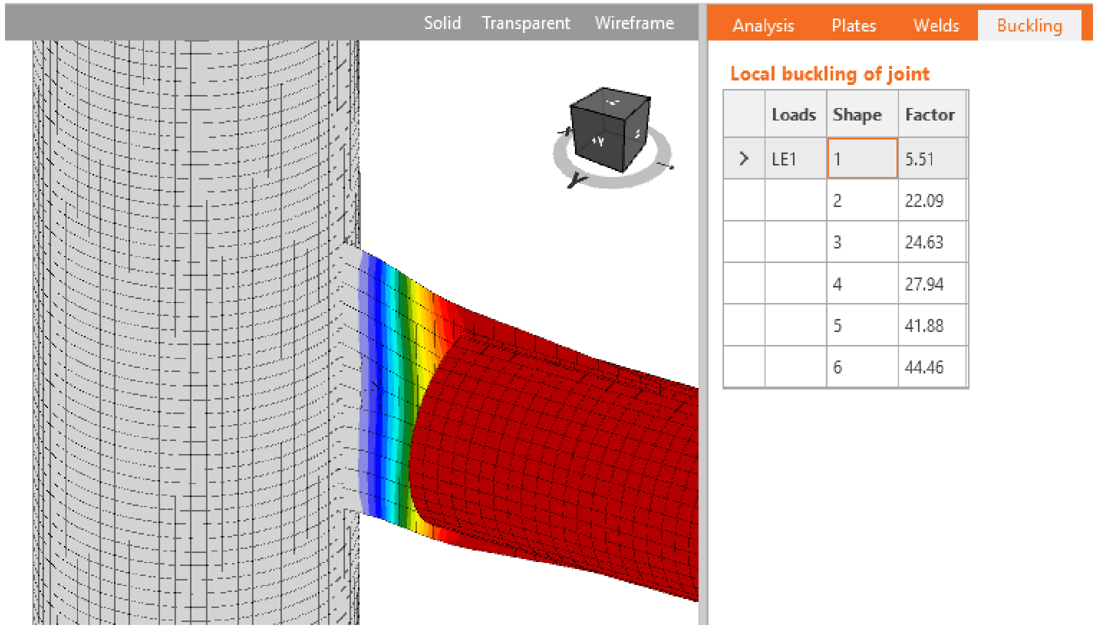
Buckling analysis

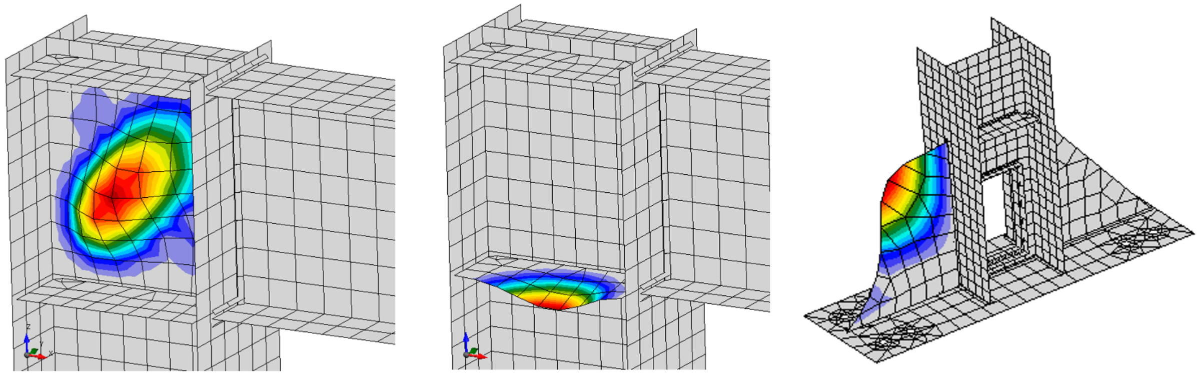
- Linear buckling analysis that provides buckling load factor
- Buckling mode shapes
- Deformation is unitless
- Critical mode shape is always the first



How to evaluate?

- Identify where the buckling is happening:
    a. Plates connecting individual members
    b. Stiffening plates in the joint – stiffeners, ribs, short haunches
    c. Closed sections and thin-walled sections
- Compare buckling factor vs recommended limit factors





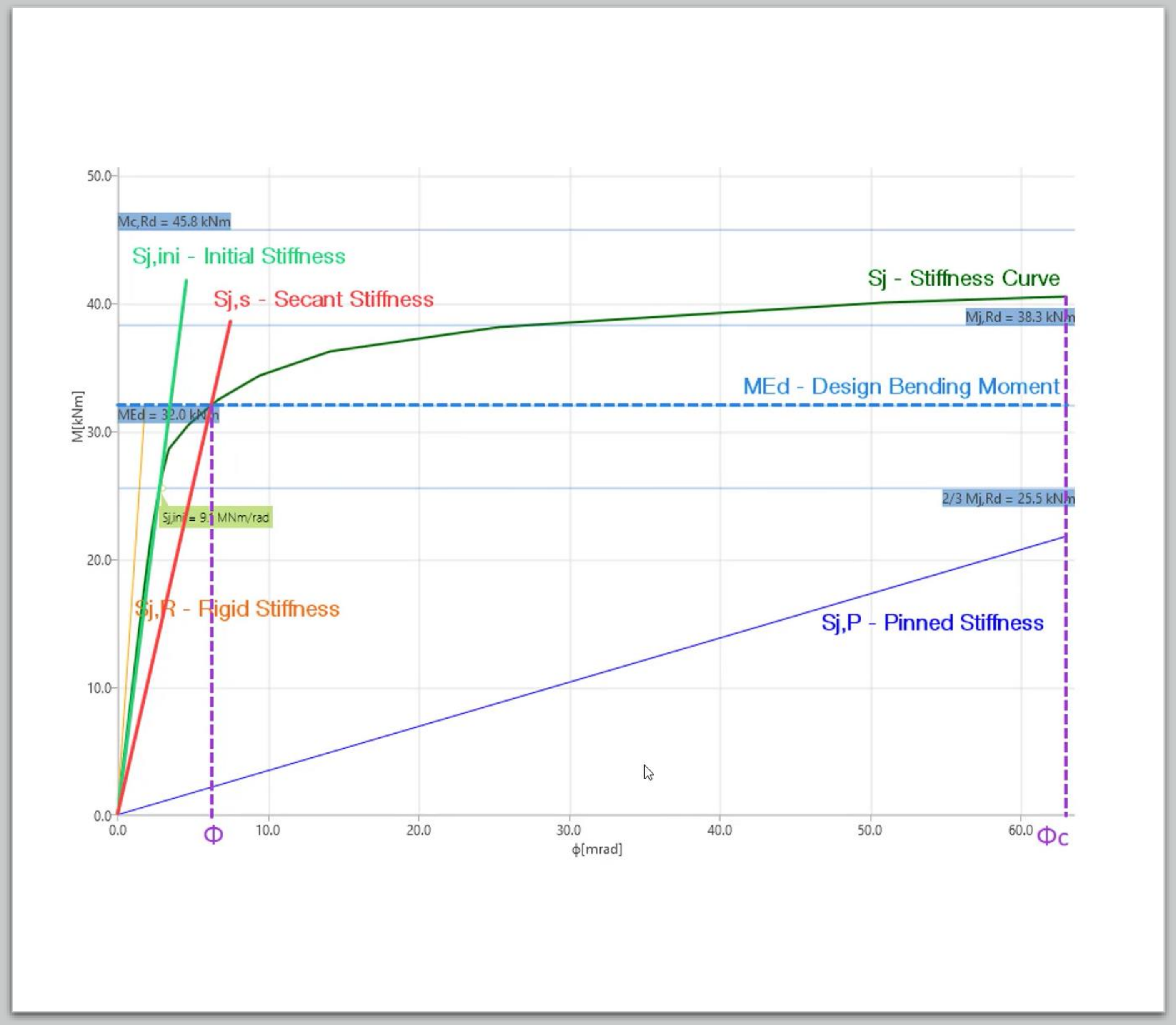
Recommended limit factors

- Global buckling: affecting the stability of the joint
- Local buckling: not affecting the stability of the joint, but influencing the plates in other parts of the connection
- Buckling factor- AISC
- Research Stability of bracket plates

Buckling type	Steel Fy	Recommended limit factor
Global	36 ksi	$\alpha cr>12.7$
Global	50 ksi	$\alpha cr>9.16$
Local		$\alpha cr>3$ – Member plates $\alpha cr>4$ – Bracket plates

Stiffness analysis

- Analyze the rotational/axial stiffness of the selected member
- Loads only applied to the analyzed member
- Only My, Mz or N forces
- Creates a moment vs rotation diagram
- Stiffness classification according AISC
- [Stiffness analysis blog]



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Results

Moment resistance by the connection

Secant stiffness

Rotational capacity of the connection

Classification according AISC

Rotational stiffness of joint component

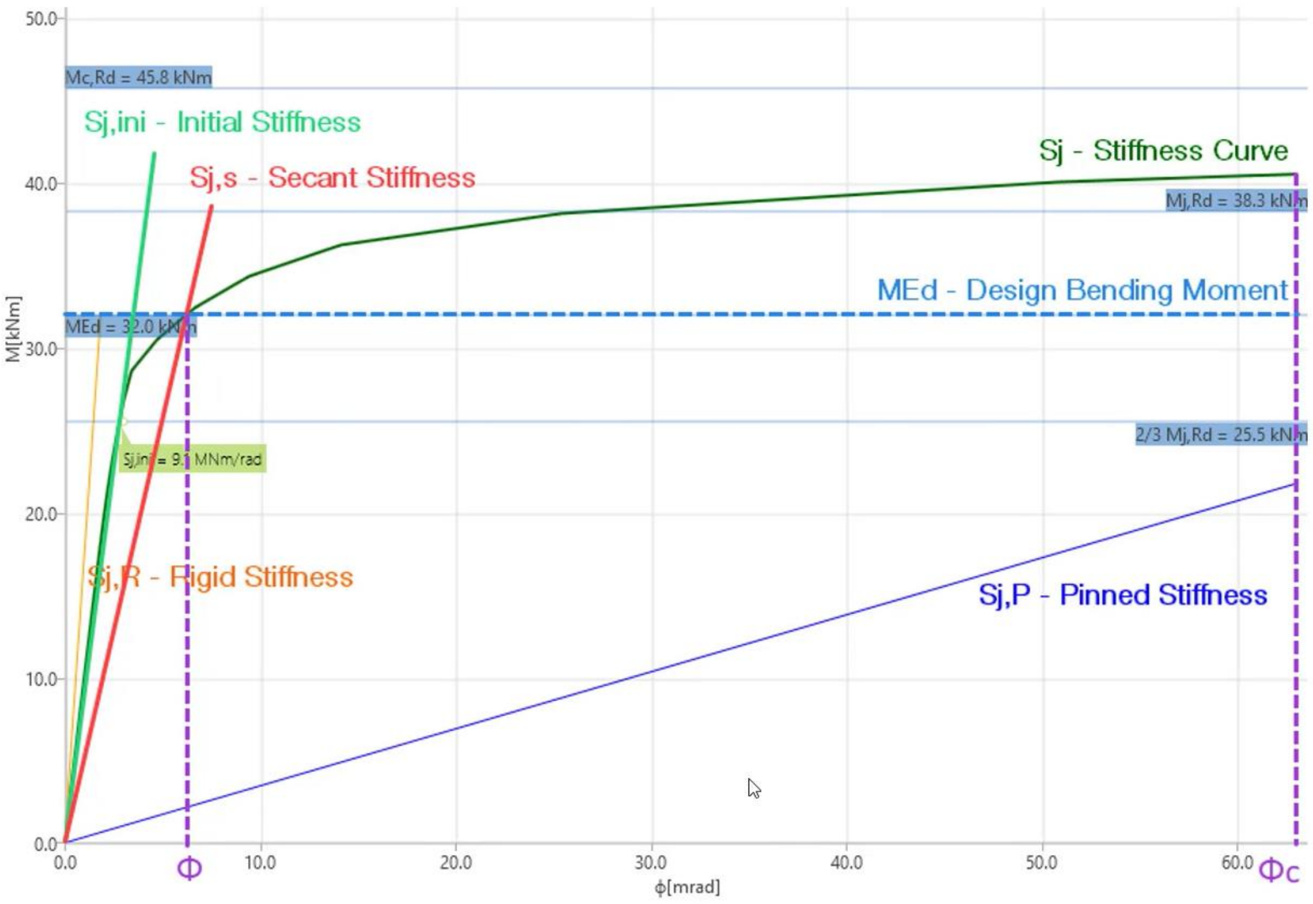
	Item	Comp.	Loads	MEd [kip.ft]	Mj,Rd [kip.ft]	Sj,ini [kip-in/deg]	Sjs [kip-in/deg]	ϕ [mrad]	ϕc [mrad]	L [in]	Sj,R [kip-in/deg]	Sj,P [kip-in/deg]	Class
>	2-71	My	CO 3061 (1.200 D + 1.600 Lp)(2)	473.20	1027.55	120594.9	124183.2	0.8	2.4	19'-8"1/4	208303.7	20830.4	Semi-rigid

Applied moment

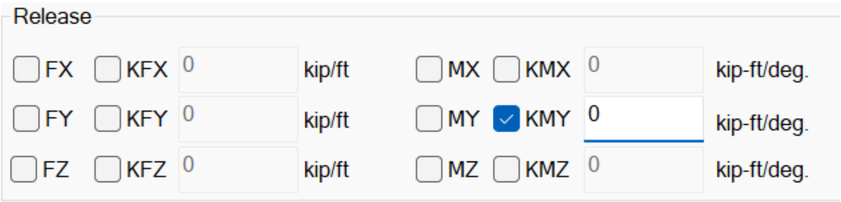
Initial stiffness

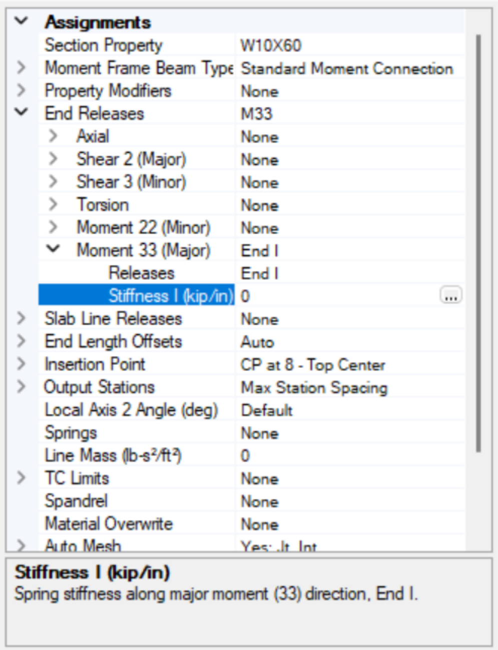
Rotational deformation

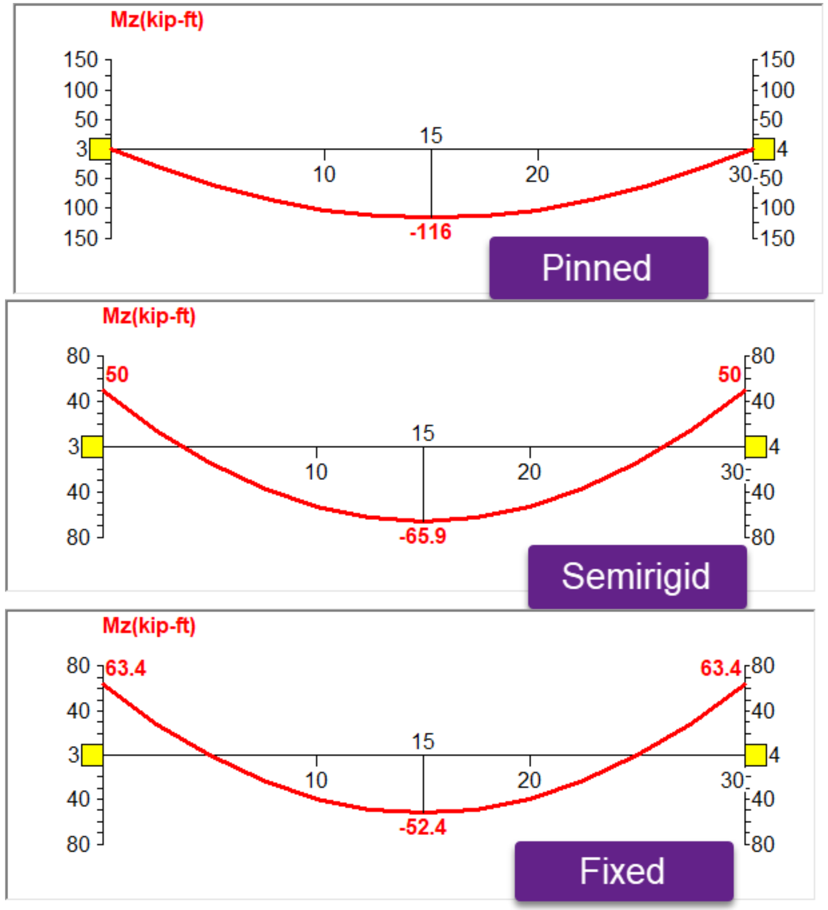
Limits for the classification of connections



Stiffness input in your global FEM Model

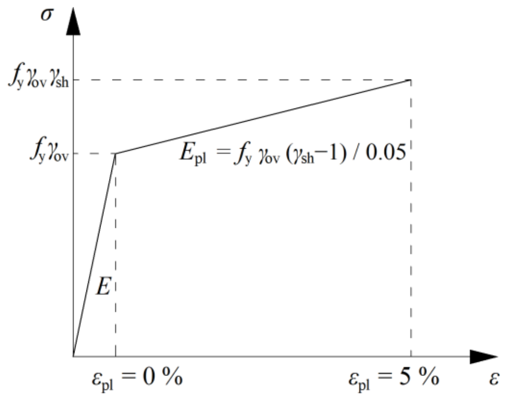


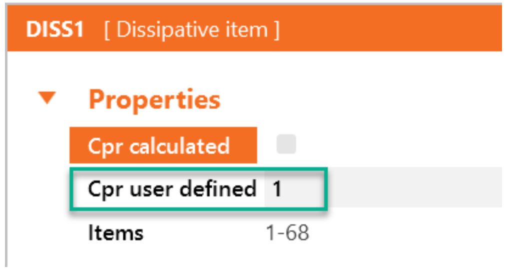




Capacity design

- A member (dissipative item) is selected to increase its strength and modify its material properties.
- Overstrength factor, Ry
- Hardening factor, Cpr



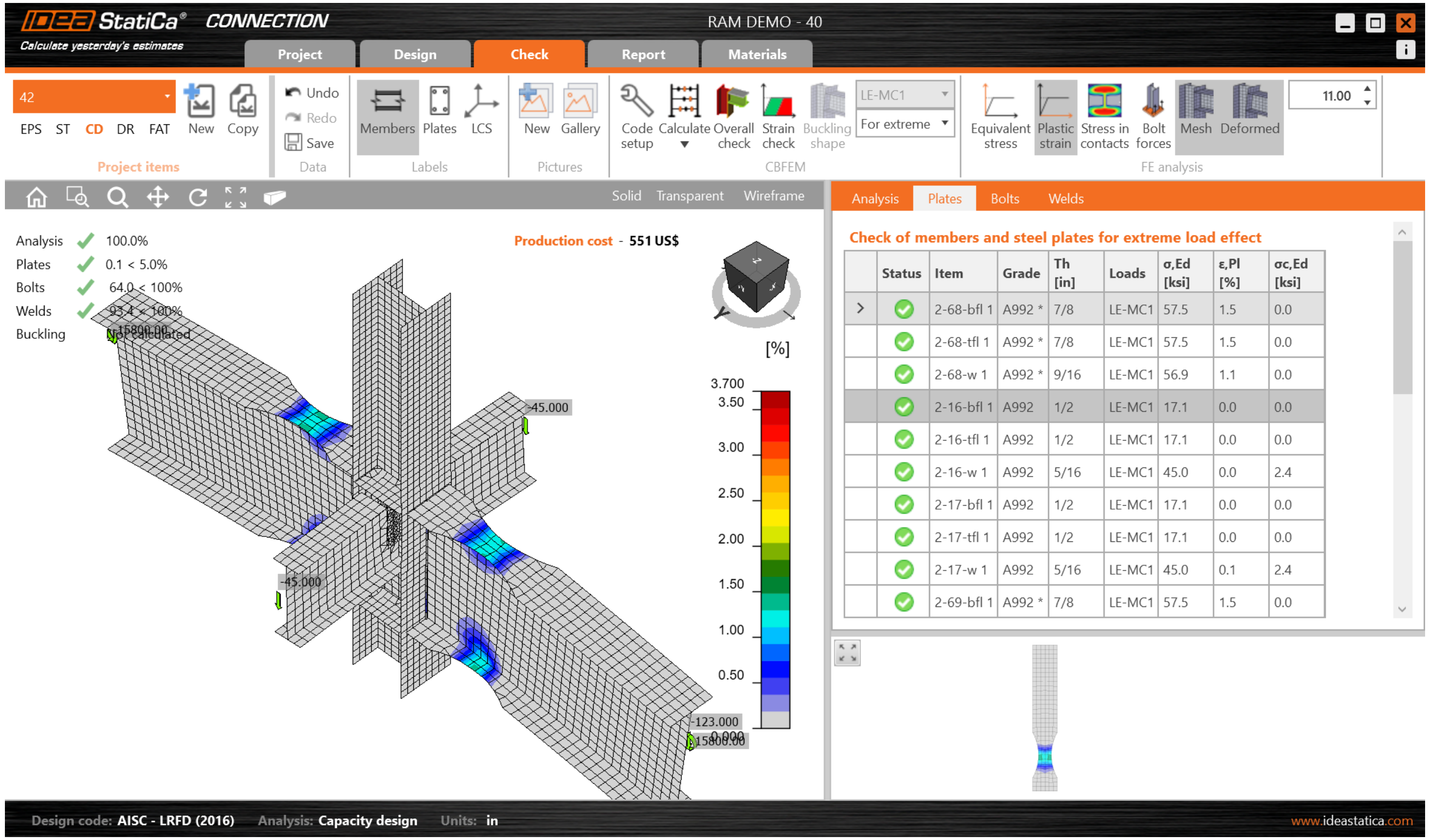


Design data

	Grade	ϕ [-]	Ry [-]	Fy [ksi]	Fy,FEM [ksi]	Cpr [-]	ε,lim [%]
>	A992	0.90	-	50.0	45.0	-	5.0
	A992 *	-	1.10	50.0	55.0	1.15	5.0

Capacity design fit

- Prequalified connections modeling and plastic hinge confirmation
- Interaction with other members and connections
- Panel zone shear check
- Continuity plates
- [Tutorial]



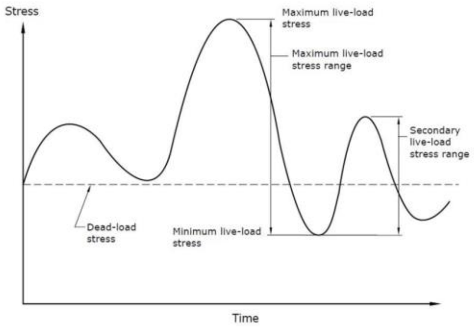
Design Resistance

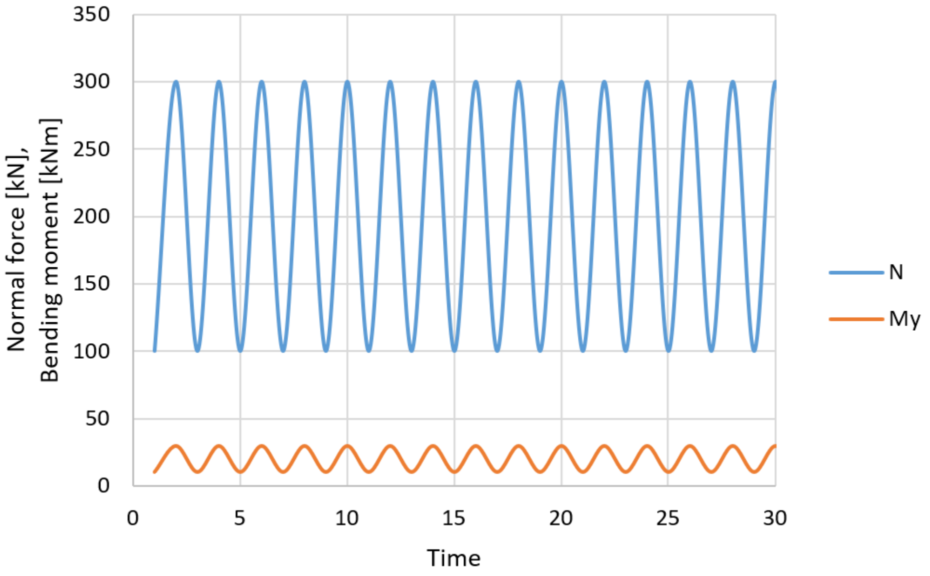
- Provides a percentage of extra load that the joint can support until it fails
- Starting load input is needed
- DR checks for the following components:
  - Plastic strain in plates
  - Bolts – shear, tension, and a combination of tension and shear
  - Anchors – tension and shear steel resistance
  - Welds

Fatigue analysis

- Determine normal and shear stress range between two load cases
- It is assumed to be used for the design of high-cycle fatigue details, where no yielding is expected.
- Stresses are available for: bolts, welds and plates
- [Fatigue due to cyclic loading]

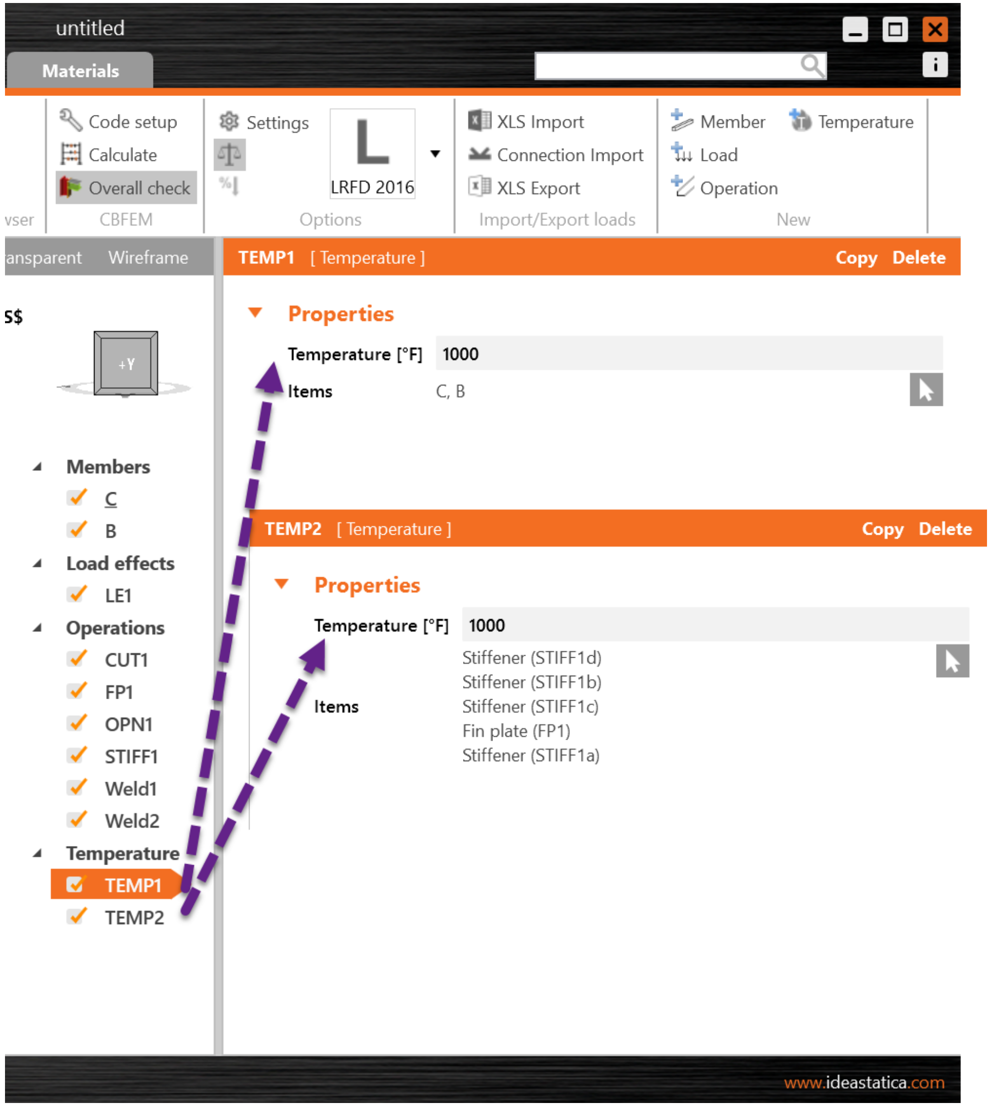
	Item	Edge	Section	Th [in]	L [in]	Loads	σ_{max} [ksi]	τ [ksi]	τ_{max} [ksi]	σ [ksi]	Elastic
	B1-bfl 1	B2-bfl 1	B1-bfl 1	3/16	3"15/16	LE2	-13.0	-0.1	1.0	-12.9	✓
	B1-bfl 1	B2-bfl 1	B2-bfl 1	3/16	3"15/16	LE2	-14.5	0.0	1.0	-14.3	✓
	B1-tfl 1	B2-tfl 1	B1-tfl 1	3/16	3"15/16	LE2	33.3	0.0	-0.6	33.1	✓
	B1-tfl 1	B2-tfl 1	B2-tfl 1	3/16	3"15/16	LE2	34.3	0.0	-0.6	34.0	✓
>	B1-w 1	B2-w 1	B1-w 1	3/16	7"9/16	LE2	32.1	-4.1	-7.0	0.7	✓
	B1-w 1	B2-w 1	B2-w 1	3/16	7"9/16	LE2	33.1	3.8	7.4	-0.1	✓





Fire design

- Set the temperature for each member or plate separately.
- Reduced material characteristics are used based on preset temperature and material degradation curve.
- Resistance of bolts and welds is reduced. Their stiffness remains the same as at ambient temperature.
- Thermal expansion is neglected and not assumed in any models.



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AISC Material properties at elevated Temperatures

TABLE A-4.2.1
Properties of Steel at Elevated Temperatures

Steel Temperature, °F (°C)	$k_E = E(T)/E = G(T)/G$	$k_p = F_p(T)/F_y$	$k_y = F_y(T)/F_y$	$k_u = F_u(T)/F_y$
68 (20)	1.00	1.00	*	*
200 (93)	1.00	1.00	*	*
400 (200)	0.90	0.80	*	*
600 (320)	0.78	0.58	*	*
750 (400)	0.70	0.42	1.00	1.00
800 (430)	0.67	0.40	0.94	0.94
1000 (540)	0.49	0.29	0.66	0.66
1200 (650)	0.22	0.13	0.35	0.35
1400 (760)	0.11	0.06	0.16	0.16
1600 (870)	0.07	0.04	0.07	0.07
1800 (980)	0.05	0.03	0.04	0.04
2000 (1100)	0.02	0.01	0.02	0.02
2200 (1200)	0.00	0.00	0.00	0.00

*Use ambient properties

TABLE A-4.2.3
Properties of Group A and Group B High-Strength Bolts at Elevated Temperatures

Bolt Temperature, °F (°C)	$F_{nt}(T)/F_{nt}$ or $F_{nv}(T)/F_{nv}$
68 (20)	1.00
200 (93)	0.97
300 (150)	0.95
400 (200)	0.93
600 (320)	0.88
800 (430)	0.71
900 (480)	0.59
1000 (540)	0.42
1200 (650)	0.16
1400 (760)	0.08
1600 (870)	0.04
1800 (980)	0.01
2000 (1100)	0.00

Q&A

Thank you

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