Connection Design Using Advanced FEA

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Connection Design Using Advanced FEA

PDH CODE: 19142

Who We Are

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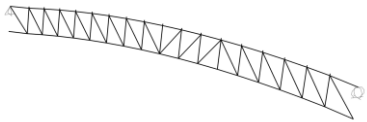
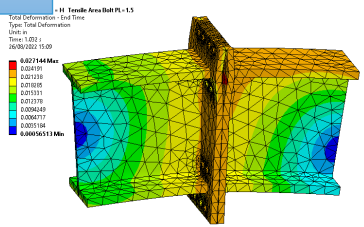
NASCC: THE STEEL CONFERENCE 2023

Presentation Outline – FEA for Connections

BOTH FEA





FEA used for Connection Design

PRESENTATION OUTLINE

- Applicability of FEA
- Modelling Strategies and Non-Linearities
- Understanding Results
- Capacity checks
- Comparison Examples
- Questions

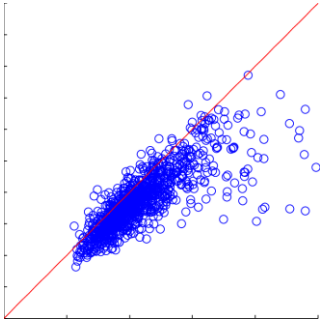
Learning Outcome

Identify **when FEA is applicable,** understand the **setup of the basic parameters** and **capture results** to perform a FE design of a connection.

Situations where FEA is NOT Efficiently applicable

REPETITION

15min



ANALYTICAL ROUTE EXISTS

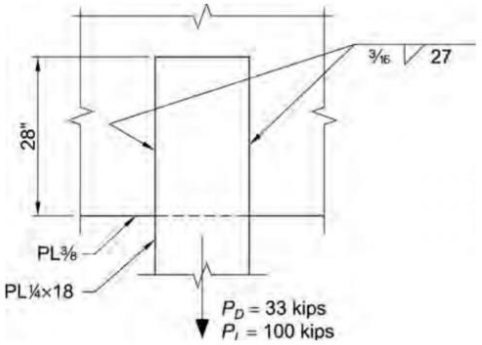


Fig. J.1-1. Geometry and loading for Example J.1.

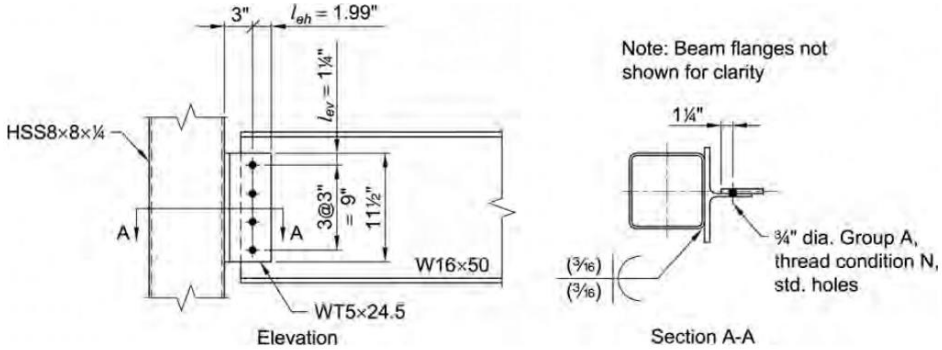
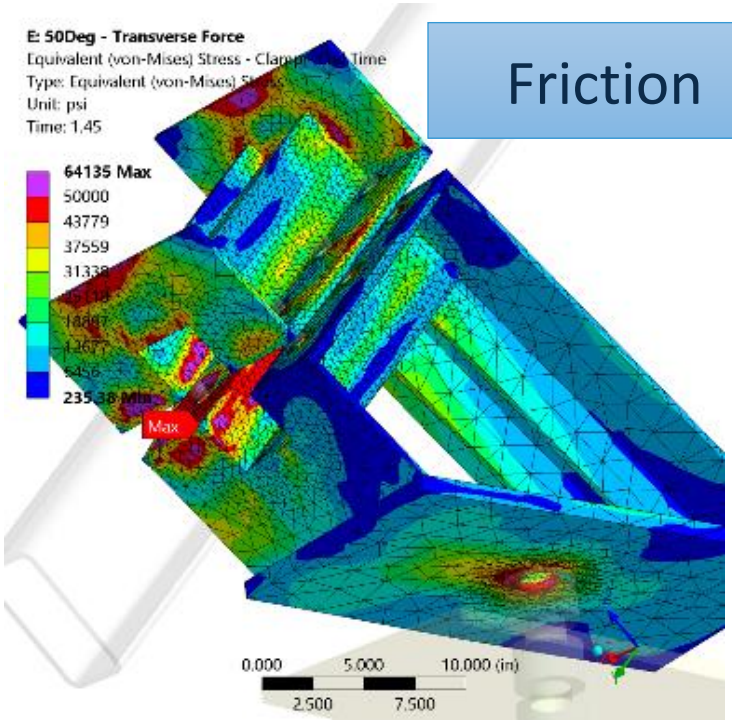


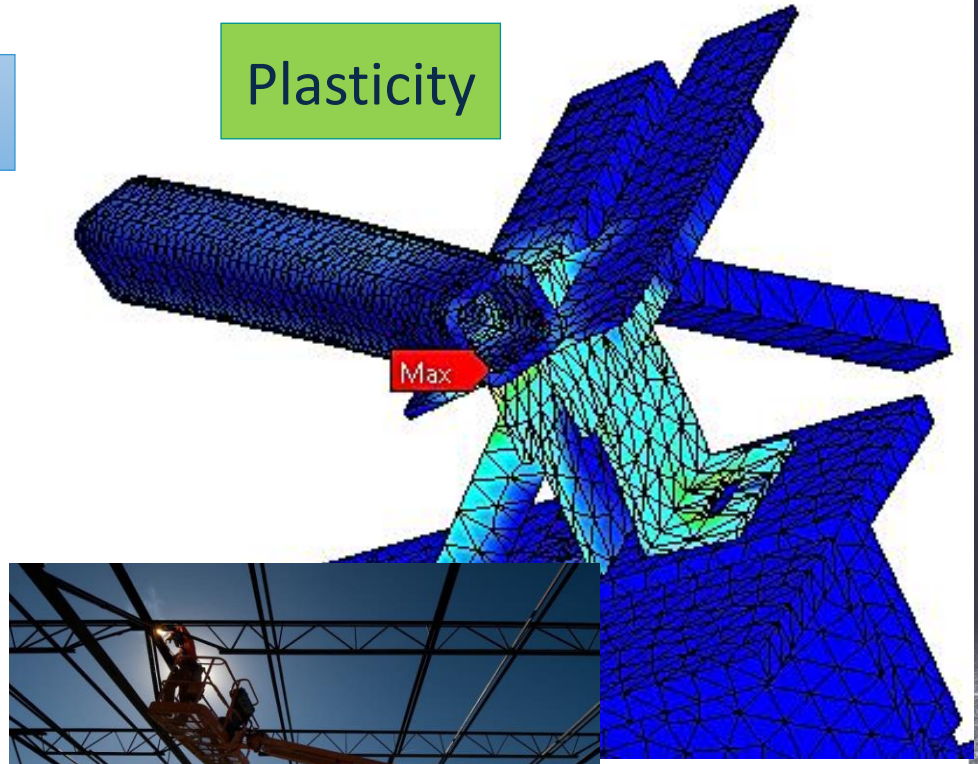
Fig K.1-1. Connection geometry for Example K.1.

Situations where FEA is applicable – Non Linearities



Friction

Plasticity



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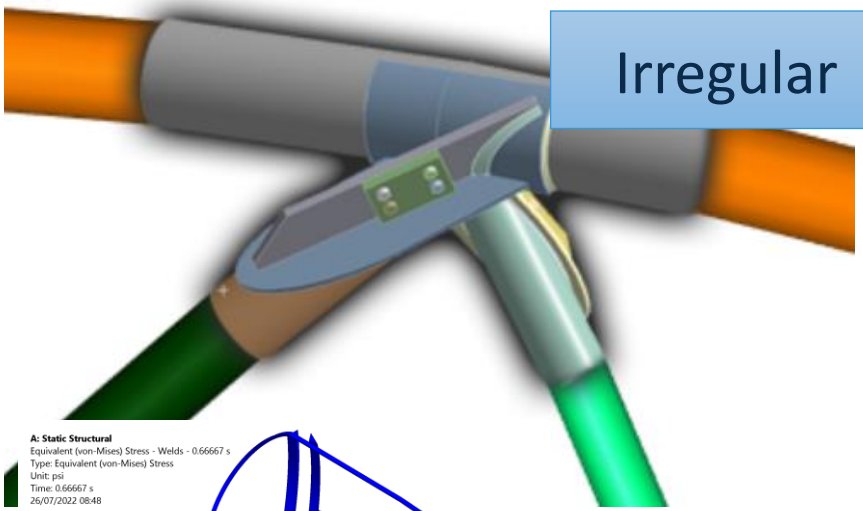
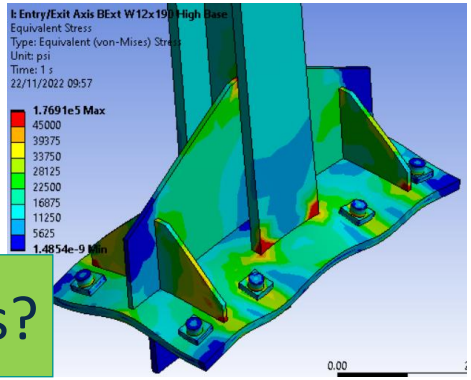
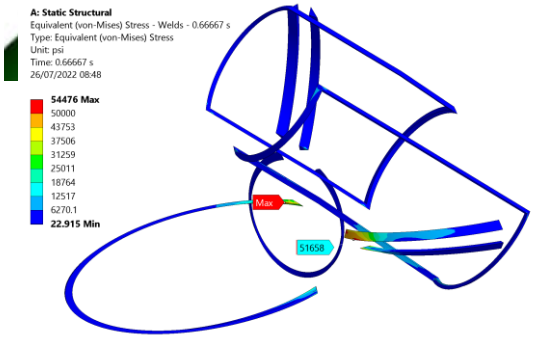
Situations where FEA is applicable – Irregularities

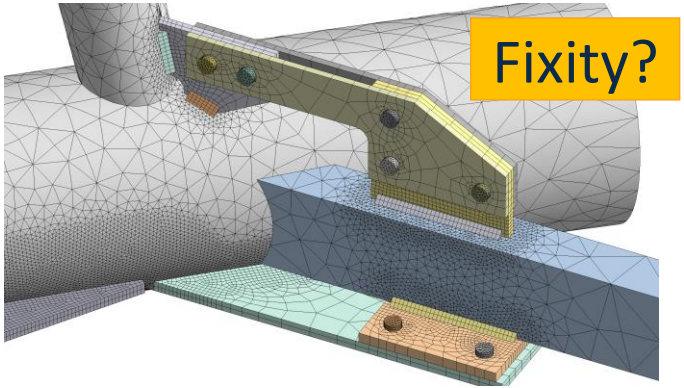


Irregular



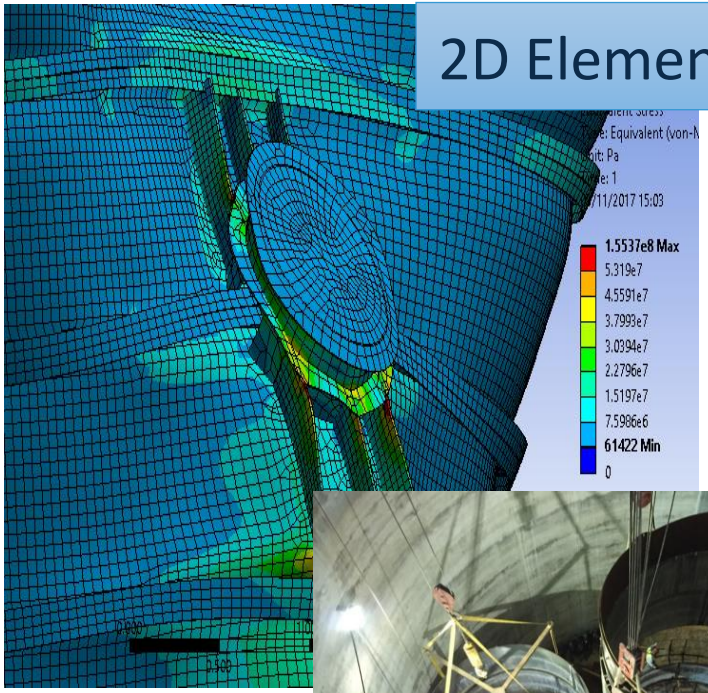
Stiffness?





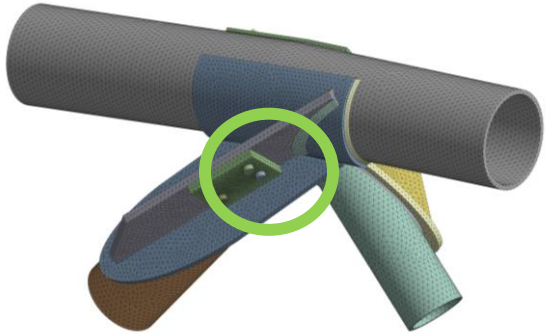
Fixity?

Modelling Strategies Planar Elements or Volumes?



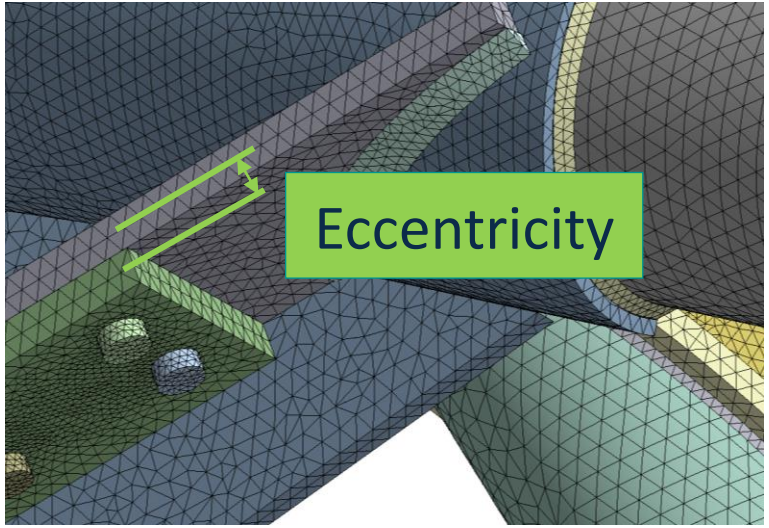
2D Elements

Large D/t



3D Elements

Well Behaved



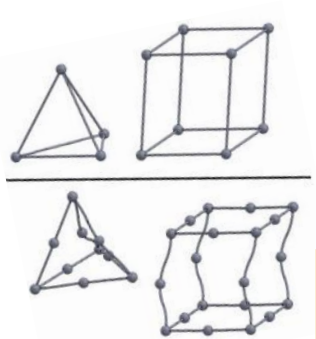
Eccentricity

Modelling Strategies

ASPECT RATIO

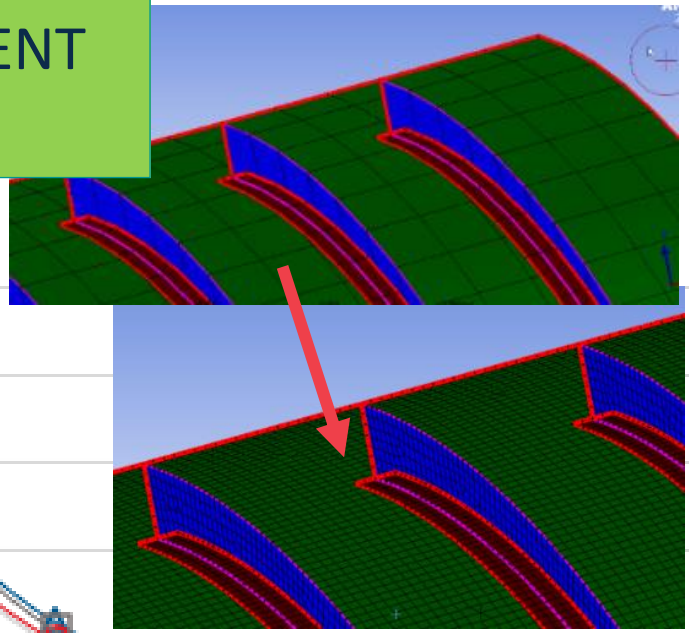
OK

NOT OK

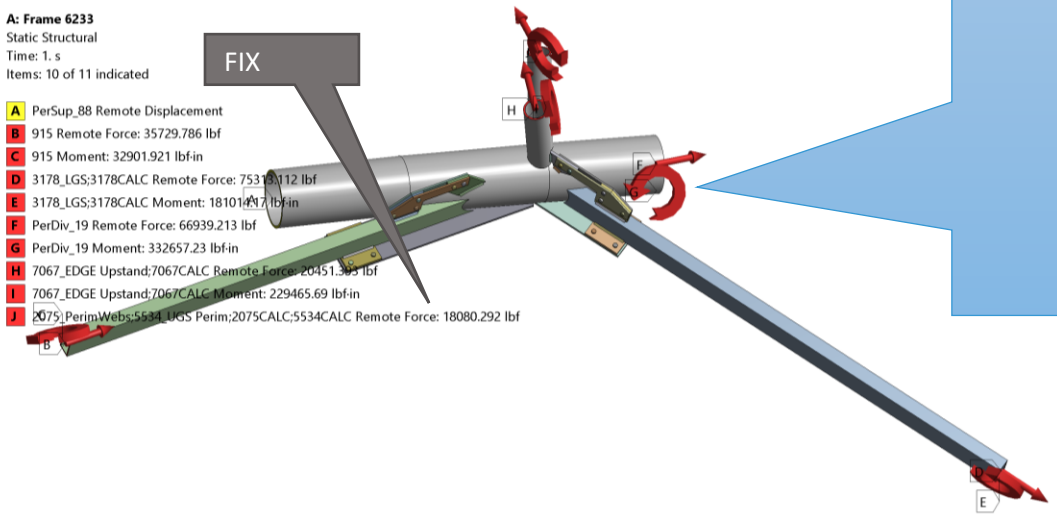


ORDER?

MESH REFINEMENT STUDY



Modelling Strategies - Loading



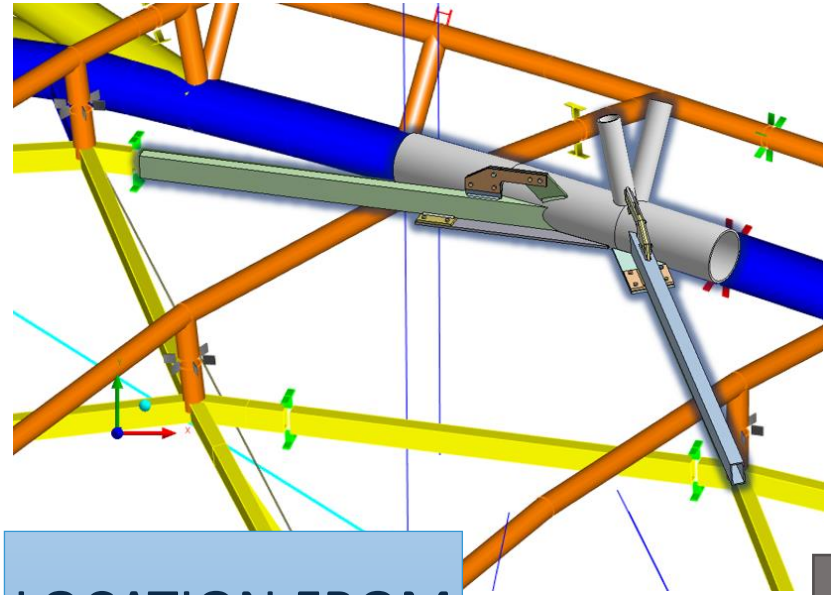
STRESS RESULTANTS = FORCE CONTROLLED

DISPLACEMENTS = DISPLACEMENT CONTROLLED

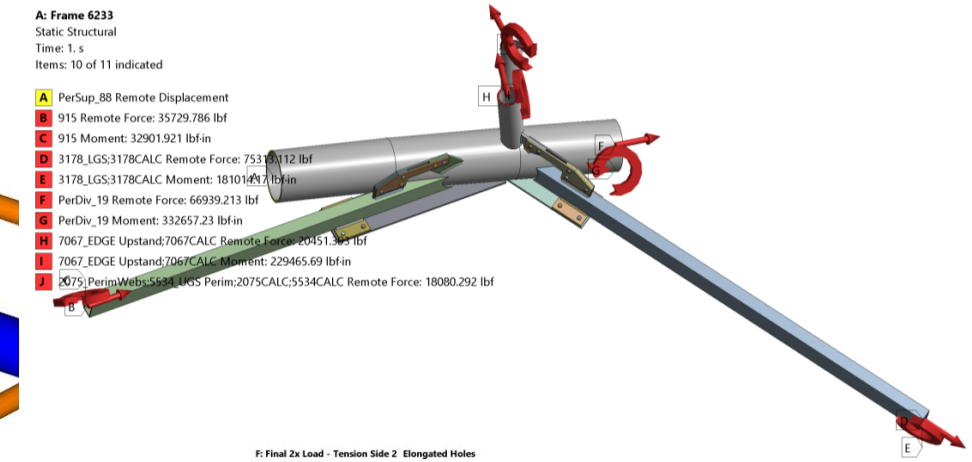
SEARCH FOR ULTIMATE CAPACITY IN MOST CASES ➔ FORCE CTRL

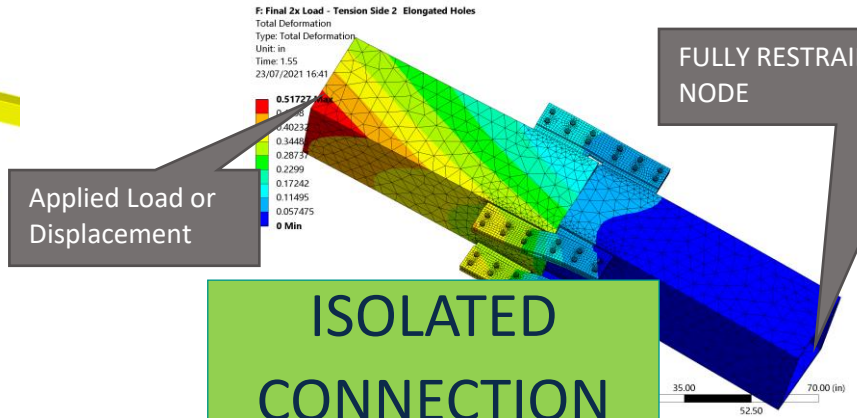
INSTABILITIES; HIGH NON-LINEARITIES OR BUCKLING ➔ DISP. CTRL

Modelling Strategies - Loading



LOCATION FROM GLOBAL MODEL





Applied Load or Displacement

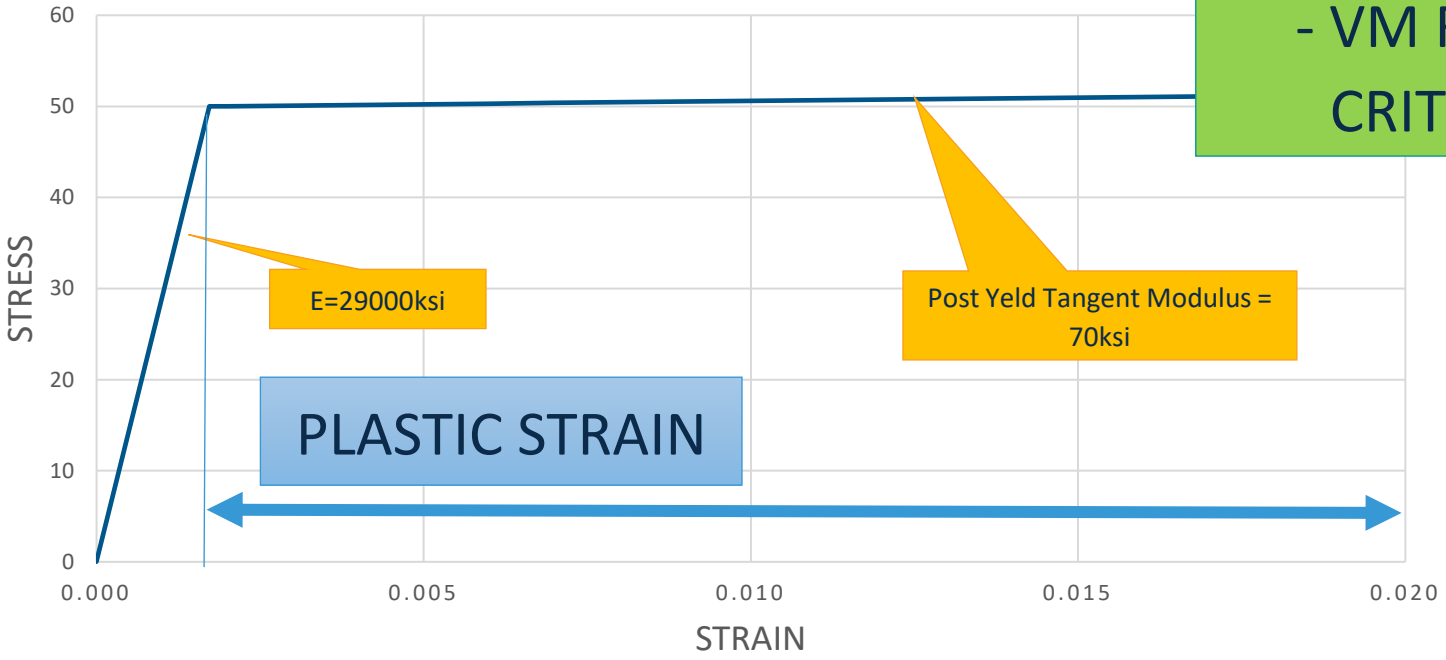
FULLY RESTRAINED NODE

ISOLATED CONNECTION

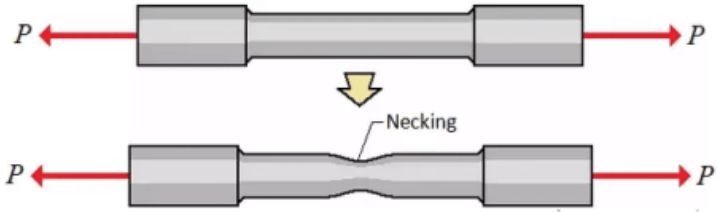
Non-linearities - Material

MATERIAL CURVE - A572-GR50

- BILINEAR CURVE
- VM FAILURE CRITERION



Non-linearities – Advanced Material



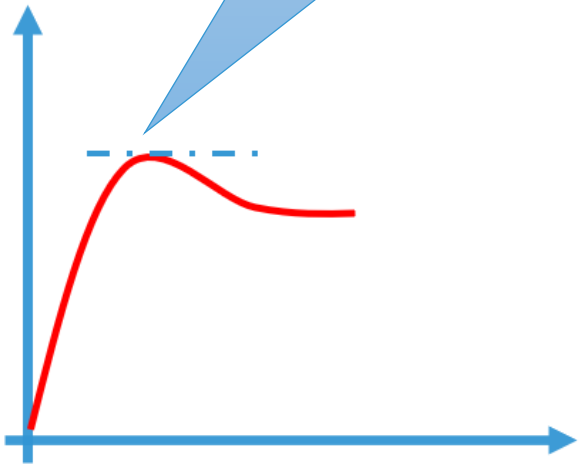
CURVE FOR SMOOTH BAR:
-NECKING FREE
-RESIDUAL STRESSES?
-EXTERNAL RESTRAINS?

"TRUE" MATERIAL CURVE – ASME - MPC

STIFFNESS LOSS

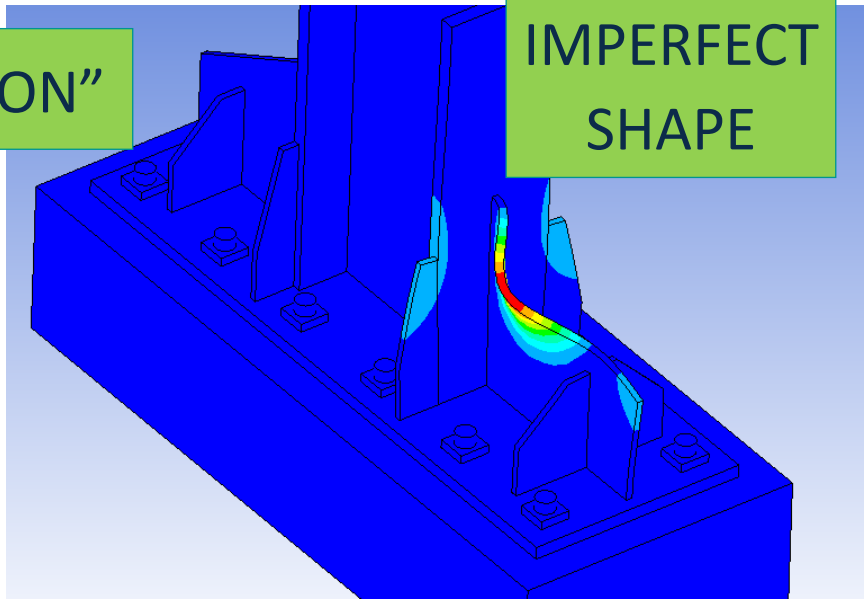
Non-linearities - Geometrical

ZERO STIFFNESS
= BUCKLING



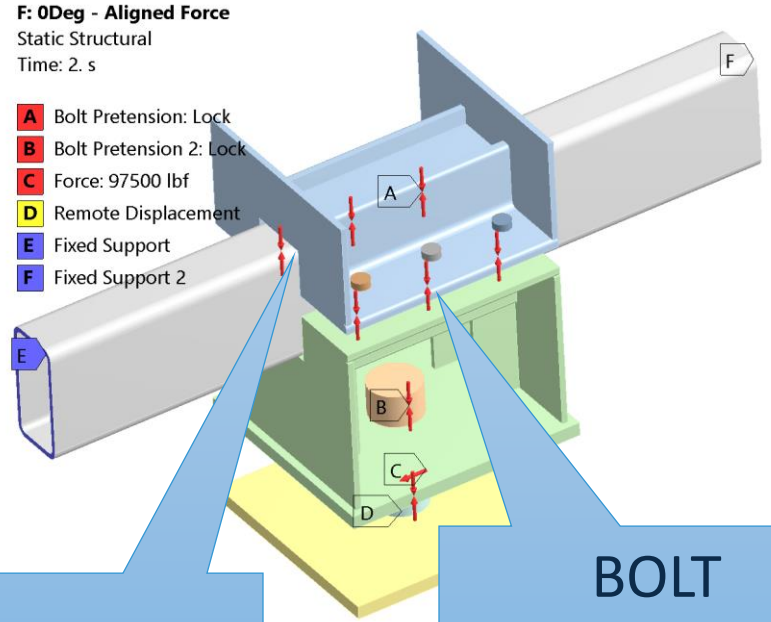
LD-”ON”

IMPERFECT
SHAPE



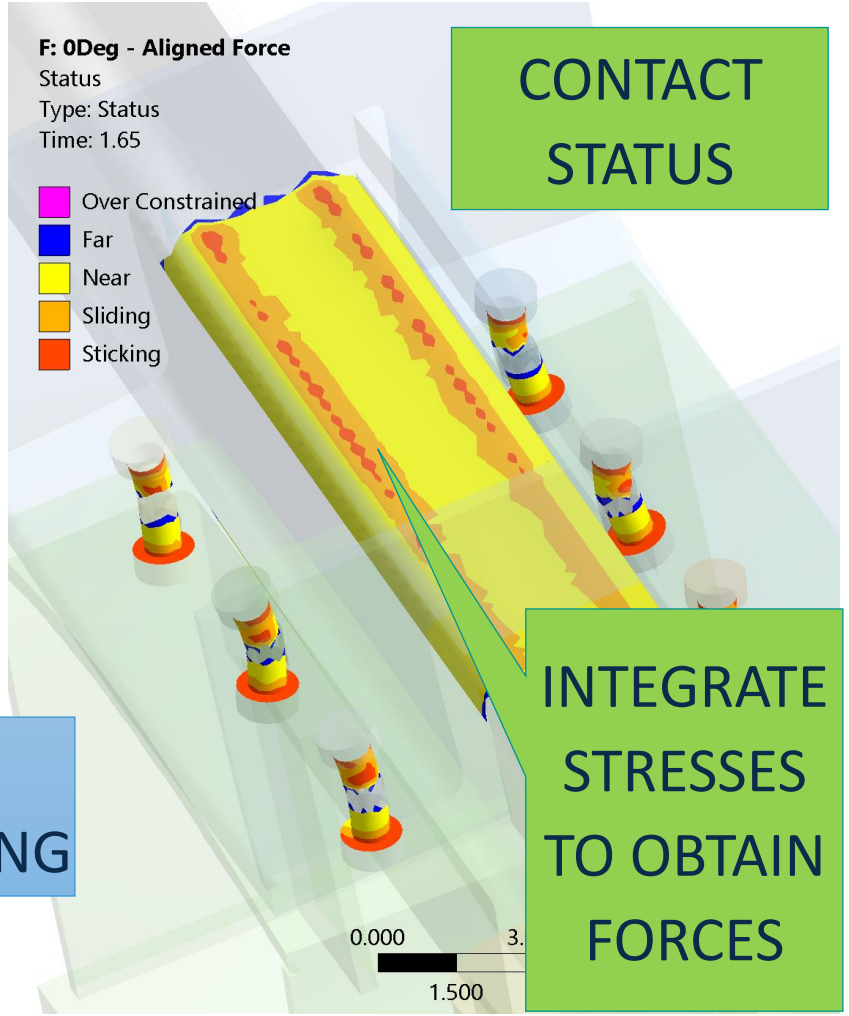
DISPLACEMENT
CONTROLLED ANALYSIS

Non-linearities - Contact



FRICTION

BOLT PRETENSIONING

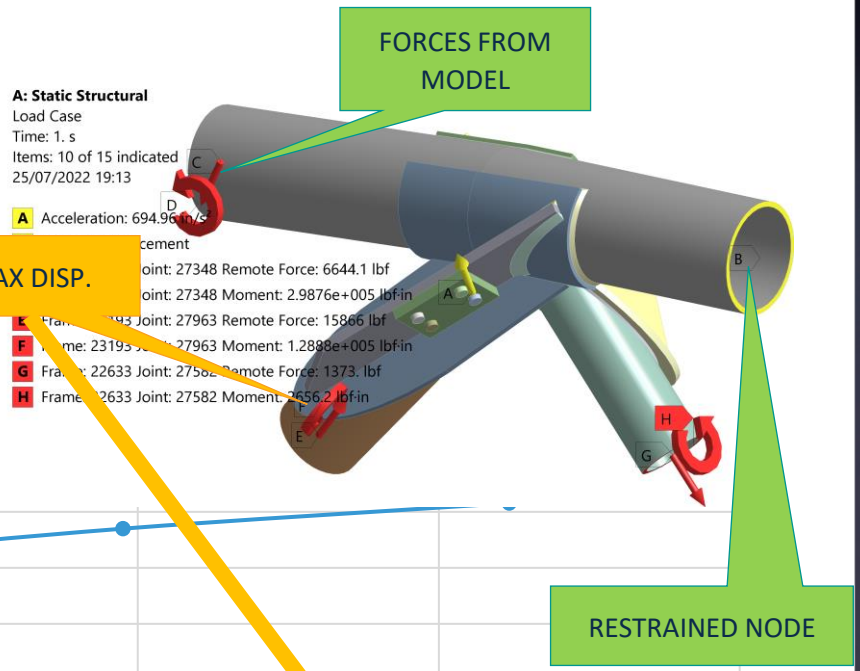


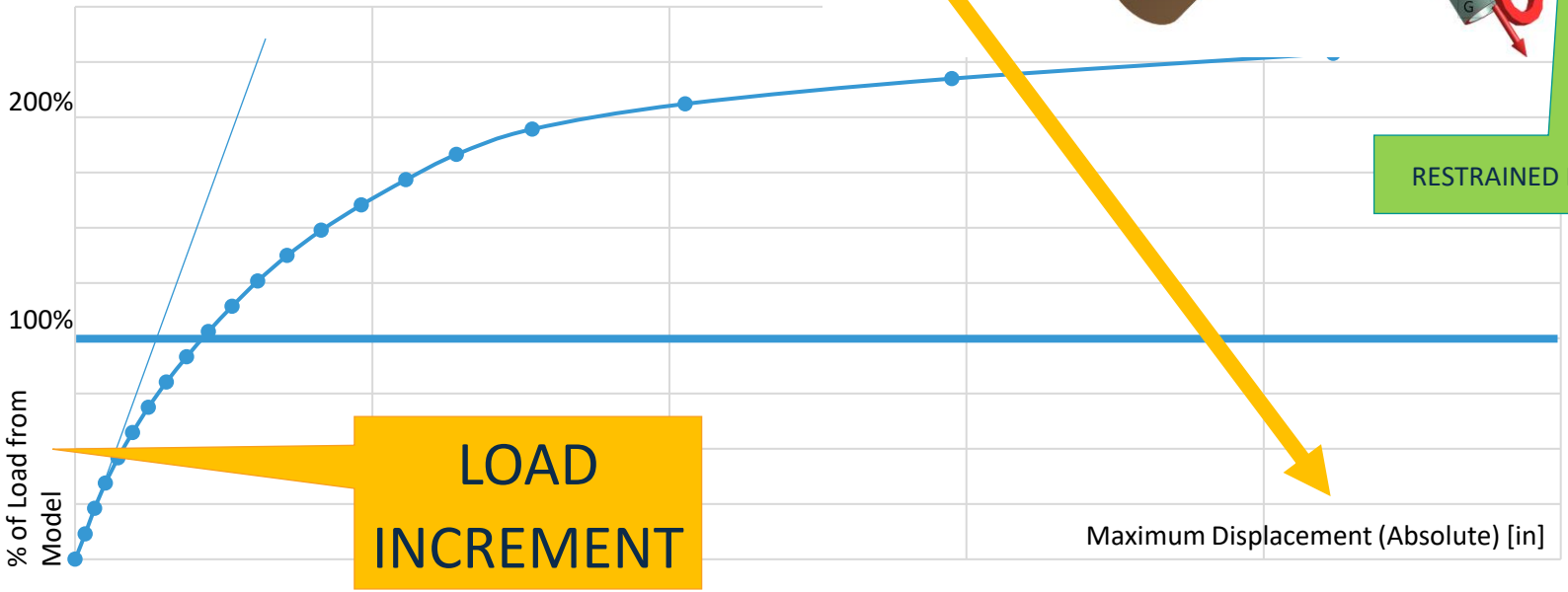
CONTACT STATUS

INTEGRATE STRESSES TO OBTAIN FORCES

Understanding the Results

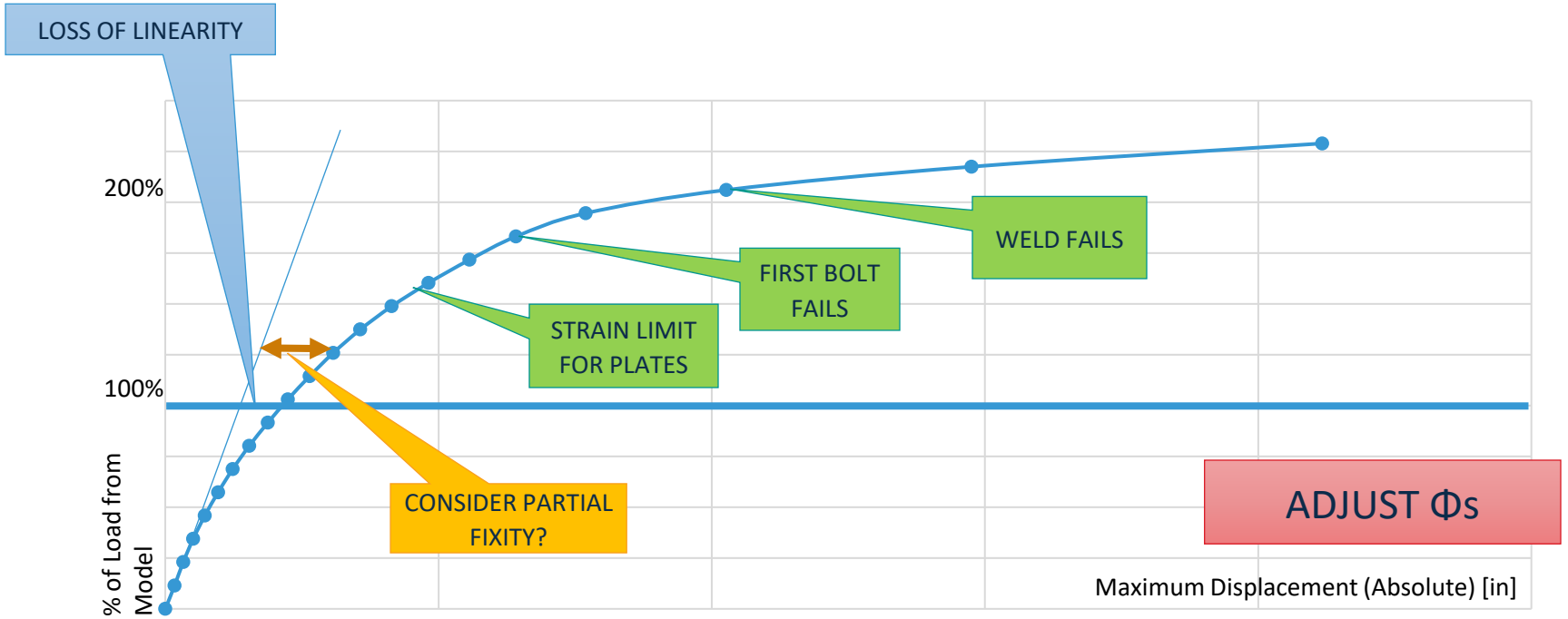
CHARACTERISTIC LOAD-DISPLACEMENT PLOT





Understanding the Results

IMPORTANT TO NOTE:



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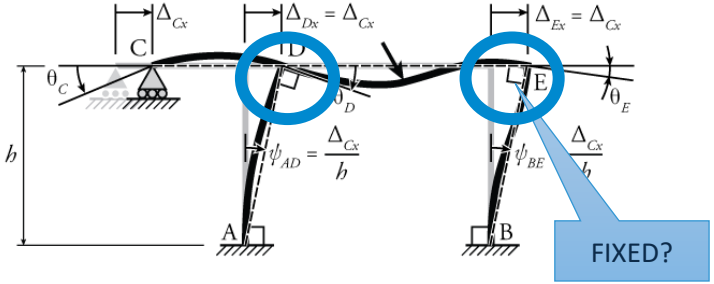
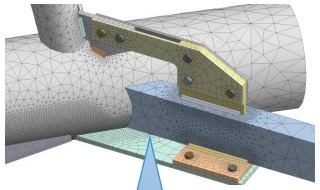
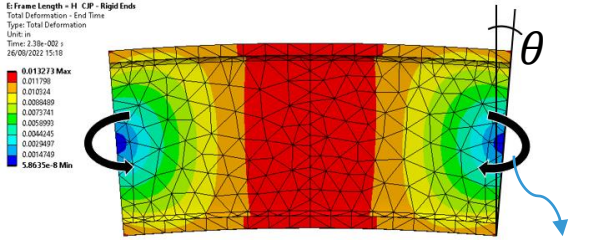
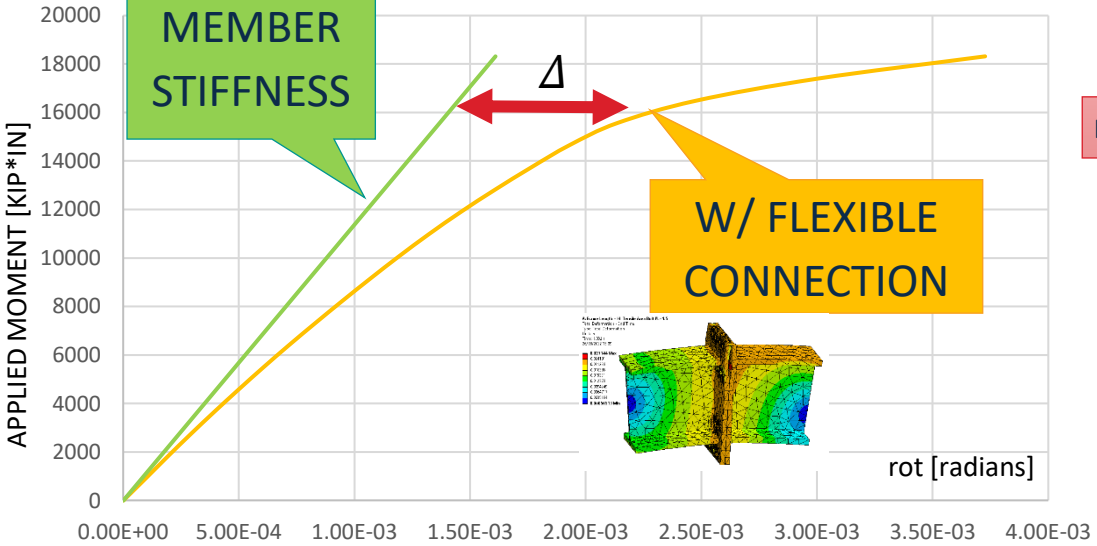
Deriving stiffness –Between Fix and Pin

MEMBER STIFFNESS



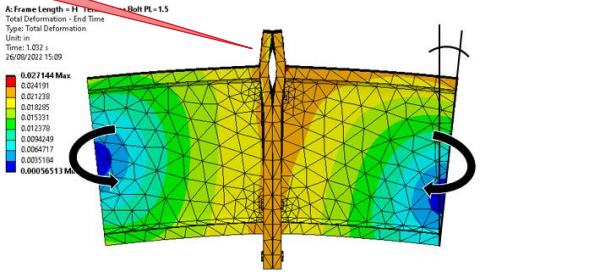






MEMBER+CONN STIFFNESS

PRETENSION



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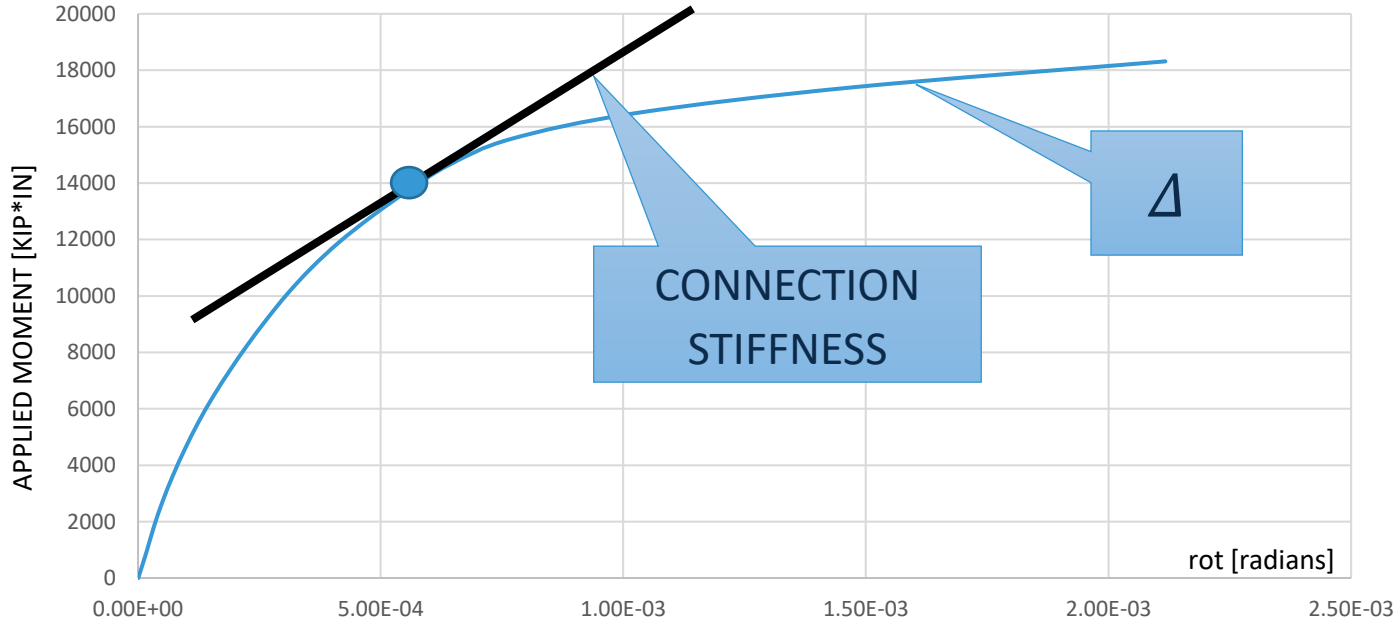
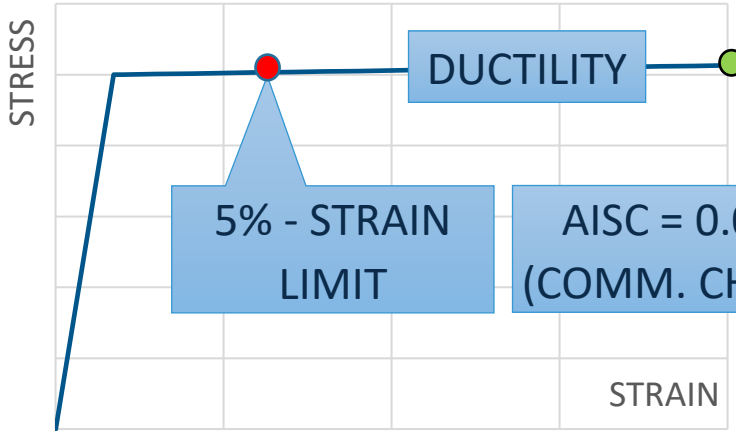
Deriving stiffness –Between Fix and Pin



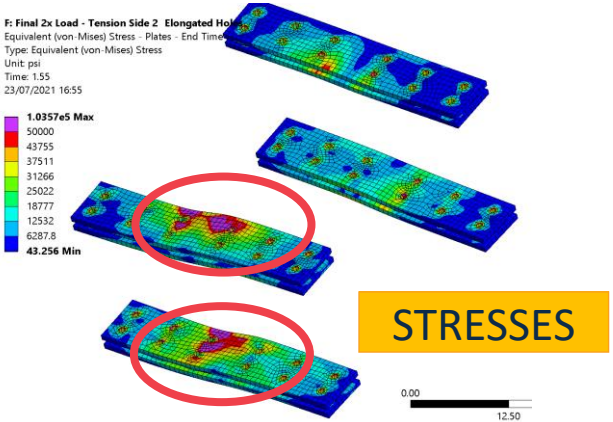
Specific checks for Plates



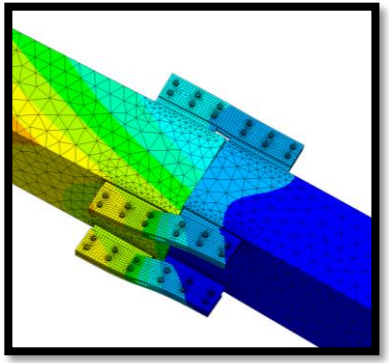
20% ENLONGATION LIMIT

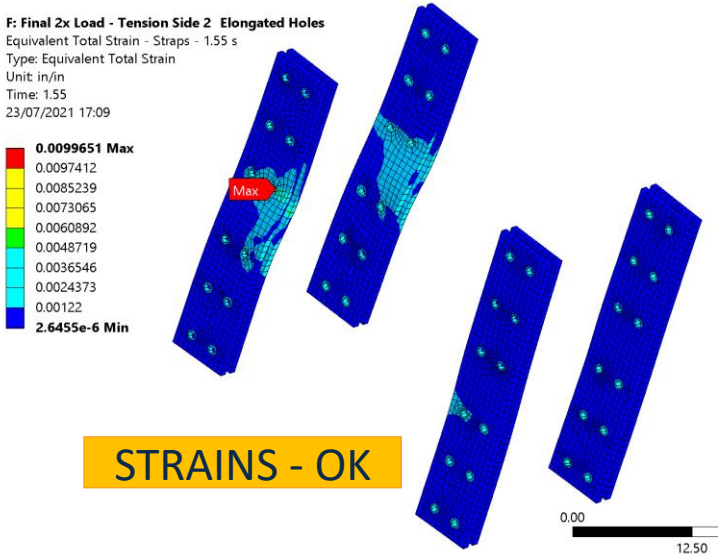
DOES NOT CONSIDER:

- NOTCHES;
- RESIDUAL STRESSES;
- NECKING RESTRAINS



STRESSES





STRAINS - OK

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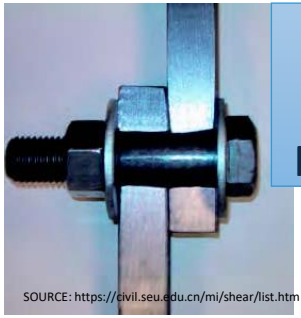
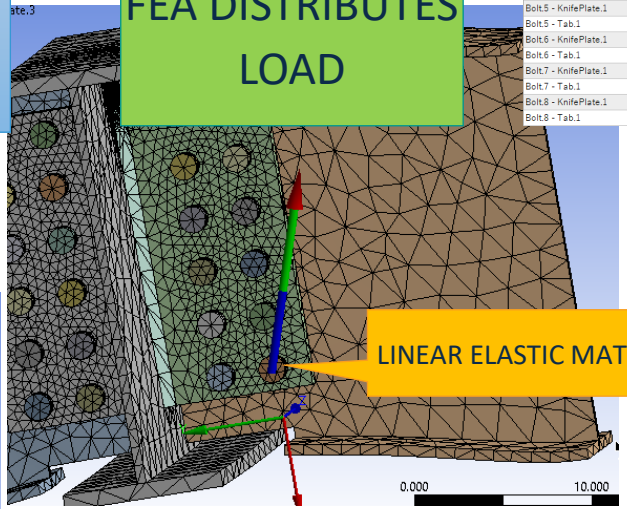
Specific checks for bolts



SOURCE: https://civil.seu.edu.cn/mi/shear/list.htm

CODE CAPACITY FROM TESTS

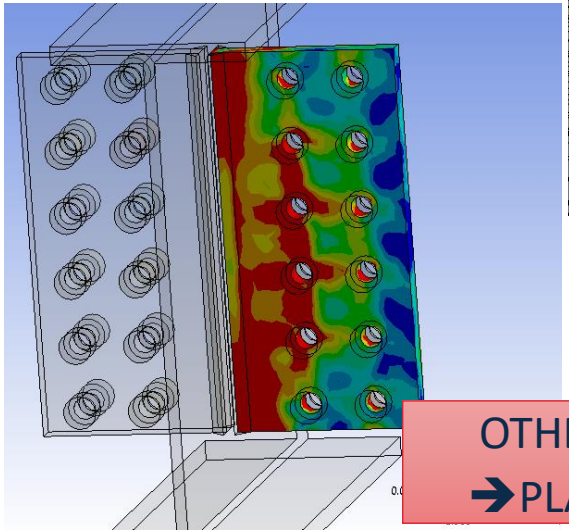
FEA DISTRIBUTES LOAD



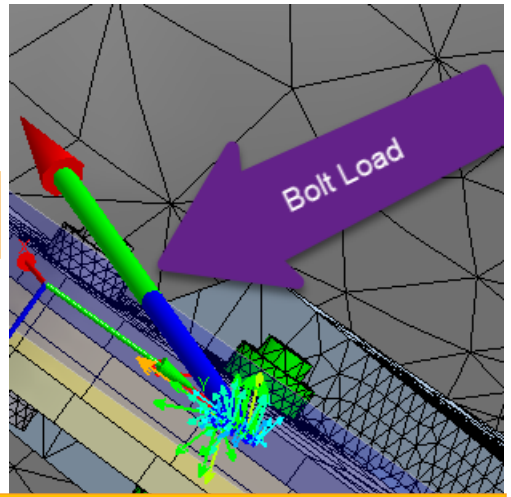
LINEAR ELASTIC MATERIAL

	Data From Solid FEA			Acting		Slip Critical Design						
Bolt - Cut Plane	X Axis	Y Axis	Z Axis	Shear [lbf]	Tension [lbf]	Hole Type	Phi Factor	Surface Class	Mi	Pretension [lbf]	Design Slip Resistance [lbf]	Check Slip
Bolt.1 - Tab.2	-3395.97	10581.2	-1686	11113	1686	Long-slotted //	0.7	Class B	0.5	28000	11113	1.000
Bolt.1 - KnifePlate.2	3390.13	-10586	-1698	11116	1698	Long-slotted //	0.7	Class B	0.5	28000	11109	1.001
Bolt.2 - Tab.2	-3985.47	1843.49	-757.6	4391	758	Long-slotted //	0.7	Class B	0.5	28000	11457	0.383
Bolt.2 - KnifePlate.2	3985.03	-1848.4	-765.2	4393	765	Long-slotted //	0.7	Class B	0.5	28000	11455	0.384
Bolt.3 - Tab.2	-4447.89	3007.58	-10265	5369	10265	Long-slotted //	0.7	Class B	0.5	28000	7030	0.677
Bolt.3 - KnifePlate.2	4449.98	-2991.7	-10275	5362	10275	Long-s						
Bolt.4 - Tab.2	-1905.5	-6023.1	-10585	6317	10585	Long-s						
Bolt.4 - KnifePlate.2	1913.49	6055.5	-10630	6351	10630	Long-s						
Bolt.5 - KnifePlate.1	-62.6562	-202.96	0	212	0	Long-s						
Bolt.5 - Tab.1	62.2874	202.685	-0.106	212	0	Long-s						
Bolt.6 - KnifePlate.1	-796.233	-330.78	-774.8	862	775	Long-s						
Bolt.6 - Tab.1	795.671	329.921	-773.8	861	774	Long-s						
Bolt.7 - KnifePlate.1	-604.354	-65.483	-746.2	608	746	Long-s						
Bolt.7 - Tab.1	604.64	65.459	-745.6	608	746	Long-s						
Bolt.8 - KnifePlate.1	405.371	579.053	-241.3	707	241	Long-s						
Bolt.8 - Tab.1	-405.843	-578.46	-242.6	707	243	Long-s						

CHECKS USING SPREADSHEETS



OTHER EFFECTS
➔PLATE CHECKS



INTERGATION OF STRESS AT THE CONTACT SURFACE

Specific checks for welds

CAPACITY FROM TESTS

DUCTILITY?

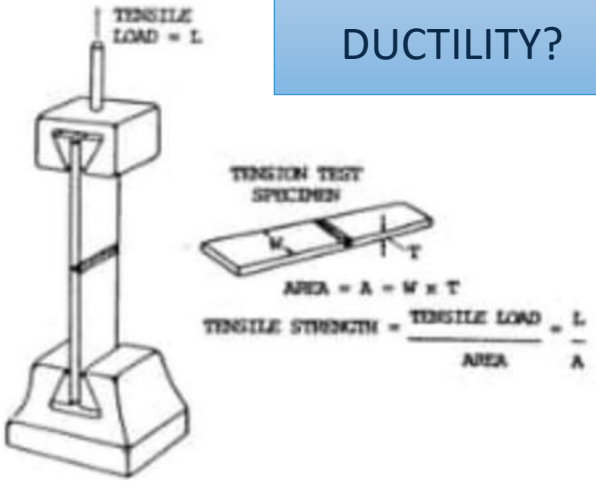
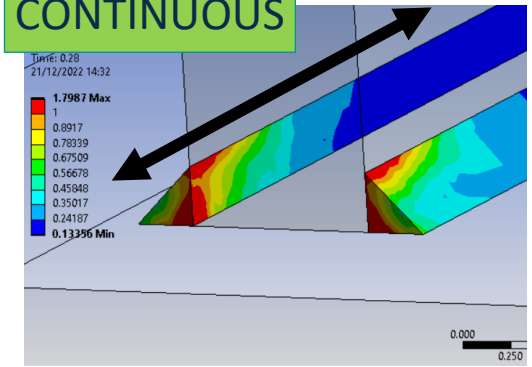


Image credit: Arcraft Plasma

CONTINUOUS

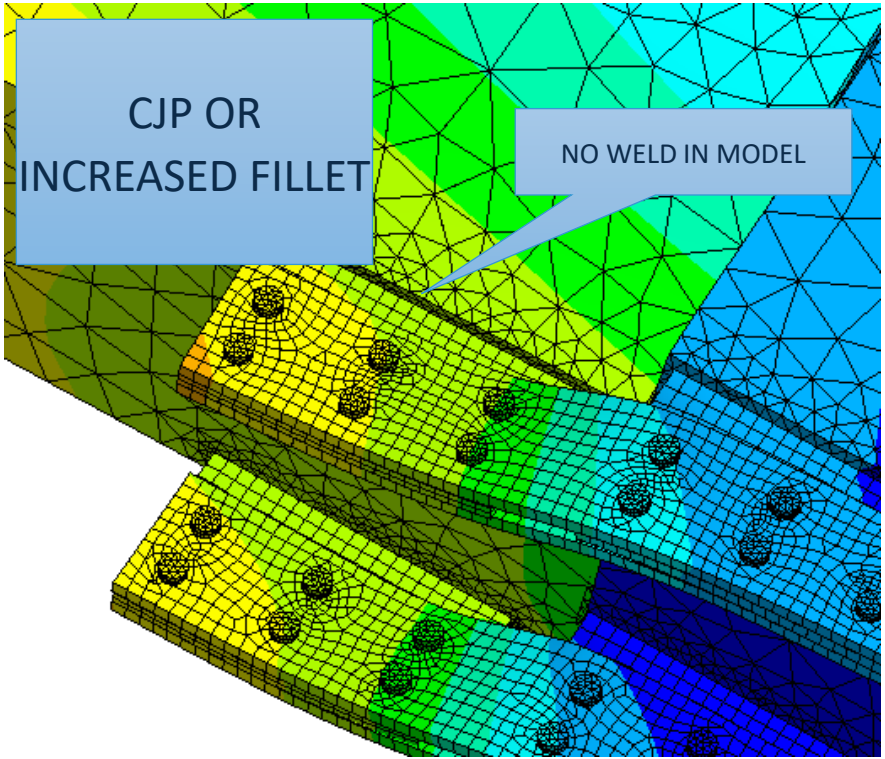


4 FEA DESIGN APPROACHES FOR STATIC LOADING

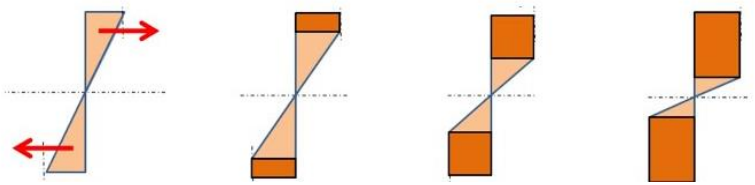
NOT ACADEMICAL OR FATIGUE AND FRACTURE CHECK

OBJECTIVE: PRACTICAL CRITERION FOR FEA

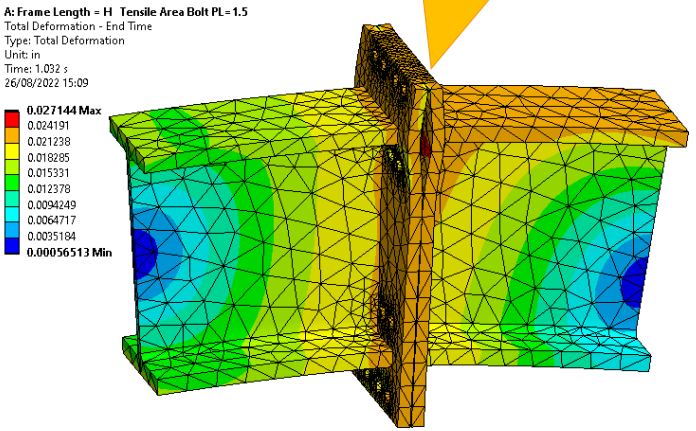
Specific checks for welds



WE DESIGN FOR BENDING
USING “Z”

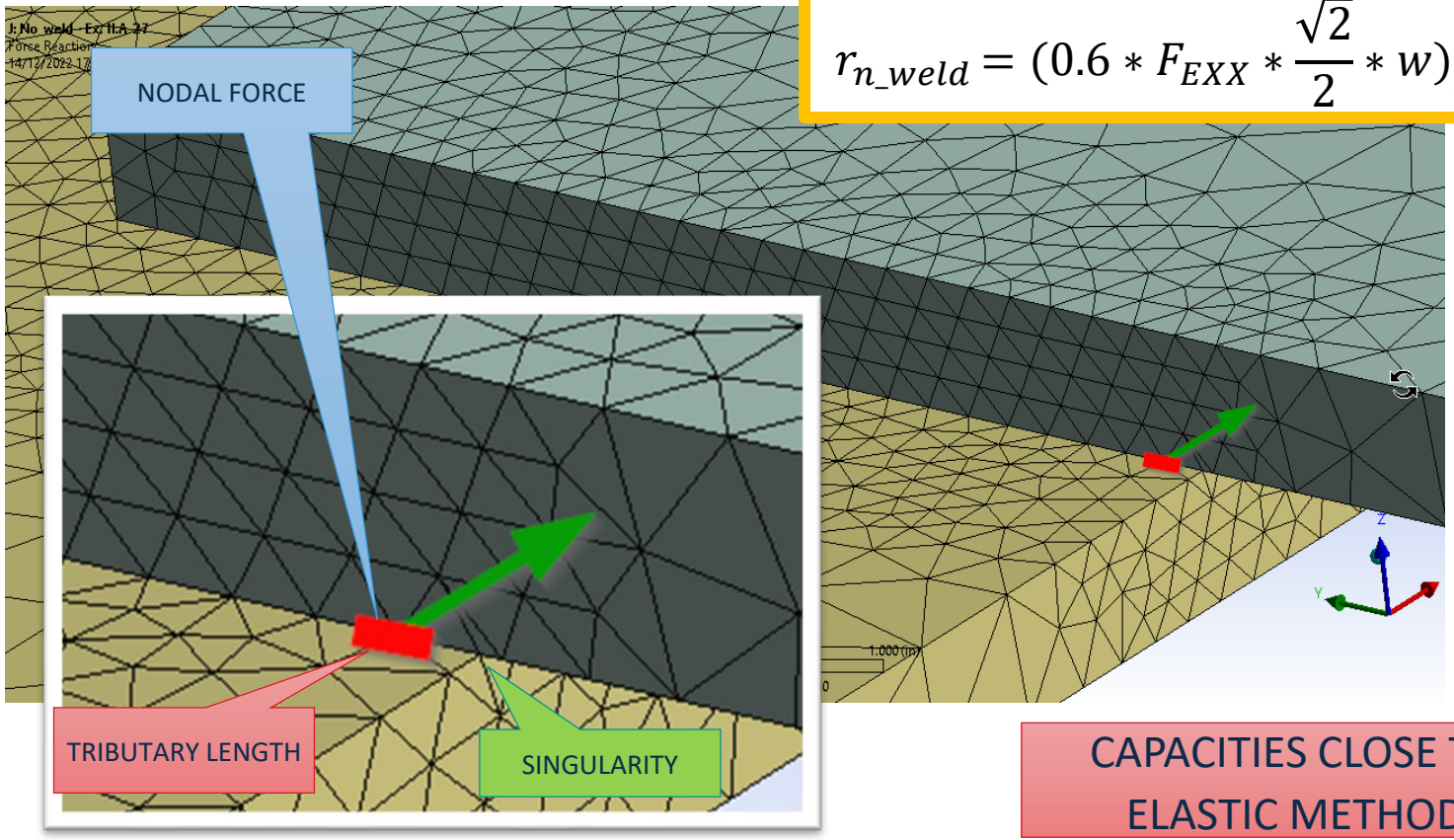


UNREASONABLY LARGE



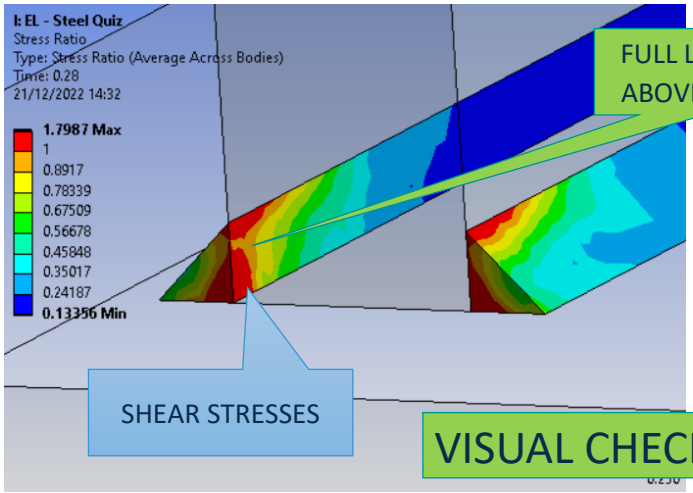
Specific checks for welds

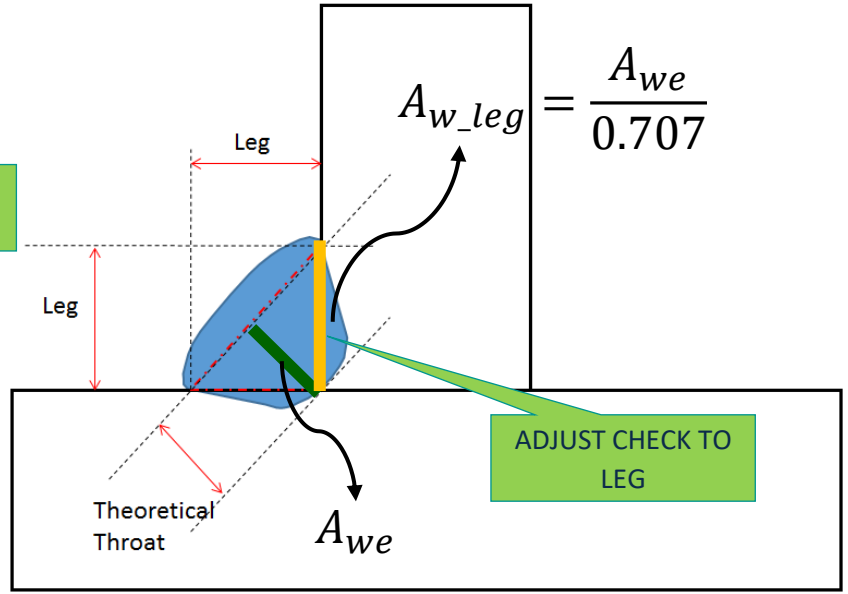
$$r_{n\_weld} = (0.6 * F_{EXX} * \frac{\sqrt{2}}{2} * w)/in.$$

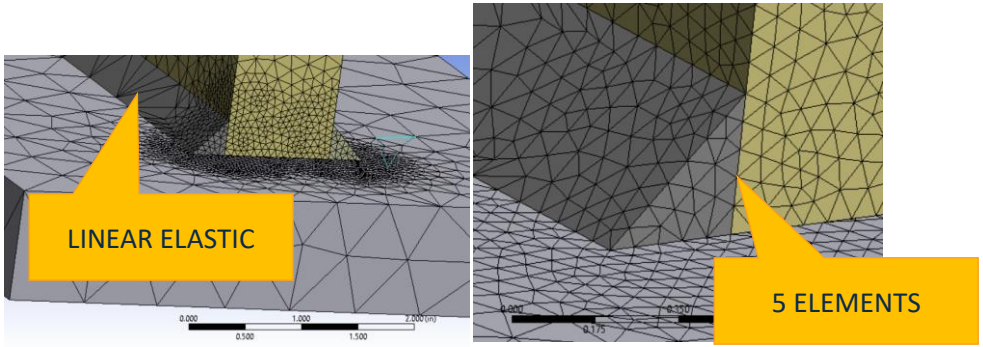


CAPACITIES CLOSE TO ELASTIC METHOD

Specific checks for welds







FOR FILLET WELDS

$$\tau_{n\_w\_leg} = \mathbf{0.707} * 0.6 * F_{EXX}$$

CAPACITIES CLOSE TO ELASTIC METHOD

Specific checks for welds - Ductility

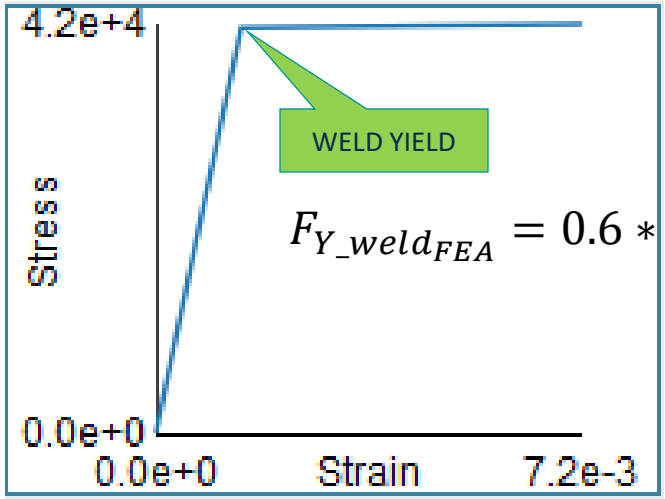
Δ_{ui} = $1.087(\theta_i + 6)^{-0.65}\, w \le 0.17w$, in. (8-4)

= deformation of the ith weld element at ultimate stress (rupture), in.

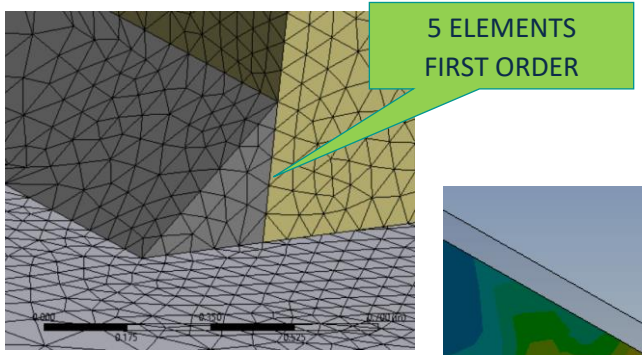
FROM ICR

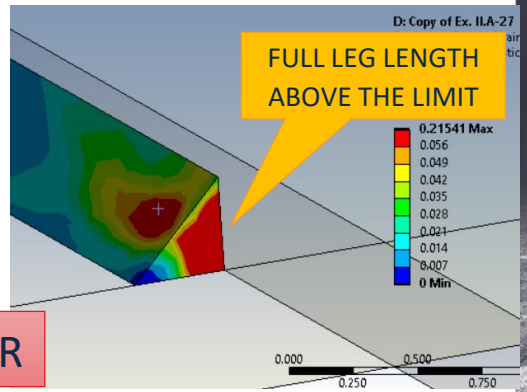
STRAIN LIMIT

$$\frac{\Delta_{ui\_min}}{w} = minimum\ rupture\ strain = 1.087(90^o + 6)^{-0.65} = \mathbf{0.056}$$



$$F_{Y\_weld_{FEA}} = 0.6 * F_{EXX}$$





CAPACITIES CLOSE TO ICR

Specific checks for welds - Comparison

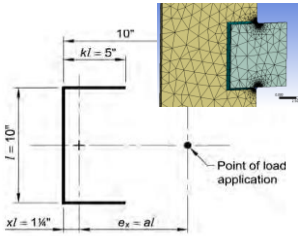


Fig. II.A-26-1. Weld geometry—Solution A ($\theta = 0°$).

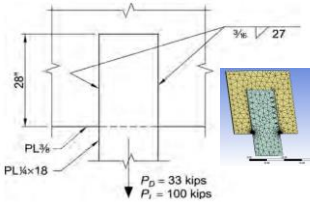
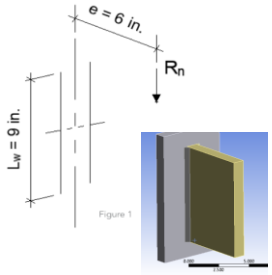


Fig. J.1-1. Geometry and loading for Example J.1.



		WELD ϕRn COMPARISON [kips]							
		WELD DUCTILITY CONSIDERED				**WELD DUCTILITY NOT CONSIDERED**			
NUMBER	*DESIGN CASE*	ANALYTICAL		FEA		ANALYTICAL		FEA	
		φRn [kips]	METHOD	φRn [kips]	METHOD	φRn [kips]	METHOD	φRn [kips]	METHOD
1	*J1 - Fillet weld in Longitudinal Shear*	**206**	Spec. Eq. J2-2	**180**	PLASTIC STRAIN LIMIT	--	--	**49.5**	SHEAR STRESS LIMIT
2	*II.A-26 Excentrically Loaded Weld Group ϑ=00*	**84.8**	ICR	**85.5**	PLASTIC STRAIN LIMIT	**47.2**	ELASTIC METHOD	**39**	SHEAR STRESS LIMIT
3	*II.A-26 Excentrically Loaded Weld Group ϑ=75*	**155**	ICR	**164**	PLASTIC STRAIN LIMIT	--	--	**68.4**	SHEAR STRESS LIMIT
4	*Steel Quiz*	**62.1**	ICR	**57**	PLASTIC STRAIN LIMIT	**30.4**	ELASTIC METHOD	**21.8**	SHEAR STRESS LIMIT

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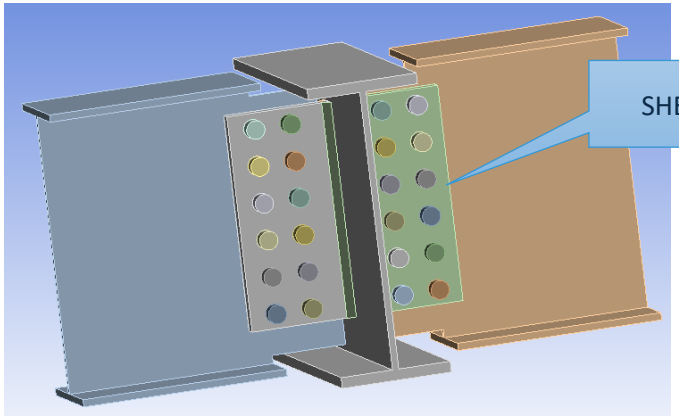
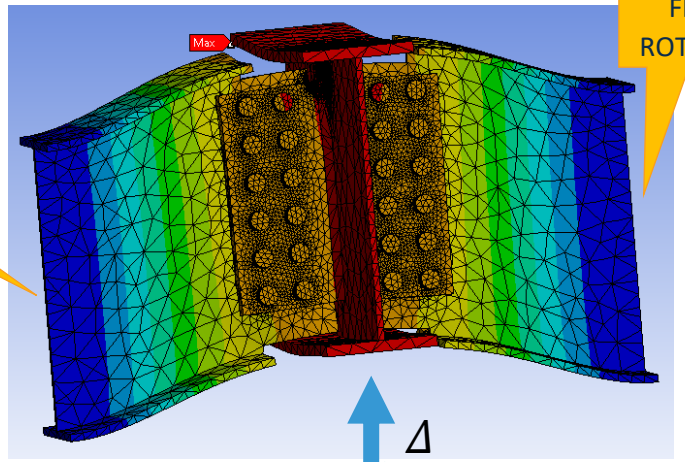
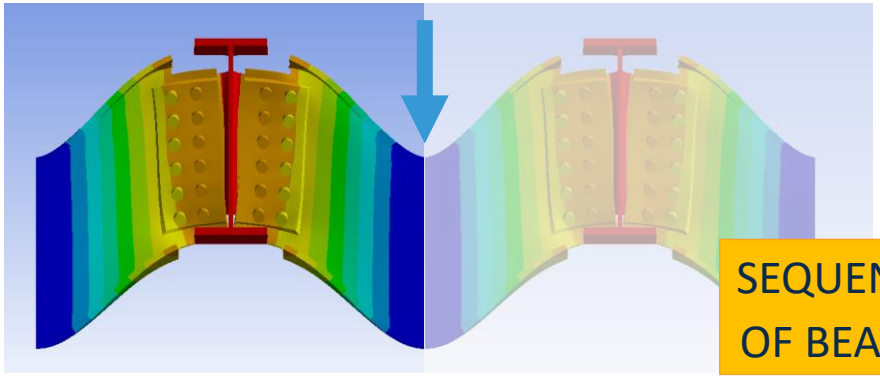
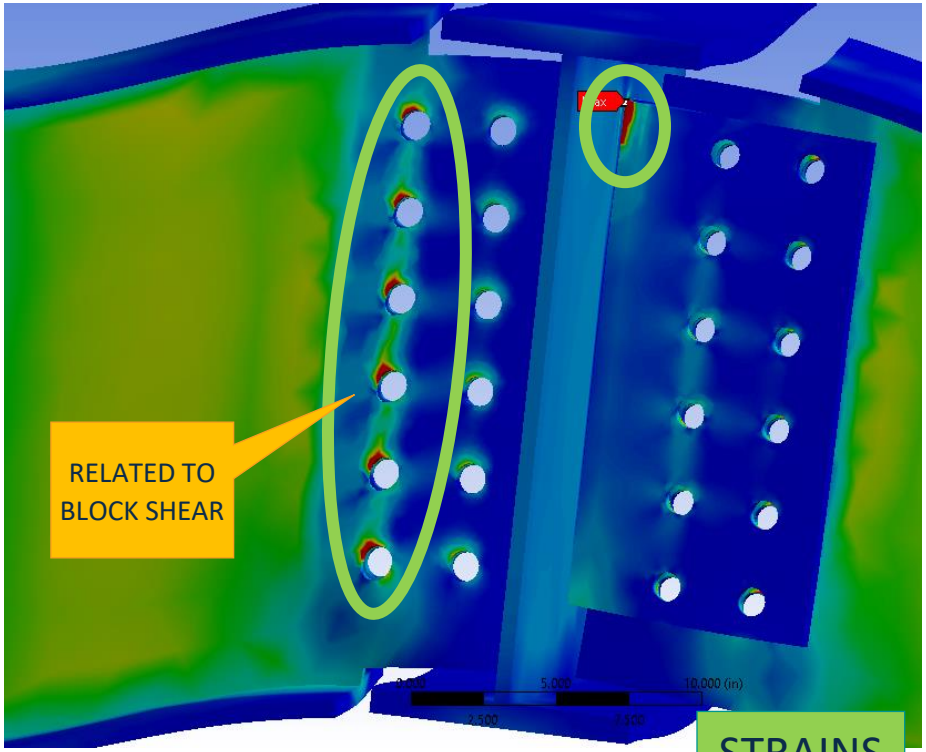
Comparison to analytical results

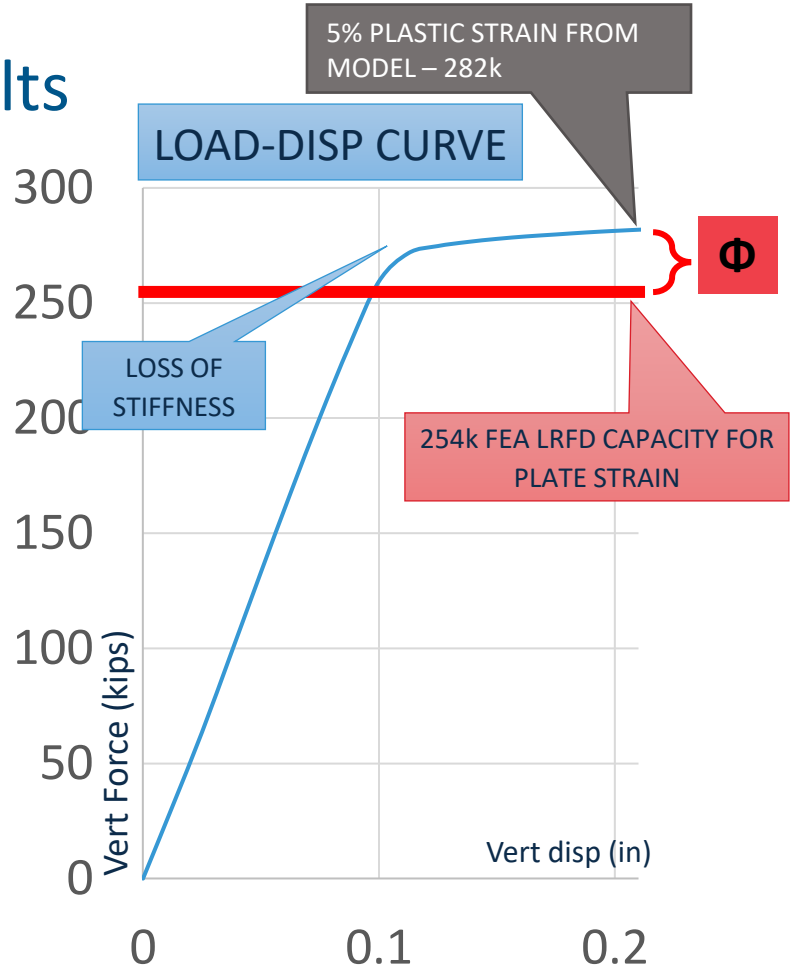




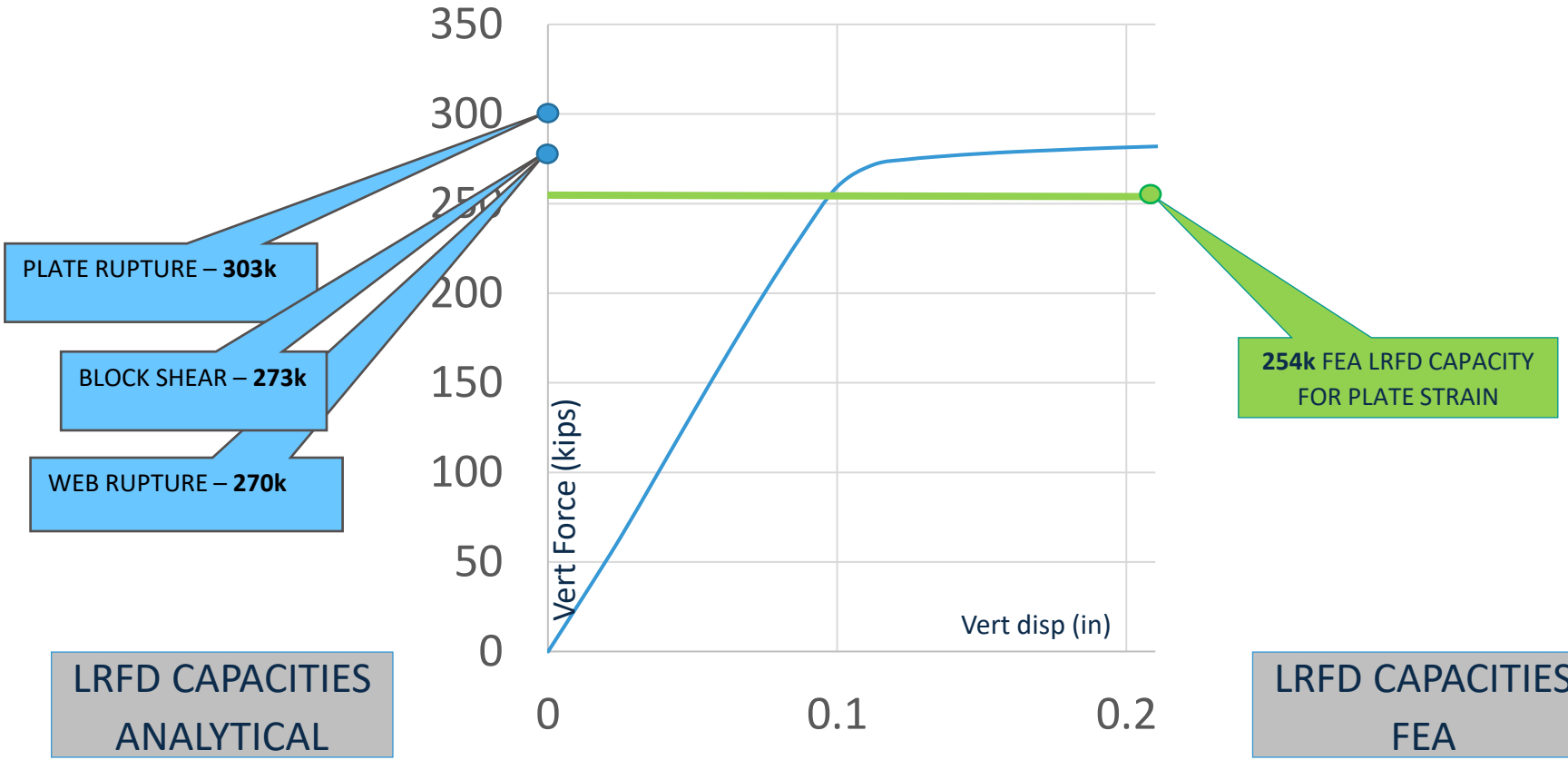


Comparison to analytical results





Comparison to analytical results

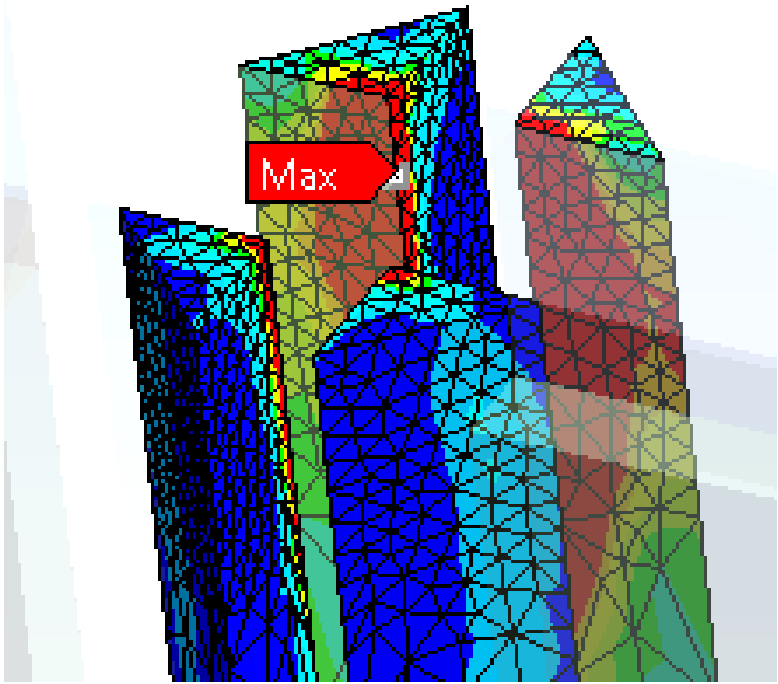


Comparison to analytical results

PLATES – LINEAR ELASTIC

WELD CAPACITY – ANALYTICAL = 490k

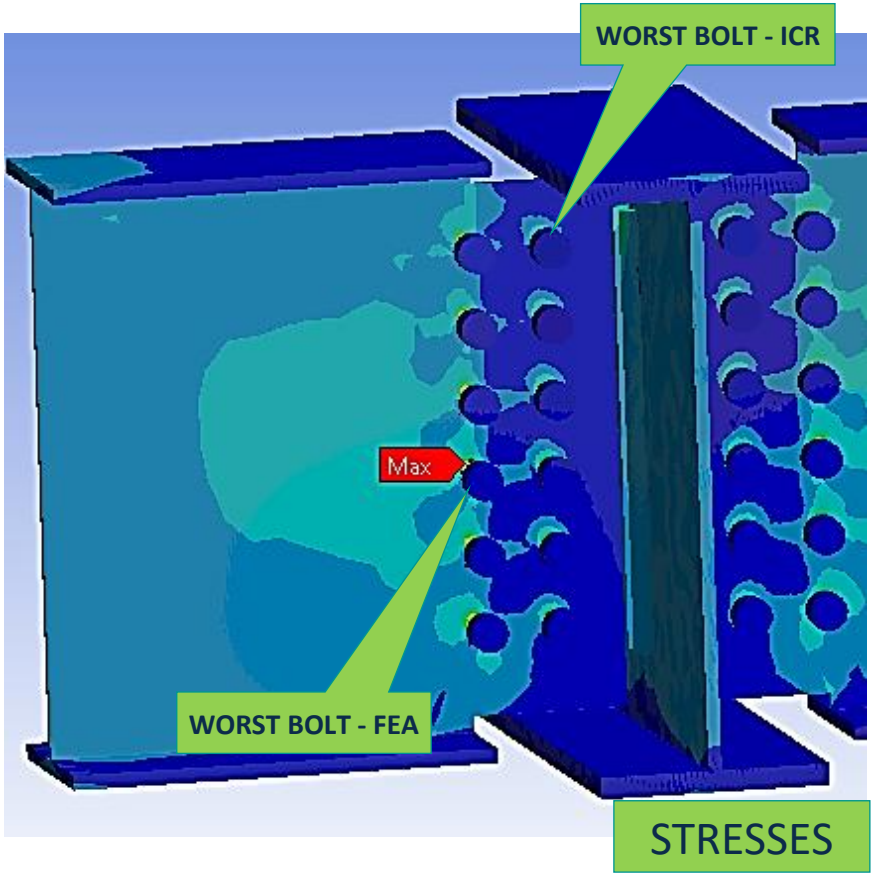
WELD CAPACITY – FEA = 348k



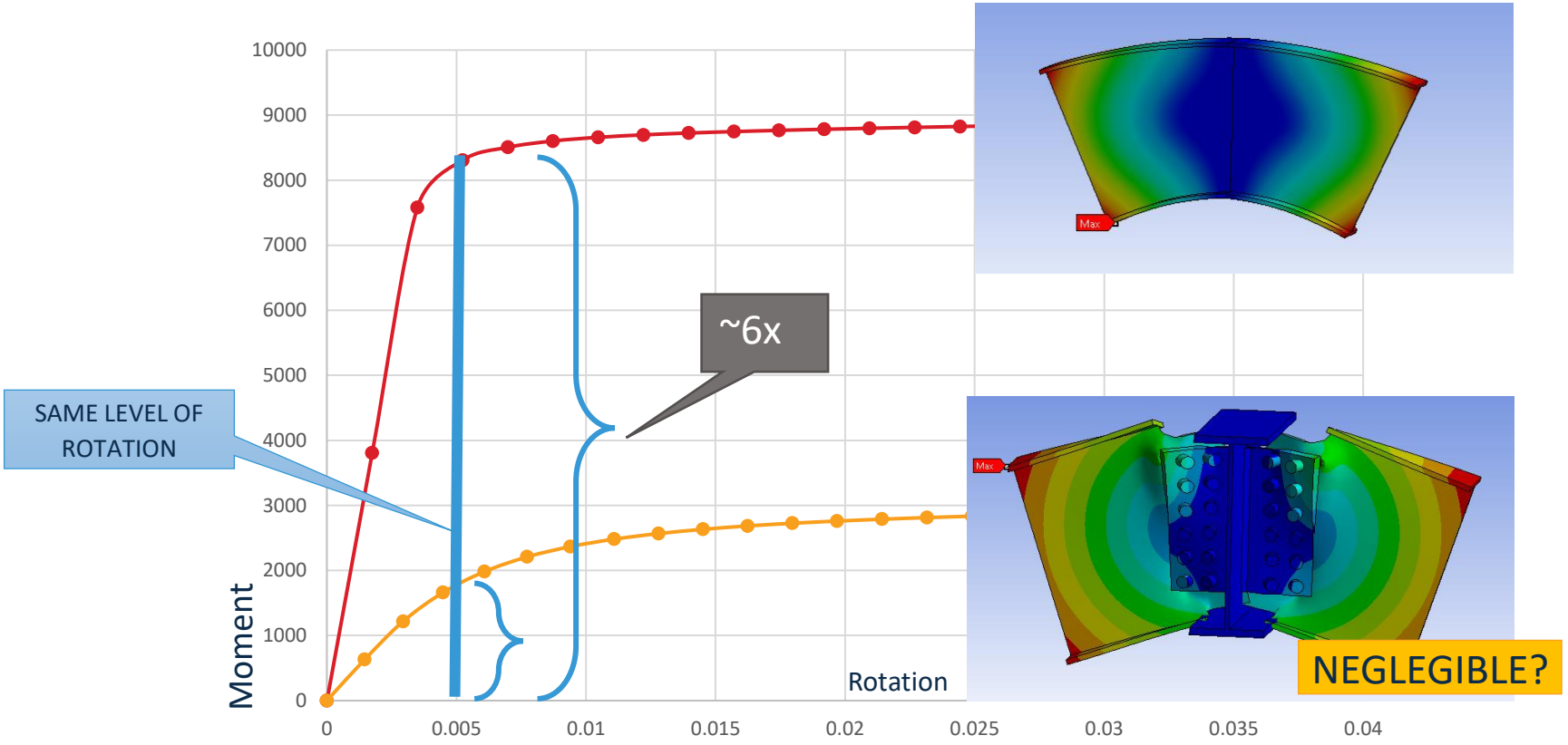
Comparison to analytical results

BOLT SHEAR CAPACITY
ANALYTICAL= 254k

BOLT SHEAR CAPACITY
FEA= 331k

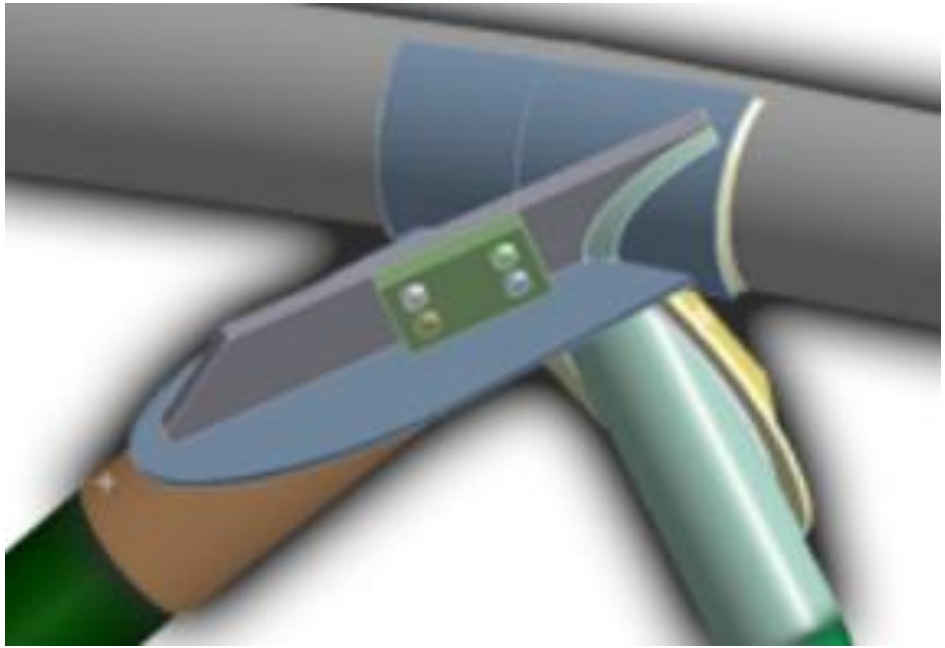


Comparison to analytical results - Stiffness



Assessment Question

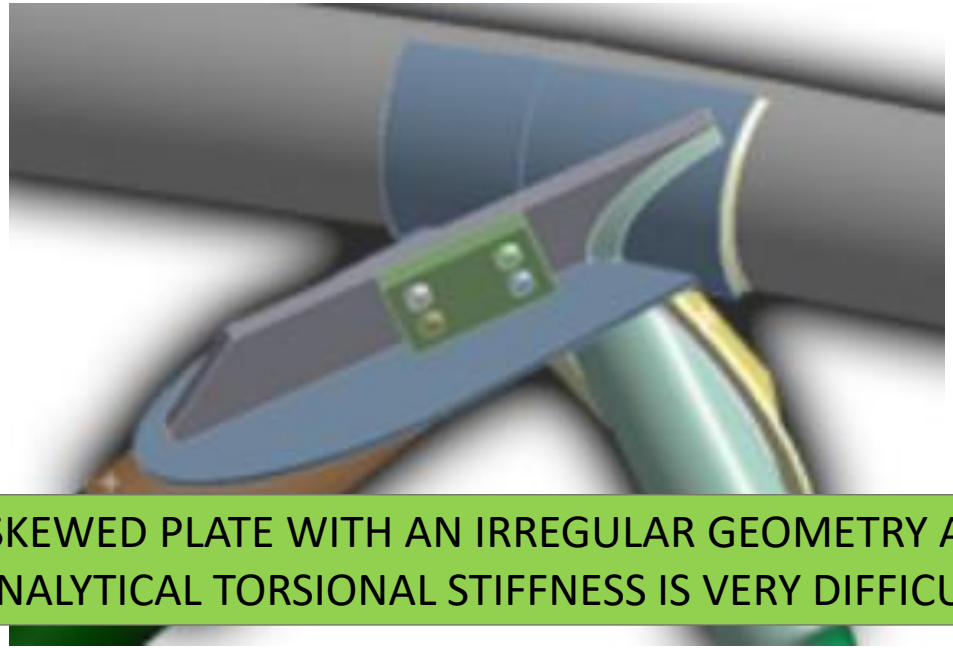
- We are designing the erection aid below and need to count on the torsional stiffness of it to stabilize our calculation model. Is a FEA a suitable option?



- Yes
- No

Assessment Question

- We are designing the erection aid below and need to count on the torsional stiffness of it to stabilize our calculation model. Is a FEA a suitable option?



- Yes
- No

WE ARE DEALING WITH A SKEWED PLATE WITH AN IRREGULAR GEOMETRY AND THE DERIVATION OF AN ANALYTICAL TORSIONAL STIFFNESS IS VERY DIFFICULT

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