Discussion of Current Issues Related to Steel Telecommunications Monopole Structures

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About Paul J. Ford and Company

- Founded in 1965 by Paul J. Ford
- Employee-Owned (ESOP) Since 1994
- Since 1976; Design of Self-Support and Guyed Towers for Cable TV and Long-Distance Telephone
- Since 1985; Design of Telecom/Cellular Towers
- Mid-1990's; Telecom Act of '96; Boom in Design of Telecom Towers and Monopoles
- Yearly Average of 2,000 Analyses, Designs and/or Reinforcement of Towers and Monopoles

About the Author

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- Education: BS (‘83), MS (‘89), The Ohio State University
- Experience: 25 years with Paul J. Ford and Company, Structural Engineers
- Member, TIA TR-14.7 Engineering Subcommittee
- Member, TIA TR-14.7 Structural Reliability Task Group
- Chair, TIA TR-14.7 Monopole Design Sub-Task Group

Overview -- Types of Tubular Steel Poles:

- Flagpoles
- Electric Utility Poles
- Traffic Signal Poles
- Highway Light and Sign Poles
- Commercial Sign Poles
- Telecommunications Antenna Support Poles (Monopoles)

Telecommunications Monopoles

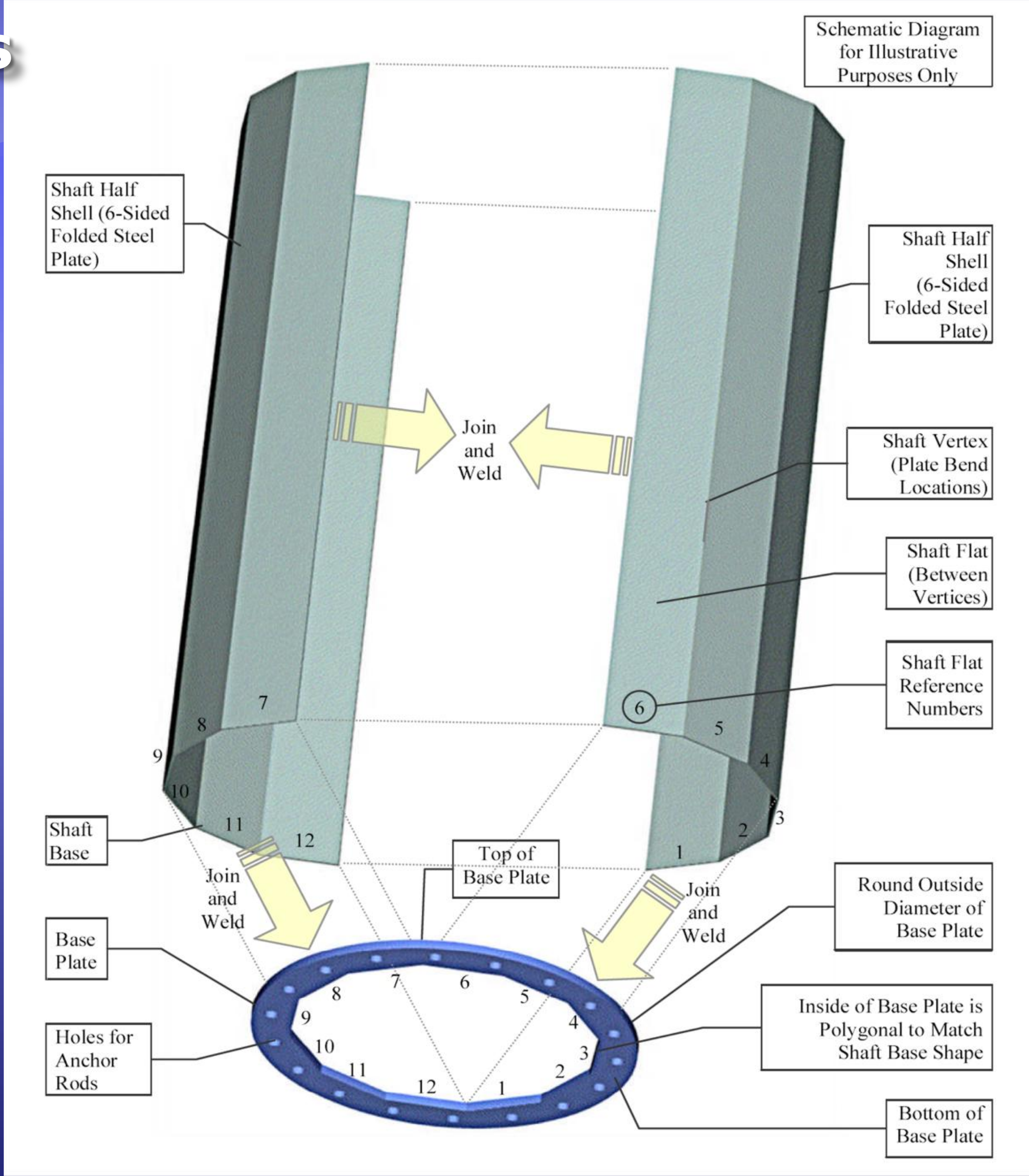
Generally categorized into two main types:

(1.) **Tubular Round** Shafts
with bolted flange splices

(2.) **Polygonal Tapered** Shafts
with slip-joint splices and
bolted base plate connections.
(12 and 18-sided are common)

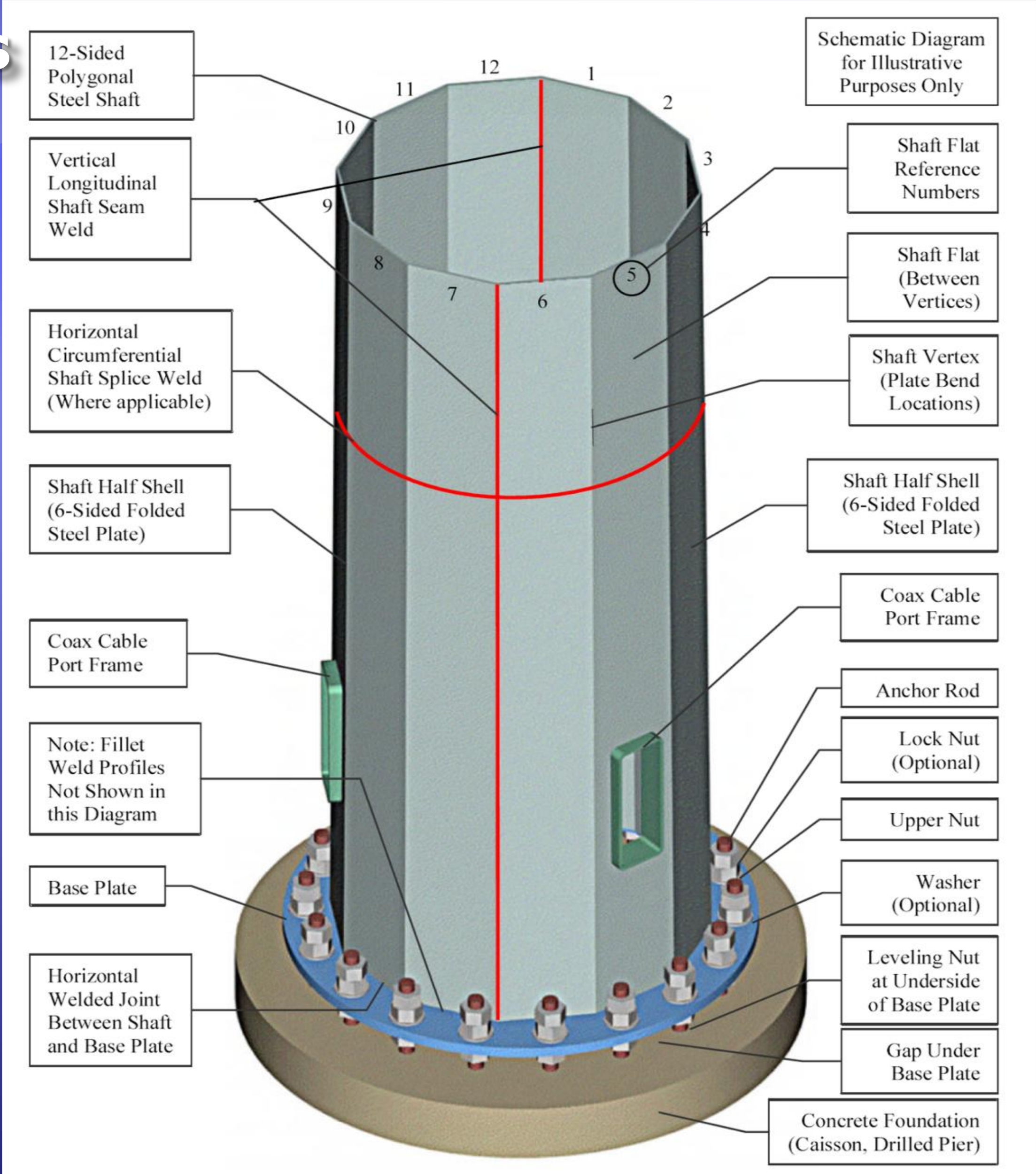
Telecommunications Monopoles

Polygonal Pole Fabrication



Telecommunications Monopoles

Polygonal Pole Components



Telecommunications Design Reference Standards

TIA/EIA-222-F-96 (1996)

- Referenced by IBC 2006 (Ch. 35)
- Sections 1609.1.1, 3108.4

TIA-222-G-2005 (2005)

- Referenced by 2007 Supplement to the IBC (Ch. 35; Sect. 1609.1.1)
- Referenced by IBC 2009 (Ch. 35) Sections 1609.1.1, 3108.4

Telecommunications Design Reference Standards

TIA-222-F (1996)

- ASCE 7-88 Fastest Mile Winds
- AISC ASD (elastic; 1/3 stress increase)

TIA-222-G (2005)

- ASCE 7-02 3-sec Gust Winds
- AISC LRFD (elastic limit states)

TIA-222-G-2 (2009)

- AISC LRFD (plastic limit states)

Compare TIA-222-G with G-2

TIA-222-G and G-1 (Addendum 1):

Factored Loads with Elastic Limit States

TIA-222-G-2 (Addendum 2):

Factored Loads with Plastic Limit States

Compare TIA-222-G with G-2

Table 4-8: Effective Yield Stress for Polygonal Tubular Members

TIA-222-G and G-1 (Addendum 1) Upper Limits:

Effective Yield Stress, F'y = Fy

Moment Capacity, Mn = F'y S (Elastic)

TIA-222-G-2 (Addendum 2) Upper Limits:

Effective Yield Stress, F'y = 1.27 Fy

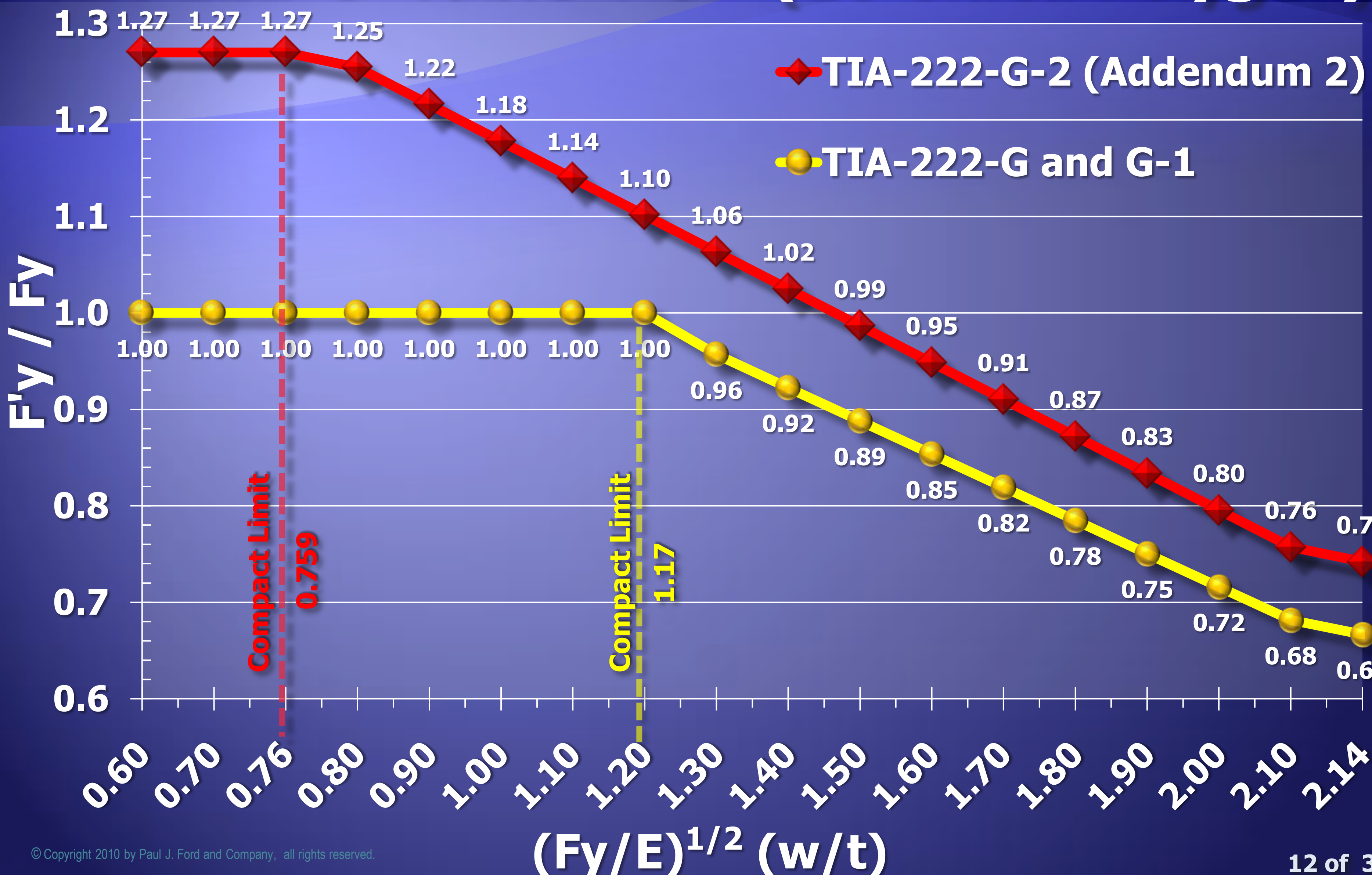
Moment Capacity, Mn = F'y S

= (1.27 Fy) S

(where Z ≈ 1.27 S for 18-sided polygon)

= Fy Z (Plastic)

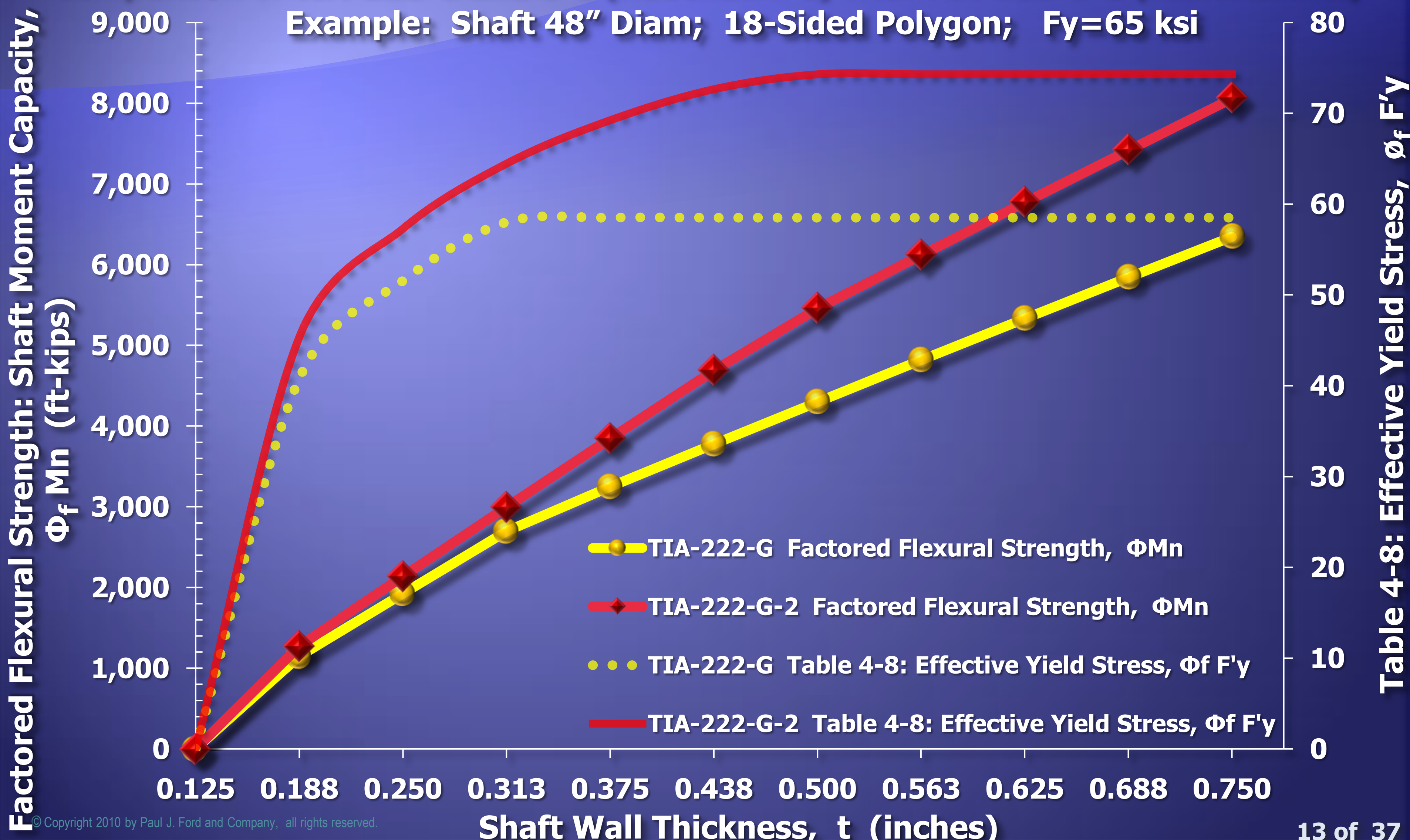
TIA-222-G Table 4-8 (18-sided Polygon)



Factored Flexural Strength (Shaft Moment Capacity) Chart

Comparison of TIA-222-G and G-1 (Addendum 1) with TIA-222-G-2 (Addendum 2)

Example: Shaft 48" Diam; 18-Sided Polygon; Fy=65 ksi



Compare TIA-222-G with G-2

Summary:

Effective Shaft Flexural Strength for Polygonal Poles

Can be 10% to 27% Higher

With TIA-222-G-2

(Addendum 2)

Fatigue and Vortex Shedding Issues

- Criteria for fatigue and dynamic effects from vortex shedding are not currently addressed in TIA-222-G.
- AASHTO has fatigue criteria for highway structures, but may not be appropriate for telecommunications poles.
- ASCE Manual 72 (1990) and ASCE 48-05 Standard (2006) mention vortex shedding and fatigue but do not provide specific criteria.
- TIA TR-14.7 Subcommittee intends to address fatigue and vortex shedding criteria in future revisions of the TIA-222 Standard.
- Additional research and testing is needed to develop fatigue design criteria for poles.

Shaft Upgrades and Reinforcing

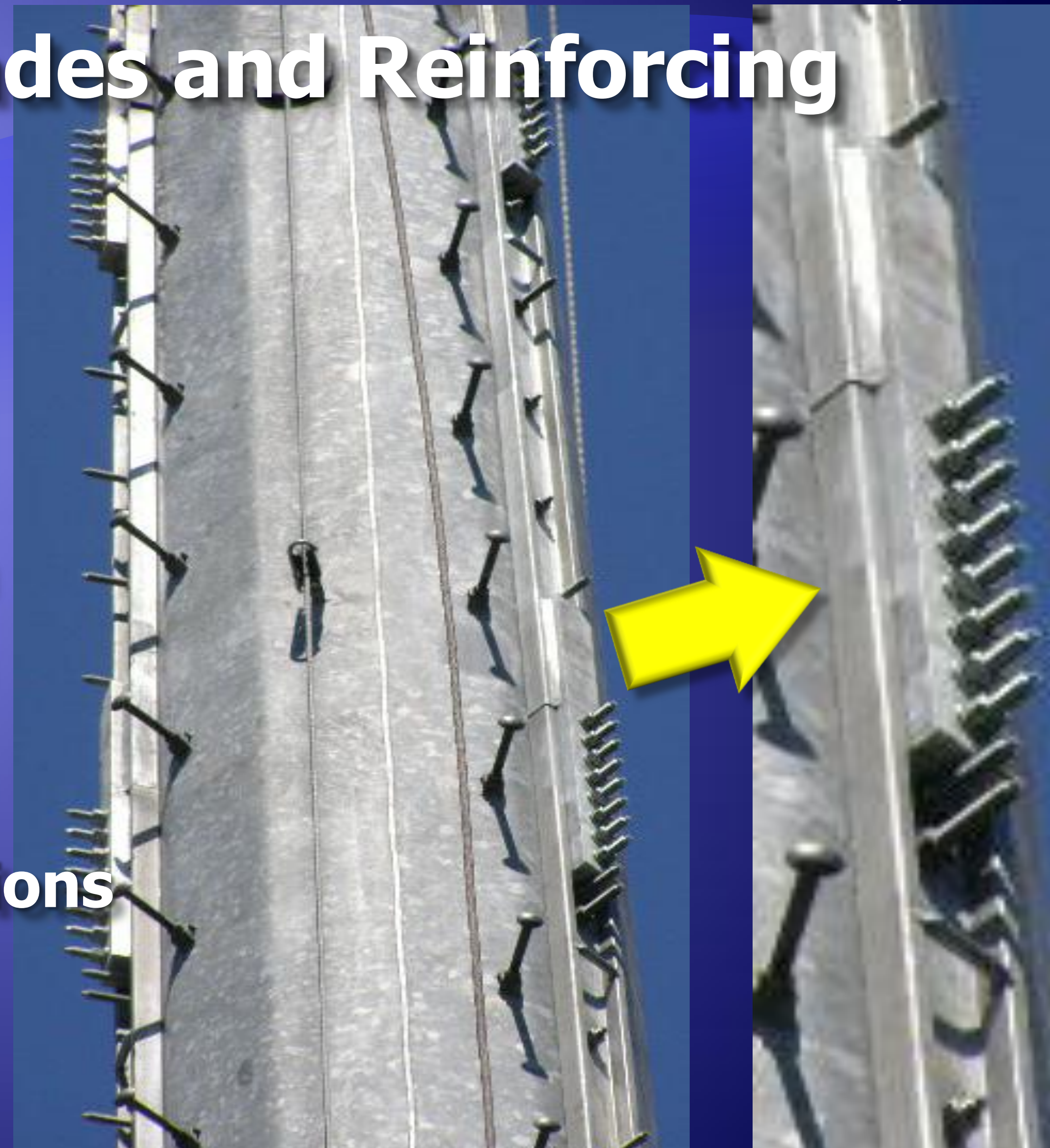
Main Types:

1. Field Welded

Risks: Fire, Corrosion

2. Field Bolted

Cons: Larger connections than welded



Polygonal pole shaft with field bolted channel reinforcements. (Courtesy B. Reese)

Discussion of Monopole Failures

Man-Caused:

- Monopole Fires
- Vandalism
- Cracks in Poor Welds in Base Plates

Environmental Influence:

- Extreme Wind with Debris
- Vortex Shedding Fatigue

Monopole Fires


(Courtesy B. Reese)


(Courtesy B. Reese)


(Courtesy B. Reese)

Most fires are caused by field activities such as flame torching holes in the shaft and field welding. Heat from careless burning and welding ignites debris, such as bird nests, in the pole which then ignites the plastic coated coaxial cables.

Monopole Flange Connection Failures

(Courtesy B. Reese)

(D. Hawkins)

Collapse of pipe poles with bolted flange splices

Monopole Flange Connection Failures


(D. Hawkins)

(D. Hawkins)

Collapse of pipe poles with bolted flange splices

Monopole Flange Connection Failures

(D. Hawkins)

(D. Hawkins)

Collapse of pipe poles with bolted flange splices

Monopole Flange Connection Failures

Toe crack at top of weld at vertex in shaft to base plate connection.
(Courtesy B. Reese)

Toe crack at vertex in shaft.
(Courtesy B. Reese)

"Toe Cracks" in Base Plate Welds at Shaft Vertex in Polygonal Poles

Monopole Flange Connection Failures

(Courtesy B. Reese)

(Courtesy B. Reese)

Magnetic Particle (MT)

Ultrasonic (UT) Testing

NDT Testing for “Toe Cracks” in Base Plate Welds

Base Plate and Flange Plate Connections

- Base Plates Without Stiffeners

- Base Plates With Gusset Plate Stiffeners

- Flange to Shaft Connection Types:

(a) "Socket" Type with fillet welds

(b) "Tee" Joint Type with CJP Welds

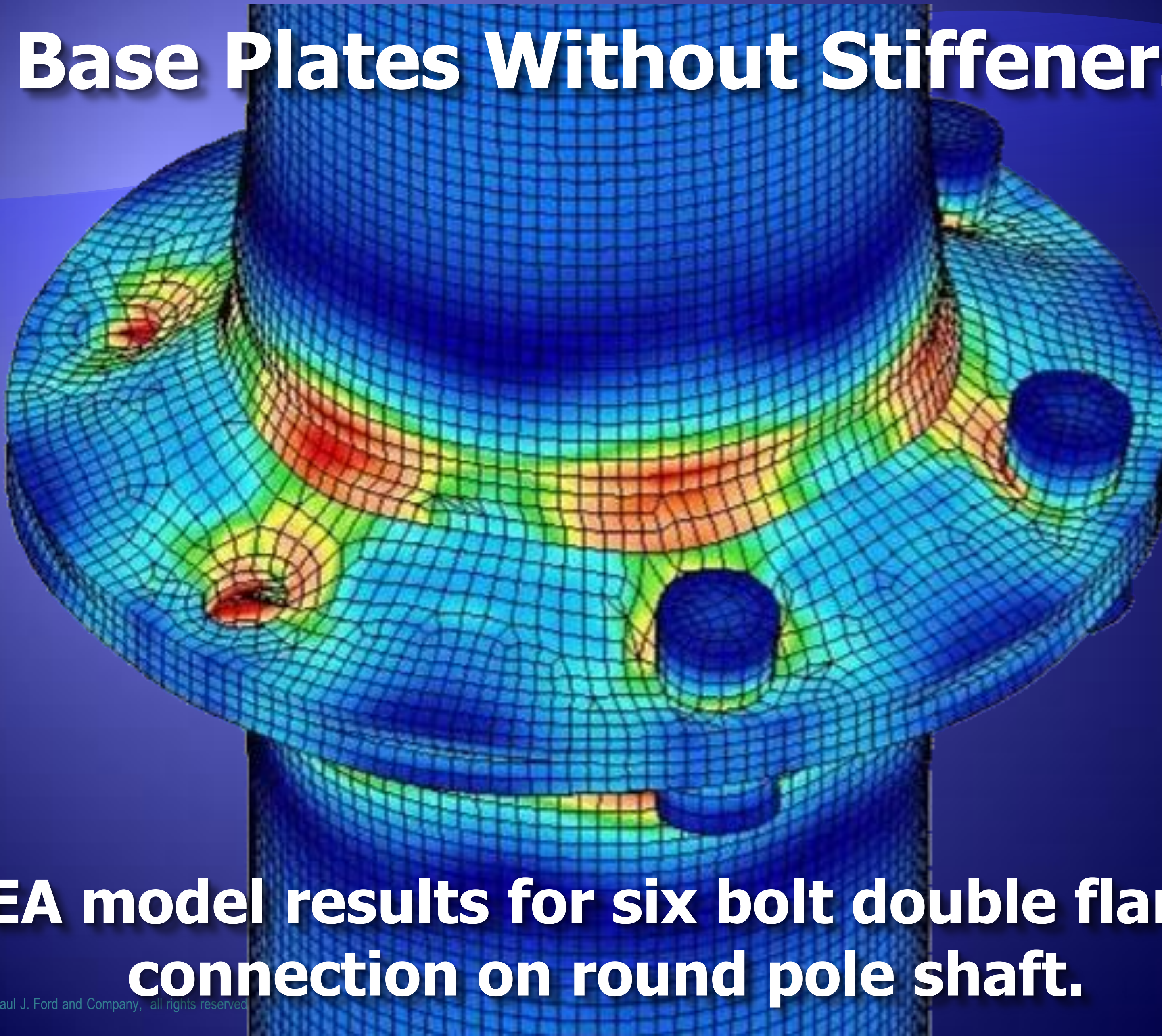
Base Plates Without Stiffeners

Current design methodologies assume linear elastic bending of the base plate. Typically used with AISC-ASD with TIA-222-F working loads.

TIA TR-14.7 Subcommittee researching new base plate design criteria:

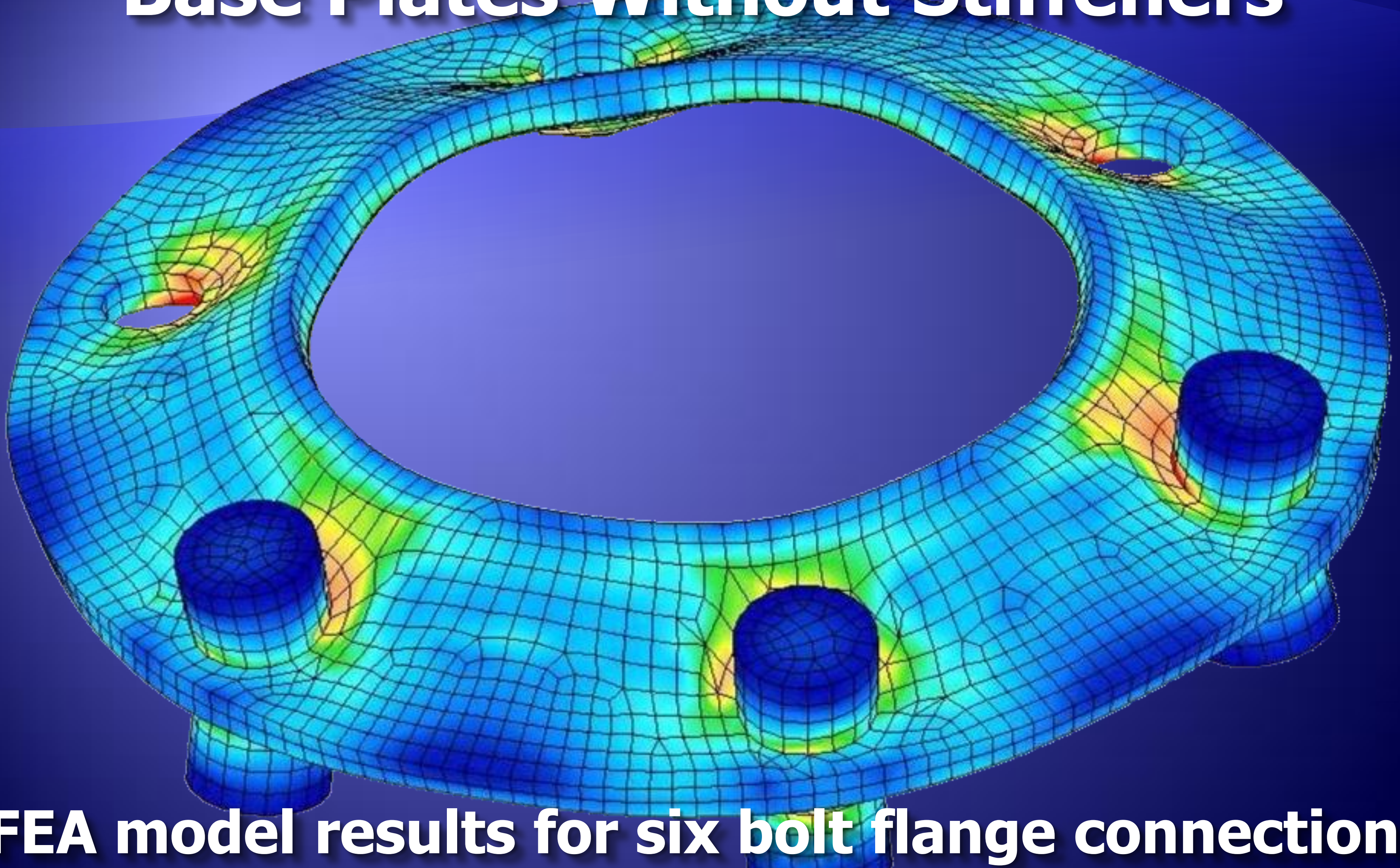
- **Plastic yield line methods at limit states. Analogous to yield lines in concrete slabs, uses balanced energy approach.**
- **Uses AISC-LRFD with TIA-222-G factored loads.**
- **Base plate is proportioned for minimum thickness to eliminate prying forces on the bolts.**
- **Plate ultimate capacity determined by plastic bending limits (FyZ).**
- **Results indicate plate thickness should be at least equal to anchor rod diameter.**
- **Preliminary FEA studies of unstiffened base plates show yield line distribution of stress.**

Base Plates Without Stiffeners



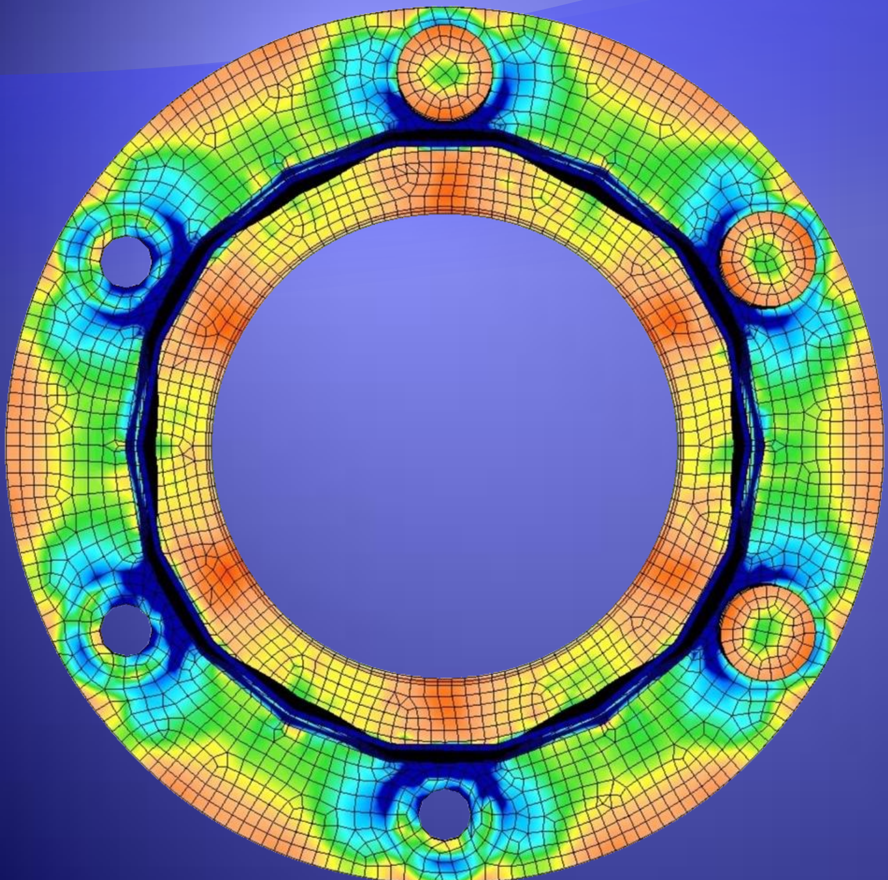
FEA model results for six bolt double flange connection on round pole shaft.

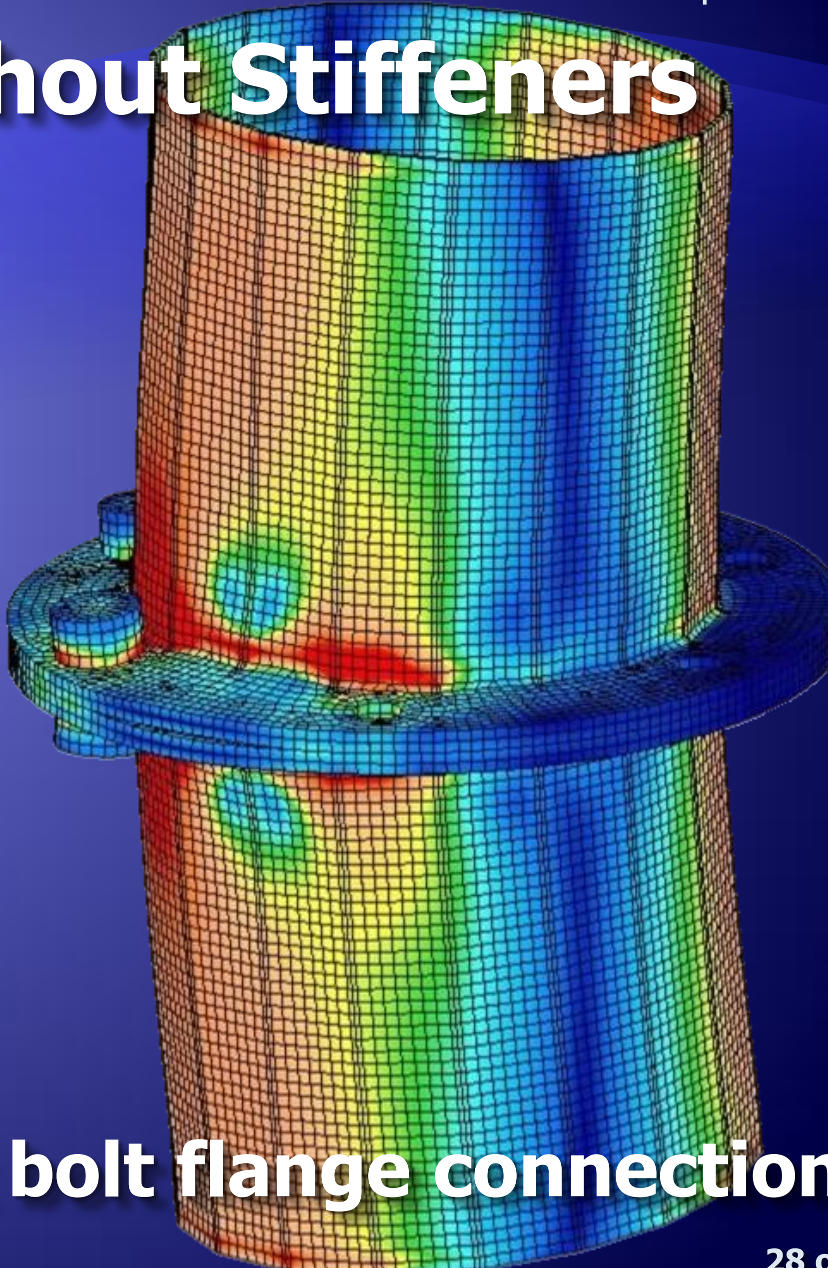
Base Plates Without Stiffeners



FEA model results for six bolt flange connection. Round pole shaft elements hidden.

Base Plates Without Stiffeners





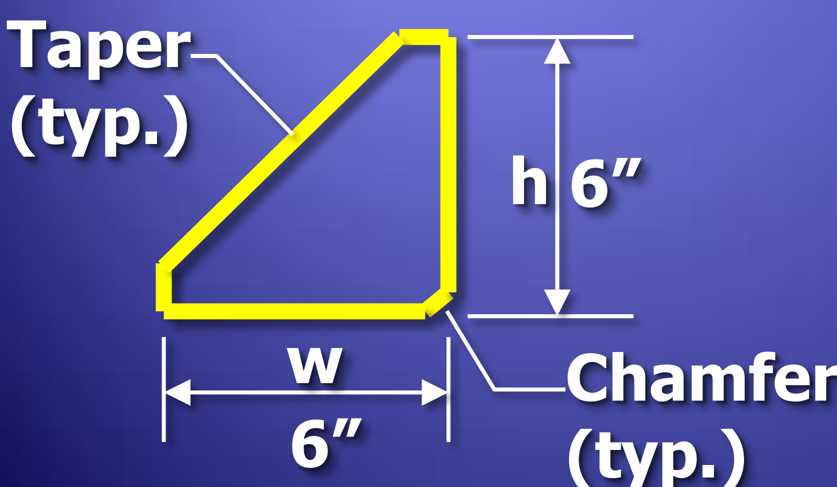
FEA model results for six bolt flange connection.

Base Plates Reinforced With Gusset Plate Stiffeners

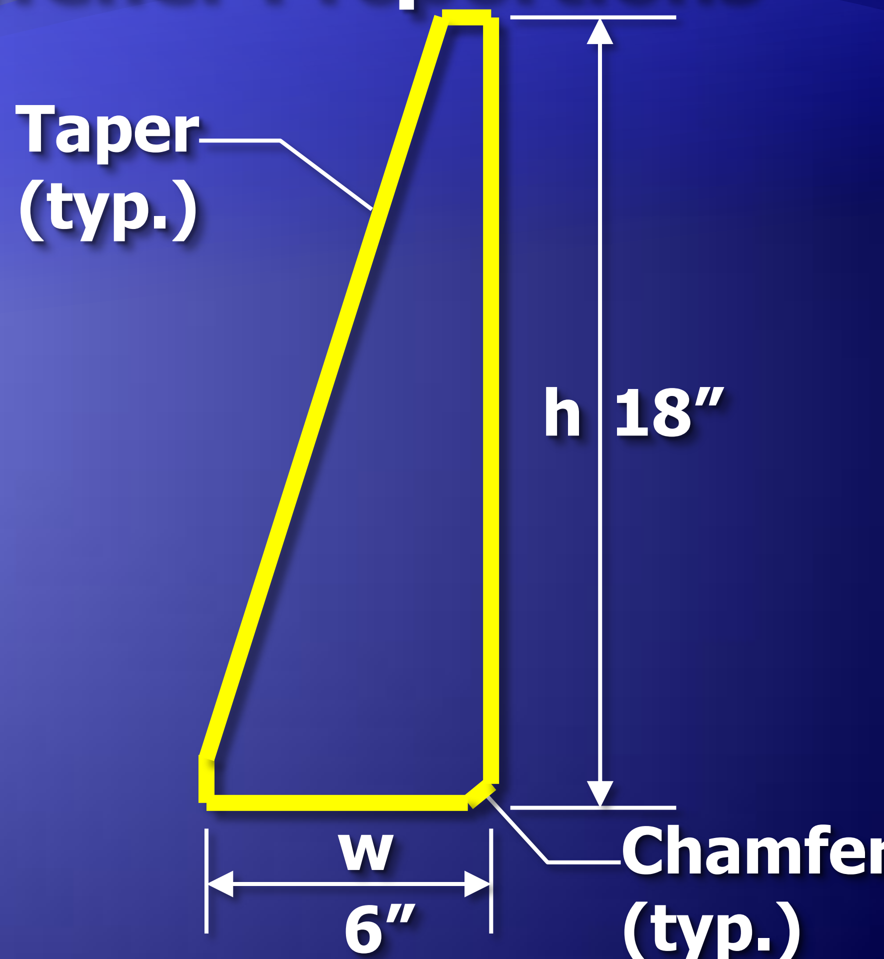
Base plate reinforcement with 'Tall' gusset plate stiffeners. (Courtesy B. Reese)

Base plate reinforcement with 'Tall' gusset plate stiffeners, new anchor rods and brackets. (Courtesy B. Reese)

Gusset Plate Stiffener Proportions

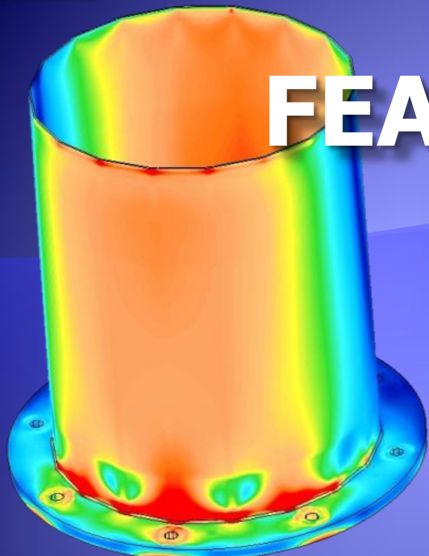


'Short' Stiffener with
h:w = 1:1 aspect ratio
(Not recommended)

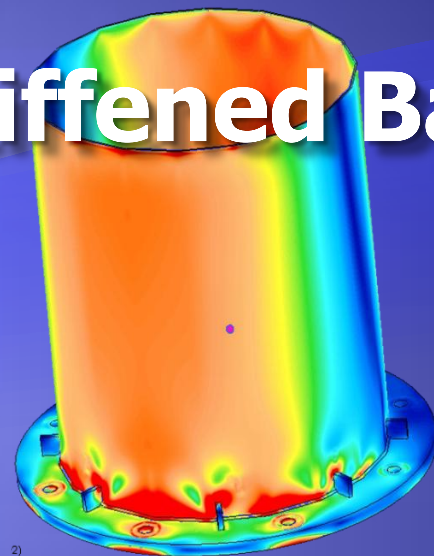


'Tall' Stiffener with
h:w = 3:1 aspect ratio
(Recommended)

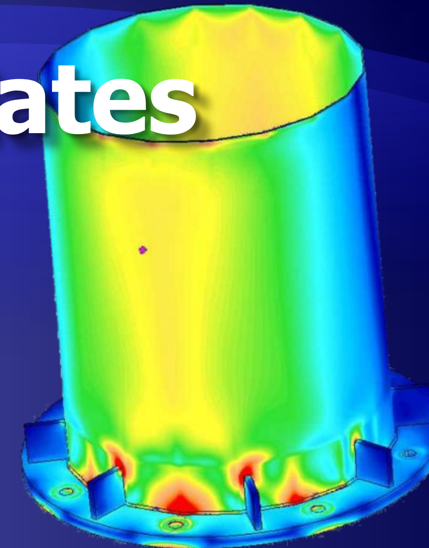
FEA of Stiffened Base Plates



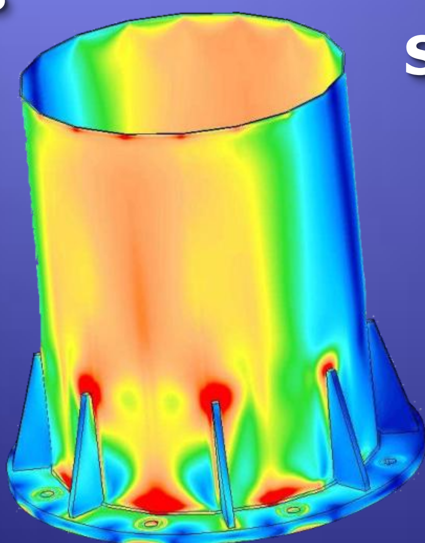
No Stiffeners



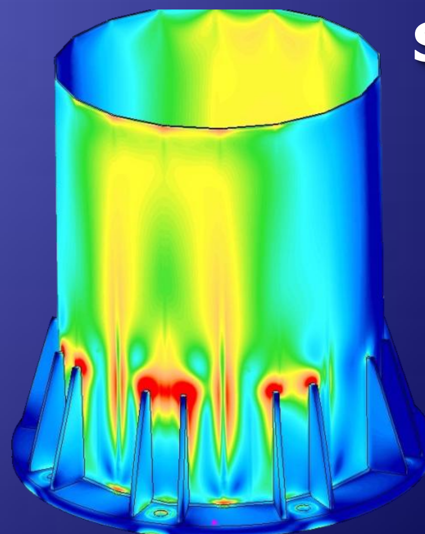
3x3 Stiffeners



6x6 Stiffeners

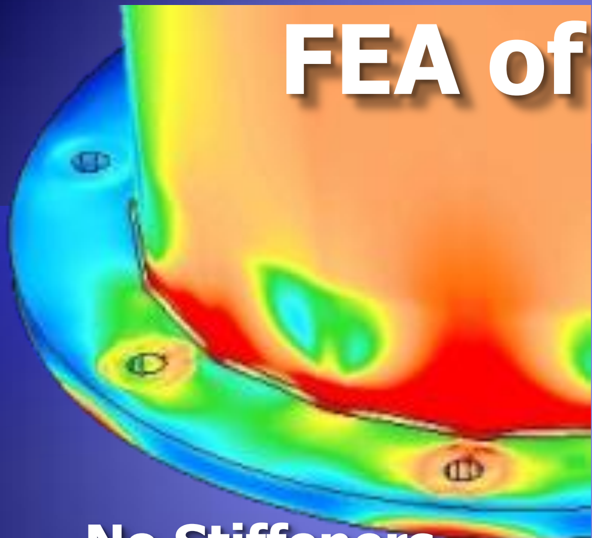


6x18 Stiffeners

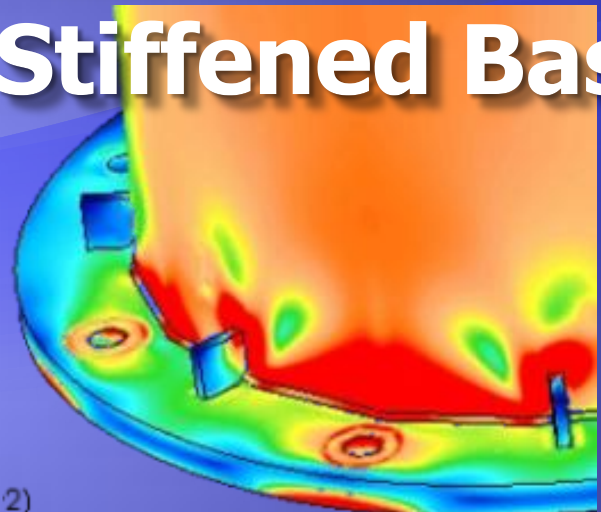


Dbl 6x18 Stiffeners

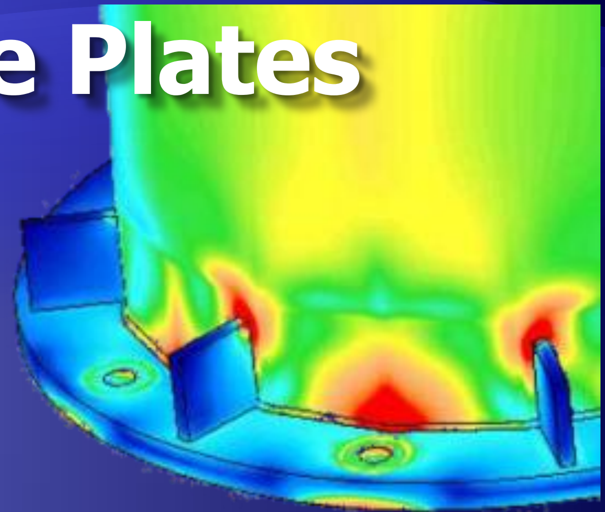
FEA of Stiffened Base Plates



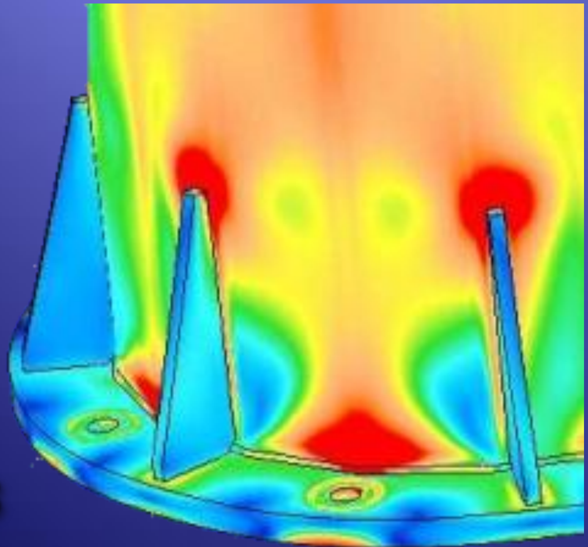
No Stiffeners



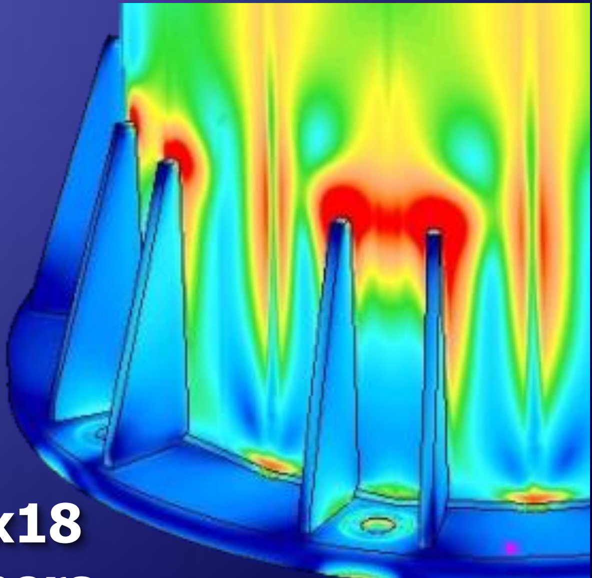
3x3 Stiffeners



6x6 Stiffeners



6x18 Stiffeners



Dbl 6x18 Stiffeners

Further Research Needed

Issues:

TIA TR-14.7 Subcommittee has voluntary members from engineering firms, tower owners, fabricators and contractors.

There has been no significant funding available for research. Each group contributes their own time and resources for any research work done.

Further Research Needed

Opportunities for Additional Research:

- Develop **base plate design methods** using limit states and reliability based approaches.
- **FEA** studies of unstiffened and stiffened base plates using **non linear** methods.
- Full scale **physical testing** of unstiffened and stiffened base plates to correlate with FEA.
- **Fatigue** research for base plate connections, with and without stiffeners.

Additional Research Needed

FEA Simulations:

- 'Non-Rigid' Base Plates with **Bolt Prying**
- **Square** Base Plates (bolts in quadrants)
- Base Plates with **Stiffeners** (incl. **fatigue**)
- Using **Nonlinear Material** (Plastic) Methods
- **Parametric studies** (plate thickness, bolt size, shaft type, bolt circle, flange diameter, etc.) to determine empirical relationships

Additional Research Needed
(continued)

Physical Testing:

- Full scale physical testing of base plates
- Full scale physical testing of base plates with stiffeners

THANK YOU

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