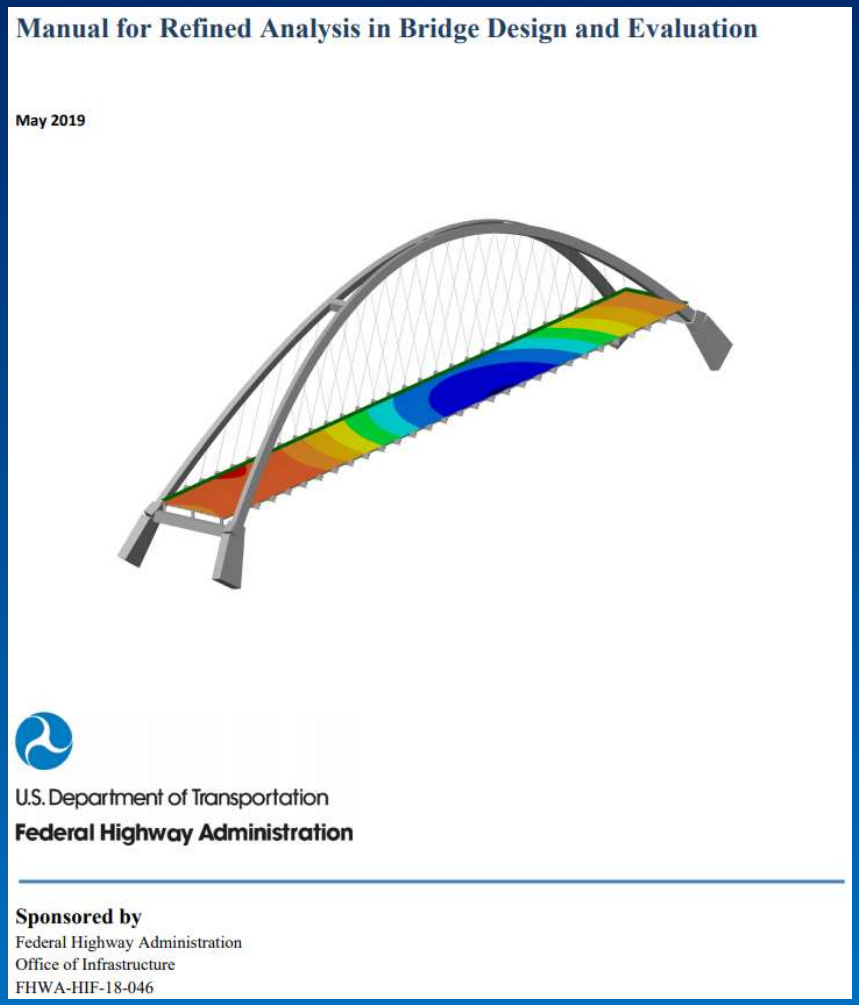
mBrace3D, Refined Analyses for Curved Steel Bridges

FHWA Manual for Refined Analysis in Bridge Design and Evaluation, May 2019



Reference document for FEA applied to bridges

- Different types of analyses:

Line girder analysis (1D)
Plate on eccentric beam analysis (2D)
Finite element analysis (3D)

- Detailed examples -> Benchmark problems

https://www.fhwa.dot.gov/bridge/pubs/hif18046.pdf

FHWA Manual for Refined Analysis in Bridge Design and Evaluation, May 2019

Why use a Refined Analysis?

• "Capturing behavior not adequately accounted for by approximate methods and/or outside the limits of the Specifications. Even within the limits of applicability, approximate methods can give erroneous indications of a **structure's true behavior**.

• Obtaining **more accurate**, and **less conservative**, demands for existing structures, especially when approximate methods result in conservative demands which in turn result in extensive repair or replacement of structures."

FHWA Manual for Refined Analysis in Bridge Design and Evaluation, May 2019

Why use a Refined Analysis?

- "Improved **structural safety** by more rigorous assessment of limit states
- Increased **economy** by going beyond use of approximate, conservative design formulae
- Increased safety and economy by accurate modeling of **system or local behavior**"

FHWA Manual for Refined Analysis in Bridge Design and Evaluation, May 2019

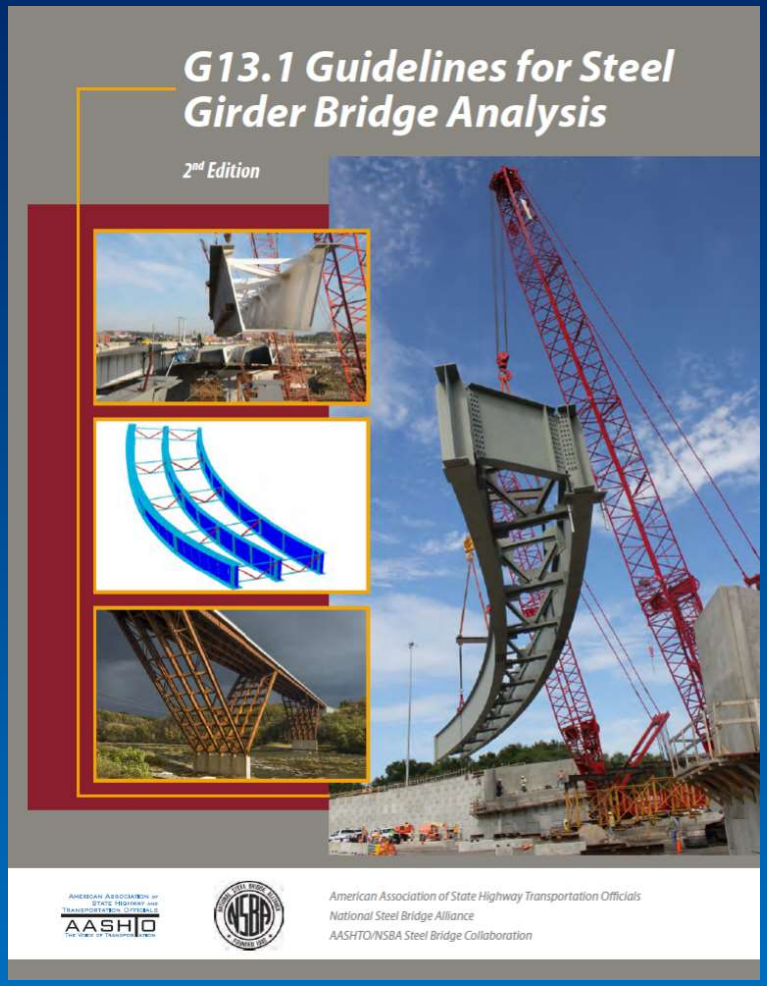
Why use a Refined Analysis?

"This Manual promotes a **fundamental change in the practice of bridge engineering** and attempts to move our industry past the use of simplistic design specifications to achieve more optimal solutions.

(…)

This Manual is seen as an essential component to **defining proper criteria for software vendors to follow** and for engineers to demand from their tools."

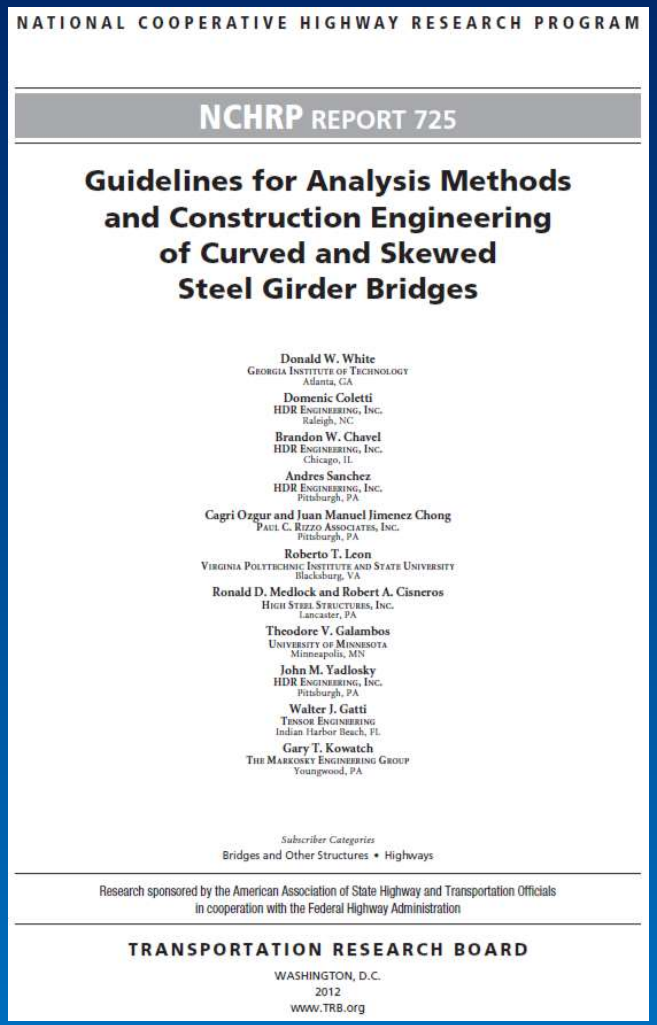
Further References



AASHTO/NSBA Steel Bridge Collaboration – G 13.1 Guidelines for Steel Girder Bridge Analysis, 2nd Edition, 2014

D. Coletti et al.

Further References



NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 725

Guidelines for Analysis Methods and Construction Engineering of Curved and Skewed Steel Girder Bridges

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TRANSPORTATION RESEARCH BOARD
WASHINGTON, D.C.
2012
www.TRB.org

NCHRP Report 725 – Guidelines for Analysis Methods and Construction Engineering of Curved and Skewed Steel Girder Bridges, 2012

D. White, D. Coletti et al.

Arequa Gulch Bridge, Cripple Creek, CO (2001)

Straight plate girder bridge. 1,212 ft long, 266 ft main span, $6 million (AISC)

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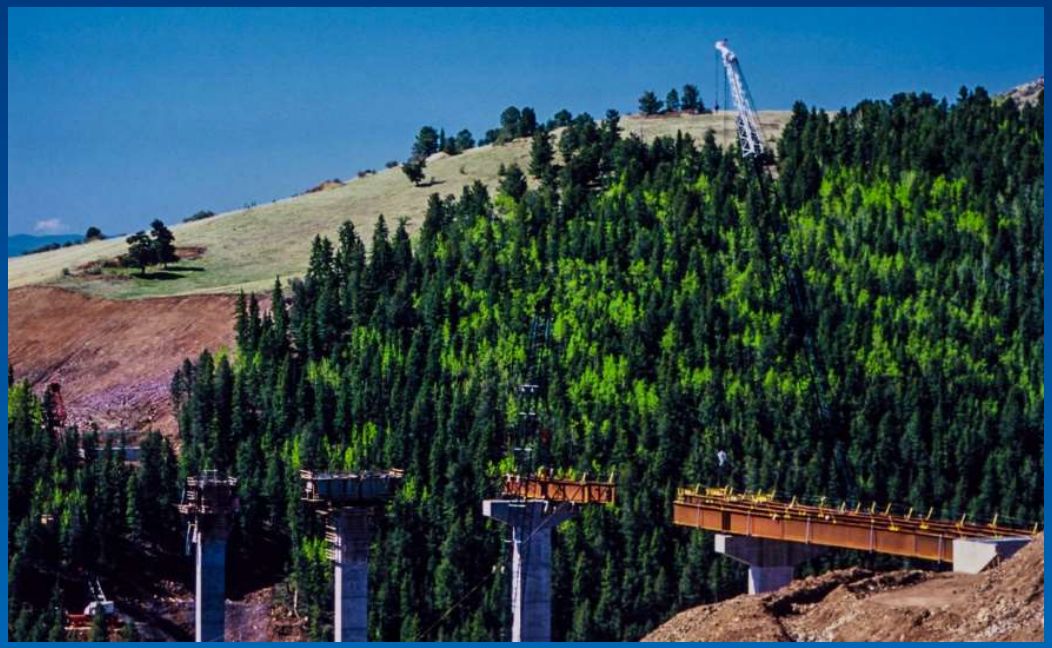


Raccoon Creek Bridge, Pike County, KY (2006)

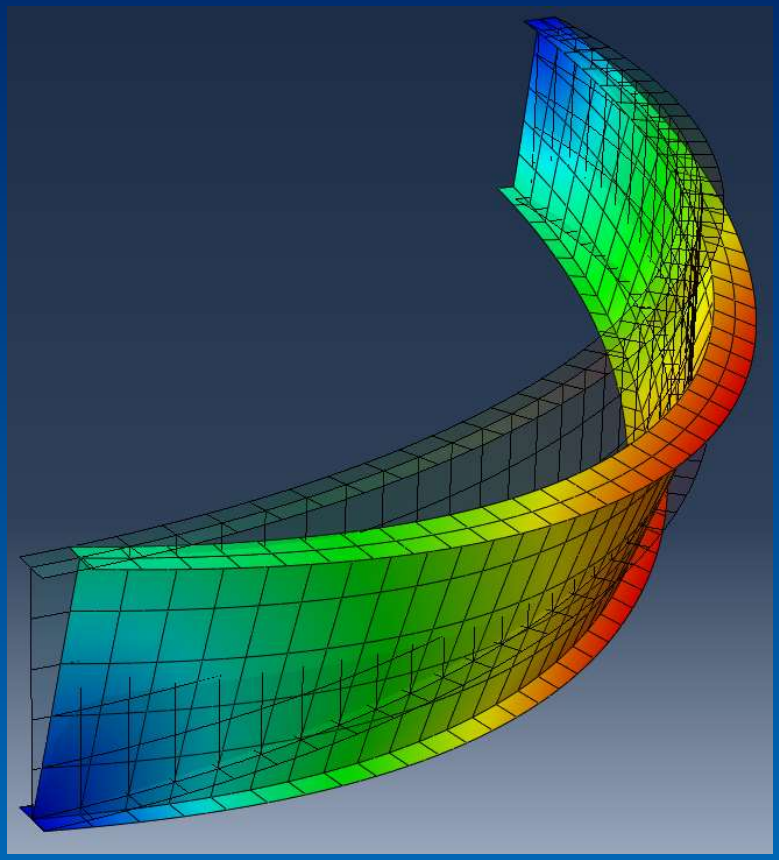
Curved tub girder bridge. 1,275 ft long, 380 ft main span, $20.4 million (AISC)

Raccoon Creek Bridge, Pike County, KY (2006)

Curved tub girder bridge. 1,275 ft long, 380 ft main span, $20.4 million (AISC)

Benefits of a Refined Analysis for Curved Steel Bridges

- Curved geometries induce a combination of **bending and torsion**
- **Stability** during **erection and deck placement** is often critical due to large unbraced lengths and uncertainty in loads and support conditions
- 1D line analyses and 2D grid models are often inadequate for the construction phase



Program: ABAQUS

mBrace3D – “Refined” Analysis – Modeling

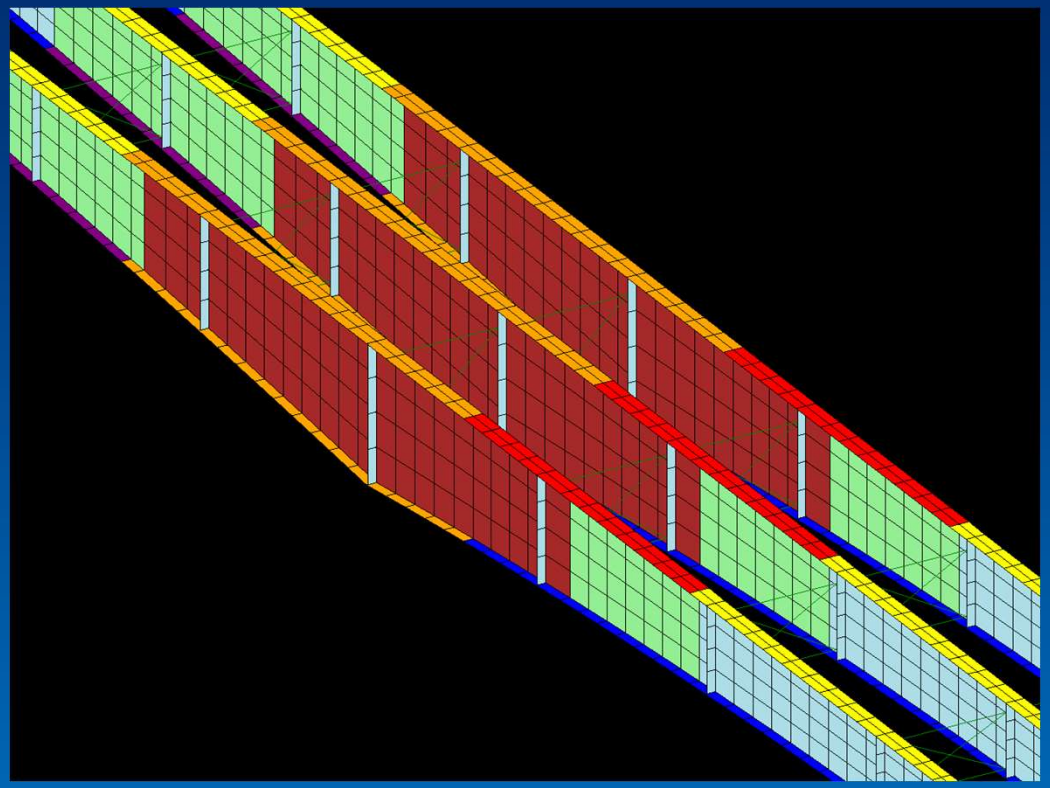
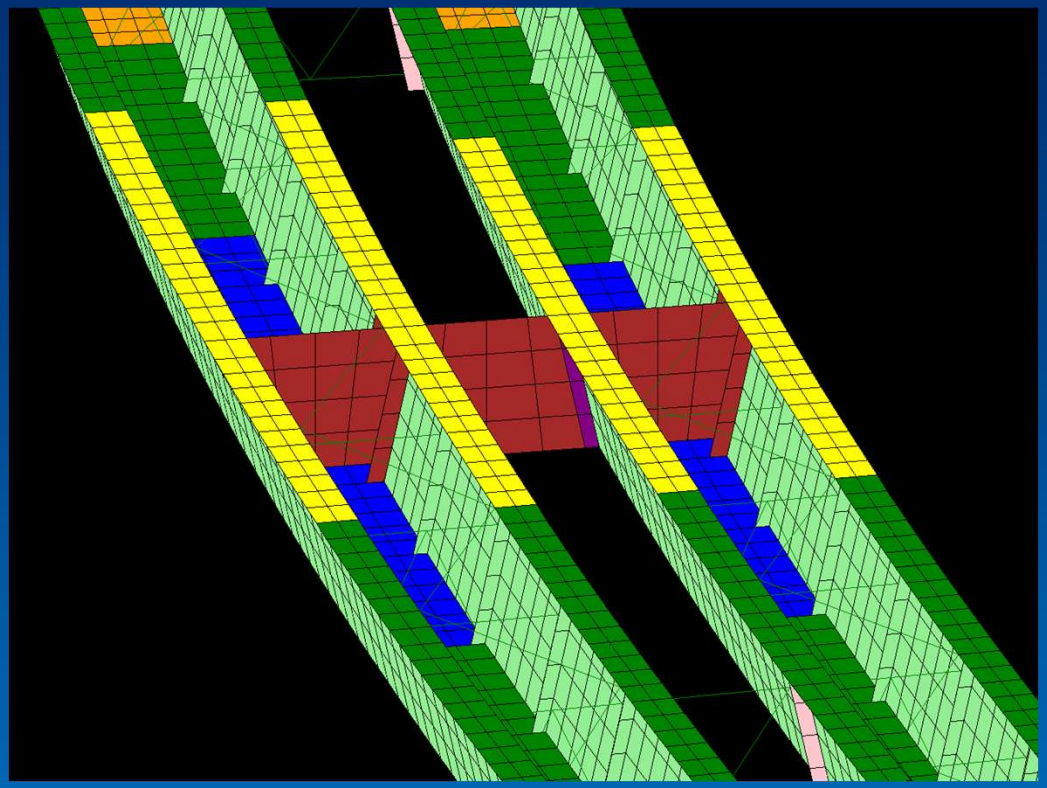
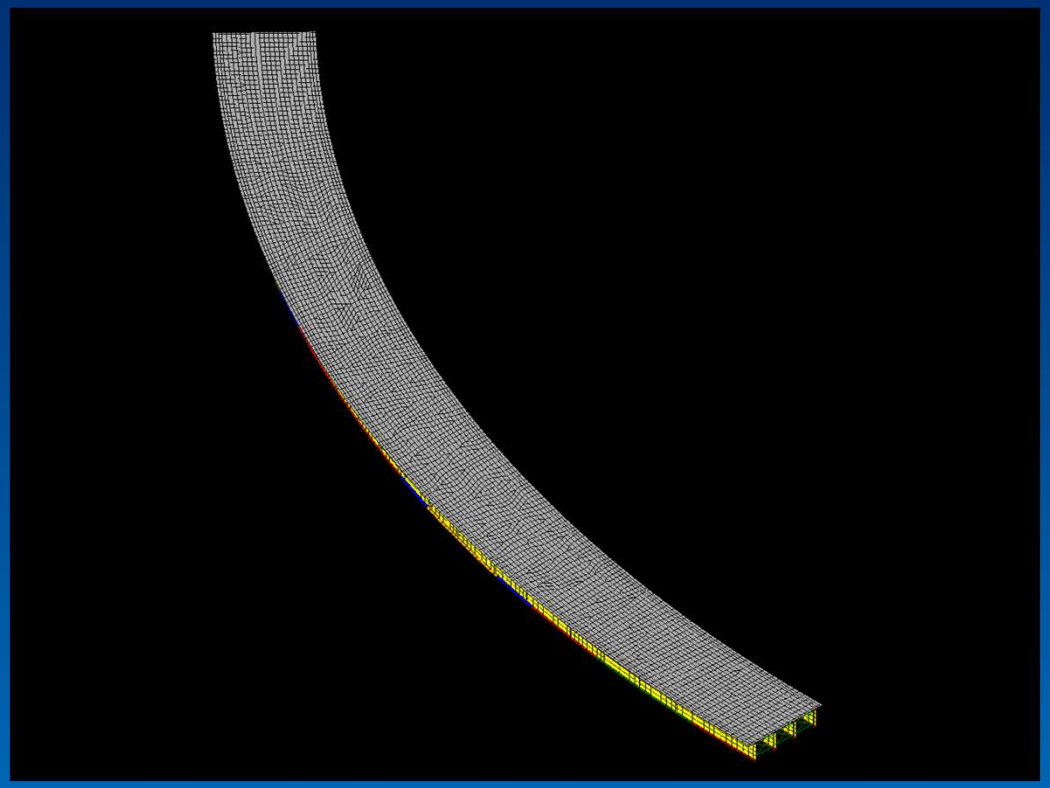


Plate girders (parabolic haunch)

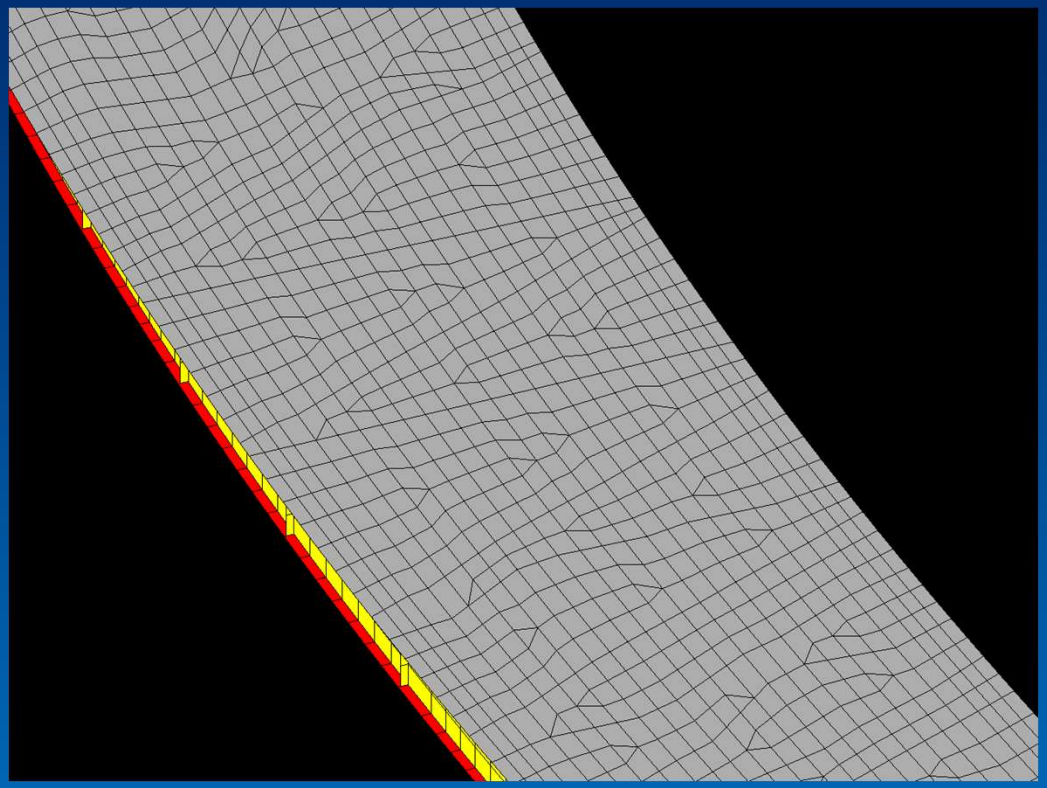


Tub girders

mBrace3D – “Refined” Analysis – Deck Modeling

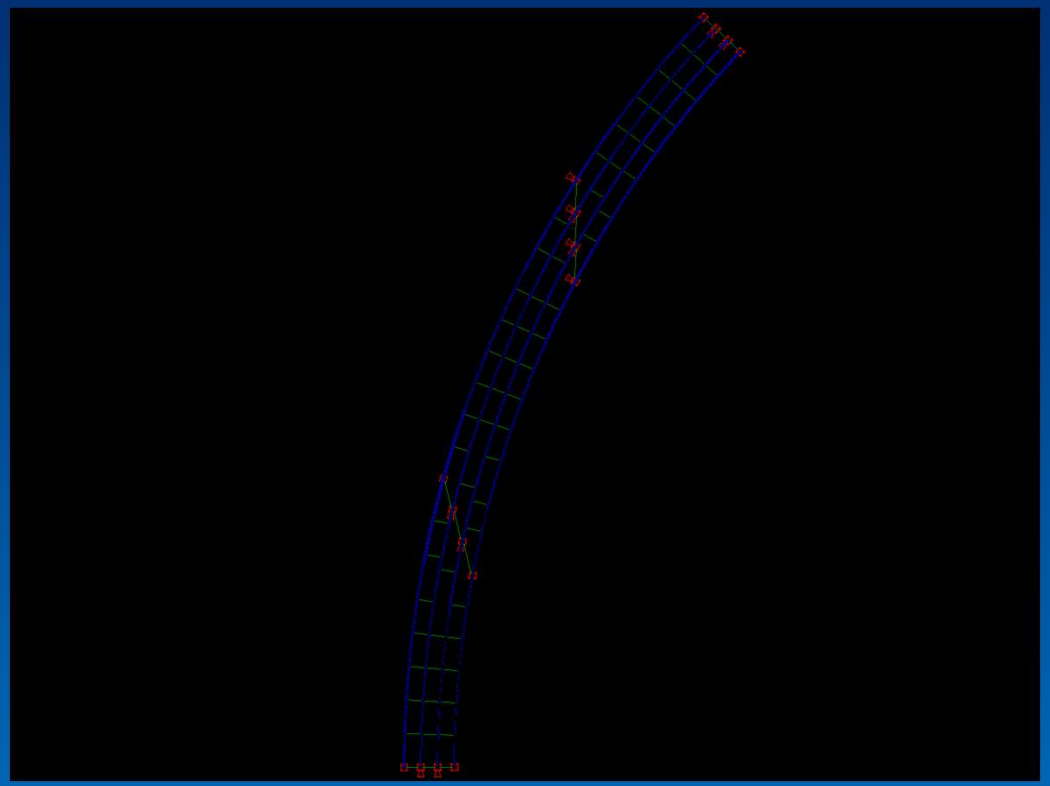


Curved plate girders with skewed supports

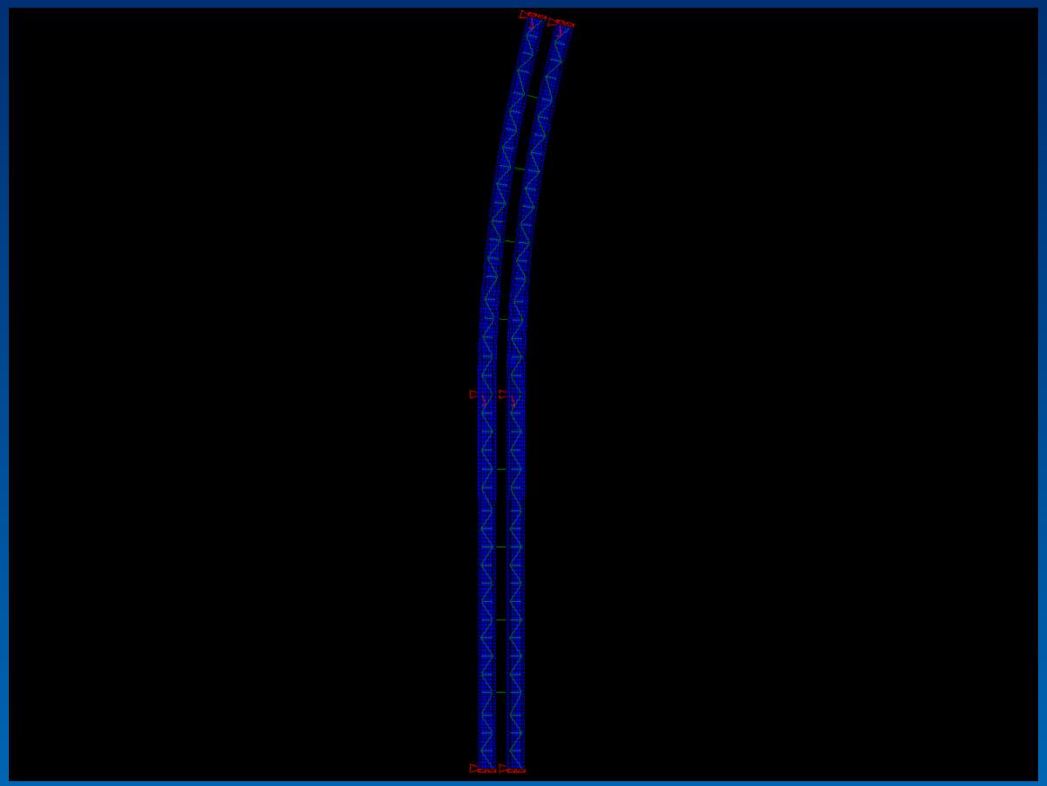


Deck meshing on irregular geometries

mBrace3D – “Refined” Analysis – Complex Geometries

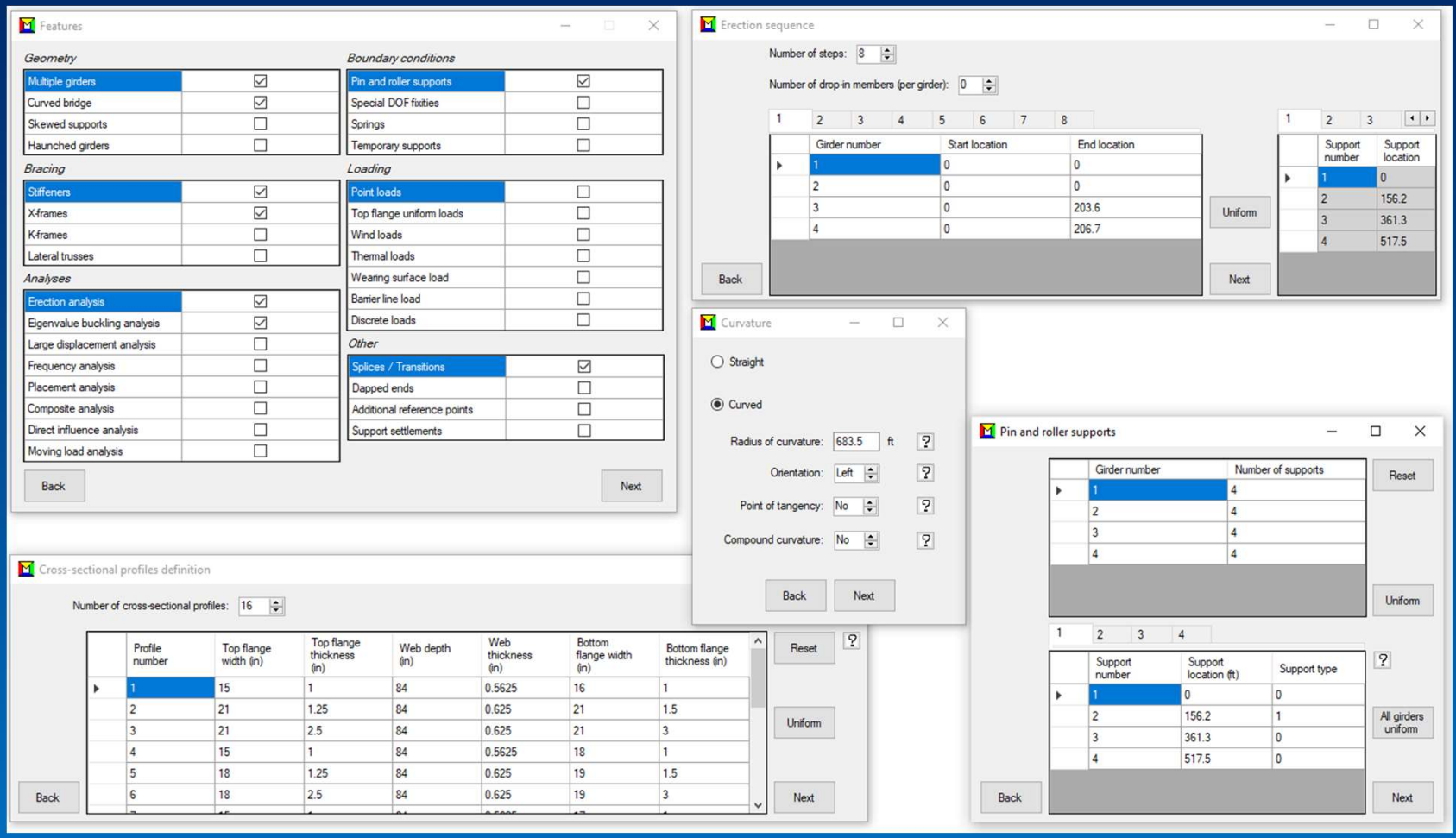


Curved plate girders with skewed supports

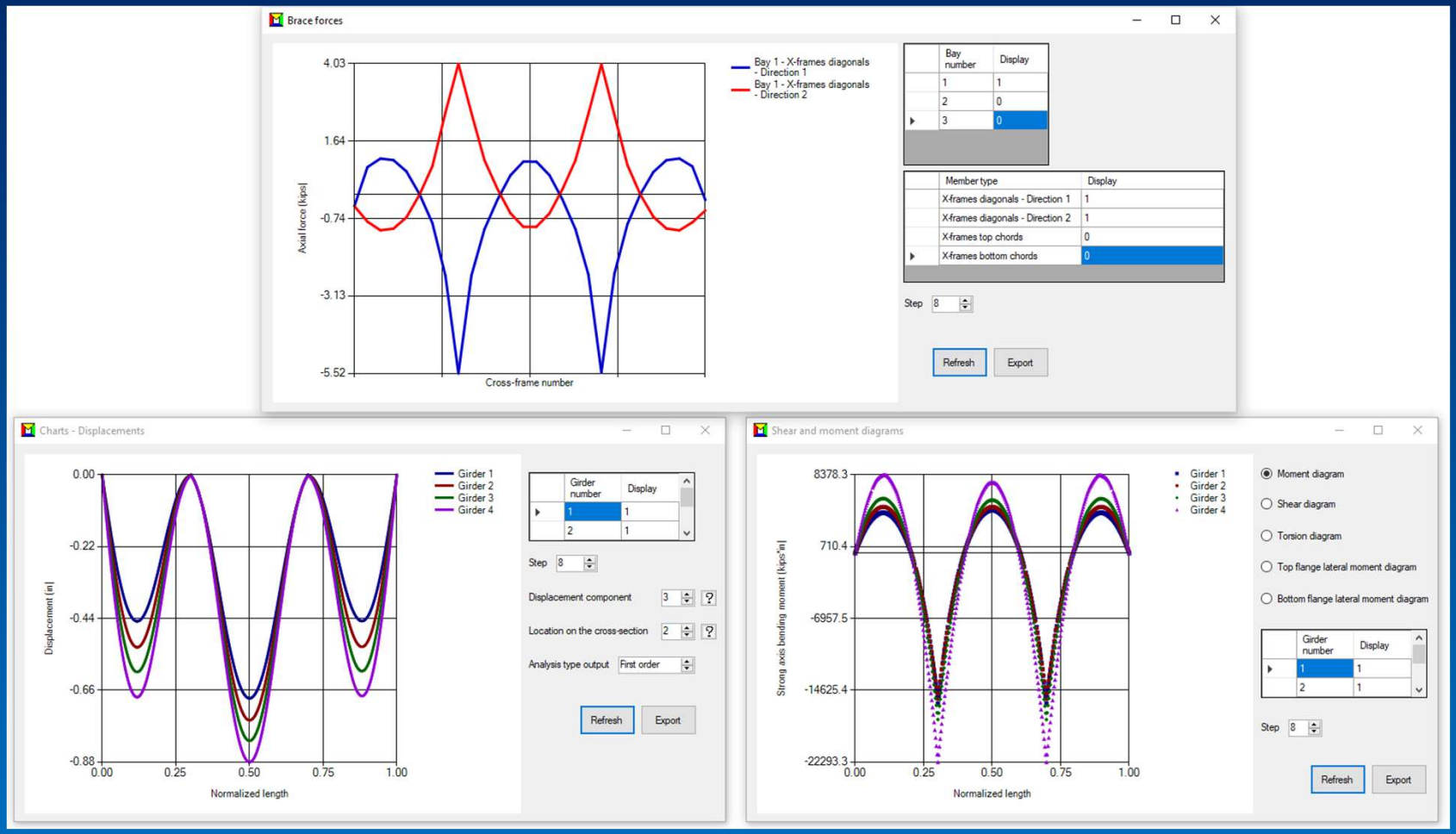


Curved tubs with a point of tangency

Parametric Modeling – Quick, user-friendly, no drawing on screen



Automatic Post-Processing – Moment, Shear, Torsion, Brace Forces, etc.



mBrace3D Capabilities

Analysis Types

- First-order linear elastic analysis
- Second-order geometric nonlinear analysis **(with initial imperfections)**
- Eigenvalue buckling analysis
- Eigenvalue frequency analysis
- **Influence analysis**
- **Vehicle load optimization**

Loadings

- Gravity
- Wind loads
- **Flange lateral loads**
- **Wearing surface load / Barrier line load**
- Thermal loads
- **Vehicle loads (any configuration)**

Geometries

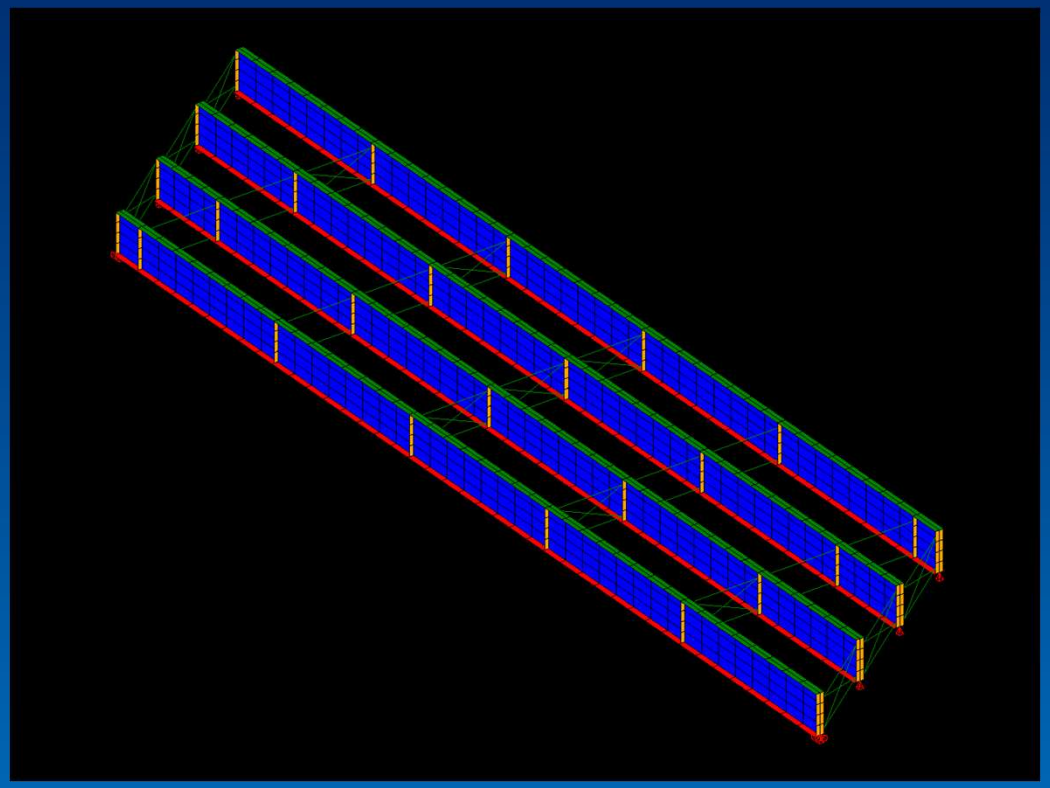
- Straight
- Curved
- **Points of tangency**
- **Points of compound curvature**
- **Haunched girders (parabolic)**

Cross-Frame Fatigue Analysis

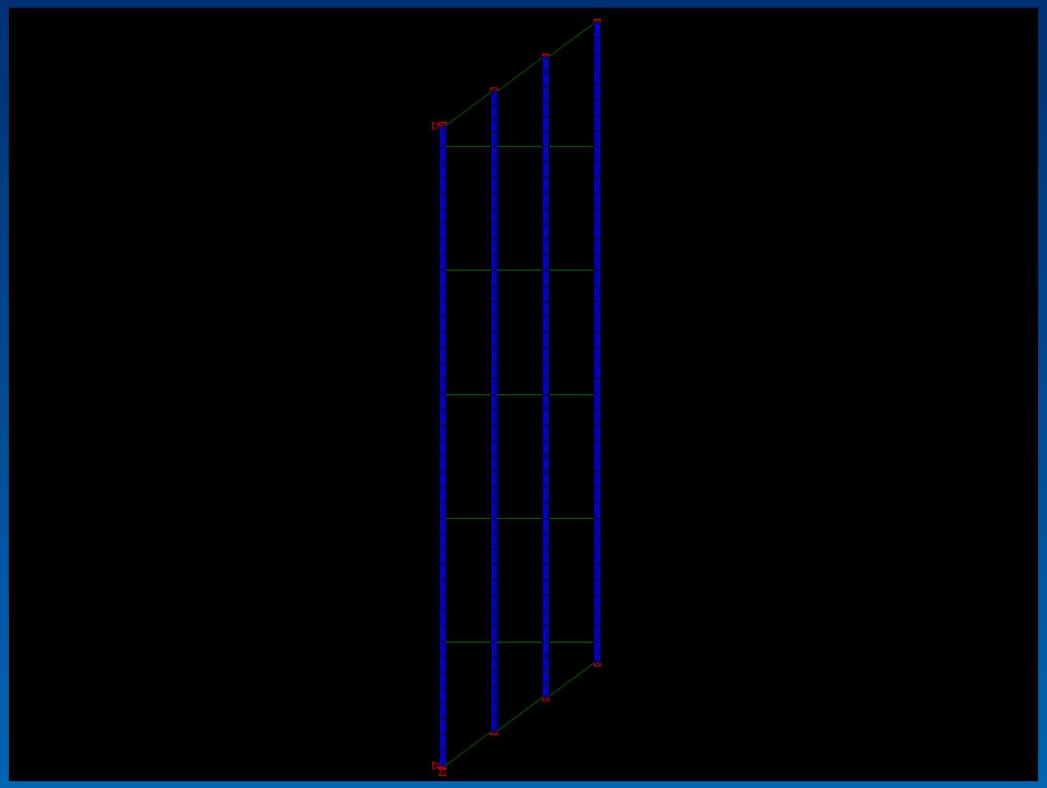
D. Altman, B. Chavel, “Keeping Cross-Frames in Check”, Modern Steel Construction, October 2020

“**Strategy 1.** The AASHTO *LRFD Specifications* 2020/9th Edition Commentary Article C6.6.1.2.1 recommends that the fatigue truck be positioned to determine the **maximum range of stress** or torque, as applicable, **with the truck confined to one critical transverse position** per each longitudinal position throughout the length of the bridge in the analysis.”

mBrace3D – Vehicle Load Optimization for Fatigue Analysis

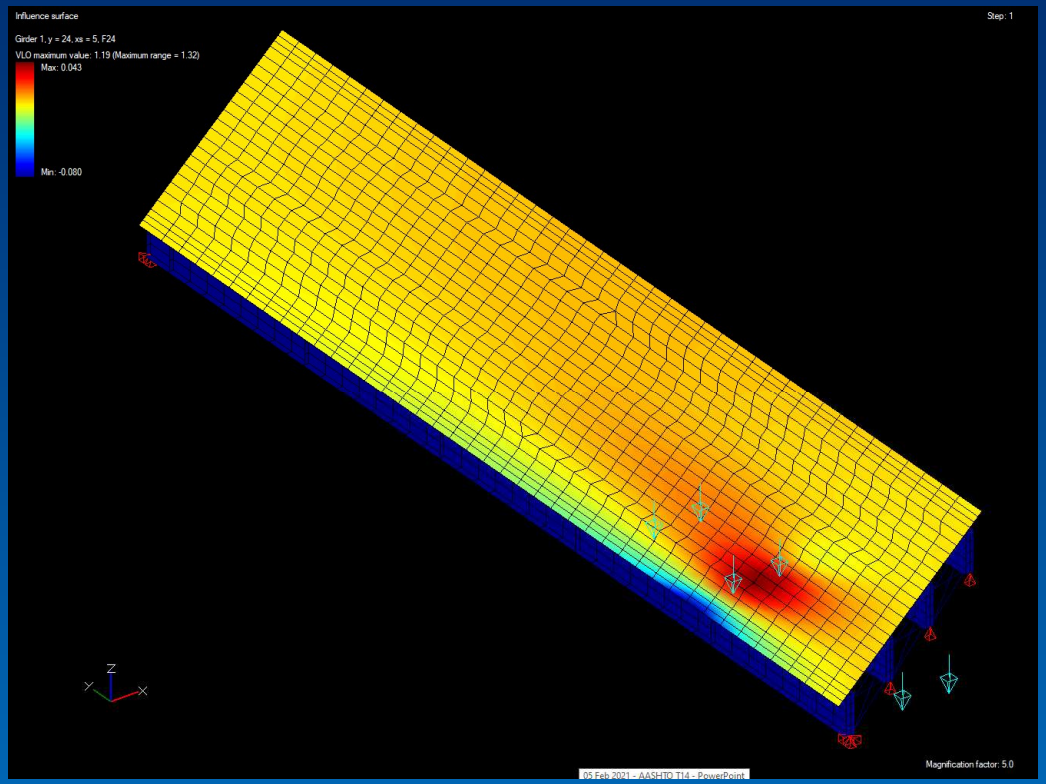


Left isometric view

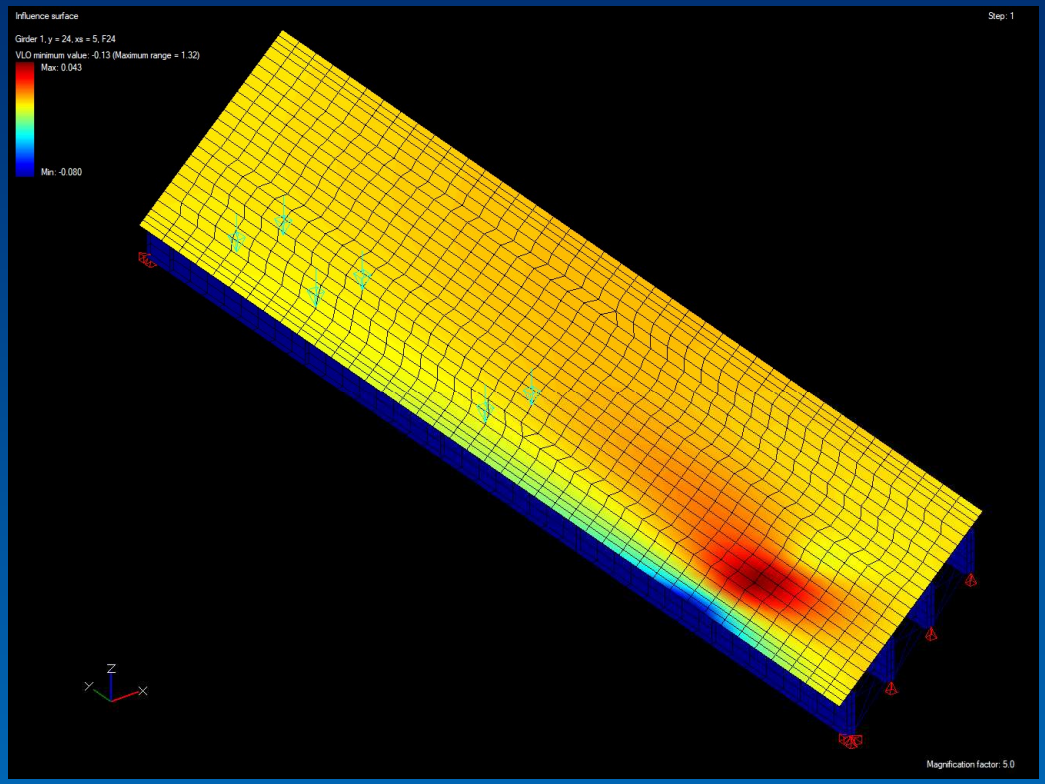


Top view

mBrace3D – Vehicle Load Optimization for Fatigue Analysis

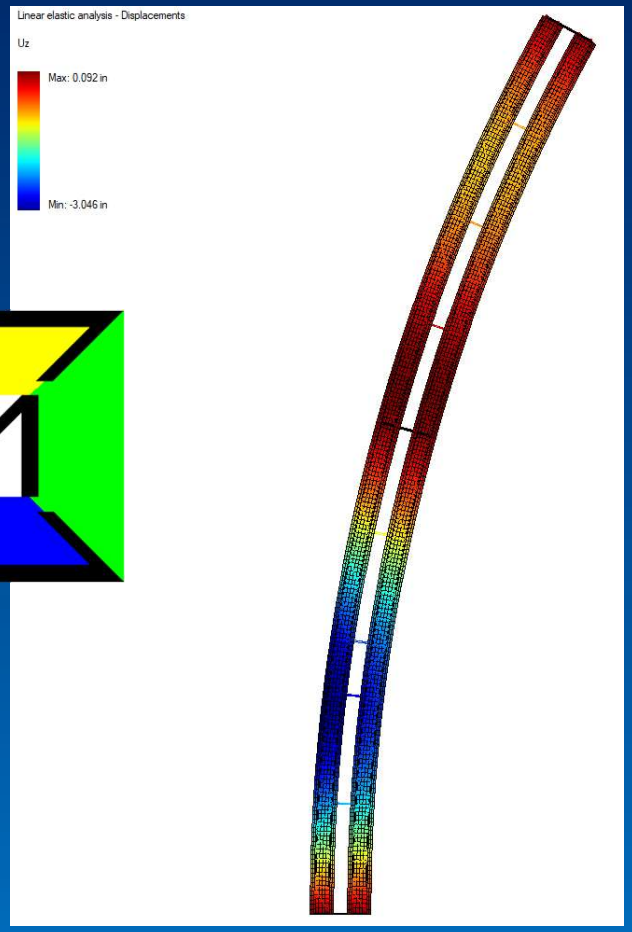


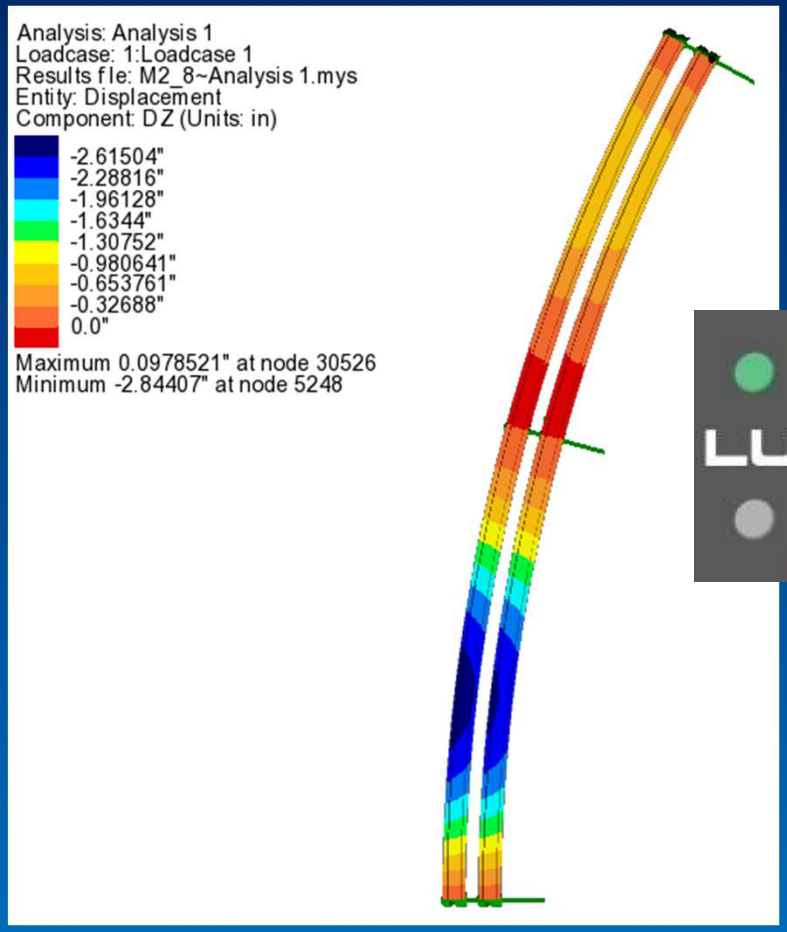
Maximum stress range | maximum brace force



Maximum stress range | minimum brace force

mBrace3D – Results Validation with LUSAS





mBrace3D – Closing Remarks

-> mBrace3D is a tool that conducts “REFINED” analyses in a **minimal amount of time** and with **limited FEA knowledge**, for the benefit of steel bridge **erectors and designers**

-> The software is a **cost-effective** alternative to other commercial programs