Lifting analysis of a curved plate girder

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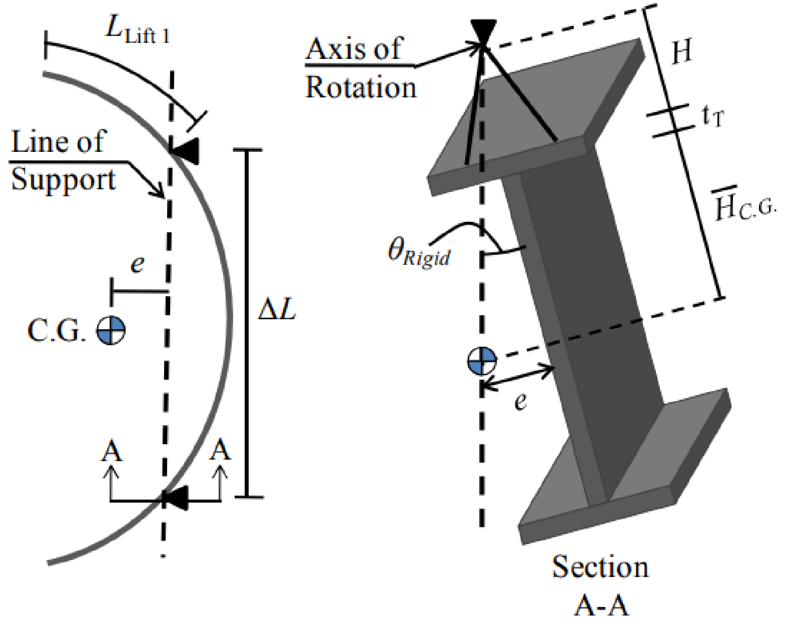
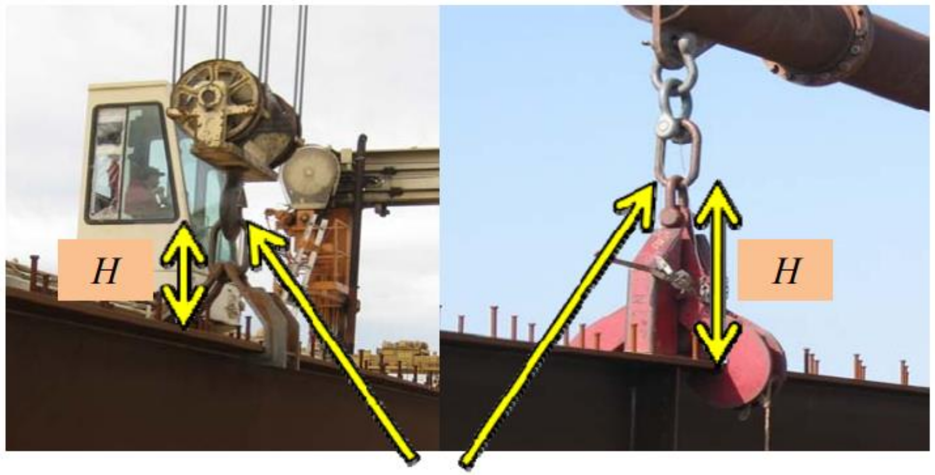
Purpose

Evaluate the rotations, stresses and stability during lifting, including:

1. The rigid body rotation due to the girder's curvature

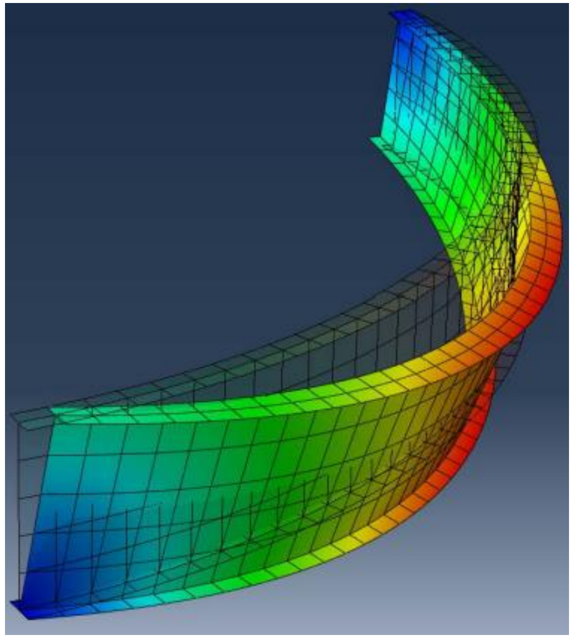


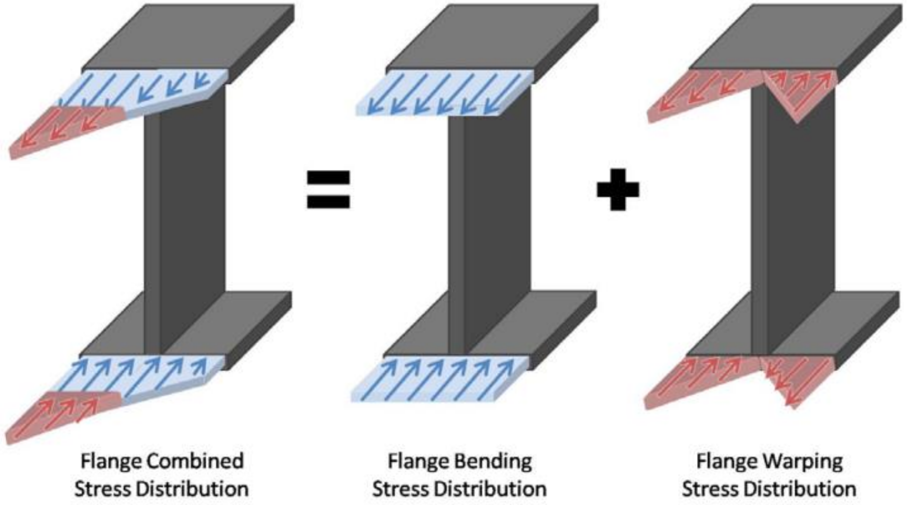


Source: J. Stith, Predicting the Behavior of Horizontally Curved I-Girders During Construction, PhD Dissertation, The University of Texas at Austin, 2010

Purpose

2. The rotation due to the girder's torsion under its own self-weight





Sources:

- J. Farris, Behavior of Horizontally Curved Steel I-Girders During Construction, Master's Thesis, The University of Texas at Austin, 2008
- P. Biju-Duval, Development of Three-Dimensional Finite Element Software for Curved Plate Girder and Tub Girder Bridges During Construction, PhD Dissertation, The University of Texas at Austin, 2017

Targets

For a safe lifting and erection process, the targets are as follows:

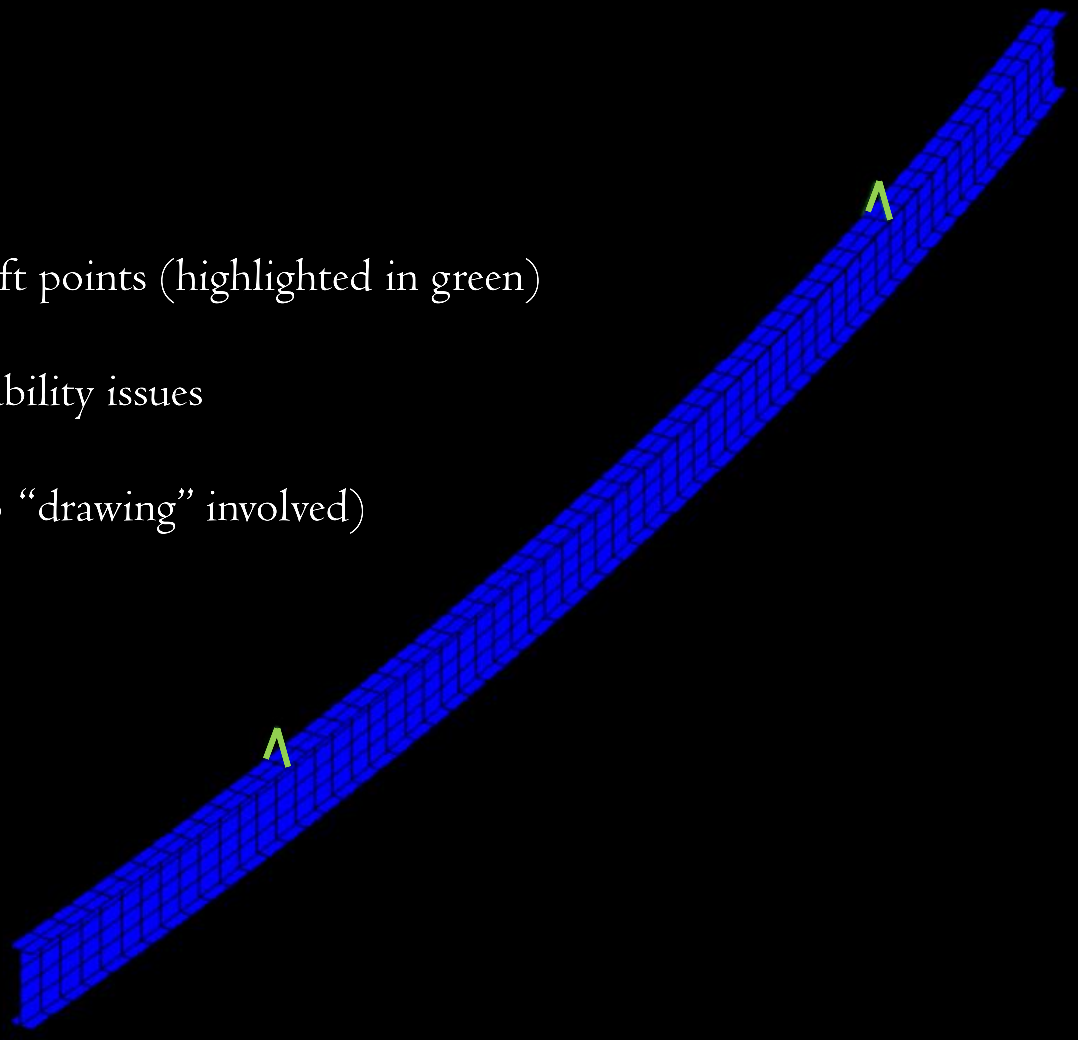
- Limit the end rotations to 1.5 degrees (to have easy splice connections)
- Limit maximum stresses to $F_y/2$ (to prevent any form of yielding, in absence of detailed information on the residual stresses)
- Have the 1st buckling eigenvalue be well above 1 (to prevent any stability issues)

-> In practice, the first criterion (end rotations $< 1.5°$) is the one that usually governs.

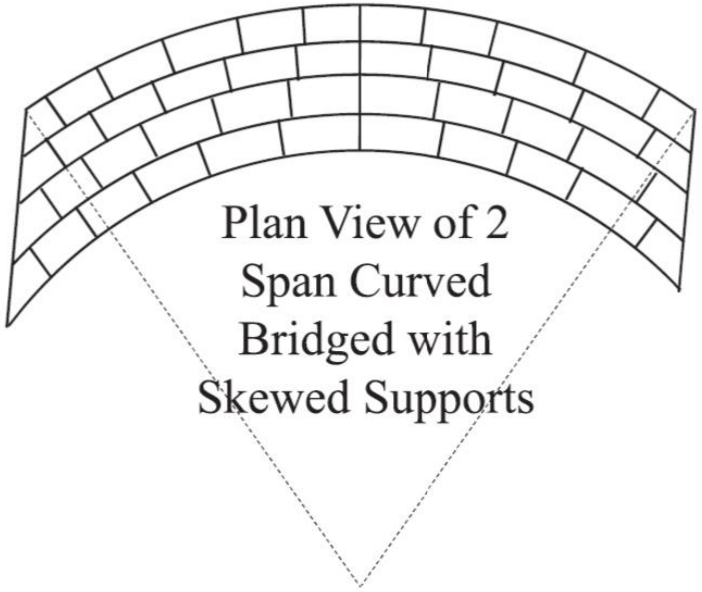
Source: J. Stith, T. Helwig et. al, , Behavior of Horizontally Curved I-Girders During Lifting, ASCE Journal of Structural Engineering, Vol. 139, No. 4, April, 2013

Implementation in mBrace3D

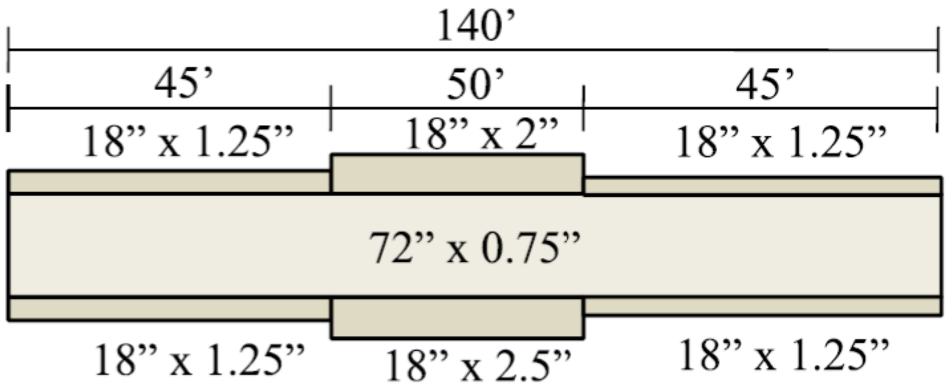
- Rigid axial members modelling the clamps at the lift points (highlighted in green)
- Dummy springs at the bottom flange to prevent stability issues
- Note: This model was generated parametrically (no "drawing" involved)



Example



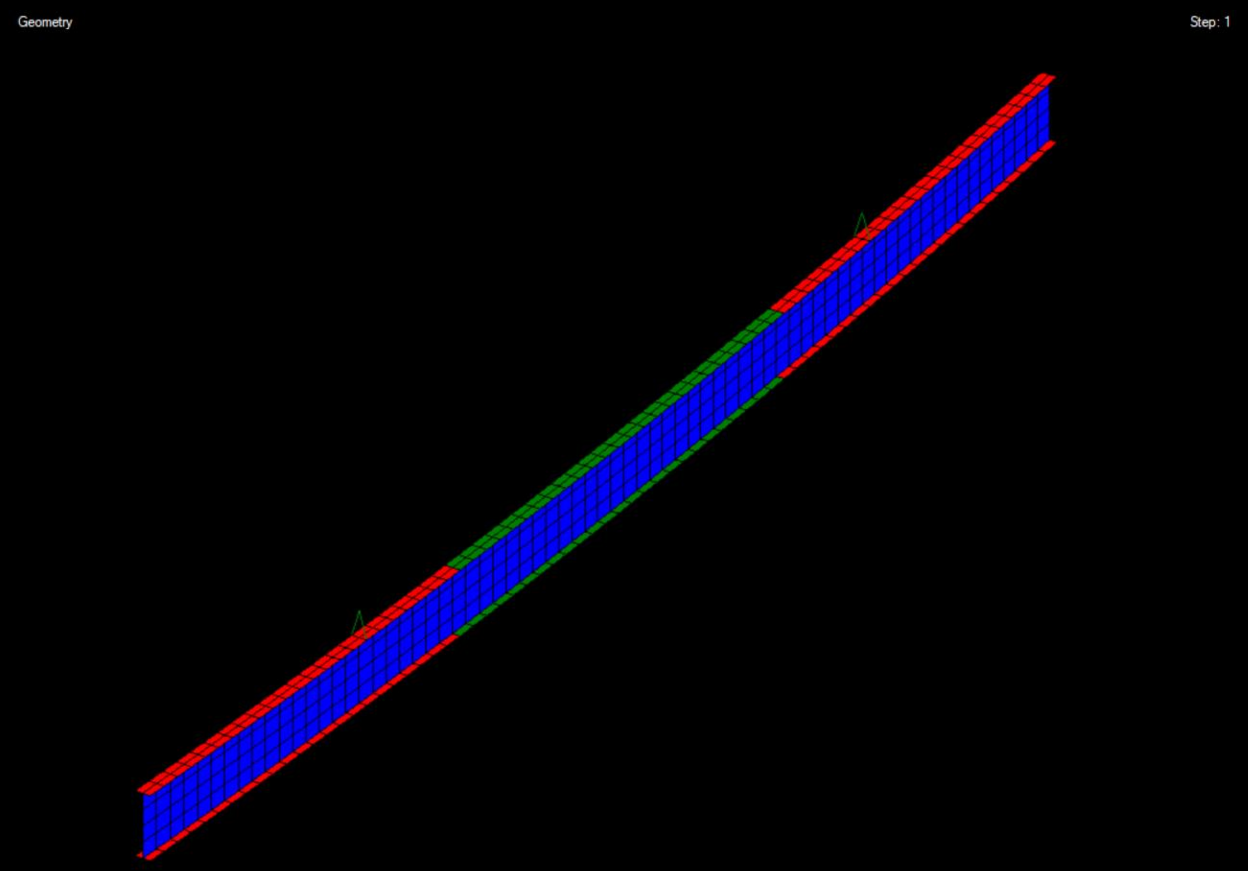
Middle girder (radius of curvature = 1,200-ft.):



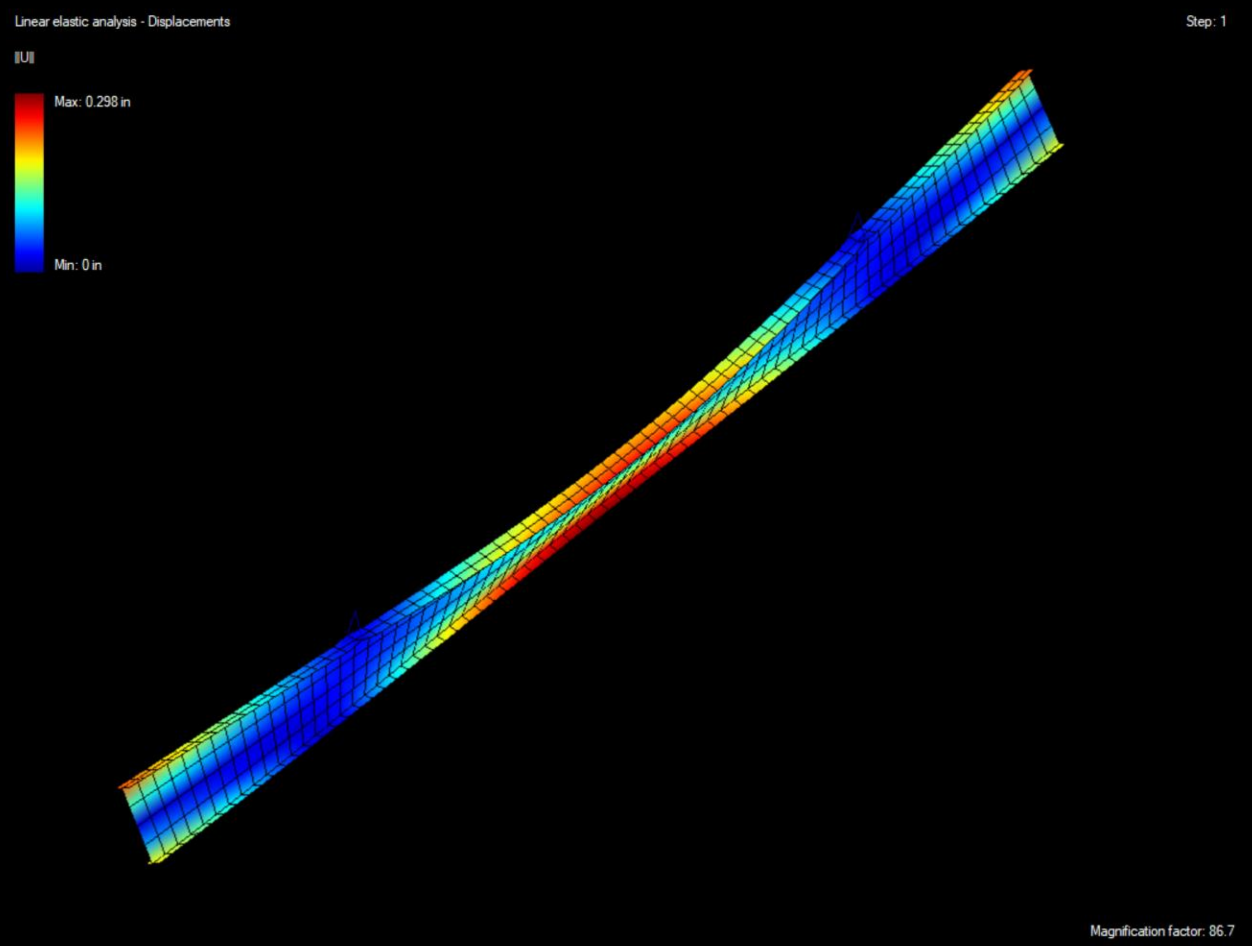
Lift points at 31.2-ft. and 108.2-ft. along the girder

Source: J. Stith, T. Helwig et. al, , Behavior of Horizontally Curved I-Girders During Lifting, ASCE Journal of Structural Engineering, Vol. 139, No. 4, April, 2013

Results (1/4)

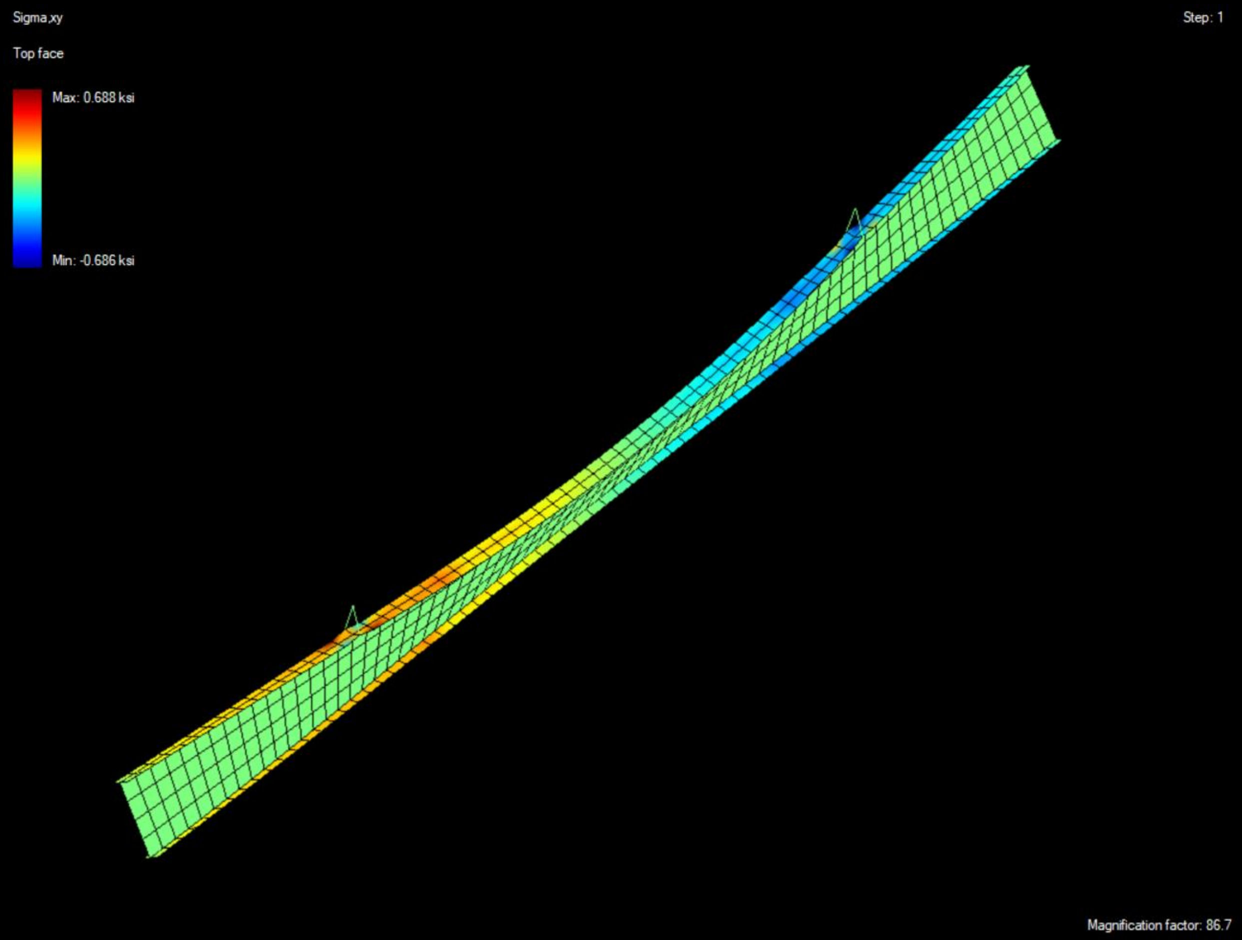


Geometry

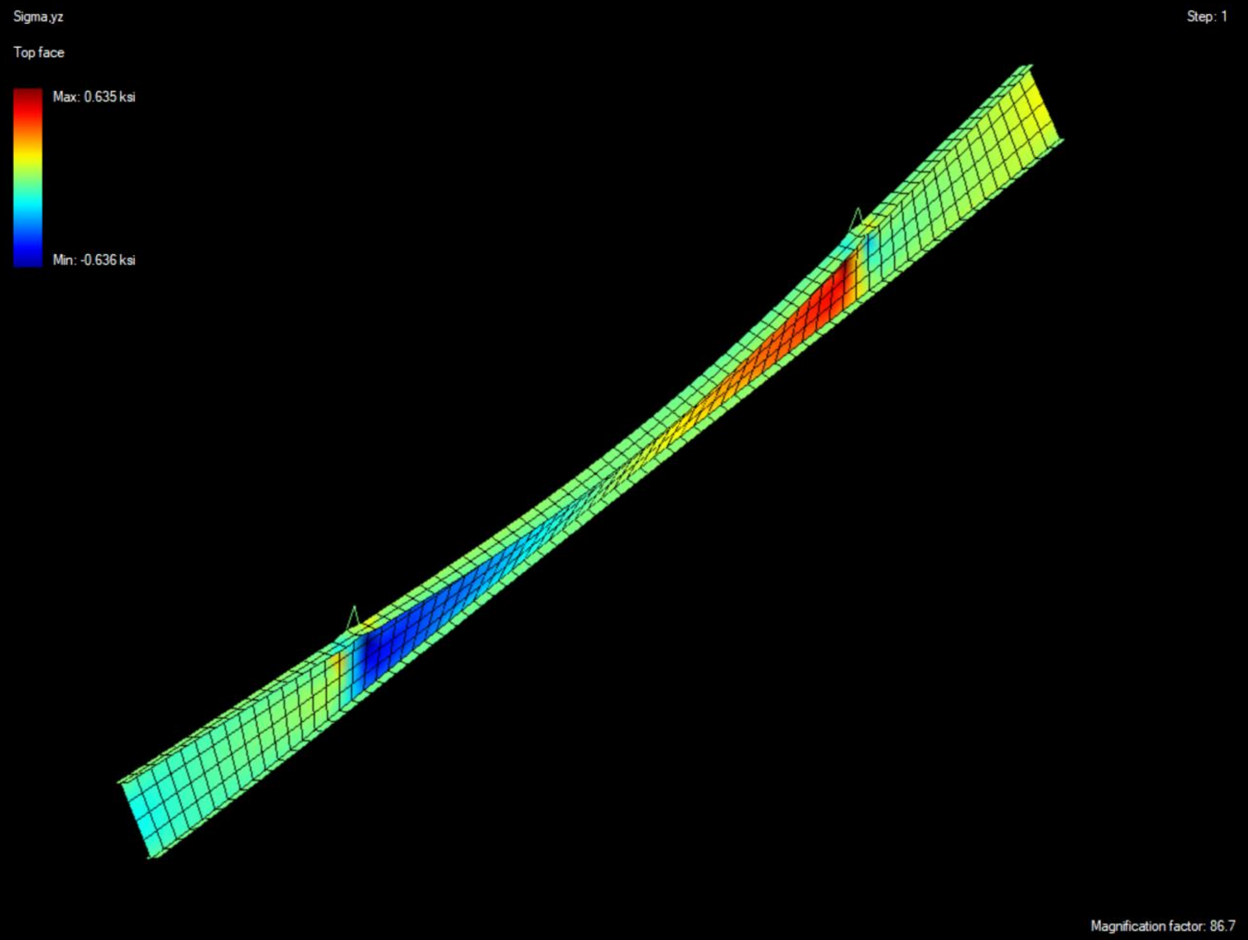


Deflected shape (U_{max} = 0.3-in.)

Results (2/4)

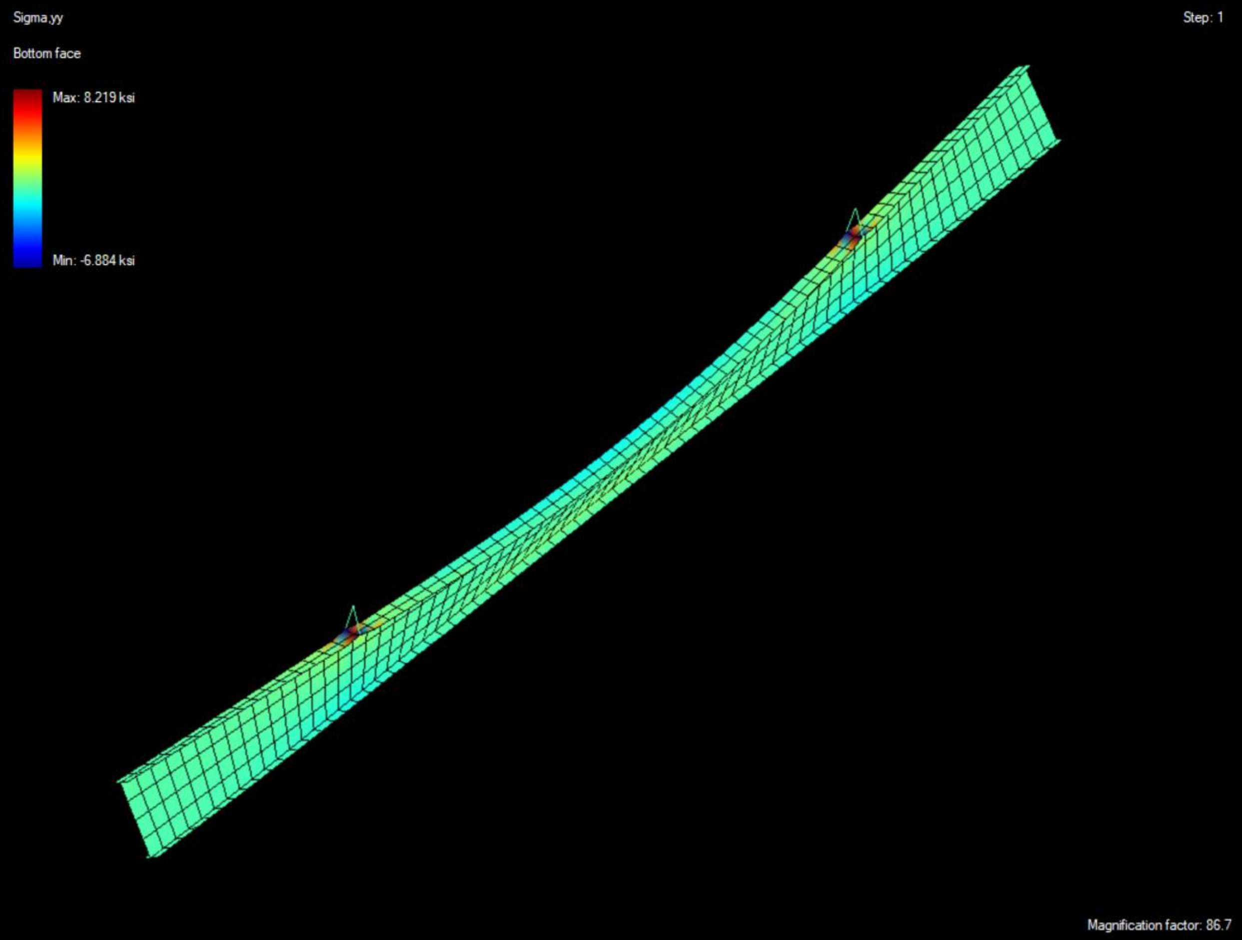


σ_{xy} stresses (torsion in the flanges)

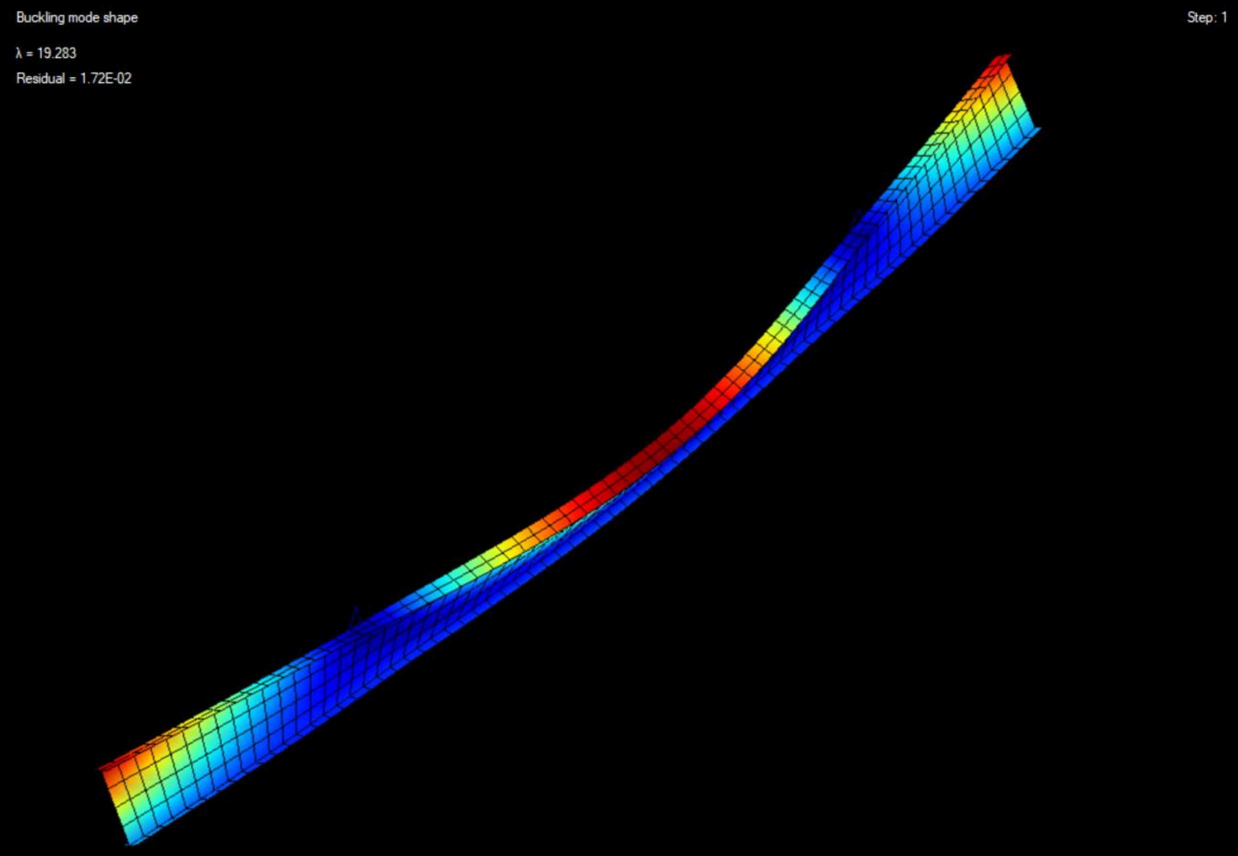


σ_{xy} stresses (torsion in the web)

Results (3/4)



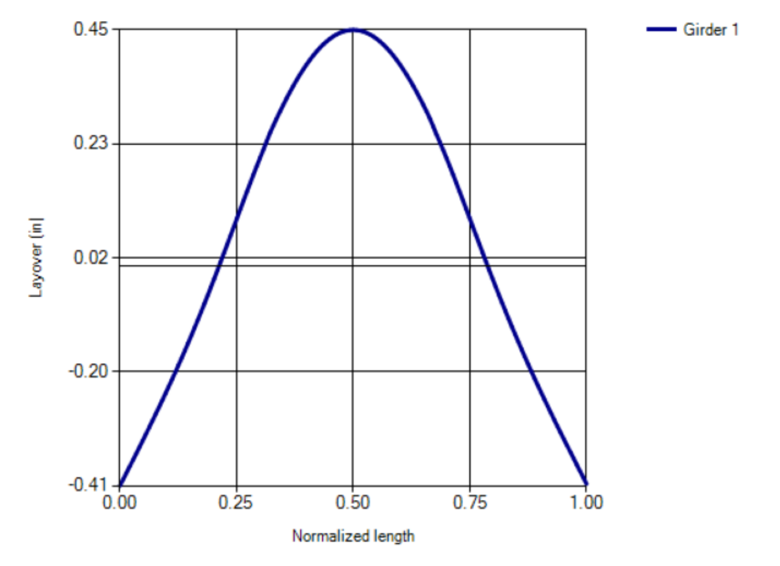
σ_{yy} stresses (longitudinal stresses)



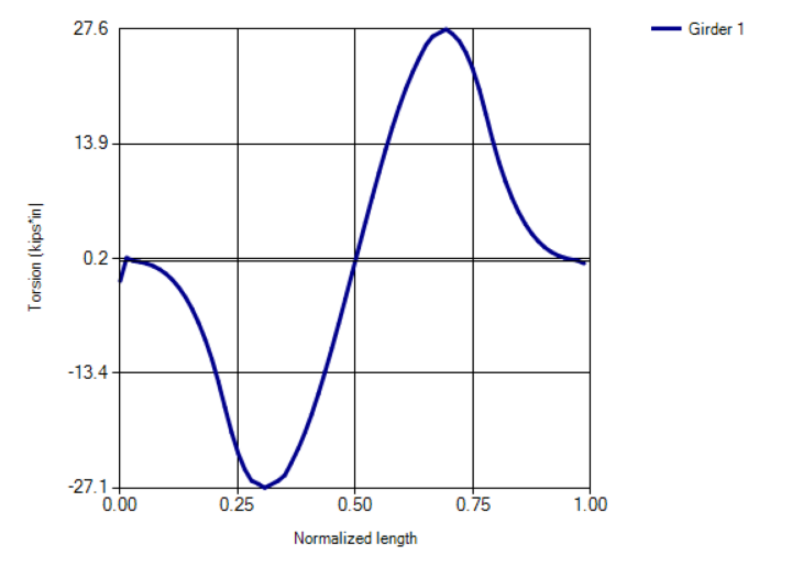
Eigenvalue buckling mode (lambda = 19.3)

Results (4/4)

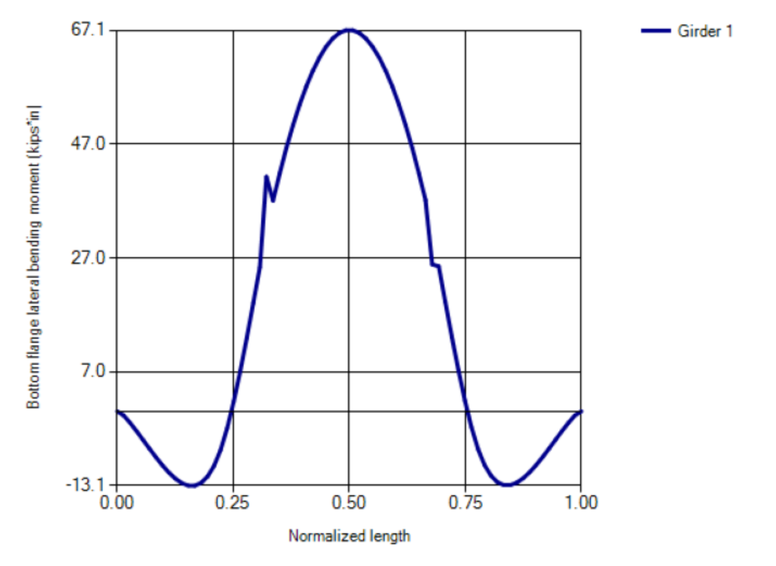
Layovers (cross-sectional rotations)



Torque diagram



Lateral bending diagram



<u>Notes:</u>

- All these plots are generated automatically in mBrace3D
- For the torque and lateral bending diagrams, this involves the integration of the cross-sectional stresses
- Other plots are also immediately available, such as the moment and shear diagrams

Concluding remarks

- Lifting analyses are easily implemented in mBrace3D and yield meaningful results: end rotations, stresses, stability
- This feature shall gives erectors further confidence in their lifting plans
- Additional levels of complexity may be added to the example presented earlier, such as wind loads, point loads (to model any cross-frame present during the lifting operation), etc.

Final note:

Another valuable tool for lifting analyses is UT Lift, which was developed by J. Stith in 2010 and is available for free at the link below:

https://fsel.engr.utexas.edu/facilities/software/ut-lift

UT Lift is an Excel spreadsheet which gives the optimal lift points to minimize rotations during lifting, among other interesting features.