Lateral-Torsional Buckling of C Purlins Restrained by Solar Modules

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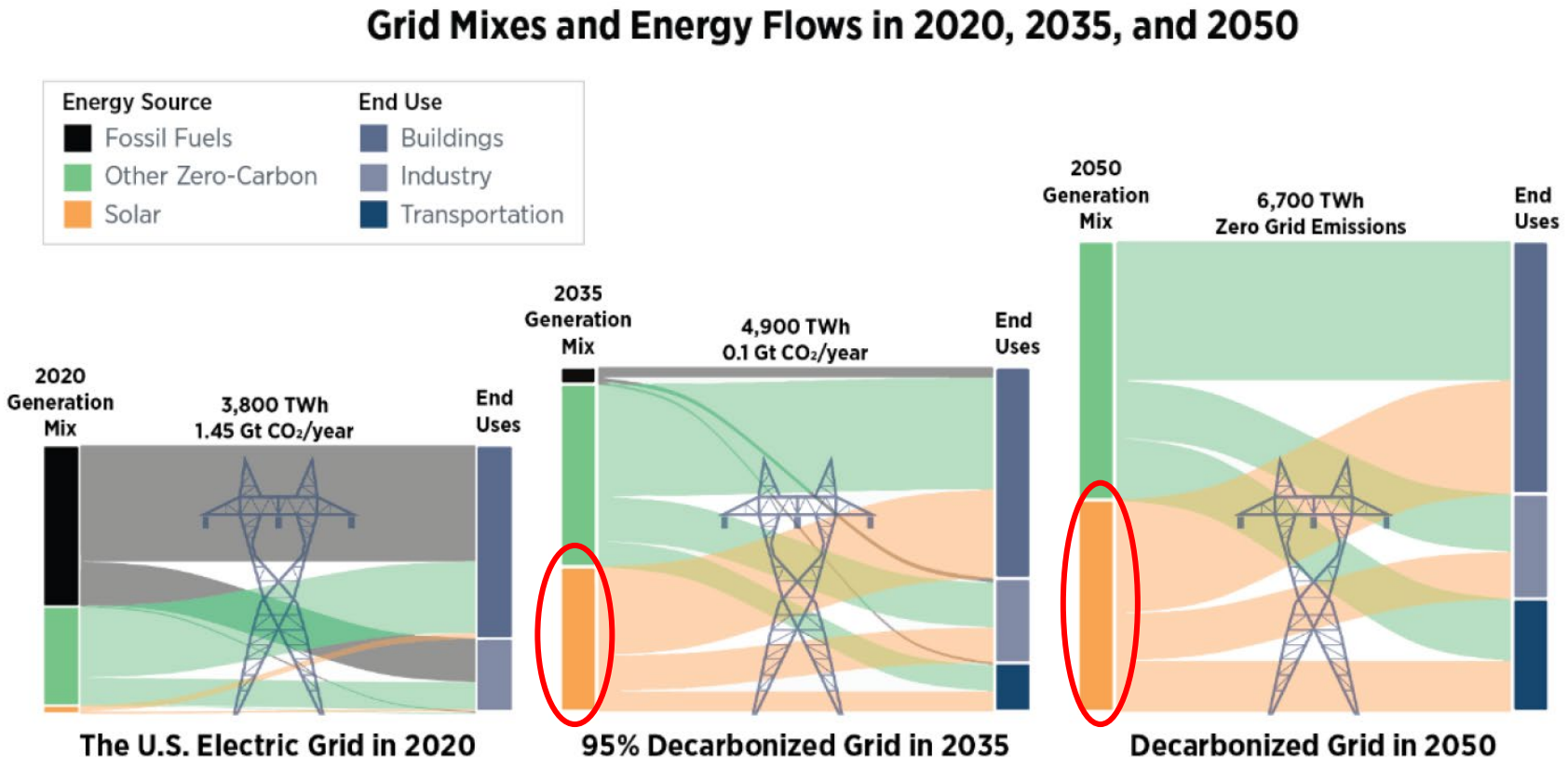
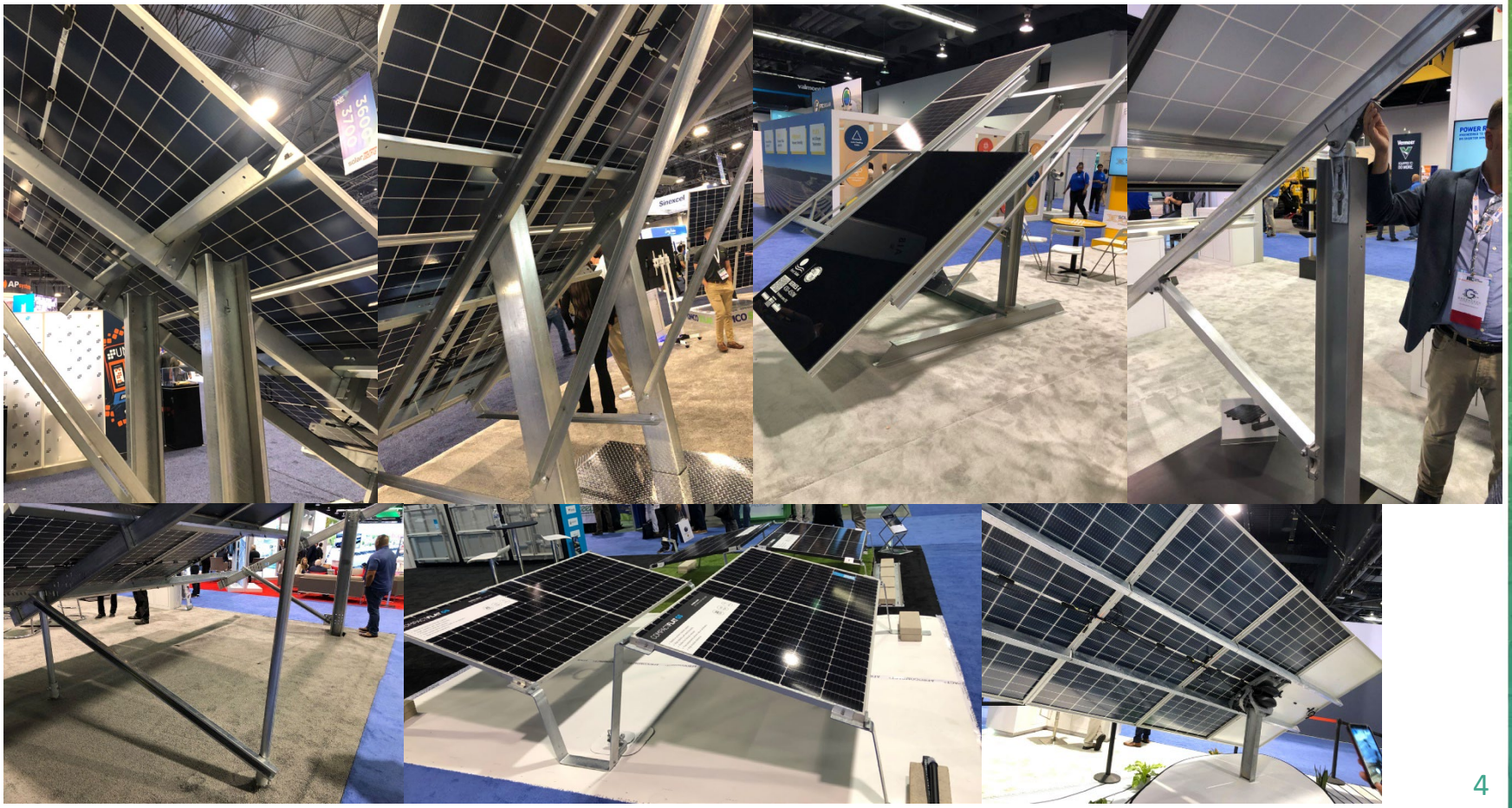
Transition to renewable energy



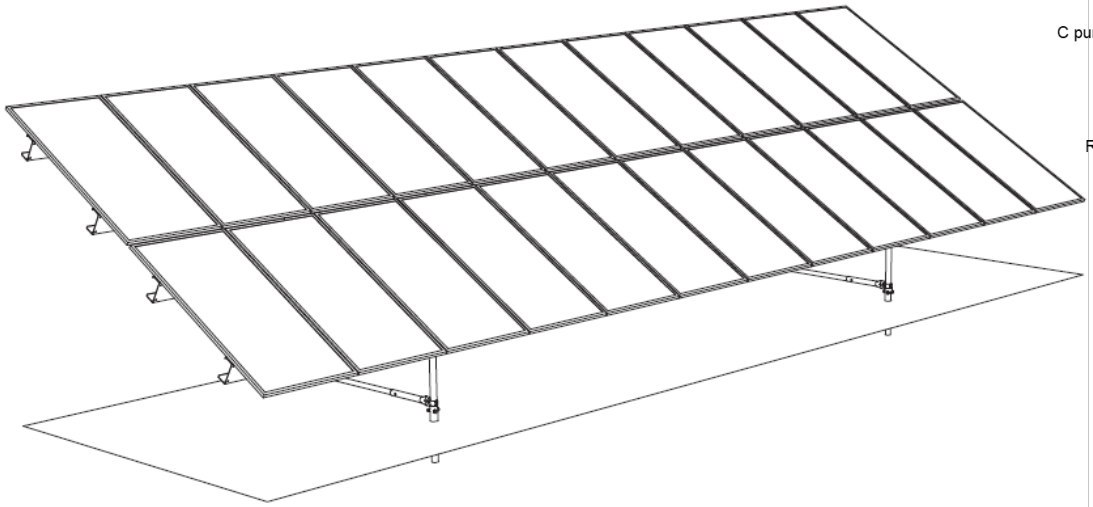
Source: DOE. Solar Futures Study. https://www.energy.gov/eere/solar/solar-futures-study

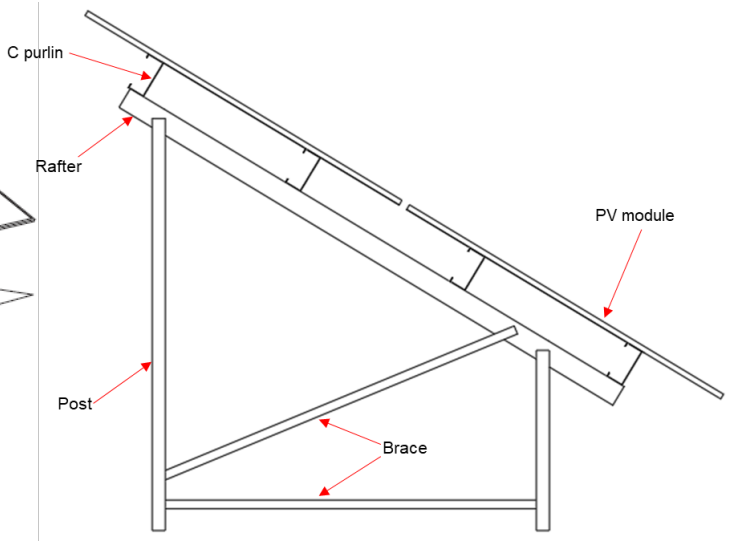
Examples of solar supports



Prototype structure

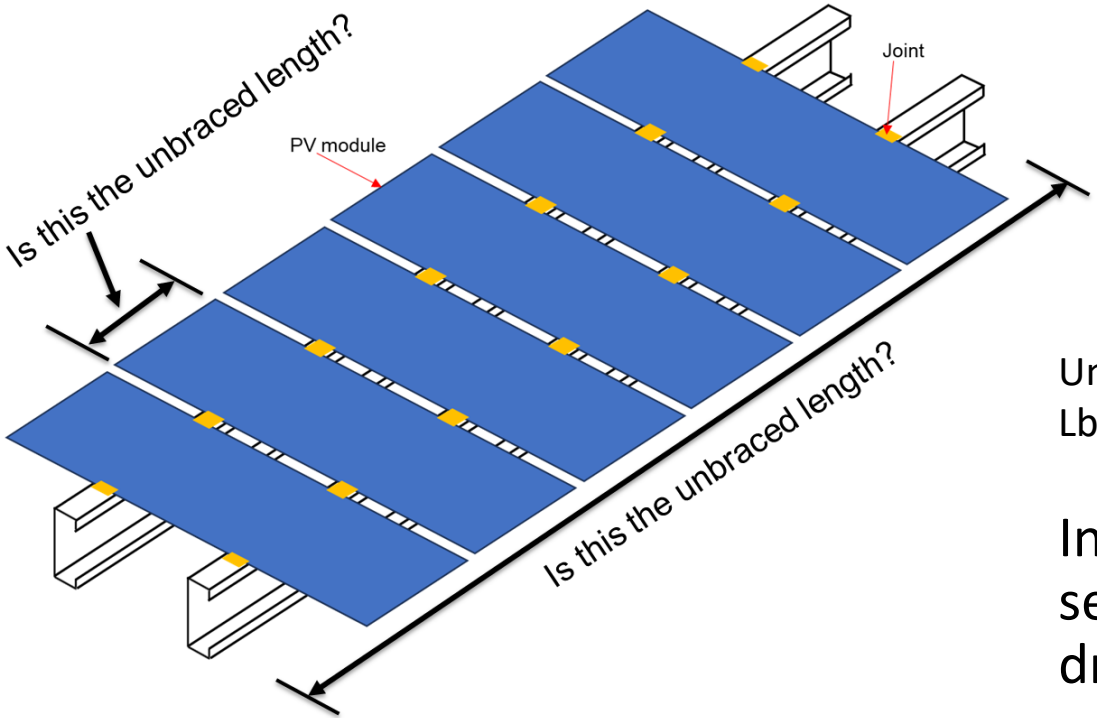
- Practitioners continuously invent new structural systems and joints
- No codes and standards





How to design purlins for lateral-torsional buckling (LTB)?

Focus on this 6-module subassembly:

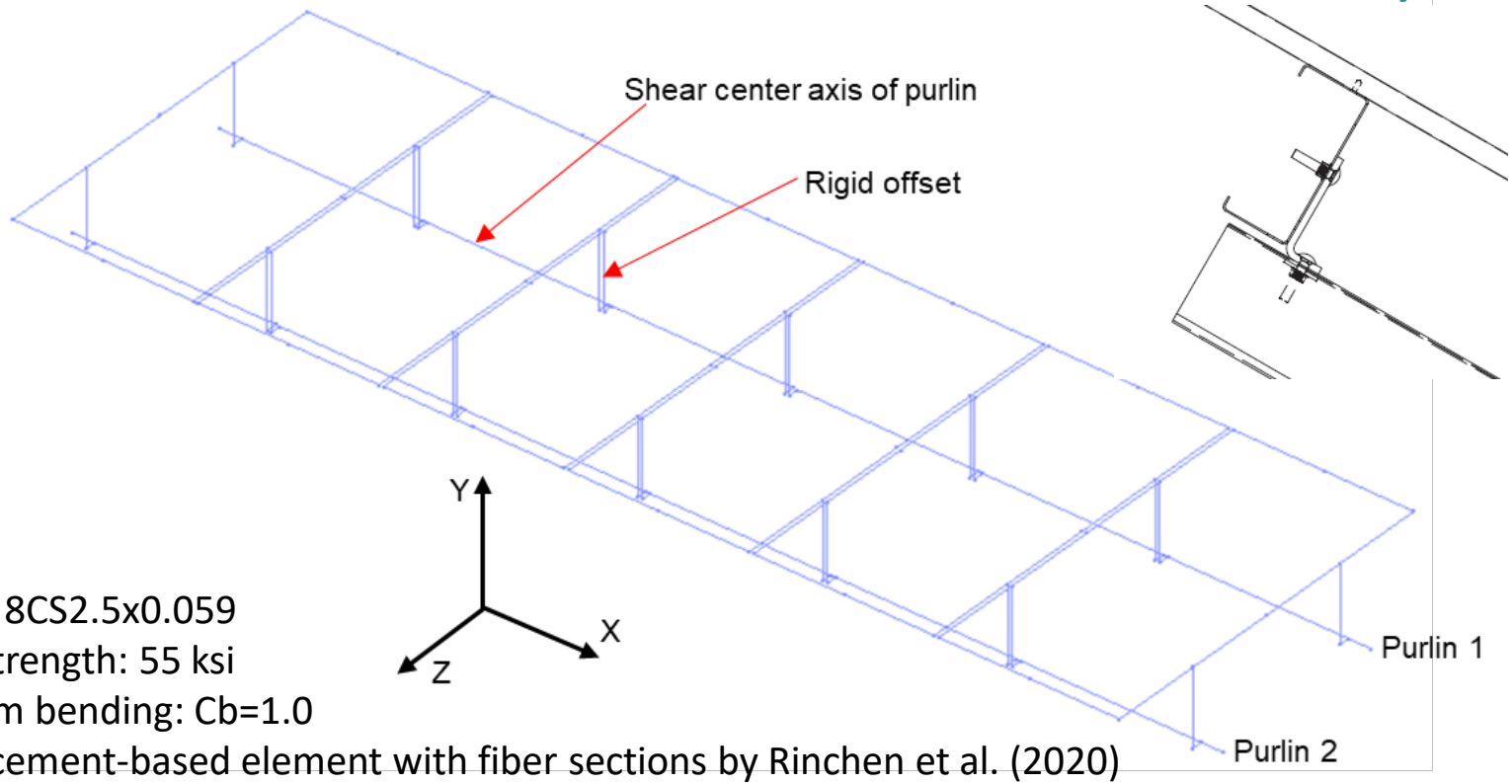


Unbraced length
Lb = whole span

Unbraced length
Lb = module width

Industry tend to use small sections. Cost pressures may drive unsafe design!

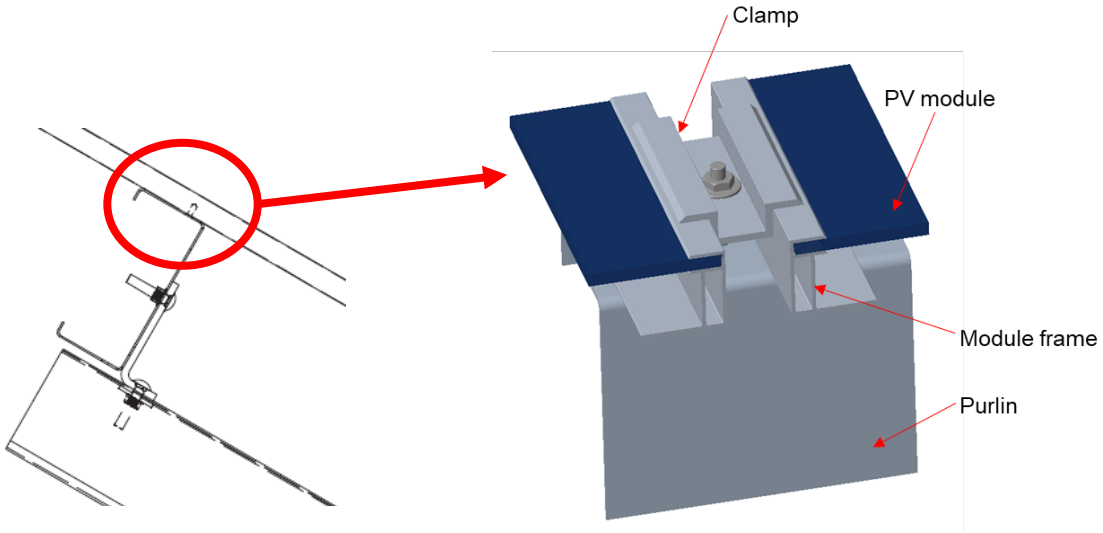
Finite element model of the 6-module subassembly



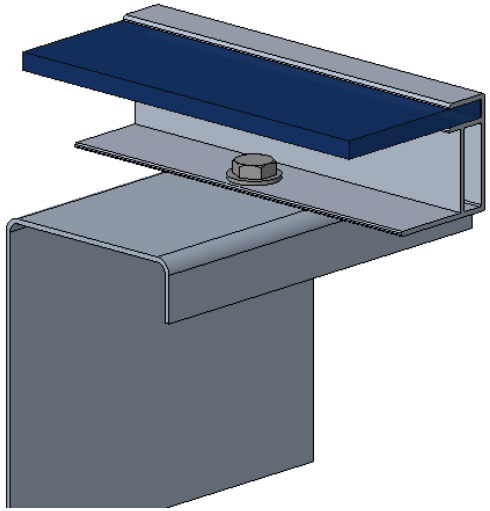
Purlin: 8CS2.5x0.059
Yield strength: 55 ksi
Uniform bending: Cb=1.0
Displacement-based element with fiber sections by Rinchen et al. (2020)

Richen, Hancock, G. J., and Rasmussen, K. J. (2020). Geometric and material nonlinear analysis of thin-walled members with arbitrary open cross-section. Thin-Walled Structures, 153, 106783.

LTB of purlins depends on the purlin-module joints



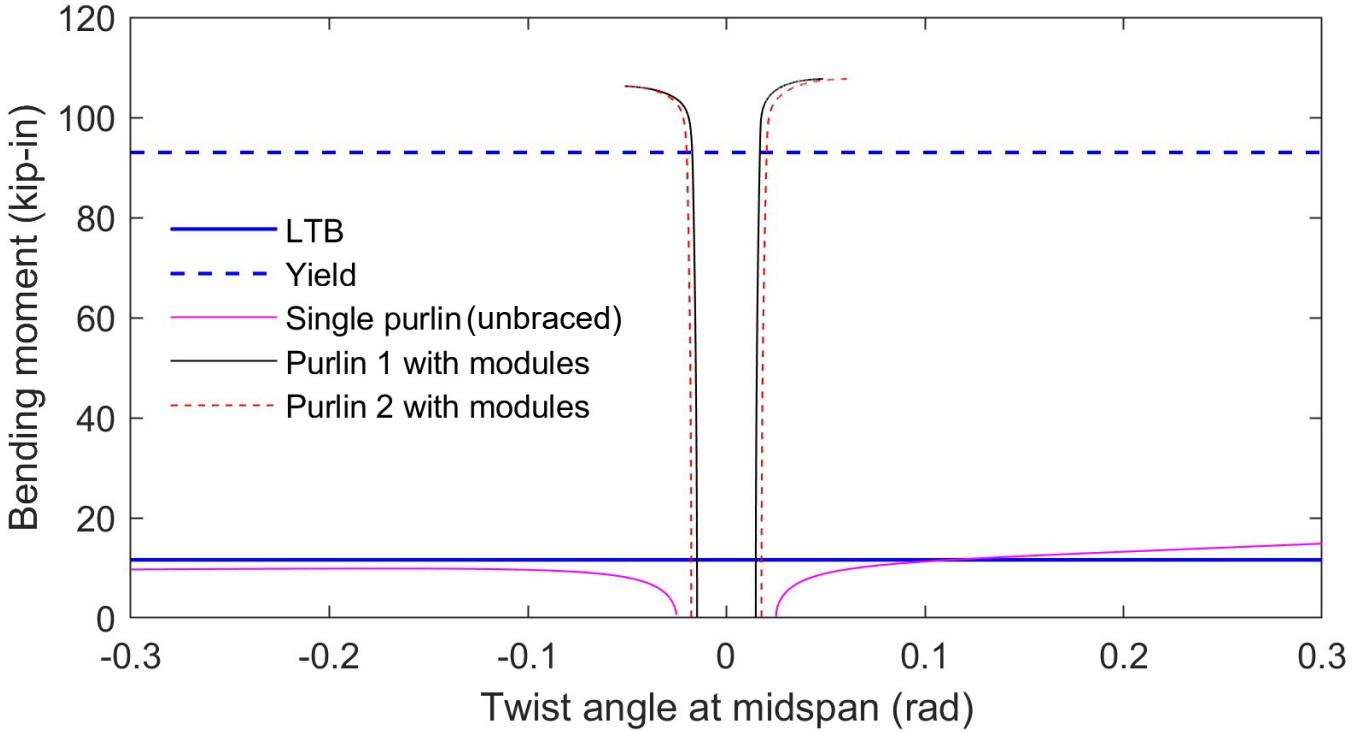
Top-down clamp



Through bolted joint

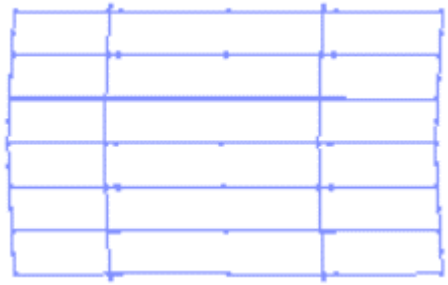
- Nonlinear analysis with 3 different models for purlin-module joints
  - Fully restrained joints
  - Pin joints
  - Nonlinear spring models for top-down clamps

LTB with fully restrained purlin-module joints

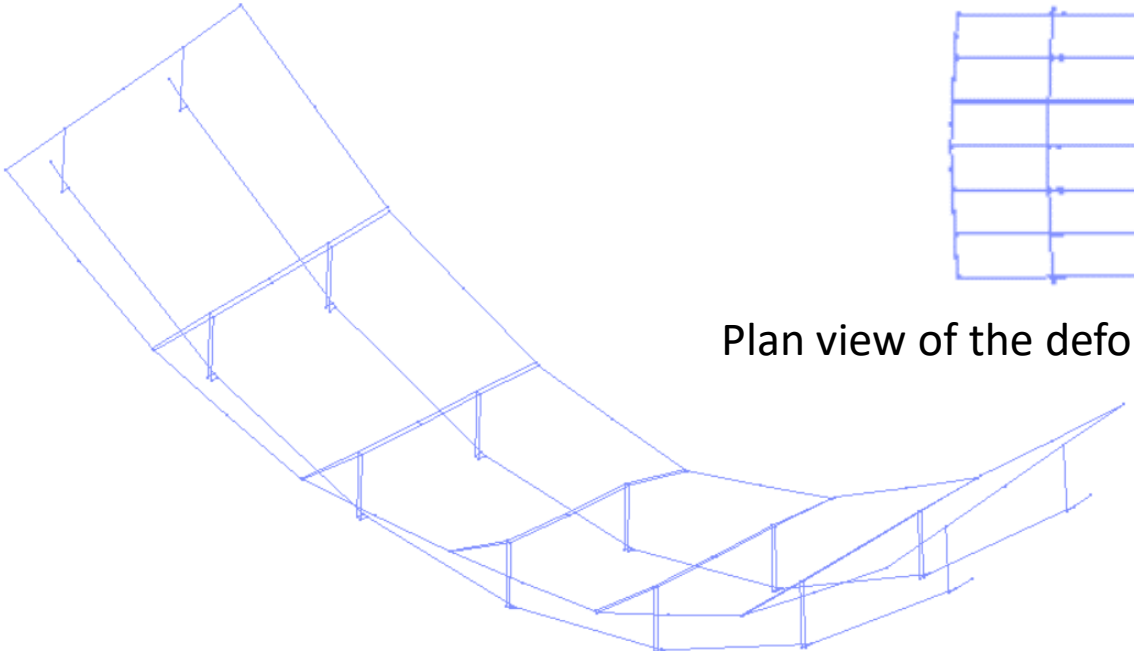


LTB with fully restrained purlin-module joints

- Deformed shape just before yielding

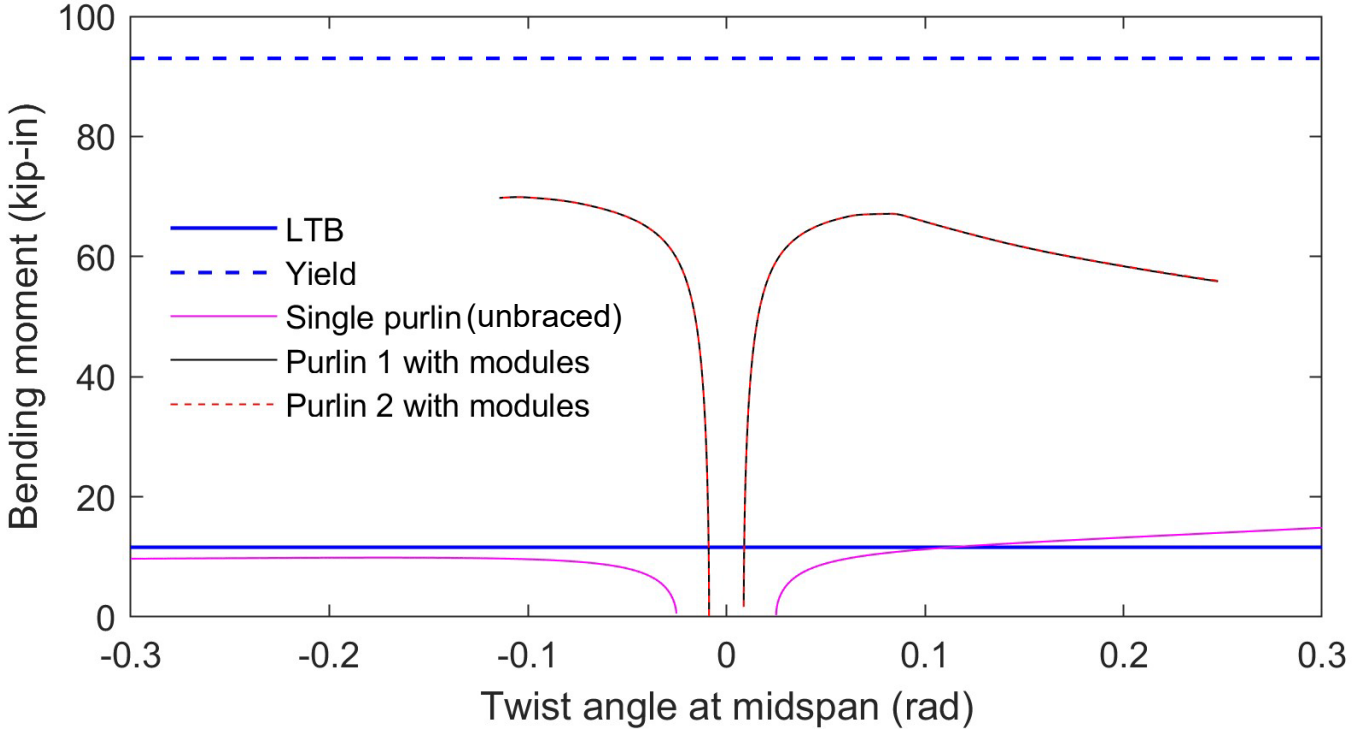


Plan view of the deformed shape (not to scale)



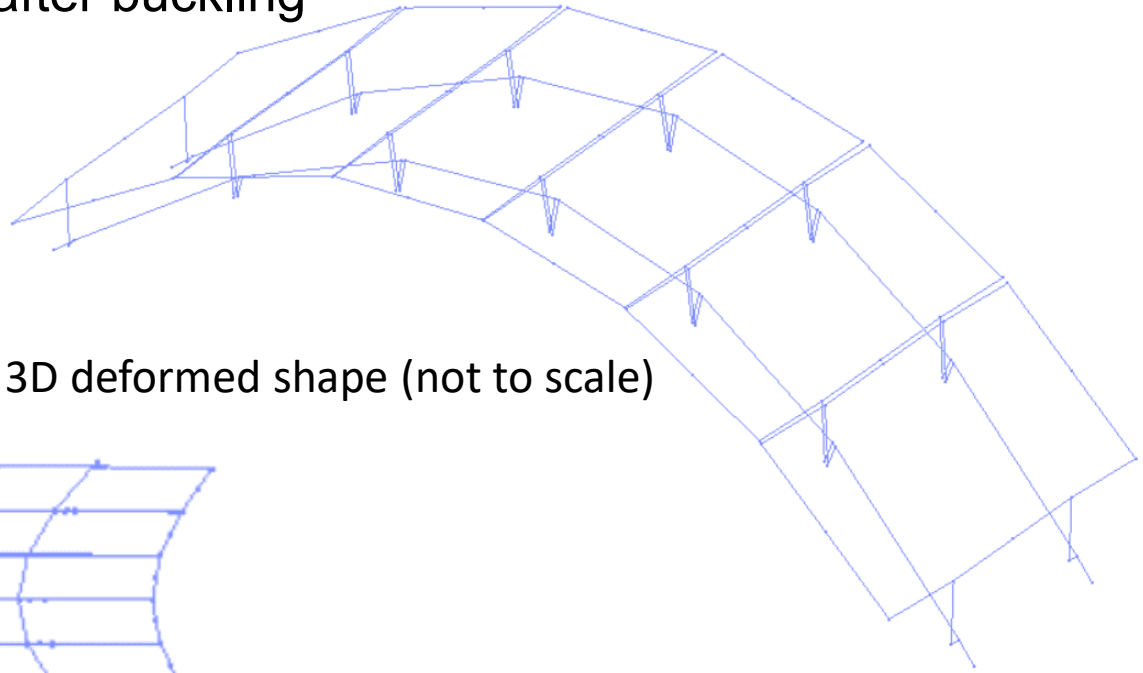
3D Deformed shape (not to scale)

LTB with pin purlin-module joints

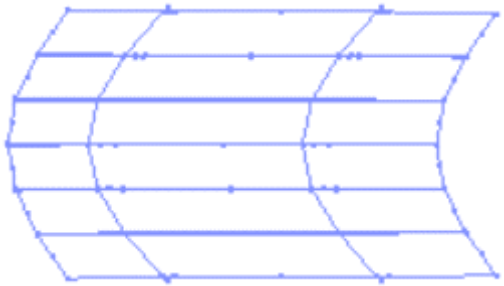


LTB with pin purlin-module joints

- Deformed shape after buckling



3D deformed shape (not to scale)



Plan view of the deformed shape (not to scale)

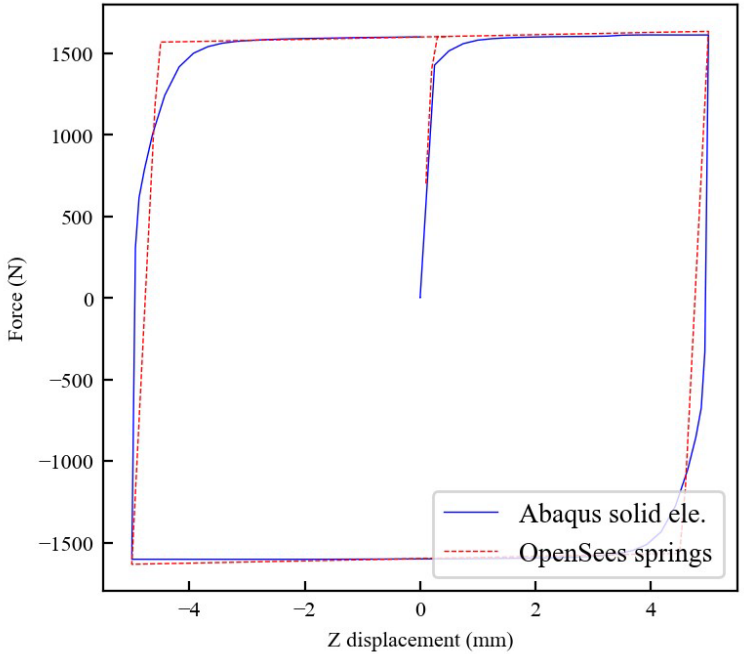
LTB with nonlinear spring models for joints

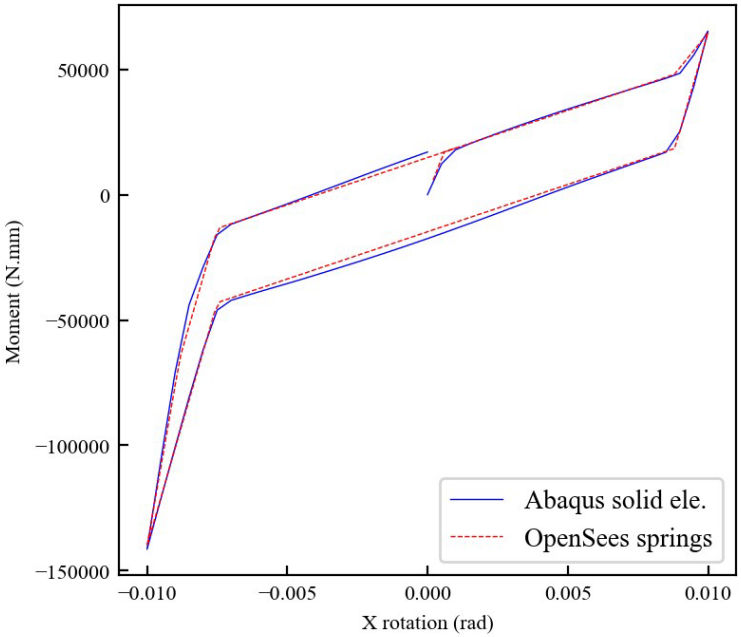
- The purlin-module joints such as top-down clamps are neither fully restrained nor pin joints.
- Model top-down clamps as nonlinear springs using the ZeroLength element in OpenSees.
- The 7-DOF element by Rinchen et al. (2020) is not compatible with other 6-DOF elements including the ZeroLength element.
- Used a 6-DOF element by Du and Hajjar (2021), which can model LTB but cannot consider warping.
- As a preliminary study, use section 3.94CS1.97x0.138 (in.), which is not prone to warping. The error without considering warping is smaller than 5%.

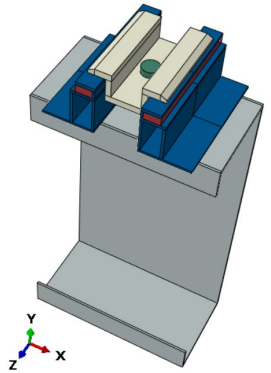
Du, X. and Hajjar, J. (2021). Three-dimensional nonlinear displacement-based beam element for members with angle and tee sections. Engineering Structures, 239, 112239.

LTB with nonlinear spring models for joints

- Each purlin-module joint is modeled as 6 nonlinear springs



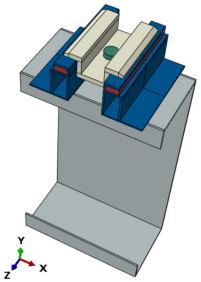




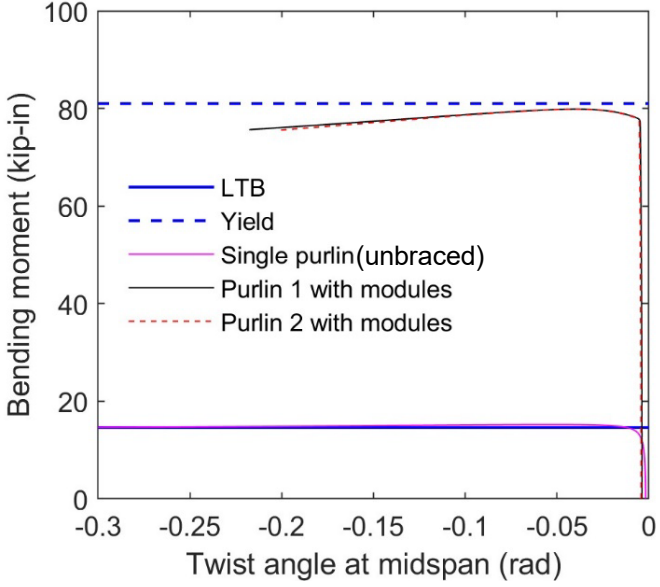
Abaqus model

Example: nonlinear spring models for 2 DOFs of the joint

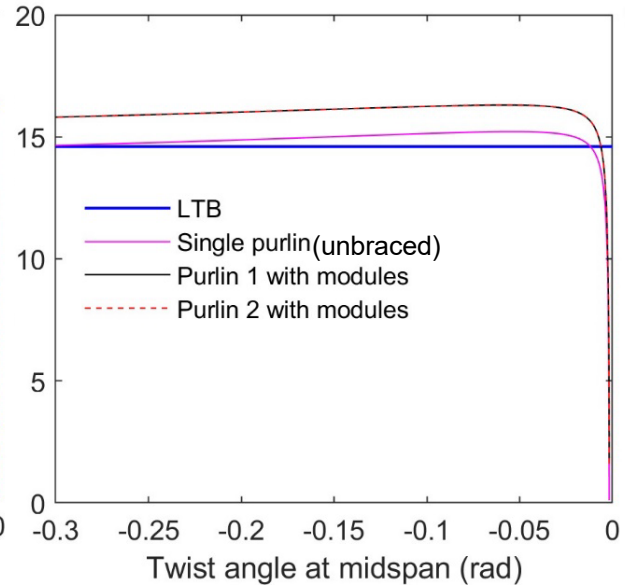
LTB with nonlinear spring models for joints



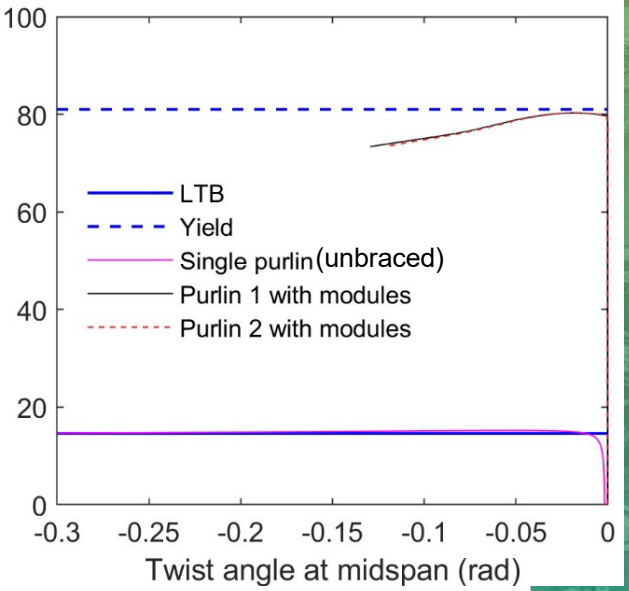
3.94CS1.97x0.138 in. with a lip of 0.650 in.



Fully restrained joints



Pin joints



Nonlinear spring joints

Conclusions and future work

- Based on preliminary study, both fully restrained joints and top-down clamps can delay LTB until yielding of purlins.
- Compared to an unbraced purlin, purlins with pin purlin-module joints have higher LTB capacity, while the increase in the LTB capacity may depend on the size of the purlin section.
- Local and distortional buckling is not considered in this work.
- Further numerical and experimental research may be needed.

Acknowledgements

The material is based upon work supported by the US Department of Energy, Solar Energy Technologies Office. This support is gratefully acknowledged. Any opinions, findings, and conclusions expressed in this material are those of the authors and do not necessarily reflect the views of the sponsors.