Fracture mechanics model width for non-flat geometries

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AFGROW Workshop
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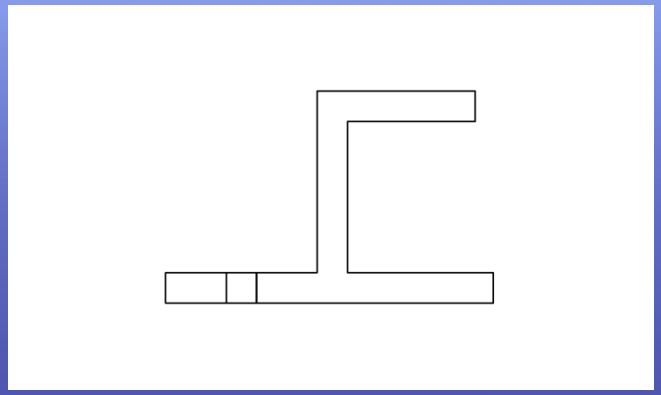
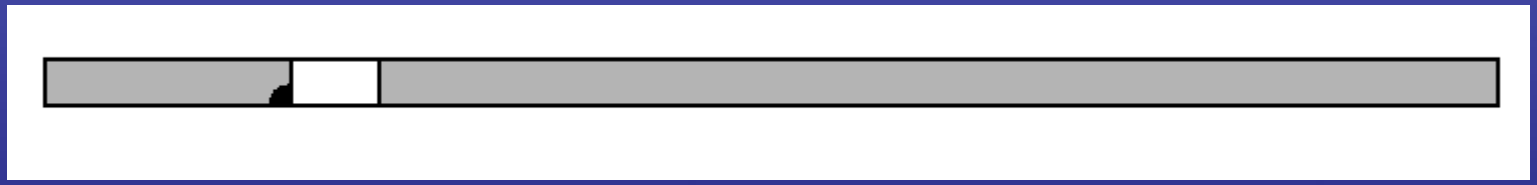
The problem

If I want to run a DTA on a part that looks like this:



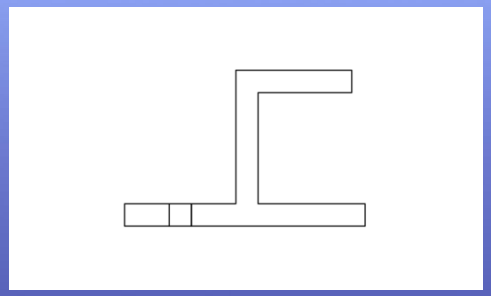
…and I want to analyze it with a fracture mechanics model that looks like this:

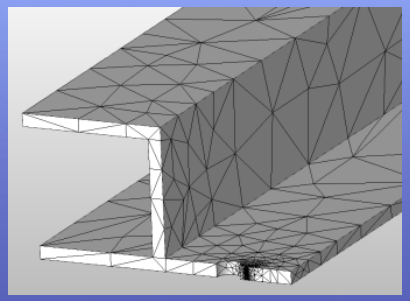


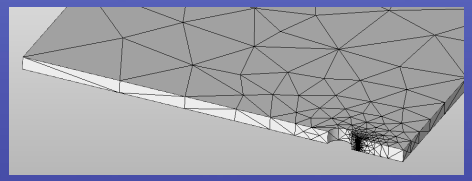
What width should I use?

The solution

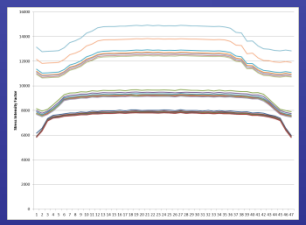
Create FEMs of flat and non-flat geometries:

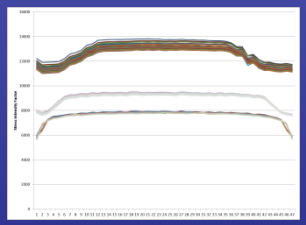






…calculate stress intensities for each:





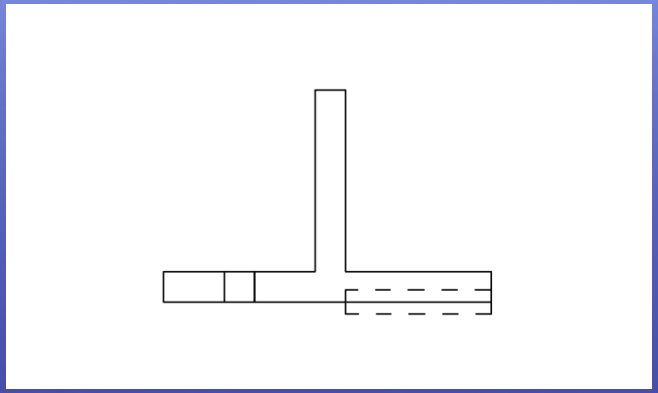
…and figure out which combination of geometric parameters gives a width for which the stress intensities match.

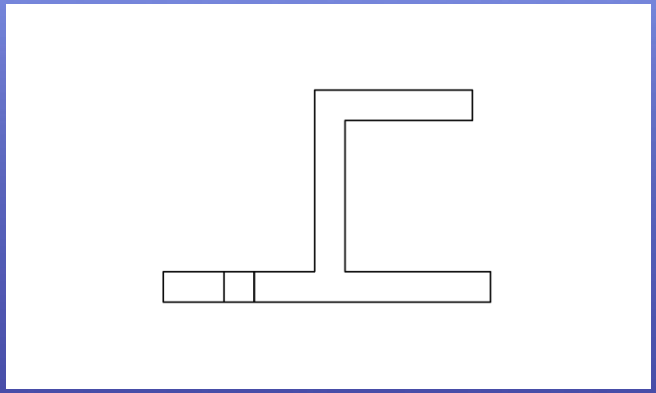
Presentation outline

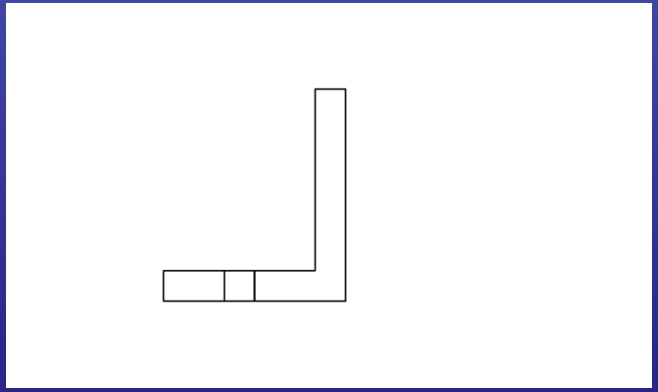
- Geometries investigated
- Creation of StressCheck models
- Comparison of flat and non-flat model SIFs
- Recommendations for model width

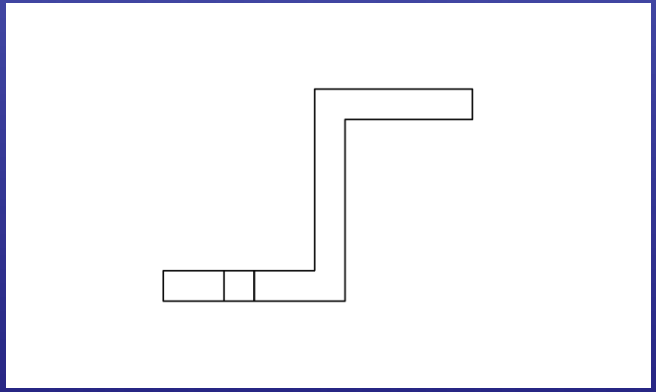
Geometries investigated

- Four shapes of interest based on structural locations analyzed



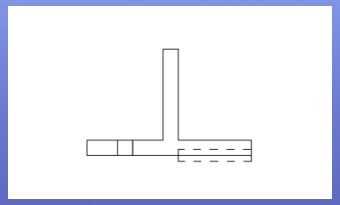


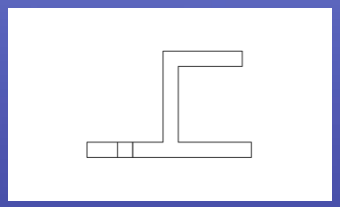


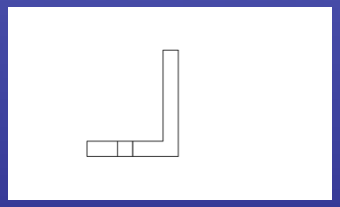


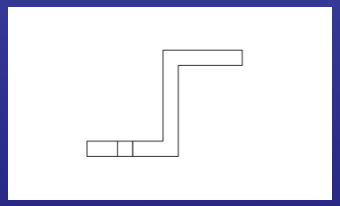
Geometries investigated

- All shapes:
  - Straight through crack at hole
  - Hole diameter constant
  - Hole edge distance constant
  - 3 crack lengths: 0.050 in, 0.150 in, 0.300 in
- Developed matrix to analyze from geometries of critical locations
- Combinations of dimensions in matrix
  - T section: 120 geometries
  - J section: 7 geometries
  - L section: 31 geometries
  - Z section: 1 geometry



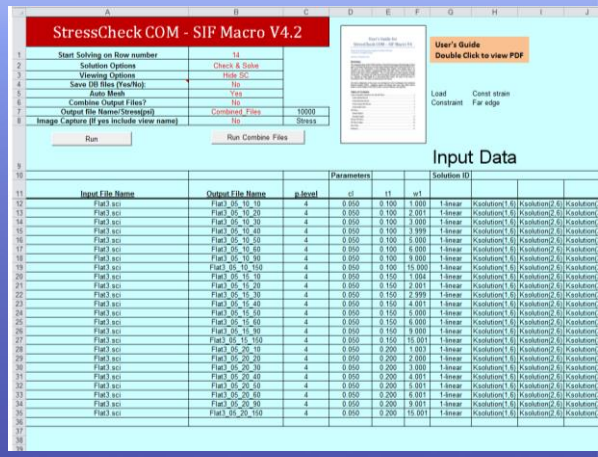


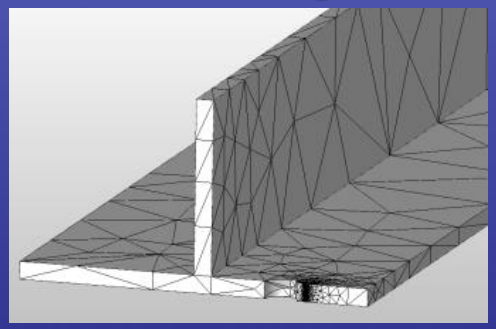


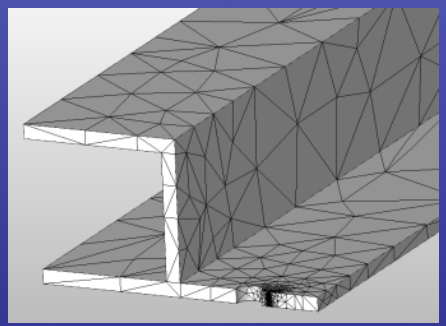


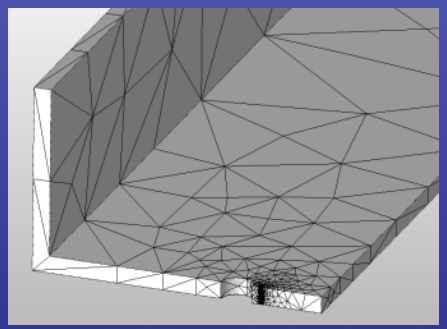
StressCheck models

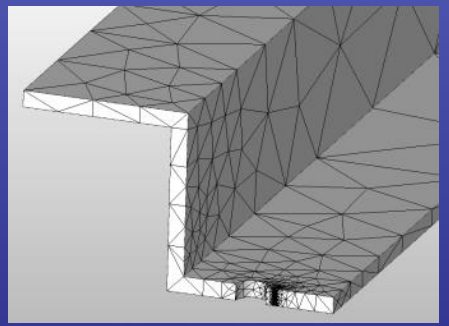
- ~850 StressCheck models created:
  - Used COM interface to automate
    - Models creation
    - Meshing
    - Model run
    - K extraction
  - Allowed comparison of SIFs from all geometries to those for flat plates

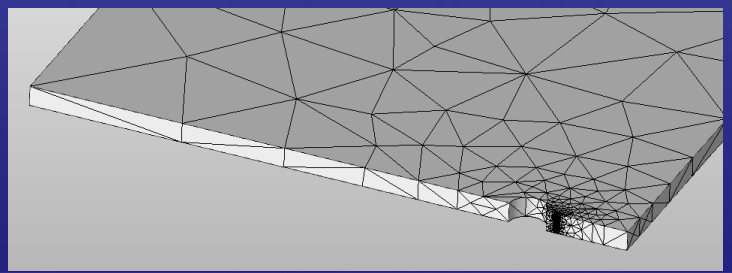






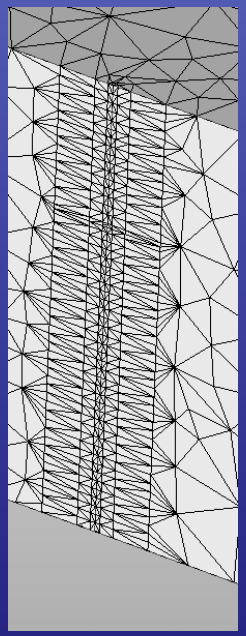


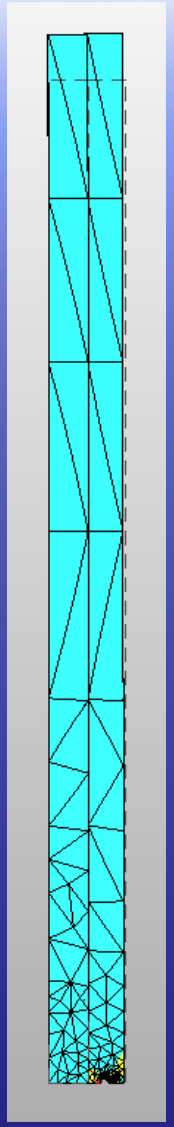




StressCheck models

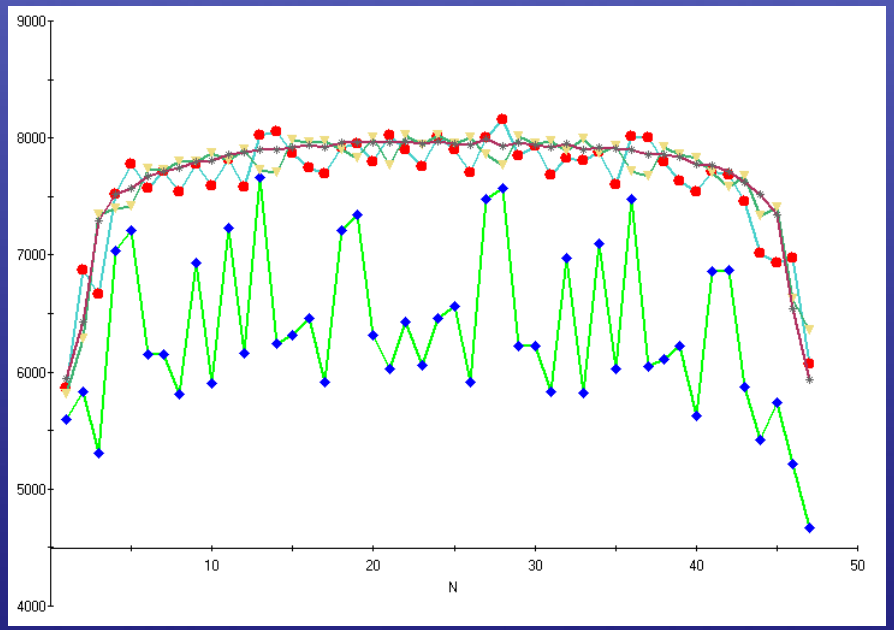
- StressCheck models followed guidelines from previous efforts
- Geometry and constraints
  - 25 in. long model with symmetry constraint
  - No in-plane bending constraint
- Meshing
  - Global tetrahedral automesh
  - 3 boundary layers around crack with size dependent on crack length

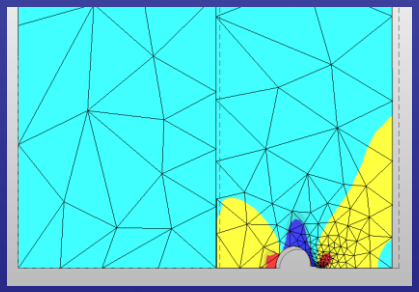


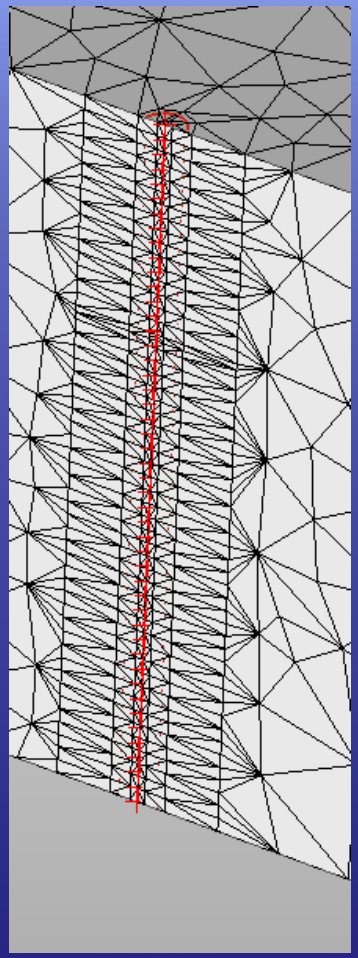


StressCheck models

- StressCheck models followed guidelines from previous efforts
- Solution and K extraction
  - P-Level = 4
  - K extracted from second boundary layer



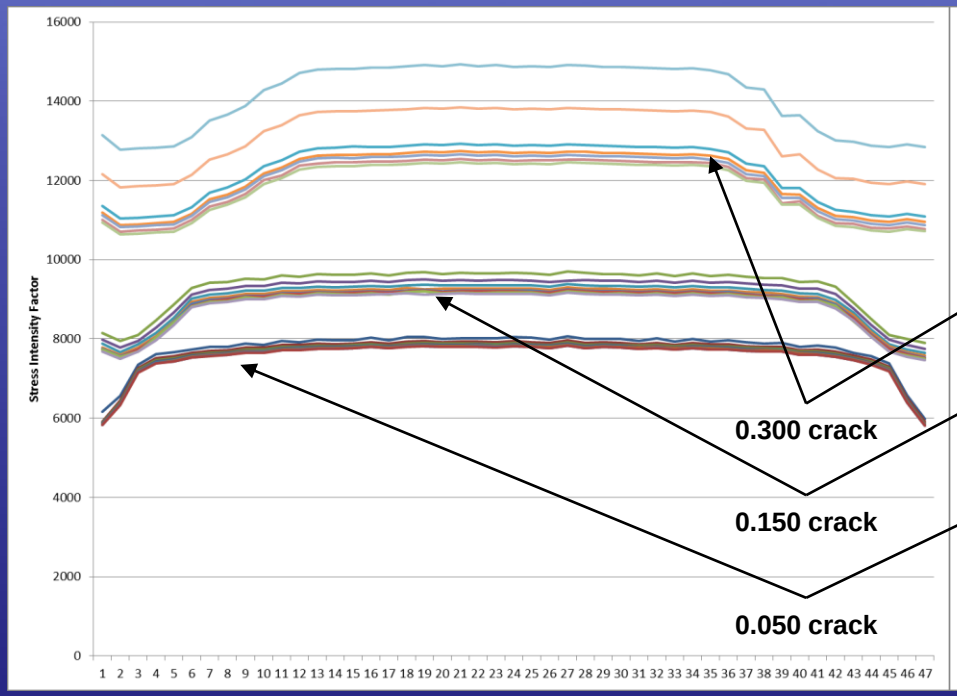




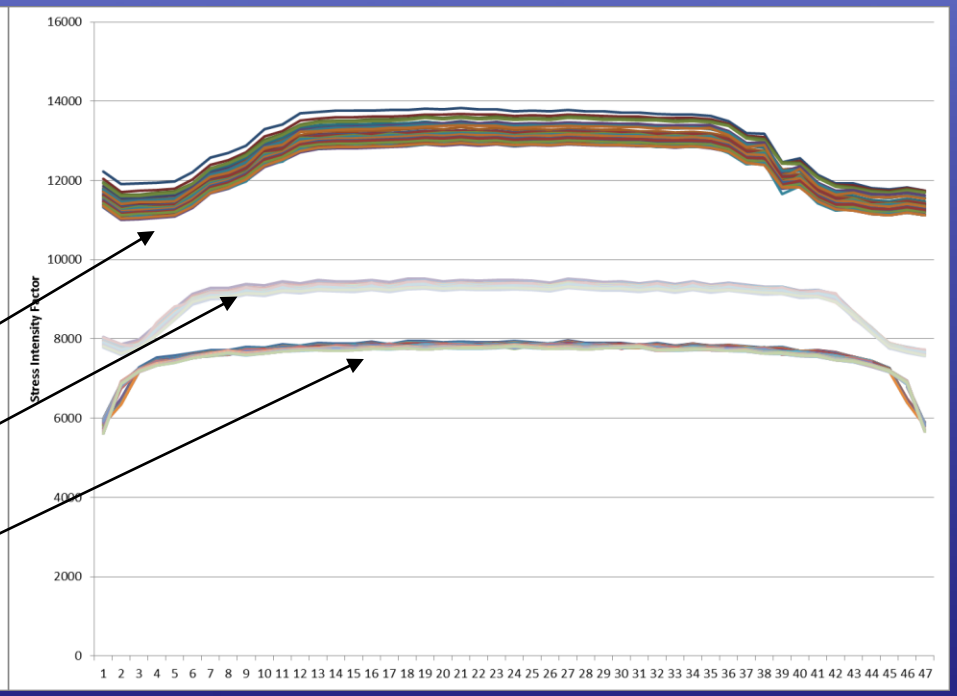
Verification of results

- COM extracted SIFs from models into Excel files
- Plotted SIFs along crack front

Flat Plate

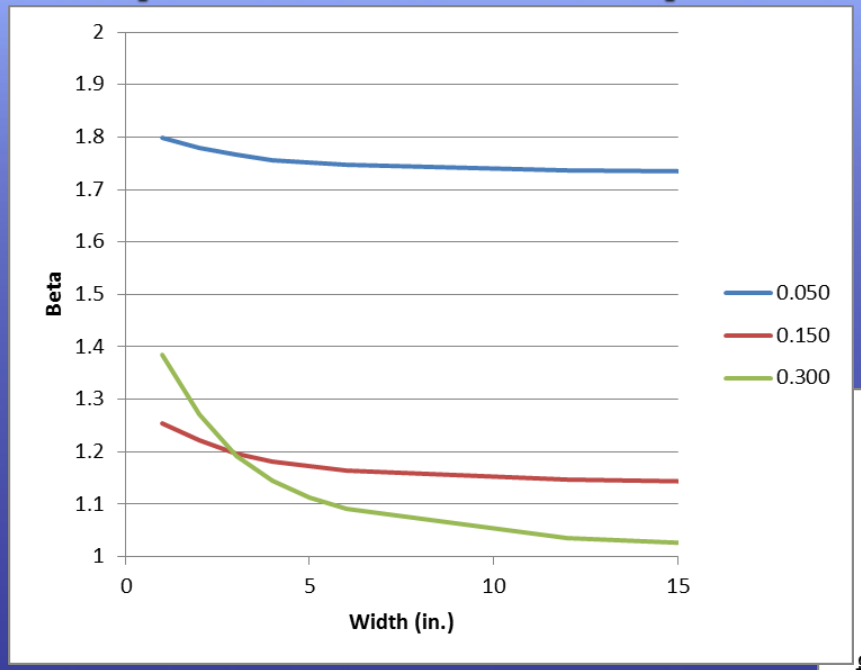


T Section



Verification of results

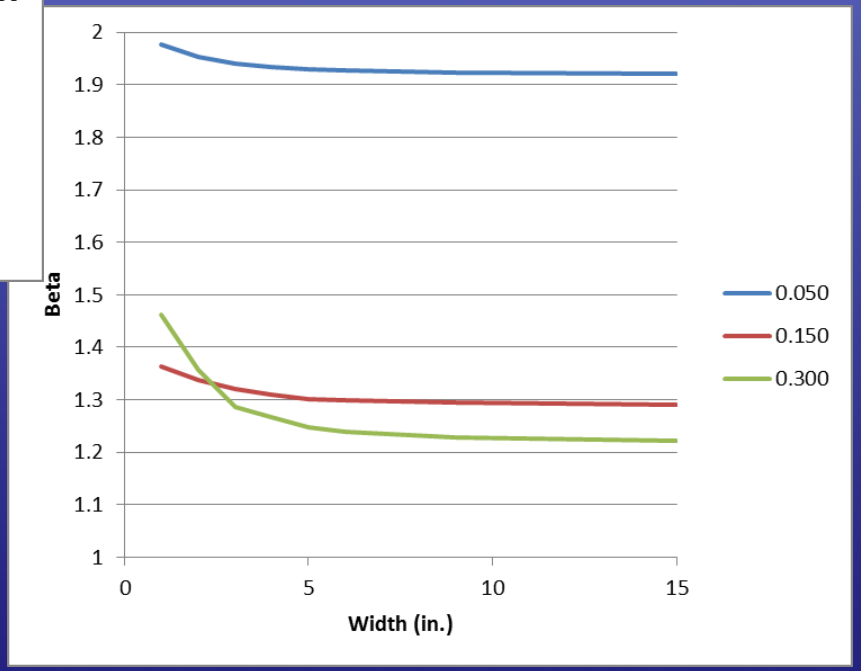
- Flat plate results compared to AFGROW



AFGROW

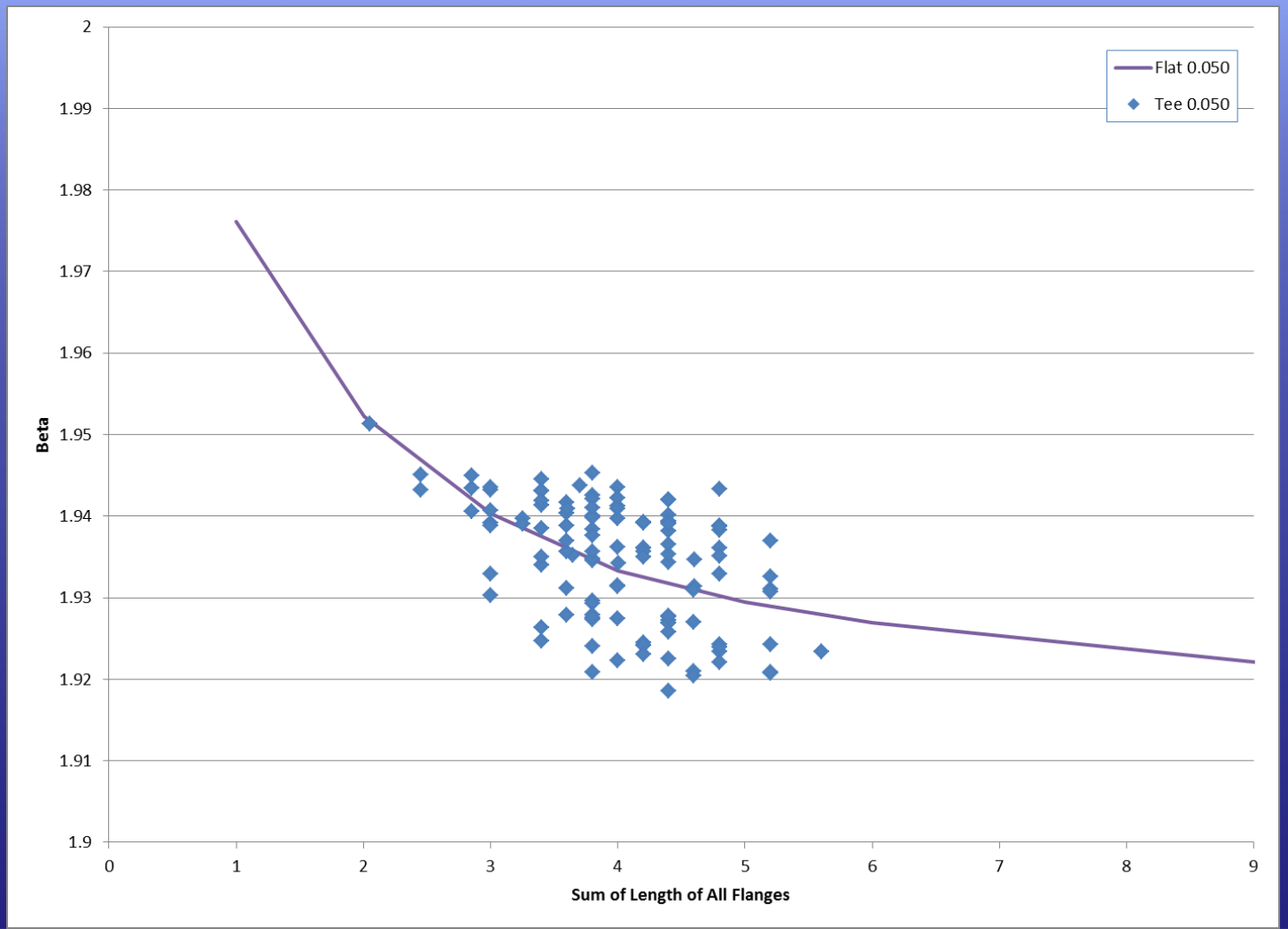
V5.01.06.17

StressCheck



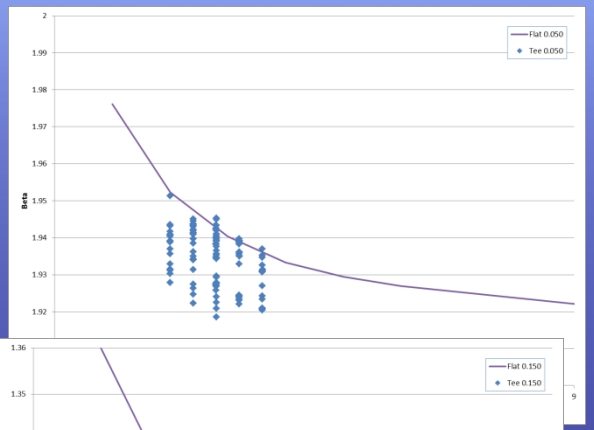
Comparison of model SIFs

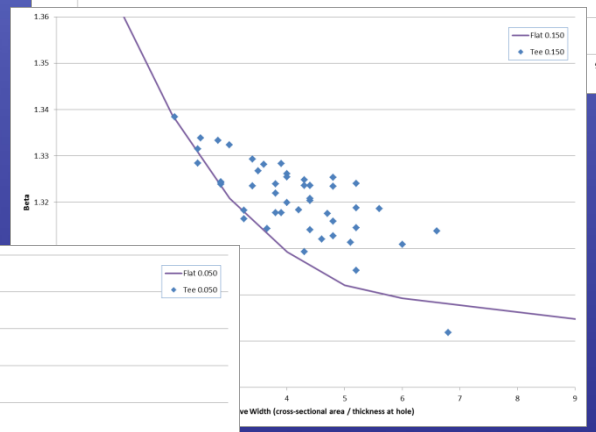
- Started comparison of betas:

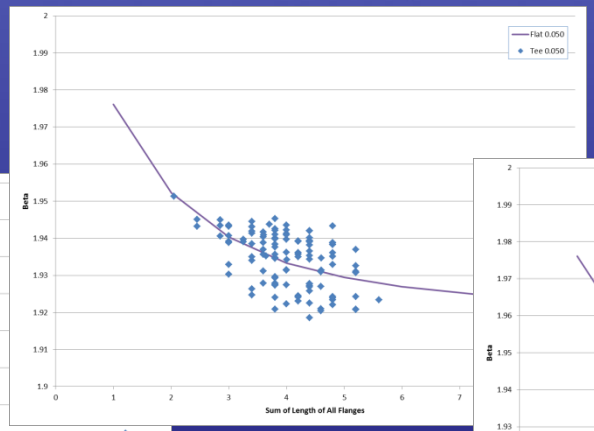


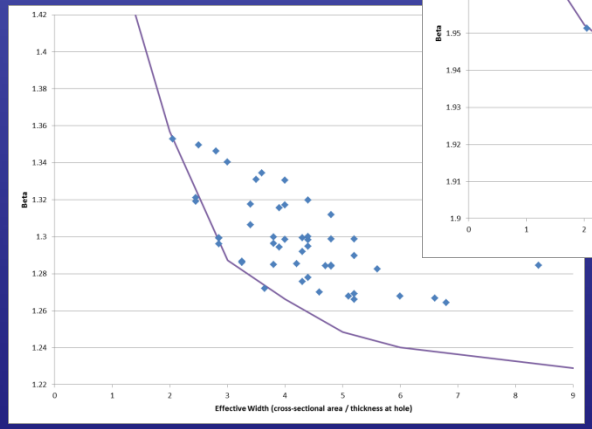
Comparison of model SIFs

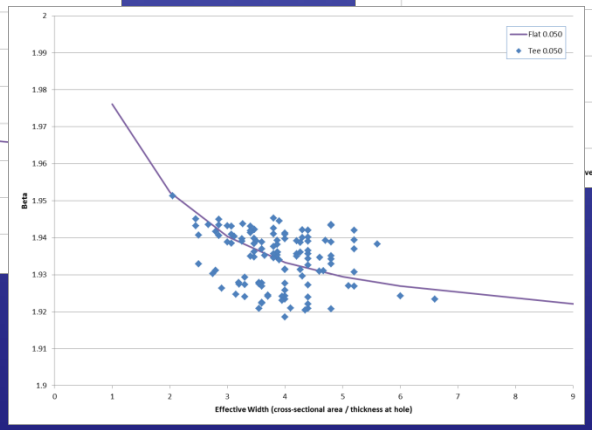
- Compared betas for T Section to those for flat plate using various parameters:
  - Sum of all flange lengths
  - Sum of horizontal flange lengths
  - Cross-sectional area
  - Effective width
    - Cross-sectional area / thickness at crack
  - etc.





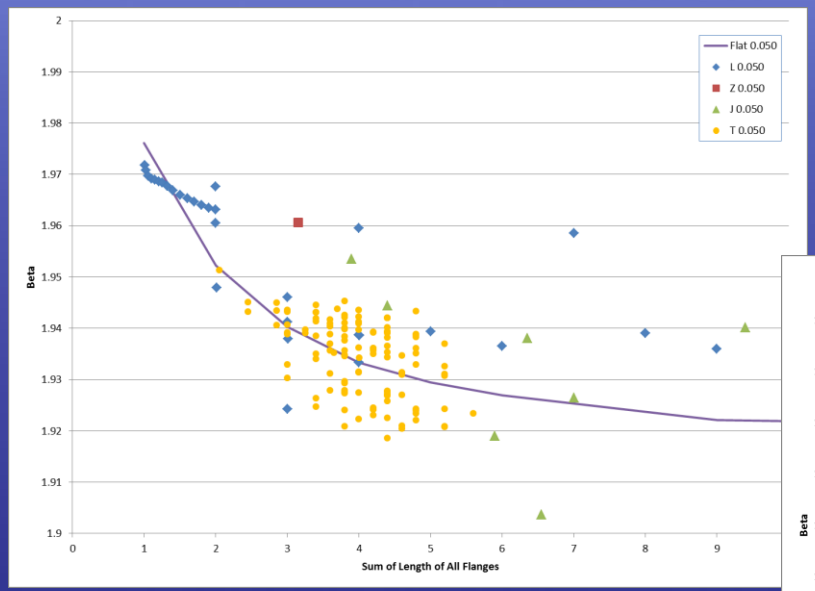


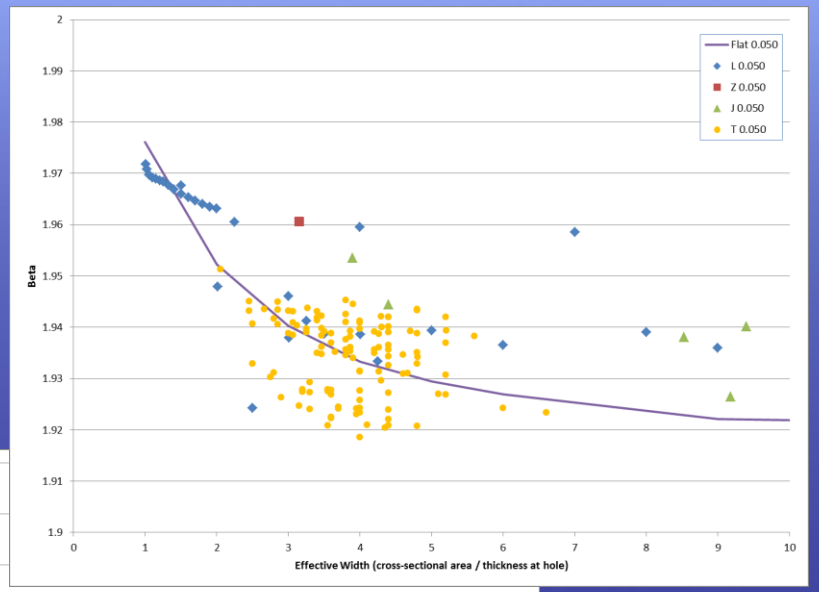


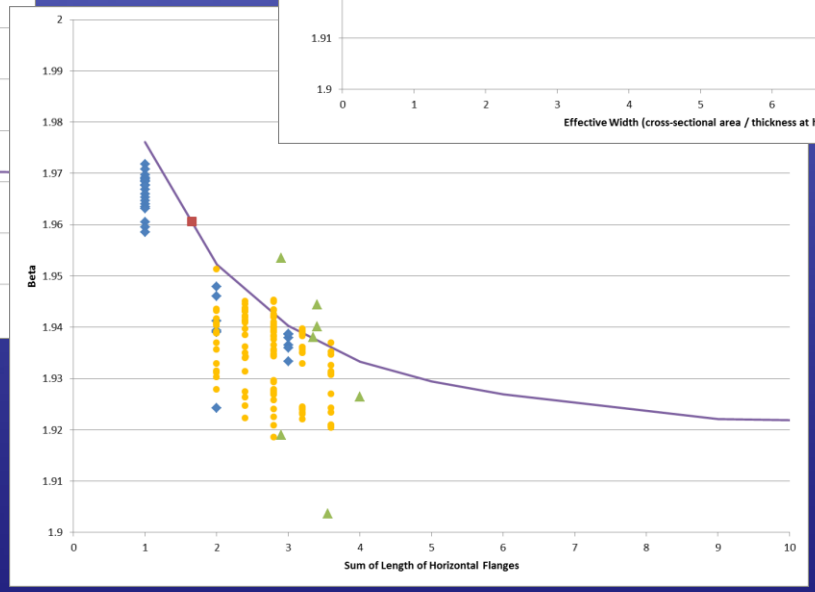


Comparison of model SIFs

- Expanded comparison to all four geometry types analyzed (T, J, L, Z)
  - Visual results inconclusive

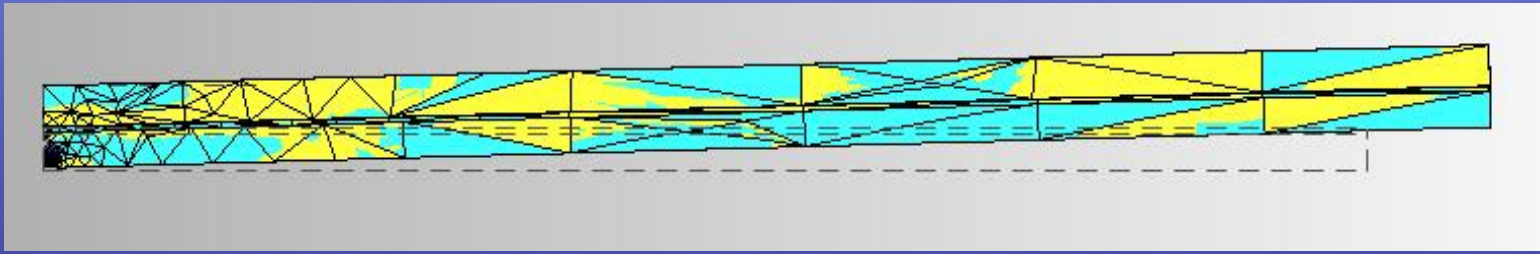


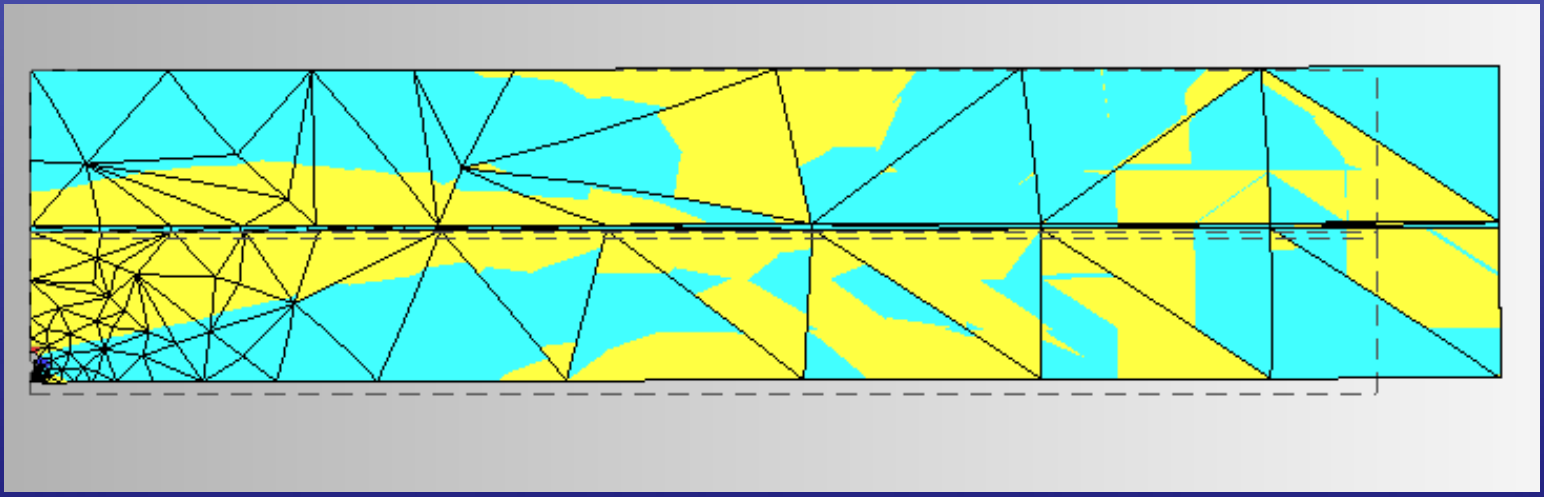




Comparison of model SIFs

- Beta inversely related to the resistance to in-plane bending:
  - Investigated area moment of inertia: $I = bh^3/12 + bhr^2$





Comparison of model SIFs

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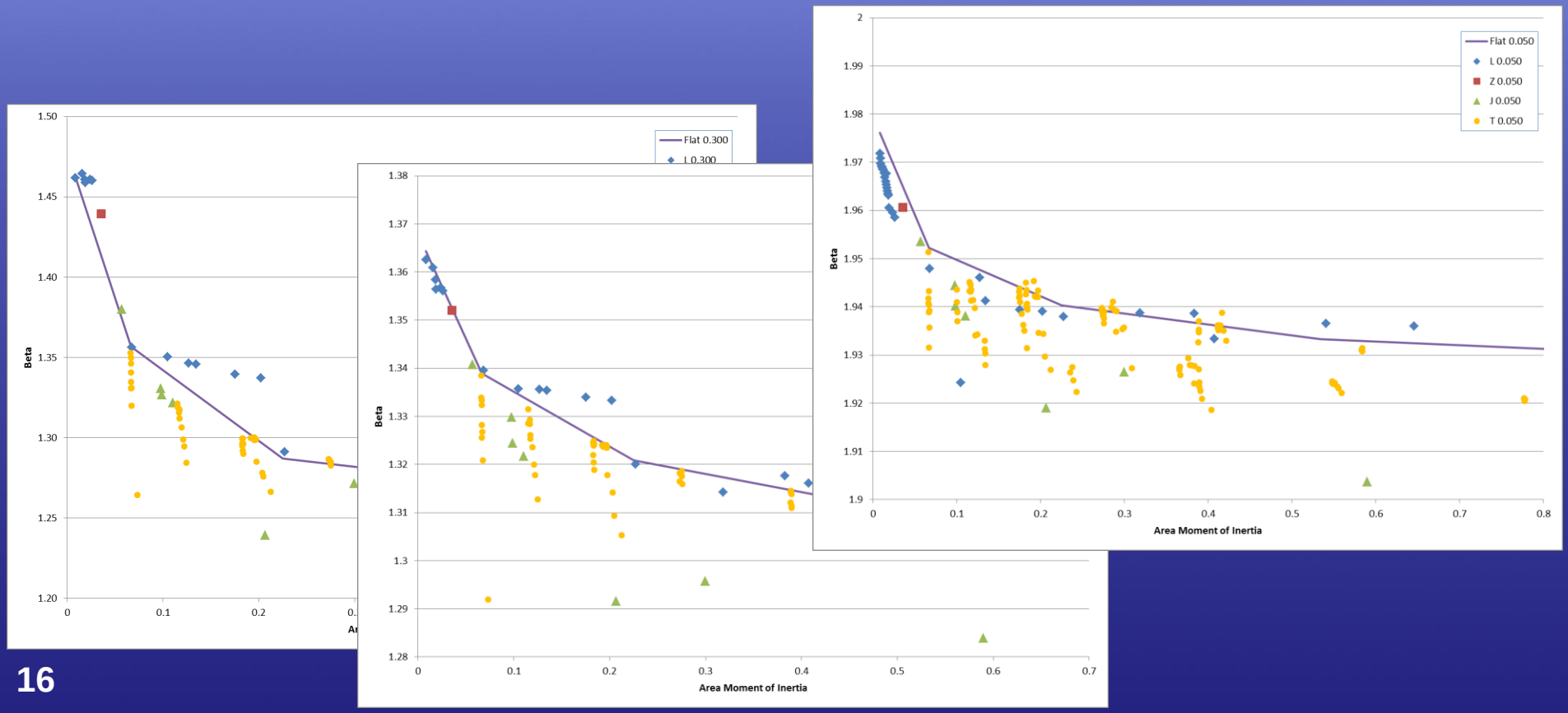
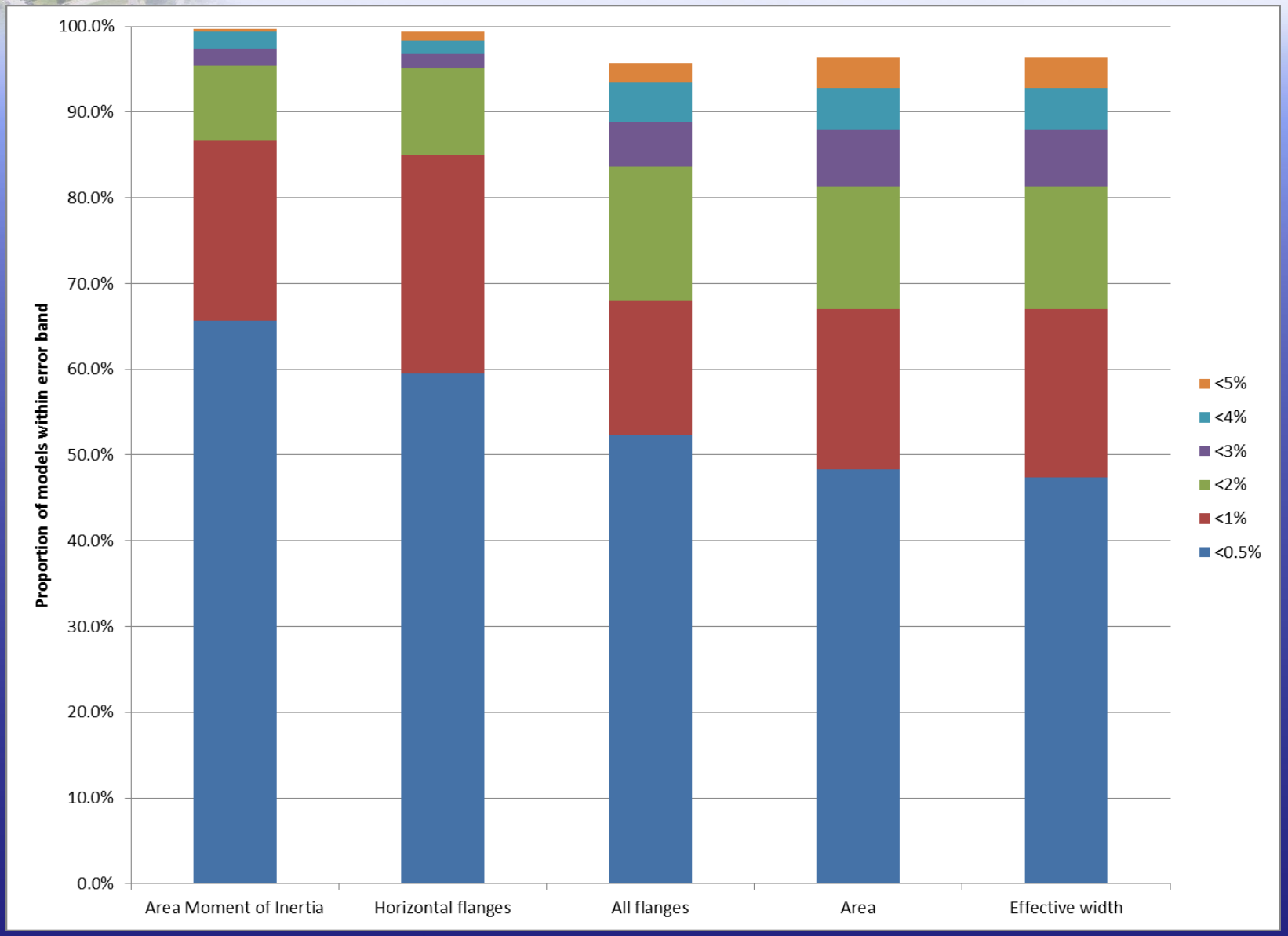


Comparison of model SIFs

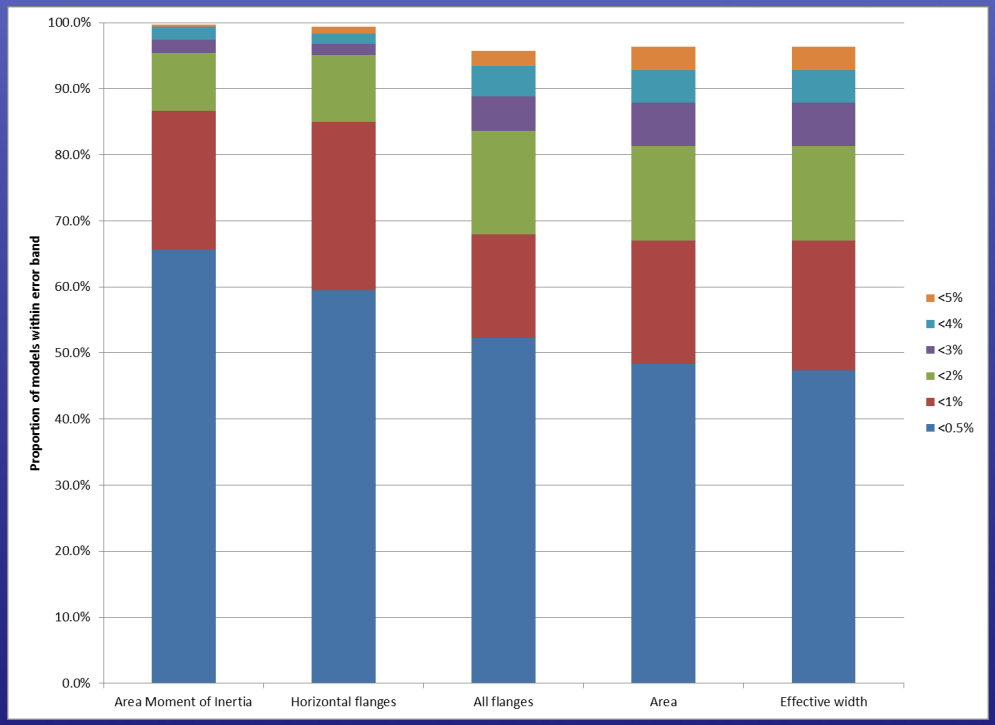
- Compared statistical measures for percent error:
  - Sum of horizontal flange lengths
  - Sum of all flange lengths
  - Cross-sectional area
  - Effective width
  - Area moment of inertia
- Some trends, but all were relatively accurate
- Clearest indicator was a comparison of the percentage of models within certain error bands

Comparison of model SIFs



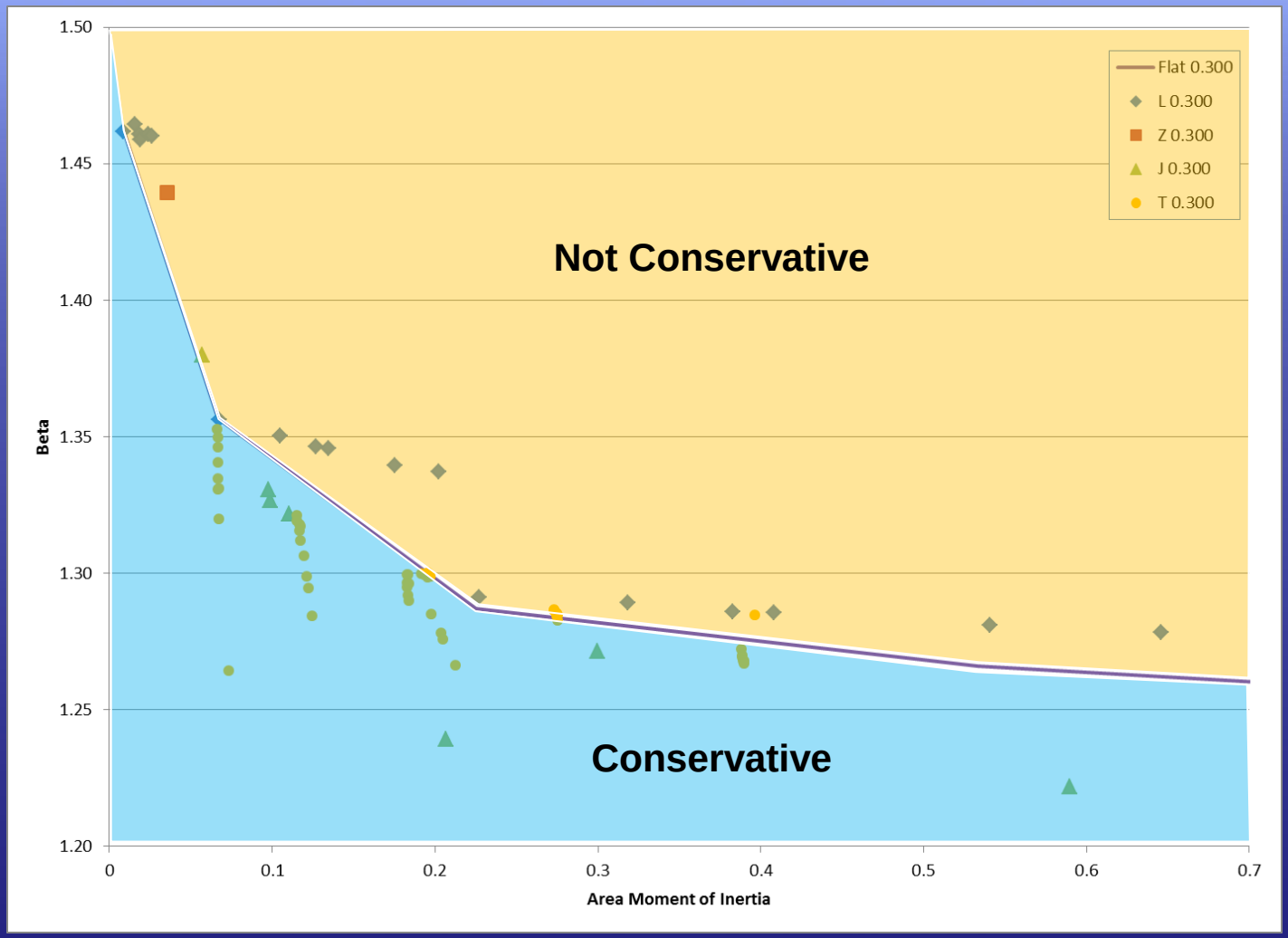
Comparison of model SIFs

- Two tiers of accuracy:
  - First tier:
    - Area moment of inertia
    - Sum of horizontal flange lengths
  - Second tier:
    - Sum of all flange lengths
    - Cross-sectional area
    - Effective width



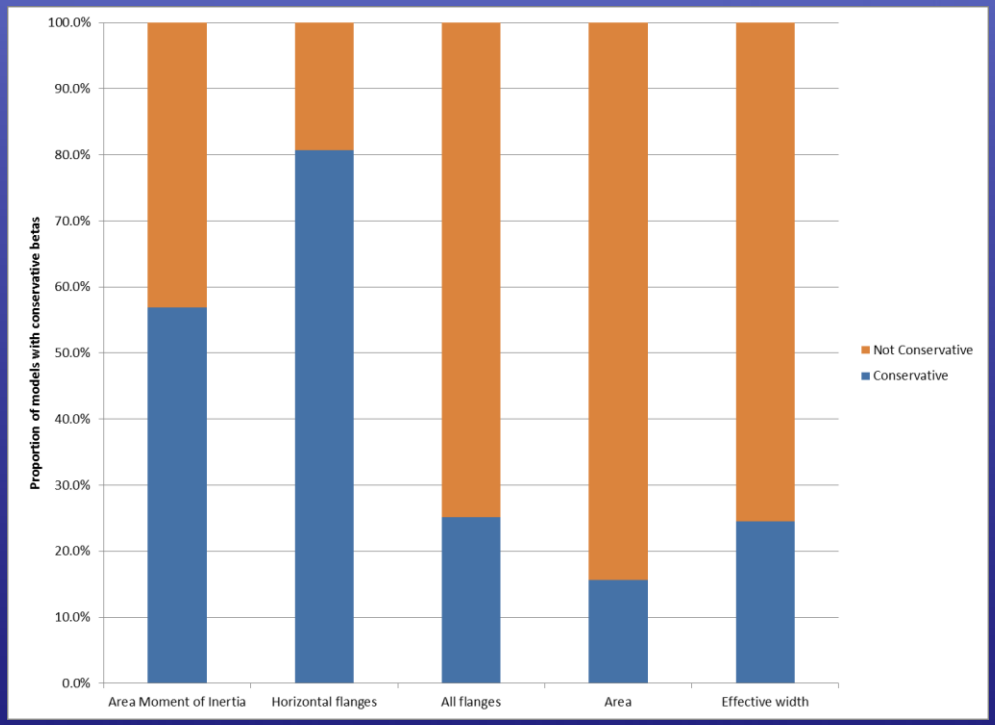
Comparison of model SIFs

- Conservative vs. unconservative betas:



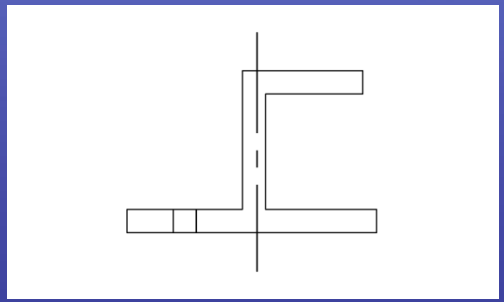
Comparison of model SIFs

- **Conservative vs. unconservative betas:**
  - **More conservative:**
    - Area moment of inertia
    - Sum of horizontal flange lengths
  - **Less conservative:**
    - Sum of all flange lengths
    - Cross-sectional area
    - Effective width



Recommendations

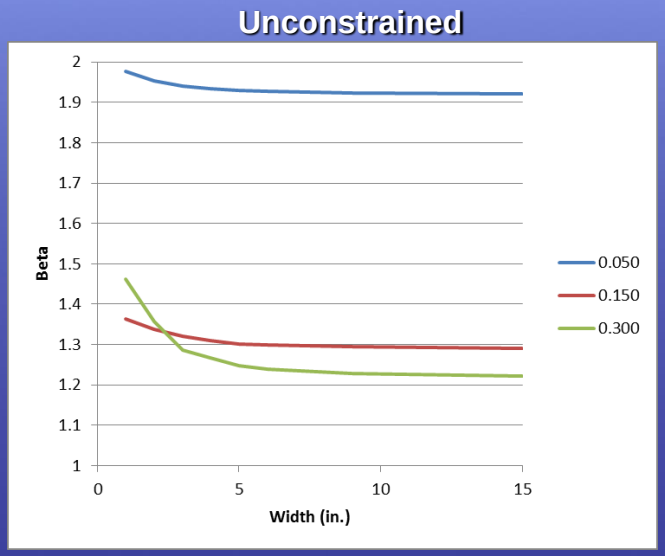
- Use the sum of horizontal flange lengths as the flat plate width
- Very similar to the width based on area moment of inertia, as the vertical flanges provide little resistance to bending

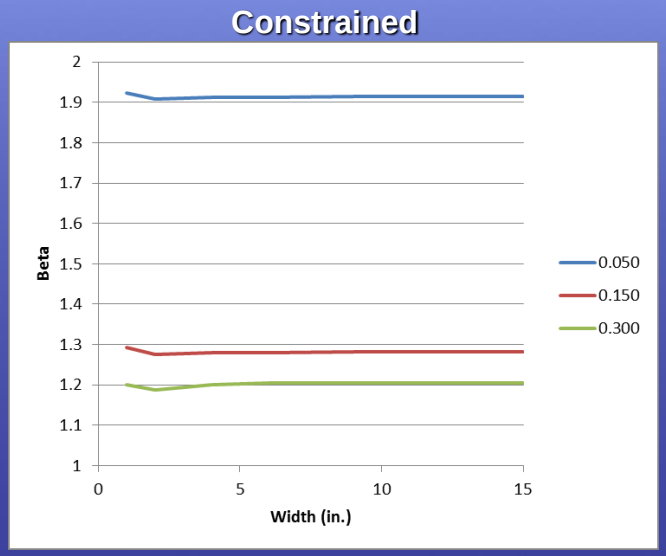


- Why horizontal flanges, not moment of inertia:
  - Slightly less accurate
  - Much easier to calculate
  - Higher likelihood of being conservative

Recommendations

- Flat plate and T Section models were also created with no in-plane bending allowed





  - All constrained results within 1% of each other
  - Equal to unconstrained results for infinite width

- So what: Our structures are often constrained
  - Consider for inspection interval relief

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