

# Ogden Air Logistics Center



**U.S. AIR FORCE**

*Comparison of  
Advanced Continuing Damage  
Model  
&  
Classic Single Edge Through Crack  
Model*

*Tim Allred  
A-10 ASIP Group  
Hill AFB, UT  
801-586-2474*



# Acknowledgements



*OGDEN AIR LOGISTICS CENTER*

- James A. Harter, AFRL/VASM
- Alexander V. Litvinov, LexTech, Inc.
- A-10 ASIP Group



# Overview



*OGDEN AIR LOGISTICS CENTER*

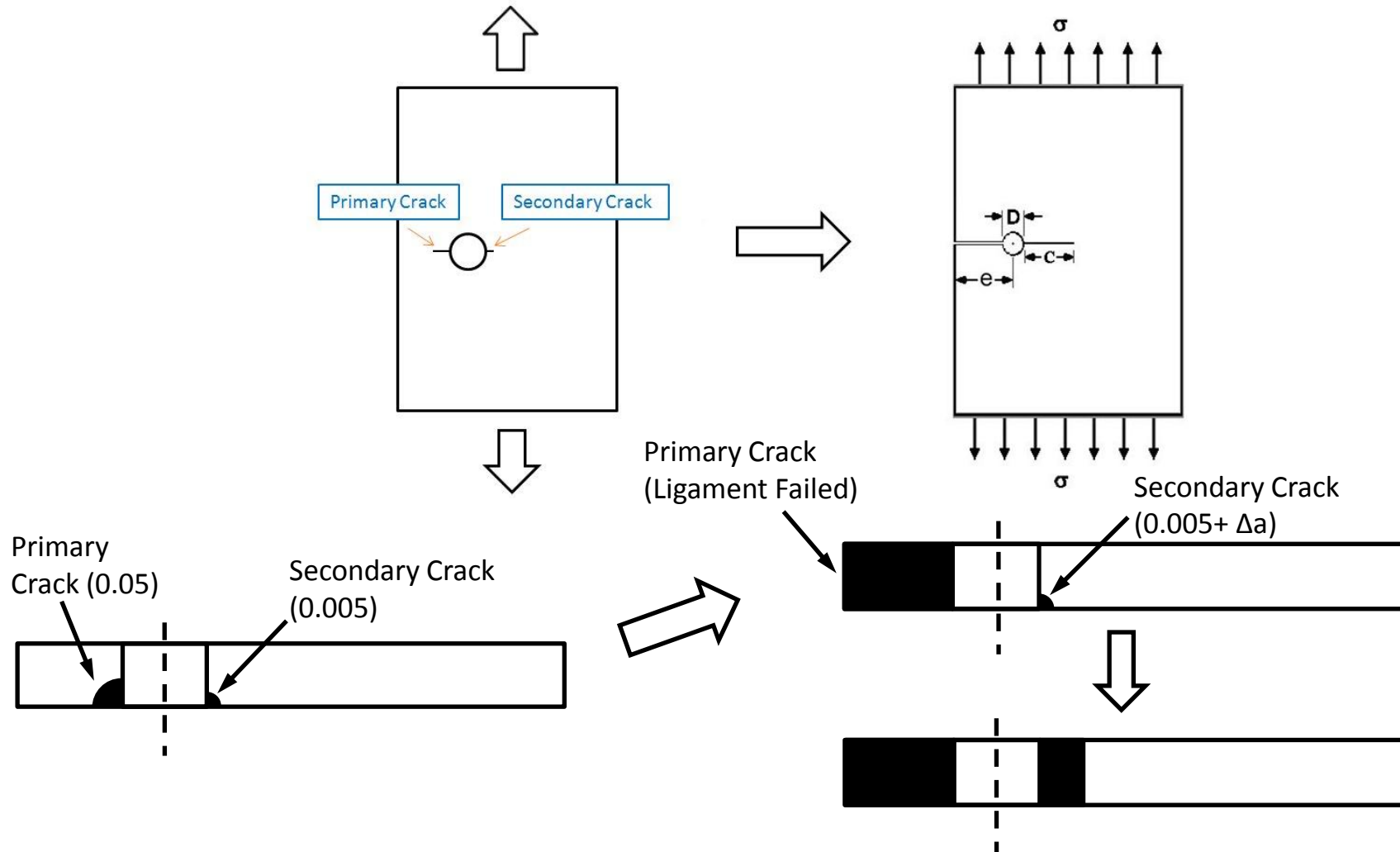
- AFGROW Models
  - Advanced Continuing Damage Model
  - Classic Single Edge Through Crack
- In Plane Bending
- K Solution Comparisons
- FEM Constraints
- Conclusions and Recommendations



# Continuing Damage



OGDEN AIR LOGISTICS CENTER



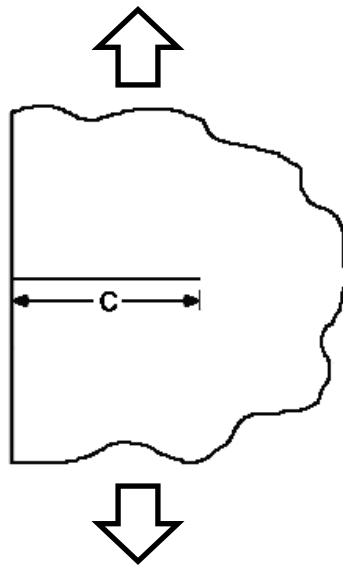


# Equivalent Edge Crack Solution



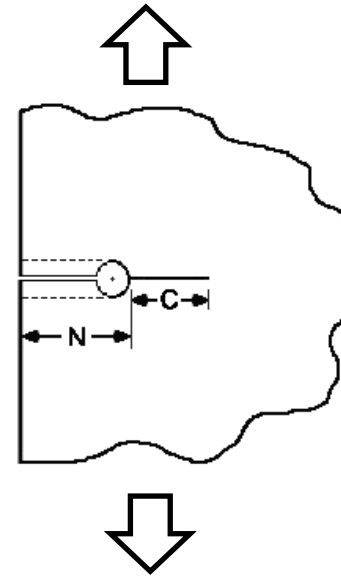
OGDEN AIR LOGISTICS CENTER

Solution for Continuing Damage Model converges with  
Edge Crack Solution when  $C \geq$  Hole Radius  
(Semi-Infinite Plate)



$$K = \sigma \sqrt{\pi C} \beta$$

$$\beta = 1.1221$$



$$\sigma \sqrt{\pi (C + N)} (1.1221) = \sigma \sqrt{\pi C} \beta$$

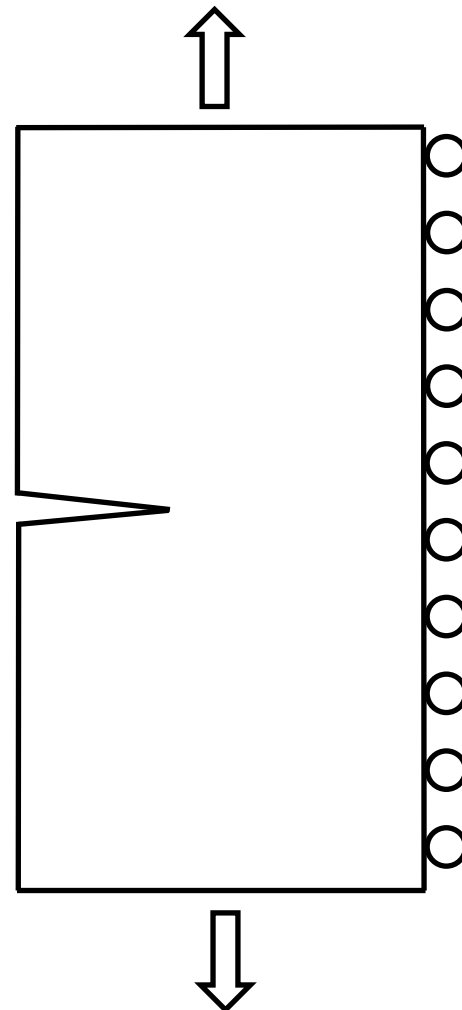
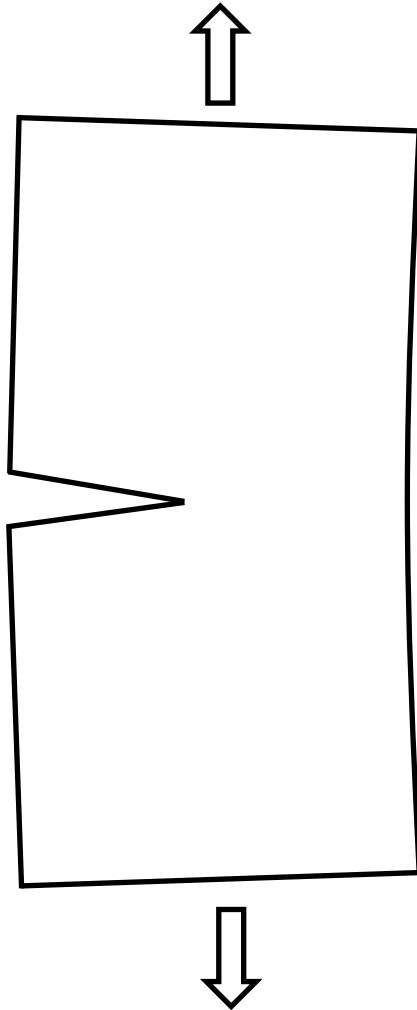
$$\beta = \frac{1.1221}{\sqrt{C/(C + N)}}$$



# Finite Width Plates In Plane Bending



*OGDEN AIR LOGISTICS CENTER*



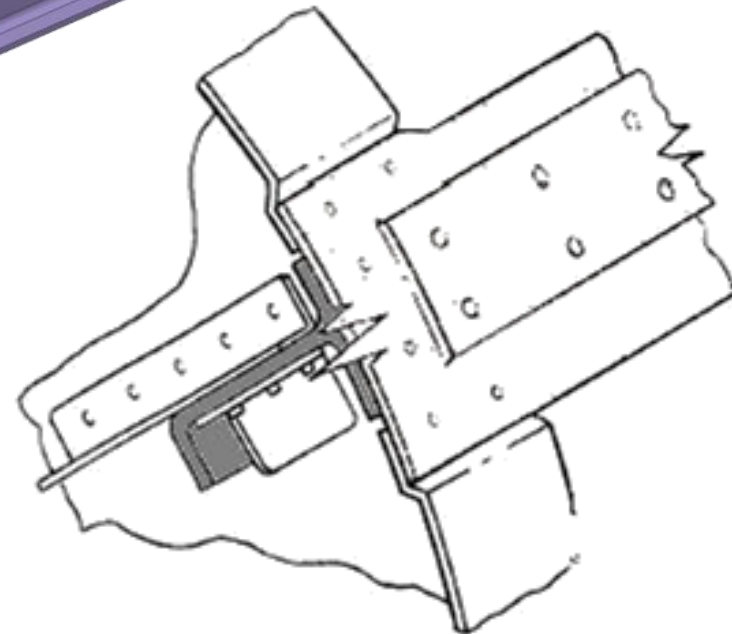
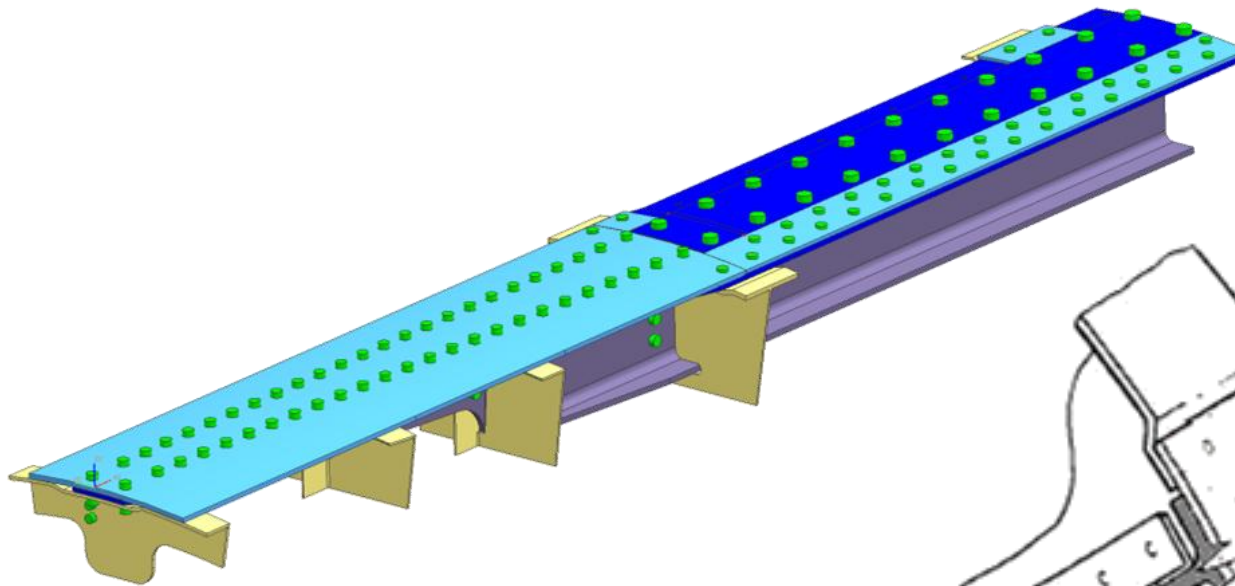


# In Plane Bending Constraint



*OGDEN AIR LOGISTICS CENTER*

Built Up Structure on Aircraft





# Stress Intensity Solutions



OGDEN AIR LOGISTICS CENTER

Model	In Plane Bending Constrained ?	Solution Source	Ref
Advanced Continuing Damage	X	FEM (ABAQUS w/ FRANC3D/NG)	Harter
Classic Single Edge Through Crack	X	FEM (FRANC2D)	Taluk
Advanced Continuing Damage		FEM (ABAQUS w/ FRANC3D/NG)	Harter
Classic Single Edge Through Crack		??	Tada, Paris, Irwin

## References:

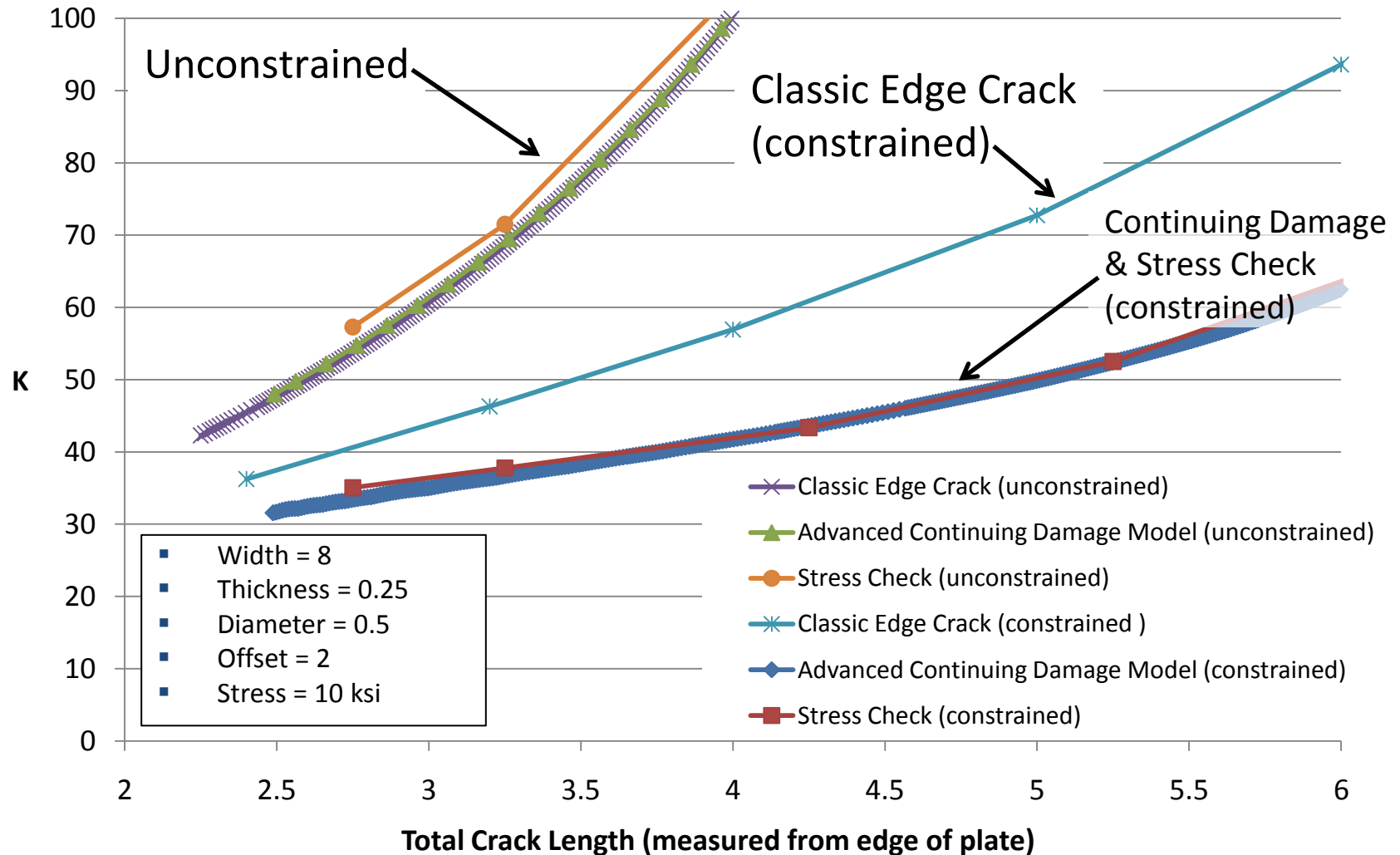
- Harter, James A, AFRL/VASM, 2009
- Taluk, Deviprasad, Eagle Aeronautics, Inc., 1998
- Tada, H., Paris, P.C., and Irwin, G.R., "The Stress Analysis of Cracks Handbook," Second Edition, p. 2.11, Paris Productions, Inc., St Louis, MO, 1985



# AFGROW Finite Width Plate K Solutions



OGDEN AIR LOGISTICS CENTER

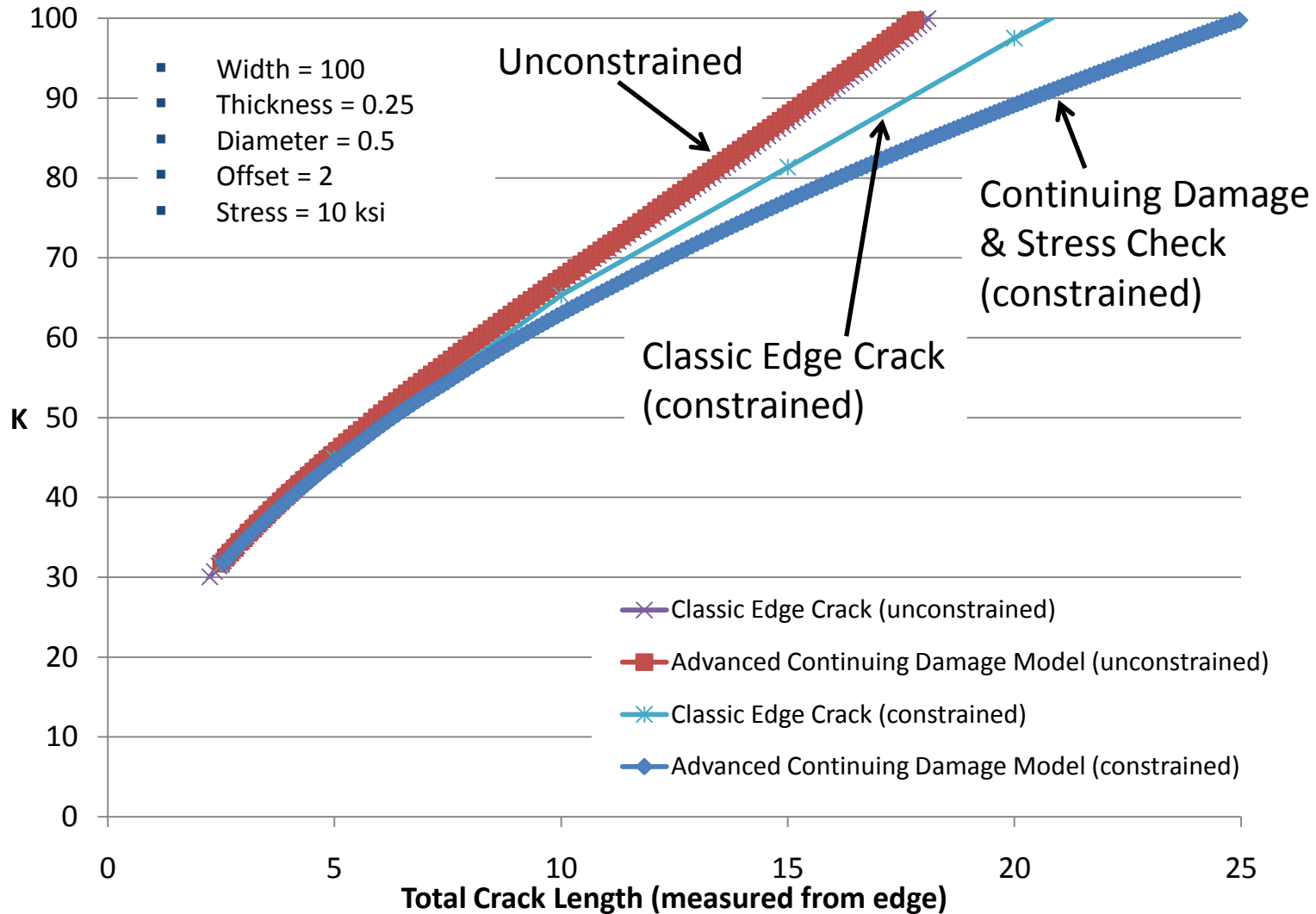




# AFGROW Large Width Plate K Solutions



OGDEN AIR LOGISTICS CENTER

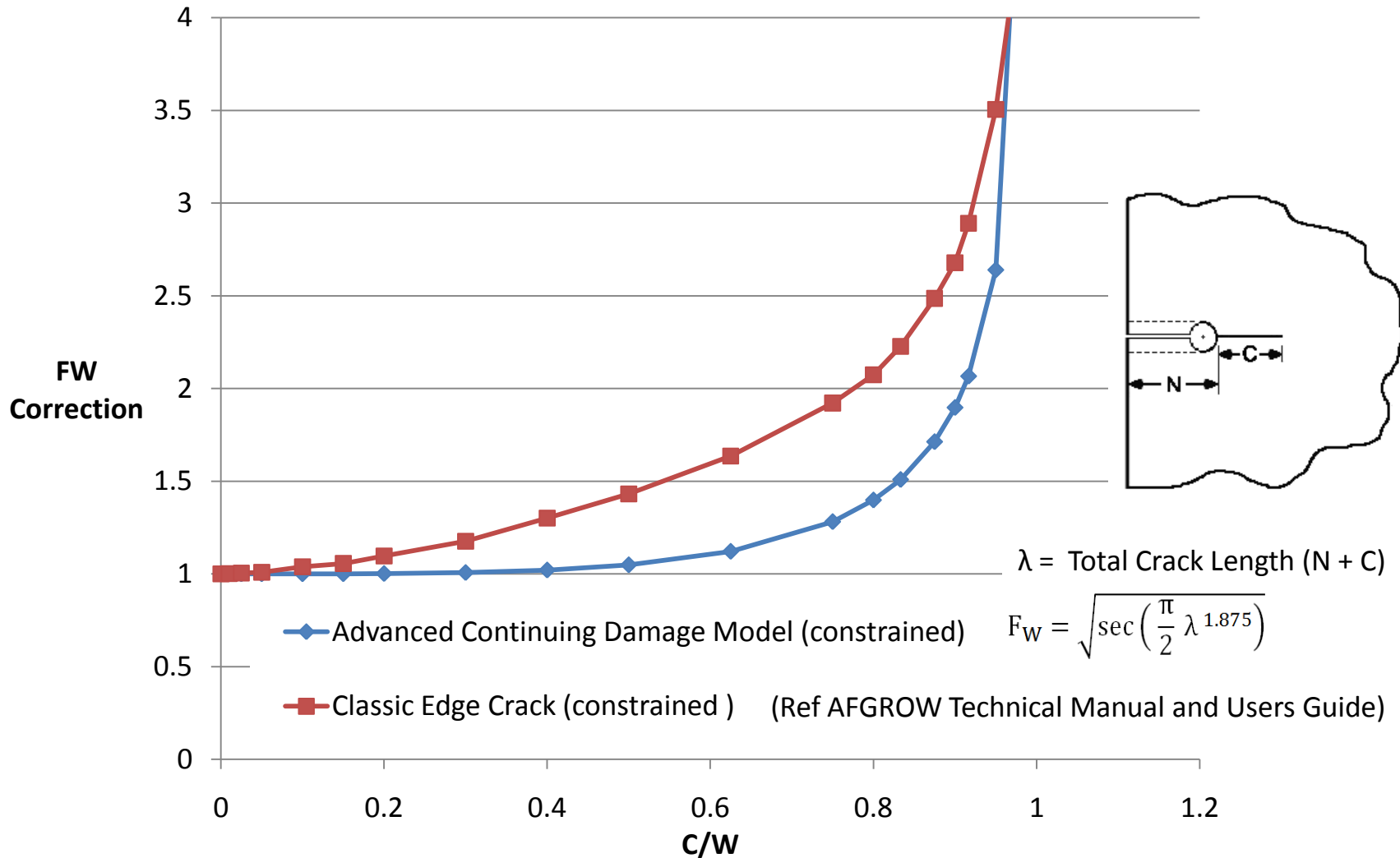




# Finite Width Correction



OGDEN AIR LOGISTICS CENTER





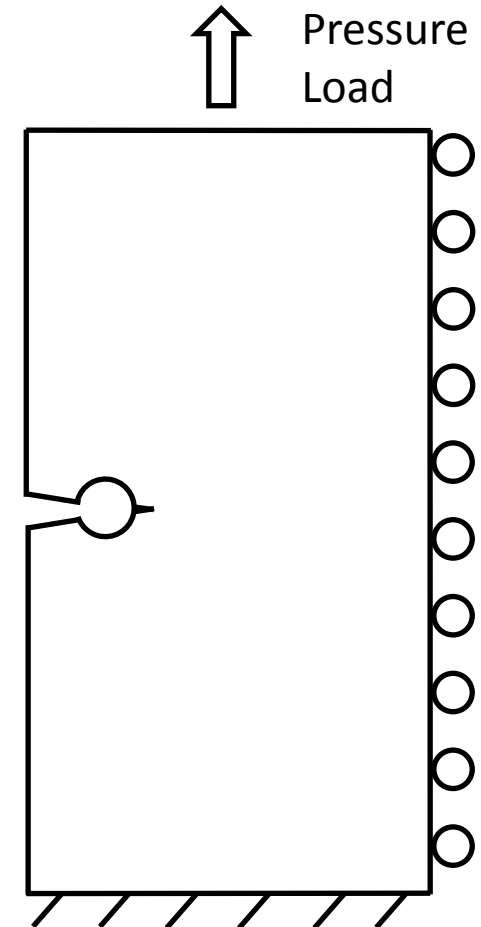
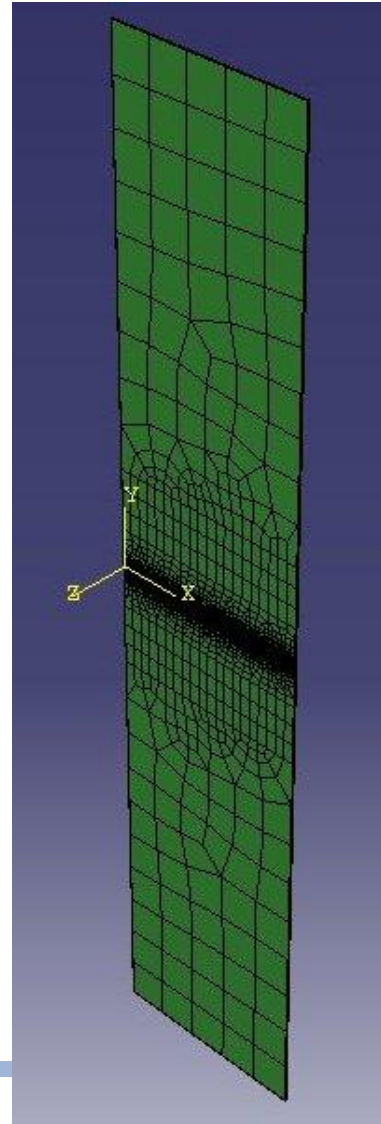
# Continuing Damage FEM Constraints



OGDEN AIR LOGISTICS CENTER

- FEM:
  - ABAQUS w/FRANC3D/NG
- Dimensions
  - Width =  $100 * N$
  - Thickness = 1
  - Total Height =  $500 * N$
- Loading
  - Top Edge: Pressure Load
- Boundary Conditions:
  - Bottom Edge: Fixed in Y-Dir
  - Bottom Edge: Mid-Plane in Z-Dir
  - Right Edge: Fixed in X-Dir (Counteracts In-Plane Bending)

Ref: Harter, James A, AFRL/VASM,  
2009



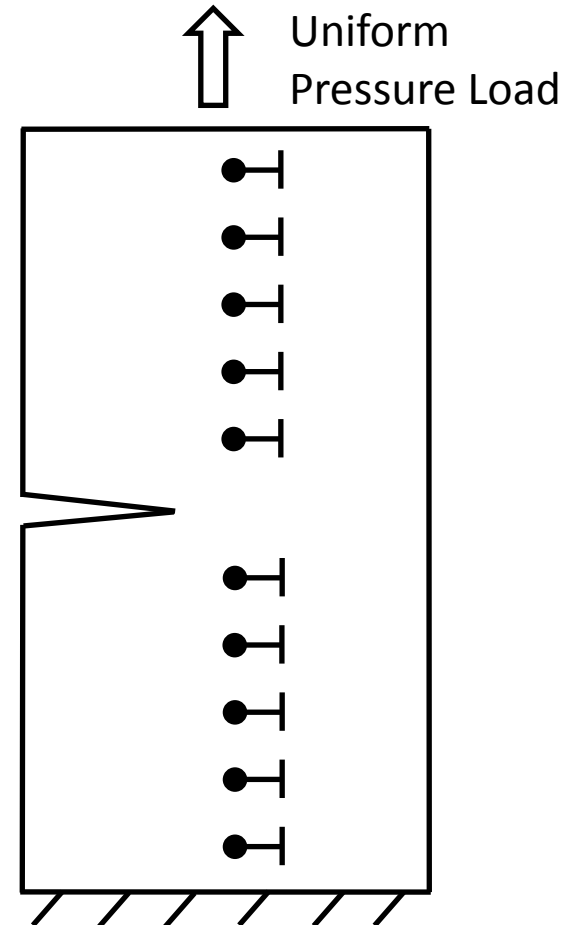


# Classic Edge Crack FEM Constraints



OGDEN AIR LOGISTICS CENTER

- FEM:
  - FRANC2D
- Loading
  - Top Edge: Pressure Load
- Boundary Conditions:
  - Bottom Edge: Fixed in Y-Dir
  - Mid-Plane Nodes: Fixed in X-Dir
    - upper and lower portions of the plate only
    - Nodes in the area of the crack plane not constrained



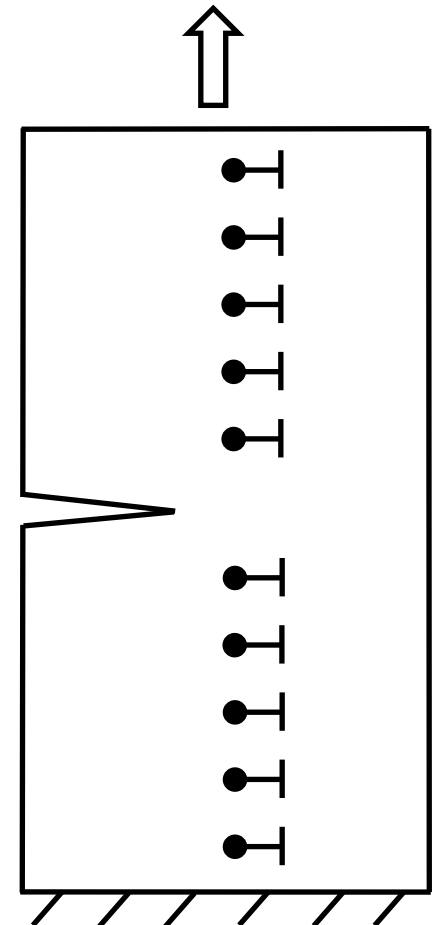
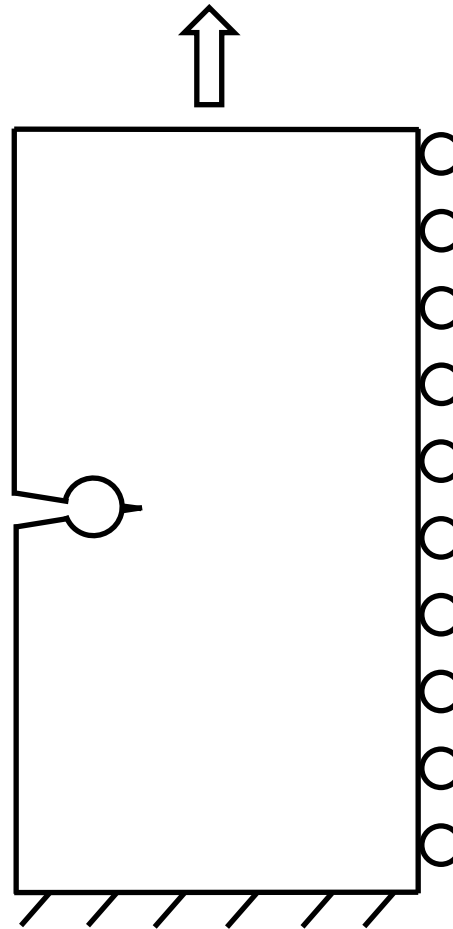


# Appropriate Constraints?



OGDEN AIR LOGISTICS CENTER

- Comparison to Actual Structure
  - Fasteners constrain structure





# Conclusions & Recommendations



*OGDEN AIR LOGISTICS CENTER*

- **Conclusions:**
  - Stress Intensity Solutions are significantly different when comparing Continuing Damage Model and Classic Edge Crack Model (In-Plane Bending Constrained)
  - Differences originate with FEM (constraints)
  - How much does it matter?
    - Continuing Damage Life (especially through crack) is typically small
      - Constraint assumption would also affect corner crack continuing damage life
    - Critical Crack Size
- **Recommendations:**
  - Replicate Edge Crack FEM and verify solutions
  - Investigate different constraint assumptions
  - Test data for a continuing damage case