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Damage Tolerance Test Method Development for Sandwich Composites

2013 Technical Review

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University of Utah

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FAA Sponsored Project Information

- Principal Investigator: **Dr. Dan Adams**
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- FAA Technical Monitor:
  David Westlund
- Collaborators:

  ASTM Committee D30
  Boeing
  Materials Sciences Corporation

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BACKGROUND:
Damage Tolerance Test Methods for Sandwich Composites

- **Damage tolerance test methods for monolithic composites have reached a relatively high level of maturity**
  - Damage Resistance: ASTM D 7136 – Drop-Weight Impacting
  - Damage Tolerance: ASTM D 7137 – Compression After Impact
- **Less attention to sandwich composites…until recently**
  - **SAMPE/ASTM D30 Panel at Joint Meeting October 2009**

    "*Damage Resistance and Damage Tolerance of Sandwich Structures*"

    Dan Adams, organizer, panelist Carl Rousseau, moderator
  - **ASTM D30 publishes standard for sandwich damage resistance**
    - ASTM D7766 (2011) *"Standard Practice for Damage Resistance* Testing of *Sandwich* Constructions"
  - **SAMPE/ASTM D30 Panel at Joint Meeting October 2011**

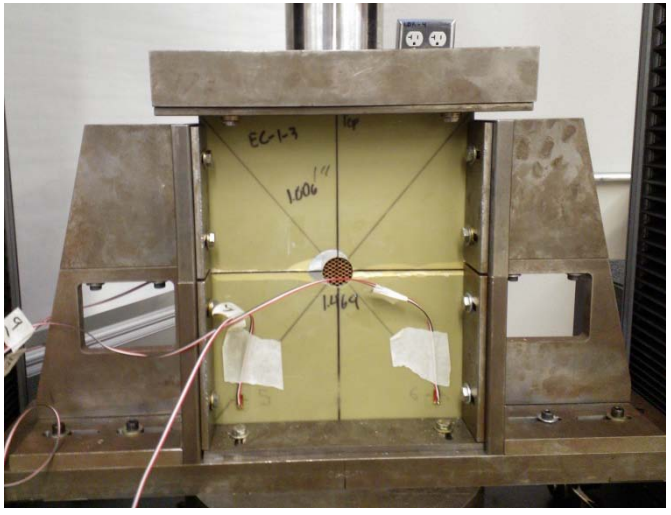
    "*Damage Resistance of Composite Sandwich Structures*"

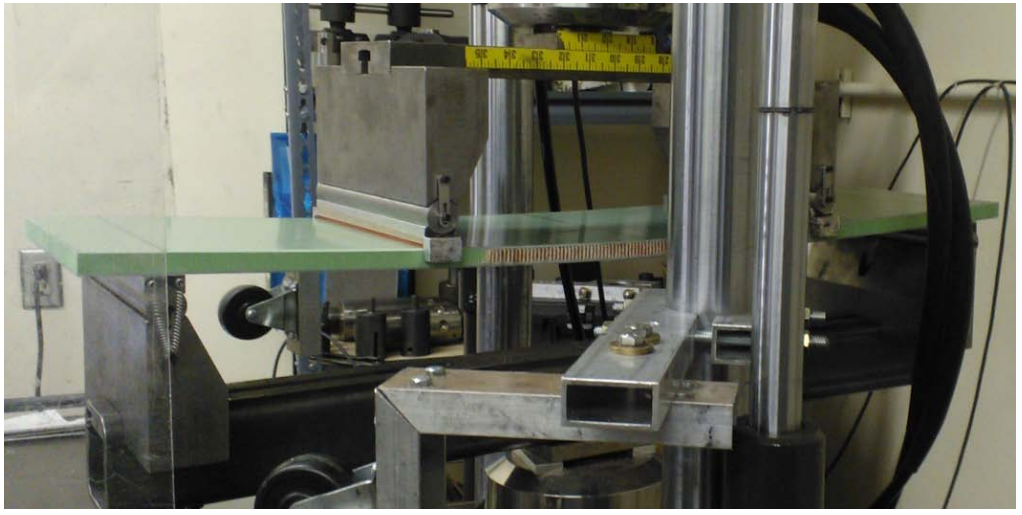
    Dan Adams, organizer Carl Rousseau, moderator

RESEARCH OBJECTIVES:

Damage Tolerance Test Methods for Sandwich Composites

- Develop a standardized ASTM test method
- Evaluate candidate test methodologies
- Compare residual strength results of sandwich panels using proposed test methods
- Investigate scaling of test results





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TEST METHOD DEVELOPMENT:
Intended Usage Likely to Affect Test Method

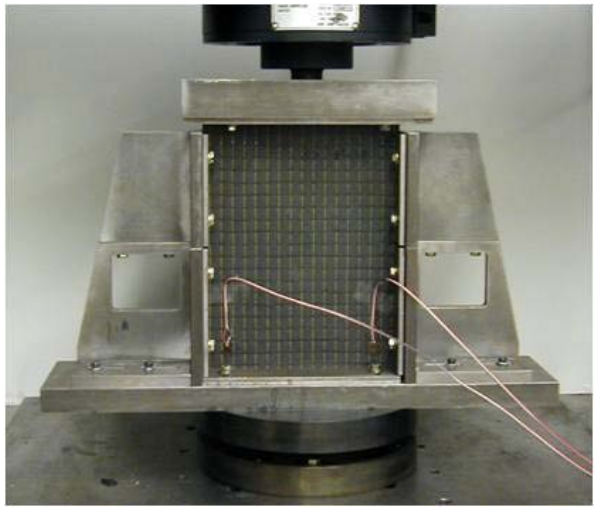
- ***Material ranking/selection/specification***
  - **Specify a sandwich panel configuration**

    Example: D 7137: Specified lay-up and target laminate thickness for CAI testing

- ***Establishing design properties/allowables***
  - **Allow wide range of sandwich panel configurations**

    Example: C 364: Edgewise compression strength of sandwich panels

CANDIDATE TEST CONFIGURATIONS:
Damage Tolerance of Sandwich Composites



Edgewise Compression

- Preferred DT test method for monolithic laminates
- High interest level for sandwich composites

Four-Point Flexure

- Constant bending moment and zero shear in damaged section of panel
- Damaged facesheet can be placed under compression or tension

Pressure Loading

- Simply supported sandwich panel
- Distributed load
- Of interest for pressure loaded applications

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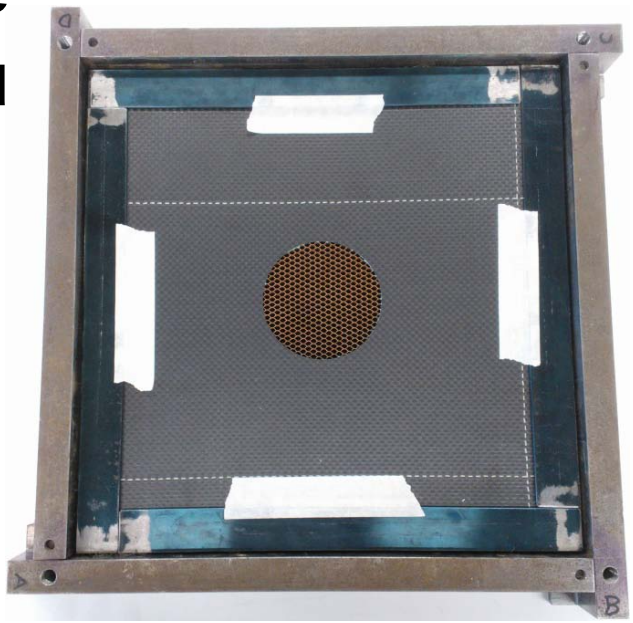
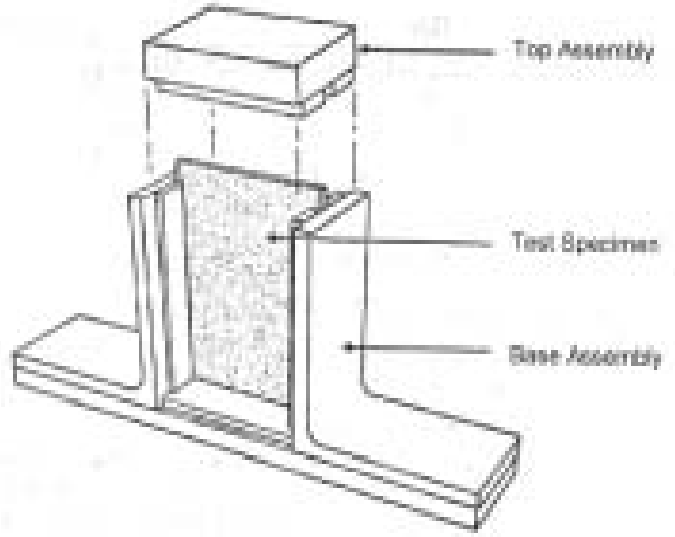
INITIAL EXPERIMENTAL EVALUATION:
Use of Idealized Impact Damage

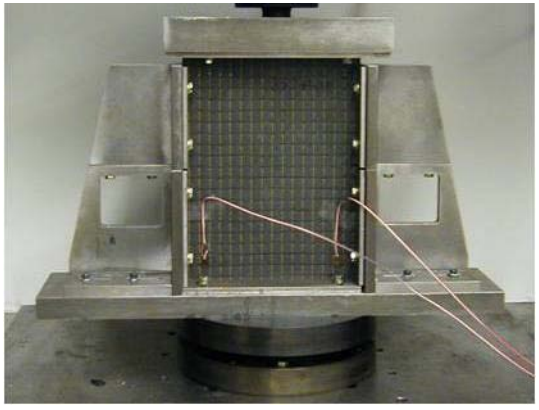
- G11 glass/epoxy and carbon/epoxy facesheets
- Nomex honeycomb core
- "Idealized" damage: 1 in. and 3 in. hole in facesheet
- Develop a recommended procedure for each method
- Initial assessment of damage tolerance
  - Develop familiarity with each test method
  - Identify additional issues requiring investigation
  - Initial assessment of each test method
  - Identification of test method limitations



Edgewise Compression Testing For Damage Tolerance: Testing Considerations

- **Specimen size – Scaling**
- **Test fixture**
  - **End supports**
    - **Clamping of top and bottom**
    - **Potting of core**
  - **Side edge supports**
    - **Knife edge (pinned)**
    - **Clamped (reduce rotation)**
- **Method of specimen alignment**
- **Strain measurement**
  - **Alignment**
  - **Determination of load paths**

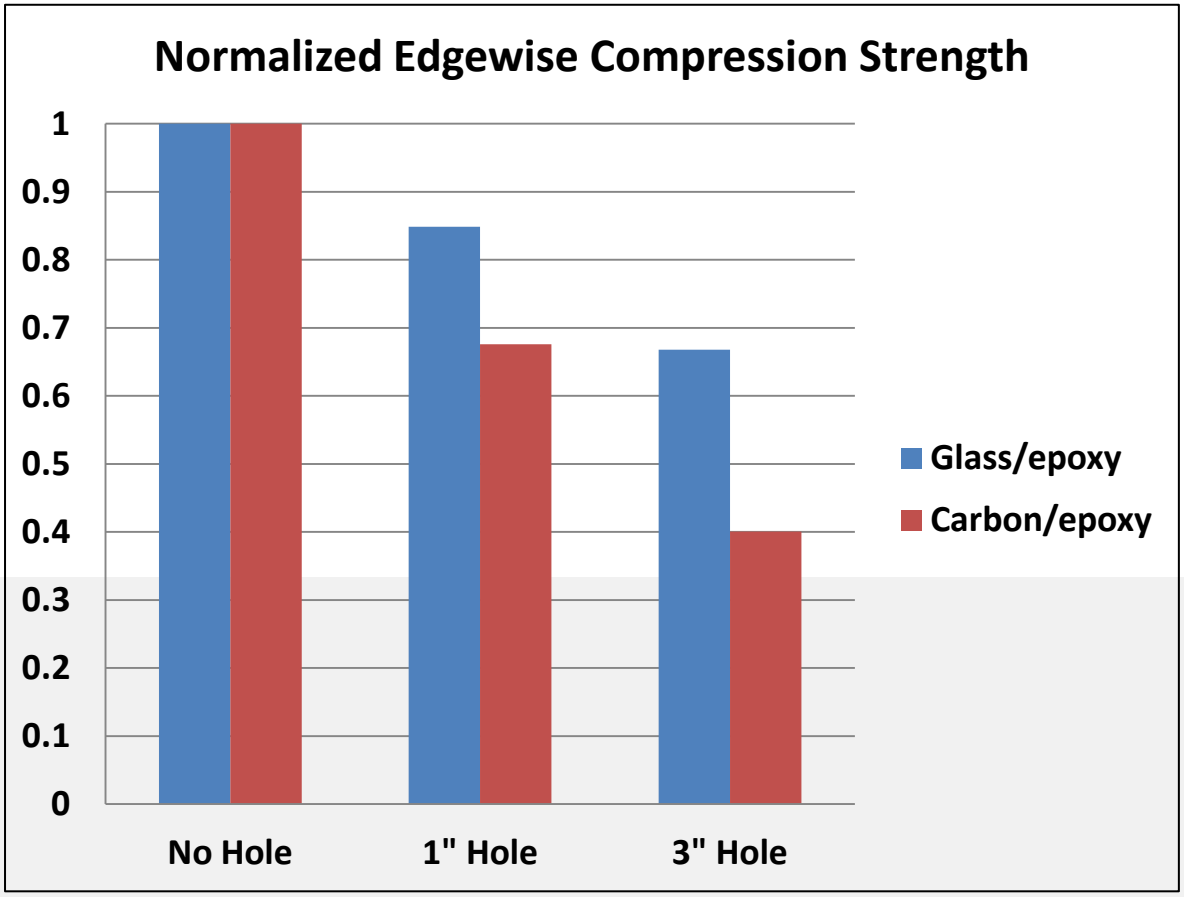


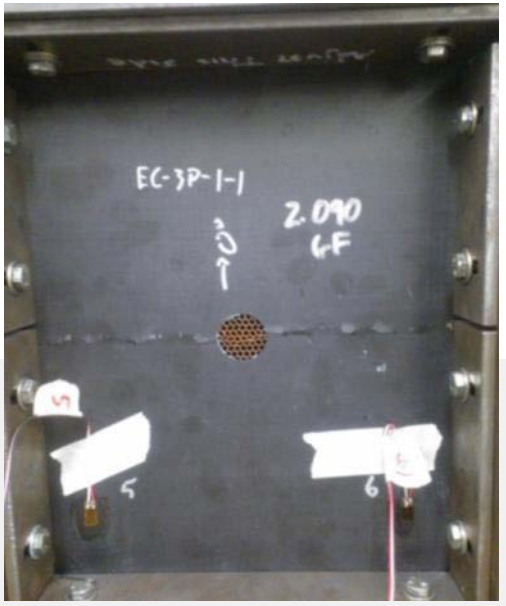


Edgewise Compression Testing For Damage Tolerance: Initial Evaluations

- Glass/epoxy and carbon/epoxy facesheets
- Nomex honeycomb core
- "Idealized" damage – 1 in. & 3 in. through hole in one facesheet

Failure of specimen with no damage

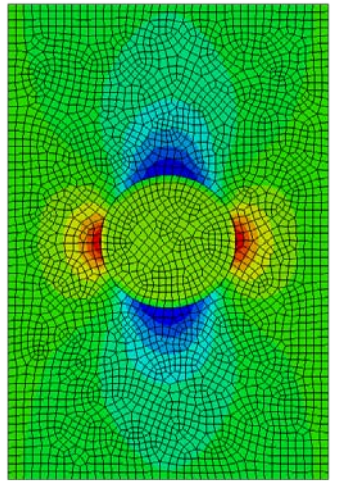




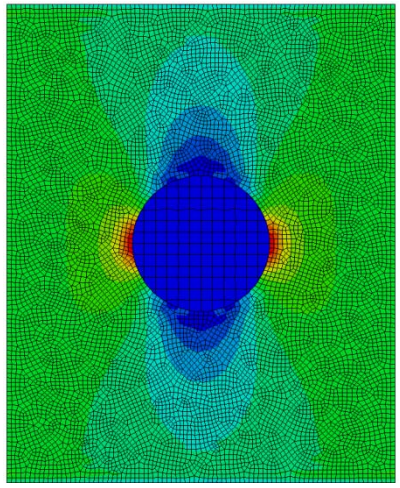
Failure of specimen with 1 in. hole

Edgewise Compression Testing For Damage Tolerance: Investigating Required Specimen Dimensions

- **Comparison with laminate damage tolerance test method ASTM D 7137**
  - **Damage size limited to half unsupported specimen width (1.7 in.)**
- **Laminate and sandwich specimens modeled with idealized through and partial thickness hole**
  - **4” x 6” crossply and quasi-isotropic laminates**
  - **8.5” x 10.5” sandwich specimens**
    - **Crossply and quasi-isotropic facesheets**
    - **Nomex honeycomb core**



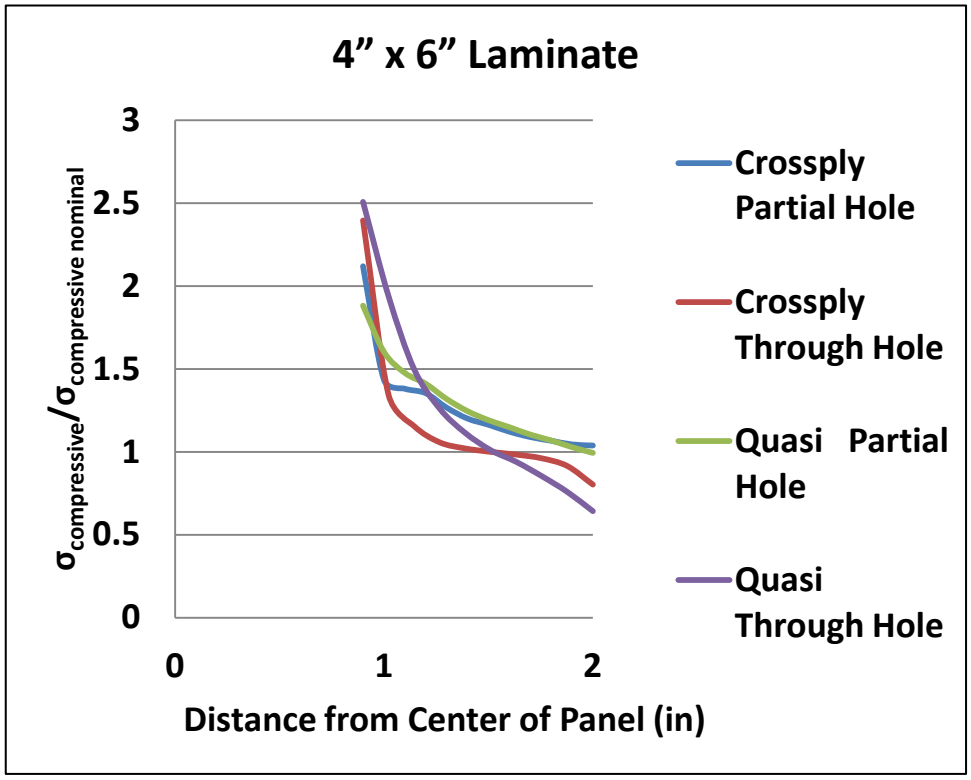
Laminate

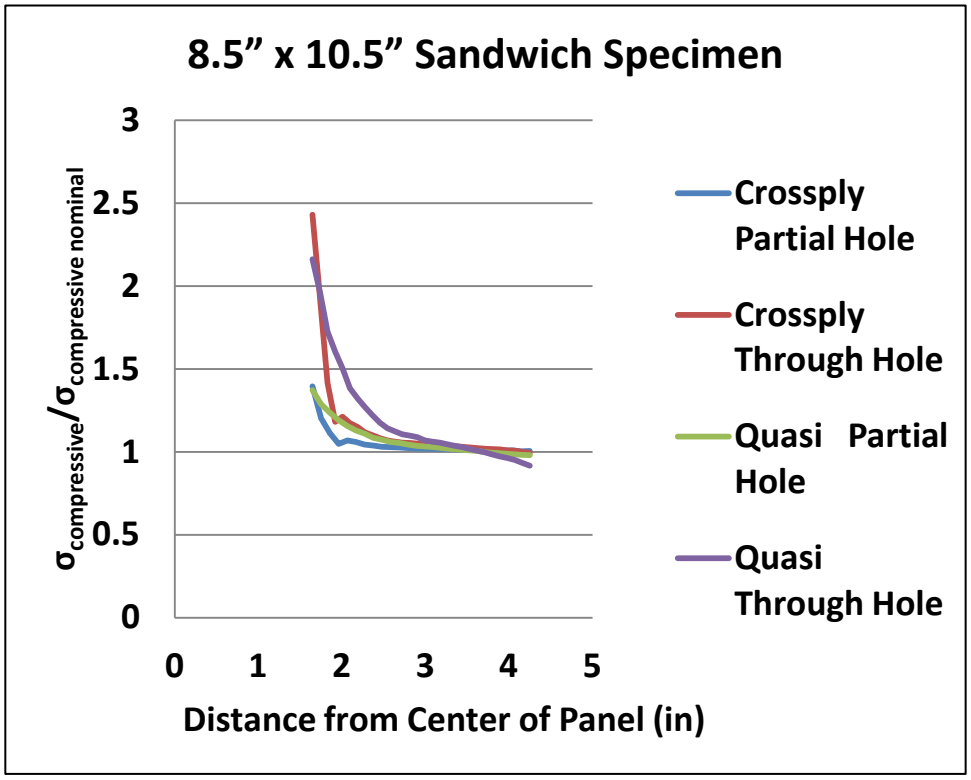


Sandwich

Edgewise Compression Testing For Damage Tolerance: Investigating Required Specimen Dimensions

Comparison of compressive stress distribution across specimen width





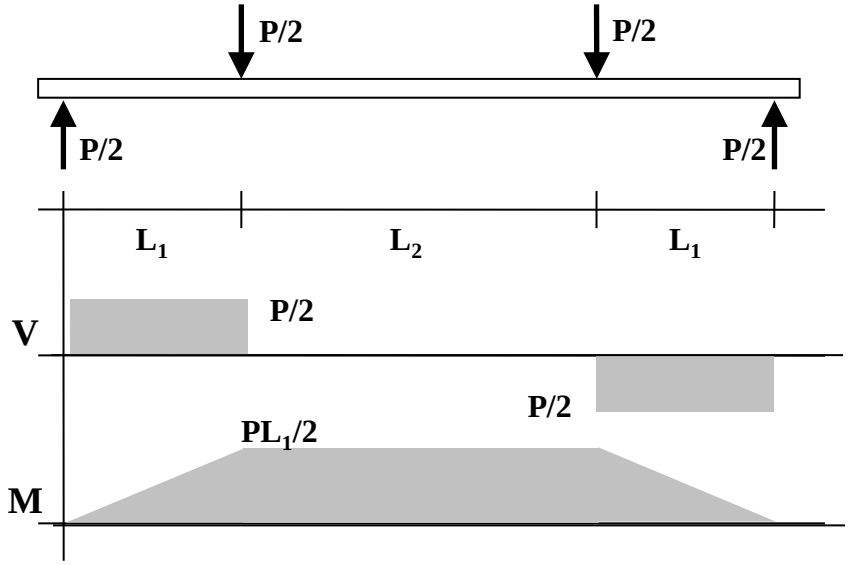
Comparable stress distributions between tests

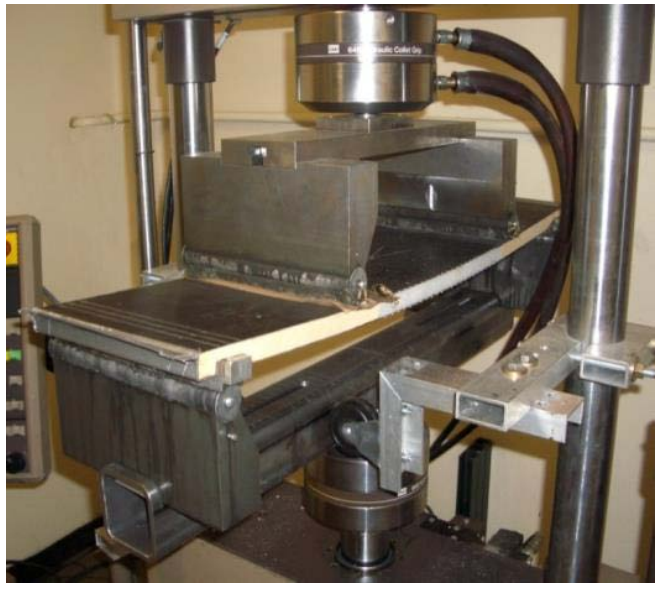
Edgewise Compression Testing For Damage Tolerance: Summary

- **Acceptable facesheet failures for a range of sandwich configurations and damage states**
- **8.5” x 10.5” sandwich specimen appears sufficient**
  - **Similar stress distribution to laminate test method**
  - **Minimal stress concentration at specimen edges**
- **Finite element modeling of progressive damage underway**
- **Further testing to ensure valid results for a wide range of sandwich configurations and damage states**

Four-Point Flexure Testing For Damage Tolerance:
Testing Considerations

- Location of damage: tension or compression loading?
- Sandwich panel dimensions (length & width)
- Required length of central test section (damage region) of panel
- Required length of outer regions to develop bending moment
- Core requirements for shear stress - outer panel sections
- Facesheet /core requirements at loading points





Four-Point Flexure Testing For Damage Tolerance:
Initial Evaluation

Undesirable failures in non-damaged specimens

- Shear failure of honeycomb core in outer regions
- Reaching deflection limit of fixture
- Localized failure at loading point

Undesired core shear failure

Facesheet failure at upper loading point

Large deflection using filled core specimen

Four-Point Flexure Testing For Damage Tolerance: Initial Evaluation

Designing a specimen for acceptable failures

- Developing sufficient bending moment
  - Fill honeycomb cells
  - Substitute higher strength core
  - Increasing support span
- Reducing stress concentrations at loading points
  - Distribute load over larger area
  - Fill honeycomb cells at loading points
- Width same as edgewise compression specimen

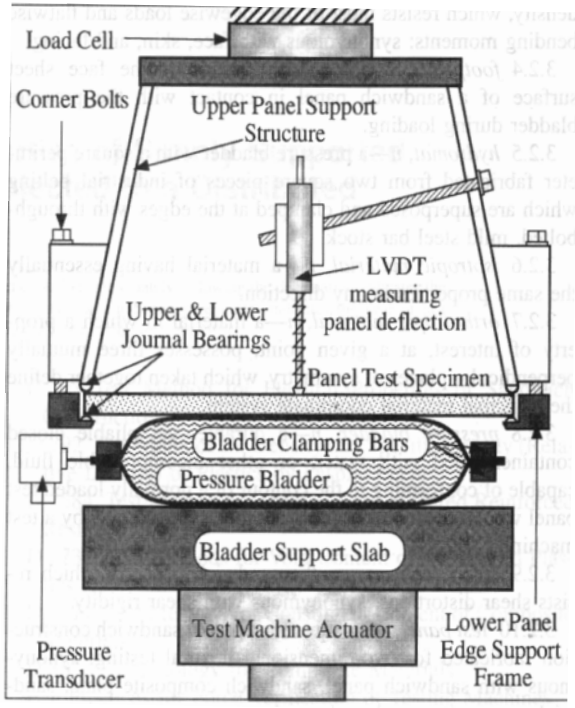
Four-Point Flexure Testing For Damage Tolerance: Summary

- **Glass/epoxy and carbon/epoxy testing resulted undesired failures**
- **Further testing underway**
  - **Core splicing/optimization to prevent core crushing and shear failures**
  - **Support span length to develop sufficient bending moment**
- **Determine required length from damage region to the loading points**

Uniform Pressure "Hydromat" Test

Based on Existing Standard: ASTM D 6146

- Simulates hydrostatic pressure loading
- Pressure loading of sandwich panel using pressure bladder
- Test machine used to press bladder against test panel
- Quasi-static or cyclic fatigue loading
- Size of sandwich panel dependent on sandwich properties
- Current usage primarily in marine industry



Hydromat Testing For Damage Tolerance:

Initial Evaluation

- **Idealized damage located on tension-loaded facesheet**
- **12” x 12” specimens with ½” Nomex honeycomb core**

Upper panel edge support

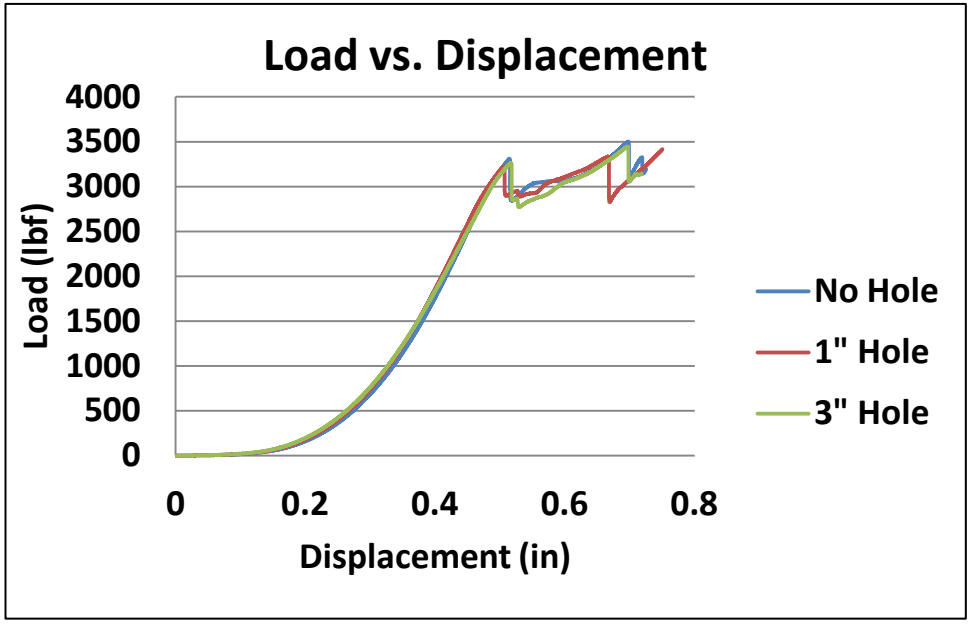
Lower panel edge support

Lowered onto pressure bladder

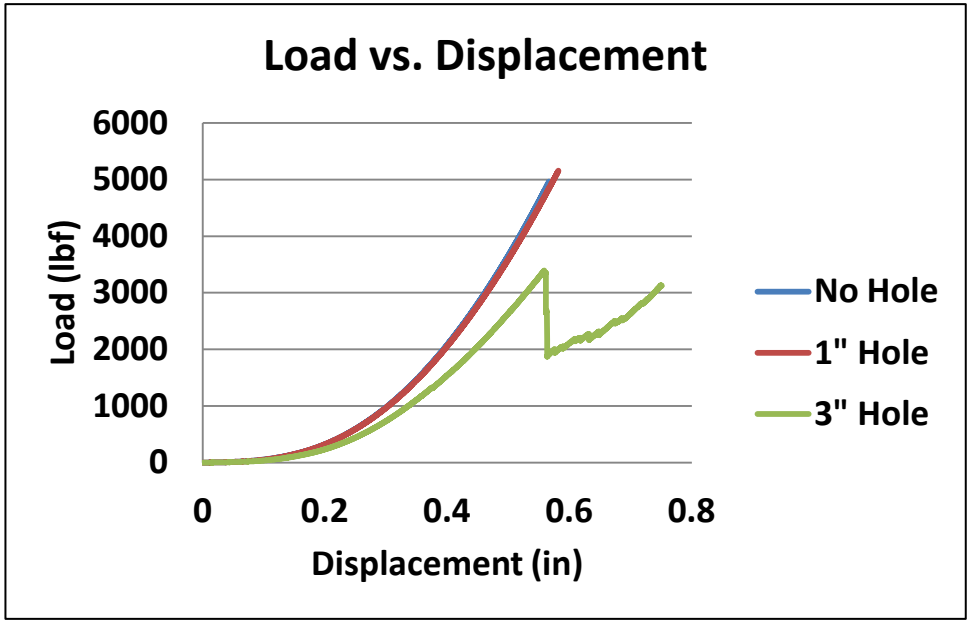
Hydromat Testing For Damage Tolerance:

Initial Evaluation

- Core shear failures on glass/epoxy specimens
- Undamaged and 1” hole carbon/epoxy tests stopped at fixture limits



G11 glass/epoxy with 3pcf Nomex honeycomb



2 ply woven carbon/epoxy with 8pcf Nomex honeycomb

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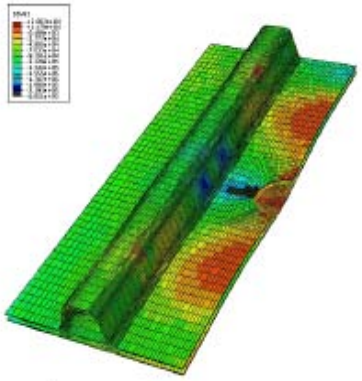
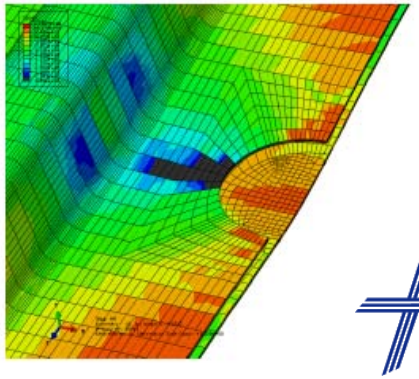
Hydromat Testing For Damage Tolerance: Summary

- Specimens failed due to core failure or fixture limits
- Test not sensitive to facesheet damage on sandwich configurations tested
- Further investigation using alternate sandwich panel sizing
- Further investigation required to determine suitablilty as damage tolerance method

Scaling of Test Results

- **Progressive failure analysis of sandwich panels with idealized damage**
  - **ABAQUS finite element code**
  - **NDBILIN progressive damage user material subroutine**
- **Verify model using experimental results**
- **Use model to scale to components/structures**





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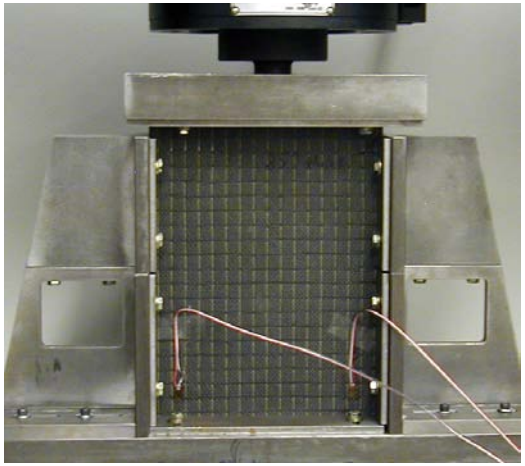
SUMMARY

Benefits to Aviation

- **Standardized damage tolerance test method for sandwich composites**
- **Test results used to predict damage tolerance of sandwich composites**
- **Scaling of test results for application on composite sandwich structures**



Questions?