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# Damage Tolerance Test Method Development For Sandwich Composites

2012 Technical Review

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University of Utah



# FAA Sponsored Project Information

- **Principal Investigator: Dr. Dan Adams**
- **Graduate Student Researcher:**
  - Brad Kuramoto
- **FAA Technical Monitor**
  - David Westlund
- **Collaborators:**
  - Boeing
  - Materials Sciences Corporation

# BACKGROUND: DAMAGE TOLERANCE

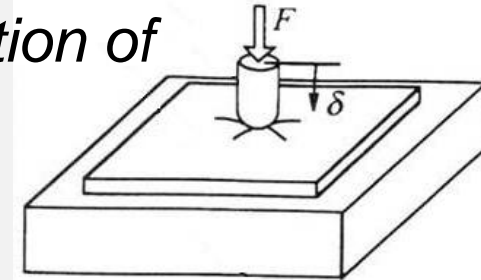
## Damage Resistance Versus Damage Tolerance

**Damage Resistance**: “Concerned with the creation of damage due to a specific impact event” \*

**Variables:** Facesheet: material, layup, thickness

Core: type, density, thickness

Test specimen: size, shape, boundary conditions

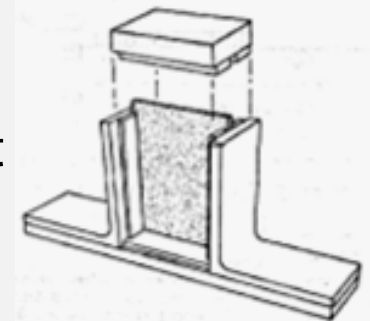


➔ **Damage Tolerance**: “Concerned with the structural response and integrity associated with a given damage state of a structure” \*

**Variables:** Damage state: type, extent, location

Sandwich configuration: same facesheet and core variables as above

Test type: loading, specimen size, support conditions



\* Tomblin, Lacy, Smith, Hooper, Vizzini, and Lee, “Review of Damage Tolerance for Composite Airframe Structures, DOT/FAA/AR-99/49 , August, 1999.

# BACKGROUND:

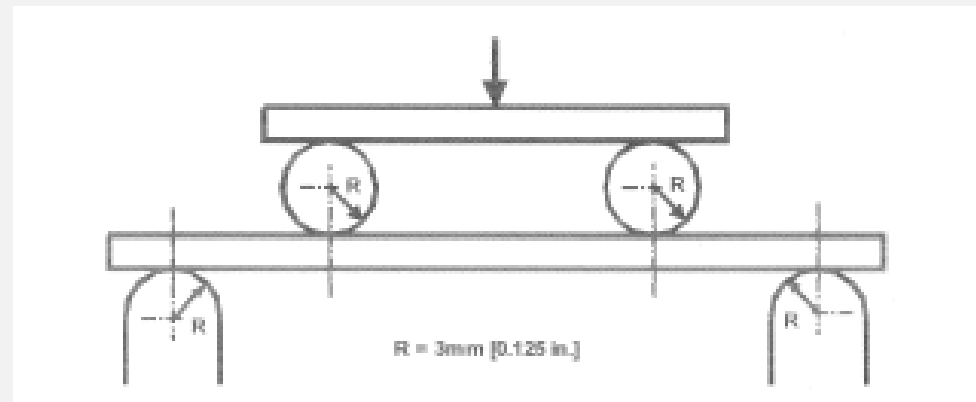
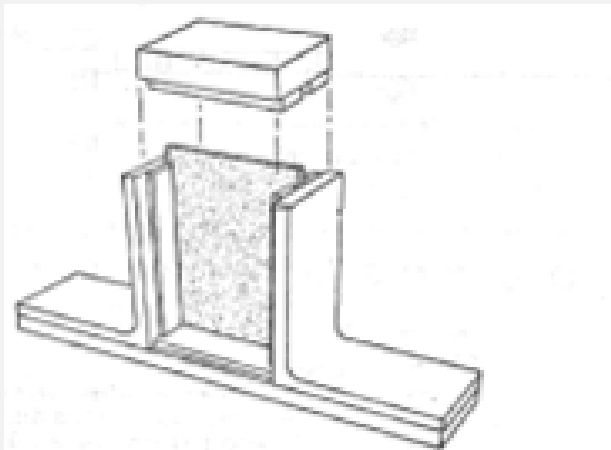
## Damage Tolerance Test Methods for Sandwich Composites

- **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

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



# Where Do We Start?

*What is the intended usage of a damage tolerance test method for sandwich composites?*

Ideas from “relevant” test methods, discussions with industry personnel, and the literature:

- Quality assurance
- Material ranking/selection/specification
- Establishing design properties/allowables
- Research and development activities
- Product development

# Intended Usage Likely to Affect Test Method

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

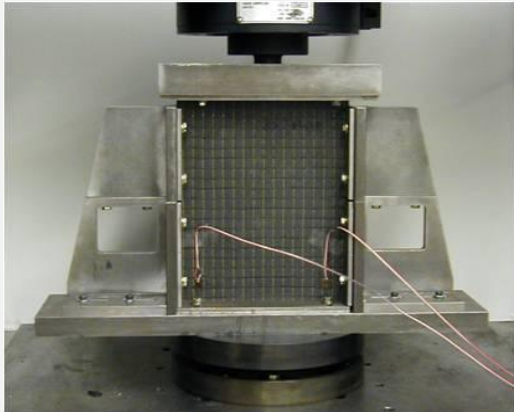
Example: D 7137: Specified lay-up and target laminate thickness for CAI testing
- *Establishing design properties/allowables*
  - **Allow a wide range of sandwich panel configurations**

Example: C 364: Edgewise compression strength of sandwich panels



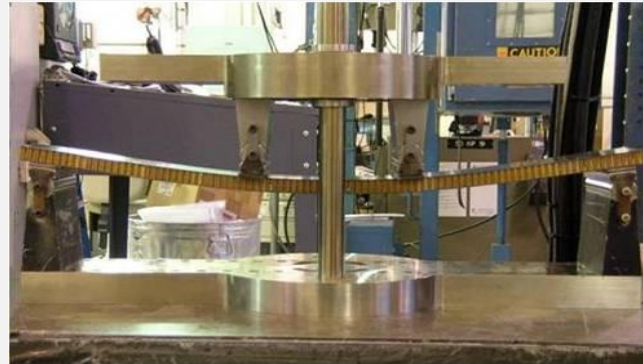
# CANDIDATE TEST CONFIGURATIONS:

## Damage Tolerance of Sandwich Composites



### Edgewise Compression

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



Boeing

### Four-Point Flexure

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



Gougeon Brothers, Inc.

### Pressure Loading

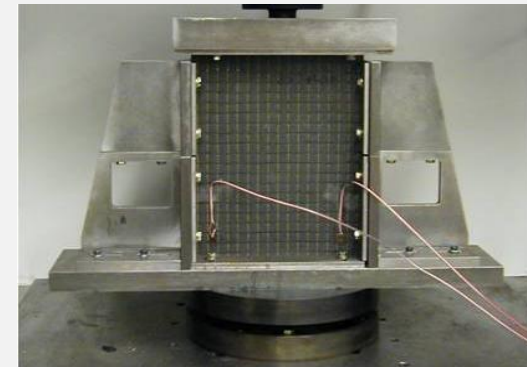
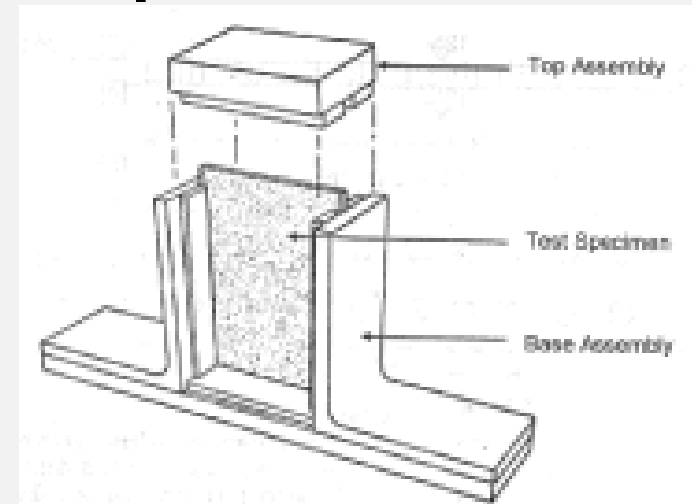
- Simply supported sandwich panel
- Distributed load
- Of interest for pressure loaded applications



# Edgewise Compression Testing For Damage Tolerance:

## Testing Considerations

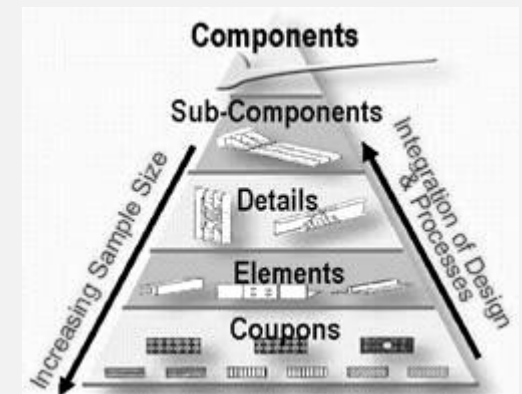
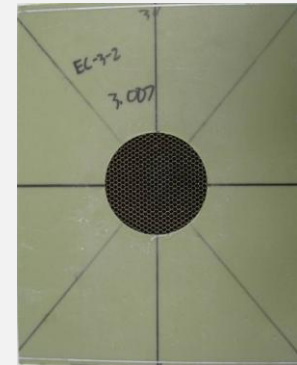
- **Test fixture support of sandwich specimen**
  - **End supports**
    - Clamping of top and bottom
    - Potting of core
  - **Side edge supports**
    - Knife edge (pinned)
    - Clamped (reduce rotation)
- **Method of specimen alignment**
- **Strain measurement**
  - Alignment
  - Determination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



# Edgewise Compression Testing For Damage Tolerance: Scaling of Test Results

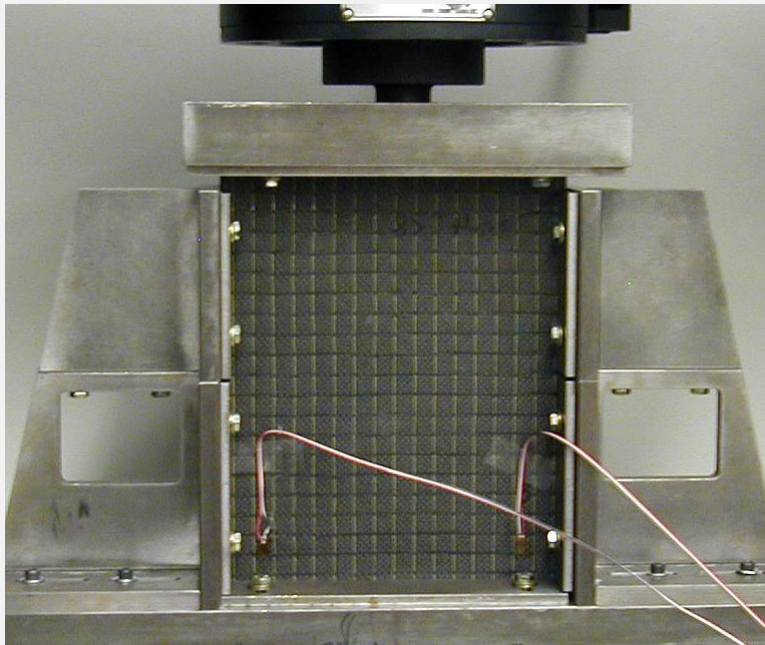
## Applying results to composite sandwich structures

- Sandwich configuration
- Specimen size
- Specimen support conditions
- Type of damage
- Extent of damage relative to specimen size

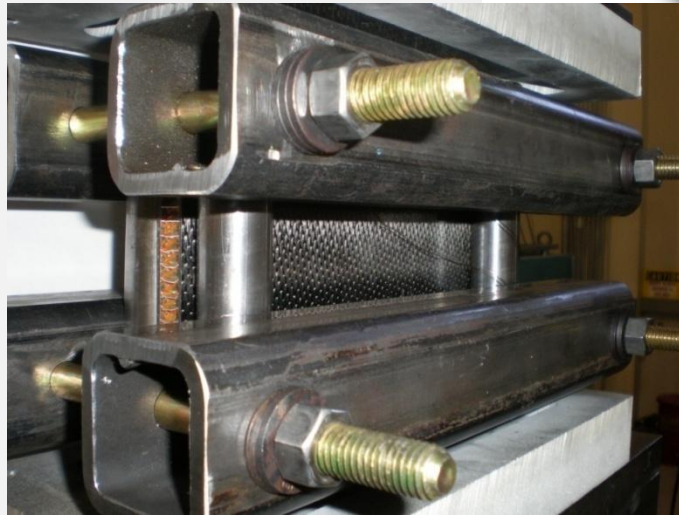
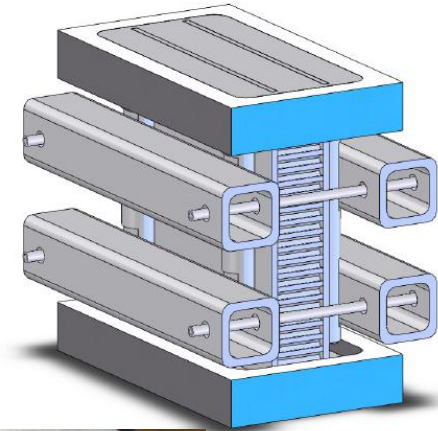


# Edgewise Compression Testing

## Testing with Supported Gage Section



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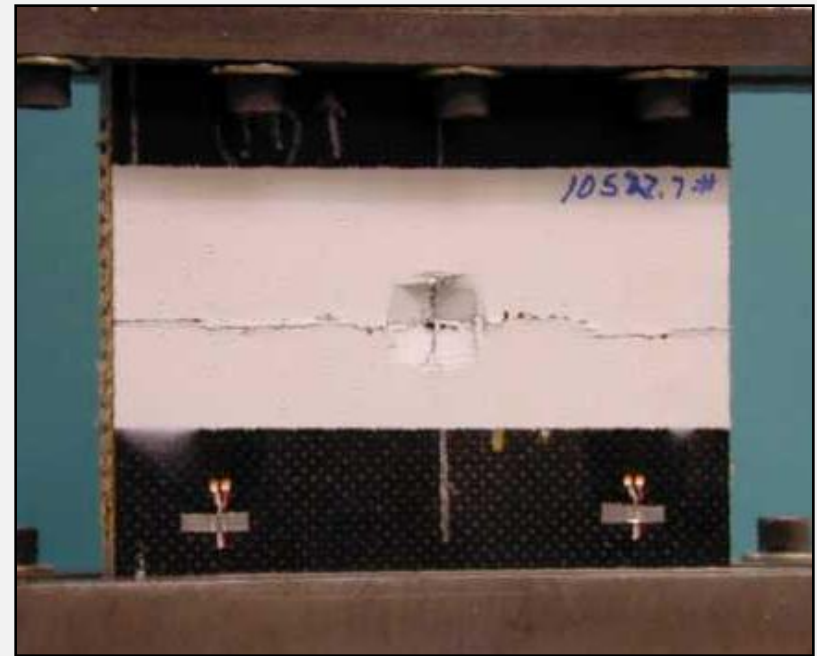


# Edgewise Compression Testing

## Testing with Unsupported Gage Section



NASA Langley

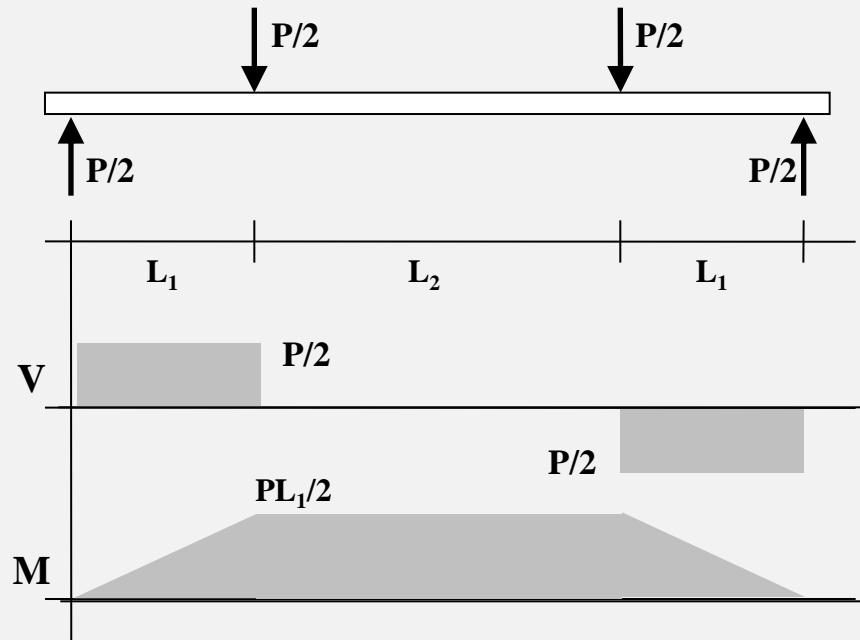


NASA Langley



# Damage Tolerance Testing:

## Four-Point Flexure Testing



### Within central test region:

- No shear forces/stresses
- Uniform bending moment

# Four-Point Flexure Testing For Damage Tolerance:

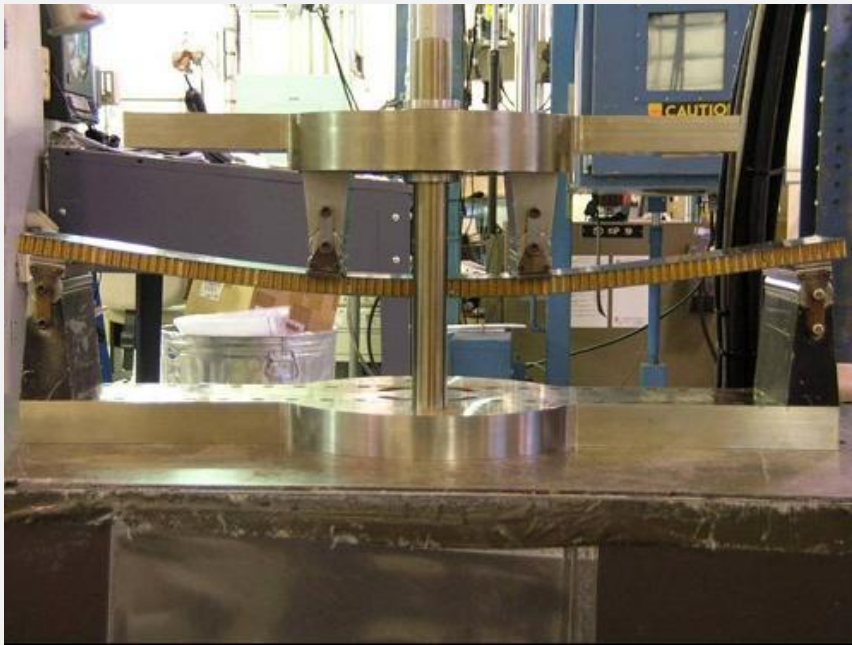
## Testing Considerations

- Location of Damage: tension or compression loading?
- Required length of central test section of panel
  - Minimum distance from damage region to loading points
- Required length of outer regions of panel
  - Sufficient distance to develop bending moment
- Core requirements for shear stress - outer panel sections
- Facesheet /core requirements at loading points
- Overall panel length

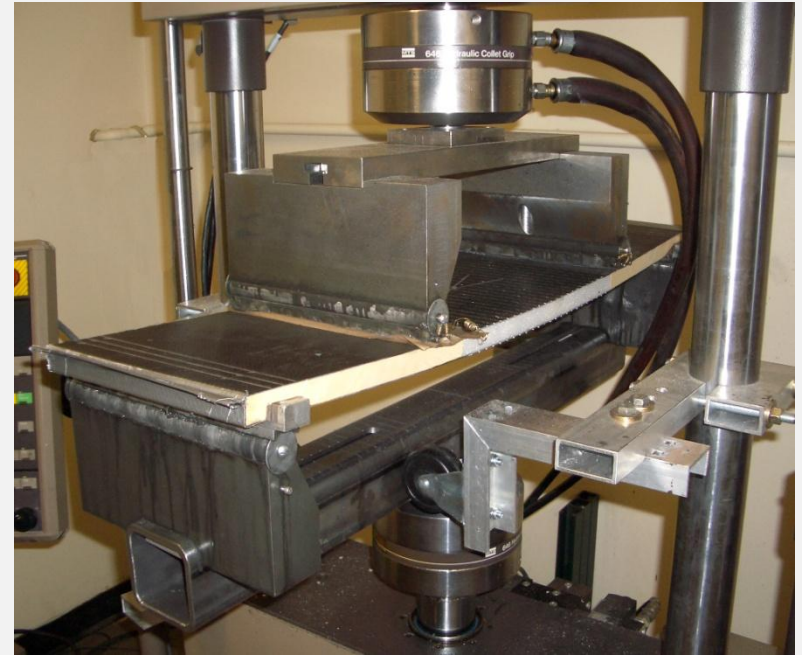




# Four-Point Flexure Testing For Damage Tolerance: Examples of Efforts to Date



Boeing

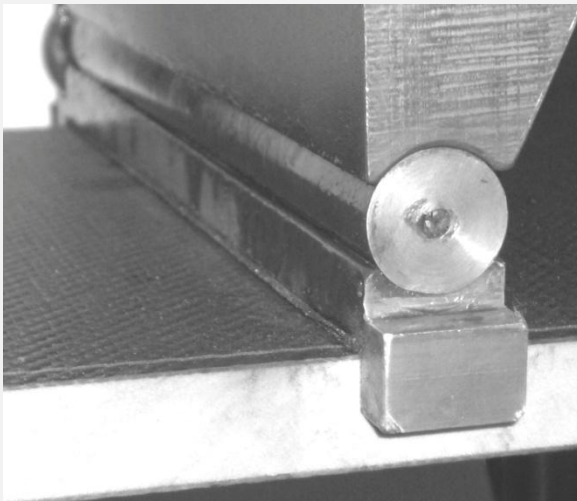


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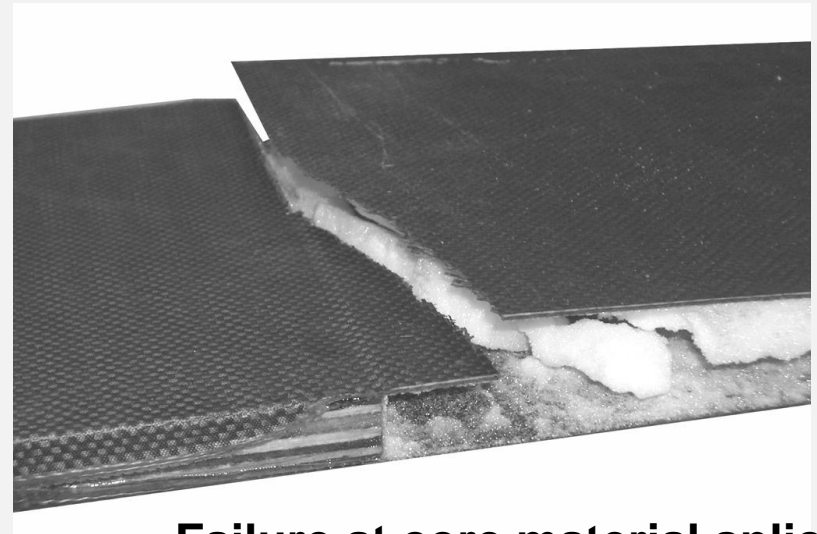
# Four-Point Flexure Testing: Undesirable Failures



Core failure in  
outer region

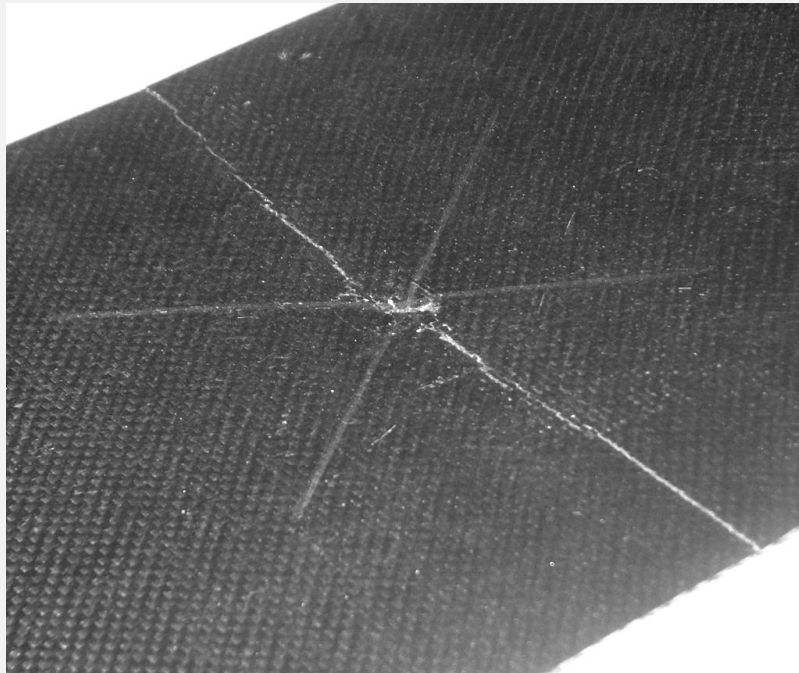


Failure at loading point

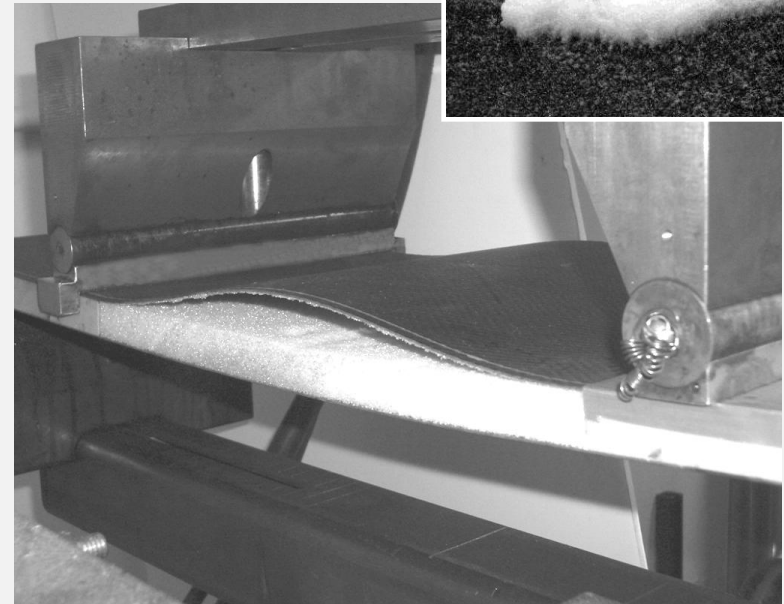


Failure at core material splice

# Four-Point Flexure Testing: Acceptable Failures



Failure of facesheet



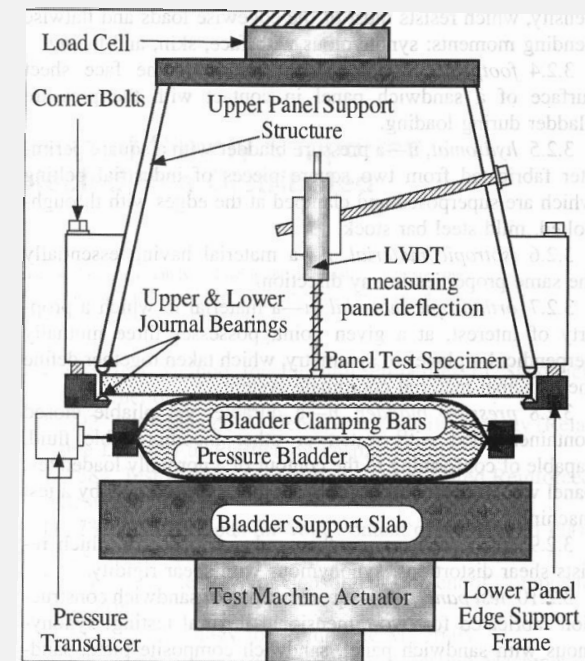
Delamination/buckling of facesheet



# Uniform Pressure Test

## Based on Existing Standard: ASTM D 6416

- 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



# Uniform Pressure Test



Gougeon Brothers, Inc.



12 in. x 12 in. test panel  
22-kip test machine  
(Gougeon Brothers, Inc.)

# Development of an ASTM Standard:

## Damage Tolerance of Sandwich Composites

### Process Includes:

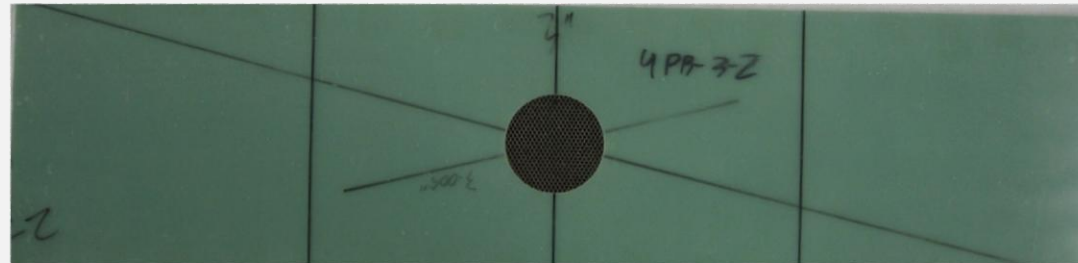
- Review of Similar/Relevant Standards
- Establish intended usage(s)
- Develop suitable test fixturing
- Establish suitable range of sandwich configurations
  - Facesheet parameters
  - Core parameters
- Specify suitable specimen geometries
- Develop proper test procedures



# Initial Experimental Evaluation

## Damage Tolerance of Sandwich Composites

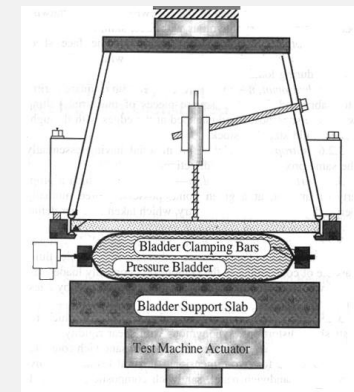
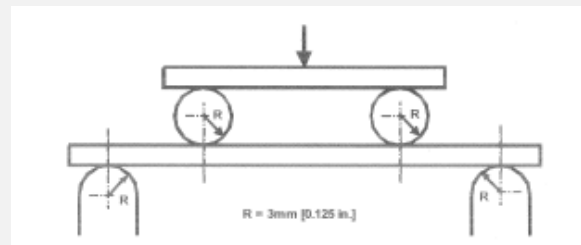
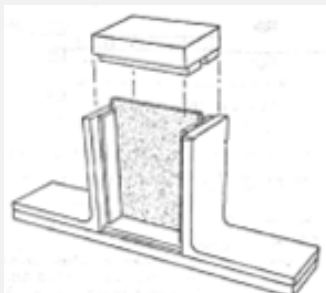
- Investigate all three proposed test methods
  - Edgewise compression
  - Four-point flexure
  - Uniform pressure loading (D6416)
- Determine residual strength of sandwich panels using the three test methods
- Initial comparison : Sensitivity to idealized impact damage



# Initial Experimental Evaluation

## Use of Idealized Impact Damage

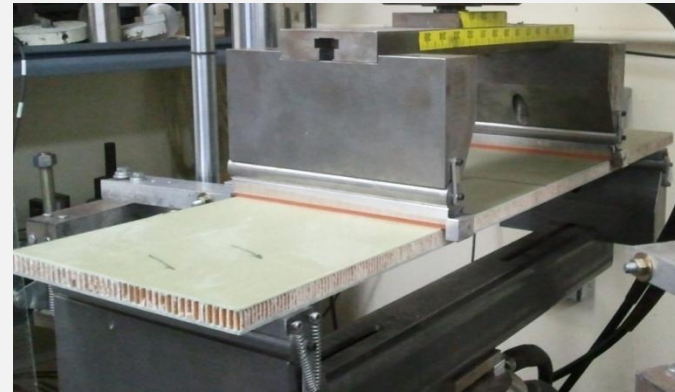
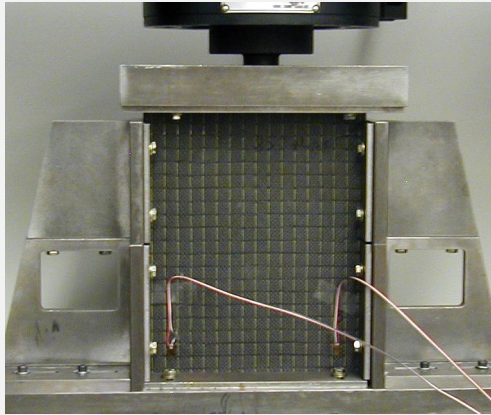
- G11 glass/epoxy facesheets & Nomex honeycomb core
- “Idealized” damage: 1 in. and 3 in. hole in facesheet
- Develop a recommended procedure for each method
- Initial assessment of damage tolerance
  - Develop familiarity with each test method
  - Identify additional issues requiring investigation
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



# Summary

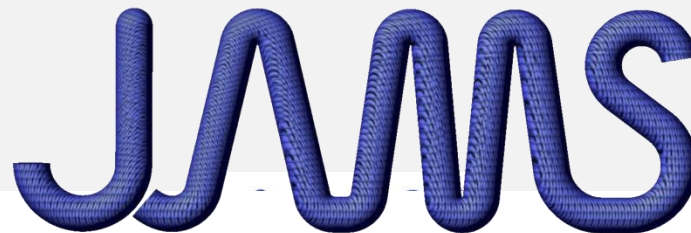
## Benefits to Aviation Include...

- Standardized damage tolerance test method for sandwich composites
- Test results used to predict damage tolerance of sandwich composites
- Research results on scaling of results towards composite sandwich structures



**Thank you for your attention!**

**Questions?**



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