

DURABILITY OF ADHESIVELY BONDED JOINTS FOR AIRCRAFT STRUCTURES

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FAA Sponsored Project Information

- **Principal Investigators: Dr. Dan Adams
Dr. Larry DeVries**
- **Graduate Student Researcher: Clint Child**
- **FAA Technical Monitor: David Westlund**
- **Primary Collaborators:**
 - **Boeing: Kay Blohowiak and Will Grace**
 - **Air Force Research Laboratory: Jim Mazza**

Adhesive Bonding Group Research Tasks

I. Composite bond surface characterization

II. Composite bond integrity and long-term durability testing of composite bonds

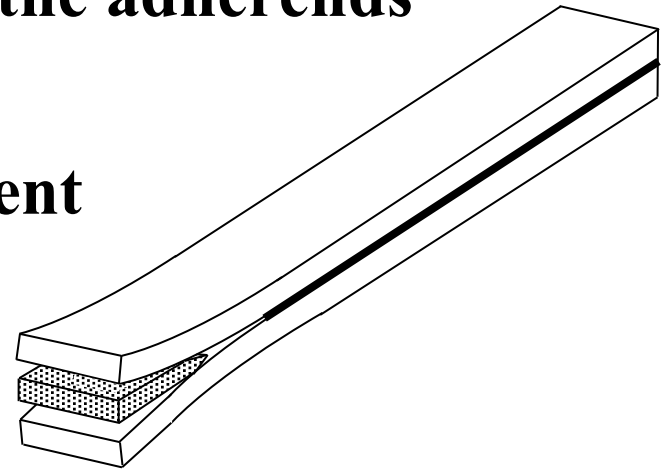
 **III. Revising the ASTM D 3762 metal wedge crack durability test**

Background:

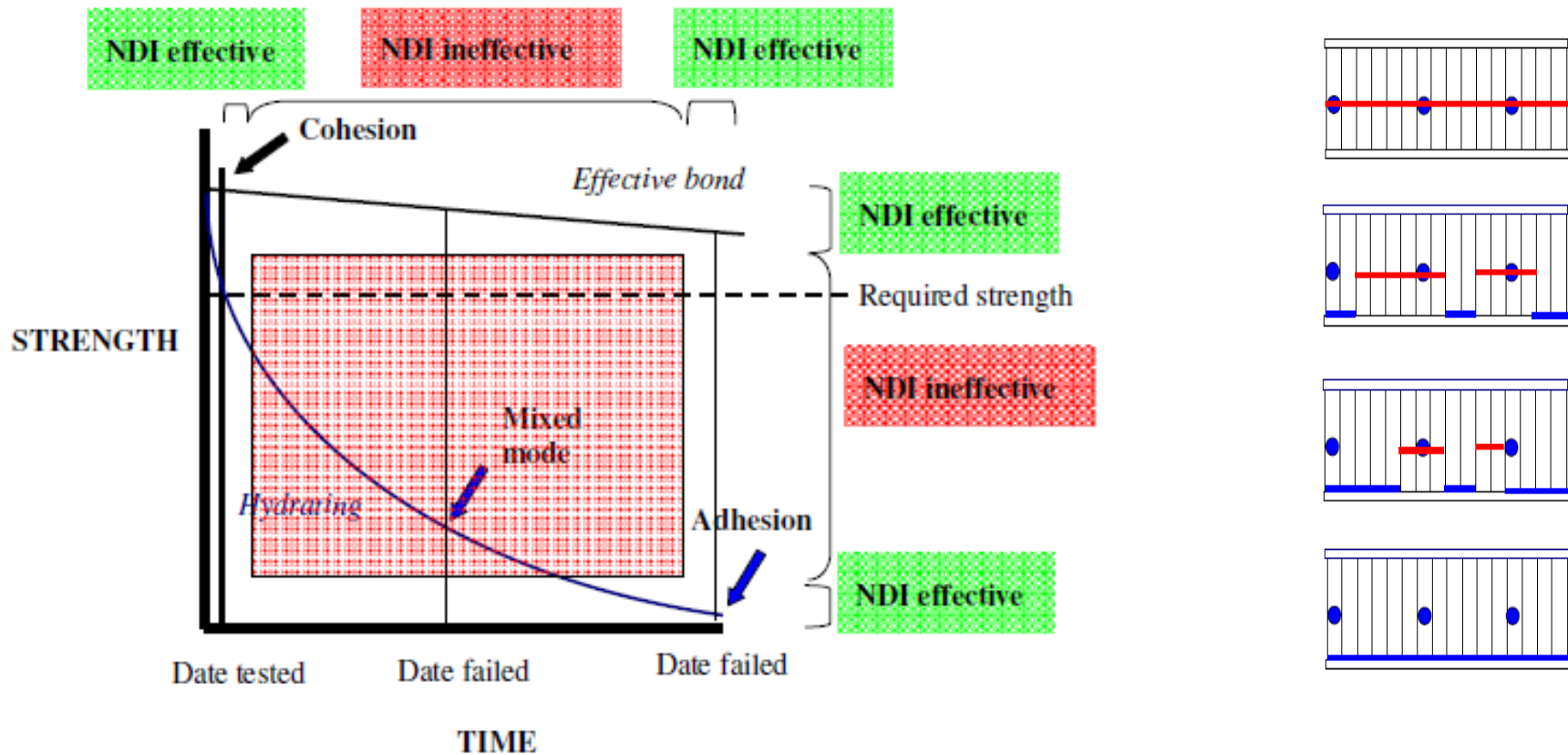
Metal Wedge Crack Durability Test

ASTM D 3762, "Standard Test Method for Adhesive-Bonded Surface Durability of Aluminum (Wedge Test)"

- Bonded aluminum double cantilever beam specimen is loaded by forcing a wedge between the adherends
- Wedge is retained in the specimen
- Assembly placed into a test environment
 - Aqueous environment
 - Elevated temperature
- Further crack growth is measured following a prescribed time period



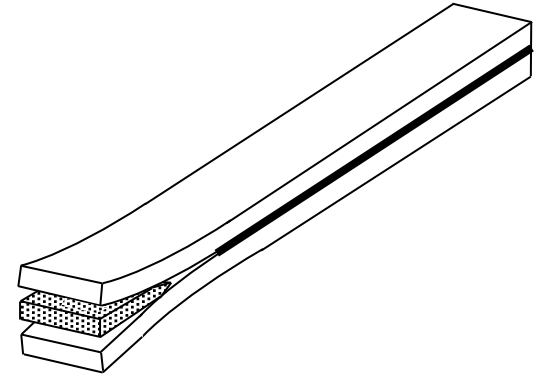
AREA OF CONCERN: Reduction in Bond Strength Through Hydration



Davis, M.J., and McGregor, A. "Assessing Adhesive Bond Failures: Mixed-Mode Bond Failures Explained," I SASI Australian Safety Seminar, Canberra, 4-6 June 2010.

GENERAL PERCEPTIONS: Current ASTM D 3762 Standard

- **Well-suited test methodology for assessing adhesive bond durability**
- **Standard includes a good description of test specimen**
- **Additional guidance needed in specimen manufacturing**
- **More detail required in test procedure**
- **Lacking sufficient guidance regarding conditions and requirements that constitute an acceptable metal bonded joint**



FROM THE LITERATURE:

Investigations Involving ASTM D 3762

- **Effects of surface preparation on durability**
 - Most common investigation
 - Create surface and bond that is *hydration resistant*
- **Comparison of adhesive durability**
- **Comparison of environment severity**
- **Establishment of acceptance criteria**
- **Predict long term behavior of adhesive joints**

CURRENT QUESTIONS/CONCERNS: ASTM D 3762 Wedge Test

Specimen Manufacturing

- Controlling bondline thickness
- Machining specimens from panel

Testing Procedure

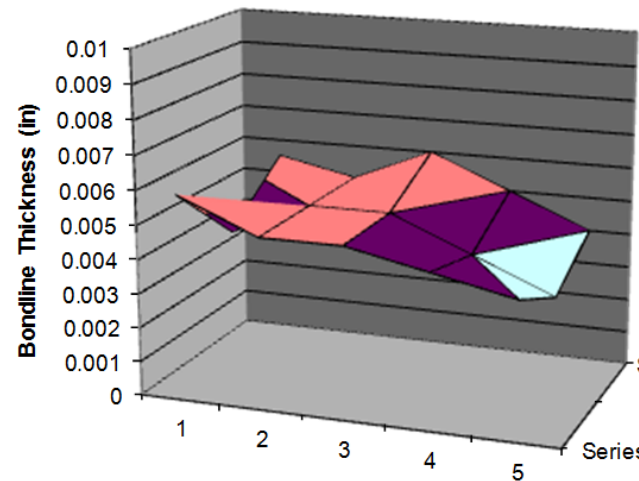
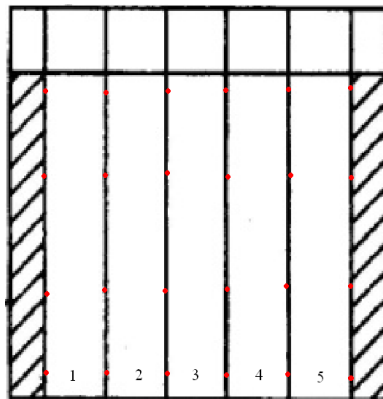
- Method of wedge insertion
- Measurement of initial crack length
- Specimen orientation during testing
- Specification of test environment
- Identification of failure mode

CURRENT QUESTIONS/CONCERNS:

Controlling Bondline Thickness

- Uniform bondline thickness believed to be important for durability testing
- Without precautions, different bondline thicknesses will likely result across panel

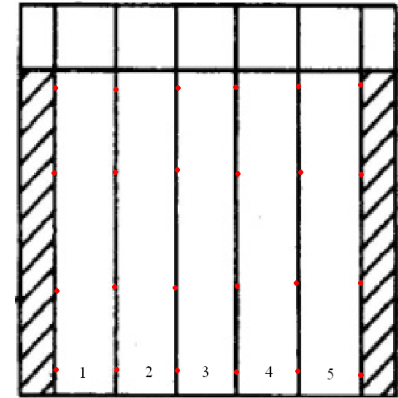
Can guidance be placed into standard?



CURRENT QUESTIONS/CONCERNS:

Cutting Panel into Test Specimens

- **Many methods in use**
 - Band saw and mill
 - Gang saw
 - Water jet cutting
 - ???



- **Are all current methods acceptable?**
- **What are current best practices?**
- **Can guidance be placed into standard?**

CURRENT QUESTIONS/CONCERNS:

Method of Wedge Insertion

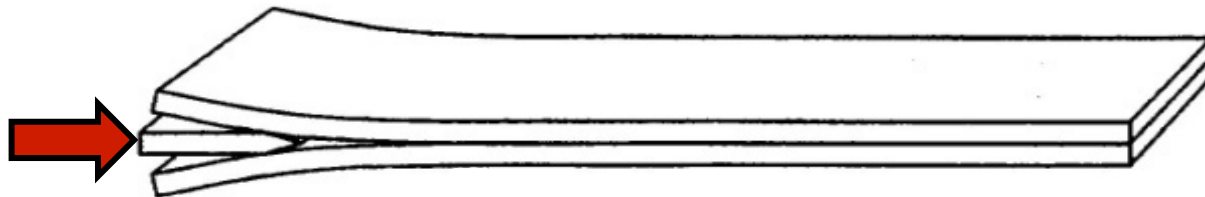
- **Guidance from ASTM D 3762:**

“Open the end of the test specimen that contains the separation film, and insert the wedge”

- **“Tappers” vs. “Thumpers”**

Encourage gentle hammering?

Effect on initial crack length?



CURRENT QUESTIONS/CONCERNS:

Measurement of Initial Crack Length

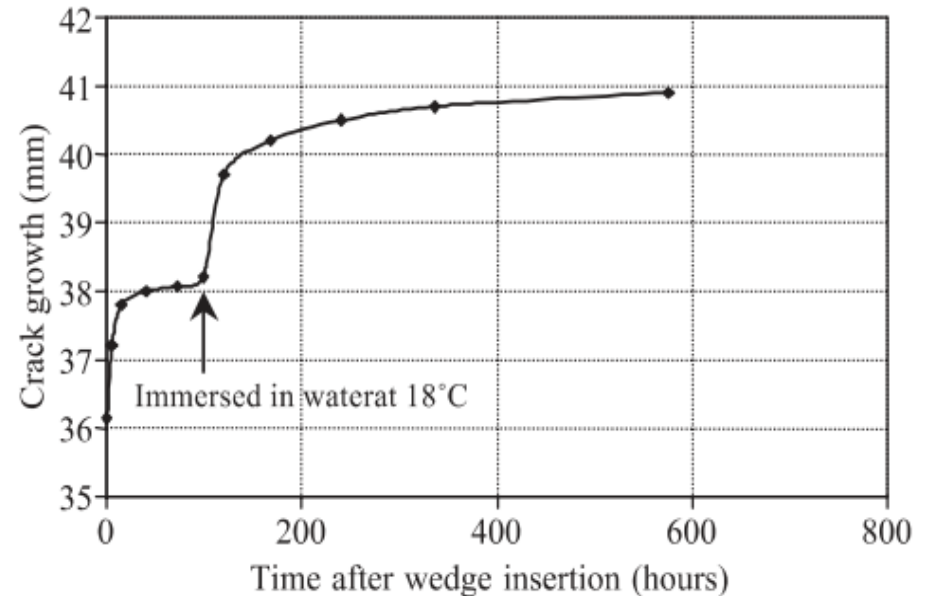
When is initial crack length measurement made?

– **ASTM D3762**

- Immediately after wedge insertion

– **TTCP AG13**

- One hour after wedge insertion



Sargent (2005)

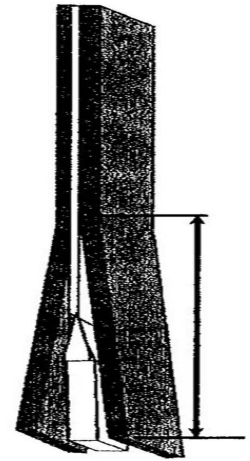
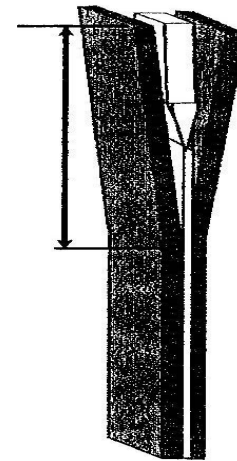
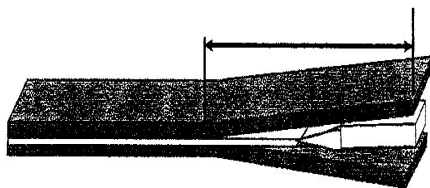
How do we ensure crack equilibrium before subjecting specimen to test environment?

CURRENT QUESTIONS/CONCERNS: Specimen Orientation During Testing

- Orientation of specimen during testing is not specified in ASTM D3762
- TTCP AG13 suggests that orientation be specified

Four Possible Orientations...

- Is one preferred?
- Required?
- Does it matter?



CURRENT QUESTIONS/CONCERNS:

Guidance on Suitable Test Environment

- **ASTM D3762:**
 - *“A typical accelerated aging environment commonly used is 50°C (122°F) and condensing humidity.”*
- **TTCP AG13**
 - *50°C (122°F), 95% RH (non-condensing)*
- **Industry users (aerospace):**
 - Dependent on intended use, type of adhesive being tested
 - 120°F, 140°F, 160°F
 - 24 hrs, 7 days, 1 month

TABLE 1 Standard Test Environments

Test Environment Number	Temperature, °C (°F) ^A	Moisture Conditions % Relative Humidity ^B
1	23 (73.4)	immersed in distilled or deionized water
2	23 (73.4)	50
3	23 (73.4)	15
4	35 (95)	90
5	35 (95)	100
6	50 (122)	90
7	50 (122)	100
8	60 (140)	100
9	71 (160)	100
10	35 (95)	5 % salt fog
11	ambient (outdoors)	ambient (outdoors)
12	other (specify)	other, including aqueous solutions or nonaqueous liquids (specify)

From ASTM D3762

- **How should user choose environment?**
- **Can guidance be placed into standard?**

CURRENT QUESTIONS/CONCERNS: Acceptance Criteria

Crack Growth

Currently in ASTM D3762:

- *“Typically good durability surface preparation is evidenced by...”*
For five specimens, 122°F and condensing humidity:
 - Average $\Delta a < 0.25$ in. after 1 hour
 - Max $\Delta a < 0.75$ in. after 1 hour

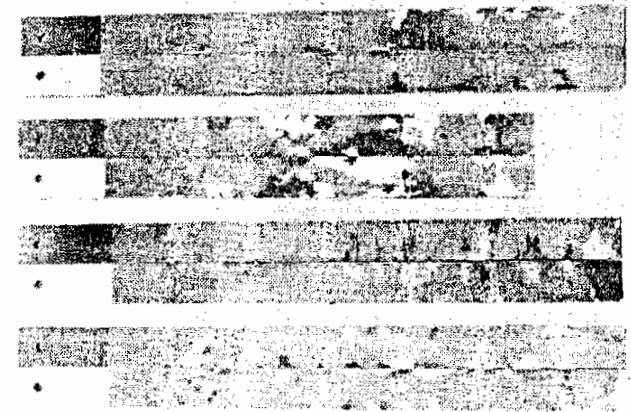
Recommended by TTCP AG13:

- For five specimens: 122°F and 95% relative humidity (non condensing):
- Average $\Delta a < 0.20$ in. after 24 hours
 - Average $\Delta a < 0.25$ in. after 48 hours

Can updated examples and guidance be placed into standard?

CURRENT QUESTIONS/CONCERNS: Evaluation of Failure Mode

- **ASTM D 3762:**
 - *“Failure mode is to be reported”*
 - No mention of failure mode in regards to acceptance criteria
- **TTCP AG13:**
 - *“The surface generated during exposure must not exhibit greater than 10% adhesion (interfacial) failure.”*



McMillan (1979)

- **Can acceptability be made to be dependent on proper failure mode?**
- **What percentage of adhesion failure is acceptable?**
- **How should failure mode percentage be determined?**

INVESTIGATING POSSIBLE REVISIONS:

Current Experimental Program

- **Specimen Preparation**
 - Controlling bond line thickness
 - Machining specimens from panel
- **Test Procedure**
 - Start at beginning of test procedure so that considerations “down the line” are not affected
 - **Method of Wedge Insertion**
 - **Measurement of Initial Crack Length**
 - **Specimen Orientation**

Other Noteworthy Events

October 11-12th, 2010 San Antonio, TX:

- Co-PI Larry DeVries attends ASTM D 14 Committee Meeting
- Introduces project to key committee members

October 5th, 2011 Seattle, WA:

- PI Dan Adams and grad. student Clint Child meet with Max Davis and Boeing personnel to discuss proposed revisions to ASTM D 3762

Yesterday Tampa, FL

- PI Dan Adams presents overview of proposed ASTM D3762 revisions to ASTM D 14 Committee
- Positive response
- Asked to start Work Item, lead Task Group

Summary

- **Several key user groups of ASTM D 3762 (metal wedge crack durability test) have been identified and consulted**
- **Several areas of possible improvement to ASTM D 3762 have been identified**
- **Experimental program underway to provide results required to support test method revisions**
- **Encouraging response from ASTM Committee D14 on Adhesives**