Cobonding Primary Structure – Processing Issues and Related Tests

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Cobonding Primary Structure – Processing Issues and Related Tests

Background and Previous Experience

- 20 Years at Boeing Working CFRP Primary Structure
- R&D, 7J7 CFRP Emp, 767X Emp, 777 Emp and Wing High Lift & Control Surfaces, and Currently Working 7E7 Airframe
- DER from 777 and on

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777 Experiences with Peel Plies

- Peel Ply can work in a highly controlled environment
- Well trained workforce
- Single source adhesive, peel ply and substrate are used to reduce risk of quality escapements. NDI will not find week bondlines!
- Peel Ply receiving inspection must be Intense. Testing every roll of every batch using drawing adhesive and CFRP substrate.
- Receiving tests must include a peel test (DCB)

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777 Experiences with Prebond Moisture

- Producing parts at typical commercial rates and in benign environments (Puget Sound) has not caused this to be an issue in the past
- Parts are dried when held for long periods after fabrication and before bonding
- Empennage structure and secondarily bonded facesheets have not worked the bondlines to their capability

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Current Experiences with Peel Plies

- Must consider multiple applications, partners and manufacturers
- Single source adhesive, peel ply and CFRP substrate are no longer viable for the long term, considering the use of bonded structure over the complete airframe.
- Not only are there multiple material systems to deal with but second sources are inevitable
- Chances for contaminated surfaces are increasing and NDI methods still can not detect weak bondlines.

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Current Experiences with Prebond Moisture

- Parts are to be manufactured in areas of high humidity

- Current bondlines are more highly loaded than typical empennage structure of the past and work to the capability of the adhesive. Reduction in peel and shear can not be tolerated
    - Fuel pressures
    - Cabin pressures
    - High shears resulting from much heavier structure

- Drying time required for in-service scarf repairs is unacceptable for large scale CFRP usage

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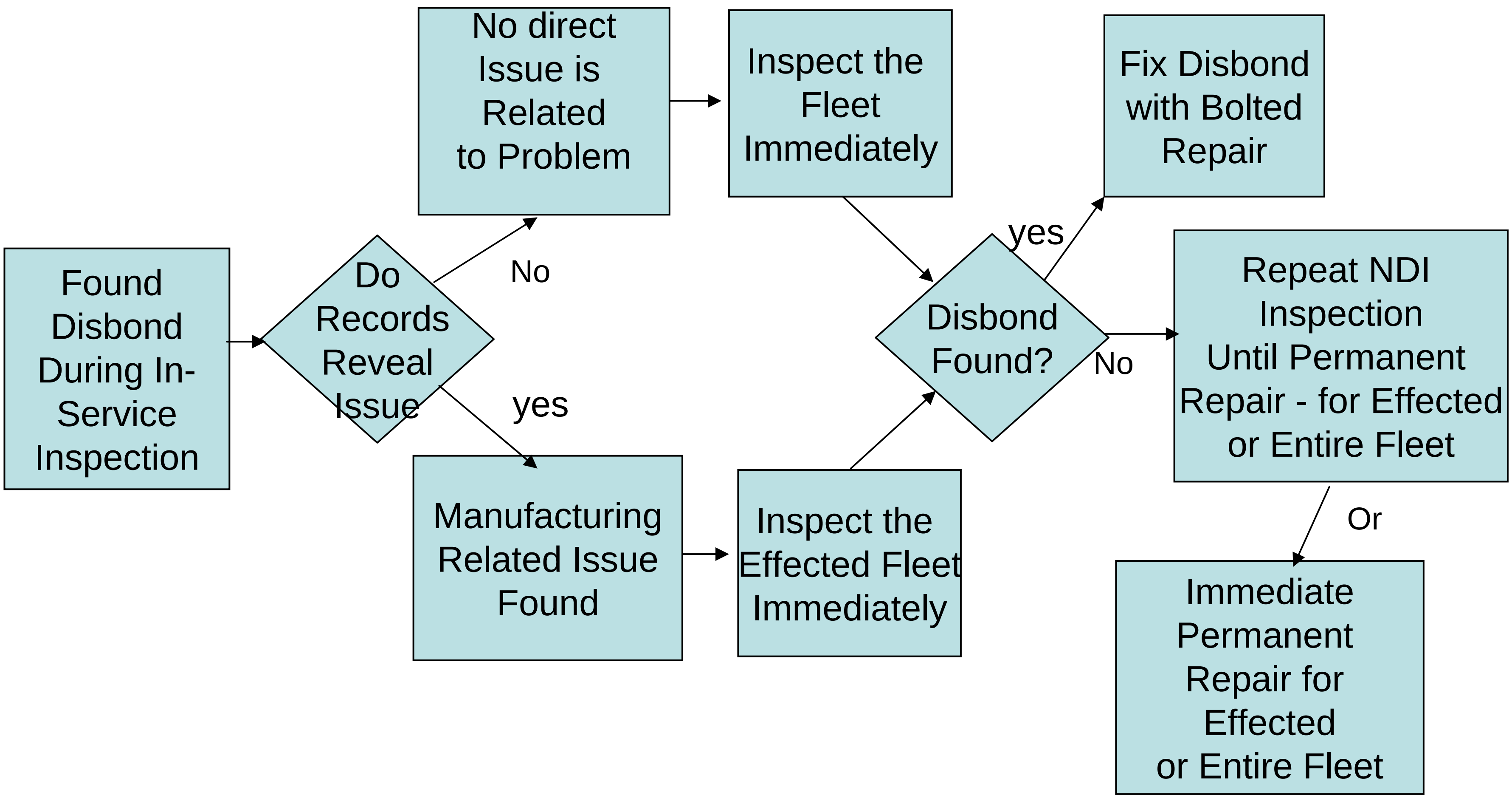
What Happens When a Bondline Fails In-Service



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What Happens When a Bondline Fails In-Service

- No current inspection available to find weak bondlines
- It is not acceptable to repair areas of high peel only
- This is an overall durability issue
- All effected or ***possibly*** effected bondlines must be repaired or repeatably inspected until a permanent can be done
- Instrumental NDI required for inspections

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Conclusion

- The primary structure bondline must have a ***robust*** processes
- The cost of developing adhesives that are insensitive to prebond moisture is a small prices to pay for much better “wet” bondline strength and shorter drying times in-service
- Realize that adding an additional manufacturing step (grit blast, plasma etch, ect) after peel ply removal is an insignificant cost compared to having in-service bondline problems
- Continue education in the use of peel plies, their sensitivities and limitations, the importance of rigorous receiving tests and tight controls in the shop environment
- Structural bonding in highly loaded primary structure will not be a viable alternative in the future if this is not done correctly

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Testing Beyond the Typical Lap Shears and DCBs

- What are some tests done beyond the DCBs, lap shears, and fracture toughness tests characterizing adhesives, preps, and strain energies.
- Highly loaded bondlines with multiple types of loads and failure modes are difficult to size using point design values (tests) and in the past have been difficult to analyze
- Size by analysis supported by testing from simple through complex validation tests.
- Testing includes process defects at the simple level and BVID at the more complex subcomponent level
- VCCT approach utilizing detailed FEM shows promise for these complex failure modes

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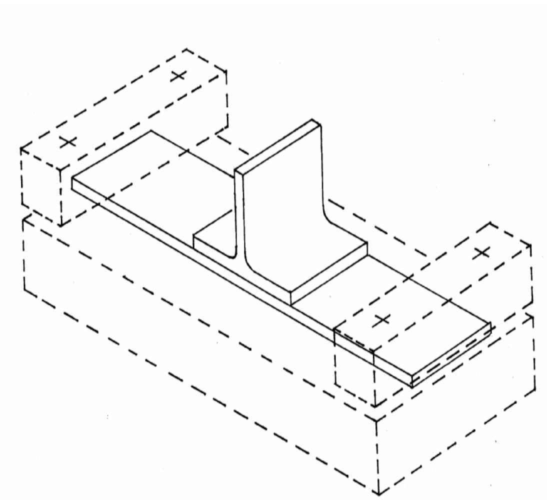
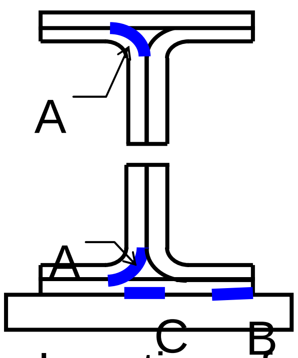
Testing Beyond the Typical Lap Shears and DCBs

- Stringer pulloff with and without process defects
- Various geometries, support widths and environments
- Static and fatigue
- Statistical confidence established with pristine RT specimens





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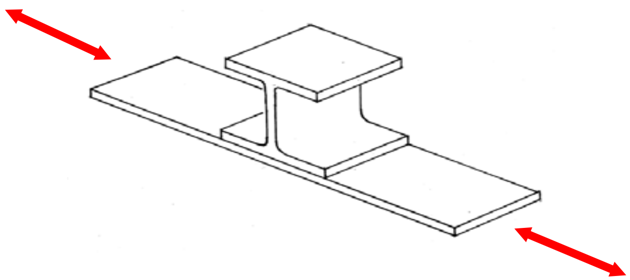
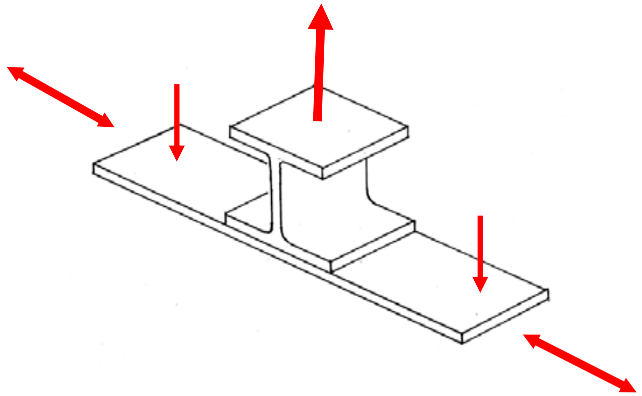
Testing Beyond the Typical Lap Shears and DCBs

- Transverse load and transverse load with pulloff
- Tested with and without process defects
- Understand the effect of bow waves and combined loads on the analysis method
- Various geometries, support widths and environments – some fatigue





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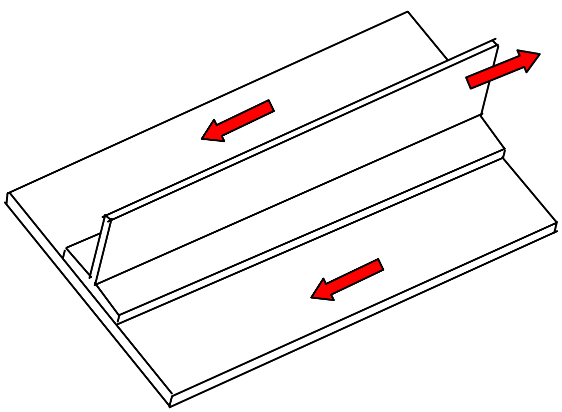
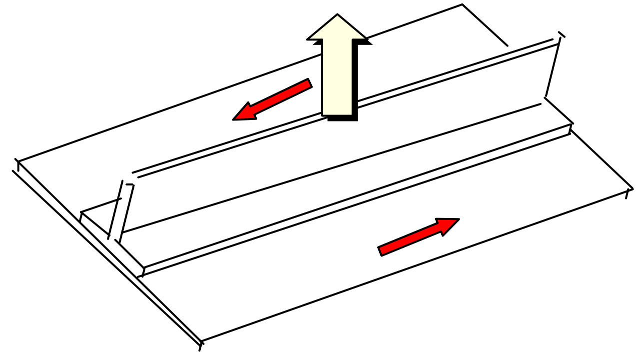
Testing Beyond the Typical Lap Shears and DCBs

- Bondline shear and rail shear with pulloff
- Tested with process defects
- Understand the effect of combine loads on the analysis method
- Various geometries, some fatigue





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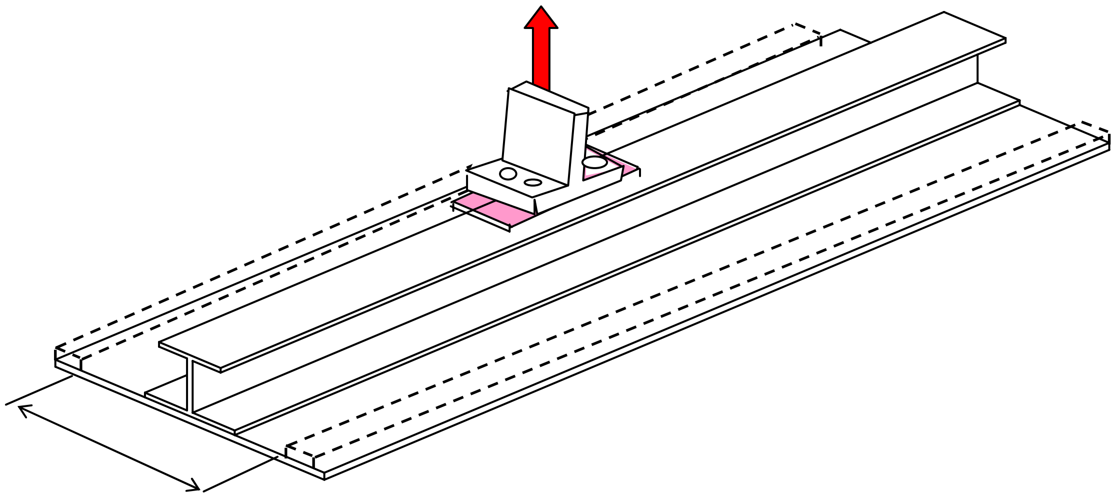
Testing Beyond the Typical Lap Shears and DCBs

- Larger scale test with correct boundary conditions for stringer pulloff
- Understand load assumptions on the bondline
- Understand the effect of BVID and process defects
- Various geometries and environments – some fatigue



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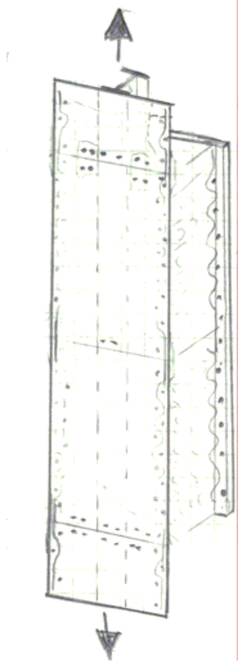
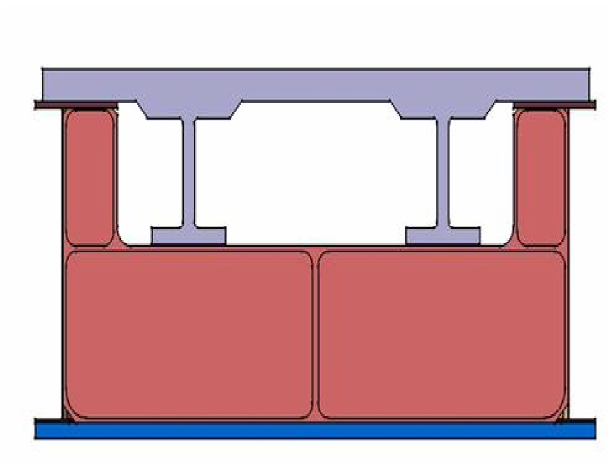
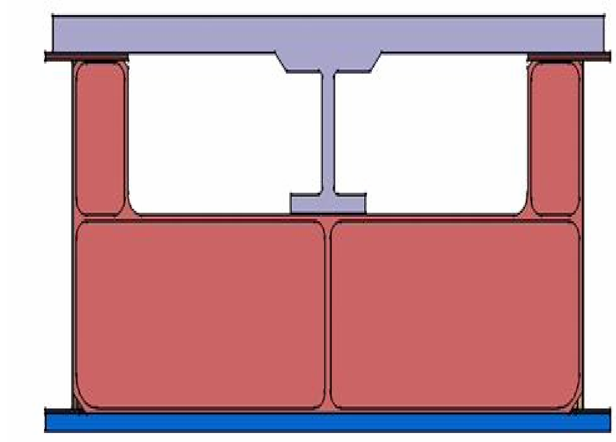
Testing Beyond the Typical Lap Shears and DCBs

- Combine in-plane axial and chordwise loads with stringer pulloff
- Validation of analysis methods
- Correct boundary conditions and loading, with and without shear ties
- Tested with BVID and process defects, effect of multiple stringers understood







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Conclusion - Testing

- The first objective is to characterize the adhesive and bond prep and understand the fracture toughness properties to support an analysis method
- Next step is to understand the design detail, simplified loads and the applicability of the analysis method with and without process defects
- Now understand the effects of combine loading on the detail and the ability of the method to account for this
- Look at larger subcomponents with correct boundary conditions to understand the true applied loads at the adhesive interface
- Final verification of the analysis method and BVID knockdowns are established at the subcomponent level using combined loads