EASA
European Union Aviation Safety Agency

Composite Materials

Presentation by:

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Rotorcraft Structures Workshop
18-19 February 2025

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An Agency of the European Union

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Composite Materials

- → Sandwich Materials and Structures
  - → CM-S-010 Sandwich Structures
  - → EPAS R&D Project DESIGN
- → Revisions of Composite Certification Memorandum
  - → CM-S-004 Issue 2: Composite Shared Database using NCAMP process
  - → CM-S-005 Issue 2: Bonded Repair Size Limits
- → SAE ARP 7520
  - → New SAE standard „*Guidelines for Certifying Aircraft Modifications Involving Composites*”

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Sandwich Materials and Structures

CM-S-010 Issue 1 – Sandwich monocoque Structures in PSE

EPAS Project DESIGN

Rotorcraft Structures Workshop
18-19 February 2025

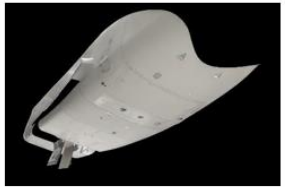
Sandwich Materials and Structures

- significant potential stiffness to weight and strength to weight ratio benefits

Sandwich Materials/Structures

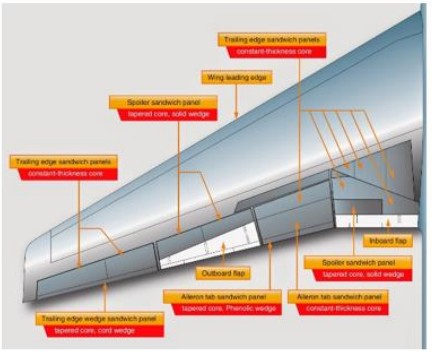
- established successful use with many sandwich materials…

- less critical structures, e.g. fairings, radomes etc



- Primary Structures, e.g. control surfaces

- PSEs….and some monocoque structures



sandwich wing covers and fuselage

sandwich rotor blades and monocoque tail boom and blades

sandwich monocoque fuselage

Sandwich Materials and Structures

Sandwich Materials - Bonded Structures:

Disbond or delamination:

- **a disbond/weak bond/delamination exists**
- **< UL capability** (large damage/disbond, critical location)
- **damage/defect remains undetected**
- **load event > Residual Strength capability** (>LL)

- all of these can occur, but typically not together…..

- most events not significant safety issue*
  (most applications have been of limited criticality)

1 incident 10^6 hrs
1 serious incident 10^8 /10^9 hrs
No fatal accidents
(CAA-UK MOR & fleet data only)

1 serious incident/accident
>10^8 hrs
- EASA database

- growing number of significant sandwich structure incidents across products

- potential support for 'green' needs if we can gain more confidence in such structure

*variable quality data

- unclear if disbond is cause or witness (either situation suggests poor process - unacceptable)
- **need to improve forensics and taxonomy**

Sandwich Materials and Structures

Sandwich Materials/Structures – other potentially critical damage modes…some not readily detectable, e.g. crushed core, shear core failure etc

(Boundary Conditions important)

- some uncertainty wrt damage metrics…

'…it was concluded that residual indentation depth is not a reliable indicator of impact damage; rather, the planar damage size better reflects the residual strength degradation in sandwich panels.'*

*DOT/FAA/AR-02/121 Guidelines for Analysis, Testing, and Non-destructive Inspection of Impact-Damaged Composite Sandwich Structures

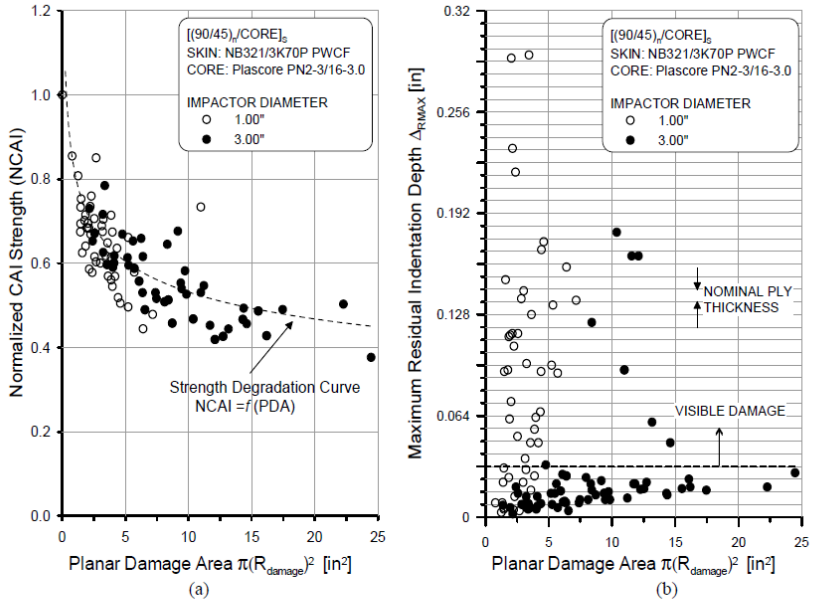
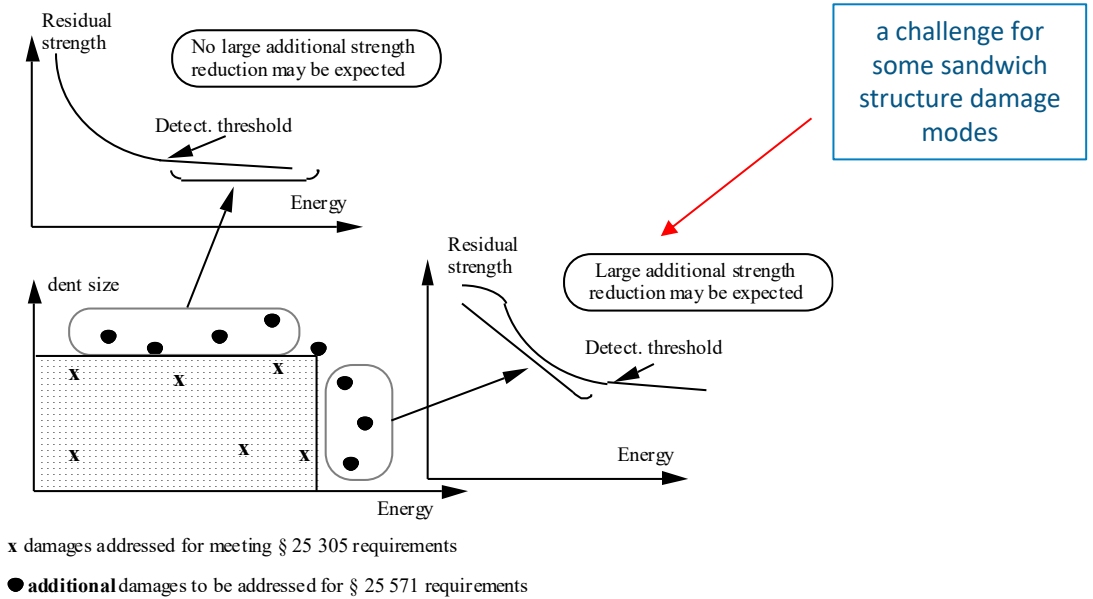


FIGURE 2-10. (a) NORMALIZED RESIDUAL STRENGTH FOR [(90/45)n/CORE]s (n=1,2,3)* SANDWICH PANELS WITH HONEYCOMB CORE (3/8″ AND 3/4″ THICK) AND (b) VARIATION OF MAXIMUM RESIDUAL INDENTATION DEPTH WITH PLANAR DAMAGE AREA FOR THE SANDWICH PANELS

Sandwich Materials and Structures

Sandwich Materials/Structures – Residual Strength

-ideally, detect damage in a configuration which demonstrates no damage growth and has a useful RS
(flat part of the curve)



x damages addressed for meeting § 25 305 requirements

● **additional** damages to be addressed for § 25 571 requirements

Sandwich Materials and Structures

Sandwich* Materials/Structures

- very broad range of constituent materials, configurations, and applications

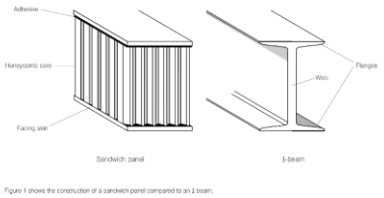


Figure 1 shows the construction of a sandwich panel compared to an I beam.

Sandwich Constructions (SAE AIR 4844):

Panels composed of a lightweight core material, such as honeycomb, foamed plastic, etc., to which two relatively thin, dense, high-strength or high-stiffness faces or skins are adhered.

- mixed structural functions (skin and core)
- typically bonded (e.g. structurally bonded, co-bonded)

…a structure or a material

sandwich structure… a bonded structure…
… need to delete misleading example
… encourages use of monocoque sandwich structure, i.e. without back-up features
… **define sandwich structure by its most limiting bonding concept… typically co-bonded or 'secondary' bonded, not co-cured**…

*Note: identified as 'co-cured' example in AR-96/75, AC29 2C MG8 (para.d7), AC29.573 (para.d11):

'para. (7) & (11) **Cocure.** The process of curing several different materials in a single step. Examples include …the curing of compatible composite materials and structural adhesives, using the same cure cycle, to produce **sandwich structure** or skins with integrally molded fittings.'

… not helpful/appropriate to our discussion….sandwich is carrying primary load through an adhesive between features with different functions, some already cured,… therefore co-bonded/'secondary bonded', would seem to be more appropriate

Sandwich Materials and Structures

Previously, actions intended to better understand and manage sandwich structures included workshops, EASA raised CM-S-010, also building upon other 'lessons learned'

- related discussion already started…

- CMH-17 Vol.6 (and other references) identifies many potential damage modes

- other than thin skin GAG configurations, organisations have shared 'lessons learned', e.g.

- B. Moitre, A. Marzano (ENAC) - EASA Bonded Structure Meeting June 2013
  - 'lessons learned' regarding monocoque sandwich structures

- A. Engleder (Airbus Helicopters, ex- EC) – CMH-17 Meeting Boston August 2012
  - several rotorcraft configuration specific monocoque sandwich structure damage modes

- D. Wernert (Textron, ex-HBC) – EASA Bonded Structure Meeting June 2013
  - practical robust monocoque sandwich structure design

- can we produce useful generic guidance for such configurations?

Sandwich Materials and Structures

EASA Composite Materials Safety Strategy – related actions:

1/ EASA CM-S-010: Composite Materials - The Safe Design and Use of Monocoque Sandwich Structures in Principal Structural Element Applications

https://www.easa.europa.eu/en/document-library/product-certification-consultations/easa-cm-s-010

Basic messages for PSEs:

Multi-load path Sandwich Structures:

– robust interpretation of existing design, production, and ICA practices required,

e.g. established in-house practices, DOT/FAA/AR-99/49 Review of Damage Tolerance of Composite Sandwich Airframe Structures etc

not new… might benefit from some standardisation

not new… simply highlights challenging issues experienced in-service and development

Sandwich Materials and Structures

Example*:

Suggested regulatory approach? *… includes extensive exploration of impact threat…

TASK 1: DAMAGE FORMATION IN SANDWICH STRUCTURES SUBJECTED TO LOW-VELOCITY IMPACT

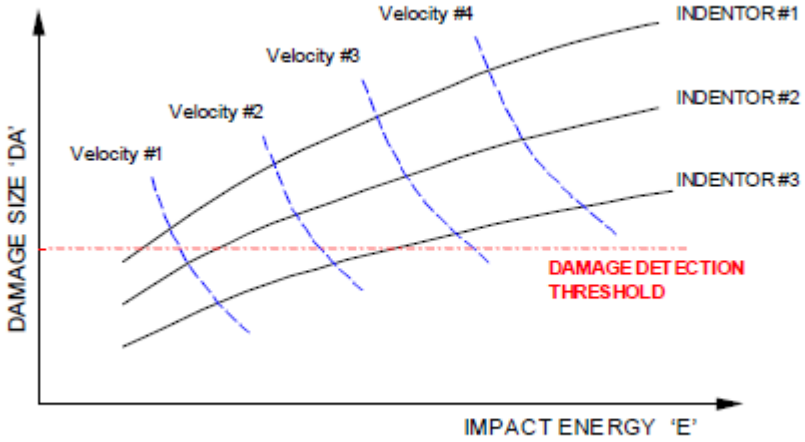


FIGURE 25. TYPICAL PLOTS EXPECTED FROM THE EXPERIMENTAL PROGRAM

* e.g. DOT/FAA/AR-99/49 Review of Damage Tolerance of Composite Sandwich Airframe Structures

Sandwich Materials and Structures

EASA Composite Materials Safety Strategy – related actions:

Basic messages for PSEs:

Monocoque Single-load path Sandwich Structures:

– as per multi-load path sandwich structures

+

- other mitigating factors*, e.g.

e.g. return to service with potentially catastrophic undetectable failure modes, following Cat.4/5? incident, to be avoided…

use of higher density/expanded core… typically part of corrective actions…

- lower strains?

- A-basis data (static and fatigue) **?**

- appropriate/more robust core density selection criteria?

- post incident inspection practices/methods?

* standardised details to be developed in later CM revision

Sandwich Materials and Structures

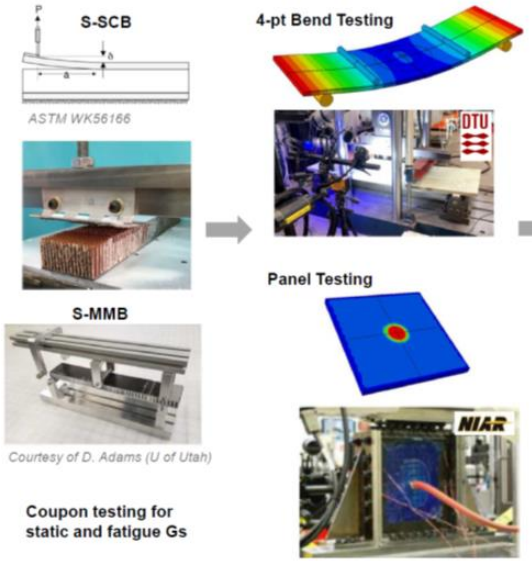
Previous R&D: Disbond of Sandwich Structures (DoSS)

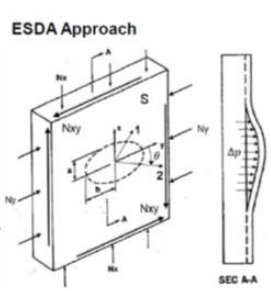
NSE COMPOSITES

Disbond of Sandwich Structures in Aviation – Phase 2 (DoSS-2)

Closed form design solution developed for large aircraft, including GAG + Delta P(see CMH-17) … to be developed for rotorcraft configurations and needs

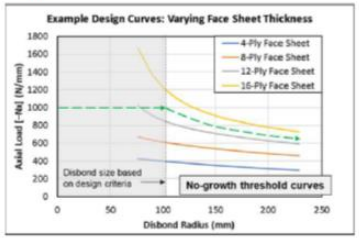
Engineering Approach for Sandwich Disbond Analysis





End result = repeatable, reliable analysis output (i.e., design curves) validated by test data.

Design Curves



- Engineering approach incorporates simplifying (conservative) assumptions and other constraints.
- Used for design studies and sizing to understand when sandwich disbond becomes critical (goal is to avoid).

Sandwich Materials and Structures

Potential further progress (building upon previous work and needs):

https://www.easa.europa.eu/en/document-library/general-publications/european-plan-aviation-safety-epas-2023-2025

RES.0027	Sandwich-structured composites

This research project shall help obtain further insight and develop guidance for the consistent and standardised design and safe use of sandwich structures in aviation. The results of the research shall be used to further complement the Composite Materials Handbook 17 and to refine the applicable regulatory material for initial and continuing airworthiness.

Status	Not started	
SIs	n/a	
SRs	n/a	
Reference(s)	Composite Material Handbook 17 (CMH-17)	
Dependencies	n/a	
Affected stakeholders	DOA holders, MOs (Part-145)	
Owner	EASA SM.2	Strategy & Programmes Department

PLANNING MILESTONES		
Starting date	**Interim report**	**Final report**
2024	2025	2027

Reaction to large pax, rotorcraft, and engine sandwich incidents

Sandwich Materials and Structures

UPDATE: EASA Project 'DESIGN' has started (3 years):
https://www.easa.europa.eu/en/research-projects/design

Tasks:

1/ Current technology summary

2/ Develop substantiated design solution: Build upon recently closed form design solution developed for large pax aircraft configurations to apply for other products, e.g. rotorcraft (main task)

3/ Correlate design solutions with current damage detection technology capabilities and damage tolerance strategies

4/ Propose other mitigations which may support acceptance of sandwich structure in more critical applications (monocoque?), e.g. identify criteria to identify candidate structure to be supported by Continued Airworthiness Strategies, e.g., Fleet Leader and Sampling etc.

5/ Summarise results

support revision to
- CM-S-010 'Safe Design and Use of Monocoque Sandwich Structures in PSEs'*
- AC29 2C MG8 (para.d7), AC29.573 (para.d11)
- add new content to CMH-17

*https://www.easa.europa.eu/en/document-library/product-certification-consultations/easa-cm-s-010

Sandwich Materials and Structures

'DESIGN'

Introduction of consortium members

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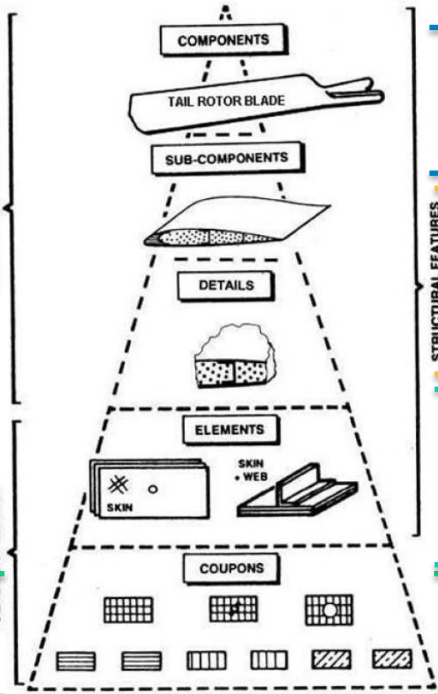
Composite CM Revisions

CM-S-004 Issue 2 – Composite Shared Database using NCAMP process

CS27 & CS29 Proof of Structure

Typical TC holder approach



X 1 to 6

X 10

X 100

"Proprietary" data specific to design/manufacturing process/loading

Components tests for compliance with static and fatigue requirements

Complex loading and combined failure modes / assemblies Analysis method validation

Design values derived for each design detail (static & fatigue)

Materials data and qualification performed by the TCH

Alternative approach

"Shared database" (AGATE, NCAMP, …)

X 100

X 1000

→ Significant reduction of number of coupons to derive material data when using "shared database"

→ Small amount of tests needed to demonstrate "equivalency" with the available database

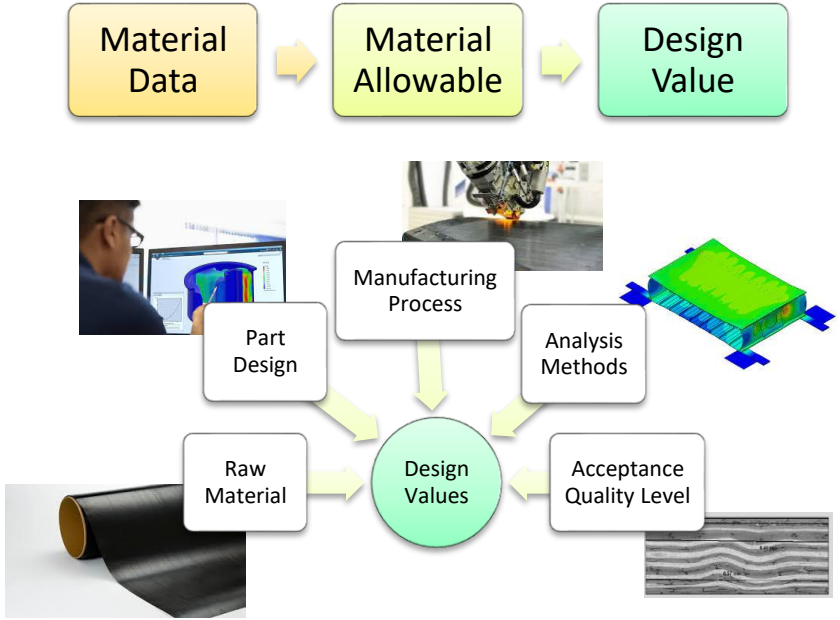
Material Allowables and Design Values

Material Allowable – A bulk material property derived from the statistical reduction of data from a stable process.

- → Material data must be statistically derived with **approved method** to generate **material allowables** (e.g. CMH17, NCAMP process)
- → Material allowables are taking into account **raw materials properties** for some standard layups, thicknesses, loading and failure modes.

Design Value – A material or structural property that is established to represent the **finished part** property.

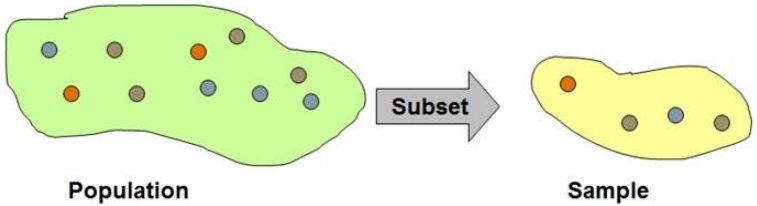
- → Typically based on material allowables and adjusted, using tests to account for geometric features and environmental conditions
- → Design values are used to compute **structural design margin**
- → Design values are **significantly** influenced by composite part design, analysis method, raw material properties and manufacturing process



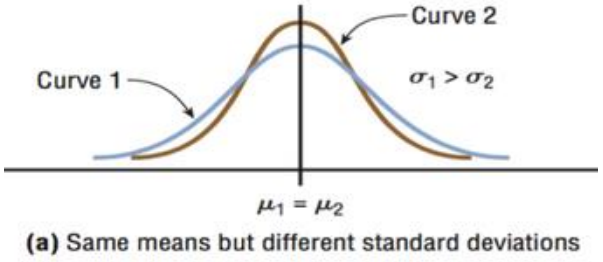
- → **Material data** should be derived from tests at coupon level for compliance with 27/29.603 and 27/29.605
- → **Design values** should be accounting for **factors having influence** on part/joint property for compliance with 27/29.613. They should cover defined **acceptance quality level**.

Using a “Shared Database”

- **Equivalency** is used to “buy into” a public database of material allowables:
  - Only a **small number** of coupon-level tests is needed to demonstrate equivalence
  - Only a **subset** of all properties needs to be tested
  - If equivalent, then the remaining published values of database may be used to **further derive design values.**
- **Curing process** (curing cycle, T°C and pressure, time) is specified for each material of shared database as applied during material qualification
- **No deviation** to the qualified material or process specification allowed !



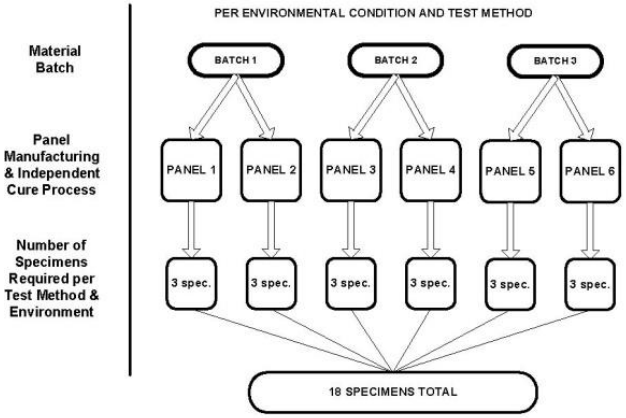
Is there statistical equivalence between sample and population?



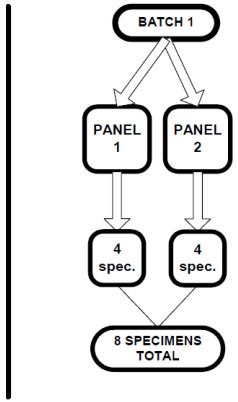
The 2 distributions should have similar standard deviations and similar means for equivalency

Statistical **equivalency** = similar **mean value** and **standard deviation**

Using a “Shared Database”



Conventional approach (reduced sampling)



Equivalence

Main benefits identified:

- → Coupons tests/cost/lead time **reduction** for basic material data
- → **Standardisation**/confidence regarding material data acquisition and material specification
- → Transfer of **testing effort** at higher level of test pyramid

But some **limitations:**

- → **Generic data** only: Material fatigue data, impact damage, bolted and bonded joints are **not generic** and require additional testing. **Effect of defects** needs also to be evaluated, as non generic.
- → **Conventional** materials (UD, fabrics), failures modes → only conventional **design and manufacturing processes**, conventional **environments** (fluids exposure, temperature, …)
- → Same **test standards** must be used as in reference database (ASTM for NCAMP)

CM-S-004 Composite Shared Database

EASA CM-S-004 Issue 01 '*Composite Materials – Shared Databases, Acceptance of Composite Specifications and Design Values Developed using the NCAMP Process*'

EASA accepts the processes and data generated, for:

- → EASA projects Certification, when applicant has fully engaged with the NCAMP SOPs (available online)
- → Project Validations, e.g. for EASA Validation of FAA projects

NIAR Wichita State University National Institute for Aviation Research

NSP 100 Rev G
Date: March 27, 2017

NCAMP National Center for Advanced Materials Performance

NCAMP Standard Operating Procedures (SOP)

CM-S-004 Issue 02:

- → Addition of **limitations** – and extra work needed (joints, fatigue, DT, ..)
- → Extension to "**other shared database**" including reuse of qualified database with some limitations
- → Extension to Ceramic, Thermoplastic NCAMP data

CMH-17 Fall Event 2024, Lilium-Toray presentation about use of shared database – nb of coupons

List of materials qualified in NCAMP database

Thermoset Prepreg Materials - Completed Qualification
Cytec, a Syensqo company 5320-1
T650 Unidirectional Tape
T650 3k-PW Fabric
Cytec, a Syensqo company MTM45-1
Style 7781 E Glass Fabric
Style 6781 S2 Glass Fabric
3K PW G30-500 Fabric
12K AS4 Unidirectional Tape
12K HTS5631 Unidirectional Tape (HTS40)
IM7 Unidirectional Tape
AS4 PW Fabric
Hexcel 8552
AS4 Unidirectional Tape
IM7 Unidirectional Tape
AS4 PW Fabric
AS4 3k 8HS
Newport NCT4708
MR60H Unidirectional Tape
Toray (formerly TenCate) BT250E-6
IM7 GP Unidirectional Tape
AS4C 3K-PW Fabric
S2 Unidirectional Tape
Toray (formerly TenCate) TC250
12k HTS40 PW Fabric

Thermoset Prepreg Repair Materials - Completed Qualification
Cytec, a Syensqo company 5320-1 Repair
T650 Unidirectional Tape

Thermoplastic Prepreg/Semipreg Materials - Completed Qualification
Teijin Tenax-E TPWF/TPCL PEEK
HTA40 E13 3K 5HS
Toray (formerly TenCate) TC1225 (Discontinued*)
T700 Unidirectional Tape
*122/1 manufacturing configuration is discontinued. For information on the improved configuration of TC1225/T700, please contact g.waldrip@toraytac-usa.com.
Victrex AE™ 250 LMPAEK
AS4 12k Unitape

AM Polymer Materials - Completed Qualification
Stratasys Fortus 900mc, ULTEM 9085
Markforged X7, Onyx FR-A w/ Carbon Fiber FR-A

Both the Federal Aviation Administration (FAA) the European Aviation Safety Agency (EASA) accept composite specification and design values developed using the NCAMP process.

FAA Memorandum AIR100-2010-120-003 →

EASA CM – S – 004 →

Contact

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- → Lots of upcoming Thermoset and Thermoplastic materials
- → Ceramic Matrix Composites (CMCs)
- → Non-Metallic Additive Manufacturing materials

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Composite CM Revisions

CM-S-005 Issue 2 – Bonded Repair Size Limits

Background – Bonded repair

Challenges of in-service bonded repair(*):

- → Lack of standards for repair design, training, process and quality controls
- → Materials and processes are different between manufacturers
- → Repair design is extremely difficult without a knowledge of base structure materials, processes, and design philosophy
- → Reverse engineering techniques are not mature

FAA PS-AIR-20-130-01: BRSL “Bonded Repair Size Limits”

*“Service experience shows past repairs were not always successful, resulting in unexpected **repair bond failures**. Without a reliable inspection technique to detect weak bonds until related bond failures, the FAA concludes that **bonded repair of critical structure** is a potential **safety threat**”*

(*)Source: “Certification of bonded aircraft structures and repairs”, C. Ashforth, L. Ilcewicz
https://www.sto.nato.int/publications/STO%20Meeting%20Proceedings/STO-MP-AVT-266/MP-AVT-266-06.pdf

CM-S-005 Bonded Repair Size Limits

- **Applicable to:** CS-23, CS-25, CS-27, CS-29
- **Restrict bonded repair size** to that which allows the structure to carry **Limit Loads**, with failed repair (patch off)
- Simply restates intent of CS23.573(a)(5) of AMC 20-29 §6c.(3) and provides a reminder that it applies to baseline structure and repair

Strict application of CM-S-005 is raising **questions/discussions**:

- Is In-production repair in scope of CM applicability?
- How to consider positive experience and good practices with bonded repair on critical structures by some well-established applicants…
- …while new organisations have no history/database to justify?

- CM-S-005 Issue 01 was reminding the **applicable bonding requirements**
- **Good practices** and **positive experience** should be taken into consideration
- Aim for **standardization** of compliance demonstration for **in-production repairs**
- Objective of next issue is to provide a **certification framework** to support/develop bonded repair

CM-S-005: Bonded Repair Size Limits Revision

- "Patch off" threat would depend on repair type, design, substantiation and qualification. Some mitigating factors will be defined to extent BRSL:
  - Repair **design principles** with **limited shear stress levels** into the bonded joint
  - **Qualified** repair **process**, tools and operators
  - Use of **parent material** for repair or **qualified repair materials**
  - Substantiation of **durability of repair** through tests at detail / subcomponent / component level
  - Demonstration of UL capability of repaired structure including cat 1 damage on repair

CM-S-005 Issue 02:

- Risk of "patch off" can be mitigated depending on repair type, design, process qualification, durability demonstration … and **good practices**
- Applicable to "**in-production**" and "**in-service**" bonded repairs
- **Limited to TCH** with positive experience on bonded repairs <u>in a first step</u>

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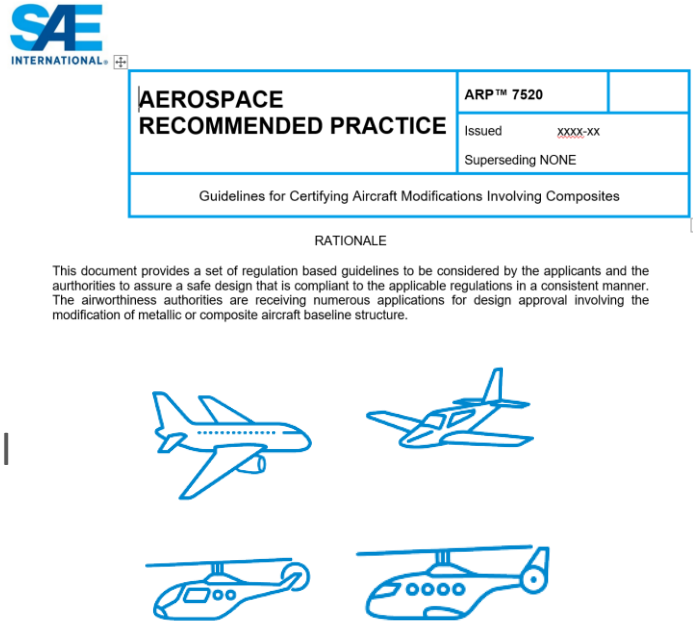
SAE ARP 7520

New SAE Standard: *"Guidelines for Certifying Aircraft Modifications Involving Composites"*

https://www.jetphotos.com/photo/10582809

SAE ARP 7520

- The document provides guidelines to help aircraft/rotorcraft **modifiers** to comply with airworthiness regulations regarding the modification of a composite or metallic aircraft using composites.
  - Example: installation of antenna on composite structure
- It is a summary of regulations, guidance, policy, and experiences that address **specific** considerations for aircraft/rotorcraft composites compared to traditional metals.
- Addresses a large range of products:
  - CS23 – CS25 – **CS27 – CS29**
- First issue expected to be released by **Q4/2025**



SAE INTERNATIONAL

AEROSPACE RECOMMENDED PRACTICE	ARP™ 7520	
	Issued xxxx-xx	
	Superseding NONE	

Guidelines for Certifying Aircraft Modifications Involving Composites

RATIONALE

This document provides a set of regulation based guidelines to be considered by the applicants and the aurthorities to assure a safe design that is compliant to the applicable regulations in a consistent manner. The airworthiness authorities are receiving numerous applications for design approval involving the modification of metallic or composite aircraft baseline structure.

Background

Challenges of composites vs. metals.

- → Proprietary composite M&P specifications and design values vs. metal handbooks.
- → Design specificities of composite structures (ply orientation, ply stacking sequence, etc.) vs metallic structures
- → Other design aspects: flammability & fire resistance, electrical bonding, maintenance & repair, etc.

Complexity due to **numerous** regulatory definitions of structures in the Parts 23, 25, 27, 29.

- → Simplified by defining 3 types of parts:
  - → Parts whose failure **directly** affecting continued safe flight and landing or occupant safety.
  - → Parts whose failure **indirectly** affecting continued safe flight and landing or occupant safety.
  - → Parts whose failure has **no affect** on continued safe flight and landing or occupant safety.

- → **Critical Parts**, specific to CS27/CS29 have been also addressed

SAE ARP 7520

- **Work in Progress !** Document still under construction
- It is informative/explanatory and not a prescriptive procedure.
- The document wording is intended to be **clear and simple**, as the readers may not be well informed regarding the modification of aircraft/rotorcraft using composites.
- Developed within **SAE CACRC composite modifications TG**
  - EASA & FAA experts reviewed and commented the document
  - OEM & DOA representatives provided inputs and comments
  - Airlines commented regarding Compatibility Assessment of Alteration, Continued Operational Safety, ICA's, Service Findings from Inspections sections.
- Several examples of design changes are provided in appendix
- Lots of relevant guidance, documents and reports provided in references

SAE ARP 7520

EASA recommendations:

- → STC designers to refer to SAE ARP 7520 for any design change on composite structures (TCH/STCH)

  (e.g. antenna installation)

- → STC purchasers to request STC holders to follow ARP 7520

  in particular for Compatibility Assessment of Alteration, Continued Operational Safety, ICA's, Service Findings from Inspections

Reminder:

➔ **CM-21.A-D-002** "External Installations on Helicopters" applies for rotorcraft

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Composite Materials - Conclusions

- Sandwich Structures
  - CM-S-010: Monocoque SLP Sandwich PSE needs additional mitigating factors
  - EPAS R&D Project DESIGN on sandwich applications launched – 2025-2027
- CM Revisions: Public Consultation planned within 2025
  - CM-S-004 Issue 2: Composite Shared Database
  - CM-S-005 Issue 2: Bonded Repair Size Limits
    - Certification framework for extension of BRSL
    - In-Production and In-Service Bonded Repairs
- SAE ARP 7520
  - New SAE standard „*Guidelines for Certifying Aircraft Modifications Involving Composites*" for CS23-25-27-29, release planned by Q4/2025

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