

Core Materials Qualification Guidance for Aircraft Design and Certification



Federal Aviation
Administration

Presented by:

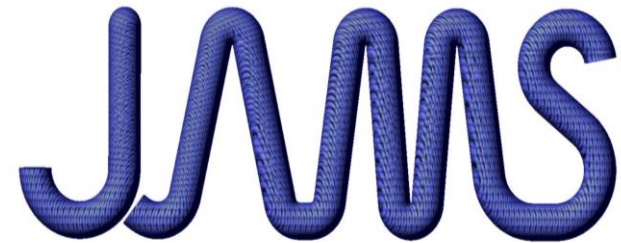
Nicole Stahl

NIAR – Wichita State University



JAMS Technical Review

September 29, 2021



Joint Centers of Excellence for Advanced Materials



Introduction

- Core Materials Qualification Guidelines for Aircraft Design and Certification
- Project Participants
 - Principal Investigators – John Tomblin, Royal Lovingfoss, Rachael Andrulonis, Nicole Stahl
- FAA Technical Monitor - Curtis Davies
- Industry Partnerships/Other Collaborations
 - Committee Members – 24 different companies and industry partners are represented

Background

- Goals
 - To develop a framework for the qualification of core materials including guidelines and recommendations for their characterization, testing, design and utilization within the aerospace industry
 - Transition the test data and guidelines generated in this program into shared databases, such as CMH-17.

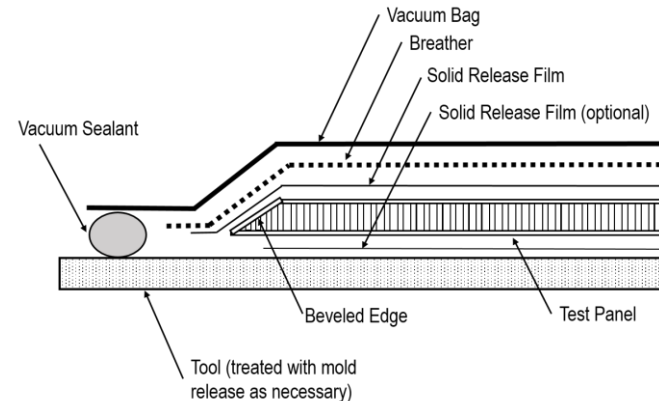
Previous Work

- Survey
 - 24 different companies/organizations represented in Survey
 - Honeycomb & Foams
 - Both currently utilizing in aircraft structures and proposed for future use (5-10 years)
- Material
 - Core: Hexcel, HRH-10-1/8-3.0', Hexcore Material, 0.5" thick, 1/8" cell size, 3pcf, largest used product by far
 - Facesheet: Hexcel 8552 PW (NCAMP qualified, NMS 128/3)
 - Adhesive: FM300 film adhesive (in process of being NCAMP qualified).

Previous Work

- Climbing drum peel will need to have a 2ply, core, 4ply layup. This is so the 2ply facesheet will wrap around the drum. If we try to wrap a 4ply facesheet it will break.
- Cure cycle will be a co-cure of the facesheets and core. See below.
 1. Ramp from RT to 350F+/-10F at 3-5F/min. Full vacuum is applied (roughly around 26-27”Hg). Ramp pressure at 2-7psi.
 2. Start vacuum reduction at 15psi+/-5psi, must be fully removed by 22psi+/-5psi.
 3. Max pressure reached at 45psi +/-5psi, hold that pressure through cure cycle until material is cooled down to 140F.
 4. Hold 350F+/-10F for 120 minutes -0 +15 minutes.
 5. Cool down at 2-7F/minute until it reaches 140F. At 140F vent pressure and remove from autoclave.
- Normal bagging scheme will be used

Please note that beveled edges will be used to ensure that edge core crush is not seen. Panels will be built 1” larger in each direction to have trim area on the edges which will be removed before machining coupons.



Previous Work



Core Trial Test Matrix						
Mechanical Test Properties						
Layup (Warp Direction)	Test Type and Direction	Property	Number of Batches x Number of Panels x Number of Test Specimens			
			Test Temperature/Moisture Condition			
			RTD	ETD1 (180F)	ETW1 (180F)	
N/A	Core Shear (L) ASTM C273 (0.5" thick core) (1)	Strength and Modulus	1x1x5	1x1x5	1x1x5	
N/A	Core Shear (W) ASTM C273 (0.5" thick core) (1)	Strength and Modulus	1x1x5	1x1x5	1x1x5	
N/A	Bare Compression ASTM C365 (0.5" thick core)	Strength	1x1x5			
4 core 4 (2)(3)	Stabilized Compression ASTM C365 (0.5" thick core)	Strength and Modulus	1x1x5	1x1x5	1x1x5	
N/A	Standard Test Method for Node Tensile Strength of Honeycomb Core Materials ASTM C363 (0.5" thick core)	Strength	1x1x5			
4 core 4 (2)(3)	Flatwise Tension ASTM C297 (0.5" thick core)	Strength	1x1x5	1x1x5	1x1x5	
4 core 4 (2)(3)	Edgewise Compression ASTM C364	Strength and Modulus	1x1x5			
4 core 2 (2)(3)	Climbing Drum Peel ASTM D1781	Strength	1x1x5			
4 core 4 (2)(3)	Core Shear Stress ASTM C393	Strength and Modulus	1x1x5	1x1x5	1x1x5	
4 core 4 (2)(3)	Long Beam Flex ASTM D7249	Strength and Modulus	1x1x5			

Note 1: The core thickness used for the qual and the thickness correction factor coupons can be changed to match what is available and/or required.

Note 2: 4 core 4 corresponds to 4 plies for top facesheet bonded to core with 2 plies of film adhesive and 4 plies for the bottom facesheet bonded to the core with 2 plies of film adhesive. Facesheet layup will be [0,90,90,0] and [0,90].

Note 3: The stacking sequence can be changed to match what is required and/or desired.

Previous Work

Trial Test Coupon Density

Average [lbm/ft ³]	3.2581
St. Dev.	0.0919
Coeff. Of Variation	2.8202
Min	3.0021
Max	3.4359
Number of Specimens	79

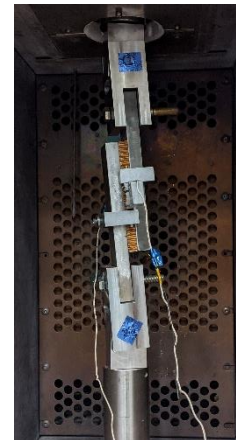
Previous Work – Core Shear Data



WICHITA STATE
UNIVERSITY

NATIONAL INSTITUTE
FOR AVIATION RESEARCH

Test	Direction	Temp	Core Shear Strength (psi)	C.V. (%)	2% Offset Core Shear Strength (psi)	C.V. (%)	Modulus (ksi)	C.V. (%)
C273	L	RTD	204.6	3.730	203.1	4.128	6.620	3.583
		ETD	170.1	2.094	165.3	2.702	5.969	3.198
		ETW	123.4	8.485	124.5	6.735	5.482	4.601
	W	RTD	110.5	3.001	108.6	3.927	3.942	2.872
		ETD	98.06	1.719	93.61	1.802	3.479	2.177
		ETW	76.90	2.513	71.84	1.970	3.326	2.867



Previous Work – Core Shear Data



WICHITA STATE UNIVERSITY

NATIONAL INSTITUTE FOR AVIATION RESEARCH

Test	Direction	Temp	Failure Mode	Specimen Geometry	Speed	
C273	L	RTD	SGE	2"X6"	TEST SPEED FOR CMH17-C273-L-RTD-1: 0.02 in/min TEST SPEED FOR CMH17-C273-L-RTD-(2-5): 0.011 in/min	
			SGE			
			SGE			
			SGE			
			SGE			
			SGE			
		ETD	SGE			TEST SPEED: 0.011 in/min
			SGE			
			SGE			
			SGE			
			SGE			
			SGE			
	ETW	SGM, ICE	TEST SPEED FOR CMH17-C273-L-ETW1-1: 0.011 in/min TEST SPEED FOR CMH17-C273-L-ETW1-2: 0.0145 in/min TEST SPEED FOR CMH17-C273-L-ETW1-(3-5): 0.01165 in/min			
		SGM, ICB				
		SGM, ICE				
		SGM, ICE				
		SGM, ICE				
		SGM, ICE				
	W	RTD			SGE	TEST SPEED FOR CMH17-C273-W-RTD-1: 0.02 in/min TEST SPEED FOR REMAINING SPECIMENS: 0.013 in/min
					SGE	
					SGE	
					SGE	
					SGE	
					SGE	
ETD		SGE	TEST SPEED: 0.013 in/min			
		SGE				
		SGE				
		SGE				
		SGE				
		SGE				
ETW	SGE, ICT	TEST SPEED FOR CMH17-C273-W-ETW1-1: 0.011 in/min TEST SPEED FOR CMH17-C273-W-ETW1-2: 0.04 in/min TEST SPEED FOR CMH17-C273-W-ETW1-(3-5): 0.028 in/min				
	SGE, ICT					
	SGE					
	SGE, ICT					
	SGE, ICT					
	SGE, ICT					

C273 Failure Codes					
First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Core Shear	S	At End	A	Top	T
Interface failure	I	Gage (within core)	G	Middle	M
Explosive	X	One Corner	C	Bottom	B
Other	O	Various	V	Entire Length	E
		Unknown	U	Various	V
				Unknown	U

Previous Work – Flatwise Tension Data

Test	Temp	Flatwise Tensile Strength (psi)	C.V. (%)
C297	RTD	340.6	0.9165
	ETD	328.2	2.473
	ETW	296.0	2.514



Previous Work – Flatwise Tension Data



Test	Temp	Failure Mode	Specimen Geometry	Speed
C297	RTD	CORE FAILURE	2"X2"	TEST SPEED FOR CMH17-Panel 1-C297-RTD-1: 0.02 in/min
		CORE FAILURE		TEST SPEED FOR CMH17-Panel 1-C297-RTD-2: 0.008 in/min
		CORE FAILURE		TEST SPEED FOR CMH17-Panel 1-C297-RTD-(3-5): 0.005 in/min
		CORE FAILURE		
	ETD	CORE FAILURE		TEST SPEED FOR CMH17-Panel 1-C297-ETD1-1: 0.02 in/min
		CORE FAILURE		TEST SPEED FOR CMH17-Panel 1-C297-ETD1-(2-5): 0.006 in/min
		CORE FAILURE		
		CORE FAILURE		
	ETW	CORE FAILURE		TEST SPEED FOR CMH17-Panel 1-C297-ETW1-1: 0.02 in/min
		CORE FAILURE		TEST SPEED FOR CMH17-Panel 1-C297-ETW1-(2-5): 0.0064 in/min
		CORE FAILURE		
		CORE FAILURE		

Previous Work – Bare and Stabilized Compression Data



Test	Direction	Temp	Flatwise Compression Strength (psi)	C.V. (%)	Flatwise Compression Modulus (ksi)	C.V. (%)
C365	Bare	RTD	335.5	1.617	N/A	N/A
	Stabilized	RTD	458.9	0.9014	29.54	2.119
	Stabilized	ETD	404.6	1.326	25.82	3.572
	Stabilized	ETW	295.8	10.83	22.51	6.326



Previous Work – Bare and Stabilized Compression Data



Test	Direction	Temp	Failure Mode	Specimen Geometry	Speed
C365	Bare	RTD	UNIFORM COMPRESSIVE FAILURE	2"X2"	TEST SPEED: 0.0039 in/min
			UNIFORM COMPRESSIVE FAILURE		
			UNIFORM COMPRESSIVE FAILURE		
			UNIFORM COMPRESSIVE FAILURE		
			UNIFORM COMPRESSIVE FAILURE		
	Stabilized	RTD	UNIFORM COMPRESSIVE FAILURE		TEST SPEED FOR CMH17-Panel 1-C365-RTD-1: 0.02 in/min
			UNIFORM COMPRESSIVE FAILURE		TEST SPEED FOR CMH17-Panel 1-C365-RTD-(2,3): 0.0049 in/min
			UNIFORM COMPRESSIVE FAILURE		TEST SPEED FOR CMH17-Panel 1-C365-RTD-(4-6): 0.0039 in/min
			UNIFORM COMPRESSIVE FAILURE		
			UNIFORM COMPRESSIVE FAILURE		
		ETD	UNIFORM COMPRESSIVE FAILURE		TEST SPEED: 0.0039 in/min
			UNIFORM COMPRESSIVE FAILURE		
			UNIFORM COMPRESSIVE FAILURE		
			UNIFORM COMPRESSIVE FAILURE		
			UNIFORM COMPRESSIVE FAILURE		
	ETW	UNIFORM COMPRESSIVE FAILURE	TEST SPEED FOR CMH17-Panel 1-C365-ETW-1: 0.02 in/min		
		UNIFORM COMPRESSIVE FAILURE	TEST SPEED FOR CMH17-Panel 1-C365-ETW-(2-7): 0.003 in/min		
		UNIFORM COMPRESSIVE FAILURE			
		UNIFORM COMPRESSIVE FAILURE			
		UNIFORM COMPRESSIVE FAILURE			

Previous Work – Core Shear Stress Data

Test	Temp	Core Shear Ultimate Stress (psi)	C.V. (%)	Facing Bending Stress (psi)	C.V. (%)
C393	RTD	212.7	2.233	24498.2	4.965
	ETD	197.9	2.115	21647.8	2.836
	ETW	146.2	1.580	16106.6	3.682



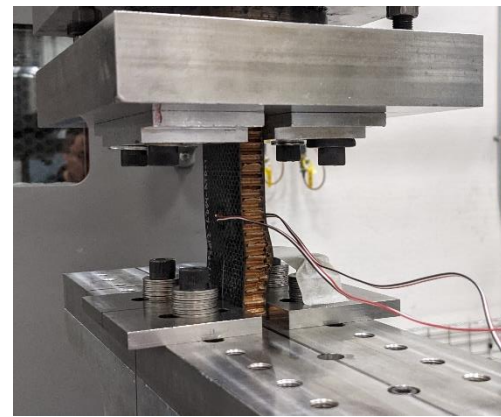
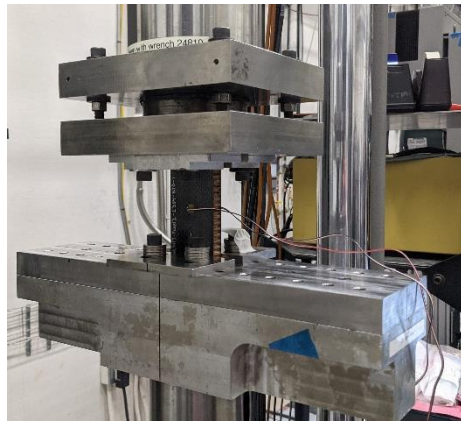
Previous Work – Core Shear Stress Data

Test	Temp	Failure Mode	Specimen Geometry	Speed
C393	RTD	SGC	3"X8"	TEST SPEED FOR CMH17-Panel 3-C393-RTD-1: 0.25 in/min
		SGC		
		SGC		
		SGC		
	ETD	SGC		TEST SPEED FOR CMH17-Panel 3-C393-RTD-(2-5): 0.035 in/min
		SGC		
		SGC		
		SGC		
		SGC		
	ETW	SGC		TEST SPEED: 0.035 in/min
		SGC		
		SGC		
		SGC		
		SGC		
		SGC		
ETW	SGC	TEST SPEED FOR CMH17-Panel 3-C393-ETW1-1: 0.032 in/min		
			TEST SPEED FOR CMH17-Panel 3-C393-ETW1-2: 0.135 in/min	
				TEST SPEED FOR CMH17-Panel 3-C393-ETW1-(3-7): 0.08 in/min
	SGC			

C393					
First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
core Crushing	C	At load bar	A	Core	C
skin to core Delamination	D	Gage	G	core-facing bond	A
Facing failure	F	Multiple areas	M	Bottom facing	B
Multi-mode	M (xyz)	Outside gage	O	Top facing	T
transverse Shear	S	Various	V	both Facings	F
eXplosive	X	Unknown	U	Various	V
Other	O			Unknown	U
Sandwich Panel Three Part Failure Identification Codes					

Previous Work – Edgewise Compression Data

Test	Temp	Compressive Strength (ksi)	C.V. (%)	Modulus (Msi)	C.V. (%)
C364	RTD	63.02	6.589	9.569	4.248



Previous Work – Edgewise Compression Data



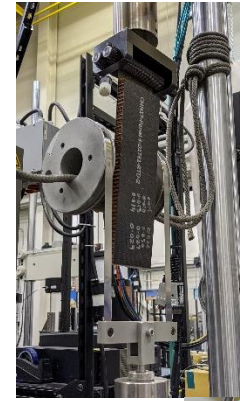
Test	Temp	Failure Mode	Specimen Geometry	Speed
C364	RTD	FGT, CGT	2"X4"	TEST SPEED FOR CMH17-Panel 2-C364-RTD-(1-3): 0.02 in/min TEST SPEED FOR CMH17-Panel 2-C364-RTD-(4,6): 0.009 in/min
		FGT, CGT, BGM		
		FGM, CGM		
		FGB, FAB		
		FGB, CGB		
		FGM, CGM		

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Facesheet Compression	F	At End	A	Top	T
Facesheet Delamination Buckling	B	Gage (>1 xt from end)	G	Middle	M
Honeycomb Facesheet Dimpling	D	Various	V	Bottom	B
Core Compression	C	Unknown	U	Various	V
Core Shear	S			Unknown	U
Overall Panel Buckling	P				
Explosive	X				
Other	O				

Previous Work – Climbing Drum Peel Data

Test	Temp	Avg Peel Torque (in-lb/in)	C.V. (%)
D1781	RTD	12.86	8.213

Test	Temp	Failure Mode	Specimen Geometry	Speed
D1781	RTD	ADHESION TO THE FACING FAILURE, FAILURE WITHIN THE CORE	3"X12" (without tabs) 3"X14" (with tabs)	TEST SPEED: 1.00 in/min
		ADHESION TO THE FACING FAILURE, FAILURE WITHIN THE CORE		
		ADHESION TO THE FACING FAILURE, FAILURE WITHIN THE CORE		
		ADHESION TO THE FACING FAILURE, FAILURE WITHIN THE CORE		
		ADHESION TO THE FACING FAILURE, FAILURE WITHIN THE CORE		



Previous Work – Long Beam Flex Data

Test	Temp	Facing Ultimate Stress (psi)	C.V. (%)	Effective Facing Chord Modulus (tensile) (Msi)	C.V. (%)	Effective Facing Chord Modulus (compressive) (Msi)	C.V. (%)	Sandwich Flexural Stiffness (M lb.in ²)	C.V. (%)
D7249	RTD	61459.7	5.281	10.91	4.137	10.07	3.670	0.1200	1.711



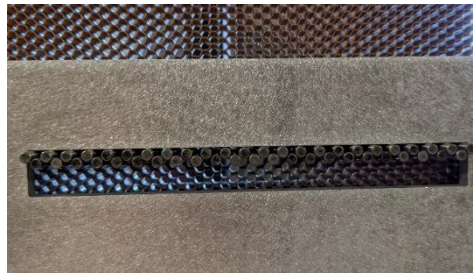
Previous Work – Long Beam Flex Data



Test	Temp	Failure Mode	Specimen Geometry	Speed
D7249	RTD	FAT	3"X24"	TEST SPEED: 0.25 in/min
		FAT		
		FAT		
		FAT		
		FAT		

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
skin to core Delamination	D	At load bar	A	Bottom Facing	B
Filament fracture	F	Gage	G	Top Facing	T
through-thickness	H	Multiple areas	M	both Facings	F
Layer instability	L	Outside gage	O	Core	C
local Wrinkling	W	Various	V	core-facing bond	A
Multi-mode	M (xyz)	Unknown	U	Various	V
core Crushing	C			Unknown	U
longitudinal splitting	P				
tensile	N				
transverse Shear	S				
explosive	X				
Other	O				

Previous Work – Node Tensile Strength Data



Specimen	Test Speed (in/min)	Max Load (lb)	Tensile-Node Bond Strength [psi]	Pins	Failure Mode
1	0.4	61.154	20.440	Staggered	Node Bond Failure, Failure at Loading Pins
2	0.4	62.661	---	Double Row	Failure at Loading Pins
3	0.4	50.979	16.917	Staggered	Node Bond Failure, Failure at Loading Pins
4	0.4	48.847	---	Staggered	Failure at Loading Pins
5	0.4	56.529	18.871	Staggered	Node Bond Failure
6	0.4	53.132	17.676	Staggered	Node Bond Failure, Failure at Loading Pins

Current Work

- Finalize Qualification Matrix
 - Node Tensile Testing and Edgewise Compression
 - Thickness Correction Factor
- Repeat Density testing using 2 batches
- Test Plan
- Specs

Thank You

- Questions?
- Contact
 - Nicole Stahl
 - nstahl@niar.wichita.edu