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TRANSMITTAL

TO: Jennifer Fitch, PE Project Manager Vermont Agency of Transportation	DATE	PROJECT NO.
	6/16/2014	Brookfield BRF FLBR (2)

XX WE ENCLOSE THE FOLLOWING: ______ UNDER SEPARATE COVER WE ARE SENDING THE FOLLOWING

COPIES	NUMBER	DESCRIPTION	CODE
1		FRP Test Sample Results - Rev 1 - 1	H

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T.Y. LIN INTERNATIONAL

THE STAMPED DOCUMENTS ARE HEREBY:

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SEE TRANSMITTAL FOR ADDITIONAL INFORMATION AS APPLICABLE.

THIS REVIEW IS FOR GENERAL CONFORMANCE WITH DESIGN CONCEPT ONLY. ANY DEVIATION FROM THE PLANS OR SPECIFICATIONS NOT CLEARLY NOTED BY THE CONTRACTOR HAS NOT BEEN REVIEWED. REVIEW BY THE ENGINEER SHALL NOT RELIEVE THE CONTRACTOR OF THE CONTRACTUAL RESPONSIBILITY FOR ANY ERRORS OR DEVIATION FROM THE CONTRACT REQUIREMENTS.

JOSH OLUND — REVIEWER
06/17/2014 — DATE

BY: Paul [signature]

The following table is a summary of the mechanical and physical property values required by the specification, values used in design calculations, and measured values from recent testing. In one instance – coefficient of thermal expansion – the measured value was outside the range of the specification by 9.5%. There are two instances – tensile strength and shear modulus – where the measured value is slightly below the design value. In both cases, all affected calculations were checked and still pass the design criteria.

Value	**Units**	**Required**	**Design**	**Measured**	**Remarks**
Density	lb/in^3	±5% of Design	0.067	0.066	pass (<1.5% deviation)
Fiber Fraction	% vol	> 45%	49.1%	48.7%	pass
Barcol Hardness	--	> 40	n/a	54	pass
Tensile Modulus	Msi	> 2.00	3.27	3.09	not used for buckling checks
Tensile Strength	ksi	> 30.0	52.3	46.69	lower strength checked in design calcs - all affected values pass
Comp. Modulus	Msi	> 1.80	3.27	3.35	pass
Compression Strength	ksi	> 30.0	34.9	56.73	pass
Shear Modulus	Msi	> 0.60	0.71	0.63	lower modulus checked in design calculations - all affected values pass
Shear Strength	ksi	> 12.0	14.3	14.45	pass
Flexural Modulus	Msi	> 1.80	n/a	2.58	pass
Flexural Strength	ksi	> 35.0	n/a	51.77	pass
Interlaminar Shear	ksi	> 3.50	n/a	5.35	pass
Bearing Strength	ksi	> 20.0	52.00	53.02	pass
Coeff. of Therm. Exp.	$x10^{-6}$/°F	8.00	n/a	8.76	CTE over spec by 9.5% - 100° change over 51' equals 0.536" ΔL vs. 0.490"
Coeff.of Friction, Wet	--	> 0.45	n/a	0.58	pass (grit blasted surface)
Water Absorption	%	< 0.70%	n/a	0.10%	pass

Physical Property Testing for Brookfield Floating Bridge

Prepared for:

Paul Holloway

Miller Construction

Prepared by:

Jacob Marquis

Kenway Corporation

May 27, 2014

THIS PAGE SUPERSEDED BY TESTS PERFORMED BY THE UMAINE ASCC TO MEET ISO 17025 REQUIREMENTS.

On May 1, 2014 Kenway fabricated a test panel for conducting physical tests of the Brookfield floating bridge laminate. The test panel was approximately 18 in. square with half of the area made up of the nominal 0.5 in. thick layup and the other half at the nominal 1.0 in. layup. This panel was maintained at approximately 70 °F until May 27, 2014 when the following tests were conducted.

ASTM D792-13 Density and Specific Gravity of Plastics by Displacement

Per the above standard, three specimens were machined to approximately 0.5 in. cubes for weighing. The volume of each was computed by measuring the distance between parallel sides. The average density and coefficient of variation are reported in the table below.

Specimen	Length (in)	Width (in)	Height (in)	Computed Vol. (in^3)	Weight (g)	Weight (lb $x10^{-3}$)	Density (lb/in^3)
1	0.506	0.508	0.462	0.119	3.564	7.857	0.066
2	0.508	0.504	0.464	0.119	3.591	7.917	0.067
3	0.509	0.504	0.459	0.118	3.529	7.780	0.066
Avg	0.508	0.505	0.462	0.118	3.561	7.851	**0.066**
CV	0.3%	0.5%	0.5%	0.5%	0.9%	0.9%	0.5%

ASTM D2584-11 Ignition Loss of Cured Reinforced Resins

Per the above standard, three specimens were machined to approximately 1.0 in. cubes for weighing. The samples were placed in a muffle furnace at 1,050 °F for four hours. The residue was weighed to calculate the fiber fraction by weight. A glass density of 0.093 lb/in^3 was used along with the laminate density calculated above to compute the fiber fraction by volume.

Specimen	Length (in)	Width (in)	Height (in)	Computed Vol. (in^3)	Weight (g)	Residue Weight (g)	Fiber Wt. (%)	Fiber Vol. (%)
1	1.022	1.022	0.997	1.041	31.059	21.244	68.4%	48.8%
2	1.024	1.026	1.001	1.052	31.268	21.307	68.1%	48.6%
3	1.018	1.024	0.997	1.039	30.816	21.051	68.3%	48.7%
Avg	**1.021**	**1.024**	**0.998**	**1.044**	**31.048**	**21.201**	**68.3%**	**48.7%**
CV	0.3%	0.2%	0.2%	0.6%	0.7%	0.6%	0.2%	0.2%

THIS PAGE SUPERSEDED BY TESTS PERFORMED BY THE UMAINE ASCC TO MEET ISO 17025 REQUIREMENTS.

ASTM D2583-13a Indentation Hardness of Rigid Plastics by Barcol Impressor

Per the above standard, ten hardness readings were taken at random locations on the test panel. The individual readings and associated average Barcol hardness are listed in the table below.

Reading	1	2	3	4	5	6	7	8	9	10	**Ave**
Hardness	57	48	46	44	62	65	56	63	48	55	**54**

Equipment

Starrett Model 799 caliper

Barber Colman Model 934-1 Barcol impressor

Intell-Lab Model PMW-320 scale

Jen-Ken Kilns Model GS muffle furnace

All remaining required testing was performed at the Advanced Structures and Composites Center at the University of Maine and those results are provided in the UMaine test report.

THIS PAGE SUPERSEDED BY TESTS PERFORMED BY THE UMAINE ASCC TO MEET ISO 17025 REQUIREMENTS.

Material Property Testing for Vtrans Floating Bridge

Prepared for:

Jake Marquis
Kenway Corporation
Augusta, Maine

University of Maine's Advanced Structures and Composites Center
Report Number: 14-24-1267

May 27, 2014

Prepared by:

Keith A. Berube, Ph.D.
Research Engineer

Reviewed by:

Olivia Sanchez
ISO Coordinator

ACCREDITED

An ISO 17025 accredited testing laboratory, accredited by the International Accreditation Service.

Project Number: 1267
Project Date: May 20, 2014
Material: E-Glass/Interplastics 8100-50 Vinyl Ester
Date Received: April 22, 2014

Project Summary: The following material property tests were conducted:

- ASTM D3039 - *Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials*
- ASTM D6641 - *Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture*
- ASTM D5379 - *Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method*
- ASTM D2344 - *Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates*
- ASTM D7264 - *Standard Test Methods for Flexural Properties of Polymer Matrix Composite Materials*
- ASTM D953 - *Standard Test Method for Bearing Strength of Plastics*
- ASTM D696 - *Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C with a Vitreous Silica Dilatometer*
- ASTM D1894 - *Standard Test Method for Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting*
- ASTM D570 - *Standard Test Method for Water Absorption of Plastics*

The client provided two composite panels: a 48 inch by 48 inch composite panel with nominal thickness of 0.22 inches, and an 11 inch by 45 inch composite panel with nominal thickness of 0.95 inches.

The standard pontoon laminate will consist of (1) 4008 ±45, (7) 5400 0/90, and (1) 4008 ±45. This results in a total fabric areal weight of 474 oz./yd^2 (16 oz./yd^2 stitched mat (3%), 80 oz./yd^2 ±45 (17%), 378 oz./yd^2 0/90 (80%)) and a total thickness of 0.508 inches. The laminate schedule for the 0.22 inch test panels was derived to provide a similar ratio of fiber orientations while resulting in a thickness of less than 0.250”. The test laminate consists of (1) 1708, (3) 5400, and (1) 1708, which has a total areal weight of 214 oz./yd^2 (16 oz./yd^2 stitched mat (7%), 36 oz./yd^2 ±45 (17%), and 162 oz./yd^2 0/90 (76%)). Due to the test laminate having a greater percentage of stitched-mat (non-structural fiber); mechanical testing will produce strength and stiffness values that are lower than the actual pontoon laminate and therefore conservative.

The layup of the 0.95 inch panel is $[V][0/90]_{14}[+-45]_4$. This thicker laminate is required in the regions that will undergo bearing loads at the bolted connections.

The bearing specimens were cut from the 0.95 inch thick panel using a water-cooled diamond-coated wet-saw. The rest the specimens were cut from the 0.22 inch thick panel using waterjet abrasive machining. Final specimen drilling and machining was performed using a milling machine.

Prior to conducting the tests, the specimens were conditioned for a minimum of 48-hours in the laboratory's Mechanical Testing Lab at a standard environment of 70 ±3°F and 50 ±5% RH. The testing was also performed in this Lab at standard environment.

The results of the various tests are summarized in the remainder of this document.

Material Property Test: Tension
Test Method: ASTM D3039 - *Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials*
Date Tested: May 5, 2014

Test Setup: Ten specimens were obtained from the panel at various locations in an effort to capture spatial variability of the properties. The nominal specimen size was 1.0 inch wide by 10 inches long.

A servo-hydraulic Instron test frame equipped with a 22 kip load cell and hydraulic grips was used to perform the tests. The tests were conducted in position control at a cross-head rate of 0.05 inches/minute. A contact extensometer with a gage length of 2.0 inches was used to measure the strain.

Results: The specimen dimensions and results of the tensile tests are presented in Table 1. The table includes the average value and coefficient of variation (CV) for the tensile strength and modulus. The modulus was computed between 1000-3000 micro-strain.

Table 1. Tension Test Results

Specimen	Width	Thickness	Area	Max Force	Strength	Modulus
ID	*in*	*in*	*in^2*	*lb*	*ksi*	*msi*
1	1.018	0.2139	0.2177	9,809	45.06	3.11
2	1.019	0.2145	0.2185	10,152	46.47	3.07
3	1.018	0.2158	0.2198	11,004	50.06	3.10
4	1.019	0.2129	0.2170	10,508	48.42	3.29
5	1.018	0.2147	0.2184	10,707	49.01	3.04
6	1.018	0.2124	0.2162	9,213	42.61	3.00
7	1.018	0.2188	0.2227	10,546	47.35	3.03
8	1.020	0.2164	0.2206	10,361	46.96	3.02
9	1.018	0.2113	0.2151	9,757	45.36	3.23
10	1.019	0.2142	0.2181	9,939	45.56	3.03
Avg	**1.018**	**0.2145**	**0.2184**	**10,200**	**46.69**	**3.09**
CV	0.1%	1.0%	1.0%	5.2%	4.7%	3.1%

Equipment used:

- Mitutoyo Caliper AS# 1199
- Mitutoyo Micrometer AS# 1200
- Instron 22-kip Test Frame AS# 108
- 22-kip Load Cell AS# 269
- Instron Extensometer AS# 1092

Material Property Test: Compression
Test Method: ASTM D6641 - *Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture*
Date Tested: May 10, 2014

Test Setup: Ten specimens were obtained from the panel at various locations in an effort to capture spatial variability of the properties. The nominal specimen size was 1.0 inch wide by 5.5 inches long.

A servo-hydraulic Instron test frame equipped with a 22 kip load cell and hydraulic grips was used to perform the tests. A combined shear and compression loading test fixture was used to conduct the tests. The tests were conducted in position control at a cross-head rate of 0.05 inches/minute. A GOM Aramis digital image correlation (DIC) system was used to measure the strain during the test.

Results: The specimen dimensions and results of the compression tests are presented in Table 2. The table includes the average value and CV for the compressive strength and modulus. The modulus was computed between 1000-3000 micro-strain.

Table 2. Compression Test Results

Specimen	Width	Thickness	Area	Max Force	Strength	Modulus
ID	*in*	*in*	*in ^{2}*	*lb*	*ksi*	*msi*
1	1.018	0.2071	0.2108	10,181	48.30	3.22
2	1.018	0.2118	0.2157	12,825	59.46	3.40
3	1.017	0.2092	0.2129	12,324	57.90	3.50
4	1.018	0.2124	0.2163	13,140	60.76	3.64
5	1.017	0.2154	0.2192	12,118	55.29	3.58
6	1.016	0.2105	0.2139	12,534	58.59	3.04
7	1.018	0.2111	0.2148	11,753	54.72	3.34
8	1.018	0.2169	0.2206	12,517	56.73	3.08
9	1.018	0.2186	0.2225	12,821	57.62	3.44
10	1.018	0.2168	0.2207	12,781	57.90	3.29
Avg	**1.018**	**0.2130**	**0.2167**	**12,299**	**56.73**	**3.35**
CV	0.1%	1.8%	1.8%	6.9%	6.1%	5.9%

Equipment used:

- Mitutoyo Caliper AS# 1199
- Mitutoyo Micrometer AS# 1200
- Instron 22-kip Test Frame AS# 107
- 22-kip Load Cell AS# 268
- CLC Test Fixture AS# 293
- GOM Aramis DIC System AS# 395

Material Property Test: In-Plane Shear
Test Method: ASTM D5379 - *Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method*
Date Tested: May 10, 2014

Test Setup: Ten specimens were obtained from the panel at various locations in an effort to capture spatial variability of the properties. The nominal specimen size was 0.75 inches wide by 3.0 inches long.

A servo-hydraulic Instron test frame equipped with a 5 kip load cell and hydraulic grips was used to perform the tests. An iosepescu (v-notch) test fixture was used to apply the shear loads to the test specimens. The tests were conducted in position control at a cross-head rate of 0.05 inches/minute. A GOM Aramis DIC system was used to measure the strain during the test.

Results: The specimen dimensions and results of the in-plane shear tests are presented in Table 3. The table includes the average value and CV for the in-plane shear strength and modulus. The modulus was computed using a 4000 micro-strain range starting between 2000 and 2400 micro-strain. (The exact same starting strain point was not available for every specimen.)

Table 3. In-Plane Shear Test Results

	Notch					
Specimen	***Width***	***Thickness***	***Area***	**Max Force**	**Strength**	**Modulus**
ID	*in*	*in*	*in* ^{2}	*lb*	*ksi*	*ksi*
1	0.482	0.2123	0.1024	1560	15.24	624.5
2	0.485	0.2137	0.1037	1507	14.53	651.7
3	0.484	0.2159	0.1044	1535	14.70	677.0
4	0.484	0.2098	0.1014	1484	14.63	606.4
5	0.483	0.2126	0.1027	1447	14.09	604.3
6	0.481	0.2067	0.0994	1481	14.90	626.8
7	0.484	0.2155	0.1043	1503	14.41	655.3
8	0.483	0.2098	0.1013	1406	13.88	619.8
9	0.487	0.2168	0.1055	1480	14.03	624.8
10	0.483	0.2138	0.1033	1451	14.05	606.0
Avg	0.484	0.2127	0.1028	1485	14.45	629.7
CV	0.3%	1.5%	1.7%	3.0%	3.0%	3.8%

Equipment used:

- Mitutoyo Caliper AS# 1199
- Mitutoyo Micrometer AS# 1200
- Instron 22-kip Test Frame AS# 107
- 5-kip Load Cell AS# 601
- Shear Test Fixture AS# 301
- GOM Aramis DIC System AS# 395

Material Property Test: Interlaminar Shear
Test Method: ASTM D2344 - *Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates*
Date Tested: May 7, 2014

Test Setup: Ten specimens were obtained from the panel at various locations in an effort to capture spatial variability of the properties. The nominal specimen size was 0.5 inches wide by 1.3 inches long.

A servo-hydraulic Instron test frame equipped with a 5 kip load cell and a 3-point flexure fixture with a support span of 0.85 inches was used to perform the tests. The tests were conducted in position control at a cross-head rate of 0.05 inches/minute.

Results: The specimen dimensions and results of the short-beam shear tests are presented in Table 4. The table includes the average value and CV for the short-beam strength.

Table 4. Short-Beam Strength Test Results

Specimen	Length	Width	Thickness	Area	Max Force	Strength
#	*in*	*in*	*in*	*in ^{2}*	*lb*	*ksi*
1	1.3010	0.5173	0.2066	0.1069	705	4.95
2	1.3025	0.5168	0.2075	0.1072	778	5.44
3	1.3030	0.5163	0.2110	0.1089	756	5.20
4	1.3005	0.5155	0.2126	0.1096	752	5.15
5	1.3055	0.5180	0.2086	0.1080	762	5.29
6	1.3025	0.5165	0.2082	0.1075	762	5.31
7	1.3050	0.5175	0.2166	0.1121	794	5.31
8	1.3025	0.5175	0.2191	0.1134	823	5.44
9	1.3045	0.5165	0.2116	0.1093	863	5.92
10	1.3025	0.5178	0.2142	0.1109	804	5.44
Avg	**1.3030**	**0.5170**	**0.2116**	**0.1094**	**780**	**5.35**
CV	*0.1%*	*0.2%*	*1.9%*	*2.0%*	*5.6%*	*4.8%*

Equipment used:

- Mitutoyo Caliper AS# 1199
- Mitutoyo Micrometer AS# 1200
- Instron 22-kip Test Frame AS# 107
- 5-kip Load Cell AS# 601
- Flexure Fixture AS# 298

Material Property Test: Flexure
Test Method: ASTM D7264 - *Standard Test Method for Flexural Properties of Polymer Matrix Composite Materials*
Date Tested: May 7, 2014

Test Setup: Ten specimens were obtained from the panel at various locations in an effort to capture spatial variability of the properties. The nominal specimen size was 1.0 inch wide by 8.5 inches long.

A servo-hydraulic Instron test frame equipped with a 5-kip load cell and a 3-point flexure fixture with a support span of 7.026 inches were used during the flexure tests. The tests were conducted in position control at a cross-head rate of 0.10 inches/minute.

Results: The specimen dimensions and results of the flexure tests are presented in Table 5. The table includes the average value and CV for the flexural strength and modulus. The modulus was computed between 1000-3000 micro-strain.

Table 5. Flexure Test Results

Specimen	**Length**	**Width**	**Thickness**	**Max Force**	**Strength**	***Modulus***
ID	*in*	*in*	*in*	*lb*	*ksi*	*Msi*
1	8.573	1.0190	0.2093	212.2	50.09	2.92
2	8.568	1.0170	0.2133	228.1	51.95	2.52
3	8.566	1.0169	0.2149	226.7	50.91	2.55
4	8.582	1.0201	0.2125	239.8	54.88	2.83
5	8.590	1.0175	0.2134	225.3	51.23	2.57
6	8.579	1.0171	0.2142	225.6	50.95	2.25
7	8.535	1.0196	0.2148	228.7	51.24	2.55
8	8.581	1.0188	0.2173	228.6	50.08	2.40
9	8.576	1.0176	0.2154	238.1	53.15	2.52
10	8.545	1.0173	0.2056	217.2	53.20	2.73
Avg	**8.5693**	**1.0181**	**0.2131**	**227.0**	**51.77**	**2.58**
CV	*0.2%*	*0.1%*	*1.6%*	*3.6%*	*3.0%*	*7.7%*

Equipment used:

- Mitutoyo Caliper AS# 1199
- Mitutoyo Micrometer AS# 1200
- Instron 22-kip Test Frame AS# 107
- 5-kip Load Cell AS# 601
- Flexure Fixture AS# 298

Material Property Test: Bearing
Test Method: ASTM D953 - *Standard Test Method for Bearing Strength of Plastics*
Date Tested: May 2-5, 2014

Test Setup: Ten specimens were obtained from the panel. The nominal specimen size was 4 inches wide by 10.5 inches long.

A servo-hydraulic Instron test frame equipped with a 110-kip load cell and hydraulic grips was used to perform the tests. A pin-bearing fixture was used to support the specimen at one end while load was applied to the 15/16 inch hole via a 7/8 inch hardened steel pin at the other end. The tests were conducted in position control at a cross-head rate of 0.05 inches/minute.

Results: The specimen dimensions and results of the bearing tests are presented in Table 6. The table includes the average value and CV for the bearing strength at the first drop in load and at the ultimate load.

Table 6. Bearing Strength Test Results

Specimen	Length	Width	Thickness	Bearing Area	Force		Strength	
					First drop	*Ultimate*	*First drop*	*Ultimate*
#	*in*	*in*	*in*	*in* ^{2}	*lb*	*lb*	*ksi*	*ksi*
1	10.568	3.893	0.9115	0.8546	31,612	43,884	36.99	51.35
2	10.561	3.898	0.9268	0.8689	30,560	44,687	35.17	51.43
3	10.582	3.911	0.9180	0.8607	32,528	47,172	37.79	54.81
4	10.597	3.919	0.9187	0.8613	31,094	47,435	36.10	55.07
5	10.597	3.913	0.9235	0.8658	32,300	46,844	37.31	54.10
6	10.578	3.906	0.9084	0.8516	30,893	47,596	36.27	55.89
7	10.561	3.910	0.9281	0.8701	32,271	48,100	37.09	55.28
8	10.555	3.904	0.9188	0.8613	30,582	47,051	35.51	54.63
9	10.538	3.907	0.9187	0.8613	28,811	44,843	33.45	52.07
10	10.543	3.897	0.9172	0.8598	30,876	45,465	35.91	52.88
11	10.573	3.906	0.9221	0.8645	28,654	39,486	33.14	45.67
Avg	**10.568**	**3.906**	**0.919**	**0.862**	**30,926**	**45,687**	**35.89**	**53.02**
CV	***0.2%***	***0.2%***	***0.6%***	***0.6%***	***4.2%***	***5.4%***	***4.2%***	***5.5%***

Equipment used:

- Mitutoyo Caliper AS# 1199
- Mitutoyo Micrometer AS# 1200
- Instron 110-kipTest Frame AS# 270
- 110-kip Load Cell AS# 110

Material Property Test: Coefficient of Thermal Expansion
Test Method: ASTM D696 - *Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C with a Vitreous Silica Dilatometer*
Date Tested: May 8-12, 2014

Test Setup: Ten specimens were obtained from the panel at various locations in an effort to capture spatial variability of the properties. The nominal specimen size was 0.5 inches wide by 2.0 inches long.

Two constant temperature baths (-22°F and 86°F) were used with a quartz dilatometer to conduct this testing as outlined in the standard. The specimens were kept in the bath until the deflection stabilized as indicated by an attached precision measuring device.

Results: The specimen dimensions and results of the coefficient of thermal expansion (CTE) tests are presented in Table 7. The table includes the average value and CV for the CTE.

Table 7. Coefficient of Thermal Expansion Test Results

Specimen	Length at room temp	Average change in length	CTE
#	*in*	*in*	*/°F x10^{-6}*
1	2.0335	0.001917	8.73
2	2.0350	0.001950	8.88
3	2.0300	0.001950	8.88
4	2.0325	0.001925	8.77
5	2.0380	0.001925	8.77
6	2.0370	0.001875	8.54
7	2.0345	0.001900	8.65
8	2.0360	0.001950	8.88
9	2.0375	0.001950	8.88
10	2.0380	0.001900	8.65
Avg	2.0352	0.001924	8.76
CV	0.13%	1.38%	1.38%

Equipment used:

- Mitutoyo Caliper AS# 1199
- Mitutoyo Micrometer AS# 1200
- VWR Scientific Bath (+30°C) AS# 226
- VWR Scientific Bath (-30°C) AS# 208
- Tinius Olsen Dilatometer AS# 609`
- Mitutoyo Digital Gage AS# 725

THIS RESULT IS ACCEPTABLE. THIS WILL RESULT IN APPROXIMATELY 1/8" OF ADDITIONAL TOTAL MOVEMENT AT EACH END OF THE FRP RAFT SPAN (259 FT SPAN)

Material Property Test: Coefficient of Friction
Test Method: ASTM D1894 - *Standard Test Method for Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting*
Date Tested: May 12-20

Test Setup: Ten specimens were obtained from the panel at various locations in an effort to capture spatial variability of the properties. The nominal specimen size was 2.5 inches by 2.5 inches for the sled attachment, while the base section was 5.0 inches wide by 10 inches long.

The testing was conducted on a servo hydraulic Instron test frame equipped with a 56 pound load cell. A test fixture with a pulley and base attachment was used during the testing. The mass of the specimen sled was 4197 grams. The specimens were tested using the mold surface as the contact surface. The specimens were tested in a wet condition by adding water to the contact surfaces. Two different tests were conducted; original surface (as received) and with a bead-blasted surface. The glass bead blasting media used to prepare the surface was a 60-120 mesh applied at 80 psi.

Results: The results of the testing are presented in Table 8. The table includes both static and kinetic friction results for the two different tests conducted. Two trials were conducted with each specimen, so the results presented are the average value of the two trials.

Table 8. Coefficient of Friction Test Results

Specimen		***Original Surface, Wet***				***Bead-Blasted Surface, Wet***			
		Force		**Coefficient of Friction**		**Force**		**Coefficient of Friction**	
#	mass (g)	static g	kinetic g	static	kinetic	static g	kinetic g	static	kinetic
1	41.083	1733	1521	0.41	0.36	2328	2154	0.55	0.51
2	40.722	1549	1489	0.37	0.35	2497	2318	0.59	0.55
3	41.157	1472	1507	0.35	0.36	2694	2339	0.64	0.55
4	41.484	1535	1388	0.36	0.33	2430	2163	0.57	0.51
5	41.693	1662	1498	0.39	0.35	2260	1950	0.53	0.46
6	40.485	1474	1534	0.35	0.36	2561	1912	0.60	0.45
7	42.103	1614	1386	0.38	0.33	2518	2280	0.59	0.54
8	41.082	1623	1541	0.38	0.36	2535	2329	0.60	0.55
9	41.125	1705	1490	0.40	0.35	2334	2208	0.55	0.52
10	40.698	1561	1572	0.37	0.37	2303	2116	0.54	0.50
Avg	41.163	1593	1493	**0.38**	**0.35**	2446	2177	**0.58**	**0.51**
CV	1.2%	5.7%	4.1%	5.7%	4.1%	5.7%	7.0%	5.7%	7.0%

Equipment used:

- Mitutoyo Caliper AS# 1199
- Mitutoyo Micrometer AS# 1200
- Instron 5-kip Test Frame AS# 511
- 56 lb. Load Cell AS# 611

Material Property Test: Water Absorption
Test Method: ASTM D570 - *Standard Test Method for Water Absorption of Plastics*
Date Tested: May 12-20

Test Setup: Ten specimens were obtained from the panel at various locations in an effort to capture spatial variability of the properties. The nominal specimen size was 1.0 inch wide by 3.0 inches long. The specimens were weighed while dry and then submerged in a bath of deionized water in a standard environment. The specimens were periodically removed from the bath, dried weighed, and then returned to soak in the bath.

Results: The results of the 24-hr soak and the 1-week soak time are presented in Table 9. The table includes the mean value and CV for the water absorption of the specimens.

Table 9. Water Absorption Test Results

Specimen	Dimensions			Dry Weight	24 Hour Soak		1 Week Soak	
	Length	Width	Thickness		Weight (g)	Water Absorption	Weight (g)	Water Absorption
#	in	in	in	g	g		g	
1	2.9775	1.0190	0.20909	19.7906	19.8003	0.05%	19.8035	0.07%
2	2.9800	1.0175	0.21157	19.6936	19.7135	0.10%	19.7099	0.08%
3	2.9920	1.0185	0.21157	20.0207	20.0402	0.10%	20.0430	0.11%
4	2.9820	1.0175	0.22018	19.8197	19.8388	0.10%	19.8383	0.09%
5	2.9805	1.0170	0.20893	19.3718	19.3891	0.09%	19.3950	0.12%
6	2.9855	1.0250	0.21673	19.9215	19.9320	0.05%	19.9427	0.11%
7	2.9845	1.0195	0.20565	19.8210	19.8419	0.11%	19.8526	0.16%
8	2.9945	1.0190	0.21005	19.9727	19.9795	0.03%	19.9889	0.08%
9	3.0665	1.0195	0.20873	20.1635	20.1745	0.05%	20.1808	0.09%
10	2.9795	1.0180	0.20752	19.7021	19.7132	0.06%	19.7155	0.07%
Avg	2.9923	1.0191	0.21100	19.8277	19.8423	0.07%	19.8470	0.10%
CV	0.9%	0.2%	2.1%	1.1%	1.1%	36.1%	1.1%	29.0%

Equipment used:

- Mitutoyo Caliper AS# 1199
- Mitutoyo Micrometer AS# 1200
- Ohaus Scale AS# 657

Rev 1 Changes

Item	Description	Resolution
1	Testing facility is to be submitted for approval	UMaine ASCS ISO 17025 Certificate is attached along with their quality manual
2	Design calculations should be resubmitted to address changes in predicted properties	Design calculations Rev 4 is attached to include all computations with actual strength, stiffness, and thickness values
3	The 0.22” thick test laminate is not considered an equivalent partial thickness	See page 40 for a justification of the selected laminate and resolution
4	The true thickness of the laminate should be carried through the design calculations	Design calculations Rev 4 is attached – some variability, however minimal, is inherent in the fabrication process – minimum thickness used is 0.492”/0.950”
5	Testing is to occur at an ISO 17025 facility	UMaine has repeated the three physical test procedures and the report is attached
6	Minimum of 10 specimens shall be tested	UMaine has repeated the tests with a minimum of 10 specimens
7	Is grit blasting reproducible in a production environment?	Kenway will use the same media following the same procedure – see page 40 for resolution

International Accreditation Service

CERTIFICATE OF ACCREDITATION

This is to signify that

ADVANCED STRUCTURES AND COMPOSITES CENTER, UNIVERSITY OF MAINE

35 FLAGSTAFF ROAD
ORONO, MAINE 04469

Testing Laboratory TL-255

has met the requirements of the IAS Accreditation Criteria for Testing Laboratories (AC89), has demonstrated compliance with ANS/ISO/IEC Standard 17025:2005, *General requirements for the competence of testing and calibration laboratories*, and has been accredited, commencing August 14, 2012, for the test methods listed in the approved scope of accreditation.

Patrick V. McCullen
Vice President

C. P. Ramani, P.E.
President

ACCREDITED

(see attached scope of accreditation for fields of testing and accredited test methods)

Print Date: 09/19/2012

International Accreditation Service

SCOPE OF ACCREDITATION

Advanced Structures and Composites Center, University of Maine TL-255

Advanced Structures and Composites Center, University of Maine
35 Flagstaff Road
Orono, ME 04469

Olivia Sanchez
ISO Coordinator
(207) 581-2052

FIELDS OF TESTING	ACCREDITED TEST METHODS
Plastic Materials	ASTM Standards D 256, D 635, D 638, D 695, D 696, D 790, D 792, D 953, D 2765 (Test methods A and C), D 3846, D 4065, D 4812, D 6109 and D 6110
Wood Products and Materials	ASTM Standards D 143 (excluding Sections 10 and 11), D 198 (excluding Sections 21-28 and 37-44), D 245, D 1037, D 2395, D 2555, D 3737, D 4442, D 4761, D 4933, D 5456 and D 6815
Composite Materials	ASTM Standards C 393, D 2344, D 2584, D 3039, D 3410, D 3479, D 3518, D 4255, D 5379, D 5528, D 5766, D 6115, D 6641 and F 1679
Adhesives	ASTM Standards D 905, D 1101, D 2339, D 2559, D 3165 and D 5868
Structural Panels and Assemblies	ASTM Standards C 273, D 7032 (excluding Sections 4.8 and 4.9), E 72 (Transverse load only), E 564 and E 2126; Test methods referenced in Section 4.0 of ICC-ES Acceptance Criteria AC273 (excluding Section 4.2.8) BS EN 408
Fasteners	ASTM Standard D 1761
Full-scale Structural Testing of WT Rotor Blades	IEC TS 61400-23

August 14, 2012
Commencement Date

IAS ACCREDITED

C. P. Ramani, P.E.
President

Print Date: 09/19/2012

Advanced Structures & Composites Center
QUALITY SYSTEM MANUAL
Issue B Rev.5

May 2014

Advanced Structures and Composites Center
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Important Notice: Hard copies of this document are not controlled and may not be the document currently in effect. The current controlled copy is on the Center network.

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Section 1: GENERAL OVERVIEW

Scope:

This Manual describes the Quality System used by the Advanced Structures & Composite Center (Center) establishing policies for management, laboratory operations and client service which ensure:

- the delivery of quality services;
- compliance with contractual and statutory requirements; and
- systematic reduction, elimination and prevention of quality deficiencies.

The Quality System is based on the applicable requirements of ISO/IEC 17025:2005.

Application:

The Quality System described in this Manual and supporting Standard Operating Procedures is applicable to all Center related work undertaken by Center personnel.

The Standard Operating Procedures and Work Instructions referenced in this document provide the procedures that put the quality system into effect.

Reference Documents:

ISO/IEC 17025:2005: General requirements for the competence of testing and calibration laboratories.

Unless otherwise specified, all standards referred to are the latest editions.

Definitions:

Service: The result of activities or processes. The term "service" is used throughout the Quality System documentation to denote contract research, development, product testing/qualification or a combination thereof and applies to "intended service" only.

Quality System: The organizational structure, responsibilities, procedures, processes and resources for implementing quality management.

Subcontractor: Person or company engaged by the Center to conduct any of the work included in the Center's scope of work.

Profile:

The Advanced Structures and Composites Center, a University of Maine research unit, is a global leader in research, development, and product testing/qualification of advanced structures and composites for public and private organizations. The Center conducts research leading to commercial development of the next generation of cost-effective, high-performance, composite materials.

The Center occupies an 84,000ft^2 complex at the University of Maine, Orono, Maine. In-house capabilities allow developing a composite material or structure from the conceptual stage through research, manufacturing of pilot- or full-scale prototypes, and subsequent, comprehensive testing and evaluation. The Center houses laboratories for composite materials manufacturing, polymer/interface science, nanocomposites R&D, environmental-durability testing, mechanical testing, nondestructive evaluation (NDE), advanced microscopy, resin infusion of composites and large-scale multi degree-of-freedom static and dynamic structural testing, as well as pilot plants for the manufacture of strand composites and wood plastic composites.

The 35,000ft^2 Offshore Wind Laboratory (OWL) has the capability of testing large high-performance hybrid composite structures. The OWL includes a structural test stand and other testing foundations required to test prototype composite components for wind energy applications, including wind blades, and floating structures up to 70 meters in length. The facility also contains environmental chambers and immersion tanks to perform durability testing of materials exposed to extreme marine environments.

Center faculty and research staff offer a wide variety of experience in multiple fields, including structural engineering, mechanical engineering, materials science, and composite manufacturing and testing. Current research initiatives include cutting-edge technology development for deepwater offshore wind, automated manufacturing, public infrastructure, consumer products, residential and light commercial construction, force protection, and homeland security.

The Center routinely conducts a broad menu of ASTM standard tests, as well as custom tests designed and performed to fill specific needs. These capabilities ensure that materials and structures under development receive an appropriately conceived and executed battery of evaluations.

ISO/IEC 17025:2005 quality systems, as outlined in this Manual, have been implemented to ensure that all client requirements are satisfied. The Quality System is applicable to all departments and to all activities undertaken by the Center.

Quality Policy Statement:

The Advanced Structures & Composites Center is dedicated to research, development and education focused on the material science and structural applications of wood-nonwood hybrid composites. Center conducts contract research, development, and product testing/qualification for public and private organizations throughout the world.

The mission of the Center is:

- ♦ To develop the underlying science and engineering principles needed to produce low-cost, high-performance structural composites.

- To support current and emerging industries as well as government agencies that produce/use these products by providing testing, engineering and consulting services.

- To actively pursue commercialization, entrepreneurship, and job creation in Maine, and beyond.

To achieve the above objectives and satisfy client expectations, the Center is committed to implementing and maintaining a Quality Management System based on ISO 17025:2005.

Quality issues arising in various areas are to be identified and solved with speed, technical proficiency and economy. The Center focuses resources, both material and human, toward the prevention of quality deficiencies to satisfy the organizational goal of "right first time...every time". All employees are responsible for the quality of their own work and will not pass on work of inferior quality.

The successful operation of the Advanced Structures & Composites Center Quality System relies upon the cooperation and involvement of personnel at all levels. Our commitment to quality and continuous improvement will ensure the continued success of our Center and the satisfaction of clients and staff.

The Quality Manager is authorized to ensure that the requirements of this Quality System are implemented. Any problems that cannot be resolved are brought to management attention for final resolution.

This policy applies to all areas of the Center.

Habib J. Dagher, Ph.D., P.E.
Director

Stephen Shaler, Ph.D
Associate Director

Section 2: Management System

1) Quality Policy:

The Director and Associate Director with executive responsibility for quality have formally issued the Quality Policy Statement (Section 1). Center management ensures that this quality policy is understood, implemented and maintained at all levels of the organization. This is achieved by:

a) the proper education of all personnel to the Quality System;

b) the display of the Quality Policy Statement at prominent locations;

c) regular reviews and audits of quality procedures (to verify their implementation and effectiveness).

The Quality System at the Advanced Structures & Composites Center includes ISO/IEC 17025:2005, the Quality System Manual, Laboratory Safety Plan Rev 10, and supporting Standard Operating Procedures (SOP).

2) Policy on Independence, Confidentiality, and Impartiality

It is the responsibility of all staff members to ensure that they understand the Advanced Structures and Composites Center and University of Maine's policies on Independence, Confidentiality, and Impartiality.

a. **Conflict of Interest:** A conflict of interest occurs when personal, family or financial interests interfere, or could appear to interfere, with the interests of the Center or the client thus preventing personnel from executing their duties and responsibilities in an ethical, professional and transparent manner. All staff members are to act in accordance with the University of Maine's conflict of interest policies, which can be found on the following University of Maine System websites.

http://www.orsp.umesp.maine.edu/ORSPDocs/Policies/ConflictofInterestinResearch.htm
http://www.umaine.edu/hr/policies/conflict.html
http://www.umaine.edu/purchasing/purchasing-policy/conflict-of-interest/

b. **Confidential and Proprietary Information:** Confidential information includes: client and employee records; research and technical data; manufacturing techniques and processes; other know-how, inventions and discoveries; financial results and information pertaining to clients served by the Center.

Any authorized communication of confidential information, internally or externally, should be limited to individuals who have a "need to know" for the purpose of fulfilling their role. As some confidential information held by the Center belongs to third parties, personnel must also consider what third-party consents may be required prior to any disclosure to persons outside the Center. All appropriate confidentiality agreements must be in place with third parties prior to sharing confidential information.

c. **Impartiality and Independence:** All activities carried out by Center staff are governed by the principles of independence, impartiality and integrity, so as to ensure that final results reported to clients are based on objective evidence and not influenced by other interests or parties.

3) Organization:

a) **Management Team:** The management team is comprised of the Director, the Associate Director, Center Operations Manager, Assistant Directors, and others at the discretion of the Director. Its purpose is to ensure that top management is provided with broad input representing the various interests of the Center in key decisions. This team ensures the continuing suitability, effectiveness, and integrity of the Quality Management System.

b) **Center Operations Manager** manages the day-to-day safety and activities of the Center and represents the management team on the Quality Council. Center Operations Manager:

(1) approves SOPs;
(2) ensures conformance with the Quality System; and
(3) with the Quality Manager, ensures that actions identified during management review are implemented.

c) **Technical Manager:** The technical manager has overall responsibility for the technical operations and the provision of the resources needed to ensure the required quality of laboratory operations.

d) **Quality Manager:**

(1) The Center's Quality Manager is responsible for and is given the authority to:
   i. ensure that the requirements specified in this Manual are implemented and maintained;
   ii. report on the performance of the Quality System to management. At a minimum, one annual review is held at a management team meeting for consideration during its annual Quality System review. The report will include the outcome of internal audits, a summary of corrective and preventive actions, assessments by external bodies, results of proficiency tests, client feedback, and complaints;
   iii. coordinate with various internal departments or external bodies on matters relating to the Center's Quality System.
(2) The Quality Manager has direct access to the Director.
(3) The Quality Manager has full organizational freedom to resolve any work or services not conforming to the requirements of the Quality System.
(4) The Quality Manager serves as the chair of the Quality Council with responsibilities for calling meetings, preparing agendas, and bringing any other relevant matters before the Council.
(5) The Quality Manager administers, controls, reviews and distributes the Quality Manual and Standard Operating Procedures.
(6) The Quality Manager implements a protocol for internal audits including scheduling, training and assignment of auditors, and maintenance of audit results.

(7) The Quality Manager ensures the quality of test results by enrolling the Center in proficiency testing programs.
   i. The Quality Manager reviews the PT reports and if necessary, initiates a Corrective Action Request to investigate and resolve the cause of any outlying data.

(8) The Quality Manager serves as liaison with the International Accreditation Service (IAS).

(9) The Quality Manager maintains a register of controlled documents that identifies the current revision status of each.

e) Quality Council - The mission of the Center Quality Council is to create, maintain, enforce and evaluate the Quality Management System for the Center. This System provides the context and controls for excellence in all Center operations including research, product testing and development, and client service.

(1) Membership of the Quality Council:
   i. The Quality Manager serves as the Quality Management Representative and chair of the Quality Council.
   ii. The Center Operations Manager serves as the management team representative.
   iii. The Laboratory Operations Manager (LOM), the Manager of Funded Accounts (MFA), and the Communications Specialist all serve as ex officio members of the Council.
   iv. One or more faculty members will serve on the Council.
   v. A graduate student representative may be appointed by the Quality Council to act as an observer at Council meetings. These representatives will be recused during discussions of specific personnel-related non-conformances.

(2) Duties of the Quality Council:
   i. To maintain, review and periodically revise the Quality System.
   ii. To perform internal audits of the Quality System to ensure continual compliance with the Center quality documents and ISO 17025:2005.
   iii. To review non-conformance request reports to ensure that corrective actions have been implemented.
   iv. To assist the Quality Manager with preparation and implementation of periodic IAS audits.
   v. To educate all Center staff concerning the Quality Management System.
   vi. To attend scheduled Quality Council meetings.

f) Center Personnel

(1) The Center organization chart (page 18) shows the interrelationship of positions and functions within the Center and the paths of responsibility and authority in relation to quality.

(2) All Center employees are to adhere to the University of Maine Employee Responsibilities, Conflict of Interest, and Misconduct in Research policies.

(3) Personnel evaluations are conducted per University of Maine System Board of Trustees policy, appropriate collective bargaining agreements, and the University of Maine Employee Information & Resource Guide.

(4) The responsibility, authority and interrelationship of every person who manages, performs and verifies work affecting quality are defined in job descriptions. These are issued to all personnel and maintained in personnel files.

(5) All personnel shall, when required, delegate responsibilities and authority to others as specified in their job descriptions. All personnel have the authority to stop work on nonconforming services.

(6) All Center employees have the responsibility to initiate a Corrective Action or Preventive Action when they observe either a technical or management system nonconformity or an opportunity for improvement. AEWC SOP-05 is to be followed. In some cases, employees may be asked to assist in the implementation and verification of the effectiveness of the action taken to resolve the request.

2) Internal Audits:

a) **Frequency**. Internal quality audits are undertaken by members of the Quality Council and performed annually.

b) **Scheduling.** The Quality Manager schedules and assigns the internal audits with the auditors. Whenever possible, auditors are independent of the function being audited.

c) **Findings.** The Quality Manager prepares an internal audit findings report that is presented to the management team for the team's review.

d) **Follow-up**. Action reports generated from internal audits are resolved per AEWC SOP-05.

3) Management Review:

a) **Purpose.** Management reviews the Center Quality System annually to ensure its continued suitability and effectiveness in satisfying:

(1) Stated Center policy and objectives;
(2) Client expectations and needs; and
(3) Quality standard ISO /IEC 17025:2005

b) **Meeting**. The review is carried out during the first quarter of the calendar year and chaired by the Director and attended by the management team and the Quality Manager.

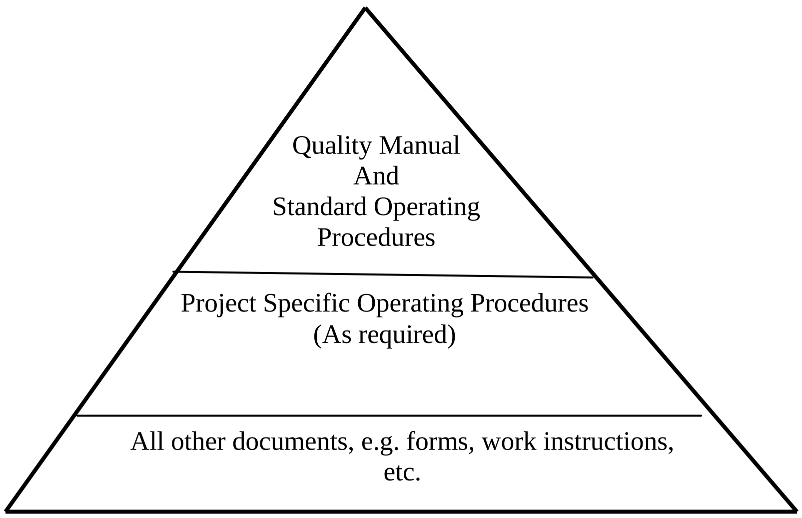
c) **Scope**. During the review, management will effectively utilize all available information, including internal and external quality audit results, client and third party complaints, quality targets (policy and objectives), non-conformance, corrective and preventive actions, to improve the system.

d) **Documentation**. Any corrective or preventive actions resulting from the meeting are documented per AEWC SOP-05 The personnel concerned implement the resulting decisions.

e) **Adequacy of resources and personnel** are reviewed annually. Resources and personnel requirements are also reviewed as part of contract or order review.

4) Document and Record Control:

a) **General.** Center Quality System ensures that only current, approved and valid documents are used for laboratory activities and records are maintained for those activities. Documents and records include: Quality Manual and SOPs; reports from internal audits; management reviews; work instructions; equipment calibration and maintenance records; as well as external documents including manuals and ASTM standards. This system produces a three-tier structure.



The Quality Manual and associated Standard Operating Procedures are the first-tier documents. They describe and include general management policy and procedures with regard to quality, organizational structure and responsibilities. It may be supplemented by project operating procedures. All employees are to ensure documents used are current prior to use.

b) **Documents.** Documents include the Quality Manual, Safety Manual, associated SOPs and associated forms. All Center documents included in the Quality System carry unique identifiers – date of issue, revision status, page numbering using page x of y, and issuing authority.

(1) The Center Quality Manager is responsible for the collection, indexing, filing, storage, maintenance and disposal of all Center Quality System documents; this authority will be delegated to project managers and/or other staff (LOM, Communications Specialist, Grants Manager, for instance) when appropriate.

(2) Document Approval and Issue – The Center Quality Council reviews, as needed, the document control system and revises, if necessary, to ensure continuing suitability and compliance with applicable requirements.

(3) Document Changes - Document changes shall be reviewed and accepted by the Quality Manager and approved by the Quality Council. Where practicable, altered or new text shall be identified. Hand amendments and changes are not allowed and will not be considered as an official document change. This policy also applies to documents maintained in electronic format.

The Quality Manager shall promptly remove invalid and/or obsolete documents to assure against unintended use; obsolete documents retained for either legal or knowledge preservation are archived.

To preclude the use of invalid and/or obsolete documents, the Quality Manager maintains a master list identifying current revision status. The Coordinator also determines the accessibility of documents based on need-to-know and ensures availability at all locations where operations essential to the effective functioning of Center laboratories are performed.

c) Records. The Center Quality System ensures the traceability of data and information concerning laboratory testing through its recordkeeping. Records include: action request reports; proposals, contracts and communication with clients; personnel records, training records, purchase orders, work notes, clients' notes and feedback, and technical reports.

(1) The Quality Manager stores records pertaining to the Quality System, including internal audit reports, external assessment reports, management review minutes, and action reports.

(2) The LOM maintains records pertaining to the operation, maintenance, calibration of laboratory equipment and laboratory training records.

(3) Project-related records are stored with project files by the responsible PI/PM. Records for each test shall contain sufficient information to establish an audit trail; to identify factors affecting uncertainty; and to enable repetition of the test under conditions as close as possible to the original.

(4) Financial records for projects are maintained by the MFA. This includes the project contracts, budget, and purchase orders.

(5) When computers or automated equipment are used for the acquisition, processing, recording, reporting, storage or retrieval of test data, software will be sufficiently validated.[1] Excel spreadsheets used to analyze data will be validated following AEWC SOP-02.

d) Information Security. All Center Quality System documents and records – relating to policy, operations, and client information- are stored on a Center server which is maintained and backed up daily by the University of Maine IT department. To prevent unauthorized access or amendment, records will be stored in password protected folders on the Center servers. The Project Manager and/or the Quality Manager determines the accessibility of the documents and records based on need-to-know. The Center's Information Security Procedure (AEWC SOP-04) provides information on what is required to be stored on the Center network and how it is maintained.

5) Impartiality and Conflict of Interest

a) The Advanced Structures and Composites Center follows the University policies and procedures to insure that employees are free from internal and external pressures that can affect the quality of the work. The purpose of the policy is to ensure continued confidence of the people of Maine in the

[1] Commercial software will be considered sufficiently validated; software developed by Center personnel will be sufficiently detailed and validated as adequate for use.

University, personnel engaged in extramurally funded work shall act at all times in a manner consistent with their public responsibilities to the University and shall exercise particular care that no detriment to the University results from conflicts between their personal financial interests and the interests of the University. The procedure for training all employees of the Center can be found in SOP –xx-yy

Section 3: Laboratory Operations

1) Safety:

The Advanced Structures and Composites Center Laboratory Safety Plan ensures that the Center provides a safe work environment. The Center Safety Coordinator establishes and maintains this document in accordance with OSHA Guideline 29 CFR Part 1910.

a) **Safety Committee.** The Center Safety Committee chaired by Center Safety Coordinator with members from all sections of the Center meets as needed to discuss safety issues.

b) **Training.** The LOM maintains all training records relevant to working in Center laboratories.
   (1) Safety - Prior to working in any Center laboratories, faculty, staff and students must complete all safety training as outlined in the Laboratory Safety Plan.
   (2) Equipment – Personnel are to be trained on any designated, specialized equipment prior to operation of this equipment.
   (3) Testing – PI/PMs are responsible for ensuring personnel working on test projects have been trained to perform the ASTM tests requested by the client.

c) **Access.** A list of personnel authorized to work in the Center labs is maintained by the LOM. Center Laboratories are open from 7am to 5pm during normal business days. Requests for lab use after hours must be approved by the LOM using the After Hours Lab Request form (FM/AR/19).

2) Corrective and Preventive Action:

All Center employees are authorized and encouraged to file the appropriate form when they observe a non-conformance (corrective action) or a potential non-conformance (preventative action). AEWC SOP-05 is to be followed.

3) Facilities:

Testing, manufacturing, and other research and development activities are conducted in one of the ten task specific areas included in the 84,000-sq.ft Center building. These areas are:

- Offshore Wind Lab
- Structural Testing Lab
- Mechanical Testing Lab
- Wood-Plastic Composites Pilot Plant
- Strand Composites Pilot Plant
- Environmental Testing Lab
- Polymer and Interface Science Lab
- Micromechanics and Non-Destructive Evaluation Lab
- Microscopy Lab
- Resin Infusion Composites Reliability (RICoR) Lab

- Nano-composite Lab
- Wood Shop

4) Accommodations:

Environmental conditions are controlled and monitored by the LOM in the following areas:

- Mechanical Testing Lab
- Polymer and Interface Science Lab
- Micromechanics and Non-Destructive Evaluation Lab
- Microscopy Lab
- Resin Infusion Composites Reliability (RICoR) Lab

5) Equipment:

a) **Labeling.** All laboratory equipment is assigned a unique AEWC equipment number. A complete list of equipment is maintained by the LOM. All new equipment is assigned a unique number and logged into the equipment database by the LOM. When applicable, all equipment will be verified to ensure it operates as specified by the manufacturer before being released for general use by using the New Equipment Acceptance Checklist (FM/AR/37).

b) **Calibration and Maintenance.** Calibration records for equipment requiring periodic calibration can be found in the LOM's office. The LOM schedules all calibrations and maintenance with appropriate ISO 17025:2005 accredited calibration labs.

Maintenance records are kept in the LOM's office in the appropriate equipment folder.

c) **Storage and Handling of Measuring Devices.** The LOM will ensure that all measuring devices are carefully handled, preserved and stored such that accuracy and fitness for use is maintained, and are safeguarded from adjustments that would invalidate the calibration settings.

d) **Usage.** Only authorized personnel are allowed to use testing and manufacturing equipment. The LOM maintains the database of authorized personnel for applicable equipment.

6) Scheduling:

The LOM maintains the Center equipment schedule calendar on the University of Maine intranet.

7) Project Material:

This includes material for use by the project purchased by the Center and material and test samples provided by the client.

a) **Receiving and Shipping:**

a. Standard shipments are received by the administrative assistant in the front office. The PI/PM/Laboratory staff that initiated the order will be notified. Project staff verifies the accuracy and condition of the materials/samples.
    i. Freight and chemical shipments are received via the lab by lab operations staff.
b. Upmost care will be taken to insure material shipped from the Center are protected and arrive at their destination in good condition.

b) Labeling. All project-related material is to be labeled upon receipt with the following information:
(1) PI/PM responsible
(2) Project number
(3) Contact phone number
(4) Date received
(5) Number of containers/packages, if more than one.
(6) Chemical label, if necessary (obtained from LOM)

c) Storage. The PI/PM should notify the LOM if the material is to be kept in an environmentally controlled room or in a secured location. Materials not requiring special accommodations are to be stored near the project site.

d) Disposal. All tested material will be disposed of at the completion of the project unless otherwise stated by the client. Any chemicals or chemical containers to be disposed of must follow the chemical hygiene plan outlined in the Laboratory Safety Plan, Section Four.

Section 4: Project Lifecycle

1) General:

This section provides the general guidelines for establishing and conducting a project at the Center. AEWC SOP-12 outlines the procedures for establishing a project administered through the University of Maine Department of Industrial Cooperation. Procedures for establishing a federally funded project administered through the University's Office of Sponsored and Research Programs follow the University of Maine OSRP guidelines.

2) Request for Services:

Requests for services are received from either industrial clients, from state or federal agencies or other units of the University of Maine. The PI/PM receiving the request is to follow the appropriate proposal reviewing procedure as outlined in Section 3 below before submitting a formal proposal to any client.

3) Writing/Reviewing Proposals:

Proposals to be submitted to clients should include sufficient information to explain the service to be provided to the client, including scope of work, deliverables and cost. Prior to being submitted to the client, all proposals are reviewed by the MFA, Center Operations Manger, and the LOM to ensure the Center has all the necessary resources to perform the work requested by the client. Proposals must also follow appropriate University of Maine procedures as mandated by the Department of Industrial Cooperation or the Office of Research and Sponsored Programs, depending on the funding source.

Amendments or changes to the original scope of work must be approved by both the PI/PM and the client in writing.

4) Obtaining a Project Number:

Establishment of a project number authorizes the PI/PM to begin work on the project. This number is also used for tracking project material and supplies received through the life of the project. Project numbers are assigned by the MFA after the proposal for work has been signed by the client and returned to Center. If the PI/PM would like to begin work without the signed contracts, the PI/PM must provide an alternative, active project number to which incurred expenses will be charged in the event the PI/PM begins work without the client signature on the contracts.

5) Project Guidelines

a) **Sampling Plan.** The Center does not perform sampling.

b) **Training.** All personnel who work in the Center laboratories must be trained on the equipment to be used or test method to be performed as described in the Laboratory Operations, Section 3 (1)(b) of this Quality Manual.

c) Traceability. Client provided specimens are to be labeled upon receipt as described in Section 3, Clause 6b. Specimens that are fabricated as part of the project are to be labeled at the time of fabrication. The Specimen Preparation and Labeling Procedure (Center SOP-08) provides guidelines for both scenarios.

d) Test Methods. Unless requested by the client, current ASTM standards are to be used. Current ASTM standards can be obtained by the Quality Manager through the University of Maine Fogler Library.

- **i.** If the Center cannot perform the requested test method, the PI/PM must notify the client. The Center does not subcontract test methods the lab is unable to perform. In the event the client requests the PI/PM's assistance in obtaining a subcontract for such testing, Subcontractors used for testing are to be an ISO 17025:2005 accredited laboratory, unless stated otherwise by the client.
- **ii.** Datasheets created are to be reviewed and validated following AEWC SOP-02.
- **iii.** Measurement uncertainty is to be calculated at the request of the client or if a new test procedure is developed.

e) Corrective Action Requests. Work being conducted in the Center laboratories that is not following the required work instruction or test standard will be investigated. The PI/PM will be notified and, if necessary, the Non-Conformance online form will be filled out and resolved for the nonconforming work following the procedures outlined in AEWC SOP-05. The client will be notified when appropriate.

f) Report Writing/Review. Project reports are written by the Project Manager or his/her designee according to the requirements of the client as specified in the project contract. Prior to being submitted to the client, the report undergoes independent, internal review to ensure its compliance with the requirements of ISO/IEC 17025:2005, Section 5.10 and AEWC SOP-06. The project's PI/PM is authorized to issue the test report after it has undergone the review process.

6) Purchasing:

Purchases for supplies and services that affect the quality of service must be from approved vendors.

a) Evaluation and Approval of Vendors. The MFA maintains a database of approved vendors. Vendors are reviewed and approved based on one of the following criteria:

(1) Has a registered quality system (i.e. ISO 9001). Vendors used to calibrate Center equipment must be ISO 17025:2005 accredited calibration laboratories, with the item to be calibrated listed on their scope of accreditation. The LOM maintains records of all calibration laboratories used.

(2) Is a vendor of record.

(3) Is a vendor of reputation.
(4) Has been audited by Center for compliance with ISO 17025:2005.

The University of Maine Purchasing Department maintains a list of non-approved vendors. Reasons for placing a vendor on the non-approved list include, but are not limited to:

(5) Poor invoicing/billing terms.
(6) Poor client service.
(7) Repeat receipt of faulty material.

b) Purchasing Process. The Purchase/Reimbursement Request Form ("PRR", FM/AR/04) is to be used for all purchase requests for supplies and services. The request form is reviewed and approved by the PI/PM or delegate to ensure:

i. Use of proper project number;
ii. Proper service/supply is being ordered.

If applicable, the PRR form is to be reviewed and approved by the Chemical Hygiene Officer if chemicals are being ordered.

c) Receipt of Purchased Material

(1) Incoming items are delivered to Room 148, where the Administrative Assistant notifies the PI/PM of the shipment.
(2) The PI/PM or delegate verifies the order and logs the item into the purchase received binder.
(3) Chemicals received are subject to the safe handling and storage procedures outlined in Laboratory Safety Plan.

7) Client Feedback:

At the completion of the project, client feedback is sought so that the Center can continue to improve the Quality System. A client survey form is sent to clients via email by the Communication Specialist at the completion of a project. Periodic reports are given to the Quality Council and Management Team summarizing the results of the survey.

8) Complaints:

Client or personnel complaints received either as a result of client or personnel feedback or otherwise are to be documented and filed with the project file. For complaints that require a Corrective Action Request (CAR), the PI/PM will fill out the Non-Conformance online form for resolution of the complaint.

9) Project Completion:

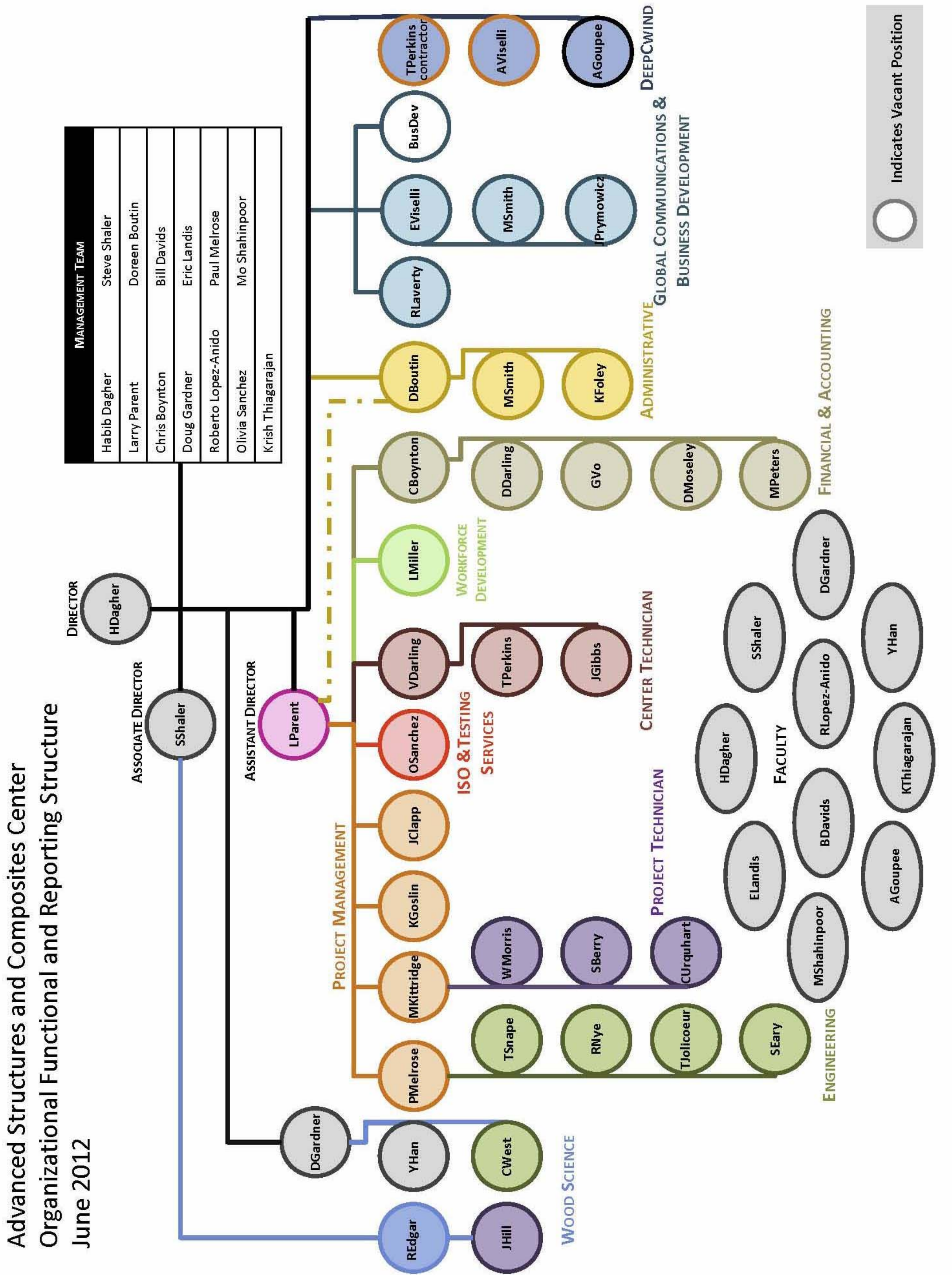
The Project Completion Form is to be filled out after the final report has been sent to the client. The form is completed by the PI/PM and LOM, authorizing the MFA to invoice the client and close the project.

a) Material Disposal:

(1) **Test Specimens.** Unless otherwise stated by the client, all test specimens will be disposed of after the Project Completion Form has been filled out and the final report sent to the client. Samples may be kept for quality control testing.

(2) **Chemical Hygiene.** Any chemicals or chemical containers to be disposed of must follow the Chemical Hygiene Plan outlined in the project work instruction and/or the Laboratory Safety Plan.

Section 5: Center Organization Chart


Advanced Structures and Composites Center
Organizational Functional and Reporting Structure
June 2012
Management Team
Habib Dagher
Steve Shaler
Larry Parent
Doreen Boutin
Chris Boynton
Bill Davids
Doug Gardner
Eric Landis
Roberto Lopez-Anido
Paul Melrose
Olivia Sanchez
Mo Shahinpoor
Krish Thiagarajan
Director
HDagher
Associate Director
SShaler
Assistant Director
LParent
DGardner
REdgar
JHill
YHan
CWest
Wood Science
PMelrose
TSnape
RNye
TJolicoeur
SEary
Engineering
MKittridge
WMorris
SBerry
CUrquhart
Project Technician
KGoslin
JClapp
Project Management
OSanchez
ISO & Testing Services
VDarling
TPerkins
JGibbs
Center Technician
LMiller
Workforce Development
CBoynton
DDarling
GVo
DMoseley
MPeters
Financial & Accounting
DBoutin
MSmith
KFoley
Administrative
RLaverty
EViselli
MSmith
JPrymowicz
BusDev
Global Communications & Business Development
TPerkins contractor
AViselli
AGoupee
DeepCwind
HDagher
SShaler
DGardner
ELandis
RLopez-Anido
YHan
BDavids
KThiagarajan
MShahinpoor
AGoupee
Faculty
Indicates Vacant Position

Section 6: References

1) AEWC Standard Operating Procedures

AEWC SOP-01	Storage and Handling Measuring Devices Procedure
AEWC SOP-02	Datasheet Creation-Validation Procedure
AEWC SOP-03	Document Control Procedure
AEWC SOP-04	Information Security Procedure
AEWC SOP-05	Action Request Procedure
AEWC SOP-06	Report Review Procedure
AEWC SOP-07	Measurement Uncertainty Procedure
AEWC SOP-08	Specimen Labeling Procedure
AEWC SOP-09	Hourly Student Payroll
AEWC SOP-10	Purchasing/Travel Procedures
AEWC SOP-11	Project Management
AEWC SOP-12	Creating a DIC Project

2) University of Maine Administrative Practice Letters relevant to the Center

APL can be found on the University of Maine System website.
The full list of the APL can also be found on the University of Maine System website

SECTION I - ACCOUNTING
G.1. General Accounting for Capital Assets - FAQ
SECTION II - ASSET MANAGEMENT
A. Facilities Procedures
B. Motor Vehicle Administration and Guidelines
C. Withholding and Reporting for Personal Use of Vehicles
D. Waste Reduction and Recycling
E. Safety and Environmental Management System
SECTION IV - GENERAL ADMINISTRATION
B. Travel and Expense Procedures
J. Reporting Workplace Wrongdoing
K. Commercializing Research and Inventions
Draft in process
SECTION V - Gifts
A. Gifts of Stocks/Bonds
B. Gift Administration
SECTION VI - INFORMATION TECHNOLOGY
B. Information Security Incident Response
C. Information Security
E. Network Services

APL list, continued

SECTION VII - PROCUREMENT
A.1 FAQ for Purchasing Procedures
A.2 University of Maine System Purchasing Procedures
B. Procurement Standards of Conduct
C. Purchasing Cards
D. Cellular Telephone Acquisition, Use and Reimbursement
E. Sales Tax
H. Determining Employee vs. Independent Contractor Status

Rev 4 Changes

$^1C_M = 0.95$ $^2C_M = 0.85$

Rev 4 is being submitted to incorporate measured values from mechanical and physical testing

	E_t^1 (Msi)	E_c^1 (Msi)	F_{tu}^2 (ksi)	F_{cu}^2 (ksi)	G^1 (Msi)	F_{su}^2 (ksi)	1/2" Lam.	1" Lam.
Predicted	3.11	3.11	44.54	29.67	0.67	12.16	0.509	1.017
Measured	2.94	3.18	39.69	48.22	0.60	12.28	0.492	0.950

Bottom Plate

Maximum vertical bending moment on raft - Strength V (bottom in compression)

$$M_u \le \lambda \phi M_n$$

Rupture (evaluated as a composite section)

$$M_n = \frac{F_C I}{y}$$

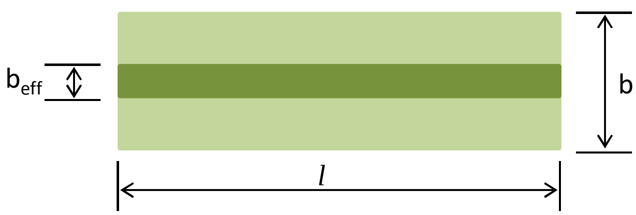
F_C =	48.22	ksi		λ =	0.90		
I =	104,251	in^4		ϕ =	0.65		
y =	20.65	in					
$\lambda\phi M_n$ =	11,868	kip-ft	>	M_u =	1,612	kip-ft	(Sheet 37)

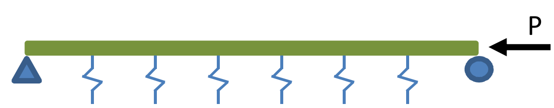
Rupture (evaluated as a plate in compression)

$$N_u^c \le \lambda \phi_c N_n^c \qquad N_n^c = F^c t \qquad N_u = \sigma t$$

F_c =	48.22	ksi		M_u =	1,612	kip-ft	(Sheet 37)
t =	0.492	in		y =	20.40	in	(N.A. to midplane)
λ =	0.90			I =	101,955	in^4	
ϕ =	0.70			σ =	3.87	ksi	(ave. stress)
$\lambda\phi_c N_n$ =	14.9	kip/in	>	N_u =	1.90	kip/in	

Buckling (evaluated as beam (strip of plate) on an elastic (foam) foundation)





$$P_u = N_u b_{eff} \qquad P_{cr} = \frac{\pi^2 EI}{l^2}\left(1 + \frac{kl^4}{EI\pi^4}\right)$$

$$P_u \le \lambda \phi_c P_{cr}$$

λ =	0.90			l =	149.5	in	
ϕ =	0.70			$E_L = E_T$ =	3.18	Msi	
b_{eff} =	12.0	in	(strip width)	I =	0.1191	in^4	(1 ft strip)
N_u =	1.90	kip/in	(see above)	k =	0.403	ksi	(foam stiffness)
$\lambda\phi_c P_{cr}$ =	575.1	kip	>	P_u =	22.86	kip	

This will be conservative since it assumes the plate is simply supported on short ends only. Spray-in foam is bonded to plate and E is the same in compression or tension = 403 psi. Foam properties have been included with other data sheets.

Top Plate

Maximum vertical bending moment on raft - Strength V (top in tension)

$$M_u \le \lambda \phi M_n$$

Rupture (evaluated as a composite section)

$$M_n = \frac{F_T I}{y}$$

F_t =	39.69	ksi	λ =	0.90	
I =	104,251	in^4	ϕ =	0.65	
y =	15.35	in			

$\lambda\phi M_n$ =	13,141	kip-ft	>	M_u =	1,612	kip-ft	(Sheet 37)

Rupture (evaluated as a plate in tension)

$$N_u^t \le \lambda \phi_t N_n^t \qquad N_n^t = 0.7 F^t t \qquad N_u = \sigma t$$

F_t =	39.69	ksi	M_u =	1,612	kip-ft	(Sheet 37)
t =	0.492	in	y =	15.10	in	(N.A. to midplane)
λ =	0.90		I =	104,251	in^4	
ϕ_t =	0.65		σ =	2.80	psi	(ave. stress)

$\lambda\phi_t N_n$ =	8.0	kip/in	>	N_u =	1.38	kip/in

Top Plate Buckling (evaluated as a plate in compression - Strength V)

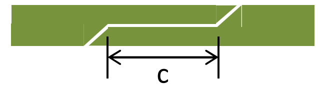
$$N_u^c \le \lambda \phi_c N_n^c \qquad N_n^c = F^{cr} t \qquad F^{cr} = \left(\frac{t}{b}\right)^2 \frac{\pi^2}{6}\left(\left(4k_{cr} - 3\right)\sqrt{E_L E_T} + k_{cr} E_T \nu_{LT} + 2k_{cr} G_{LT}\right)$$

M_u =	699	kip-ft	(Sheet 37)	y =	15.10	in	(dist. from N.A.)
σ =	1.21	psi	(ave. stress)	I =	104,251	in^4	
F^{cr} =	2.82	ksi		$E_L = E_T$ =	3.18	Msi	
t =	0.492	in		G_{LT} =	0.60	Msi	
λ =	0.90		$N_u = \sigma t$	ν_{LT} =	0.20		
ϕ =	0.70			b =	30.25	in	(unsupported width)
				k_{cr} =	1.1		(1.0 (pin) –1.3 (fixed))

$\lambda\phi_c N_n$ =	0.87	kip/in	>	N_u =	0.60	kip/in

Top plate seam at midspan - maximum moment at 0.5L on Raft 2

$$N_{LT,u} \le \lambda \phi_v N_{LT,n}$$



$$N_{LT,n} = F^v c$$

$$N_u = \sigma t$$

F^v =	1.60	ksi	(MA560 TDS)	M_u =	1,377	kip-ft	(Sheet 37)
c =	3.00	in		y =	15.10	in	(N.A. to midplane)
λ =	0.90			I =	104,251	in^4	
ϕ_v =	0.50			σ =	2.39	psi	(ave. stress)
				t =	0.492	in	
$\lambda\phi_c N_n$ =	2.16	kip/in	>	N_u =	1.18	kip/in	

<u>Longitudinal Bulkhead</u>

Maximum vertical shear on raft - Strength V

$$V_u \le \lambda \phi V_n$$

Rupture (evaluated as a composite section)

$$V_n = F_{LT} A_S$$

				V_u =	80.8	kip	(Sheet 37)
				# webs =	4		
F_{LT} =	12.28	ksi		λ =	0.90		
A_S =	17.5	in^2	(35 x 0.5)	ϕ =	0.65		
$\lambda\phi V_n$ =	126	kip	>	V_u =	20.2	kip	(V_u / 4)

Rupture (evaluated as a plate in shear)

$$N_{LT,u} \le \lambda \phi_v N_{LT,n}$$

$$N_{LT,n} = F_{LT} t$$

				V_u =	80.8	kip/in	(Sheet 37)
				# webs =	4		
F_{LT} =	12.28	ksi		λ =	0.90		
t =	0.53	in		ϕ =	0.70		
h =	35.0	in	(36 - 2(0.5))				
$\lambda\phi_v N_{LT,n}$ =	4.1	kip/in	>	$N_{LT,u}$ =	0.6	kip/in	(V_u / 4/35.0)

Web Buckling (evaluated as a composite section)

$$V_n = f_{cr} A_S$$

$$f_{cr} = \frac{t_w^2 k_{LT} \sqrt[4]{E_L E_t^3}}{3h^2}$$

$$k_{LT} = 8.1 + 5.0\frac{2G_{LT} + E_t \nu_{LT}}{\sqrt{E_L E_T}}$$

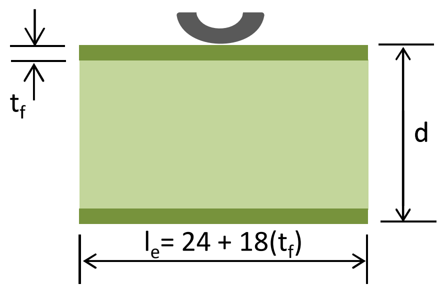
f_{cr}	2.67	ksi		V_u =	80.8	kip/in	(Sheet 37)
A_S =	18.6	in^2	(35 x 0.5)	# webs =	4		
k_{LT} =	11.0						
t_w =	0.53	in		$E_L = E_T$ =	3.18	Msi	
λ =	0.90			G_{LT} =	0.60	Msi	
ϕ =	0.80			h =	35.0	in	(36 - 2(0.5))
				ν_{LT} =	0.20		
$\lambda\phi V_n$ =	35.7	kip	>	V_u =	20.2	kip	(V_u / 4)

Buckling of longitudinal bulkhead due to tire loading

$$N_u^c \le \lambda \phi_c N_n^c$$

$$N_n^c = F^{cr} t$$

$$F^{cr} = \left(\frac{t}{b}\right)^2 \frac{\pi^2}{6}\left((4k_{cr} - 3)\sqrt{E_L E_T} + k_{cr} E_T \nu_{LT} + 2k_{cr} G_{LT}\right)$$



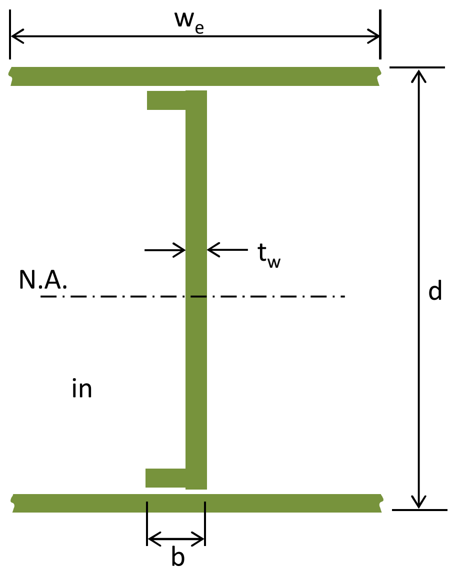
$$N_u = \frac{W_u}{l_e}$$

F^{cr} =	2.10	ksi					
t =	0.492	in					
$E_L = E_T$ =	3.18	Msi					
G_{LT} =	0.60	Msi					
ν_{LT} =	0.20						
λ =	0.90						
ϕ =	0.70			d =	35	in	(unsupported height)
				W_u =	15.5	kip	
k_{cr} =	1.1	(1.0 (pin)→1.3 (fixed))		l_e =	32.9	in	
$\lambda\phi_c N_n$ =	0.65	kip/in	>	N_u =	0.47	kip/in	

Adhesive Bond Strength

Shear transfer from longitudinal bulkhead to top/bottom plate - Strength V

$$V \le \lambda \phi F_{LT}$$ $$V = \frac{V_u Q}{Ib}$$



V_u =	80.8	kip	(Sheet 37)
# webs =	4		
V_u =	20.2	kip	(V_u / 4)
Q =	218	in^3	
w_e =	9.8	in	(20*t_w)
d =	36.0	in	
$t_f = t_w$ =	0.492	in	
b =	3.0	in	
I =	5548	in^4	
F_{LT} =	1.60	ksi	(MA560 TDS)
ϕ =	0.50		

y = 20.62 in

λ = 0.90

$\lambda\phi F_{LT}$ =	0.72	ksi	>	V =	0.26	ksi	(V_u / 4)

Bolted Connections - Top/Bottom Flanges

$$R_u = \lambda \phi R_n C_\Delta$$

Pin bearing

$$R_{br} = t d_n F_L^{br}$$

t =	0.950	in	(plate thk)	λ =	0.90
d_n =	0.875	in	(bolt dia.)	ϕ =	0.80
F_{br} =	45.07	ksi	(brng stren.)	C_Δ =	1.0

$\lambda\phi R_n$ =	27.0	kip	>	R_u =	19.40	kip	(Sheet 38)

Shear-out

$$R_{sh} = 1.4\left(e_1 - \frac{d_n}{2}\right) t F_{sh}$$

t =	0.950	in	(plate thk)			
d_n =	0.938	in	(dia. +1/16)			
F_{sh} =	12.28	ksi	(shear str.)			
λ =	0.90			e_1 =	3.75	in
ϕ =	0.50			C_Δ =	1.0	

$\lambda\phi R_n$ =	53.6	kip	>	R_u =	19.40	kip	(Sheet 38)

Net tension

$$R_{nt} = \frac{1}{K_{nt,L}}(w - nd_n)tF_L^t$$

$$K_{nt,L} = C_L\left(S_{pr} - 1.5\frac{(S_{pr}-1)}{(S_{pr}+1)}\Theta\right) + 1$$

t =	0.950	in	(plate thk)	n =	3	
d_n =	0.938	in	(dia. +1/16)	w =	10.5	(3 x g)
F_L =	39.69	ksi	(ten. stren.)	g =	3.5	
C_L =	0.40			$K_{nt,L}$ =	2.24	
λ =	0.90			S_{pr} =	4.00	(g/d)
ϕ =	0.50			Θ =	1.0	($e_1/g \geq 1$)
C_Δ =	1.0					

$\lambda\phi R_n$ =	58.23	kip	>	R_u =	58.20	kip	(Sheet 38)

Cleavage

$$R_{cl} = 0.15((e_2 + 0.5g - d_n)F_{t,L} + 2e_1F_{sh})t$$

t =	0.95	in	(plate thk)	g =	3.50	in	
d_n =	0.938	in	(dia. +1/16)	e_1 =	3.75	in	
F_{sh} =	12.28	ksi	(shear str.)	e_2 =	2.25	in	($2e_{2,min}$)*
$F_{t,L}$ =	39.69	ksi	(tensile str.)	λ =	0.90		
C_Δ =	1.0			ϕ =	0.50		

$\lambda\phi R_n$ =	30.4	kip	>	R_u =	19.40	kip	(Sheet 38)

* since the edge distance in all joints is >> $e_{2,min}$, a value of 2 x $e_{2,min}$ has been used for e_2

Bolted Connections - Vertical Webs

Since the force per bolt acting on the webs is 12.3 kips (less than 19.4 kips evaluated for the flanges), the gage length and end distance is the same as above, and the material properties ($F_{t,L}$, $F_{t,T}$, F_{sh}, etc.) are the same, the bolted connections in the web are assumed to be satisfactory based on calculations performed above for the flanges in the longitudinal direction. However, bolt loading in webs is evaluated for load angles using equations for 5-90 degress from longitudinal.

$$R_u \leq \lambda\phi R_n C_\Delta$$

Pin bearing

$$R_{br} = td_nF_L^{br}$$

t =	0.950	in	(plate thk)	λ =	0.90
d_n =	0.875	in	(dia. +1/16)	ϕ =	0.80
F_{br} =	45.07	ksi	(brng stren.)	C_Δ =	1.0

$\lambda\phi R_n$ =	27.0	kip	>	R_u =	12.30	kip	(Sheet 38)

Net tension - force from 5-90 degrees

$$R_{nt} = \frac{1}{K_{nt,T}}(w - nd_n)tF_T^t$$

$$K_{nt,T} = C_T\left(S_{pr} - 1.5\frac{(S_{pr} - 1)}{(S_{pr} + 1)}\Theta\right) + 1$$

t =	0.950	in	(plate thk)	n =	3	
d_n =	0.938	in	(dia. +1/16)	w =	10.5	(3 x g)
F_T =	39.69	ksi	(53.6 x 0.85)	g =	3.5	
C_T =	0.50	(transverse coefficient)		$K_{nt,T}$ =	2.55	
λ =	0.90			S_{pr} =	4.00	(g/d)
ϕ =	0.50			Θ =	1.0	(e_1/g ≥ 1)
C_Δ =	1.0					

λϕR_n =	51.2	kip	>	R_u =	36.90	kip	(Sheet 38)

Stainless Bolted Connections - Vertical Webs

$$R_u \le \lambda\phi R_n C_\Delta$$

Pin bearing

$$R_{br} = td_nF_L^{br}$$

t =	0.950	in	(plate thk)	λ =	0.90
d_n =	0.875	in	(bolt dia.)	ϕ =	0.80
F_{br} =	45.07	ksi	(brng stren.)	C_Δ =	1.0

λϕR_n =	27.0	kip	>	R_u =	14.80	kip	(Sheet 39)

Shear-out

$$R_{sh} = 1.4\left(e_1 - \frac{d_n}{2}\right)tF_{sh}$$

t =	0.950	in	(plate thk)			
d_n =	0.938	in	(dia. +1/16)			
F_{sh} =	12.28	ksi	(shear str.)			
λ =	0.90			e_1 =	3.5	in
ϕ =	0.50			C_Δ =	1.0	

λϕR_n =	49.5	kip	>	R_u =	14.80	kip	(Sheet 39)

Net tension

$$R_{nt} = \frac{1}{K_{nt,L}}(w - nd_n)tF_L^t$$

$$K_{nt,L} = C_L\left(S_{pr} - 1.5\frac{(S_{pr}-1)}{(S_{pr}+1)}\Theta\right) + 1$$

t =	0.950	in	(plate thk)	n =	3	
d_n =	0.938	in	(dia. +1/16)	w =	10.5	(3 x g)
F_L =	44.54	ksi	(ten. stren.)	g =	3.5	
C_L =	0.40			$K_{nt,L}$ =	2.24	
λ =	0.90			S_{pr} =	4.00	(g/d)
ϕ =	0.50			Θ =	1.0	($e_1/g \geq 1$)
C_Δ =	1.0					

$\lambda\phi R_n$ =	65.3	kip	>	R_u =	44.40	kip	(Sheet 39)

Cleavage

$$R_{cl} = 0.15((e_2 + 0.5g - d_n)F_{t,L} + 2e_1F_{sh})t$$

t =	0.95	in	(plate thk)	g =	3.50	in	
d_n =	0.938	in	(dia. +1/16)	e_1 =	3.75	in	
F_{sh} =	12.28	ksi	(shear str.)	e_2 =	3.05	in	(4-0.950)
$F_{t,L}$ =	39.69	ksi	(tensile str.)	λ =	0.90		
C_Δ =	1.0			ϕ =	0.50		

$\lambda\phi R_n$ =	35.0	kip	>	R_u =	19.40	kip	(Sheet 38)

Net tension - force from 5-90 degrees

$$R_{nt} = \frac{1}{K_{nt,T}}(w - nd_n)tF_T^t$$

$$K_{nt,T} = C_T\left(S_{pr} - 1.5\frac{(S_{pr}-1)}{(S_{pr}+1)}\Theta\right) + 1$$

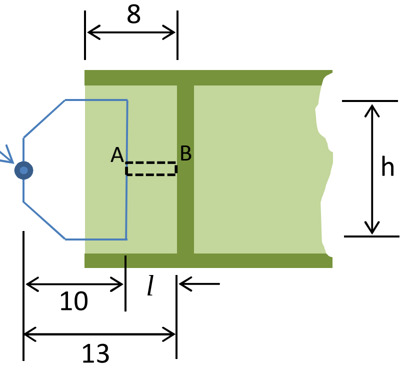
t =	0.950	in	(plate thk)	n =	3	
d_n =	0.938	in	(dia. +1/16)	w =	10.5	(3 x g)
F_T =	39.69	ksi	(53.6 x 0.85)	g =	3.5	
C_T =	0.50	(transverse coefficient)		$K_{nt,T}$ =	2.33	
λ =	0.90			S_{pr} =	3.50	(g/d)
ϕ =	0.50			Θ =	1.0	($e_1/g \geq 1$)
C_Δ =	1.0					

$\lambda\phi R_n$ =	55.9	kip	>	R_u =	44.40	kip	(Sheet 39)

Transverse load in line with HSS shelf

1. Assume the transverse load is carried entirely by the three full depth webs = 20.2 kips/3 = 6.73 kips
2. First analyze a horizontal 1" wide strip of web at mid height of the pontoon for flexure stresses
3. Second analyze the adhesive joint at the top/bottom of the web for shear stresses

P =	6.73	kip	
h =	31.0	in	(ht of plate)
l =	3	in	(length of strip)
N =	0.217	kip/in	(6.73 / h)
M_A =	2.172	kip-in	(N x 10)
$M_B = M_u$ =	2.82	kip-in	(M_A + N x l)



N = distributed load along height of support plate

M_A = applied moment at point A due to load on support plate

$$M_u \le \lambda \phi M_n$$

$$M_n = \frac{F_C I}{y}$$

F_C =	48.22	ksi		λ =	0.90
I =	0.071	in^4	($1x0.950^3/12$)	ϕ =	0.65
y =	0.475	in	(0.950/2)		

$\lambda\phi M_n$ =	4.24	kip-in	>	M_u =	2.82	kip-in

4. For shear in adhesive, assume half the force is resisted at the top joint and half at the bottom joint

$$V \le \lambda \phi F_{LT}$$

P/2 =	3.37	kip	(6.73 / 2)		
A_s =	24.0	in^2	(8 x 3)	λ =	0.90
F_{LT} =	1.60	ksi	(MA560 TDS)	ϕ =	0.50

$\lambda\phi F_{LT}$ =	0.72	ksi	>	V =	0.14	ksi	($P/2 / A_s$)

Compression Loading due to Threaded Rods

Compressive strength of FRP blister

$$P_u \le \lambda \phi F_c A_e$$

Axial force, P =	55.0	ksi	(Sheet 34)	Steel brng plt, A_s =	36.0	in^2	(6x6)
Loaded area, A_e =	34.23	in^2	(A_s - A_h)	A_h =	1.77	in^2	(∅1.5 hole)
Comp. strength, F_c =	48.22	ksi		λ =	0.40		
				ϕ =	0.70		

$C_m \lambda \phi_c P_n$ =	486	kip	>	P_u =	77.0	kip	(1.4 x 55)

Compression strength of bulkhead

$$P_u \le \lambda \phi_c F_c A_e$$

Axial force, P =	55.0	kip	(Sheet 34)	λ =	0.40
Blkhd xsec area, A_s =	18.6	in^2	(35 x 0.53)	ϕ =	0.70
Comp. strength, F_c =	48.22	ksi			

$\lambda \phi_c P_n$ =	250	kip	>	P_u =	77.0	kip	(1.4 x 55)

Buckling of transverse bulkhead

$$N_u^c \le \lambda \phi_c N_n^c$$

$$N_n^c = F^{cr} t$$

$$F^{cr} = \left(\frac{t}{b}\right)^2 \frac{\pi^2}{6}\left((4k_{cr} - 3)\sqrt{E_L E_T} + k_{cr} E_T \nu_{LT} + 2k_{cr} G_{LT}\right)$$

Foam provides uniform bracing on both sides of the bulkhead. Therefore, the unsupported length of the plate, "b", is considered to be 0 and the bulkhead is not at risk of buckling.

Shear and compression on MMA behind blister

$$V \le \lambda \phi F_{LT}$$

F_{LT} =	1.60	ksi	(MA560 TDS)	ϕ =	0.70
F_c* =	4.23	ksi	(MA560 report)	λ =	0.40

Shear component (55 kip x 1.4 x cos(75.4°)) = 19.46

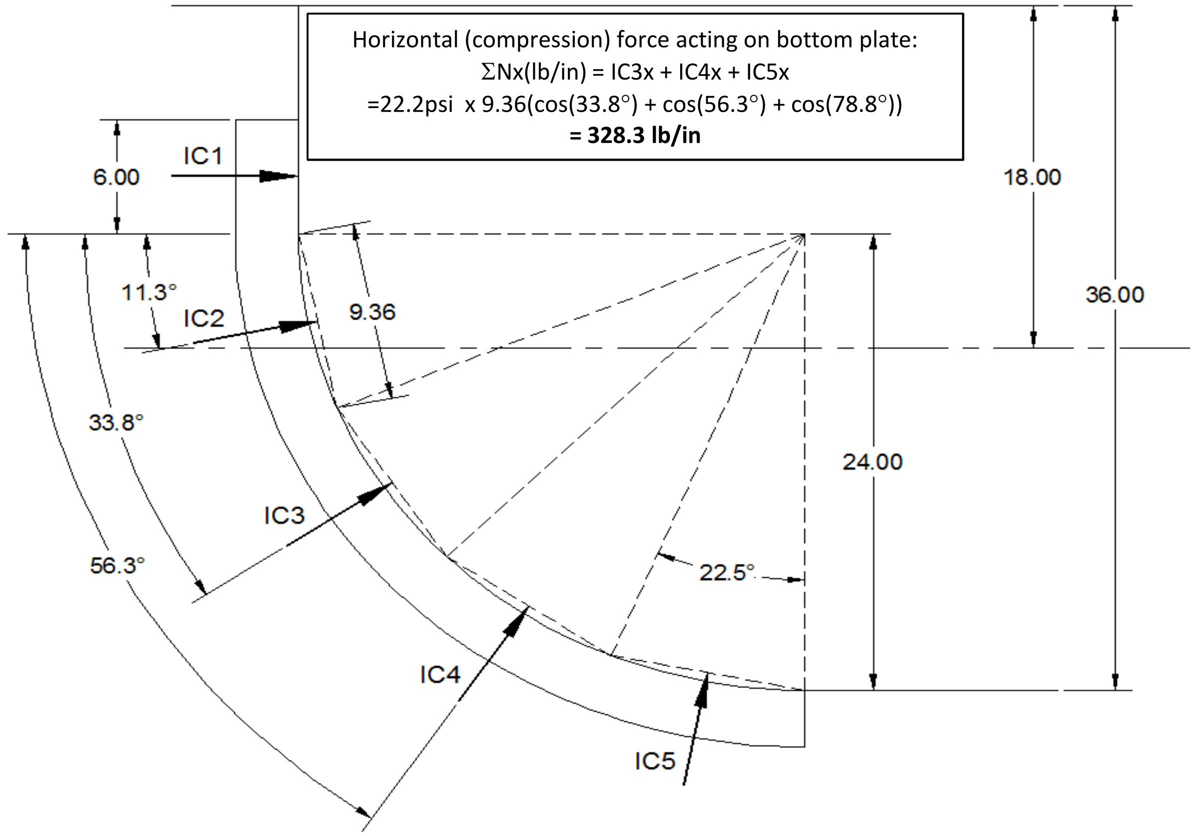
Comp. Component (55 kip x 1.4 x sin(75.4°)) = 74.50

Loaded area, A_e = 64.25 in^2 (A_b - A_h) (use 8-1/8 x 8-1/8 plate)

*Adehesive compressive strength is higher than tensile. However, since compressive strength is not listed in data sheet, the tensile value is used.

$\lambda \phi F_{LT}$ =	0.45	ksi	>	V =	0.30	ksi	(P / A_e)
$\lambda \phi F_c$ =	1.18	ksi	>	V =	1.16	ksi	(P / A_e)

Ice loading



Combined compression (bottom plate - Extreme II + Ice) ϕ = n/a per spec for ice

M_u =	952	kip-ft	(Sheet 37)	t =	0.492	in	
y =	15.10	in	(N.A. to mid)	σ =	1.66	psi	(ave. stress)
I =	104,251	in^4		N_L =	0.81	kip/in	(σ x t)
λ =	1.00	(extreme event)		N_T =	0.33	kip/in	(from above)
λN_n =	13.7	kip/in	>	N_T =	0.33	kip/in	(top plate)
λN_n =	23.7	kip/in	>	N_L =	0.81	kip/in	(bot. plate)

Plate bending between bulkheads

*Using beam on elastic foundation spreadsheet based on equations from "Formulas for Stress and Strain" R. Roark and W. Young (see next page)

Nominal 1" wide strip at 22.2 psi, w = 22.2 lb/in

$$f_u = \frac{M_u y}{I}$$

I =	0.010	in^4	($0.492^3/12$)			
M_u =	0.035	kip-ft	(BEF sheet)			
f_u =	10.41	ksi				
λF_c =	48.2	kip/in	>	F_u =	10.41	ksi

Compressive strength of foam = 37 psi at 5% strain. 5% strain over 35" thick foam = 1.75". K = 37 / 1.75 x 0.85 = 17.97 $lb/in^2/in$

Test Laminate Variance vs. Bridge Laminate

Kenway stands by the choice of laminate when fabricating test specimens for mechanical tests. An approximate thickness of 0.2" is required to perform strength and modulus testing per ASTM standards and within the physical limitations of the test equipment and instrumentation. The best combination of available materials was used to most closely match the percentage of fiber in the various orientations without going so far as to have custom fabrics manufactured at great expense. A summary of the bridge laminate and test laminate percentages is provided below.

	CSM	±45	0/90
Bridge	3 %	17 %	80 %
Test	7 %	17 %	76 %
Delta	4 %	0 %	4 %

Kenway understands the 4% difference in mat and structural fiber will result in slightly higher strength and modulus values in the bridge laminate than were measured in the test laminate. Regarding the concern over exceeding the upper global stiffness limit in the specification, the measured tensile modulus was lower than design by 5.5% while the measured compression modulus exceeded design by 2.4%. The average change in modulus is 1.5% lower than design. If modulus values from the test laminate are adjusted to exactly match the percentage of fibers in each orientation in the bridge laminate, the predicted change in modulus following the rule of mixtures is shown below.

Measured tensile and compression modulus per test laminate percentages:

$$3.09 = 1.51 \cdot 7\% + 3.55 \cdot 76\% + 1.68 \cdot 17\% \qquad 3.35 = 1.75 \cdot 7\% + 3.82 \cdot 76\% + \cdot 1.91 \cdot 17\%$$

Adjusted tensile and compression modulus per bridge laminate percentages:

$$3.17 = 1.51 \cdot \underline{3\%} + 3.55 \cdot \underline{80\%} + 1.68 \cdot 17\% \qquad 3.43 = 1.75 \cdot \underline{3\%} + 3.82 \cdot \underline{80\%} + \cdot 1.91 \cdot 17\%$$

As a result, the average change in modulus is calculated as 0.9% higher than the assumed design value – 3,302 ksi vs. 3,270 ksi. This would result in a global raft stiffness of:

$327{,}035{,}000 kip \cdot in^2 = 3{,}302 ksi \times 0.95 \times 104{,}251 in^4$, which is less than the upper limit.

Grit Blasting Process

The test pieces were grit blasted as described in the report for approximately 1 min./ft^2. To ensure consistency, Kenway will follow the same process in full scale production, which will require approximately 2.5 hours to blast the entire 3 ft by 51 ft surface.

Material Property Testing for Vtrans Floating Bridge (Addendum)

Prepared for:

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University of Maine's Advanced Structures and Composites Center
Report Number: 14-24-1267A (Addendum)

June 12, 2014

Prepared by:

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ACCREDITED

An ISO 17025 accredited testing laboratory, accredited by the International Accreditation Service.

Project Number: 1267
Project Date: June 10, 2014
Material: E-Glass/Interplastics 8100-50 Vinyl Ester
Date Received: April 22, 2014

Project Summary: The following material property tests were conducted:

- ASTM D2583-13a - *Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor*
- ASTM D792-13 - *Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement*
- ASTM D3171-11- *Standard Test Methods for Constituent Content of Composite Materials*

The client provided a 48 inch by 48 inch composite panel with nominal thickness of 0.22 inches. The standard pontoon laminate will consist of (1) 4008 ±45, (7) 5400 0/90, and (1) 4008 ±45. This results in a total fabric areal weight of 474 oz./yd^2 (16 oz./yd^2 stitched mat (3%), 80 oz./yd^2 ±45 (17%), 378 oz./yd^2 0/90 (80%)) and a total thickness of 0.508 inches. The laminate schedule for the 0.22 inch test panels was derived to provide a similar ratio of fiber orientations while resulting in a thickness of less than 0.250." The test laminate consists of (1) 1708, (3) 5400, and (1) 1708, which has a total areal weight of 214 oz./yd^2 (16 oz./yd^2 stitched mat (7%), 36 oz./yd^2 ±45 (17%), and 162 oz./yd^2 0/90 (76%)). Due to the test laminate having a greater percentage of stitched-mat (non-structural fiber); mechanical testing will produce strength and stiffness values that are lower than the actual pontoon laminate and therefore conservative.

The specimens were cut from the 0.22 inch thick panel using waterjet abrasive machining. Final specimen drilling and machining was performed using a milling machine.

Prior to conducting the tests, the specimens were conditioned for a minimum of 48-hours in the laboratory's Mechanical Testing Lab at a standard environment of 70 ±3°F and 50 ±5% RH. The testing was also performed in this lab at standard environment.

The results of the various tests are summarized in the remainder of this document.

Material Property Test: Barcol Hardness
Test Method: ASTM D2583-13a - *Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor*
Date Tested: June 9, 2014

Test Setup: Ten specimens were obtained from the panel at various locations in an effort to capture spatial variability of the properties. The nominal specimen size was 1 inch wide by 6 inches long. A Coleman GYZJ-934-1 Barcol Impressor was used for the hardness tests. Ten hardness measurements were made on each of the ten specimens.

Results: The results of the Barcol hardness tests are presented in Table 1. The table includes the mean value and coefficient of variation (CV) for both the individual measurements made on each specimen, and for the set of ten specimens.

Table 1. Barcol Hardness Results

Specimen	Barcol Hardness	
#	*Mean*	*CV*
1	58	11%
2	62	13%
3	63	10%
4	61	11%
5	56	18%
6	58	11%
7	56	9%
8	60	12%
9	59	18%
10	57	11%
Mean	**59**	
CV	**3.9%**	

Equipment used:

- Coleman Barcol Impressor AS# 893

Material Property Test: Density
Test Method: ASTM D792-13 - *Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement*
Date Tested: June 10-11, 2014

Test Setup: Ten specimens were obtained from the panel at various locations in an effort to capture spatial variability of the properties. The nominal specimen size was 1 inch wide by 6 inches long. Test Method A of ASTM D792-13 was used to perform these tests. The temperature of the water bath used for the wet mass measurements was 25.6°C (78°F).

Results: The results of the density measurements are presented in Table 2. The table includes the dry mass, the wet mass, the specific gravity, and the density for each specimen. In addition to the individual specimen results, the table includes the mean value and CV for the laminate properties.

Table 2. Laminate Density Results

Specimen				
ID	*Dry Mass*	*Wet Mass*	**Specific Gravity**	**Density**
#	*g*	*g*		*g/cm³*
1	40.5267	19.1596	1.897	1.891
2	40.0059	18.9190	1.897	1.891
3	39.9034	18.9470	1.904	1.898
4	40.0983	18.7892	1.882	1.876
5	39.6436	18.5603	1.880	1.874
6	39.4878	18.5932	1.890	1.884
7	40.5915	19.0975	1.889	1.883
8	40.0786	18.9575	1.898	1.892
9	40.7237	19.0448	1.878	1.873
10	40.1072	18.7600	1.879	1.873
Mean	**40.117**	**18.883**	**1.889**	**1.883**
CV	**1.0%**	**1.1%**	**0.49%**	**0.49%**

Equipment used:

- Ohaus Scale AS# 657
- Thermocouple Meter AS# 186

Material Property Test: Constituent Content
Test Method: ASTM D3171-11 - *Standard Test Methods for Constituent Content of Composite Materials*
Date Tested: June 10, 2014

Test Setup: Ten specimens were obtained from the panel at various locations in an effort to capture spatial variability of the properties. The nominal specimen size was 1.0 inch wide by 1.5 inches long.

Test Method I, Procedure G from ASTM D3171-11 was used for this testing. A Fisher Scientific muffle furnace was used to burn off the resin. The specimens were placed in the furnace at a temperature of 565°C for a duration of 2.5 hours. This temperature and duration were sufficient for complete removal of the resin system.

Results: The results of the constituent content tests are presented in Table 3. The table includes specimen mass, constituent weight fraction, and constituent volume fraction. The volume fractions were computed using a resin density of 1.12 g/cm^3 [1] and a glass density of 2.55 g/cm^3. In addition to the individual specimen results, the table includes the mean value and CV for the set of ten specimens.

Table 3. Constituent Content Results

Specimen		Weight Fraction		Volume Fraction	
ID	*mass*	*Fiber*	*Matrix*	*Fiber*	*Matrix*
#	g	%	%	%	%
1	12.6779	70.75	29.25	51.51	48.49
2	12.6571	70.67	29.33	51.41	48.59
3	12.6494	71.26	28.74	52.13	47.87
4	12.4486	70.33	29.67	51.00	49.00
5	12.4452	69.73	30.27	50.30	49.70
6	12.3490	70.74	29.26	51.50	48.50
7	12.7131	70.65	29.35	51.39	48.61
8	12.5314	71.02	28.98	51.84	48.16
9	12.7216	69.73	30.27	50.29	49.71
10	12.5927	69.68	30.32	50.23	49.77
Mean	**12.58**	**70.5**	**29.5**	**51.2**	**48.8**
CV	**1.0%**	**0.8%**	**1.9%**	**1.3%**	**1.4%**

Equipment used:

- Ohaus Scale AS# 657
- Fisher Scientific Furnace AS# 180

[1] CoREZYN® Vinyl Ester Resins Data Sheet, Revision 10/05 A-006b, Interplastic Corporation, 2005.