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TenCate Advance Composites

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1. Introduction

This report contains statistical analysis of the TenCate BT250E-6 AS4C 3k-PW Fabric Gr 195gsm 40% RC qualification material property data published in NCAMP Test Report CAM-RP-2015-039 Rev N/C. The lamina material property data have been generated with FAA oversight through FAA Special Project Number TD03019RC-R and also meet the requirements of NCAMP Standard Operating Procedure NSP 100. The test panels, test specimens, and test setups have been conformed by the FAA and the testing has been witnessed by the FAA.

B-Basis values, A-estimates, and B-estimates were calculated using a variety of techniques that are detailed in section two. The qualification material was procured to Erickson Air-Crane (EAC) Material Specification ES0095 Revision B dated May 22, 2013. An equivalent NCAMP Material Specification NMS 250/2 Rev Initial Release dated January 2, 2018 has been created. The qualification test panels were cured in accordance with Erickson Air Crane (EAC) Process Specification ES0098 Rev A dated June 15, 2011. An equivalent NCAMP Process Specification NPS 81250 with baseline “C” Cure Cycle Rev Initial Release dated October 20, 2017 has been created. The panels were fabricated at Advanced Technologies Inc., 875 Middle Ground Blvd. Newport News, VA 23606. The Erickson Air-Crane (EAC) test plan EAC2028 Rev C was used for this qualification program. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas.

agencies. NCAMP assumes no liability whatsoever, expressed or implied, related to the use of the material property data, material allowables, and specifications.

Part fabricators that wish to utilize the material property data, allowables, and specifications may be able to do so by demonstrating the capability to reproduce the original material properties; a process known as equivalency. More information about this equivalency process including the test statistics and its limitations can be found in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17-1G. The applicability of equivalency process must be evaluated on program-by-program basis by the applicant and certifying agency. The applicant and certifying agency must agree that the equivalency test plan along with the equivalency process described in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17-1G are adequate for the given program.

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 250/2. NMS 250/2 has additional requirements that are listed in its prepreg process control document (PCD), fiber specification, fiber PCD, and other raw material specifications and PCDs which impose essential quality controls on the raw materials and raw material manufacturing equipment and processes. *Aircraft companies and certifying agencies should assume that the material property data published in this report is not applicable when the material is not procured to NCAMP Material Specification NMS 250/2. NMS 250/2* is a free, publicly available, non-proprietary aerospace industry material specification.

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1.1 Symbols and Abbreviations

Test Property	**Abbreviation**
Warp Compression	WC
Warp Tension	WT
Fill Compression	FC
Fill Tension	FT
In-Plane Shear	IPS
Short Beam Strength	SBS

Table 1-1: Test Property Abbreviations

Test Property	Symbol
Warp Compression Strength	F_1^{cu}
Warp Compression Modulus	E_1^{c}
Warp Tension Strength	F_1^{tu}
Warp Tension Modulus	E_1^{t}
Warp Tension Poisson’s Ratio	ν_{12}^{t}
Fill Compression Strength	F_2^{cu}
Fill Compression Modulus	E_2^{c}
Fill Tension Strength	F_2^{tu}
Fill Tension Modulus	E_2^{t}
In-Plane Shear Strength at 5% strain	$F_{12}^{s5\%}$
In-Plane Shear Strength at 0.2% offset	$F_{12}^{s0.2\%}$
In-Plane Shear Modulus	G_{12}^{s}

Table 1-2: Test Property Symbols

Environmental Condition	Abbreviation	Temperature
Cold Temperature Dry	CTD	−65°F
Room Temperature Dry	RTD	70°F
Elevated Temperature Dry	ETD	180°F
Elevated Temperature Wet	ETW	180°F

Table 1-3: Environmental Conditions Abbreviations

Detailed information about the test methods and conditions used is given in test plan EAC2028 Rev C and NCAMP Test Report CAM-RP-2015-039 Rev N/C.

1.2 Pooling Across Environments

When pooling across environments was allowable, the pooled co-efficient of variation was used. CMH17 STATS v2011 r1.1 was used to determine if pooling was allowable and to compute the pooled coefficient of variation for those tests. In these cases, the modified coefficient of variation based on the pooled data was used to compute the basis values.

When pooling across environments was not advisable because the data was not eligible for pooling and engineering judgment indicated there was no justification for overriding the result, then B-Basis values were computed for each environmental condition separately, which are also provided by CMH17 STATS.

1.3 Basis Value Computational Process

The general form to compute engineering basis values is: $\text{basis value} = \bar{X} \quad kS$ where k is a factor based on the sample size and the distribution of the sample data. There are many different methods to determine the value of k in this equation, depending on the sample size and the distribution of the data. In addition, the computational formula used for the standard deviation, S, may vary depending on the distribution of the data. The details of those different computations and when each should be used are in section 2.0.

1.4 Modified Coefficient of Variation (CV) Method

A common problem with new material qualifications is that the initial specimens produced and tested do not contain all of the variability that will be encountered when the material is being produced in larger amounts over a lengthy period of time. This can result in setting basis values that are unrealistically high. The variability as measured in the qualification program is often lower than the actual material variability because of several reasons. The materials used in the qualification programs are usually manufactured within a short period of time, typically 2-3 weeks only, which is not representative of the production material. Some raw ingredients that are used to manufacture the multi-batch qualification materials may actually be from the same production batches or manufactured within a short period of time so the qualification materials, although regarded as multiple batches, may not truly be multiple batches so they are not representative of the actual production material variability.

The modified Coefficient of Variation (CV) used in this report is in accordance with section 8.4.4 of CMH-17-1G. It is a method of adjusting the original basis values downward in anticipation of the expected additional variation. Composite materials are expected to have a CV of at least 6%. The modified coefficient of variation (CV) method increases the measured coefficient of variation when it is below 8% prior to computing basis values. A higher CV will result in lower or more conservative basis values and lower specification limits. The use of the modified CV method is intended for a temporary period of time when there is minimal data available. When a sufficient number of production batches (approximately 8 to 15) have been produced and tested, the as-measured CV may be used so that the basis values and specification limits may be adjusted higher.

The material allowables in this report are calculated using both the as-measured CV and modified CV, so users have the choice of using either one. When the measured CV is greater than 8%, the modified CV method does not change the basis value. NCAMP recommended values make use of the modified CV method when it is appropriate for the data.

When the data fails the Anderson-Darling K-sample test for batch to batch variability or when the data fails the normality test, the modified CV method is not appropriate and no modified CV basis value will be provided. When the ANOVA method is used, it may produce excessively conservative basis values. When appropriate, a single batch or two batch estimate may be provided in addition to the ANOVA estimate.

In some cases a transformation of the data to fit the assumption of the modified CV resulted in the transformed data passing the ADK test and thus the data can be pooled only for the modified CV method.

NCAMP recommends that if a user decides to use the basis values that are calculated from as-measured CV, the specification limits and control limits be calculated with as-measured CV also. Similarly, if a user decides to use the basis values that are calculated from modified CV, the specification limits and control limits be calculated with modified CV also. This will ensure that the link between material allowables, specification limits, and control limits is maintained.

2.

Where *k* refers to the number of batches, S_i indicates the standard deviation of *i*th sample, and n_i refers to the number of specimens in the *i*th sample.

2.1.2.2 Pooled Coefficient of Variation

Since the mean for the normalized data is 1.0 for each condition, the pooled normalized data also has a mean of one. The coefficient of variation for the pooled normalized data is the pooled standard deviation divided by the pooled mean, as in equation 3. Since the mean for the pooled normalized data is one, the pooled coefficient of variation is equal to the pooled standard deviation of the normalized data.

Pooled Coefficient of Variation

$$\frac{S_p}{1} \quad S_p$$

Equation 5

2.1.3 Basis Value Computations

Basis values are computed using the mean and standard deviation for that environment, as follows: The mean is always the mean for the environment, but if the data meets all requirements for pooling, S_p can be used in place of the standard deviation for the environment, S.

Basis Values:

$$\begin{array}{l} A \quad basis \quad \bar{X} \quad K_a S \\ B \quad basis \quad \bar{X} \quad K_b S \end{array}$$

Equation 6

2.1.3.1 K-factor computations

K_a and K_b are computed according to the methodology documented in section 8.3.5 of CMH-17-1G. The approximation formulas are given below:

$$K_a \quad \frac{2.3263}{\sqrt{q(f)}} \quad \sqrt{\frac{1}{c_A(f) \ n_j} \quad \frac{b_A(f)}{2c_A(f)}^{2}} \quad \frac{b_A(f)}{2c_A(f)}$$

Equation 7

$$K_b \quad \frac{1.2816}{\sqrt{q(f)}} \quad \sqrt{\frac{1}{c_B(f) \ n_j} \quad \frac{b_B(f)}{2c_B(f)}^{2}} \quad \frac{b_B(f)}{2c_B(f)}$$

Equation 8

Where

r = the number of environments being pooled together
n_j= number of data values for environment j

1

Step 1: Apply the modified CV rules to each batch and compute the modified standard deviation $S_i^* \quad CV^* \quad \bar{X}_i$ for each batch. Transform the individual data values (X_{ij}) in each batch as follows:

$$X_{ij} \quad C_i \quad X_{ij} \quad \bar{X}_i \quad \bar{X}_i$$ **Equation 17**

$$C_i \quad \frac{S_i^*}{S_i}$$ **Equation 18**

Run the Anderson-Darling k-sample test for batch equivalence (see section 2.1.6) on the transformed data. If it passes, proceed to step 2. If not, stop. The data cannot be pooled.

Step 2: Another transformation is needed as applying the modified CV to each batch leads to a larger CV for the combined data than when applying the modified CV rules to

If MNR > C, then the X_i associated with the MNR is considered to be an outlier. If an outlier exists, then the X_i associated with the MNR is dropped from the dataset and the MNR procedure is applied again. This process is repeated until no outliers are detected. Additional information on this procedure can be found in references 1 and 2.

2.1.6 The k-Sample Anderson Darling Test for Batch Equivalency

The k-sample Anderson-Darling test is a nonparametric statistical procedure that tests the hypothesis that the populations from which two or more groups of data were drawn are identical. The distinct values in the combined data set are ordered from smallest to largest, denoted $z_{(1)}$, $z_{(2)}$,… $z_{(L)}$, where L will be less than n if there are tied observations. These rankings are used to

$$a = (4g-6)(k-1)+(10-6g)S$$

$$b = (2g-4)k^2+8Tk+(2g-14T-4)S-8T+4g-6$$

$$c = (6T+2g-2)k^2+(4T-4g+6)k+(2T-6)S+4T$$

$$d = (2T+6)k^2-4Tk$$

$$S = \sum_{i=1}^{k}\frac{1}{n_i}$$

$$T = \sum_{i=1}^{n-1}\frac{1}{i}$$

$$g = \sum_{i=1}^{n-2}\sum_{j=i+1}^{n-1}\frac{1}{(n-i)j}$$

The data is considered to have failed this test (i.e. the batches are not from the same population) when the test statistic is greater than the critical value. For more information on this procedure, see reference 3.

2.1.7 The Anderson Darling Test for Normality

Normal Distribution: A two parameter (μ, σ) family of probability distributions for which the probability that an observation will fall between *a* and *b* is given by the area under the curve between a and b:

$$F(x) = \int_a^b \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}\,dx \qquad \textbf{Equation 28}$$

A normal distribution with parameters (μ, σ) has population mean μ and variance σ^2.

The normal distribution is considered by comparing the cumulative normal distribution function that best fits the data with the cumulative distribution function of the data. Let

$$z_{(i)} = \frac{x_{(i)}-\overline{x}}{s}, \quad \text{for i} = 1,\ldots,n \qquad \textbf{Equation 29}$$

where $x_{(i)}$ is the smallest sample observation, $\overline{x}$ is the sample average, and s is the sample standard deviation.

The Anderson Darling test statistic (AD) is:

$$AD = \sum_{i=1}^{n}\frac{1-2i}{n}\left\{\ln\left[F_0(z_{(i)})\right]+\ln\left[1-F_0\left(z_{(n+1-i)}\right)\right]\right\}-n \qquad \textbf{Equation 30}$$

Where F_0 is the standard normal distribution function. The observed significance level (OSL) is

$$OSL = \frac{1}{1+e^{-0.48+0.78\ln(AD^*)+4.58AD^*}}, \quad AD^* = \left(1+\frac{0.2}{\sqrt{n}}\right)AD \qquad \textbf{Equation 31}$$

This OSL measures the probability of observing an Anderson-Darling statistic at least as extreme as the value calculated if, in fact, the data are a sample from a normal population. If OSL > 0.05, An observed significance level (OSL) based on the Anderson-Darling test statistic is computed for each test. The OSL measures the probability of observing an Anderson-Darling test statistic at least as extreme as the value calculated if the distribution under consideration is in fact the underlying distribution of the data. In other words, the OSL is the probability of obtaining a value of the test statistic at least as large as that obtained if the hypothesis that the data are actually from the distribution being tested is true. If the OSL is less than or equal to 0.05, then the assumption that the data are from the distribution being tested is rejected with at most a five percent risk of being in error.

If the normal distribution has an OSL greater than 0.05, then the data is assumed to be from a population with a normal distribution. If not, then if either the Weibull or lognormal distributions has an OSL greater than 0.05, then one of those can be used. If neither of these distributions has an OSL greater than 0.05, a non-parametric approach is used.

In what follows, unless otherwise noted, the sample size is denoted by n, the sample observations by $x_1, ..., x_n$, and the sample observations ordered from least to greatest by $x_{(1)}, ..., x_{(n)}$.

2.2.2 Computing Normal Distribution Basis Values

Stat17 uses a table of values for the k-factors (shown in Table 2-1) when the sample size is less than 16 and a slightly different formula than ASAP to compute approximate k-values for the normal distribution when the sample size is 16 or larger.

Norm. Dist. k Factors for N<16		
N	B-basis	A-basis
2	20.581	37.094
3	6.157	10.553
4	4.163	7.042
5	3.408	5.741
6	3.007	5.062
7	2.756	4.642
8	2.583	4.354
9	2.454	4.143
10	2.355	3.981
11	2.276	3.852
12	2.211	3.747
13	2.156	3.659
14	2.109	3.585
15	2.069	3.520

Table 2-1: K factors for normal distribution

2.2.2.1 One-sided B-basis tolerance factors, k_B, for the normal distribution when sample size is greater than 15.

The exact computation of k_B values is $1/\sqrt{n}$ times the 0.95th quantile of the noncentral t-distribution with noncentrality parameter $1.282\sqrt{n}$ and $n - 1$ degrees of freedom. Since this in not a calculation that Excel can handle, the following approximation to the k_B values is used:

/

This approximation is accurate to within 0.2% of the tabulated values for sample sizes greater than or equal to 16.

2.2.2.2 One-sided A-basis tolerance factors, k_A, for the normal distribution

The exact computation of k_B values is $1/\sqrt{n}$ times the 0.95th quantile of the noncentral t-distribution with noncentrality parameter $2.326\sqrt{n}$ and $n-1$ degrees of freedom (Reference 11). Since this is not a calculation that Excel can handle easily, the following approximation to the k_B values is used:

$$k_A \quad 2.326 \quad \exp\{1.34 \quad 0.522\ln(n) \quad 3.87/n\} \qquad \textbf{Equation 34}$$

This approximation is accurate to within 0.2% of the tabulated values for sample sizes greater than or equal to 16.

2.2.2.3 Two-parameter Weibull Distribution

A probability distribution for which the probability that a randomly selected observation from this population lies between a and b $0 \quad a \quad b$ is given by

$$e^{a/} \qquad e^{b/} \qquad \textbf{Equation 35}$$

where α is called the scale parameter and β is called the shape parameter.

In order to compute a check of the fit of a data set to the Weibull distribution and com2-.72 17.25o5-.1488 TD-

2.2.2.3.2 Goodness-of-fit test for the Weibull distribution

The two-parameter Weibull distribution is considered by comparing the cumulative Weibull distribution function that best fits the data with the cumulative distribution function of the data. Using the shape and scale parameter estimates from section 2.2.2.3.1, let

$$z_i = \left[x_i / \hat{\alpha}\right]^{\hat{\beta}}, \text{ for } i = 1, \ldots, n$$ **Equation 38**

The Anderson-Darling test statistic is

$$\mathrm{AD} = \sum_{i=1}^{n} \frac{1-2i}{n} \left\{ \ln\left[1-\exp\left(-z_{(i)}\right)\right] - z_{(n+1-i)} \right\} - n$$ **Equation 39**

and the observed significance level is

$$\mathrm{OSL} = 1/\left\{1+\exp[-0.10+1.24\ln(\mathrm{AD}^*)+4.48\mathrm{AD}^*]\right\}$$ **Equation 40**

where

$$AD^* = \left(1 + \frac{0.2}{\sqrt{n}}\right) AD$$ **Equation 41**

This OSL measures the probability of observing an Anderson-Darling statistic at least as extreme as the value calculated if in fact the data is a sample from a two-parameter Weibull distribution. If OSL $\leq$ 0.05, one may conclude (at a five percent risk of being in error) that the population does not have a two-parameter Weibull distribution. Otherwise, the hypothesis that the population has a two-parameter Weibull distribution is not rejected. For further information on these procedures, see reference 6.

2.2.2.3.3 Basis value calculations for the Weibull distribution

For the two-parameter Weibull distribution, the B-basis value is

$$B = \hat{q} e^{-V / \hat{\beta}\sqrt{n}}$$ **Equation 42**

where

$$\hat{q} = \hat{\alpha}\,(0.10536)^{1/\hat{\beta}}$$ **Equation 43**

To calculate the A-basis value, substitute the equation below for the equation above.

$$\hat{q} = \hat{\alpha}(0.01005)^{1/\hat{\beta}}$$ **Equation 44**

V is the value in Table 2-2. when the sample size is less than 16. For sample sizes of 16 or larger, a numerical approximation to the V values is given in the two equations immediately below.

$$V_B = 3.803 + \exp\left[1.79 - 0.516\ln(n) + \frac{5.1}{n-1}\right]$$ **Equation 45**

$$V_A \quad 6.649 \quad \exp \;\; 2.55 \quad 0.526\ln(n) \quad \frac{4.76}{n}$$ **Equation 46**

This approximation is accurate within 0.5% of the tabulated values for n greater than or equal to 16.

Weibull Dist. K Factors for N<16		
N	B-basis	A-basis
2	690.804	1284.895
3	47.318	88.011
4	19.836	36.895
5	13.145	24.45
6	10.392	19.329
7	8.937	16.623
8	8.047	14.967
9	7.449	13.855
10	6.711	12.573
11	6.477	12.093
12	6.286	11.701
13	6.127	11.375
14	5.992	11.098
15	5.875	10.861

Table 2-2: Weibull Distribution Basis Value Factors

2.2.2.4 Lognormal Distribution

A probability distribution for which the probability that an observation selected at random from this population falls between a and b $0 \quad a \quad b$ is given by the area under the normal distribution between ln(a) and ln(b).

The lognormal distribution is a positively skewed distributio value calculated if in fact the data are a

2.2.3.2 Non-parametric Basis Values for small samples

The Hanson-Koopmans method (references 8 and 9) is used for obtaining a B-basis value for sample sizes not exceeding 28 and A-basis values for sample sizes less than 299. This procedure requires the assumption that the observations are a random sample from a population for which

B-Basis Hanson-Koopmans Table		
n	r	k
2	2	35.177
3	3	7.859
4	4	4.505
5	4	4.101
6	5	3.064
7	5	2.858
8	6	2.382
9	6	2.253
10	6	2.137
11	7	1.897
12	7	1.814
13	7	1.738
14	8	1.599
15	8	1.540
16	8	1.485
17	8	1.434
18	9	1.354
19	9	1.311
20	10	1.253
21	10	1.218
22	10	1.184
23	11	1.143
24	11	1.114
25	11	1.087
26	11	1.060
27	11	1.035
28	12	1.010

Table 2-3: B-Basis Hanson-Koopmans Table

n	k	n	k	n	k
2	80.00380	38	1.79301	96	1.32324
3	16.91220	39	1.77546	98	1.31553
4	9.49579	40	1.75868	100	1.30806
5	6.89049	41	1.74260	105	1.29036
6	5.57681	42	1.72718	110	1.27392
7	4.78352	43	1.71239	115	1.25859
8	4.25011	44	1.69817	120	1.24425
9	3.86502	45	1.68449	125	1.23080
10	3.57267	46	1.67132	130	1.21814
11	3.34227	47	1.65862	135	1.20620
12	3.15540	48	1.64638	140	1.19491
13	3.00033	49	1.63456	145	1.18421
14	2.86924	50	1.62313	150	1.17406
15	2.75672	52	1.60139	155	1.16440
16	2.65889	54	1.58101	160	1.15519

Two k-factors are computed using the methodology of section 2.2.2 using a sample size of n (denoted k_0) and a sample size of k (denoted k_1). Whether this value is an A- or B-basis value depends only on whether k_0 and k_1 are computed for A or B-basis values.
Denote the ratio of mean squares by

$$u \quad \frac{MSB}{MSE}$$ **Equation 59**

If u is less than one, it is set equal to one. The tolerance limit factor is

$$\frac{\sqrt{} \qquad\qquad \sqrt{\frac{}{}}}{\sqrt{}}$$

However, if the laminate CV is larger than the corresponding lamina CV, the larger laminate CV value is used.

The LVM B-basis value is then computed as:

LVM Estimated B-Basis = $\bar{X}_1 \quad K_{N_1,N_2} \quad \bar{X}_1 \ \max \ CV_1, CV_2$

3. Summary of Results

The basis values for all tests are summarized in the following tables. The NCAMP recommended B-basis values meet all requirements of CMH-17-1G. However, not all test data meets those requirements. The summary tables provide a complete listing of all computed basis values and estimates of basis values. Data that does not

NCAMP Recommended B-basis Values for
TenCate Advance Composites AS4C 3KPW with BT250E-6 Resin Material

All B-basis values in this table meet the standards for publication in CMH-17G Handbook
Values are for normalized data unless otherwise noted

Lamina Strength Tests

Environment	Statistic	WT	FT	WC	FC	SBS*	IPS*	
							0.2% Offset	5% Strain
CTD (-65 F)	B-basis	108.980	107.321	88.943	82.084	7.508	7.436	11.731
	Mean	125.113	120.271	102.760	93.260	8.466	8.396	13.246
	CV	6.694	6.244	7.127	7.414	6.000	6.000	6.000
RTD (70 F)	B-basis	NA:A	111.800	81.362	73.946	7.242	5.671	9.154
	Mean	132.294	124.751	93.092	85.122	8.157	6.403	10.335
	CV	4.792	6.000	6.612	6.604	6.000	6.000	6.000
ETD (180 F)	B-basis				NA:I	6.254		
	Mean				73.543	7.109		
	CV				9.239	6.308		
ETW (180 F)	B-basis	110.945	97.437	48.906	NA:A	4.452	3.267	5.071
	Mean	124.698	110.388	56.398	50.327	5.044	3.688	5.733
	CV	6.000	6.767	6.971	7.059	6.222	6.000	6.000

Notes: The modified CV B-basis value is recommended when available.
The CV provided corresponds with the B-basis value. If no B-basis, then actual CV is shown.
NA implies that tests were run but data did not meet NCAMP recommended requirements.
"NA: A" indicates ANOVA with 3 batches, "NA: I" indicates insufficient data,
Shaded empty boxes indicate that no test data is available for that property and condition.
* Data is as-measured rather than normalized
** Derived from cross-ply using back-out factor
*** indicates the Stat17 B-basis value is greater than 90% of the mean value.

Table 3-1: NCAMP recommended B-basis values for lamina test data

3.2 Lamina Summary Tables

Prepreg Material:	TenCate Advance Composites AS4C 3k-PW Fabric with BT250E-6 Resin
Material Specification:	NMS 250/2

Warp Tension Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	125.113	132.294	124.698	124.754	131.913	123.157
Stdev	6.741	6.340	3.762	7.272	6.541	4.944
CV	5.388	4.792	3.017	5.829	4.959	4.015
Mod CV	6.694	6.396	6.000	6.915	6.479	6.007
Min	110.920	112.881	117.096	110.386	112.748	113.780
Max	137.895	141.459	129.636	135.538	141.422	131.283
No. Batches	3	3	3	3	3	3
No. Spec.	20	22	25	20	22	25
B-estimate	89.686	96.323	101.390	84.777	95.054	93.993
A-estimate	64.402	70.640	84.744	56.245	68.736	73.161
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	108.980		110.945			109.557
B-estimate		116.331		108.137	115.788	
A-estimate	97.514	104.935	101.070	96.327	104.277	99.793
Method	Normal	Normal	Normal	Normal	Normal	Normal

Table 4-1: Statistics and Basis values for WT strength

Warp Tension Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	8.631	8.560	8.558	8.592	8.536	8.452
Stdev	0.085	0.057	0.085	0.215	0.188	0.179
CV	0.981	0.663	0.994	2.504	2.205	2.118
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	8.485	8.468	8.411	8.257	8.212	8.057
Max	8.829	8.698	8.747	9.004	8.911	8.715
No. Batches	3	3	3	3	3	3
No. Spec.	18	22	28	18	22	28

4.2 Fill Tension (FT)

Fill Tension data was normalized. The CTD dataset, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which meant the CTD condition required using the ANOVA analysis according to CMH-17-1G guidelines. With fewer than 5 batches, this is considered an estimate. The CTD dataset passed the ADK test after applying the modified CV transformation to the data, thus modified CV results are available. Pooling the three environments was acceptable for the modified CV basis value computations.

There were two outliers, the largest value in batch one of the CTD condition and the lowest value in batch two of the ETW condition. Both outliers were outliers only for the as-measured data, not for the normalized data, and both were outliers only for their respective batches, not for their respective conditions. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for strength data as-measured in Table 4-3 and for the modulus data as-measured in Table 4-4. The data and the B-basis values and B-estimates are shown graphically in Figure 4-2.

4.3 Warp Compression (WC)

Warp Compression Strength Basis Values and Statistics

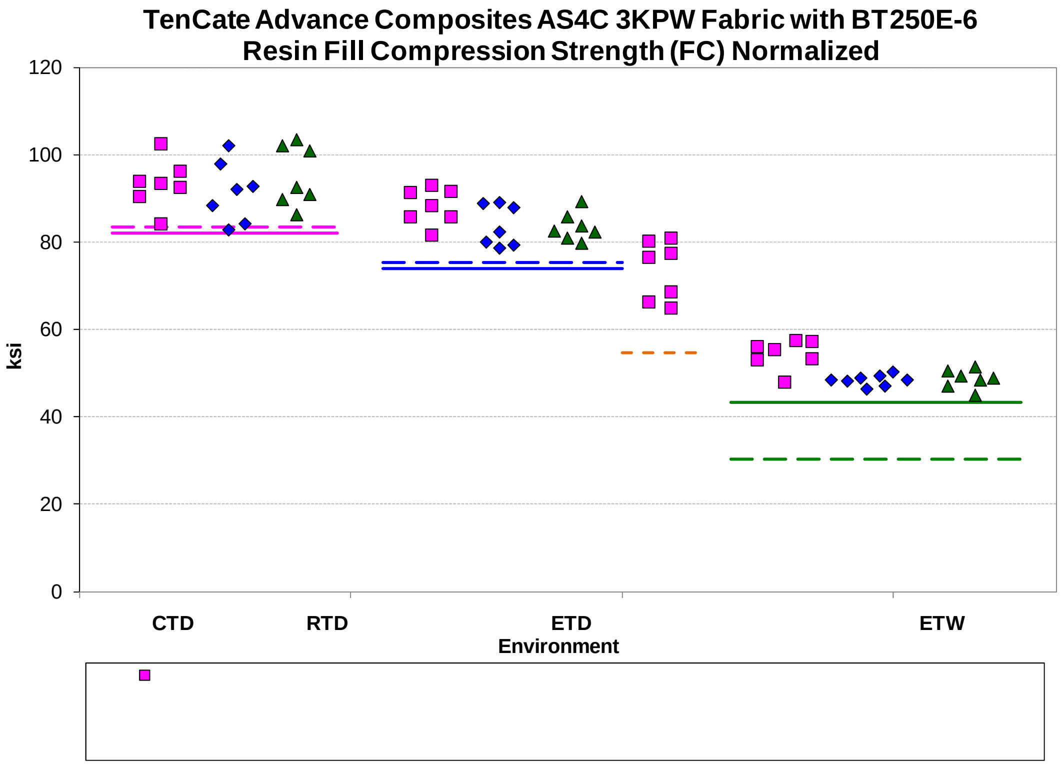
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	102.760	93.092	56.398	101.147	92.800	55.442
Stdev	6.426	4.863	3.351	6.753	4.974	3.457
CV	6.254	5.224	5.942	6.677	5.359	6.236
Mod CV	7.127	6.612	6.971	7.338	6.680	7.118
Min	89.515	82.364	49.677	87.625	81.462	47.952
Max	113.672	100.158	61.373	112.219	101.045	60.572
No. Batches	3	3	3	3	3	3
No. Spec.	22	21	21	22	21	21

Basis Value Estimates

Env	CTD	RTD	ETW	CTD	RTD	ETW
B-basis Value		83.827	50.014		83.326	48.855
B-estimate	76.273			71.527		
A-Estimate	57.361	77.222	45.462	50.376	76.571	44.160
Method	ANOVA	Normal	Normal	ANOVA	Normal	Normal

Modified CV Basis Value Estimates

Env	CTD	RTD	ETW	CTD	RTD	ETW
B-basis Value	88.943	81.362	48.906	87.144	80.988	47.921
A-Estimate	79.080	73.007	43.569	77.147	72.574	42.565
Method	Normal	Normal	Normal	Normal	Normal	Normal


TenCate Advance Composites AS4C 3KPW Fabric with BT250E-6
Resin Fill Compression Strength (FC) Normalized
120
100
80
60
40
20
0
ksi
CTD
RTD
ETD
ETW
Environment

Fill Compression Modulus Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	8.111	7.862	7.896	7.906	8.109	7.882	7.724	7.886
Stdev	0.177	0.178	0.263	0.097	0.233	0.211	0.135	0.120
CV	2.181	2.269	3.329	1.222	2.873	2.676	1.751	1.521
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Min	7.688	7.576	7.629	7.737	7.691	7.661	7.555	7.682
Max	8.439	8.450	8.157	8.101	8.526	8.596	7.868	8.065
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	21	18	18	6	21

Table 4-8: Statistics from FC Modulus data

4.5 In-Plane Shear (IPS)

In Plane Shear data is not normalized. The 0.2% offset strength dataset for the CTD condition failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means

In-Plane Shear Strength Basis Values and Statistics						
	Strength at 5% Strain			0.2% Offset Strength		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	13.246	10.335	5.733	8.396	6.403	3.688
Stdev	0.365	0.206	0.190	0.197	0.141	0.111
CV	2.753	1.991	3.319	2.348	2.207	3.004
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	12.517	10.050	5.337	7.957	6.134	3.497
Max	13.973	10.779	6.010	8.724	6.583	3.873
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	20	21	21	21
Basis Values and Estimates						
B-basis Value	12.551	9.943	5.367		6.112	3.477
B-estimate				7.567		
A-estimate	12.056	9.664	5.106	6.975	5.789	3.327
Method	Normal	Normal	Normal	ANOVA	Weibull	Normal
ModifiedBasis Values and Estimates						
B-basis Value	11.731	9.154	5.071	7.436	5.671	3.267
A-estimate	10.652	8.312	4.600	6.752	5.149	2.966
Method	Normal	Normal	Normal	Normal	Normal	Normal

Table 4-9: Statistics and Basis Values for IPS Strength data

4.6 Lamina Short-Beam Strength (SBS)

The Short Beam Strength data is not normalized

Short Beam Strength Basis Values and Statistics As-measured				
Env	CTD	RTD	ETD	ETW
Mean	8.466	8.157	7.109	5.044
Stdev	0.281	0.282	0.328	0.224
CV	3.323	3.458	4.617	4.444
Mod CV	6.000	6.000	6.308	6.222
Min	7.885	7.745	6.443	4.597
Max	8.948	8.896	7.554	5.630
No. Batches	3	3	3	3
No. Spec.	22	23	21	22
Basis Values and Estimates				
B-estimate	7.990	7.682	6.630	4.568
A-estimate	7.671	7.363	6.311	4.249
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-estimate	7.508	7.242	6.254	4.452
A-estimate	6.824	6.588	5.645	4.030
Method	Normal	Normal	Normal	Normal

Table 4-11: Statistics and Basis Values for SBS data

5. Outliers

Outliers were identified according to the standards documented in section 2.1.5, which are in accordance with the guidelines developed in section 8.3.3 of CMH-17-1G. An outlier may be an outlier in the normalized data, the as-measured data, or both. A specimen may be an outlier for the batch only (before pooling the three batches within a condition together) or for the condition (after pooling the three batches within a condition together) or both.

Approximately 5 out of 100 specimens will be identified as outliers due to the expected random variation of the data. This test is used only to identify specimens to be investigated for a cause of the extreme observation. Outliers that have an identifiable cause are removed from the dataset as they inject bias into the computation of statistics and basis values. Specimens that are outliers for the condition and in both the normalized and as-measured data

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