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VICTREX AE^{TM}250 LM PEAK with Hexcel AS4 12k Unitape 34% RC Material Allowables Statistical Analysis Report

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1. Introduction

This report contains statistical analysis of the VICTREX AE™ 250 T-071 unidirectional tape prepreg material property data published in NCAMP Test Report CAM-RP-2021-025 N/C. The lamina and laminate material property data have been generated in accordance with NCAMP Standard Operating Procedures NSP 100. The test panels, test specimens, and test setups have been conformed by an NCAMP appointed AIR and the testing has been witnessed by an NCAMP AER.

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 NCAMP Material Specification NMS 125/1 Rev A dated Feb 25, 2021. The qualification test panels were fabricated per NPS 81250. The panels were fabricated at TxV Aero Composites, 55 Broadcommon Rd #2, Briston, RI. The NCAMP Test Plan NTP 1250Q1 Rev A was used for this qualification program. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas.

Basis numbers are labeled as ‘values’ when the data meets all the requirements of CMH-17-1G. When those requirements are not met, they will be labeled as ‘estimates.’ When the data does not meet all requirements, the failure to meet these requirements is reported and the specific requirement(s) the data fails to meet is identified. The method used to compute the basis value is noted for each basis value provided. When appropriate, in addition to the traditional computational methods, values computed using the modified coefficient of variation method is also provided.

The material property data acquisition process is designed to generate basic material property data with sufficient pedigree for submission to Complete Documentation sections of the Composite Materials Handbook (CMH-17 Rev G).

The NCAMP shared material property database contains material property data of common usefulness to a wide range of aerospace projects. However, the data may not fulfill all the needs of a project. Specific properties, environments, laminate architecture, and loading situations that individual projects need may require additional testing.

The use of NCAMP material and process specifications do not guarantee material or structural performance. Material users should be actively involved in evaluating material performance and quality including, but not limited to, performing regular purchaser quality control tests, performing periodic equivalency/additional testing, participating in material change management activities, conducting statistical process control, and conducting regular supplier audits.

The applicability and accuracy of NCAMP material property data, material allowables, and specifications must be evaluated on case-by-case basis by aircraft companies and certifying 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 125/1. NMS 125/1 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 125/1. NMS 125/1* is a free, publicly available, non-proprietary aerospace industry material specification.

This report is intended for general distribution to the public, either freely or at a price that does not exceed the cost of reproduction (e.g. printing) and distribution (e.g. postage).

1.1 Symbols and Abbreviations

Test Property	**Abbreviation**
Longitudinal Compression	LC
Longitudinal Tension	LT
Transverse Tension	TT
In-Plane Shear	IPS
Double Notched Shear	DNS
V-Notched Rail Shear	VNS
Flexure	FLEX
Unnotched Tension	UNT
Unnotched Compression	UNC
Filled Hole Tension	FHT
Filled Hole Compression	FHC
Open Hole Tension	OHT
Open Hole Compression	OHC
Single Shear Bearing	SSB
Interlaminar Tension	ILT
Curved Beam Strength	CBS
Compression After Impact	CAI

Table 1-1: Test Property Abbreviations

Test Property	**Symbol**
Longitudinal Compression Strength	F_1^{cu}
Longitudinal Compression Modulus	E_1^{c}
Longitudinal Tension Strength	F_1^{tu}
Longitudinal Tension Modulus	E_1^{t}
Longitudinal Tension Poisson's Ratio	ν_{12}^{t}
Transverse Compression Strength	F_2^{cu}
Transverse Compression Modulus	E_2^{c}
Transverse Tension Strength	F_2^{tu}
Transverse Tension Modulus	E_2^{t}
In-Plane Shear Strength at 5% strain	F_{12}^{ult}
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 Ambient	CTA	–65±5°F
Room Temperature Ambient	RTA	70±10°F
Elevated Temperature Ambient	ETA	275±5°F
Elevated Temperature Wet	ETW2	250±5°F
Elevated Temperature Wet	ETW	275±5°F

Table 1-3: Environmental Conditions Abbreviations

Tests with a number immediately after the abbreviation indicate the lay-up:

1 refers to a 25/50/25 layup. This is also referred to as "Quasi-Isotropic"
2 refers to a 10/80/10 layup. This is also referred to as “Soft”
3 refers to a 50/40/10 layup. This is also referred to as “Hard”

EX: OHT1 is an open hole tension test with a 25/50/25 layup

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2021-025.

1.2 Pooling Across Environments

When pooling across environments was allowable, the pooled co-efficient of variation was used. CMH17 STATS (CMH17 Approved **S**tatistical Analysis Program) 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: $\text{basis value} = \overline{X} - kS$ 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. Background

Statistical computations are performed with CMH17 STATS. Pooling across environments will be used whenever it is permissible according to CMH-17-1G guidelines. If pooling is not permissible, the results of a single point analysis provided by CMH17 STATS is included instead. If the data does not meet CMH-17-1G requirements for a single point analysis, estimates are created by a variety of methods depending on which is most appropriate for the dataset available. Specific procedures used are presented in the individual sections where the data is presented.

2.1 CMH17 STATS Statistical Formulas and Computations

This section contains the details of the specific formulas CMH17 STATS uses in its computations.

2.1.1 Basic Descriptive Statistics

The basic descriptive statistics shown are computed according to the usual formulas, which are shown below:

Mean: $$\bar{X} = \sum_{i=1}^{n} \frac{X_i}{n}$$ **Equation 1**

Std. Dev.: $$S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2}$$ **Equation 2**

% Co. Variation: $$\frac{S}{\bar{X}} \times 100$$ **Equation 3**

Where n refers to the number of specimens in the sample and X_i refers to the individual specimen measurements.

2.1.2 Statistics for Pooled Data

Prior to computing statistics for the pooled dataset, the data is normalized to a mean of one by dividing each value by the mean of all the data for that condition. This transformation does not affect the coefficients of variation for the individual conditions.

2.1.2.1 Pooled Standard Deviation

The formula to compute a pooled standard deviation is given below:

Pooled Std. Dev.: $$S_p = \sqrt{\frac{\sum_{i=1}^{k}(n_i - 1)S_i^2}{\sum_{i=1}^{k}(n_i - 1)}}$$ **Equation 4**

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 $$= \frac{S_p}{1} = S_p$$ **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: $$A-basis = \bar{X} - K_a S$$ $$B-basis = \bar{X} - K_b S$$ **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:

$$K_a = \frac{2.3263}{\sqrt{q(f)}} + \sqrt{\frac{1}{c_A(f)\cdot n_j} + \left(\frac{b_A(f)}{2c_A(f)}\right)^2} - \frac{b_A(f)}{2c_A(f)}$$ **Equation 7**

$$K_b = \frac{1.2816}{\sqrt{q(f)}} + \sqrt{\frac{1}{c_B(f)\cdot n_j} + \left(\frac{b_B(f)}{2c_B(f)}\right)^2} - \frac{b_B(f)}{2c_B(f)}$$ **Equation 8**

Where

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

$$N = \sum_{j=1}^{r} n_j$$
$$f = N - r$$

$$q(f) = 1 - \frac{2.323}{\sqrt{f}} + \frac{1.064}{f} + \frac{0.9157}{f\sqrt{f}} - \frac{0.6530}{f^2}$$ **Equation 9**

$$b_B(f) = \frac{1.1372}{\sqrt{f}} - \frac{0.49162}{f} + \frac{0.18612}{f\sqrt{f}}$$ **Equation 10**

$$c_B(f) = 0.36961 + \frac{0.0040342}{\sqrt{f}} - \frac{0.71750}{f} + \frac{0.19693}{f\sqrt{f}}$$ **Equation 11**

$$b_A(f) = \frac{2.0643}{\sqrt{f}} - \frac{0.95145}{f} + \frac{0.51251}{f\sqrt{f}}$$ **Equation 12**

$$c_A(f) = 0.36961 + \frac{0.0026958}{\sqrt{f}} - \frac{0.65201}{f} + \frac{0.011320}{f\sqrt{f}}$$ **Equation 13**

2.1.4 Modified Coefficient of Variation

The coefficient of variation is modified according to the following rules:

Modified CV = $$CV^* = \begin{cases} .06 & if\ CV < .04 \\ \frac{CV}{2} + .04 & if\ .04 \le CV < .08 \\ CV & if\ CV \ge .08 \end{cases}$$ **Equation 14**

This is converted to percent by multiplying by 100%.

CV^* is used to compute a modified standard deviation S^*.

$$S^* = CV^* \cdot \overline{X}$$ **Equation 15**

To compute the pooled standard deviation based on the modified CV:

$$S_p^* = \sqrt{\frac{\sum_{i=1}^{k}\left((n_i - 1)\left(CV_i^* \cdot \overline{X}_i\right)^2\right)}{\sum_{i=1}^{k}(n_i - 1)}}$$ **Equation 16**

The A-basis and B-basis values under the assumption of the modified CV method are computed by replacing S with S^*

2.1.4.1 Transformation of data based on Modified CV

In order to determine if the data would pass the diagnostic tests under the assumption of the modified CV, the data must be transformed such that the batch means remain the same while the standard deviation of transformed data (all batches) matches the modified standard deviation.

To accomplish this requires a transformation in two steps:

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

$$X'_{ij} = C_i \left(X_{ij} - \overline{X}_i \right) + \overline{X}_i \qquad \textbf{Equation 17}$$

$$C_i = \frac{S_i^*}{S_i} \qquad \textbf{Equation 18}$$

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 the combined data (due to the addition of between batch variation when combining data from multiple batches). In order to alter the data to match S^*, the transformed data is transformed again, this time setting using the same value of C′ for all batches.

$$X''_{ij} = C' \left(X'_{ij} - \overline{X}_i \right) + \overline{X}_i \qquad \textbf{Equation 19}$$

$$C' = \sqrt{\frac{SSE^*}{SSE'}} \qquad \textbf{Equation 20}$$

$$SSE^* = (n-1)\left(CV^* \cdot \overline{X} \right)^2 - \sum_{i=1}^{k} n_i \left(\overline{X}_i - \overline{X} \right)^2 \qquad \textbf{Equation 21}$$

$$SSE' = \sum_{i=1}^{k} \sum_{j=1}^{n_i} \left(X'_{ij} - \overline{X}_i \right)^2 \qquad \textbf{Equation 22}$$

Once this second transformation has been completed, the k-sample Anderson Darling test for batch equivalence can be run on the transformed data to determine if the modified co-efficient of variation will permit pooling of the data.

2.1.5 Determination of Outliers

All outliers are identified in text and graphics. If an outlier is removed from the dataset, it will be specified and the reason why will be documented in the text. Outliers are identified using the Maximum Normed Residual Test for Outliers as specified in section 8.3.3 of CMH-17-1G.

$$MNR = \frac{\max_{all\ i} \left| X_i - \bar{X} \right|}{S}, i = 1 \ldots n$$ **Equation 23**

$$C = \frac{n-1}{\sqrt{n}} \sqrt{\frac{t^2}{n-2+t^2}}$$ **Equation 24**

where t is the $1-\frac{.05}{2n}$ quartile of a t distribution with n−2 degrees of freedom, n being the total number of data values.

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 $z_{(1)}$, $z_{(2)}, \ldots z_{(L)}$, where L will be less than n if there are tied observations. These rankings are used to compute the test statistic.

The k-sample Anderson-Darling test statistic is:

$$ADK = \frac{n-1}{n^2(k-1)} \sum_{i=1}^{k} \left[\frac{1}{n_i} \sum_{j=1}^{L} h_j \frac{\left(nF_{ij} - n_i H_j\right)^2}{H_j\left(n - H_j\right) - \frac{nh_j}{4}} \right]$$ **Equation 25**

Where

n_i = the number of test specimens in each batch

$n = n_1 + n_2 + \ldots + n_k$

h_j = the number of values in the combined samples equal to $z_{(j)}$

H_j = the number of values in the combined samples less than $z_{(j)}$ plus ½ the number of values in the combined samples equal to $z_{(j)}$

F_{ij} = the number of values in the i^{th} group which are less than $z_{(j)}$ plus ½ the number of values in this group which are equal to $z_{(j)}$.

The critical value for the test statistic at 1−α level is computed:

$$ADC = 1 + \sigma_n \left[z_\alpha + \frac{0.678}{\sqrt{k-1}} - \frac{0.362}{k-1} \right]$$ **Equation 26**

This formula is based on the formula in reference 3 at the end of section 5, using a Taylor's expansion to estimate the critical value via the normal distribution rather than using the t distribution with k-1 degrees of freedom.

$$\sigma_n^2 = VAR(ADK) = \frac{an^3 + bn^2 + cn + d}{(n-1)(n-2)(n-3)(k-1)^2} \qquad \textbf{Equation 27}$$

With

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

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

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

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

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

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

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

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

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

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

$$OSL = \frac{1}{1+e^{-0.48+0.78\ln(AD^*)+4.58AD^*}}, \quad AD^* = \left(1+\frac{4}{n}-\frac{25}{n^2}\right)AD \qquad \textbf{Equation 31}$$

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, the data is considered sufficiently close to a normal distribution.

2.1.8 Levene's Test for Equality of Coefficient of Variation

Levene's test performs an Analysis of Variance on the absolute deviations from their sample medians. The absolute value of the deviation from the median is computed for each data value. $w_{ij} = \left| y_{ij} - \tilde{y}_i \right|$ An F-test is then performed on the transformed data values as follows:

$$F = \frac{\sum_{i=1}^{k} n_i \left(\overline{w}_i - \overline{w}\right)^2 / (k-1)}{\sum_{i=1}^{k}\sum_{j=1}^{n_i} {}_i\left(w_{ij} - \overline{w}_i\right)^2 / (n-k)} \qquad \textbf{Equation 32}$$

If this computed F statistic is less than the critical value for the F-distribution having k-1 numerator and n-k denominator degrees of freedom at the 1-α level of confidence, then the data is not rejected as being too different in terms of the co-efficient of variation. CMH-17 STATS provides the appropriate critical values for F at α levels of 0.10, 0.05, 0.025, and 0.01. For more information on this procedure, see references 4 and 5.

2.1.9 Distribution Tests

In addition to testing for normality using the Anderson-Darling test (see 2.1.7), CMH17 STATS also tests to see if the Weibull or Lognormal distribution is a good fit for the data.

Each distribution is considered using the Anderson-Darling test statistic which is sensitive to discrepancies in the tail regions. The Anderson-Darling test compares the cumulative distribution function for the distribution of interest with the cumulative distribution function of the data.

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 $x_{(1)}, ..., x_{(n)}$.

2.1.9.1 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:

$$k_B \approx 1.282 + \exp\{0.958 - 0.520\ln(n) + 3.19/n\}$$ **Equation 33**

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

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

The exact computation of k_A 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_A values is used:

$$k_A \approx 2.326 + \exp\{1.34 - 0.522\ln(n) + 3.87/n\}$$ **Equation 34**

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

2.1.9.3 Two-parameter Weibull Distribution

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

$$e^{-(a/\alpha)^{\beta}} - e^{-(b/\alpha)^{\beta}}$$ **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 compute basis values assuming Weibull, it is first necessary to obtain estimates of the population shape and scale parameters (Section 2.1.9.3.1). Calculations specific to the goodness-of-fit test for the Weibull distribution are provided in section 2.1.9.3.2.

2.1.9.3.1 Estimating Weibull Parameters

This section describes the *maximum likelihood* method for estimating the parameters of the two-parameter Weibull distribution. The maximum-likelihood estimates of the shape and scale parameters are denoted $\hat{\beta}$ and $\hat{\alpha}$. The estimates are the solution to the pair of equations:

$$\hat{\alpha}\hat{\beta}\mathrm{n} - \frac{\hat{\beta}}{\hat{\alpha}^{\hat{\beta}-1}} \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{x}_{\mathrm{i}}^{\hat{\beta}} = 0$$ **Equation 36**

$$\frac{n}{\hat{\beta}} - n \ln \hat{\alpha} + \sum_{i=1}^{n} \ln x_i - \sum_{i=1}^{n} \left[\frac{x_i}{\hat{\alpha}}\right]^{\hat{\beta}} \left(\ln x_i - \ln \hat{\alpha}\right) = 0$$ **Equation 37**

CMH17 STATS solves these equations numerically for $\hat{\beta}$ and $\hat{\alpha}$ in order to compute basis values.

2.1.9.3.2 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 2.1.9.3.1, let

$$z_{(i)} = \left[x_{(i)} / \hat{\alpha} \right]^{\hat{\beta}}, \quad \text{for } i = 1, \ldots, n$$ **Equation 38**

The Anderson-Darling test statistic is

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

and the observed significance level is

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

2.1.9.3.3 Basis value calculations for the Weibull distribution

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

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

where

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

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

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

V is the value in Table 2-1 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.

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

$$V_A \approx 6.649 + \exp\left[2.55 - 0.526\ln(n) + \frac{4.76}{n}\right] \qquad \textbf{Equation 46}$$

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 2-1: Weibull Distribution Basis Value Factors

2.1.9.4 Lognormal Distribution

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

The lognormal distribution is a positively skewed distribution that is simply related to the normal distribution. If something is lognormally distributed, then its logarithm is normally distributed. The natural (base e) logarithm is used.

2.1.9.4.1 Goodness-of-fit test for the Lognormal distribution

In order to test the goodness-of-fit of the lognormal distribution, take the logarithm of the data and perform the Anderson-Darling test for normality from Section 2.1.7. Using the natural logarithm, replace Equation 29 above with Equation 47 below:

$$z_{(i)} = \frac{\ln\left(x_{(i)}\right) - \bar{x}_L}{s_L}, \quad \text{for } i = 1, \ldots, n \qquad \textbf{Equation 47}$$

where $x_{(i)}$ is the i^{th} smallest sample observation, $\bar{x}_L$ and s_L are the mean and standard deviation of the $\ln(x_i)$ values.

The Anderson-Darling statistic is then computed using Equation 30 above and the observed significance level (OSL) is computed using Equation 31 above. 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 lognormal distribution. If OSL ≤ 0.05, one may conclude (at a five percent risk of being in error) that the population is not lognormally distributed. Otherwise, the hypothesis that the population is lognormally distributed is not rejected. For further information on these procedures, see reference 6.

2.1.9.4.2 Basis value calculations for the Lognormal distribution

If the data set is assumed to be from a population with a lognormal distribution, basis values are calculated using the equation above in section 2.1.3. However, the calculations are performed using the logarithms of the data rather than the original observations. The computed basis values are then transformed back to the original units by applying the inverse of the log transformation.

2.1.10 Non-parametric Basis Values

Non-parametric techniques do not assume any particularly underlying distribution for the population the sample comes from. It does require that the batches be similar enough to be grouped together, so the ADK test must have a positive result. While it can be used instead of assuming the normal, lognormal or Weibull distribution, it typically results in lower basis values. One of following two methods should be used, depending on the sample size.

2.1.10.1 Non-parametric Basis Values for large samples

The required sample sizes for this ranking method differ for A and B basis values. A sample size of at least 29 is needed for the B-basis value while a sample size of 299 is required for the A-basis.

To calculate a B-basis value for n > 28, the value of r is determined with the following formulas:

For B-basis values:

$$r_B = \frac{n}{10} - 1.645\sqrt{\frac{9n}{100}} + 0.23$$ **Equation 48**

For A-Basis values:

$$r_A = \frac{n}{100} - 1.645\sqrt{\frac{99n}{10,000}} + 0.29 + \frac{19.1}{n}$$ **Equation 49**

The formula for the A-basis values should be rounded to the nearest integer. This approximation is exact for most values and for a small percentage of values (less than 0.2%), the approximation errs by one rank on the conservative side.

The B-basis value is the r_B^{th} lowest observation in the data set, while the A-basis value is the r_A^{th} lowest observation in the data set. For example, in a sample of size n = 30, the lowest (r = 1) observation is the B-basis value. Further information on this procedure may be found in reference 7.

2.1.10.2 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 the logarithm of the cumulative distribution function is concave, an assumption satisfied by a large class of probability distributions. There is substantial empirical evidence that suggests that composite strength data satisfies this assumption.

The Hanson-Koopmans B-basis value is:

$$B = x_{(r)} \left[\frac{x_{(1)}}{x_{(r)}} \right]^k$$

Equation 50

The A-basis value is:

$$A = x_{(n)} \left[\frac{x_{(1)}}{x_{(n)}} \right]^k$$

Equation 51

where $x_{(n)}$ is the largest data value, $x_{(1)}$ is the smallest, and $x_{(r)}$ is the r^{th} largest data value. The values of r and k depend on n and are listed in Table 2-2. This method is not used for the B-basis value when $x_{(r)} = x_{(1)}$.

The Hanson-Koopmans method can be used to calculate A-basis values for n less than 299. Find the value k_A corresponding to the sample size n in Table 2-3. For an A-basis value that meets all the requirements of CMH-17-1G, there must be at least five batches represented in the data and at least 55 data points. For a B-basis value, there must be at least three batches represented in the data and at least 18 data points.

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 2-2: B-Basis Hanson-Koopmans Table

A-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
17	2.57290	56	1.56184	165	1.14640
18	2.49660	58	1.54377	170	1.13801
19	2.42833	60	1.52670	175	1.12997
20	2.36683	62	1.51053	180	1.12226
21	2.31106	64	1.49520	185	1.11486
22	2.26020	66	1.48063	190	1.10776
23	2.21359	68	1.46675	195	1.10092
24	2.17067	70	1.45352	200	1.09434
25	2.13100	72	1.44089	205	1.08799
26	2.09419	74	1.42881	210	1.08187
27	2.05991	76	1.41724	215	1.07595
28	2.02790	78	1.40614	220	1.07024
29	1.99791	80	1.39549	225	1.06471
30	1.96975	82	1.38525	230	1.05935
31	1.94324	84	1.37541	235	1.05417
32	1.91822	86	1.36592	240	1.04914
33	1.89457	88	1.35678	245	1.04426
34	1.87215	90	1.34796	250	1.03952
35	1.85088	92	1.33944	275	1.01773
36	1.83065	94	1.33120	299	1.00000
37	1.81139				

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

2.1.11 Analysis of Variance (ANOVA) Basis Values

ANOVA is used to compute basis values when the batch to batch variability of the data does not pass the ADK test. Since ANOVA makes the assumption that the different batches have equal variances, the data is checked to make sure the assumption is valid. Levene's test for equality of variance is used (see section 2.1.8). If the dataset fails Levene's test, the basis values computed are likely to be conservative. Thus this method can still be used but the values produced will be listed as estimates.

2.1.11.1 Calculation of basis values using ANOVA

The following calculations address batch-to-batch variability. In other words, the only grouping is due to batches and the k-sample Anderson-Darling test (Section 2.1.6) indicates that the batch to batch variability is too large to pool the data. The method is based on the one-way analysis of variance random-effects model, and the procedure is documented in reference 10.

ANOVA separates the total variation (called the sum of squares) of the data into two sources: between batch variation and within batch variation.

First, statistics are computed for each batch, which are indicated with a subscript $\left(n_i, \overline{x}_i, s_i^2\right)$ while statistics that were computed with the entire dataset do not have a subscript. Individual data values are represented with a double subscript, the first number indicated the batch and the second distinguishing between the individual data values within the batch. k stands for the number of batches in the analysis. With these statistics, the Sum of Squares Between batches (SSB) and the Total Sum of Squares (SST) are computed:

$$SSB = \sum_{i=1}^{k} n_i \overline{x}_I^2 - n\overline{x}^2 \quad \textbf{Equation 52}$$

$$SST = \sum_{i=1}^{k} \sum_{j=1}^{n_i} x_{ij}^2 - n\overline{x}^2 \quad \textbf{Equation 53}$$

The within-batch, or error, sum of squares (SSE) is computed by subtraction

$$SSE = SST - SSB \quad \textbf{Equation 54}$$

Next, the mean sums of squares are computed:

$$MSB = \frac{SSB}{k-1} \quad \textbf{Equation 55}$$

$$MSE = \frac{SSE}{n-k} \quad \textbf{Equation 56}$$

Since the batches need not have equal numbers of specimens, an 'effective batch size,' is defined as

$$n' = \frac{n - \frac{1}{n}\sum_{i=1}^{k} n_i^2}{k-1} \quad \textbf{Equation 57}$$

Using the two mean squares and the effective batch size, an estimate of the population standard deviation is computed:

$$S = \sqrt{\frac{MSB}{n'} + \left(\frac{n'-1}{n'}\right) MSE} \quad \textbf{Equation 58}$$

Two k-factors are computed using the methodology of section 8.3.5 of CMH-17-1Gusing 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

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

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

$$T = \frac{k_0 - \frac{k_1}{\sqrt{n'}} + \left(k_1 - k_0\right)\sqrt{\frac{u}{u + n' - 1}}}{1 - \frac{1}{\sqrt{n'}}}$$ **Equation 60**

The basis value is $\bar{x} - TS$.

The ANOVA method can produce extremely conservative basis values when a small number of batches are available. Therefore, when less than five (5) batches are available and the ANOVA method is used, the basis values produced will be listed as estimates.

2.2 Single Batch and Two Batch Estimates using Modified CV

This method has not been approved for use by the CMH-17 organization. Values computed in this manner are estimates only. It is used only when fewer than three batches are available and no valid B-basis value could be computed using any other method. The estimate is made using the mean of the data and setting the coefficient of variation to 8 percent if it was less than that. A modified standard deviation (S_{adj}) was computed by multiplying the mean by 0.08 and computing the A and B-basis values using this inflated value for the standard deviation.

Estimated B-Basis = $\bar{X} - k_b S_{adj} = \bar{X} - k_b \cdot 0.08 \cdot \bar{X}$ **Equation 61**

2.3 Lamina Variability Method (LVM)

This method has not been approved for use by the CMH-17 organization. Values computed in this manner are estimates only. It is used only when the sample size is less than 16 and no valid B-basis value could be computed using any other method. The prime assumption for applying the LVM is that the intrinsic strength variability of the laminate (small) dataset is no greater than the strength variability of the lamina (large) dataset. This assumption was tested and found to be reasonable for composite materials as documented by Tomblin and Seneviratne [12].

To compute the estimate, the coefficients of variation (CVs) of laminate data are paired with lamina CV's for the same loading condition and environmental condition. For example, the 0º compression lamina CV CTD condition is used with open hole compression CTD condition. Bearing and in-plane shear laminate CV's are paired with 0º compression lamina CV's.

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 = $\bar{X}_1 - K_{(N_1,N_2)} \cdot \bar{X}_1 \cdot \max\left(CV_1, CV_2\right)$ **Equation 62**

When used in conjunction with the modified CV approach, a minimum value of 8% is used for the CV.

Mod CV LVM Estimated B-Basis = $\bar{X}_1 - K_{(N_1,N_2)} \cdot \bar{X}_1 \cdot Max\left(8\%, CV_1, CV_2\right)$ **Equation 63**

With:

$\bar{X}_1$ the mean of the laminate (small dataset)
N_1 the sample size of the laminate (small dataset)
N_2 the sample size of the lamina (large dataset)
CV_1 is the coefficient of variation of the laminate (small dataset)
CV_2 is the coefficient of variation of the lamina (large dataset)
$K_{(N_1,N_2)}$ is given in Table 2-4

	N1													
N1+N2-2	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4.508	0	0	0	0	0	0	0	0	0	0	0	0	0
4	3.827	3.607	0	0	0	0	0	0	0	0	0	0	0	0
5	3.481	3.263	3.141	0	0	0	0	0	0	0	0	0	0	0
6	3.273	3.056	2.934	2.854	0	0	0	0	0	0	0	0	0	0
7	3.134	2.918	2.796	2.715	2.658	0	0	0	0	0	0	0	0	0
8	3.035	2.820	2.697	2.616	2.558	2.515	0	0	0	0	0	0	0	0
9	2.960	2.746	2.623	2.541	2.483	2.440	2.405	0	0	0	0	0	0	0
10	2.903	2.688	2.565	2.484	2.425	2.381	2.346	2.318	0	0	0	0	0	0
11	2.856	2.643	2.519	2.437	2.378	2.334	2.299	2.270	2.247	0	0	0	0	0
12	2.819	2.605	2.481	2.399	2.340	2.295	2.260	2.231	2.207	2.187	0	0	0	0
13	2.787	2.574	2.450	2.367	2.308	2.263	2.227	2.198	2.174	2.154	2.137	0	0	0
14	2.761	2.547	2.423	2.341	2.281	2.236	2.200	2.171	2.147	2.126	2.109	2.093	0	0
15	2.738	2.525	2.401	2.318	2.258	2.212	2.176	2.147	2.123	2.102	2.084	2.069	2.056	0
16	2.719	2.505	2.381	2.298	2.238	2.192	2.156	2.126	2.102	2.081	2.063	2.048	2.034	2.022
17	2.701	2.488	2.364	2.280	2.220	2.174	2.138	2.108	2.083	2.062	2.045	2.029	2.015	2.003
18	2.686	2.473	2.348	2.265	2.204	2.158	2.122	2.092	2.067	2.046	2.028	2.012	1.999	1.986
19	2.673	2.459	2.335	2.251	2.191	2.144	2.108	2.078	2.053	2.032	2.013	1.998	1.984	1.971
20	2.661	2.447	2.323	2.239	2.178	2.132	2.095	2.065	2.040	2.019	2.000	1.984	1.970	1.958
21	2.650	2.437	2.312	2.228	2.167	2.121	2.084	2.053	2.028	2.007	1.988	1.972	1.958	1.946
22	2.640	2.427	2.302	2.218	2.157	2.110	2.073	2.043	2.018	1.996	1.978	1.962	1.947	1.935
23	2.631	2.418	2.293	2.209	2.148	2.101	2.064	2.033	2.008	1.987	1.968	1.952	1.938	1.925
24	2.623	2.410	2.285	2.201	2.139	2.092	2.055	2.025	1.999	1.978	1.959	1.943	1.928	1.916
25	2.616	2.402	2.277	2.193	2.132	2.085	2.047	2.017	1.991	1.969	1.951	1.934	1.920	1.907
26	2.609	2.396	2.270	2.186	2.125	2.078	2.040	2.009	1.984	1.962	1.943	1.927	1.912	1.900
27	2.602	2.389	2.264	2.180	2.118	2.071	2.033	2.003	1.977	1.955	1.936	1.920	1.905	1.892
28	2.597	2.383	2.258	2.174	2.112	2.065	2.027	1.996	1.971	1.949	1.930	1.913	1.899	1.886
29	2.591	2.378	2.252	2.168	2.106	2.059	2.021	1.990	1.965	1.943	1.924	1.907	1.893	1.880
30	2.586	2.373	2.247	2.163	2.101	2.054	2.016	1.985	1.959	1.937	1.918	1.901	1.887	1.874
40	2.550	2.337	2.211	2.126	2.063	2.015	1.977	1.946	1.919	1.897	1.877	1.860	1.845	1.832
50	2.528	2.315	2.189	2.104	2.041	1.993	1.954	1.922	1.896	1.873	1.853	1.836	1.820	1.807
60	2.514	2.301	2.175	2.089	2.026	1.978	1.939	1.907	1.880	1.857	1.837	1.819	1.804	1.790
70	2.504	2.291	2.164	2.079	2.016	1.967	1.928	1.896	1.869	1.846	1.825	1.808	1.792	1.778
80	2.496	2.283	2.157	2.071	2.008	1.959	1.920	1.887	1.860	1.837	1.817	1.799	1.783	1.769
90	2.491	2.277	2.151	2.065	2.002	1.953	1.913	1.881	1.854	1.830	1.810	1.792	1.776	1.762
100	2.486	2.273	2.146	2.060	1.997	1.948	1.908	1.876	1.849	1.825	1.805	1.787	1.771	1.757
125	2.478	2.264	2.138	2.051	1.988	1.939	1.899	1.867	1.839	1.816	1.795	1.777	1.761	1.747
150	2.472	2.259	2.132	2.046	1.982	1.933	1.893	1.861	1.833	1.809	1.789	1.770	1.754	1.740
175	2.468	2.255	2.128	2.042	1.978	1.929	1.889	1.856	1.828	1.805	1.784	1.766	1.750	1.735
200	2.465	2.252	2.125	2.039	1.975	1.925	1.886	1.853	1.825	1.801	1.781	1.762	1.746	1.732

Table 2-4: B-Basis factors for small datasets using variability of corresponding large dataset

2.4 0º Lamina Strength Derivation

Lamina strength values in the 0º direction were not obtained directly for any conditions during compression tests. They are derived from the cross-ply lamina test results using a back out formula. Unless stated otherwise, the 0° lamina strength values were derived using the following formula:

$F^u_{0^\circ} = F^u_{0^\circ/90^\circ} \cdot BF$ where BF is the backout factor.

$F^u_{0^\circ/90^\circ}$ =UNC0 or UNT0 strength values

$$BF = \frac{E_1\left[V_0E_2 + (1-V_0)E_1\right] - (\nu_{12}E_2)^2}{\left[V_0E_1 + (1-V_0)E_2\right]\left[V_0E_2 + (1-V_0)E_1\right] - (\nu_{12}E_2)^2}$$ **Equation 64**

V_0=fraction of 0º plies in the cross-ply laminate (½ for UNT0 and 1/3 for UNC0)
E_1 = Average across of batches of modulus for LC and LT as appropriate
E_2 = Average across of batches of modulus for TC and TT as appropriate
ν_{12} = major Poisson's ratio of 0º plies from an average of all batches

This formula can also be found in section 2.4.2, equation 2.4.2.1(b) of CMH-17-1G.

In computing these strength values, the values for each environment are computed separately. The compression values are computed using only compression data, the tension values are computed using only tension data. Both normalized and as-measured computations are done using the as-measured and normalized strength values from the UNC0 and UNT0 strength values.

2.4.1 0º Lamina Strength Derivation (Alternate Formula)

In some cases, the previous formula cannot be used. For example, if there were no ETD tests run for transverse tension and compression, the value for E_2 would not be available. In that case, this alternative formula is used to compute the strength values for longitudinal tension and compression. It is similar to, but not quite the same as the formula detailed above. It requires the UNC0 and UNT0 strength and modulus data in addition to the LC and LT modulus data.

The 0° lamina strength values for the LC ETD condition were derived using the formula:

$$F^{cu}_{0^\circ} = F^{cu}_{0^\circ/90^\circ}\frac{E^c_1}{E^c_{0^\circ/90^\circ}}, \quad F^{tu}_{0^\circ} = F^{tu}_{0^\circ/90^\circ}\frac{E^t_1}{E^t_{0^\circ/90^\circ}}$$ **Equation 65**

with

$F^{cu}_{0^\circ}$, $F^{tu}_{0^\circ}$ the derived mean lamina strength value for compression and tension respectively

$F^{cu}_{0^\circ/90^\circ}$, $F^{tu}_{0^\circ/90^\circ}$ are the mean strength values for UNC0 and UNT0 respectively

E^c_1, E^t_1 are the modulus values for LC and LT respectively

$E^c_{0^\circ/90^\circ}$, $E^t_{0^\circ/90^\circ}$ are the modulus values for UNC0 and UNT0 respectively

This formula can also be found in section 2.4.2, equation 2.4.2.1(d) of CMH-17-1G.

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 meet the requirements of CMH-17-1G are shown in shaded boxes and labeled as estimates. Basis values computed with the modified coefficient of variation (CV) are presented whenever possible. Basis values and estimates computed without that modification are presented for all tests.

3.1 NCAMP Recommended B-basis Values

The following rules are used in determining what B-basis value, if any, is included in tables Table 3-1 and Table 3-2 of recommended values.

1. Recommended values are NEVER estimates. Only B-basis values that meet all requirements of CMH-17-1G are recommended.
2. Modified CV basis values are preferred. Recommended values will be the modified CV basis value when available. The CV provided with the recommended basis value will be the one used in the computation of the basis value.
3. Only normalized basis values are given for properties that are normalized.
4. ANOVA B-basis values are not recommended since only three batches of material are available and CMH-17-1G recommends that no less than five batches be used when computing basis values with the ANOVA method.
5. Basis values of 90% or more of the mean value imply that the CV is unusually low and may not be conservative. Caution is recommended with B-Basis values calculated from CMH-17 STATS when the B-basis value is 90% or more of the average value. Such values will be indicated.
6. If the data appear questionable (e.g. when the CTA-RTA-ETW trend of the basis values is not consistent with the CTA-RTA-ETW trend of the average values), then the B-basis values will not be recommended.

NCAMP Recommended B-basis Values for

Victrex AE™ 250 LM PAEK, AS4 12k Unitape 143 gsm 34% RC

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 (ksi) Tests

Environment	Statistic	LT	LC from UNC0**	TC*	DNS*	VNS* 0.2% Offset	VNS* 5% Strain	IPS* 0.2% Offset	IPS* 5% Strain	0° Flex	UNC0
CTA (-65º F)	B-basis	304.0	201.9	33.48***	12.72	6.071	11.53	5.875	10.93	207.7	107.9
	Mean	342.6	225.6	37.07	14.25	6.745	12.76	6.514	12.10	232.6	120.6
	CV	6.000	6.017	6.000	6.650	6.000	6.000	6.000	6.000	6.000	6.017
RTA (70º F)	B-basis	271.7	184.0	24.40	10.47	4.861	8.181	4.466	7.886	172.2	98.95
	Mean	310.1	207.7	27.99	12.01	5.535	9.406	5.106	9.053	197.1	111.7
	CV	7.047	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.806	6.000
ETW (275º F)	B-basis	NA: A	149.0***	12.48	5.829	1.052	3.210	NA: A	3.136	92.52	75.55***
	Mean	272.1	164.0	14.16	6.670	1.618	3.840	1.246	3.596	104.8	83.15
	CV	8.600	4.712	6.000	6.392	18.35	8.616	7.559	6.489	6.000	4.712

Notes: The modified CV B-basis value is recommended when available.
The CV provided corresponds with the B-basis value given.
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 Single Point B-basis value is greater than 90% of the mean value.

Table 3-1: NCAMP Recommended B-basis Values for Lamina Test Data

NCAMP Recommended B-basis Values for
Victrex AE™ 250 LM PAEK, AS4 12k Unitape 143 gsm 34% RC

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 (ksi) Tests

Lay-up	ENV	Statistic	OHT	OHC	FHT	FHC	UNT	UNC	SSB 2% Offset	SSB Ultimate	VNS*	DNS*
Quasi Isotropic	CTA (-65° F)	B-basis	51.95		57.36		107.2					
		Mean	58.22		64.13		120.1					
		CV	6.000		6.000		6.000					
	RTA (70° F)	B-basis	50.33	40.17	52.88	65.98	102.6	71.73	95.38	109.9	36.60	NA: A
		Mean	56.60	45.57	59.65	74.84	115.4	81.36	108.5	124.7	42.92	10.17
		CV	6.000	6.000	6.000	6.000	6.000	6.000	6.129	6.000	7.642	6.113
	ETW2 (250° F)	B-basis		30.78				58.68				
		Mean		34.91				66.56				
		CV		6.000				6.000				
	ETW (275° F)	B-basis	45.12	27.29	53.02**	45.36	90.79	53.08	76.55	82.53	21.34	4.954
		Mean	51.18	30.95	54.65	51.45	103.0	61.08	87.69	94.63	30.36	5.783
		CV	6.000	6.000	1.863	6.000	6.000	6.637	6.435	6.479	15.24	7.258
"Soft"	CTA (-65° F)	B-basis	43.28		48.68		63.02					
		Mean	47.85		53.66		69.61					
		CV	6.241		6.255		6.000					
	RTA (70° F)	B-basis	39.46	38.17	42.11	51.69	56.22	52.71	99.11	120.2		
		Mean	44.02	42.09	47.09	57.09	62.77	58.36	110.0	132.7		
		CV	6.083	6.000	6.000	6.000	6.000	6.000	6.000	6.000		
	ETW (275° F)	B-basis	28.17	24.37	30.26	32.35	45.94	34.83	73.66	80.29		
		Mean	32.73	28.29	35.24	37.75	52.52	40.48	84.52	92.81		
		CV	6.000	6.000	6.000	6.401	6.000	6.522	6.202	6.000		
"Hard"	CTA (-65° F)	B-basis	69.35		NA: A		149.5					
		Mean	78.39		83.79		166.9					
		CV	6.571		4.665		6.000					
	RTA (70° F)	B-basis	69.09	50.25	NA: A	81.16	150.3	98.25	95.36	115.1		
		Mean	78.08	57.27	79.85	89.56	167.7	108.8	109.3	127.0		
		CV	6.150	6.296	3.884	6.000	6.000	6.000	6.000	6.000		
	ETW (275° F)	B-basis	NA: A	34.56	66.32	53.65	140.3	64.60	66.90	78.28		
		Mean	75.28	39.39	75.23	62.09	157.6	75.14	80.77	90.19		
		CV	4.603	6.206	6.000	6.000	6.000	6.562	10.63	6.030		

Notes: The modified CV B-basis value is recommended when available.
The CV provided corresponds with the B-basis value given.
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
** indicates the Single Point B-basis value is greater than 90% of the mean value.

Table 3-2: NCAMP Recommended B-basis Values for Laminate Test Data

3.2 Lamina and Laminate Summary Tables

Material: Victrex AE™ 250 LM PAEK, AS4 12k Unitape 143 gsm 34% RC

Fiber: HEXCEL HexTow® AS4 12K carbon fiber

Resin: Victrex AE™ 250 Low Melt Polyaryletherketone (PAEK)

Tg(dry): 290.4˚F **Tg(wet):** 276.7˚F **Tg METHOD:** ASTM D7028

PROCESSING: NPS 81250

VICTREX AE™ 250 T-071
Unidirectional Tape
Lamina Properties Summary

Date of composite manufacture
Lot 1 - July 2019
Lot 2 - October 2019
Lot 3 - November 2019

Date of testing: Jun. 2021 to Oct. 2021
Date of data submittal: Dec. 2021
Date of analysis: Nov. 2021

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY
Data reported: As-measured followed by normalized values in parentheses, normalizing tply: 0.0054 in

Values shown in shaded boxes do not meet CMH17 Rev G requirements and are estimates only
These values may not be used for certification unless specifically allowed by the certifying agency

	CTA (−65˚ F)			RTA (70˚ F)			ETA (275˚ F)			ETW (275˚ F)		
	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean
F_1^{tu}	280.2	314.6	357.1	274.7	278.1	320.4	246.6	226.1	297.9	115.1	NA	281.1
(ksi)	(321.1)	(304.0)	(342.6)	(273.2)	(271.7)	(310.1)	(239.9)	(214.5)	(282.7)	(129.1)	NA	(272.1)
E_1^t			19.76			19.72			19.10			20.20
(Msi)			(18.96)			(19.10)			(18.13)			(19.58)
ν_{12}^t			0.3235			0.2836			0.2986			0.3033
F_1^{cu} (ksi)	208.9	200.0	223.5	191.9	182.9	206.4	160.1	124.8	171.8	149.8	143.7	163.9
from UNC0*	(210.9)	(201.9)	(225.6)	(193.0)	(184.0)	(207.7)	(161.6)	(125.0)	(172.1)	(149.0)	NA	(164.0)
E_1^c			17.38			17.58			18.00			17.70
(Msi)			(16.72)			(16.91)			(17.38)			(17.24)
ν_{12}^c			0.3263			0.3363			0.3422			0.3577
F_2^{cu} (ksi)	34.51	33.48	37.07	26.87	24.40	27.99	14.27	11.60	15.29	13.54	12.48	14.16
E_2^c (Msi)			1.494			1.406			1.285			1.034
$F_{12}^{s5\%}$ (ksi)	10.89	10.93	12.10	7.766	7.886	9.053	3.905	3.248	4.280	3.243	3.136	3.596
$F_{12}^{s0.2\%}$ (ksi)	6.320	5.875	6.514	4.911	4.466	5.106	1.389	NA	1.900	0.7856	NA	1.246
G_{12}^s (Msi)			0.7000			0.6562			0.4991			0.3590
$VNS^{s5\%}$ (ksi)	10.53	11.53	12.76	8.846	8.181	9.406	4.335	NA	4.769	3.210	NA	3.840
$VNS^{s0.2\%}$ (ksi)	6.571	6.071	6.745	5.361	4.861	5.535	2.119	1.976	2.604	1.052	NA	1.618
VNS (Msi)			0.7119			0.6715			0.5826			0.4211
DNS (ksi)	10.31	12.72	14.25	9.458	10.47	12.01	5.841	5.055	6.660	6.040	5.829	6.670
0° FLEX	229.0	213.3	239.3	150.8	177.5	203.5	120.4	100.3	132.2	86.92	94.69	107.2
(ksi)	(220.9)	(207.7)	(232.6)	(175.3)	(172.2)	(197.1)	(116.6)	(97.30)	(128.2)	(98.11)	(92.52)	(104.8)
90° FLEX				NA	NA	15.81						
(ksi)				NA	NA	(15.39)						
UNC0	111.7	106.9	119.5	103.2	98.36	111.0	81.99	63.93	88.00	75.96	72.84	83.11
(ksi)	(112.7)	(107.9)	(120.6)	(103.8)	(98.95)	(111.7)	(82.77)	(64.03)	(88.13)	(75.55)	NA	(83.15)
(Msi)			9.294			9.451			9.220			8.976
			(9.386)			(9.514)			(9.217)			(8.991)

**** Derived from cross-ply using back-out factor***

Table 3-3: Summary of Test Results for Lamina Data

Material: Victrex AE™ 250 LM PAEK, AS4 12k Unitape 143 gsm 34% RC

Fiber: HEXCEL HexTow® AS4 12K carbon fiber

Resin: Victrex AE™ 250 Low Melt Polyaryletherketone (PAEK)

Tg(dry): 290.4˚F **Tg(wet):** 276.7˚F **Tg METHOD :** ASTM D7028

PROCESSING: NPS 81250

VICTREX AE™ 250 T-071 Unidirectional Tape
Laminate Properties Summary

Date of composite manufacture
Lot 1 - July 2019
Lot 2 - October 2019
Lot 3 - November 2019

Date of testing: Jun. 2021 to Oct. 2021
Date of data submittal: Dec. 2021
Date of analysis: Nov. 2021

LAMINATE MECHANICAL PROPERTY B-BASIS SUMMARY
Data reported as normalized used a normalizing t_{ply} of 0.0054 in

Values shown in shaded boxes do not meet CMH17 Rev G requirements and are estimates only
These values may not be used for certification unless specifically allowed by the certifying agency

Test	Property	Test Condition	Unit	Quasi Isotropic 25/50/25 B-value	Quasi Isotropic 25/50/25 Mod. CV B-value	Quasi Isotropic 25/50/25 Mean	"Soft" 10/80/10 B-value	"Soft" 10/80/10 Mod. CV B-value	"Soft" 10/80/10 Mean	"Hard" 50/40/10 B-value	"Hard" 50/40/10 Mod. CV B-value	"Hard" 50/40/10 Mean
OHT (normalized)	Strength	CTA (−65˚ F)	ksi	56.42	51.95	58.22	36.67	43.28	47.85	55.27	69.35	78.39
		RTA (70˚ F)	ksi	54.80	50.33	56.60	33.54	39.46	44.02	59.64	69.09	78.08
		ETA (275˚ F)	ksi	49.51	39.39	51.90	---	---	---	---	---	---
		ETW (275˚ F)	ksi	45.07	45.12	51.18	31.80	28.17	32.73	54.83	NA	75.28
OHC (normalized)	Strength	RTA (70˚ F)	ksi	37.55	40.17	45.57	34.61	38.17	42.09	43.05	50.25	57.27
		ETA (275˚ F)	ksi	31.94	25.48	33.57	---	---	---	---	---	---
		ETW2 (250˚ F)	ksi	33.15	30.78	34.91	---	---	---	---	---	---
		ETW (275˚ F)	ksi	27.46	27.29	30.95	26.23	24.37	28.29	28.53	34.56	39.39
UNT (Normalized)	Strength	CTA (−65˚ F)	ksi	112.9	107.2	120.1	66.11	63.02	69.61	156.7	149.5	166.9
	Modulus		Msi	---	---	7.067	---	---	4.602	---	---	10.96
	Strength	RTA (70˚ F)	ksi	108.3	102.6	115.4	59.29	56.22	62.77	137.4	150.3	167.7
	Modulus		Msi	---	---	7.259	---	---	4.553	---	---	10.98
	Strength	ETA (275˚ F)	ksi	94.04	80.38	105.9	---	---	---	---	---	---
	Modulus		Msi	---	---	6.654	---	---	---	---	---	---
	Strength	ETW (275˚ F)	ksi	98.93	90.79	103.0	49.02	45.94	52.52	142.4	140.3	157.6
	Modulus		Msi	---	---	6.486	---	---	3.516	---	---	10.35
UNC (Normalized)	Strength	RTA (70˚ F)	ksi	65.81	71.73	81.36	54.47	52.71	58.36	102.3	98.25	108.8
	Modulus		Msi	---	---	6.599	---	---	4.308	---	---	9.980
	Strength	ETA (275˚ F)	ksi	59.08	50.09	65.99	---	---	---	---	---	---
	Modulus		Msi	---	---	6.340	---	---	---	---	---	---
	Strength	ETW2 (250˚ F)	ksi	62.19	58.68	66.56						
	Modulus		Msi	---	---	6.342						
	Strength	ETW (275˚ F)	ksi	54.72	53.08	61.08	36.60	34.83	40.48	68.69	64.60	75.14
	Modulus		Msi	---	---	6.024	---	---	3.598	---	---	9.470
FHT (normalized)	Strength	CTA (−65˚ F)	ksi	61.88	57.36	64.13	48.88	48.68	53.66	56.91	NA	83.79
		RTA (70˚ F)	ksi	57.40	52.88	59.65	40.57	42.11	47.09	59.04	NA	79.85
		ETA (275˚ F)	ksi	51.05	42.29	55.73	---	---	---	---	---	---
		ETW (275˚ F)	ksi	53.02	NA	54.65	33.83	30.26	35.24	55.45	66.32	75.23
FHC (normalized)	Strength	RTA (70˚ F)	ksi	69.89	65.98	74.84	48.18	51.69	57.09	84.74	81.16	89.56
		ETA (275˚ F)	ksi	53.50	43.19	56.91	---	---	---	---	---	---
		ETW (275˚ F)	ksi	48.23	45.36	51.45	34.17	32.35	37.75	57.25	53.65	62.09
VNS1 (as-measured)	Ult. Strength	RTA (70˚ F)	ksi	36.90	36.60	42.92	---	---	---	---	---	---
	Modulus		Msi	---	---	2.633	---	---	---	---	---	---
	Ult. Strength	ETA (275˚ F)	ksi	29.53	27.40	36.11	---	---	---	---	---	---
	Modulus		Msi	---	---	2.494	---	---	---	---	---	---
	Ult. Strength	ETW (275˚ F)	ksi	21.34	NA	30.36	---	---	---	---	---	---
	Modulus		Msi	---	---	2.504	---	---	---	---	---	---
DNS1 (as-measured)	Strength	CTA (−65˚ F)	ksi	6.461	NA	10.17	---	---	---	---	---	---
		RTA (70˚ F)	ksi	5.495	4.546	5.989	---	---	---	---	---	---
		ETW (275˚ F)	ksi	5.039	4.954	5.783	---	---	---	---	---	---
Single Shear Bearing (normalized)	2% Offset	RTA (70˚ F)	ksi	99.39	95.38	108.5	103.8	99.11	110.0	102.8	95.36	109.3
	Ultimate		ksi	119.1	109.9	124.7	127.0	120.2	132.7	109.1	115.1	127.0
	2% Offset	ETA (275˚ F)	ksi	67.64	62.65	82.55	---	---	---	---	---	---
	Ultimate		ksi	79.12	72.15	95.06	---	---	---	---	---	---
	2% Offset	ETW (275˚ F)	ksi	82.75	76.55	87.69	78.33	73.66	84.52	64.04	66.90	80.77
	Ultimate		ksi	85.86	82.53	94.63	87.16	80.29	92.81	83.06	78.28	90.19
ILT (as-measured)	Strength	CTA (−65˚ F)	ksi	---	---	19.16	---	---	---	---	---	---
		RTA (70˚ F)	ksi	---	---	13.50	---	---	---	---	---	---
		ETA (275˚ F)	ksi			8.944						
		ETW (275˚ F)	ksi	---	---	5.387	---	---	---	---	---	---
CBS (as-measured)	Strength	CTA (−65˚ F)	lb	---	---	652.3	---	---	---	---	---	---
		RTA (70˚ F)	lb	---	---	455.1	---	---	---	---	---	---
		ETA (275˚ F)	lb	---	---	298.8						
		ETW (275˚ F)	lb	---	---	180.9	---	---	---	---	---	---
CAI (Normalized)	Strength	RTA (70˚ F)	ksi	---	---	42.40	---	---	---	---	---	---
		ETA (275˚ F)	ksi	---	---	32.63	---	---	---	---	---	---
		ETW (275˚ F)	ksi	---	---	29.63	---	---	---	---	---	---

Table 3-4: Summary of Test Results for Laminate Data

4. Test Results, Statistics, Basis Values, and Graphs

Test data for fiber dominated properties was normalized according to nominal cured ply thickness. Both normalized and as-measured statistics were included in the tables, but only the normalized data values were graphed. Test failures, outliers and explanations regarding computational choices were noted in the accompanying text for each test.

All individual specimen results are graphed for each test by batch and environmental condition with a line indicating the recommended basis values for each environmental condition. The data is jittered (moved slightly to the left or right) in order for all specimen values to be clearly visible. The strength values are always graphed on the vertical axis with the scale adjusted to include all data values and their corresponding basis values. The vertical axis may not include zero. The horizontal axis values will vary depending on the data and how much overlapping there was of the data within and between batches. When there was little variation, the batches were graphed from left to right. The environmental conditions were identified by the shape and color of the symbol used to plot the data. Otherwise, the environmental conditions were graphed from left to right and the batches were identified by the shape and color of the symbol.

When a dataset fails the Anderson-Darling k-sample (ADK) test for batch-to-batch variation, an ANOVA analysis is required. In order for B-basis values to be computed using the ANOVA method, data from five batches are required. Since this qualification dataset has only three batches, the basis values computed using ANOVA are considered estimates only. However, the basis values resulting from the ANOVA method using only three batches may be overly conservative. The ADK test is performed again after a transformation of the data according to the assumptions of the modified CV method (see section 2.1.4 for details). If the dataset still passes the ADK test at this point, modified CV basis values are provided. If the dataset does not pass the ADK test after the transformation, estimates may be computed using the modified CV method per the guidelines in CMH-17 Vol 1 Chapter 8 section 8.3.10.

4.1 Longitudinal Tension (LT)

Longitudinal Tension data is normalized, so both normalized and as-measured values are provided. Data is available for two properties, strength and modulus. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

The ETW datasets, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. These datasets failed the ADK test after applying the modified CV transformation to the data. A-Estimates were below zero using the ANOVA method and are indicated with NA for that reason. Pooling the CTA and RTA conditions was acceptable for the modified CV basis values for both normalized and as-measured datasets.

There were no statistical outliers.

Statistics and basis values are given for strength data in Table 4-1 and for the modulus data in Table 4-2. The data and the B-basis values are shown graphically in Figure 4-1.

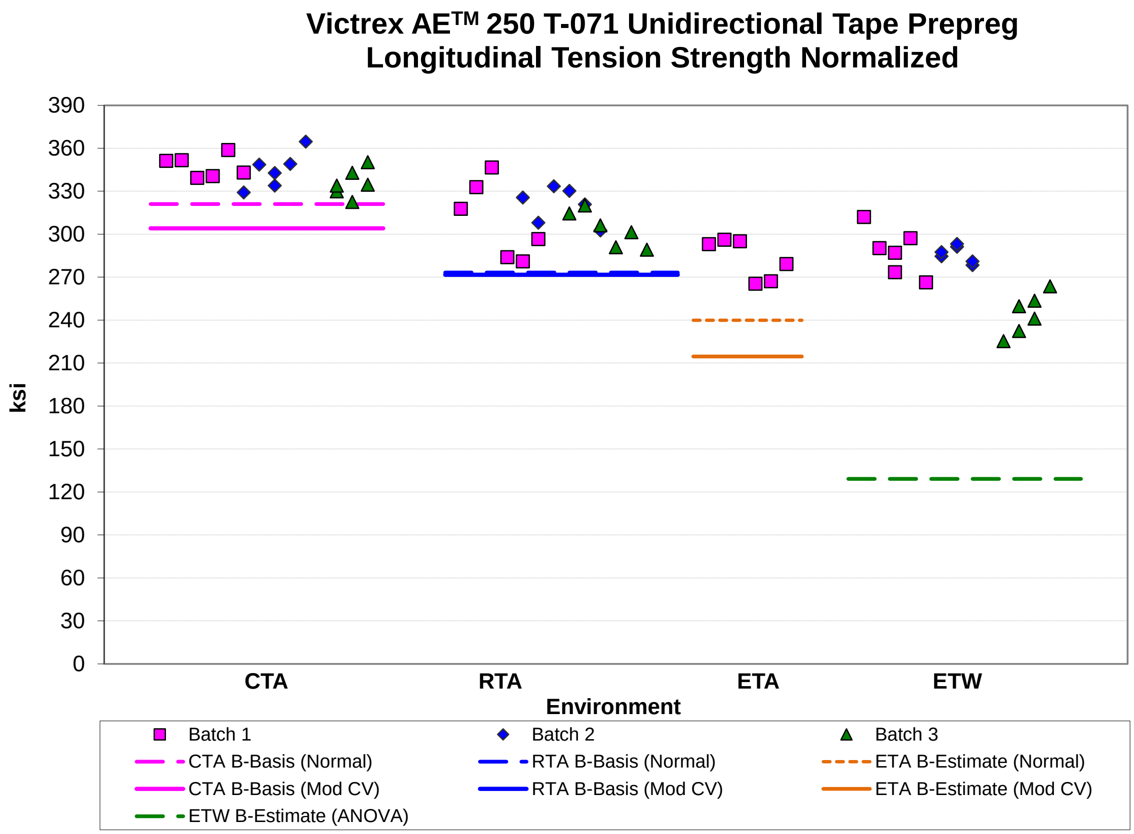

Figure 4-1 Batch plot for LT strength normalized

Longitudinal Tension Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	342.6	310.1	282.7	272.1	357.1	320.4	297.9	281.1
Stdev	10.88	18.89	14.11	23.40	15.64	23.44	16.94	26.27
CV	3.175	6.094	4.992	8.600	4.380	7.317	5.685	9.346
Mod CV	6.000	7.047	8.000	8.600	6.190	7.658	8.000	9.346
Min	322.5	281.0	265.4	225.3	333.2	291.4	277.5	228.8
Max	364.7	346.6	296.2	312.1	381.2	370.6	314.1	324.3
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	19	6	19	18	19	6	19
Basis Values and Estimates								
B-basis Value	321.1	273.2				274.7		
B-Estimate			239.9	129.1	280.2		246.6	115.1
A-estimate	305.9	247.1	209.5	27.08	225.3	242.2	210.1	NA
Method	Normal	Normal	Normal	ANOVA	ANOVA	Normal	Normal	ANOVA
Modified CV Basis Values and Estimates								
B-basis Value	304.0	271.7			314.6	278.1		
B-Estimate			214.5				226.1	
A-estimate	277.8	245.4	167.9		285.7	249.2	177.0	
Method	pooled	pooled	normal		pooled	pooled	normal	

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

Longitudinal Tension Modulus Statistics								
	Normalized				As-measured			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	18.96	19.10	18.13	19.58	19.76	19.72	19.10	20.20
Stdev	0.4793	0.3374	0.0849	0.3342	0.4877	0.3180	0.1424	0.2979
CV	2.528	1.766	0.468	1.707	2.469	1.613	0.7452	1.475
Mod CV	6.000	6.000	8.000	6.000	6.000	6.000	8.000	6.000
Min	18.03	18.42	18.04	18.83	18.63	18.99	18.91	19.53
Max	19.70	19.55	18.22	20.29	20.61	20.24	19.32	20.78
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	19	6	19	18	19	6	19

Table 4-2: Statistics from LT modulus

4.2 Longitudinal Compression (LC)

Longitudinal Compression data is normalized, so both normalized and as-measured values are provided. Data is available for two properties, strength and modulus. Strength values are not available directly from the LC test specimens. Strength values for LC were computed via the formula specified in section 2.4 using equation 65. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. The CTA and RTA conditions met all requirements for pooling. The ETW datasets, both normalized and as-measured, failed normality with the Weibull distribution provided the best fit for the dataset. The as-measured ETW dataset passed the normality test applying the modified CV transformation to the data, so modified CV basis values could be computed for the as-measured ETW condition.

There are three outliers. The largest value in batch two of the as-measured RTA dataset is an outlier for batch two only, but not for the RTA condition and not for the normalized dataset. The lowest value in batch three of the as-measured RTA dataset is outlier for the RTA condition, but not for batch three only and not for the normalized dataset. The lowest value of batch three of ETW is an outlier for batch three (both normalized and as-measured datasets) and for the ETW condition for the as-measured dataset but not for the normalized dataset. All three outliers were retained for this analysis.

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

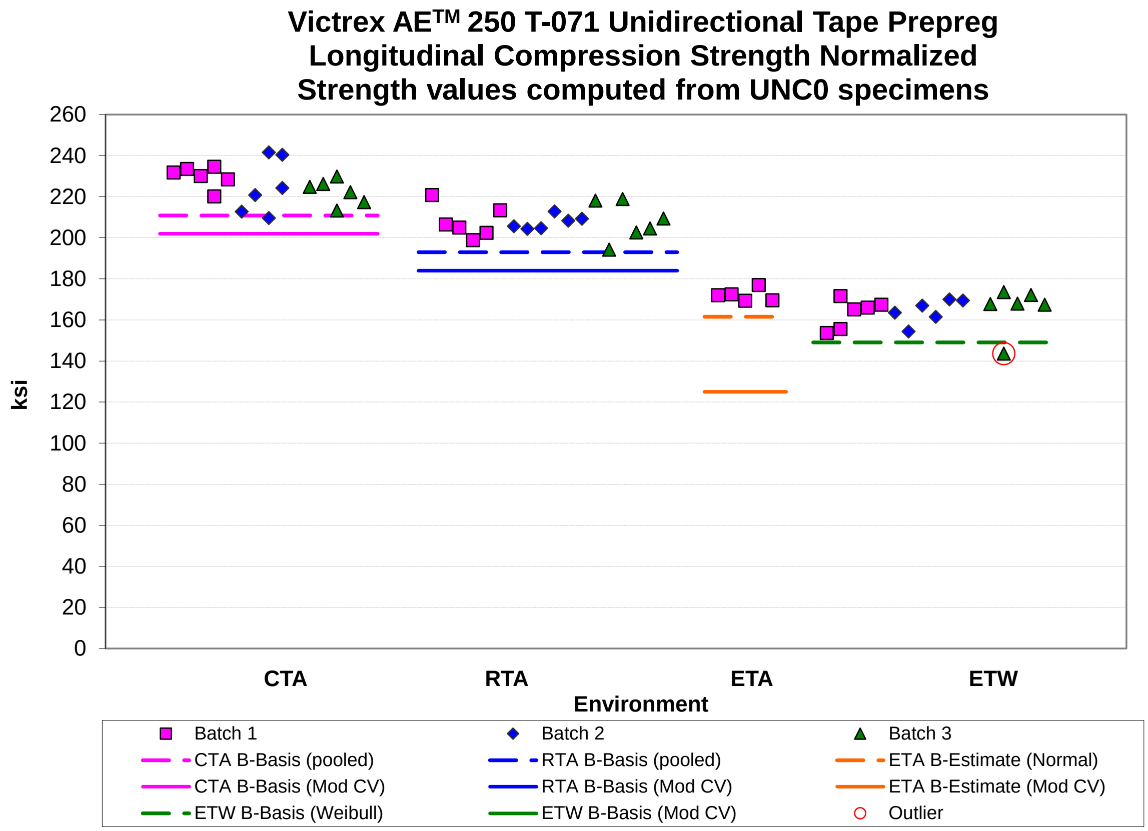

Figure 4-2 Batch plot for LC strength normalized

Longitudinal Compression Strength (Backout Computation) Basis Values and Statistics								
	Normalized				As-measured			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	225.6	207.7	172.1	164.0	223.5	206.4	171.8	163.9
Stdev	9.100	6.975	3.066	7.727	8.761	7.109	3.435	7.670
CV	4.033	3.358	1.782	4.712	3.920	3.444	1.999	4.679
Mod CV	6.017	6.000	8.000	6.356	6.000	6.000	8.000	6.340
Min	209.6	194.2	169.4	143.6	209.5	186.6	168.2	140.0
Max	241.6	220.8	177.0	173.6	238.0	220.6	175.9	172.7
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	5	19	18	18	5	19
Basis Value Estimates								
B-basis Value	210.9	193.0		149.0	208.9	191.9		149.8
B-Estimate			161.6				160.1	
A-estimate	200.8	182.9	154.0	133.3	199.1	182.0	151.5	134.9
Method	pooled	pooled	Normal	Weibull	pooled	pooled	Normal	Weibull
Modified CV Basis Value Estimates								
B-basis Value	201.9	184.0		NA	200.0	182.9		143.7
B-Estimate			125.0				124.8	
A-estimate	185.7	167.8	92.73		184.0	166.9	92.59	129.3
Method	pooled	pooled	normal		pooled	pooled	normal	normal

Table 4-3: Statistics and Basis Values for LC strength derived from UNC0

Longitudinal Compression Modulus Statistics								
	Normalized				As-measured			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	16.72	16.91	17.38	17.24	17.38	17.58	18.00	17.70
Stdev	0.3416	0.2533	0.1479	0.2327	0.2878	0.2476	0.1623	0.2830
CV	2.043	1.498	0.8512	1.350	1.656	1.408	0.9014	1.598
Mod CV	6.000	6.000	8.000	6.000	6.000	6.000	8.000	6.000
Min	15.90	16.21	17.18	16.86	16.86	16.99	17.80	17.16
Max	17.06	17.22	17.60	17.72	17.65	17.89	18.27	18.14
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	18	18	18	6	18

Table 4-4: Statistics from LC modulus

4.3 Transverse Compression (TC)

The Transverse Compression data is not normalized. Data is available for two properties, strength and modulus. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. The CTA dataset failed normality but the Weibull distribution provided the best fit for the dataset. However, the pooled dataset passed the normality test after applying the modified CV transformation to the data, so modified CV basis values could be computed for CTA and RTA conditions. The modified CV CTA and RTA conditions met all requirements for pooling, so those two datasets were pooled to compute the modified CV basis values and estimates.

There were two statistical outliers, both in CTA condition. The lowest value in batch one was an outlier for the CTA condition but not for batch one alone. The lowest value in batch two was an outlier for batch two only but not for the CTA condition. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for strength data in Table 4-5 and for the modulus data in Table 4-6. The data, B-estimates, and B-basis values are shown graphically in Figure 4-3.

Victrex AE™ 250 T-071 Unidirectional Tape Prepreg
Transverse Compression Strength as measured

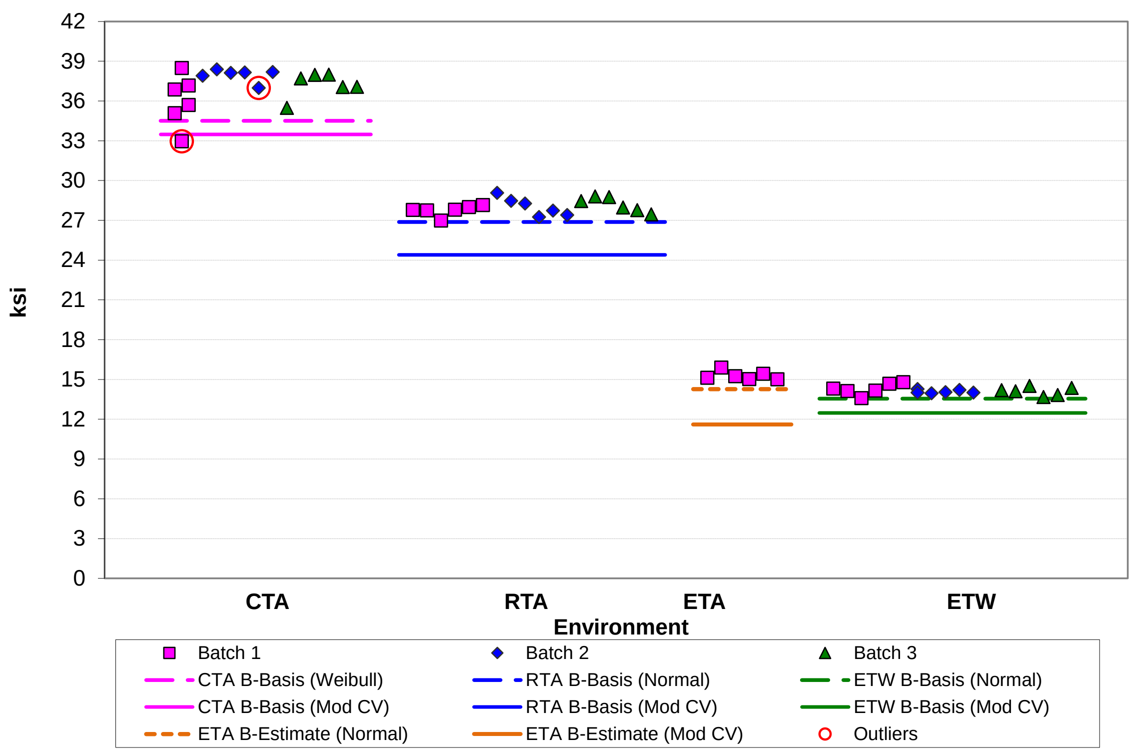

Figure 4-3: Batch Plot for TC strength as-measured

Transverse Compression Strength Basis Values and Statistics				
As-measured				
Env	CTA	RTA	ETA	ETW
Mean	37.07	27.99	15.29	14.16
Stdev	1.440	0.5670	0.3349	0.3114
CV	3.884	2.025	2.191	2.199
Mod CV	6.000	6.000	8.000	6.000
Min	32.96	26.98	15.01	13.60
Max	38.49	29.08	15.89	14.79
No. Batches	3	3	1	3
No. Spec.	18	18	6	18
Basis Values and Estimates				
B-basis Value	34.51	26.87		13.54
B-estimate			14.27	
A-estimate	31.73	26.08	13.55	13.11
Method	Weibull	Normal	Normal	Normal
Modified CV Basis Values and Estimates				
B-basis Value	33.48	24.40		12.48
B-estimate			11.60	
A-estimate	31.04	21.96	9.083	11.30
Method	pooled	pooled	normal	normal

Table 4-5: Statistics and Basis Values for TC Strength data

Transverse Compression Modulus Statistics				
	As-measured			
Env	CTA	RTA	ETA	ETW
Mean	1.494	1.406	1.285	1.034
Stdev	0.03860	0.01512	0.04741	0.06418
CV	2.583	1.076	3.690	6.206
Mod CV	6.000	6.000	8.000	7.103
Min	1.432	1.377	1.245	0.9531
Max	1.577	1.436	1.377	1.153
No. Batches	3	3	1	3
No. Spec.	18	18	6	18

Table 4-6: Statistics from TC Modulus data

4.4 In-Plane Shear (IPS)

The In-Plane Shear data is not normalized. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. Data is provided on three different properties, 0.2% Offset Strength, Strength at 5% Strain, and Modulus.

The CTA and RTA conditions met all requirements for pooling for the 0.2% Offset.

The CTA and RTA datasets for Strength at 5% Strain and the ETW dataset for 0.2% Offset Strength failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. The CTA and RTA datasets for Strength at 5% Strain were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. These datasets met all requirements for pooling. The ETW dataset for 0.2% Offset Strength failed the ADK test after they were transformed according to the assumptions of the modified CV method, so no modified CV basis values could be provided for those datasets.

There was one statistical outlier. The lowest value in the ETA dataset for the Strength at 5% Strain property was an outlier. It was retained for this analysis.

Statistics, estimates and basis values are given for the 0.2% Offset Strength and Strength at 5% Strain data in Table 4-7 and modulus data in Table 4-8. The data, B-estimates and B-basis values for 0.2% Offset Strength and Strength at 5% Strain are shown graphically in Figure 4-4.

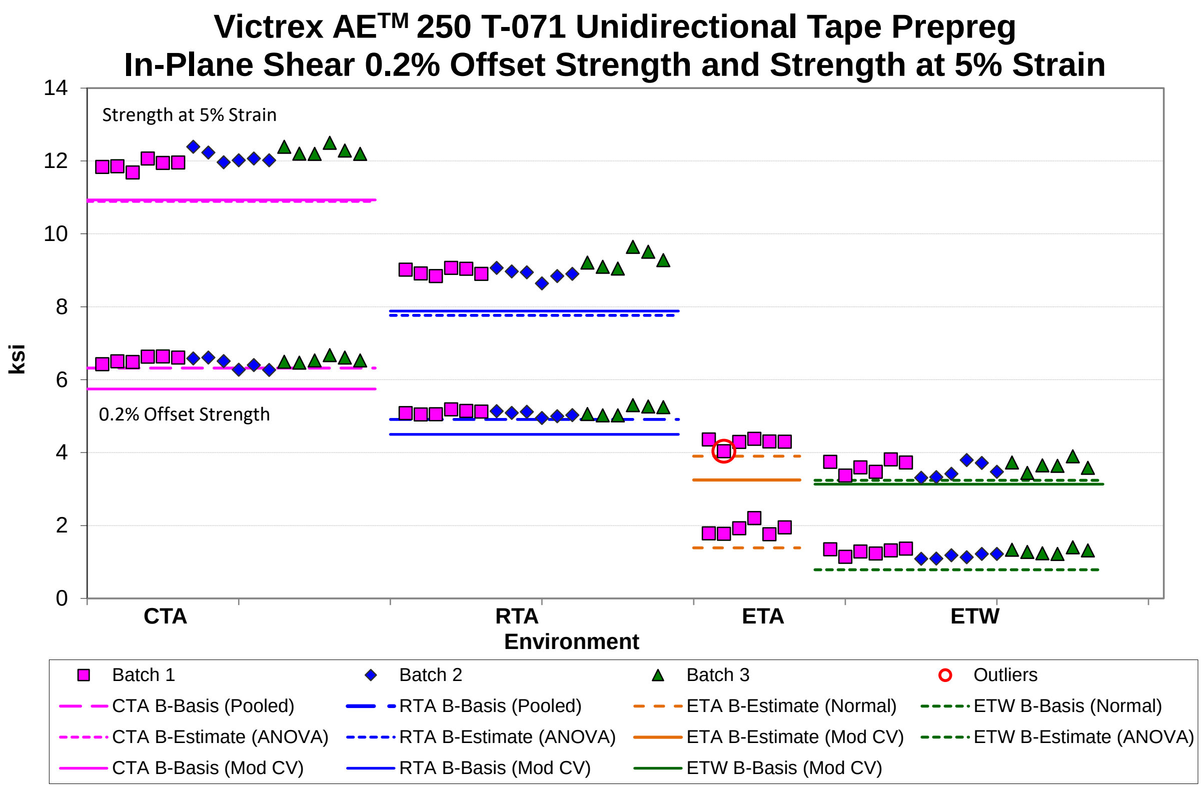

Figure 4-4: Batch plot for IPS for 0.2% Offset Strength and Strength at 5% Strain as-measured

In-Plane Shear Strength Basis Values and Statistics								
	Strength at 5% Strain				0.2% Offset Strength			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	12.10	9.053	4.280	3.596	6.514	5.106	1.900	1.246
Stdev	0.2149	0.2396	0.1236	0.1790	0.1165	0.09645	0.1688	0.09417
CV	1.776	2.647	2.888	4.977	1.788	1.889	8.885	7.559
Mod CV	6.000	6.000	8.000	6.489	6.000	6.000	8.885	7.780
Min	11.69	8.644	4.038	3.313	6.267	4.953	1.762	1.086
Max	12.50	9.641	4.381	3.899	6.678	5.301	2.203	1.404
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	18	18	18	6	18
Basis Values and Estimates								
B-basis Value				3.243	6.320	4.911		
B-estimate	10.89	7.766	3.905				1.389	0.7856
A-estimate	10.03	6.847	3.639	2.992	6.187	4.778	1.025	0.4576
Method	ANOVA	ANOVA	Normal	Normal	pooled	pooled	Normal	ANOVA
Modified CV Basis Values and Estimates								
B-basis Value	10.93	7.886		3.136	5.875	4.466	NA	NA
B-estimate			3.248					
A-estimate	10.14	7.091	2.543	2.810	5.440	4.031		
Method	pooled	pooled	normal	normal	pooled	pooled		

Table 4-7: Statistics and Basis Values for IPS Strength at 5% Strain and 0.2% Offset data

In Plane Shear Modulus Statistics				
Modulus Statistics				
Env	CTA	RTA	ETA	ETW
Mean	0.7000	0.6562	0.4991	0.3590
Stdev	0.00875	0.01179	0.03104	0.02275
CV	1.250	1.796	6.219	6.337
Mod CV	6.000	6.000	8.000	7.168
Min	0.6859	0.6330	0.4688	0.3084
Max	0.7159	0.6728	0.5533	0.3934
No. Batches	3	3	1	3
No. Spec.	18	18	6	18

Table 4-8: Statistics from IPS Modulus data

4.5 V-Notched Rail Shear (VNS)

The V-Notched Rail Shear data is not normalized. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. Data is provided on three different properties, 0.2% Offset Strength, Strength at 5% Strain and Modulus.

The CTA and RTA conditions for the 0.2% Offset Strength met all requirements for pooling.

The CTA and RTA datasets for Strength at 5% Strain failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the CTA and RTA datasets for Strength at 5% Strain were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. These datasets met all requirements for pooling.

The 0.2% Offset Strength ETW datasets, both normalized and as-measured, had a CV greater than 8%, which is too large to apply the modified CV approach.

There were three statistical outliers. The largest value in batch two of the CTA condition for the Strength at 5% Strain property was an outlier for both the CTA condition and batch two alone. The largest value in batch three of the 0.2% Offset Strength was an outlier for both the ETW condition and batch three alone. The lowest value in batch two of the ETW condition was an outlier for both the 0.2% Offset Strength and for Strength at 5% Strain for batch two but not for the ETW condition. All three outliers were retained for this analysis.

Statistics, estimates and basis values are given for the strength properties data in Table 4-9, and modulus data in Table 4-10. The data, B-estimates and B-basis values for 0.2% Offset Strength and Strength at 5% Strain are shown graphically in Figure 4-5.

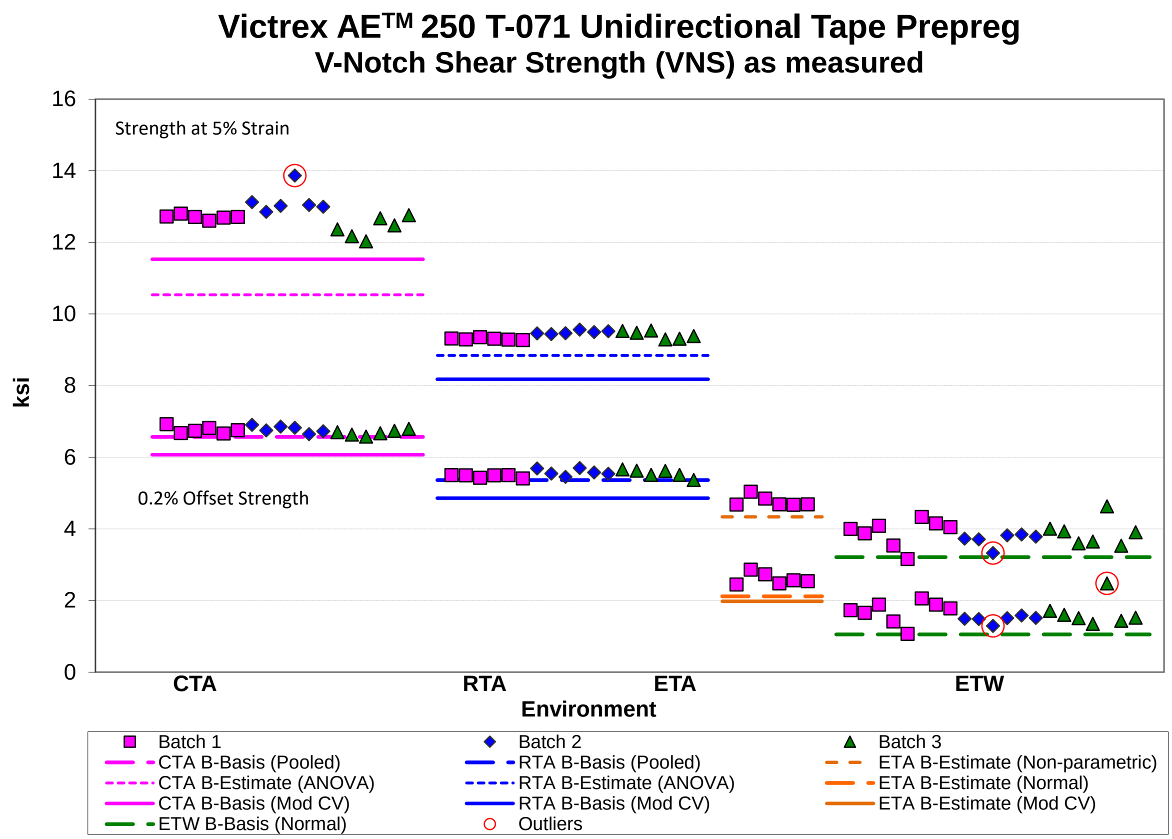

Figure 4-5: Batch plot for VNS for 0.2% Offset Strength and Strength at 5% Strain as-measured

V-Notched Rail Shear Strength Basis Values and Statistics								
	0.2% Offset Strength				Strength at 5% Strain			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	6.745	5.535	2.604	1.618	12.76	9.406	4.769	3.840
Stdev	0.09560	0.09523	0.1603	0.2968	0.4012	0.1028	0.1491	0.3309
CV	1.417	1.720	6.155	18.35	3.146	1.093	3.126	8.616
Mod CV	6.000	6.000	8.000	18.35	6.000	6.000	8.000	8.616
Min	6.576	5.367	2.449	1.071	12.03	9.271	4.674	3.159
Max	6.927	5.701	2.862	2.479	13.87	9.566	5.041	4.633
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	21	18	18	6	21
Basis Values and Estimates								
B-basis Value	6.571	5.361		1.052				3.210
B-estimate			2.119		10.53	8.846	4.335	
A-estimate	6.453	5.243	1.773	0.6493	8.951	8.446	3.308	2.761
Method	pooled	pooled	Normal	Normal	ANOVA	ANOVA	Non-Parametric	Normal
Modified CV Basis Values and Estimates								
B-basis Value	6.071	4.861		NA	11.53	8.181	NA	NA
B-estimate			1.976					
A-estimate	5.612	4.402	1.547		10.70	7.348		
Method	pooled	pooled	normal		pooled	pooled		

Table 4-9: Statistics and Basis Values for VNS 0.2% Offset Strength and Strength at 5% Strain data

V-Notched Rail Shear Modulus Statistics				
Modulus Statistics				
Env	CTA	RTA	ETA	ETW
Mean	0.7119	0.6715	0.5826	0.4211
Stdev	0.01068	0.008319	0.01457	0.05666
CV	1.500	1.239	2.501	13.45
Mod CV	6.000	6.000	8.000	13.45
Min	0.6922	0.6571	0.5682	0.3155
Max	0.7356	0.6881	0.6059	0.5284
No. Batches	3	3	1	3
No. Spec.	18	18	6	21

Table 4-10: Statistics from VNS Modulus data

4.6 Quasi Isotropic V-Notched Rail Shear (VNS1)

The VNS1 data is not normalized. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. Data is provided on two properties, Ultimate Shear Strength and Modulus.

There were no diagnostic test failures. Pooling was not acceptable due to the insufficient number of specimens in the ETA condition.

There was one statistical outlier. The largest value in batch one of the RTA condition was an outlier for batch one only, not for the RTA condition. It was retained for this analysis.

Statistics, estimates and basis values are given for the ultimate shear strength properties data in Table 4-11, and modulus data in Table 4-12. The data, B-estimates and B-basis values for strength are shown graphically in Figure 4-6.

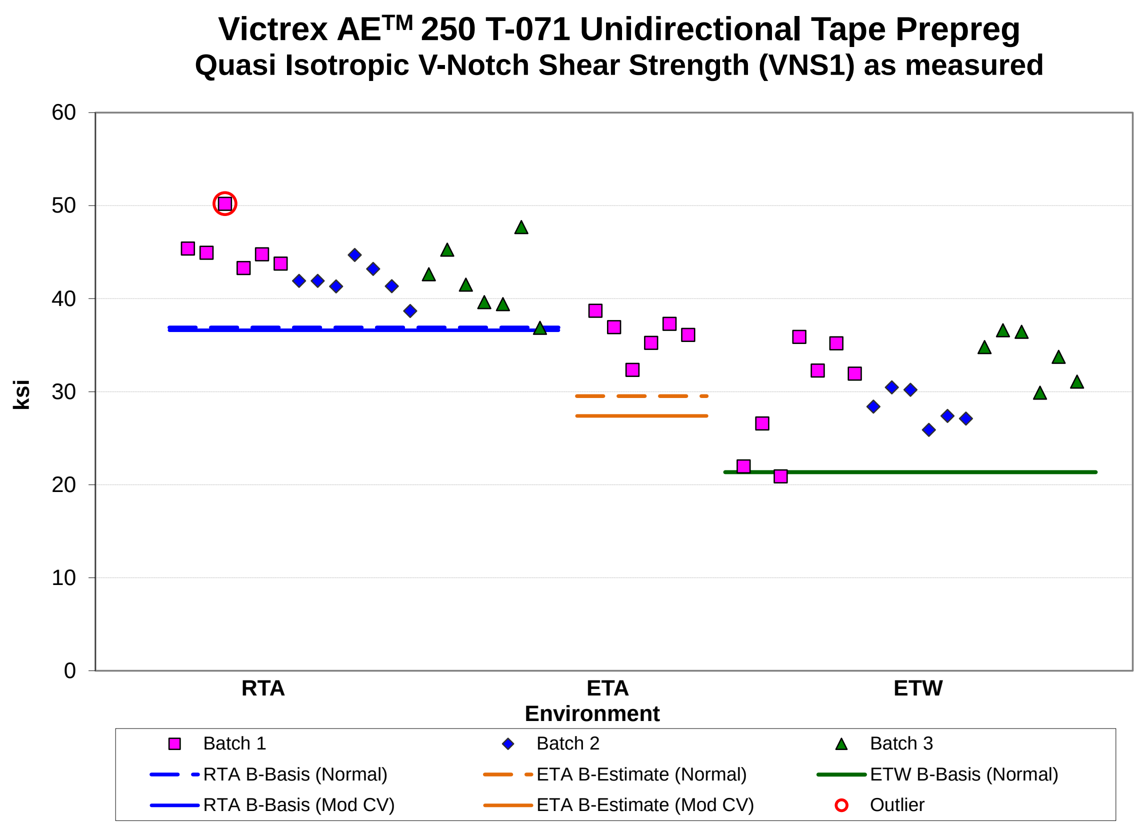

Figure 4-6: Batch plot for VNS1 for Ultimate Strength as-measured

Quasi Isotropic V-Notched Rail Shear Ultimate Strength Basis Values and Statistics			
As-measured			
Env	RTA	ETA	ETW
Mean	42.92	36.11	30.36
Stdev	3.126	2.172	4.626
CV	7.285	6.017	15.24
Mod CV	7.642	8.000	15.24
Min	36.86	32.35	20.91
Max	50.19	38.69	36.61
No. Batches	3	1	3
No. Spec.	20	6	19
Basis Values and Estimates			
B-basis Value	36.90		21.34
B-estimate		29.53	
A-estimate	32.61	24.85	14.94
Method	Normal	Normal	Normal
Modified CV Basis Values and Estimates			
B-basis Value	36.60		NA
B-estimate		27.40	
A-estimate	32.11	21.45	
Method	normal	normal	

Table 4-11: Statistics and Basis Values for VNS1 Ultimate Shear Strength data

Quasi Isotropic V-Notched Rail Shear Modulus Statistics			
Modulus Statistics			
Env	RTA	ETA	ETW
Mean	2.633	2.494	2.504
Stdev	0.05231	0.02450	0.07657
CV	1.987	0.9822	3.057
Mod CV	6.000	8.000	6.000
Min	2.549	2.456	2.374
Max	2.719	2.525	2.639
No. Batches	3	1	3
No. Spec.	20	6	19

Table 4-12: Statistics from VNS1 Modulus data

4.7 0° Flexure (FLEX)

The Flexure data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only for one property, strength. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. Tests were run in both the 0° and 90° directions.

The 90° direction tests were run only in the RTA condition. No basis values could be provided for the 90° direction results because both the normalized and as-measured datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability and CMH-17 Rev G guidelines required using the ANOVA analysis. The ANOVA method returned negative values for both datasets. Because both datasets had a CV greater than 8%, which is too large to apply the modified CV approach, no basis values can be provided for the 90° direction Flexure test results.

The as-measured 0° direction RTA and ETW datasets failed the ADK test, but passed when they were transformed according to the assumptions of the modified CV method, so the modified CV basis values are provided. The normalized CTA and RTA pooled dataset did not pass Levene's test for equality of variances, so could not be pooled. But the CTA and RTA conditions, both normalized and as-measured, met all requirements for pooling after applying the modified CV transformation to the data.

There were no statistical outliers.

Statistics and basis values are given for 0° Flex strength data in Table 4-13 and for statistics for 90° Flex strength data in Table 4-14. The normalized data and the B-basis values are shown graphically in Figure 4-7.

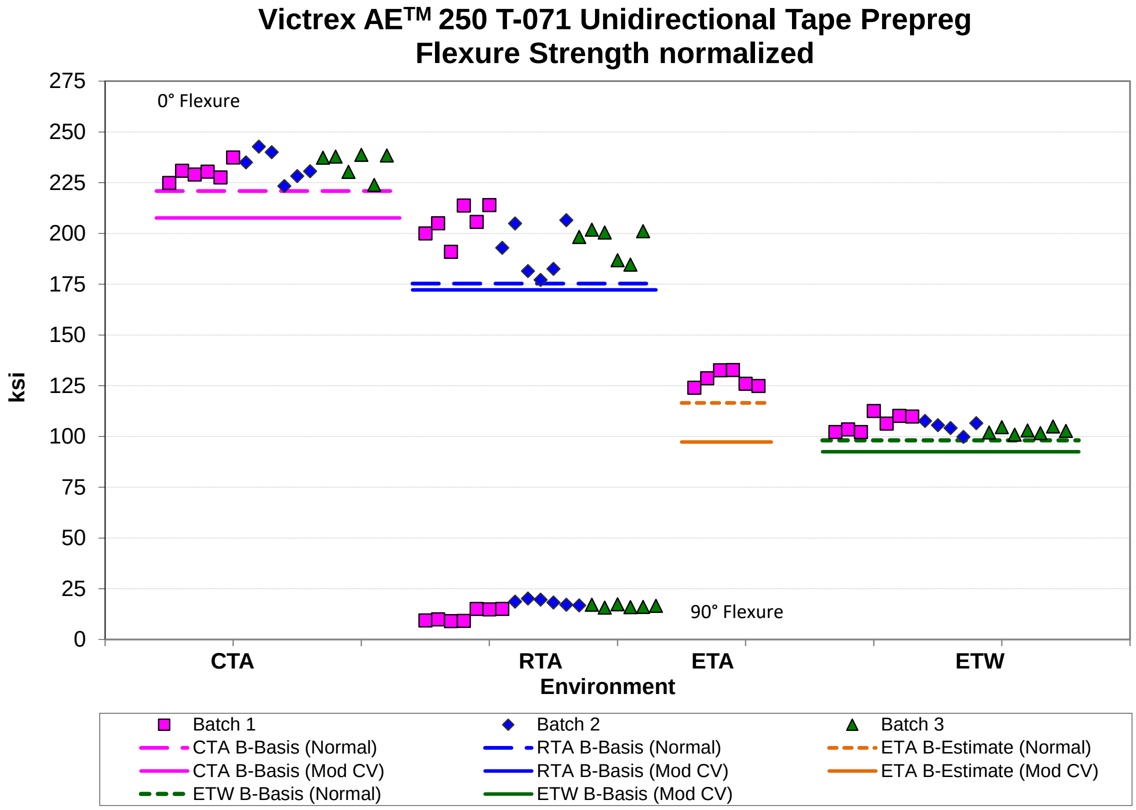

Figure 4-7: Batch Plot for Flexure strength normalized

0° Flexure Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	232.6	197.1	128.2	104.8	239.3	203.5	132.2	107.2
Stdev	5.953	11.06	3.835	3.417	5.180	12.13	3.890	4.234
CV	2.559	5.611	2.992	3.261	2.165	5.963	2.943	3.949
Mod CV	6.000	6.806	8.000	6.000	6.000	6.982	8.000	6.000
Min	223.4	177.1	124.1	99.86	227.7	183.9	128.2	102.3
Max	242.8	213.9	132.8	112.6	248.8	223.0	137.0	116.5
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	19	18	18	6	19
Basis Values and Estimates								
B-basis Value	220.9	175.3		98.11	229.0			
B-estimate			116.6			150.8	120.4	86.92
A-estimate	212.6	159.8	108.3	93.38	221.8	113.3	112.0	72.44
Method	Normal	Normal	Normal	Normal	Normal	ANOVA	Normal	ANOVA
Modified CV Basis Values and Estimates								
B-basis Value	207.7	172.2		92.52	213.3	177.5		94.69
B-estimate			97.30				100.3	
A-estimate	190.7	155.2	76.16	83.83	195.6	159.8	78.52	85.80
Method	pooled	pooled	normal	normal	pooled	pooled	normal	normal

Table 4-13: Statistics and Basis Values for 0° Flexure Strength data

90° Flexure Strength Statistics		
RTA Condition		
Env	Norm	As-meas
Mean	15.39	15.81
Stdev	3.485	3.512
CV	22.64	22.22
Mod CV	22.64	22.22
Min	9.120	9.483
Max	20.21	20.69
No. Batches	3	3
No. Spec.	19	19

Table 4-14: Statistics from 90° Flexure Strength data

4.8 Double Notched Shear (DNS)

The Double Notched Shear data is not normalized. Data is available for only one property, strength. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

The CTA and RTA datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the CTA and RTA datasets were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. These datasets met all requirements for pooling.

There were no statistical outliers.

Statistics, basis values and estimates are given for DNS strength data in Table 4-15. The data, B-estimates and B-basis values are shown graphically in Figure 4-8.

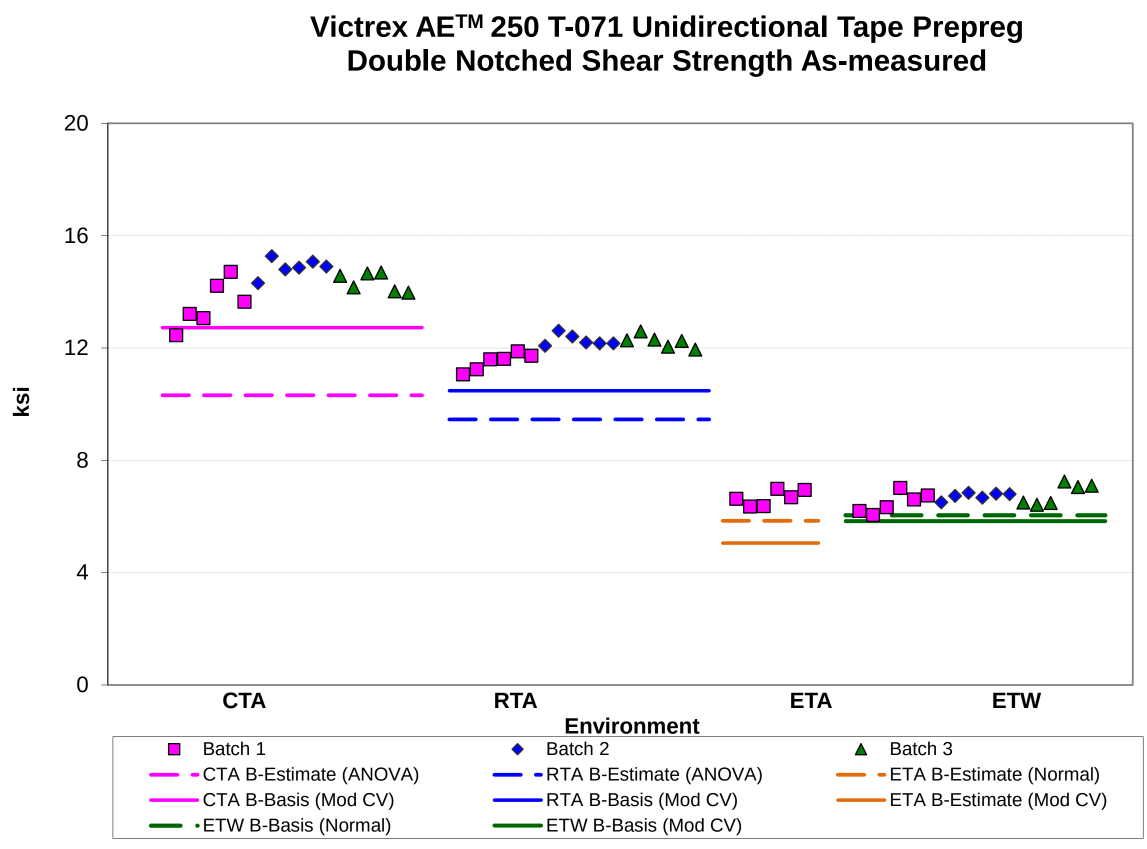

Figure 4-8: Batch Plot for DNS strength normalized

Double Notched Shear Strength Basis Values and Statistics				
As-measured				
Env	CTA	RTA	ETA	ETW
Mean	14.25	12.01	6.660	6.670
Stdev	0.7554	0.4257	0.2705	0.3191
CV	5.300	3.545	4.061	4.784
Mod CV	6.650	6.000	8.000	6.392
Min	12.46	11.06	6.349	6.050
Max	15.27	12.62	6.981	7.246
No. Batches	3	3	1	3
No. Spec.	18	18	6	18
Basis Values and Estimates				
B-basis Value				6.040
B-estimate	10.31	9.458	5.841	
A-estimate	7.505	7.639	5.258	5.594
Method	ANOVA	ANOVA	Normal	Normal
Modified CV Basis Values and Estimates				
B-basis Value	12.72	10.47		5.829
B-estimate			5.055	
A-estimate	11.68	9.431	3.957	5.233
Method	pooled	pooled	normal	normal

Table 4-15: Statistics and Basis Values for DNS Strength data

4.9 Quasi Isotropic Double Notched Shear (DNS1)

The DNS1 Shear data is not normalized. Data is available for only one property, strength. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

The RTA dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the RTA dataset was transformed according to the assumptions of the modified CV method, it did not pass the ADK test, so no modified CV basis values are provided.

There were no statistical outliers.

Statistics, basis values and estimates are given for DNS1 strength data in Table 4-16. The data, B-estimates and B-basis values are shown graphically in Figure 4-9.

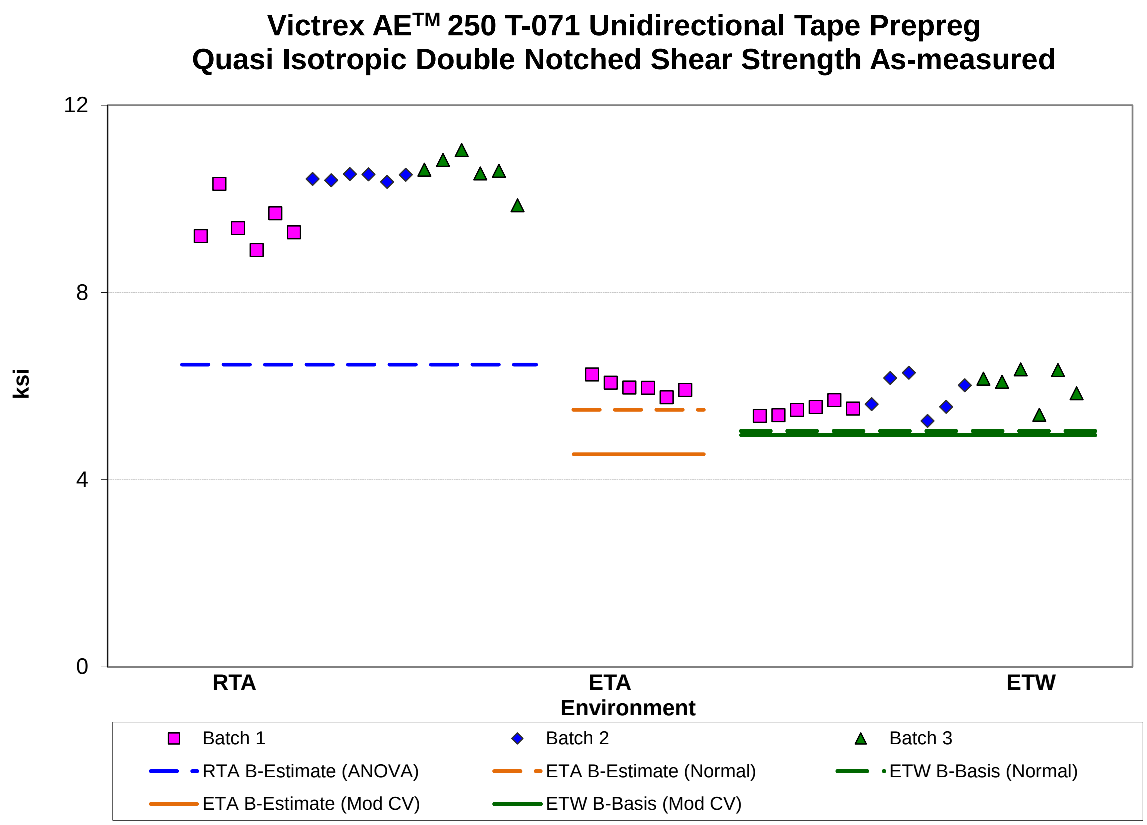

Figure 4-9: Batch Plot for DNS1 strength normalized

Quasi Isotropic Double Notched Shear Strength Basis Values and Statistics			
As-measured			
Env	RTA	ETA	ETW
Mean	10.17	5.989	5.783
Stdev	0.6216	0.1632	0.3767
CV	6.113	2.726	6.515
Mod CV	7.056	8.000	7.258
Min	8.905	5.760	5.255
Max	11.04	6.249	6.356
No. Batches	3	1	3
No. Spec.	18	6	18
Basis Values and Estimates			
B-basis Value			5.039
B-estimate	6.461	5.495	
A-estimate	3.814	5.143	4.512
Method	ANOVA	Normal	Normal
Modified CV Basis Values and Estimates			
B-basis Value	NA		4.954
B-estimate		4.546	
A-estimate		3.558	4.368
Method		normal	normal

Table 4-16: Statistics and Basis Values for DNS1 Strength data

4.10 Quasi Isotropic Unnotched Tension (UNT1)

The UNT1 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for two properties, strength and modulus. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

The as-measured CTA and RTA datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these datasets were transformed according to the assumptions of the modified CV method, they all passed the ADK test, so the modified CV basis values are provided. The CTA and RTA datasets met all requirements for pooling after the modified CV transformation of the data.

The as-measured ETW dataset failed the normality test and the Weibull distribution provided the best fit to the data. After the modified CV transformation of the data, this dataset had an adequate fit to the normal distribution so modified CV basis values and estimates are provided.

There were two statistical outliers. The lowest value in batch one of the CTA condition was an outlier for both normalized and as measured and in batch one only, not for the CTA condition. The lowest value in batch one of the ETW condition was an outlier for the ETW condition but not for batch one alone. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for UNT1 strength data in Table 4-17 and for the modulus data in Table 4-18. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-10.

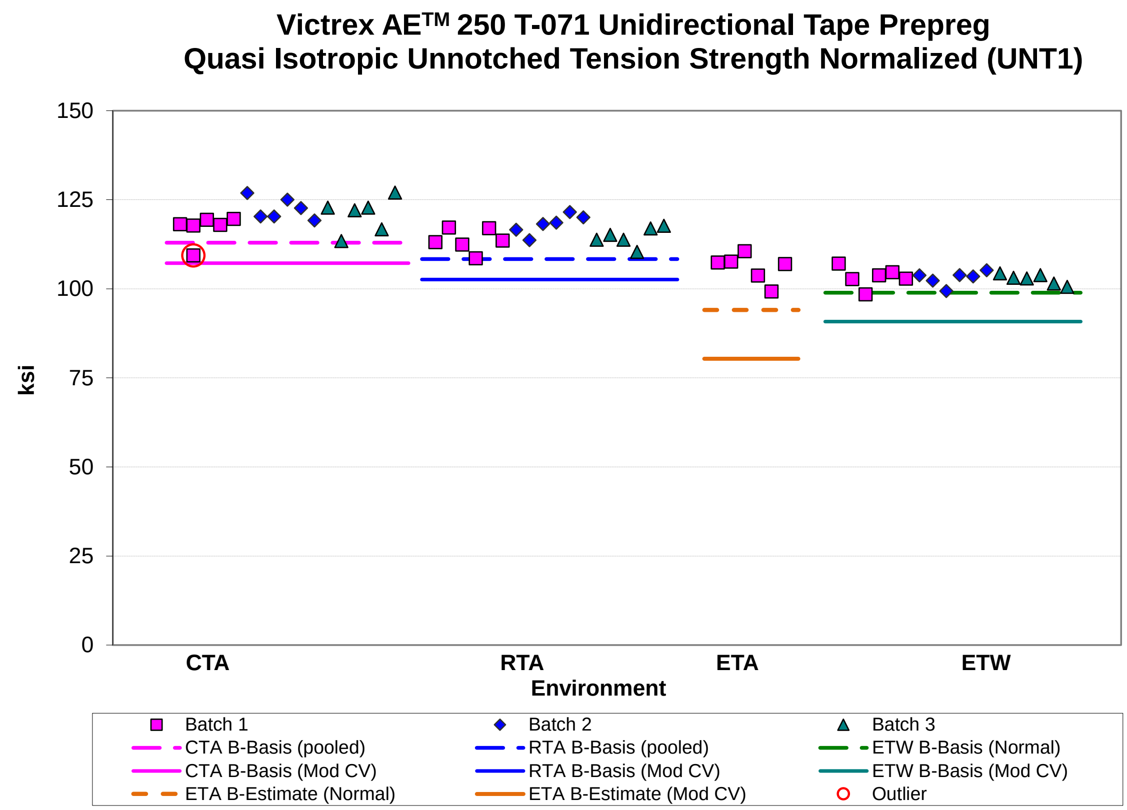

Figure 4-10: Batch Plot for UNT1 strength normalized

Unnotched Tension (UNT1) Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	120.1	115.4	105.9	103.0	120.5	114.4	103.4	103.2
Stdev	4.405	3.340	3.917	2.055	5.855	4.359	2.898	2.702
CV	3.669	2.893	3.699	1.995	4.861	3.810	2.802	2.617
Modified CV	6.000	6.000	8.000	6.000	6.430	6.000	8.000	6.000
Min	109.4	108.6	99.24	98.44	106.3	105.7	98.18	95.42
Max	127.0	121.5	110.5	107.1	130.1	121.2	106.3	107.2
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	18	18	18	6	18
Basis Values and Estimates								
B-basis Value	112.9	108.3		98.93				97.61
B-estimate			94.04		90.75	89.44	94.65	
A-estimate	108.1	103.5	85.60	96.05	69.57	71.62	88.41	91.52
Method	pooled	pooled	Normal	Normal	ANOVA	ANOVA	Normal	Weibull
Modified CV Basis Values and Estimates								
B-basis Value	107.2	102.6		90.79	107.1	101.1		91.01
B-estimate			80.38				78.50	
A-estimate	98.43	93.81	62.92	82.16	98.05	92.01	61.45	82.36
Method	pooled	pooled	normal	normal	pooled	pooled	normal	normal

Table 4-17: Statistics and Basis Values for UNT1 Strength data

Unnotched Tension (UNT1) Modulus Statistics								
	Normalized				As-measured			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	7.067	7.259	6.654	6.486	7.087	7.194	6.500	6.504
Stdev	0.2154	0.2178	0.08937	0.1466	0.2348	0.2843	0.04481	0.2468
CV	3.048	3.001	1.343	2.260	3.314	3.951	0.6894	3.794
Modified CV	6.000	6.000	8.000	6.000	6.000	6.000	8.000	6.000
Min	6.361	6.969	6.532	6.198	6.440	6.758	6.458	6.008
Max	7.361	7.757	6.744	6.682	7.458	7.717	6.587	6.811
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	18	18	18	6	18

Table 4-18: Statistics from UNT1 Modulus data

4.11 "Soft" Unnotched Tension 2 (UNT2)

The UNT2 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for two properties, strength and modulus.

There were no outliers or diagnostic test failures. All three conditions could be pooled for both normalized and as-measured datasets.

Statistics, basis values and estimates are given for UNT2 strength data in Table 4-19 and for the modulus data in Table 4-20. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-11.

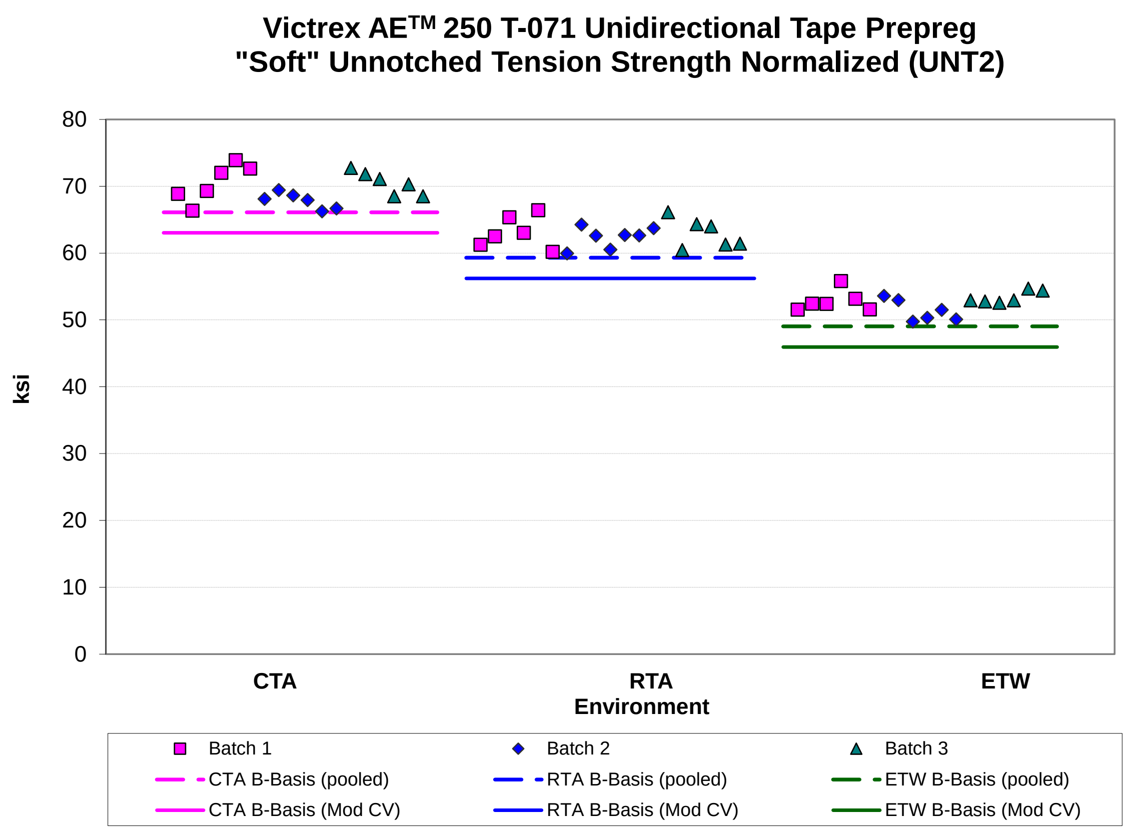

Figure 4-11: Batch Plot for UNT2 strength normalized

Unnotched Tension (UNT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTA	RTA	ETW	CTA	RTA	ETW
Mean	69.61	62.77	52.52	70.57	63.26	53.24
Stdev	2.309	1.972	1.584	2.184	1.985	1.609
CV	3.317	3.141	3.015	3.095	3.138	3.022
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	66.24	59.96	49.75	66.33	60.07	50.76
Max	73.91	66.41	55.80	75.09	67.27	56.77
No. Batches	3	3	3	3	3	3
No. Spec.	18	19	18	18	19	18
Basis Values and Estimates						
B-basis Value	66.11	59.29	49.02	67.14	59.84	49.81
A-estimate	63.78	56.96	46.69	64.85	57.55	47.52
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	63.02	56.22	45.94	63.91	56.63	46.58
A-estimate	58.63	51.83	41.55	59.47	52.18	42.14
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-19: Statistics and Basis Values for UNT2 Strength data

Unnotched Tension (UNT2) Modulus Statistics						
	Normalized			As-measured		
Env	CTA	RTA	ETW	CTA	RTA	ETW
Mean	4.602	4.553	3.516	4.666	4.587	3.564
Stdev	0.08017	0.1397	0.08872	0.07885	0.1611	0.1055
CV	1.742	3.068	2.523	1.690	3.513	2.959
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	4.431	4.371	3.355	4.543	4.374	3.359
Max	4.747	4.842	3.763	4.800	4.919	3.824
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18

Table 4-20: Statistics from UNT2 Modulus data

4.12 “Hard” Unnotched Tension 3 (UNT3)

The UNT3 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for two properties, strength and modulus.

The as-measured CTA, RTA and ETW datasets and the normalized RTA datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these four datasets were transformed according to the assumptions of the modified CV method, they all passed the ADK test, so the modified CV basis values are provided. All three conditions met all requirements for pooling after the modified CV transformation of the data for both the normalized and the as-measured datasets.

The normalized ETW dataset failed all distribution tests (Normal, Lognormal and Weibull) and required the non-parametric method to compute basis values. After this dataset was transformed according to the assumptions of the modified CV method, it had an adequate fit to the normal distribution, so modified CV basis values are provided.

There was one statistical outlier. The lowest value in batch two of the normalized RTA dataset was an outlier for batch two only. It was not an outlier for the RTA condition or in the as-measured dataset. It was retained for this analysis.

Statistics and basis values are given for UNT3 strength data in Table 4-21 and for the modulus data in Table 4-22. The normalized data and the B-basis values are shown graphically in Figure 4-12.

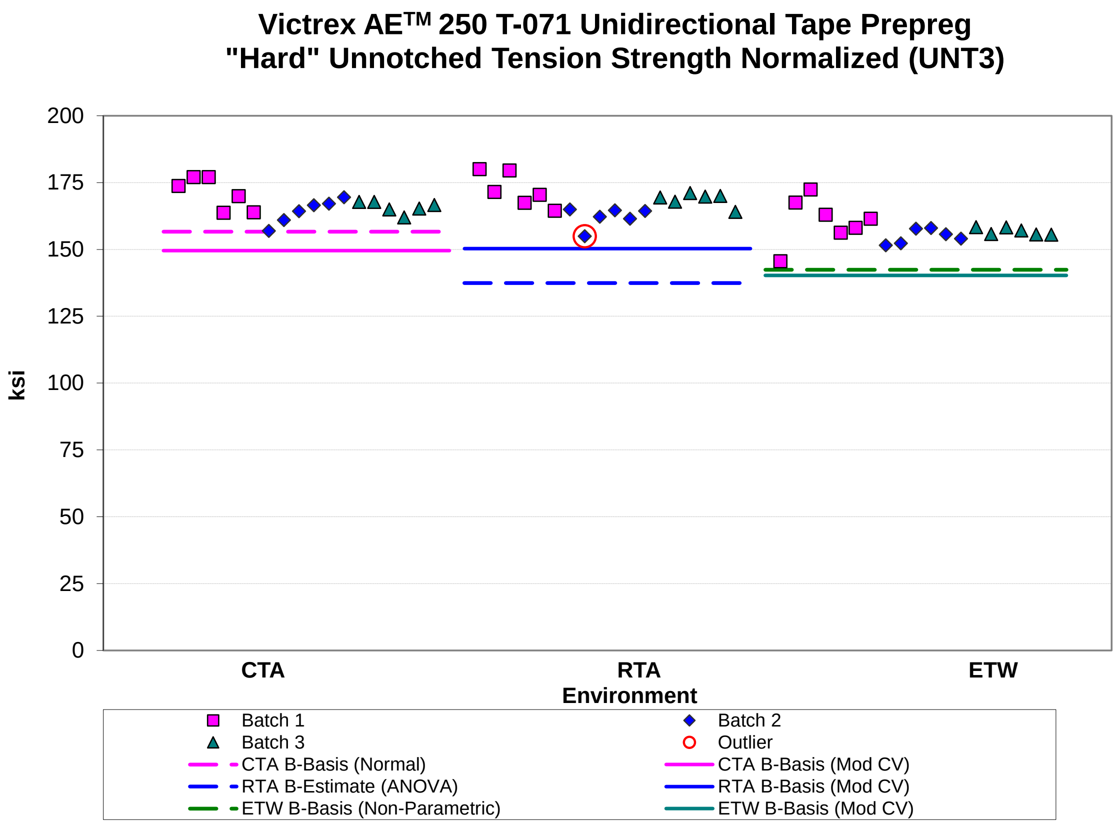

Figure 4-12: Batch Plot for UNT3 strength normalized

Unnotched Tension (UNT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTA	RTA	ETW	CTA	RTA	ETW
Mean	166.9	167.7	157.6	170.7	170.2	160.7
Stdev	5.204	6.033	5.798	5.353	6.438	6.214
CV	3.117	3.599	3.680	3.136	3.783	3.866
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	156.9	155.0	145.6	160.1	157.9	146.2
Max	177.1	180.0	172.4	180.7	181.4	174.4
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	19	18	18	19
Basis Values and Estimates						
B-basis Value	156.7		142.4			
B-estimate		137.4		149.5	134.4	141.9
A-estimate	149.4	115.8	114.3	134.3	108.9	128.4
Method	Normal	ANOVA	Non-Parametric	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	149.5	150.3	140.3	153.0	152.4	143.1
A-estimate	137.9	138.7	128.6	141.1	140.6	131.2
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-21: Statistics and Basis Values for UNT3 Strength data

Unnotched Tension (UNT3) Modulus Statistics						
	Normalized			As-measured		
Env	CTA	RTA	ETW	CTA	RTA	ETW
Mean	10.96	10.98	10.35	11.21	11.15	10.56
Stdev	0.1404	0.1635	0.1698	0.1790	0.2345	0.2157
CV	1.280	1.489	1.641	1.597	2.103	2.043
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	10.71	10.71	9.906	10.91	10.80	10.06
Max	11.21	11.26	10.68	11.46	11.65	10.92
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	20	18	18	20

Table 4-22: Statistics from UNT3 Modulus data

4.13 Unnotched Compression 90/0 (UNC0)

The UNC0 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for two properties, strength and modulus. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

The CTA and RTA conditions met all requirements for pooling. The ETW datasets, both normalized and as-measured, failed normality and the Weibull distribution provided the best fit for the dataset. The as-measured ETW dataset passed the normality test applying the modified CV transformation to the data, so modified CV basis values could be computed for the as-measured ETW condition. However, the normalized ETW did not pass normality so no modified CV basis values were computed.

There are three outliers. The largest value in batch two of the as-measured RTA dataset is an outlier for batch two only, but not for the RTA condition and not for the normalized dataset. The lowest value in batch three of the as-measured RTA dataset is outlier for the RTA condition, but not for batch three only and not for the normalized dataset. The lowest value in batch three of the ETW dataset is an outlier for batch three (both normalized and as-measured datasets) and for the ETW condition for the as-measured dataset but not for the normalized dataset. All three outliers were retained for this analysis.

Statistics and estimates of basis values are given for strength data in Table 4-23 and for the modulus data in Table 4-24. The normalized data and the B-estimates are shown graphically in Figure 4-13.

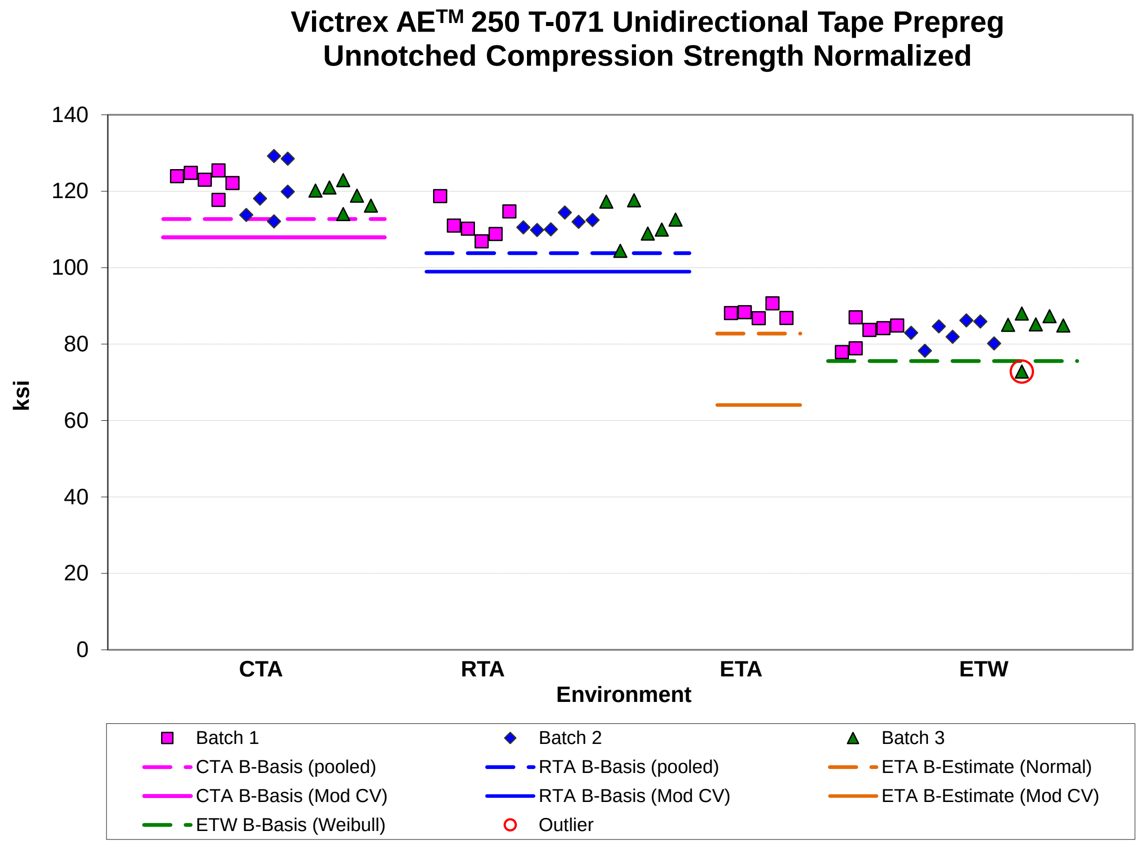

Figure 4-13: Batch Plot for UNC0 strength normalized

Unnotched Compression (UNC0) Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	120.6	111.7	88.13	83.15	119.5	111.0	88.00	83.11
Stdev	4.866	3.750	1.571	3.918	4.684	3.822	1.759	3.889
CV	4.033	3.358	1.782	4.712	3.920	3.444	1.999	4.679
Modified CV	6.017	6.000	8.000	6.356	6.000	6.000	8.000	6.340
Min	112.1	104.4	86.75	72.83	112.0	100.3	86.13	70.98
Max	129.2	118.7	90.64	88.00	127.3	118.6	90.12	87.56
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	5	19	18	18	5	19
Basis Values and Estimates								
B-basis Value	112.7	103.8		75.55	111.7	103.2		75.96
B-estimate			82.77				81.99	
A-estimate	107.3	98.38	78.87	67.57	106.4	97.88	77.62	68.39
Method	pooled	pooled	Normal	Weibull	pooled	pooled	Normal	Weibull
Modified CV Basis Values and Estimates								
B-basis Value	107.9	98.95		NA	106.9	98.36		72.84
B-estimate			64.03				63.93	
A-estimate	99.26	90.30	47.50		98.32	89.79	47.42	65.56
Method	pooled	pooled	normal		pooled	pooled	normal	normal

Table 4-23: Statistics and Basis Values for UNC0 Strength data

Unnotched Compression (UNC0) Modulus Statistics								
	Normalized				As-measured			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	9.386	9.514	9.217	8.991	9.294	9.451	9.220	8.976
Stdev	0.1777	0.1449	0.05857	0.1037	0.2976	0.1417	0.08394	0.1531
CV	1.893	1.523	0.6355	1.153	3.202	1.500	0.9104	1.706
Mod CV	6.000	6.000	8.000	6.000	6.000	6.000	8.000	6.000
Min	9.058	9.286	9.129	8.768	8.879	9.201	9.125	8.684
Max	9.770	9.807	9.284	9.194	9.980	9.699	9.354	9.258
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	18	18	18	6	18

Table 4-24: Statistics from UNC0 Modulus data

4.14 Quasi Isotropic Unnotched Compression 1 (UNC1)

The UNC1 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for two properties, strength and modulus. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

Both as-measured and the normalized RTA datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these two datasets were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable for the as-measured Mod CV basis value computations, but could not be applied to the normalized datasets due to a failure of Levene's test.

There was one statistical outlier. The lowest value in the normalized ETA dataset (which had only one batch) was an outlier. It was retained for this analysis.

Statistics, basis values and estimates are given for UNC1 strength data in Table 4-25 and for the modulus data in Table 4-26. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-14.

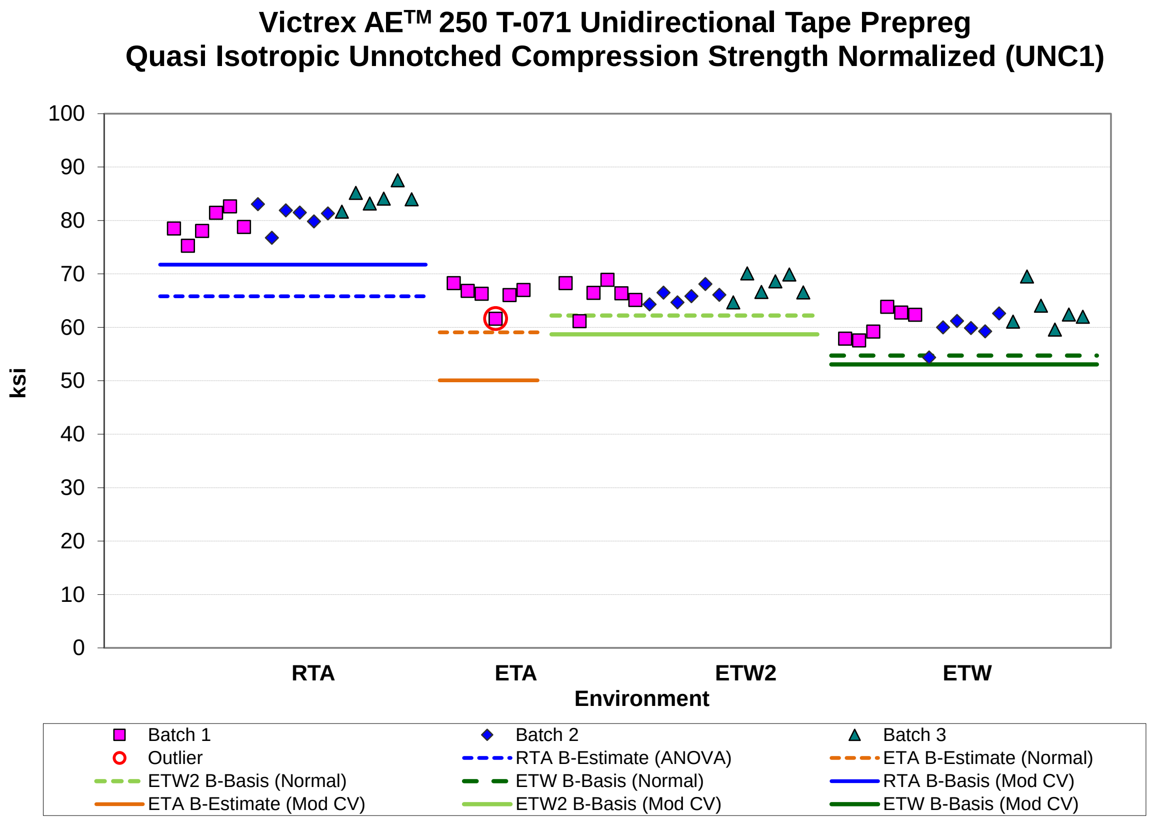

Figure 4-14: Batch plot for UNC1 strength normalized

Unnotched Compression (UNC1) Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	RTA	ETA	ETW2	ETW	RTA	ETA	ETW2	ETW
Mean	81.36	65.99	66.56	61.08	81.89	67.67	67.76	62.60
Stdev	3.078	2.284	2.212	3.221	3.048	2.930	2.527	3.676
CV	3.784	3.461	3.323	5.273	3.722	4.329	3.730	5.872
Modified CV	6.000	8.000	6.000	6.637	6.000	8.000	6.000	6.936
Min	75.26	61.62	61.14	54.38	75.82	62.30	61.77	55.31
Max	87.53	68.28	70.11	69.50	88.70	70.88	72.72	72.33
No. Batches	3	1	3	3	3	1	3	3
No. Spec.	18	6	18	18	18	6	18	18
Basis Values and Estimates								
B-basis Value			62.19	54.72			62.77	55.34
B-estimate	65.81	59.08			65.29	58.79		
A-estimate	54.71	54.16	59.10	50.22	53.45	52.48	59.23	50.20
Method	ANOVA	Normal	Normal	Normal	ANOVA	Normal	Normal	Normal
Modified CV Basis Values and Estimates								
B-basis Value	71.73		58.68	53.08	74.09		59.96	54.80
B-estimate		50.09				58.68		
A-estimate	64.91	39.21	53.10	47.42	68.90	53.63	54.77	49.61
Method	normal	normal	normal	normal	pooled	pooled	pooled	pooled

Table 4-25: Statistics and Basis Values for UNC1 Strength data

Unnotched Compression (UNC1) Modulus Statistics								
	Normalized				As-measured			
Env	RTA	ETA	ETW2	ETW	RTA	ETA	ETW2	ETW
Mean	6.599	6.340	6.342	6.024	6.642	6.499	6.455	6.173
Stdev	0.1318	0.06609	0.08202	0.09583	0.1359	0.05877	0.0930	0.1532
CV	1.997	1.043	1.293	1.591	2.046	0.9044	1.440	2.482
Modified CV	6.000	8.000	6.000	6.000	6.000	8.000	6.000	6.000
Min	6.316	6.212	6.158	5.806	6.380	6.449	6.268	5.906
Max	6.890	6.396	6.488	6.186	6.956	6.589	6.615	6.478
No. Batches	3	1	3	3	3	1	3	3
No. Spec.	18	6	18	18	18	6	18	18

Table 4-26: Statistics from UNC1 Modulus data

4.15 “Soft” Unnotched Compression 2 (UNC2)

The UNC2 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for two properties, strength and modulus.

The as-measured RTA dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When this dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test, so the modified CV basis values are provided.

There were no statistical outliers.

Statistics and basis values are given for UNC2 strength data in Table 4-27 and for the modulus data in Table 4-28. The normalized data and the B-basis values are shown graphically in Figure 4-15.

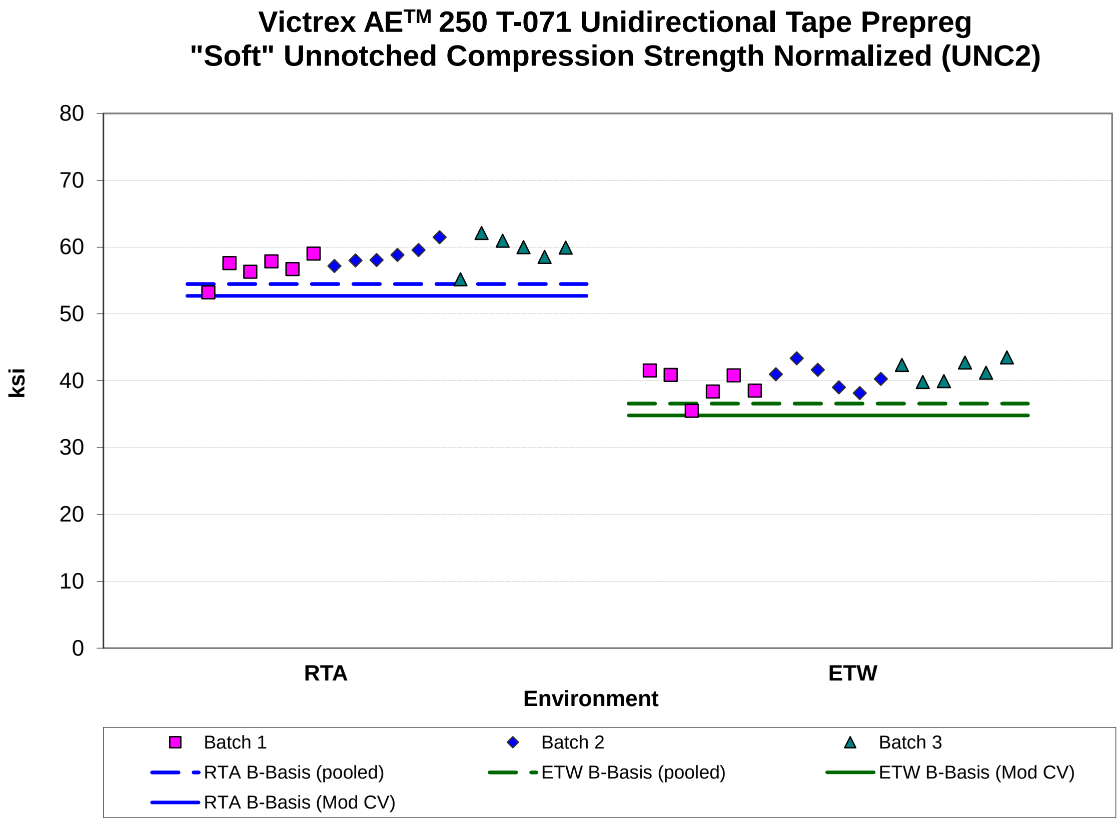

Figure 4-15: Batch plot for UNC2 strength normalized

Unnotched Compression (UNC2) Strength Basis Values				
	Normalized		As-measured	
Env	RTA	ETW	RTA	ETW
Mean	58.36	40.48	58.70	40.80
Stdev	2.219	2.042	3.050	2.428
CV	3.802	5.043	5.196	5.951
Modified CV	6.000	6.522	6.598	6.976
Min	53.22	35.50	51.50	34.55
Max	62.10	43.50	63.55	44.43
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and Estimates				
B-basis Value	54.47	36.60		36.00
B-estimate			43.24	
A-estimate	51.83	33.95	32.22	32.61
Method	pooled	pooled	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-basis Value	52.71	34.83	52.51	34.61
A-estimate	48.87	30.99	48.29	30.40
Method	pooled	pooled	pooled	pooled

Table 4-27: Statistics and Basis Values for UNC2 Strength data

Unnotched Compression (UNC2) Modulus Statistics				
	Normalized		As-measured	
Env	RTA	ETW	RTA	ETW
Mean	4.308	3.598	4.331	3.625
Stdev	0.07467	0.07976	0.08815	0.08491
CV	1.733	2.217	2.036	2.343
Modified CV	6.000	6.000	6.000	6.000
Min	4.199	3.420	4.129	3.477
Max	4.457	3.715	4.454	3.774
No. Batches	3	3	3	3
No. Spec.	18	18	18	18

Table 4-28: Statistics from UNC2 Modulus data

4.16 "Hard" Unnotched Compression 3 (UNC3)

The UNC3 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for two properties, strength and modulus.

The RTA and ETW conditions could be pooled for the normalized data.

The as-measured ETW dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When this dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable for the modified CV basis value computations.

There were no statistical outliers.

Statistics, basis values and estimates are given for UNC3 strength data in Table 4-29 and for the modulus data in Table 4-30. The normalized data and the B-basis values are shown graphically in Figure 4-16.

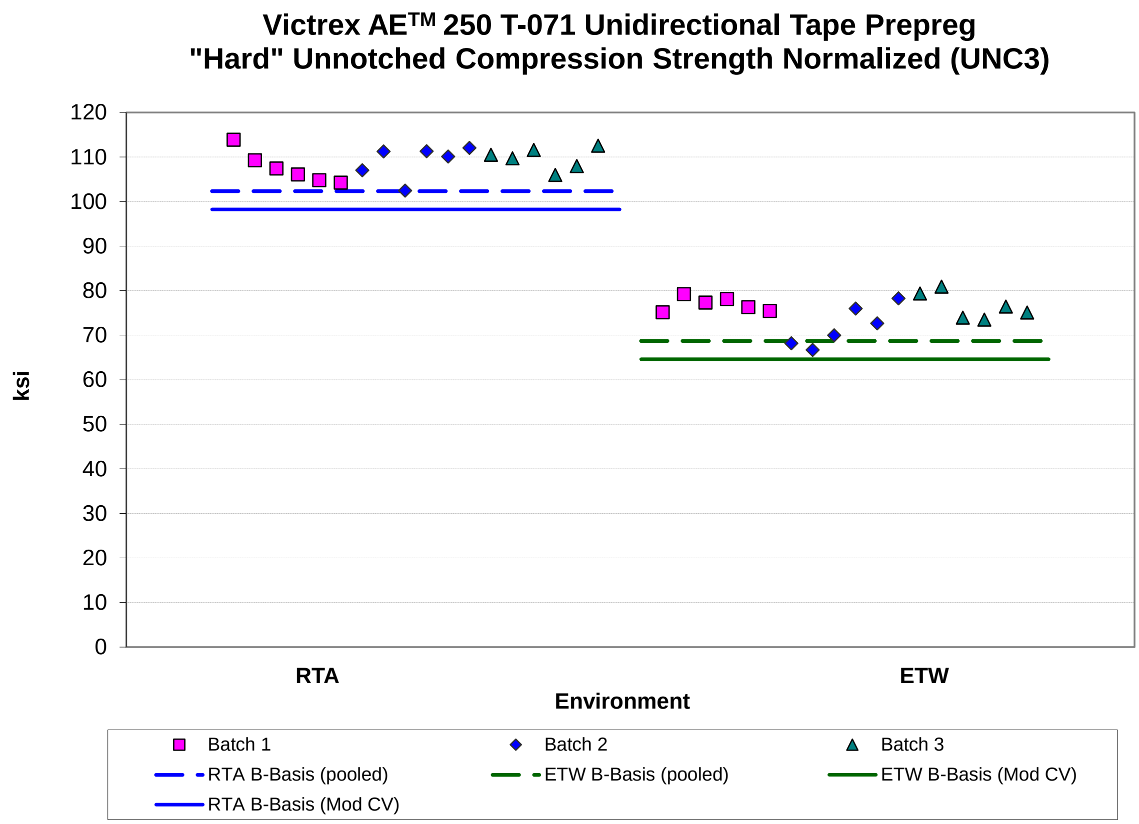

Figure 4-16: Batch plot for UNC3 strength normalized

Unnotched Compression (UNC3) Strength Basis Values				
	Normalized		As-measured	
Env	RTA	ETW	RTA	ETW
Mean	108.8	75.14	111.6	76.93
Stdev	3.197	3.850	3.759	4.931
CV	2.938	5.125	3.367	6.410
Modified CV	6.000	6.562	6.000	7.205
Min	102.5	66.68	102.6	66.18
Max	113.9	80.91	118.0	83.18
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and Estimates				
B-basis Value	102.3	68.69	104.2	
B-estimate				53.54
A-estimate	97.96	64.31	98.97	36.87
Method	pooled	pooled	Normal	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	98.25	64.60	100.4	65.73
A-estimate	91.09	57.43	92.83	58.11
Method	pooled	pooled	pooled	pooled

Table 4-29: Statistics and Basis Values for UNC3 Strength data

Unnotched Compression (UNC3) Modulus Statistics				
	Normalized		As-measured	
Env	RTA	ETW	RTA	ETW
Mean	9.980	9.470	10.24	9.691
Stdev	0.1461	0.2869	0.1517	0.4106
CV	1.464	3.030	1.481	4.237
Modified CV	6.000	6.000	6.000	6.118
Min	9.689	8.838	9.979	8.772
Max	10.21	9.789	10.57	10.02
No. Batches	3	3	3	3
No. Spec.	18	18	18	18

Table 4-30: Statistics from UNC3 Modulus data

4.17 Quasi Isotropic Open-Hole Tension 1 (OHT1)

The OHT1 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only one property, strength. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

The CTA and RTA conditions could be pooled for the normalized data.

The as-measured CTA and both the normalized and as-measured ETW datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these three datasets were transformed according to the assumptions of the modified CV method, they all passed the ADK test, so the modified CV basis values are provided. The as-measured CTA and RTA datasets could be pooled for the modified CV basis value computations.

There were no statistical outliers.

Statistics, basis values and estimates are given for OHT1 strength data in Table 4-31. The normalized data, B-basis values and B-estimates are shown graphically in Figure 4-17.

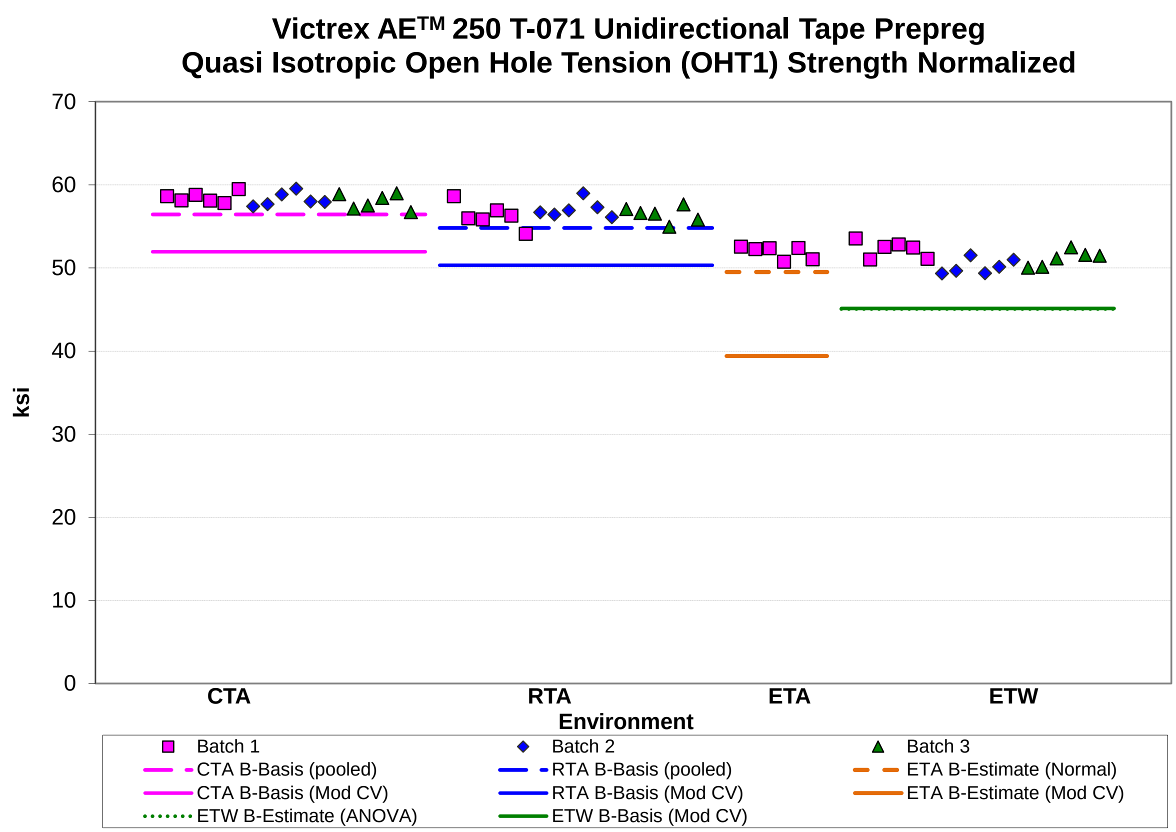

Figure 4-17: Batch Plot for OHT1 strength normalized

Open Hole Tension (OHT1) Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	58.22	56.60	51.90	51.18	58.94	56.73	53.20	51.98
Stdev	0.7872	1.156	0.7902	1.244	1.072	1.269	0.7927	1.476
CV	1.352	2.042	1.522	2.430	1.819	2.236	1.490	2.840
Modified CV	6.000	6.000	8.000	6.000	6.000	6.000	8.000	6.000
Min	56.71	54.10	50.75	49.33	57.37	54.54	52.12	49.92
Max	59.54	58.97	52.56	53.55	61.01	59.57	53.92	54.74
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	18	18	18	6	18
Basis Values and Estimates								
B-basis Value	56.42	54.80				54.22		
B-estimate			49.51	45.07	53.46		50.80	43.87
A-estimate	55.20	53.57	47.81	40.71	49.54	52.45	49.09	38.08
Method	pooled	pooled	Normal	ANOVA	ANOVA	Normal	Normal	ANOVA
Modified CV Basis Values and Estimates								
B-basis Value	51.95	50.33		45.12	52.62	50.41		45.82
B-estimate			39.39				40.38	
A-estimate	47.68	46.06	30.83	40.83	48.32	46.11	31.61	41.46
Method	pooled	pooled	Normal	Normal	pooled	pooled	Normal	Normal

Table 4-31: Statistics and Basis Values for OHT1 Strength data

4.18 “Soft” Open-Hole Tension 2 (OHT2)

The OHT2 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only one property, strength.

The as-measured and normalized dataset for both CTA and RTA failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these datasets were transformed according to the assumptions of the modified CV method, they all passed the ADK test, so the modified CV basis values are provided. The as-measured and normalized CTA, RTA and ETW datasets could be pooled for the modified CV basis value computations.

There was one outlier. The largest value in batch one of the as-measured CTA dataset was an outlier for batch one only. It was not an outlier for the CTA condition or in the normalized dataset. It was retained for this analysis.

Statistics, basis values and estimates are given for OHT2 strength data in Table 4-32. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-18.

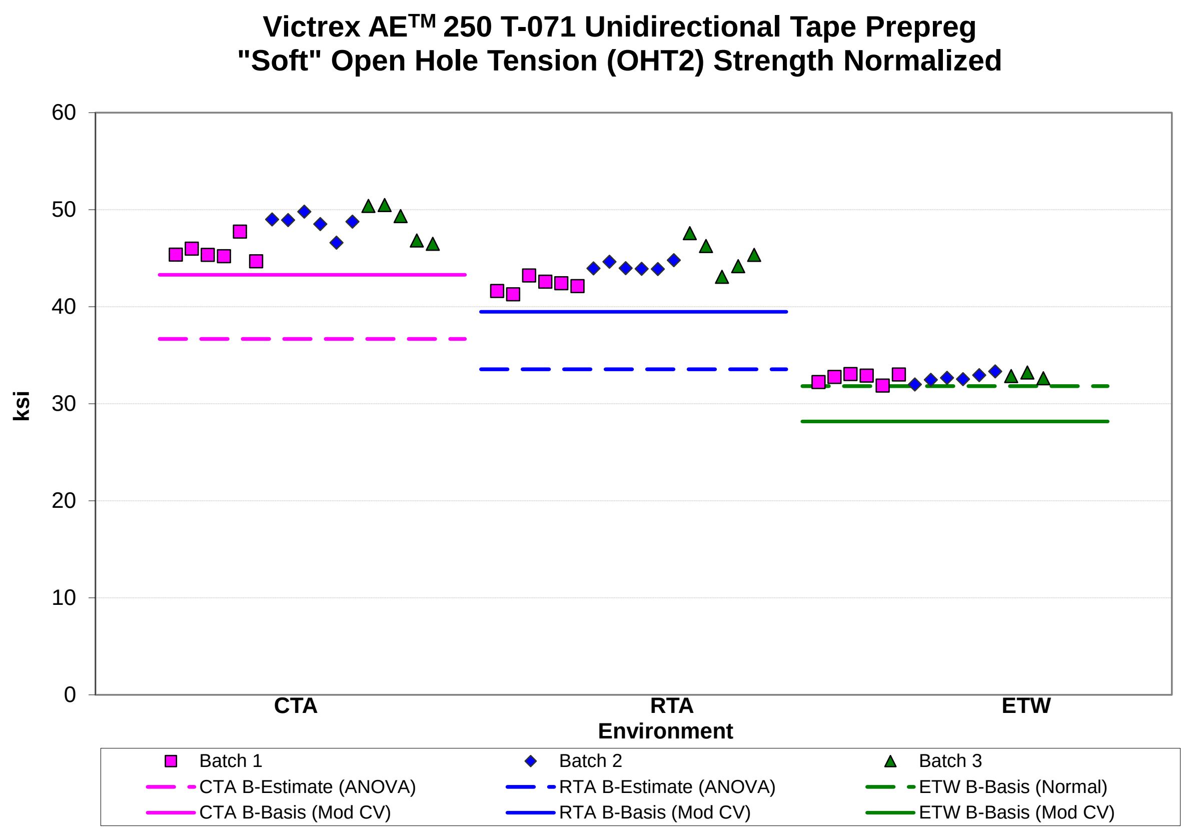

Figure 4-18: Batch Plot for OHT2 strength normalized

Open Hole Tension (OHT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTA	RTA	ETW	CTA	RTA	ETW
Mean	47.85	44.02	32.73	48.08	43.64	33.16
Stdev	2.145	1.834	0.4707	1.808	1.385	0.5832
CV	4.482	4.166	1.438	3.760	3.174	1.759
Modified CV	6.241	6.083	6.000	6.000	6.000	6.000
Min	44.66	41.28	31.86	45.57	41.12	31.99
Max	52.02	47.72	33.73	51.51	46.34	34.05
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and Estimates						
B-basis Value			31.80			32.00
B-estimate	36.67	33.54		39.96	36.53	
A-estimate	28.70	26.07	31.14	34.17	31.46	31.19
Method	ANOVA	ANOVA	Normal	ANOVA	ANOVA	Normal
Modified CV Basis Values and Estimates						
B-basis Value	43.28	39.46	28.17	43.61	39.17	28.68
A-estimate	40.24	36.41	25.12	40.62	36.19	25.70
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-32: Statistics and Basis Values for OHT2 Strength data

4.19 "Hard" Open-Hole Tension 3 (OHT3)

The OHT3 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only one property, strength.

All six datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these three datasets were transformed according to the assumptions of the modified CV method, all but the normalized ETW dataset passed the ADK test, so the modified CV basis values are provided. The as-measured CTA, RTA and ETW datasets could be pooled for the modified CV basis value computations, and the normalized CTA and RTA datasets could be pooled. No modified CV basis values could be computed for the normalized ETW dataset.

There was one outlier. The lowest value in batch two of the as-measured and normalized ETW dataset was an outlier for batch two but not for the ETW dataset. It was retained for this analysis.

Statistics, basis values and estimates are given for OHT3 strength data in Table 4-33. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-19.

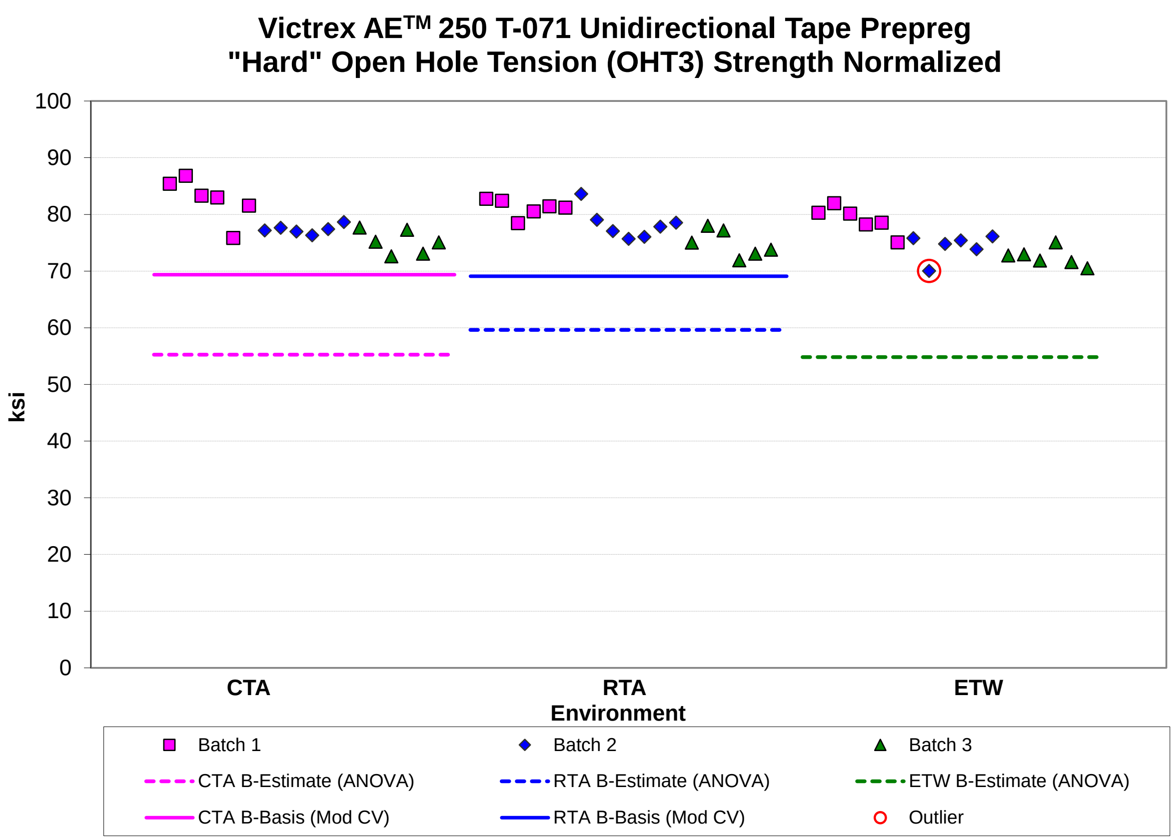

Figure 4-19: Batch Plot for OHT3 strength normalized

Open Hole Tension (OHT3) Strength (ksi) Basis Values and Statistics						
	Normalized			As-measured		
Env	CTA	RTA	ETW	CTA	RTA	ETW
Mean	78.39	78.08	75.28	80.35	78.65	77.76
Stdev	4.031	3.357	3.465	3.705	3.267	3.135
CV	5.142	4.299	4.603	4.611	4.154	4.031
Modified CV	6.571	6.150	6.301	6.305	6.077	6.016
Min	72.61	71.90	70.02	74.77	72.16	72.75
Max	86.80	83.62	81.96	87.48	82.90	83.41
No. Batches	3	3	3	3	3	3
No. Spec.	18	19	18	18	19	18
Basis Value Estimates						
B-estimate	55.27	59.64	54.83	58.34	60.49	59.29
A-estimate	38.77	46.48	40.24	42.63	47.54	46.11
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	69.35	69.09	NA	71.79	70.13	69.20
A-estimate	63.21	62.94		66.08	64.42	63.49
Method	pooled	pooled		pooled	pooled	pooled

Table 4-33: Statistics and Basis Values for OHT3 Strength data

4.20 Quasi Isotropic Open-Hole Compression 1 (OHC1)

The OHC1 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only one property, strength. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

The normalized and as-measured RTA datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these two datasets were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. The normalized ETW dataset failed all distribution tests (Normal, Lognormal and Weibull) and required the non-parametric method to compute basis values. After this dataset was transformed according to the assumptions of the modified CV method, it had an adequate fit to the normal distribution, so modified CV basis values are provided.

There was one statistical outlier. The largest value in batch three of the ETW dataset was an outlier for batch three in both the normalized and as-measured datasets. It was an outlier for the ETW condition for the as-measured dataset but not for the normalized dataset. It was retained for this analysis.

Statistics, estimates and basis values are given for OHC1 strength data in Table 4-34. The normalized data and the B-basis values are shown graphically in Figure 4-20.

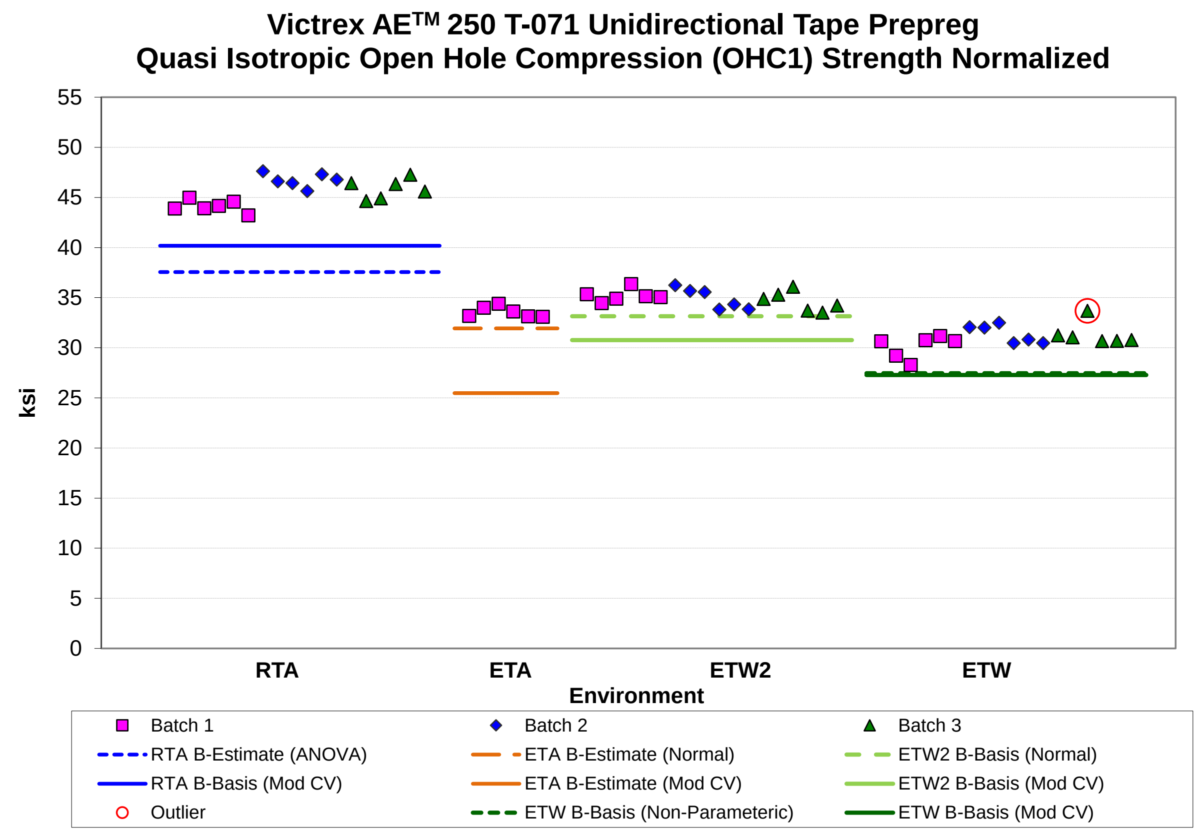

Figure 4-20: Batch plot for OHC1 strength normalized

Open Hole Compression (OHC1) Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	RTA	ETA	ETW2	ETW	RTA	ETA	ETW2	ETW
Mean	45.57	33.57	34.91	30.95	45.60	34.14	35.31	31.33
Stdev	1.340	0.5401	0.8908	1.172	1.100	0.6686	0.995	1.133
CV	2.941	1.609	2.551	3.787	2.412	1.958	2.818	3.614
Modified CV	6.000	8.000	6.000	6.000	6.000	8.000	6.000	6.000
Min	43.20	33.09	33.50	28.29	43.58	33.55	33.65	29.04
Max	47.62	34.40	36.36	33.69	47.49	35.21	36.83	34.39
No. Batches	3	1	3	3	3	1	3	3
No. Spec.	18	6	18	18	18	6	18	18
Basis Values and Estimates								
B-basis Value			33.15	27.46			33.34	29.10
B-estimate	37.55	31.94			39.80	32.12		
A-estimate	31.83	30.77	31.91	21.78	35.67	30.68	31.95	27.51
Method	ANOVA	Normal	Normal	Non-Parametric	ANOVA	Normal	Normal	Normal
Modified CV Basis Values and Estimates								
B-basis Value	40.17		30.78	27.29	40.20		31.12	27.62
B-estimate		25.48				25.91		
A-estimate	36.35	19.95	27.85	24.69	36.38	20.28	28.17	25.00
Method	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal

Table 4-34: Statistics and Basis Values for OHC1 Strength data

4.21 "Soft" Open-Hole Compression 2 (OHC2)

The OHC2 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only one property, strength.

The normalized and as-measured RTA datasets and the as-measured ETW dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these datasets were transformed according to the assumptions of the modified CV method, they passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable for the normalized modified CV basis value computations but the as-measured datasets failed Levene's test after the modified CV transformation of the data. Data could not be pooled.

There was one outlier. The lowest value in batch two of both the normalized and as-measured ETW datasets was an outlier for batch two but not the ETW condition. It was retained for this analysis.

Statistics, estimates and basis values are given for OHC2 strength data in Table 4-35. The normalized data and the B-basis values are shown graphically in Figure 4-21.

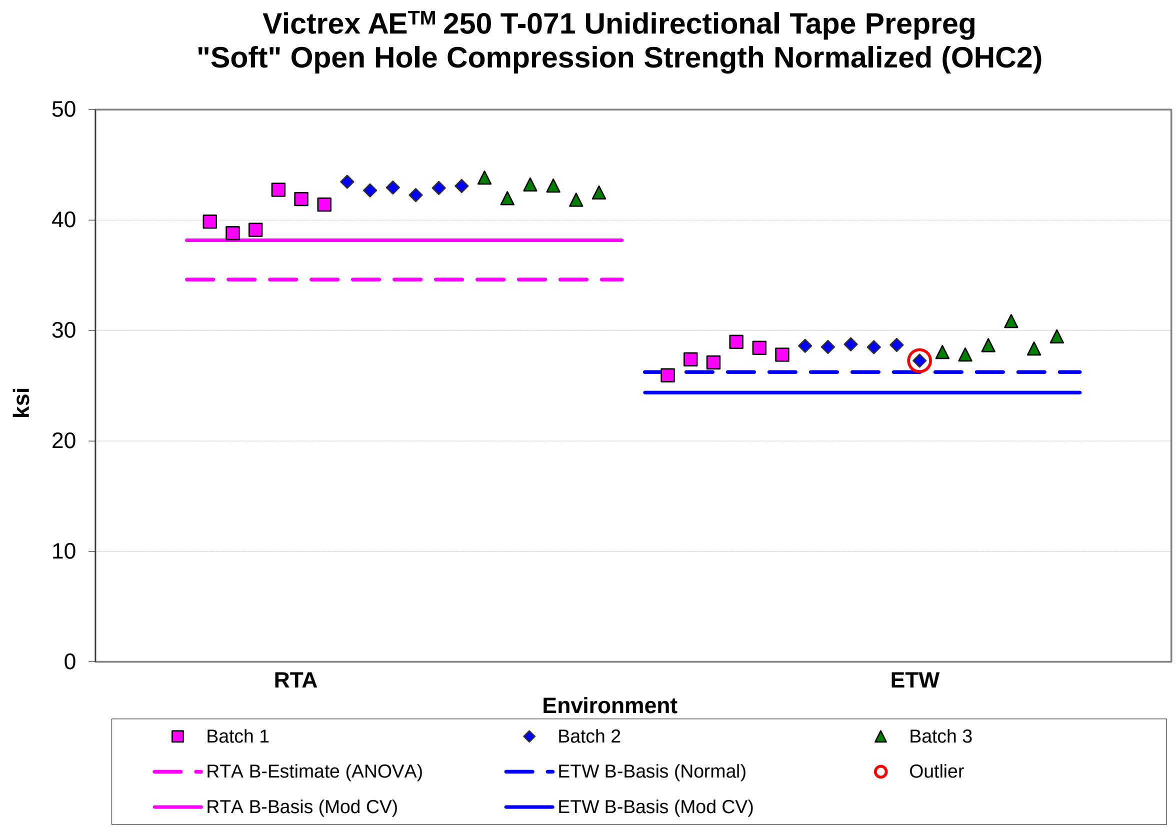

Figure 4-21: Batch plot for OHC2 strength normalized

Open-Hole Compression (OHC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTA	ETW	RTA	ETW
Mean	42.09	28.29	41.91	28.36
Stdev	1.451	1.042	1.389	1.096
CV	3.447	3.682	3.314	3.866
Modified CV	6.000	6.000	6.000	6.000
Min	38.81	25.93	39.13	26.08
Max	43.83	30.85	43.45	31.08
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and Estimates				
B-basis Value		26.23		
B-estimate	34.61		33.02	23.58
A-estimate	29.28	24.78	26.68	20.17
Method	ANOVA	Normal	ANOVA	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	38.17	24.37	36.95	25.00
A-estimate	35.50	21.70	33.44	22.63
Method	pooled	pooled	Normal	Normal

Table 4-35: Statistics and Basis Values for OHC2 Strength data

4.22 "Hard" Open-Hole Compression 3 (OHC3)

The OHC3 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only one property, strength.

All four datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the normalized datasets were transformed according to the assumptions of the modified CV method, they both passed the ADK test, but the as-measured datasets did not. Modified CV basis values are provided for the normalized datasets but pooling was not acceptable due to failure of Levene's test for equality of variance.

There were no statistical outliers.

Statistics, estimates and basis values are given for OHC3 strength data in Table 4-36. The normalized data and the B-basis values are shown graphically in Figure 4-22.

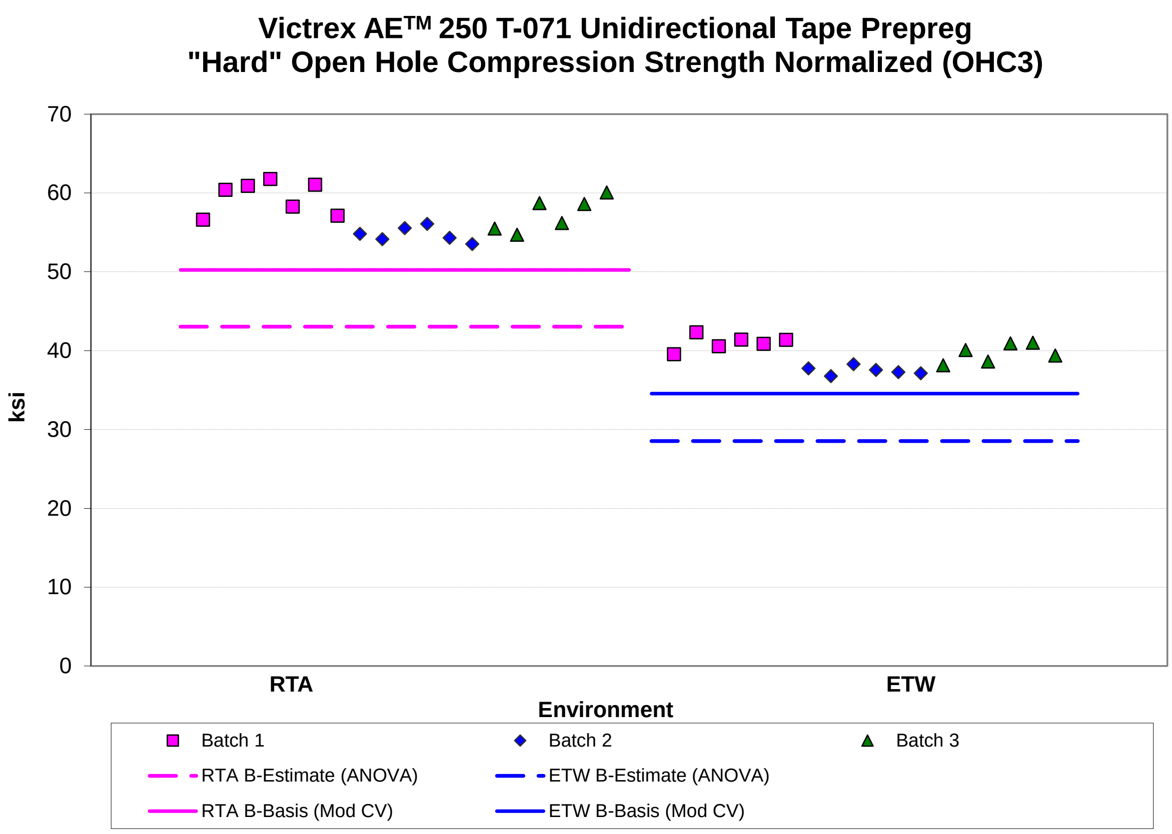

Figure 4-22: Batch plot for OHC3 strength normalized

Open-Hole Compression (OHC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTA	ETW	RTA	ETW
Mean	57.27	39.39	58.21	40.29
Stdev	2.630	1.738	3.302	2.259
CV	4.591	4.411	5.672	5.606
Modified CV	6.296	6.206	6.836	6.803
Min	53.53	36.77	54.05	37.05
Max	61.76	42.33	63.93	44.00
No. Batches	3	3	3	3
No. Spec.	19	18	19	18
Basis Value Estimates				
B-estimate	43.05	28.53	38.98	25.30
A-estimate	32.90	20.78	25.25	14.61
Method	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	50.25	34.56	NA	NA
A-estimate	45.26	31.15		
Method	Normal	Normal		

Table 4-36: Statistics and Basis Values for OHC3 Strength data

4.23 Quasi Isotropic Filled-Hole Tension 1 (FHT1)

The FHT1 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only one property, strength. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

Pooling was acceptable for the CTA and RTA conditions for both normalized and as-measured datasets. The ETA and ETW conditions could not pooled due to insufficient specimens in the ETA condition.

The normalized ETW dataset failed all distribution tests (Normal, Lognormal and Weibull) and required the non-parametric method to compute basis values. After this dataset was transformed according to the assumptions of the modified CV method, it still failed to the normal distribution, so modified CV basis values could not be provided for that dataset.

There was one statistical outlier. The lowest value in batch two of the as-measured RTA dataset was an outlier for batch two only, not for the RTA condition or for the normalized dataset. It was retained for this analysis.

Statistics, estimates and basis values are given for FHT1 strength data in Table 4-37. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-23.

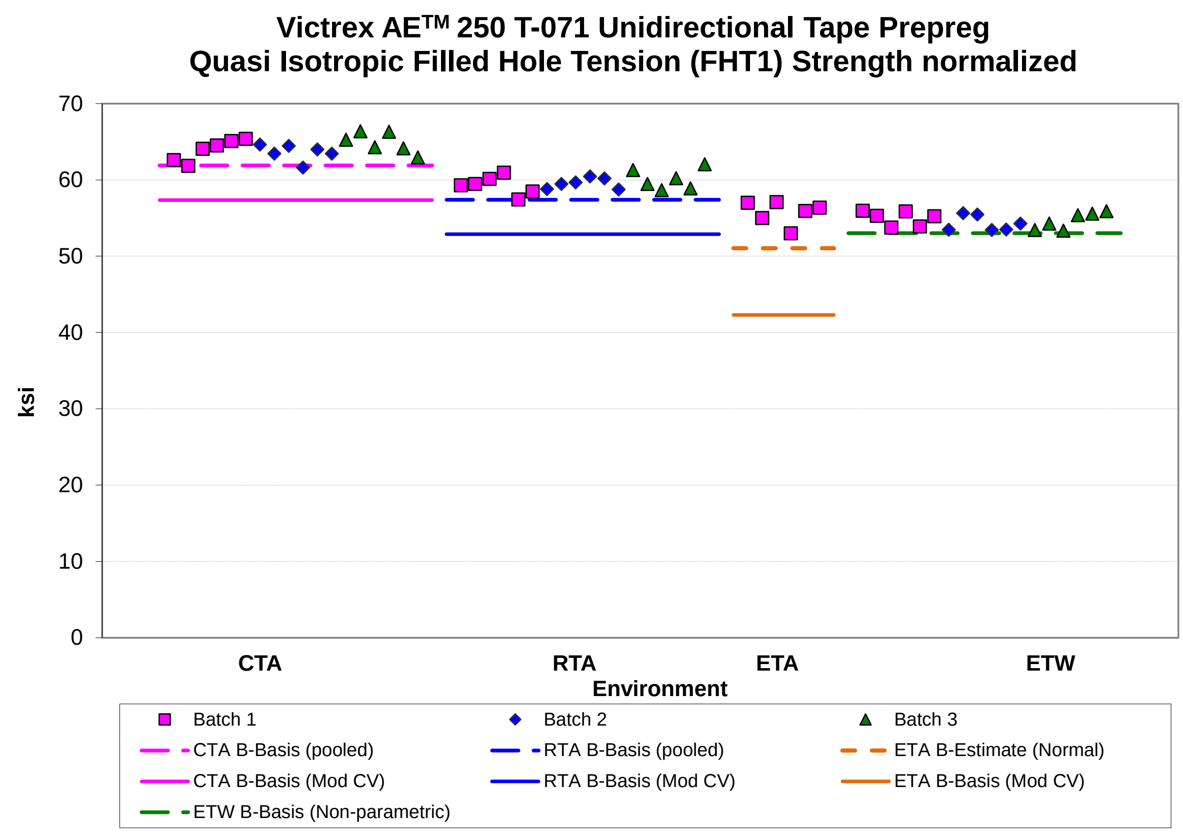

Figure 4-23: Batch plot for FHT1 strength normalized

Filled-Hole Tension (FHT1) Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	64.13	59.65	55.73	54.65	64.87	60.25	57.11	55.39
Stdev	1.339	1.121	1.544	1.0183	1.498	1.131	1.334	1.228
CV	2.088	1.879	2.770	1.863	2.309	1.877	2.336	2.217
Modified CV	6.000	6.000	8.000	6.000	6.000	6.000	8.000	6.000
Min	61.61	57.43	52.99	53.35	61.42	58.39	54.86	53.19
Max	66.37	62.06	57.09	55.96	67.09	62.80	58.18	57.28
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	18	18	18	6	18
Basis Values and Estimates								
B-basis Value	61.88	57.40		53.02	62.45	57.83		52.97
B-estimate			51.05				53.06	
A-estimate	60.35	55.87	47.72	49.67	60.81	56.19	50.19	51.25
Method	pooled	pooled	Normal	Non-Parametric	pooled	pooled	Normal	Normal
Modified CV Basis Values and Estimates								
B-basis Value	57.36	52.88		NA	58.03	53.41		48.83
B-estimate			42.29				43.34	
A-estimate	52.76	48.28	33.11		53.37	48.76	33.93	44.19
Method	pooled	pooled	Normal		pooled	pooled	Normal	Normal

Table 4-37: Statistics and Basis Values for FHT1 Strength data

4.24 "Soft" Filled-Hole Tension 2 (FHT2)

The FHT2 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only one property, strength.

The normalized RTA dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the normalized dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test. All three normalized datasets could be pooled to compute the modified CV basis values.

The three as-measured datasets could not be pooled due to a failure of Levene's test, but the RTA and ETW conditions met all requirements for pooling. After the datasets were transformed according to the assumptions of the modified CV method, they passed Levene's test and could be pooled to compute the modified CV basis values.

There were no statistical outliers.

Statistics and basis values are given for FHT2 strength data in Table 4-38. The normalized data and the B-basis values are shown graphically in Figure 4-24.

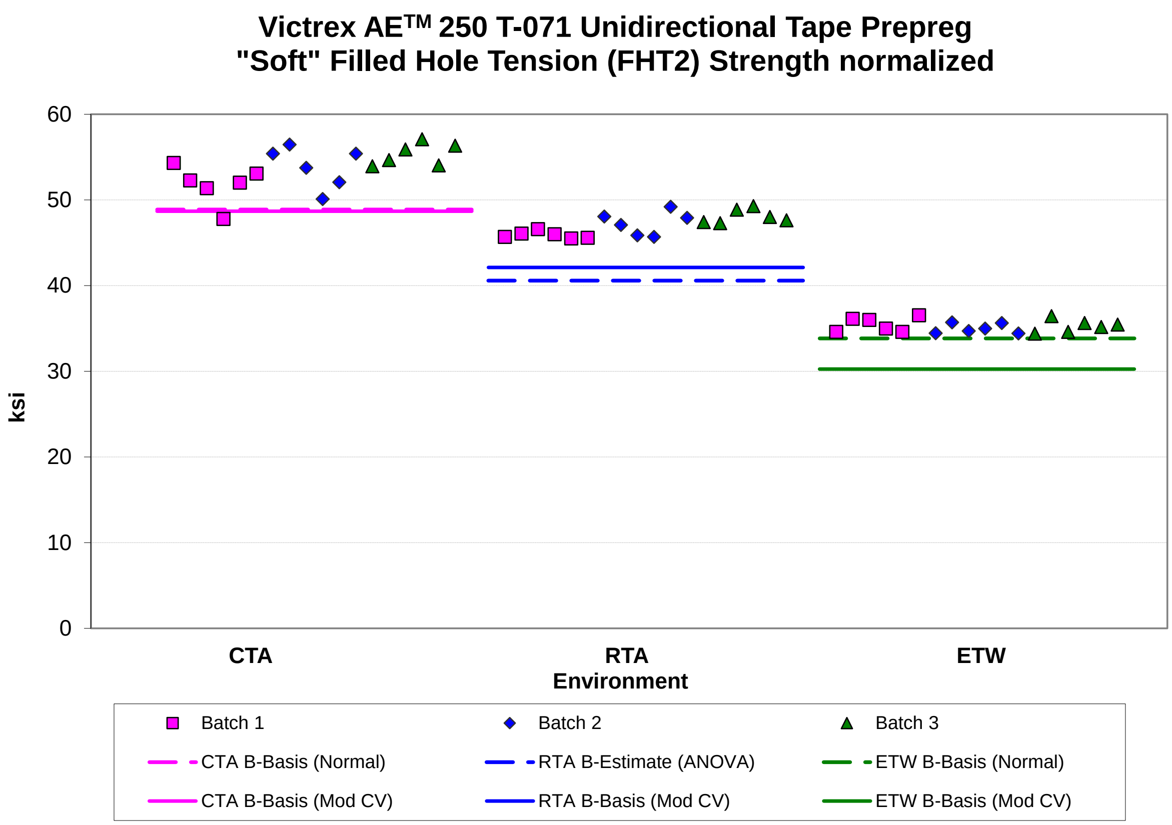

Figure 4-24: Batch plot for FHT2 strength normalized

Filled-Hole Tension (FHT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTA	RTA	ETW	CTA	RTA	ETW
Mean	53.66	47.09	35.24	54.02	46.99	35.50
Stdev	2.420	1.282	0.7180	2.234	1.114	0.8008
CV	4.510	2.723	2.037	4.135	2.372	2.256
Modified CV	6.255	6.000	6.000	6.068	6.000	6.000
Min	47.78	45.49	34.39	48.62	45.64	34.09
Max	57.08	49.27	36.54	57.41	49.20	37.23
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and Estimates						
B-basis Value	48.88		33.83	49.61	45.22	33.73
B-estimate		40.57				
A-estimate	45.50	35.92	32.82	46.48	44.02	32.53
Method	Normal	ANOVA	Normal	Normal	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	48.68	42.11	30.26	49.09	42.06	30.57
A-estimate	45.36	38.79	26.94	45.81	38.77	27.29
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-38: Statistics and Basis Values for FHT2 Strength data

4.25 "Hard" Filled-Hole Tension 3 (FHT3)

The FHT3 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only one property, strength.

All six FHT3 datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these dataset were transformed according to the assumptions of the modified CV method, the normalized ETW dataset and the as-measured RTA and ETW datasets passed the ADK test. Modified CV basis values are provided for those datasets. The as-measured RTA and ETW datasets met all requirements for pooling for the modified CV basis values.

There was one statistical outlier. The largest value in batch three of the RTA dataset was an outlier for batch three only in both the normalized and as-measured datasets. It was not an outlier for the RTA condition. It was retained for this analysis.

Statistics, estimates and basis values are given for FHT3 strength data in Table 4-39. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-25.

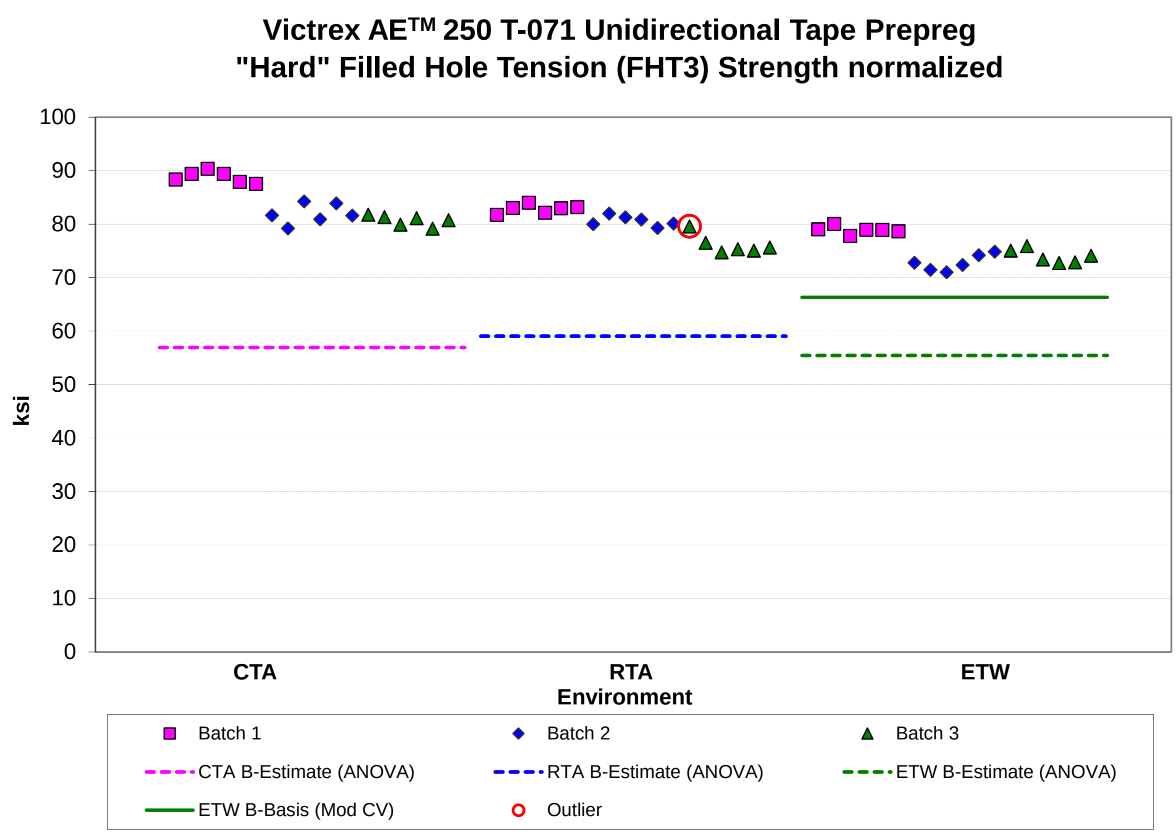

Figure 4-25: Batch plot for FHT3 strength normalized

Filled-Hole Tension (FHT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTA	RTA	ETW	CTA	RTA	ETW
Mean	83.79	79.85	75.23	85.82	80.91	77.14
Stdev	3.909	3.101	2.949	3.652	2.936	2.639
CV	4.665	3.884	3.920	4.255	3.629	3.421
Modified CV	6.332	6.000	6.000	6.127	6.000	6.000
Min	79.15	74.71	70.99	81.37	76.59	73.33
Max	90.34	83.98	80.01	91.90	84.94	81.37
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Value Estimates						
B-estimate	56.91	59.04	55.45	61.46	62.03	61.03
A-estimate	37.71	44.18	41.33	44.07	48.55	49.54
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	NA	NA	66.32	NA	72.27	68.50
A-estimate			60.02		66.39	62.62
Method			Normal		pooled	pooled

Table 4-39: Statistics and Basis Values for FHT3 Strength data

4.26 Quasi Isotropic Filled-Hole Compression 1 (FHC1)

The FHC1 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only one property, strength. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

There were no diagnostic test failures. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so pooling was not appropriate.

There was one statistical outlier in the RTA condition. The lowest value in batch two was an outlier for batch two only, but not the RTA condition. It was an outlier for both the normalized and as-measured data.

Statistics, estimates and basis values are given for FHC1 strength data in Table 4-40. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-26.

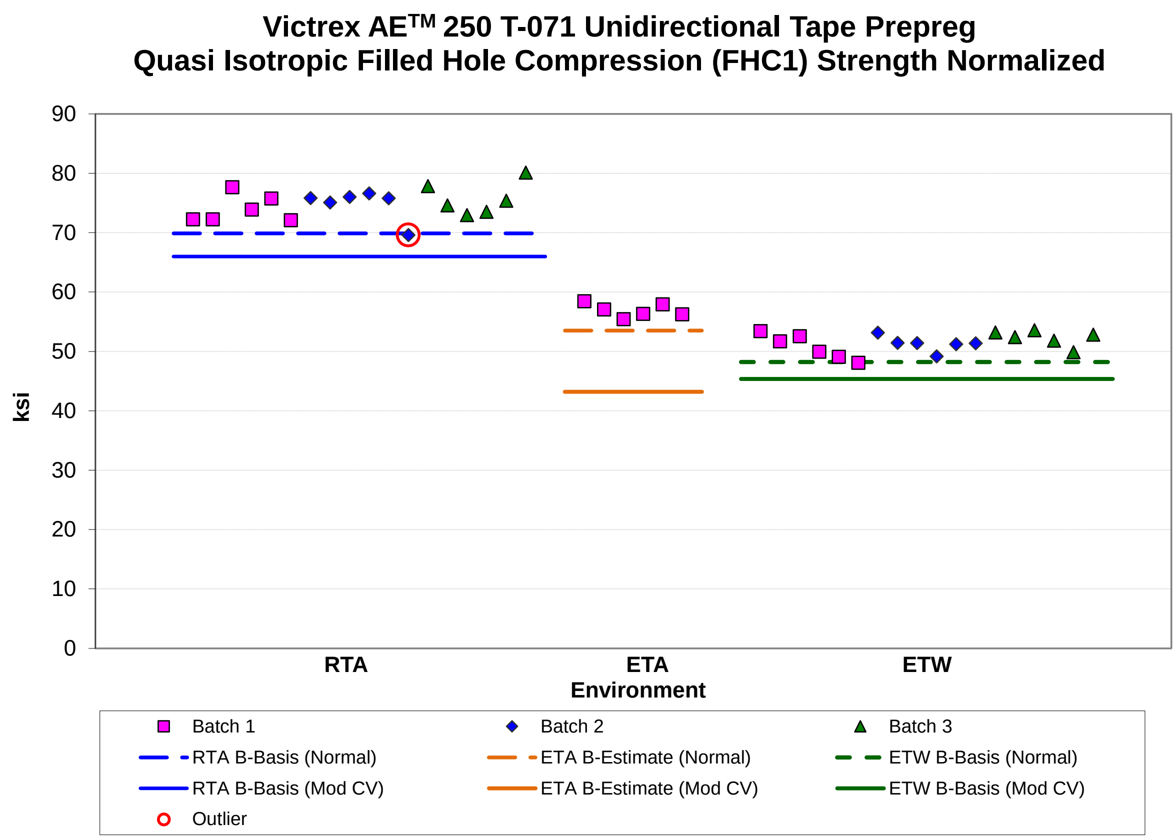

Figure 4-26: Batch plot for FHC1 strength normalized

Filled-Hole Compression (FHC1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	RTA	ETA	ETW	RTA	ETA	ETW
Mean	74.84	56.91	51.45	75.41	57.90	52.20
Stdev	2.511	1.126	1.632	2.539	1.092	1.784
CV	3.354	1.979	3.172	3.367	1.885	3.418
Modified CV	6.000	8.000	6.000	6.000	8.000	6.000
Min	69.60	55.43	48.10	69.35	56.65	48.94
Max	80.12	58.44	53.55	80.86	59.54	54.75
No. Batches	3	1	3	3	1	3
No. Spec.	18	6	18	18	6	18
Basis Values and Estimates						
B-basis Value	69.89		48.23	70.40		48.68
B-estimate		53.50			54.59	
A-estimate	66.37	51.07	45.95	66.85	52.24	46.18
Method	Normal	Normal	Normal	Normal	Normal	Normal
Modified CV Basis Values and Estimates						
B-basis Value	65.98		45.36	66.48		46.02
B-estimate		43.19			43.95	
A-estimate	59.71	33.81	41.05	60.16	34.40	41.64
Method	Normal	Normal	Normal	Normal	Normal	Normal

Table 4-40: Statistics and Basis Values for FHC1 Strength data

4.27 "Soft" Filled-Hole Compression 2 (FHC2)

The FHC2 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only one property, strength.

Both the normalized and as-measured RTA datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these dataset were transformed according to the assumptions of the modified CV method, both datasets passed the ADK test and the pooled dataset passed the normality test. Modified CV basis values are provided for those datasets. The RTA and ETW datasets met all requirements for pooling for the modified CV basis values.

There were two outliers. The lowest value in batch two of the RTA condition was an outlier for batch two but not for the RTA condition. It was an outlier in both the normalized and the as-measured datasets. The lowest value in batch one of the normalized RTA condition was an outlier for batch one only. It was not an outlier for the RTA condition or for the as-measured dataset. Both outliers were retained for this analysis.

Statistics, estimates and basis values are given for FHC2 strength data in Table 4-41. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-27.

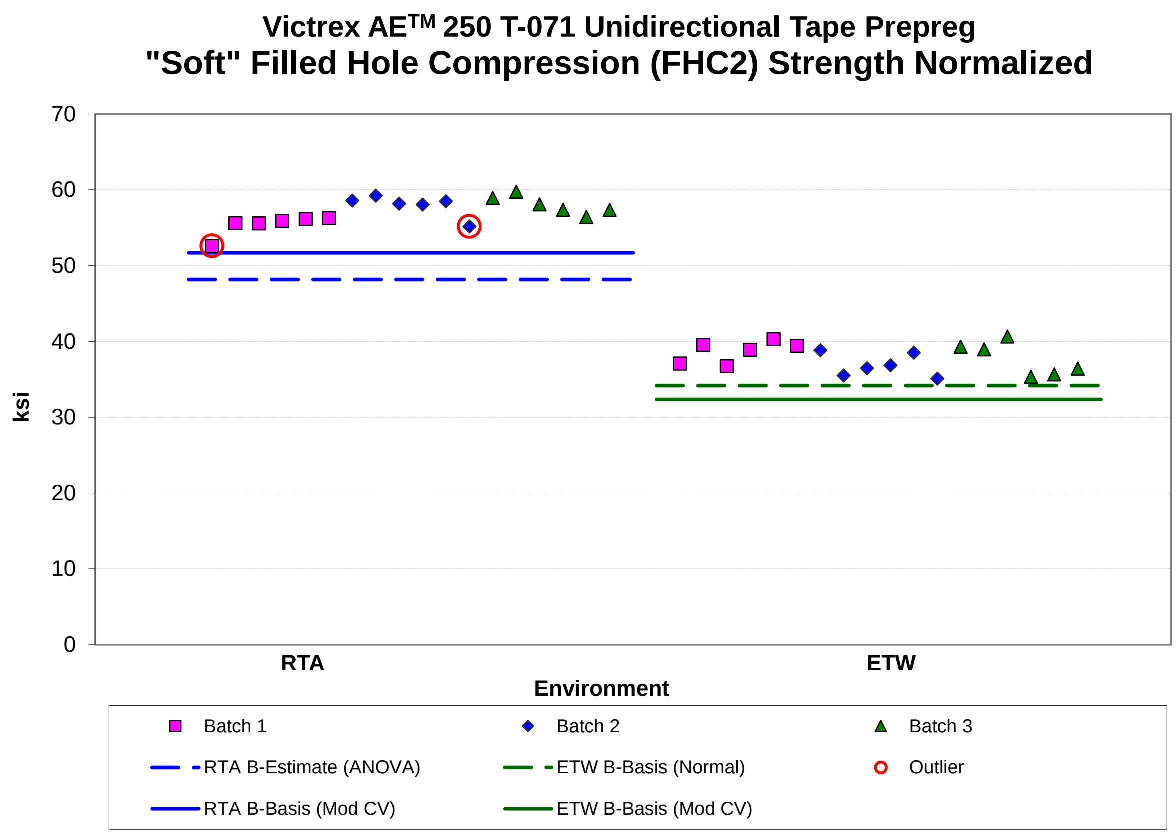

Figure 4-27: Batch plot for FHC2 strength normalized

Filled-Hole Compression (FHC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTA	ETW	RTA	ETW
Mean	57.09	37.75	57.04	37.90
Stdev	1.785	1.813	1.963	1.602
CV	3.126	4.802	3.442	4.227
Modified CV	6.000	6.401	6.000	6.113
Min	52.60	35.10	52.94	35.42
Max	59.75	40.64	59.64	40.78
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and Estimates				
B-basis Value		34.17		34.73
B-estimate	48.18		45.25	
A-estimate	41.83	31.63	36.83	32.49
Method	ANOVA	Normal	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-basis Value	51.69	32.35	51.72	32.57
A-estimate	48.02	28.68	48.10	28.95
Method	pooled	pooled	pooled	pooled

Table 4-41: Statistics and Basis Values for FHC2 Strength data

4.28 "Hard" Filled-Hole Compression 3 (FHC3)

The FHC3 data is normalized, so statistics for both as-measured and normalized are provided. Data is available for only one property, strength.

The normalized RTA and ETW datasets met all requirements for pooling.

The as-measured ETW dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When this dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test. The as-measured RTA and ETW datasets met all requirements for pooling for the modified CV basis values.

There was one statistical outlier. The lowest value in batch three of the ETW condition was an outlier for batch three only, not the for ETW condition. It was an outlier in both the as-measured and normalized datasets. It was retained for this analysis.

Statistics, estimates and basis values are given for FHC3 strength data in Table 4-42. The normalized data and the B-basis values are shown graphically in Figure 4-28.

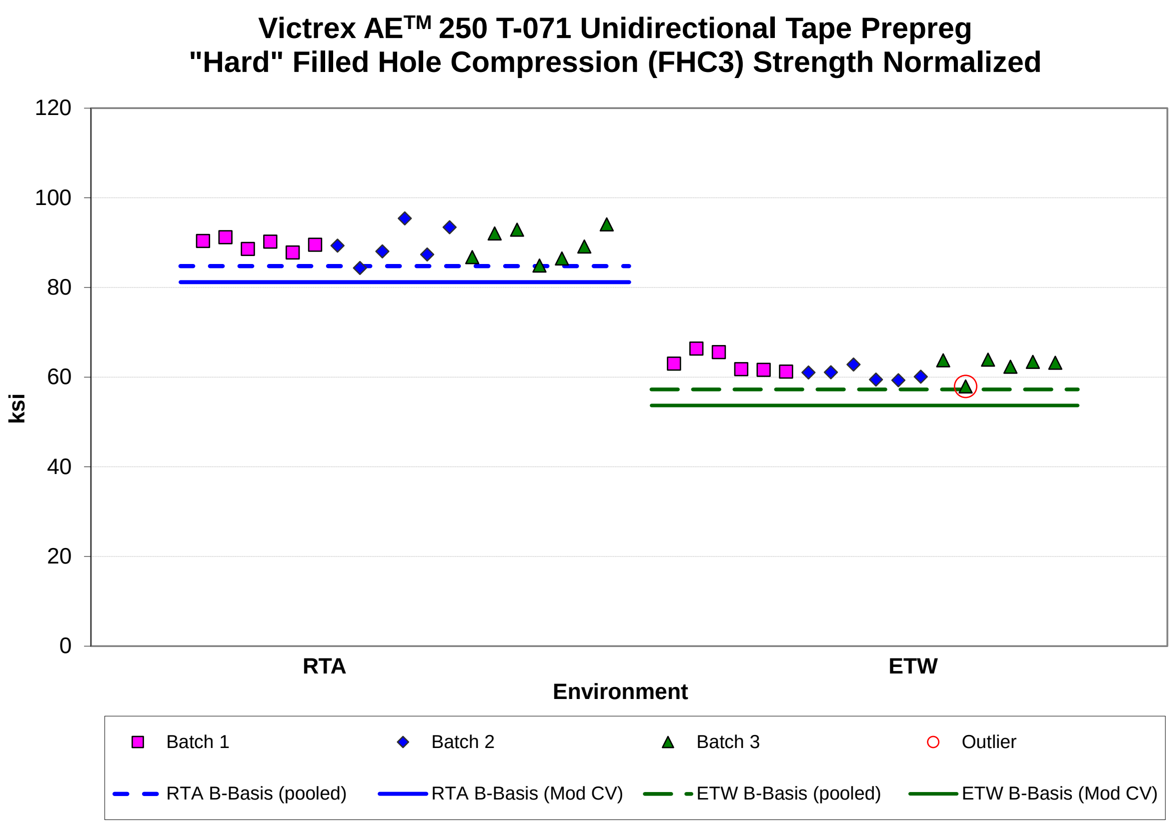

Figure 4-28: Batch plot for FHC3 strength normalized

Filled-Hole Compression (FHC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTA	ETW	RTA	ETW
Mean	89.56	62.09	91.32	63.70
Stdev	3.061	2.170	3.422	2.789
CV	3.418	3.495	3.747	4.379
Modified CV	6.000	6.000	6.000	6.189
Min	84.33	57.93	84.92	58.75
Max	95.40	66.36	96.47	69.63
No. Batches	3	3	3	3
No. Spec.	19	18	19	18
Basis Values and Estimates				
B-basis Value	84.74	57.25	84.65	
B-estimate				49.16
A-estimate	81.45	53.96	79.91	38.79
Method	pooled	pooled	Normal	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	81.16	53.65	82.65	54.99
A-estimate	75.41	47.91	76.72	49.07
Method	pooled	pooled	pooled	pooled

Table 4-42: Statistics and Basis Values for FHC3 Strength data

4.29 Quasi Isotropic Single-Shear Bearing 1 (SSB1)

The SSB1 data is normalized, so statistics for both as-measured and normalized are provided. The ETA dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. Data was available for three properties: Initial Peak Strength, 2% Offset Strength and Ultimate Strength. There was insufficient data to compute basis values and estimate for the Initial Peak property, so design values were computed for the 2% Offset Strength and Ultimate Strength properties only.

The normalized and as-measured ETW datasets for the 2% Offset Strength failed all distribution tests (Normal, Lognormal and Weibull) and required the non-parametric method to compute basis values. After these datasets were transformed according to the assumptions of the modified CV method, the normalized ETW dataset had an adequate fit to the normal distribution while the as-measured ETW dataset did not. So modified CV basis values are not provided for the as-measured ETW dataset.

The normalized ETW dataset for Ultimate Strength did not pass the normality test. The lognormal distribution provided an adequate fit to the dataset, so that distribution was used to compute basis values and estimates. After this dataset was transformed according to the assumptions of the modified CV method, it had an adequate fit to the normal distribution so modified CV basis values were provided.

There were two statistical outliers. The largest value in batch one of the ETW dataset was an outlier for the 2% Offset Strength property. It was an outlier for both the normalized and as-measured datasets and for batch one of the as-measured dataset and the ETW condition for both datasets. It was not an outlier for the Ultimate Strength property. The largest value in batch three of the ETW dataset was an outlier for both the 2% Offset Strength and the Ultimate Strength properties. It was an outlier for both the normalized and as-measured datasets and for both batch one only. Both outliers were retained for this analysis.

Statistics, estimates and basis values are given for the SSB1 2% Offset Strength data in Table 4-43 and for the Ultimate Strength data in Table 4-44. The normalized data and the B-basis values are shown graphically in for the 2% Offset Strength in Figure 4-29 and for the Ultimate Strength in Figure 4-30.

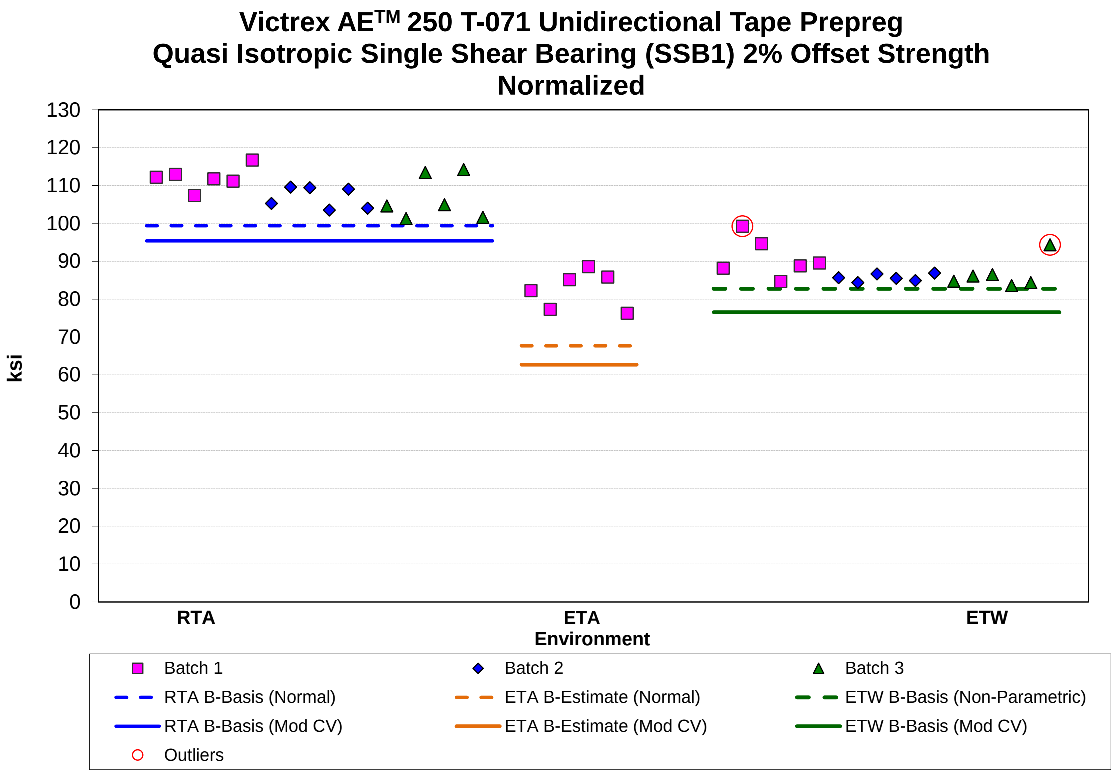

Figure 4-29: Batch plot for SSB1 2% Offset strength normalized

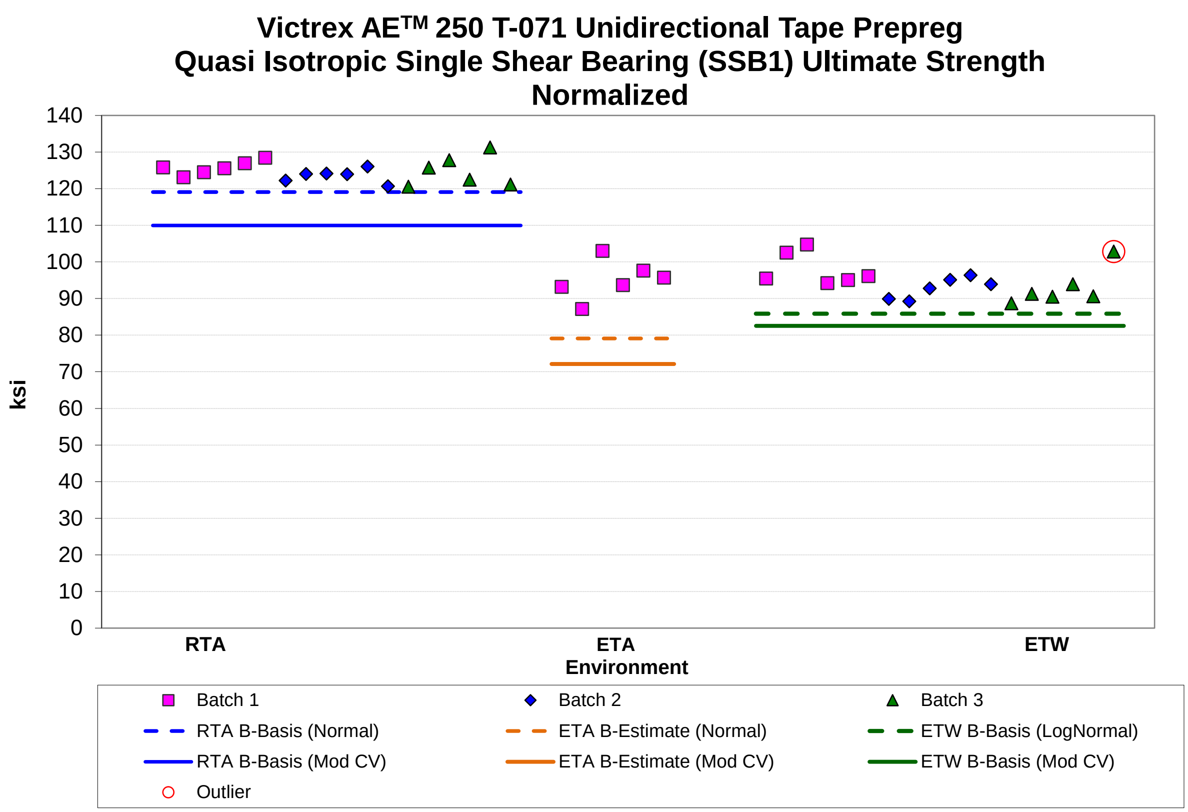

Figure 4-30: Batch plot for SSB1 Ultimate strength normalized

Single Shear Bearing (SSB1) 2% Offset Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	RTA	ETA	ETW	RTA	ETA	ETW
Mean	108.5	82.55	87.69	108.2	82.58	88.47
Stdev	4.620	4.920	4.270	3.965	4.737	3.446
CV	4.258	5.961	4.870	3.666	5.736	3.895
Modified CV	6.129	8.000	6.435	6.000	8.000	6.000
Min	101.3	76.25	83.61	100.1	75.87	84.54
Max	116.7	88.58	99.26	114.0	88.52	97.88
No. Batches	3	1	3	3	1	3
No. Spec.	18	6	18	18	6	18
Basis Values and Estimates						
B-basis Value	99.39		82.75	100.3		83.41
B-estimate		67.64			68.23	
A-estimate	92.92	57.05	64.67	94.78	58.03	67.89
Method	Normal	Normal	Non-Parametric	Normal	Normal	Non-Parametric
Modified CV Basis Values and Estimates						
B-basis Value	95.38		76.55	95.34		NA
B-estimate		62.65			62.68	
A-estimate	86.09	49.04	68.67	86.28	49.06	
Method	Normal	Normal	Normal	Normal	Normal	

Table 4-43: Statistics and Basis Values for SSB1 2% Offset Strength data

Single Shear Bearing (SSB1) Ultimate Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	RTA	ETA	ETW	RTA	ETA	ETW
Mean	124.7	95.06	94.63	124.3	95.09	95.46
Stdev	2.857	5.264	4.691	2.931	4.754	3.904
CV	2.291	5.538	4.957	2.357	5.000	4.089
Modified CV	6.000	8.000	6.479	6.000	8.000	6.045
Min	120.5	87.15	88.72	119.9	88.50	89.15
Max	131.3	103.0	104.8	131.1	102.6	103.8
No. Batches	3	1	3	3	1	3
No. Spec.	18	6	18	18	6	18
Basis Values and Estimates						
B-basis Value	119.1		85.86	118.5		87.76
B-estimate		79.12			80.69	
A-estimate	115.1	67.78	80.21	114.4	70.45	82.29
Method	Normal	Normal	Lognormal	Normal	Normal	Normal
Modified CV Basis Values and Estimates						
B-basis Value	109.9		82.53	109.6		NA
B-estimate		72.15			72.17	
A-estimate	99.48	56.48	73.96	99.18	56.49	
Method	Normal	Normal	Normal	Normal	Normal	

Table 4-44: Statistics and Basis Values for SSB1 Ultimate Strength data

4.30 "Soft" Single-Shear Bearing 2 (SSB2)

The SSB2 data is normalized, so statistics for both as-measured and normalized are provided. Data was available for two properties, 2% Offset Strength and Ultimate Strength.

While the RTA condition did not pass the normality test, the RTA and ETW conditions passed the normality test for the pooled dataset and pooling was appropriate for both 2% Offset Strength and Ultimate Strength for both the normalized and as-measured datasets.

There were two statistical outliers. The largest value in batch three of the RTA condition for the normalized 2% Offset Strength property was an outlier for batch three only. It was not an outlier for the RTA condition or in the as-measured dataset or for the Ultimate Strength property. The lowest value in batch one of the RTA condition for the Ultimate Strength property was an outlier for batch one only, not for the RTA condition. It was an outlier for both the normalized and as-measured datasets. It was not an outlier for the 2% Offset Strength property. Both outliers were retained for this analysis.

Statistics, estimates and basis values are given for the SSB2 2% offset strength data in Table 4-45. The normalized data and the B-basis values are shown graphically in Figure 4-31.

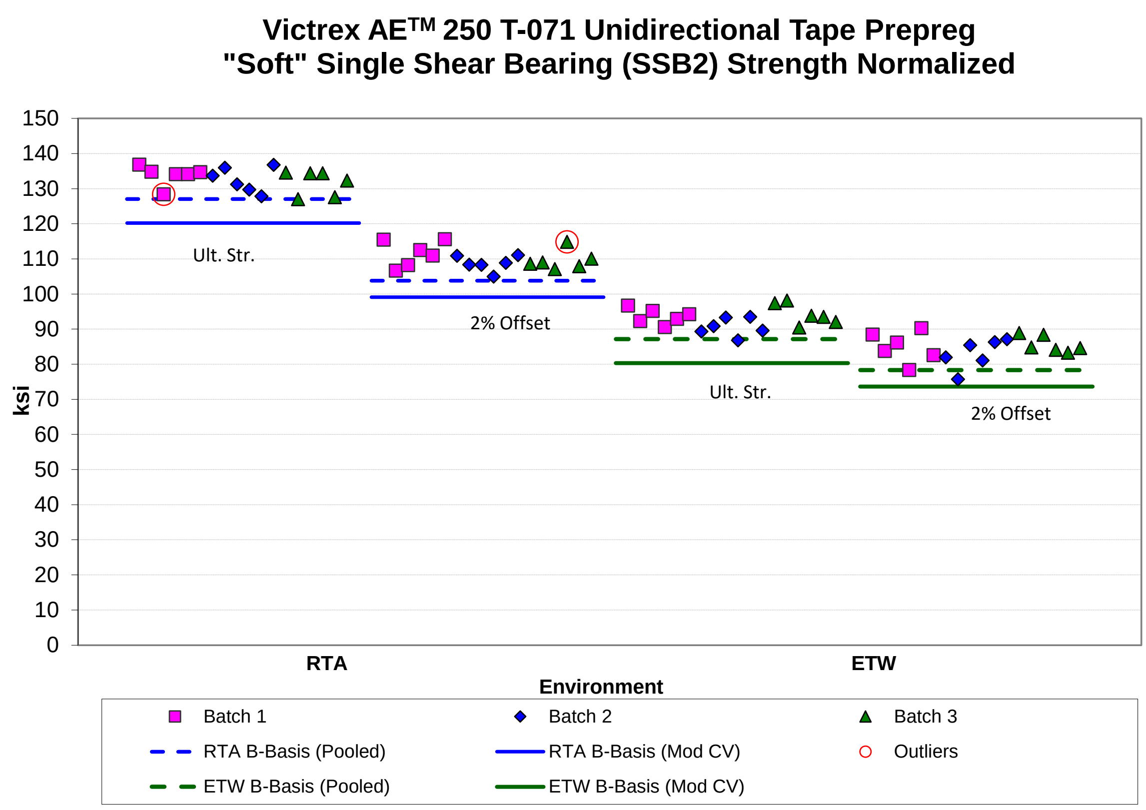

Figure 4-31: Batch plot for SSB2 strength normalized

Single Shear Bearing (SSB2) Strength Basis Values and Statistics								
	2% Offset Strength				Ultimate Strength			
	Normalized		As-measured		Normalized		As-measured	
Env	RTA	ETW	RTA	ETW	RTA	ETW	RTA	ETW
Mean	110.0	84.52	110.8	86.50	132.7	92.81	133.7	94.99
Stdev	3.038	3.723	2.901	3.583	3.246	2.946	3.295	2.598
CV	2.763	4.405	2.617	4.142	2.446	3.174	2.464	2.736
Modified CV	6.000	6.202	6.000	6.071	6.000	6.000	6.000	6.000
Min	104.9	75.71	106.3	78.60	127.0	86.82	127.9	90.01
Max	115.6	90.28	116.6	93.07	136.8	98.13	139.3	99.67
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18	18	18
Basis Values and Estimates								
B-basis Value	103.8	78.33	104.9	80.56	127.0	87.16	128.3	89.58
A-estimate	99.56	74.12	100.8	76.52	123.2	83.32	124.7	85.90
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates								
B-basis Value	99.11	73.66	99.91	75.59	120.2	80.29	121.1	82.31
A-estimate	91.72	66.28	92.49	68.16	111.7	71.78	112.4	73.69
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-45: Statistics and Basis Values for SSB2 Strength data

4.31 “Hard” Single-Shear Bearing 3 (SSB3)

The SSB3 data is normalized, so statistics for both as-measured and normalized are provided. Data was available for three properties, Initial Peak Strength, 2% Offset Strength and Ultimate Strength. There was insufficient data to compute basis values and estimate for Initial Peak, so design values were computed for the 2% Offset Strength and Ultimate Strength properties only.

The normalized and as-measured 2% offset datasets failed Levene’s test and could not be pooled. When these dataset were transformed according to the assumptions of the modified CV method, they passed Levene’s test and the pooled dataset passed normality. They could be pooled to compute the modified CV basis values.

Both the normalized and as-measured Ultimate Strength RTA datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these dataset were transformed according to the assumptions of the modified CV method, both datasets passed the ADK test. Modified CV basis values are provided for those datasets. The RTA and ETW datasets met all requirements for pooling for the modified CV basis values.

There was one statistical outlier. The lowest value in batch three of the 2% Offset RTA dataset was an outlier for batch three only for both the normalized and as-measured datasets. It was not an outlier for the RTA condition or for the Ultimate Strength property. It was retained for this analysis.

Statistics, estimates and basis values are given for the SSB3 2% offset strength data in Table 4-46.The normalized data and the B-basis values are shown graphically in Figure 4-32.

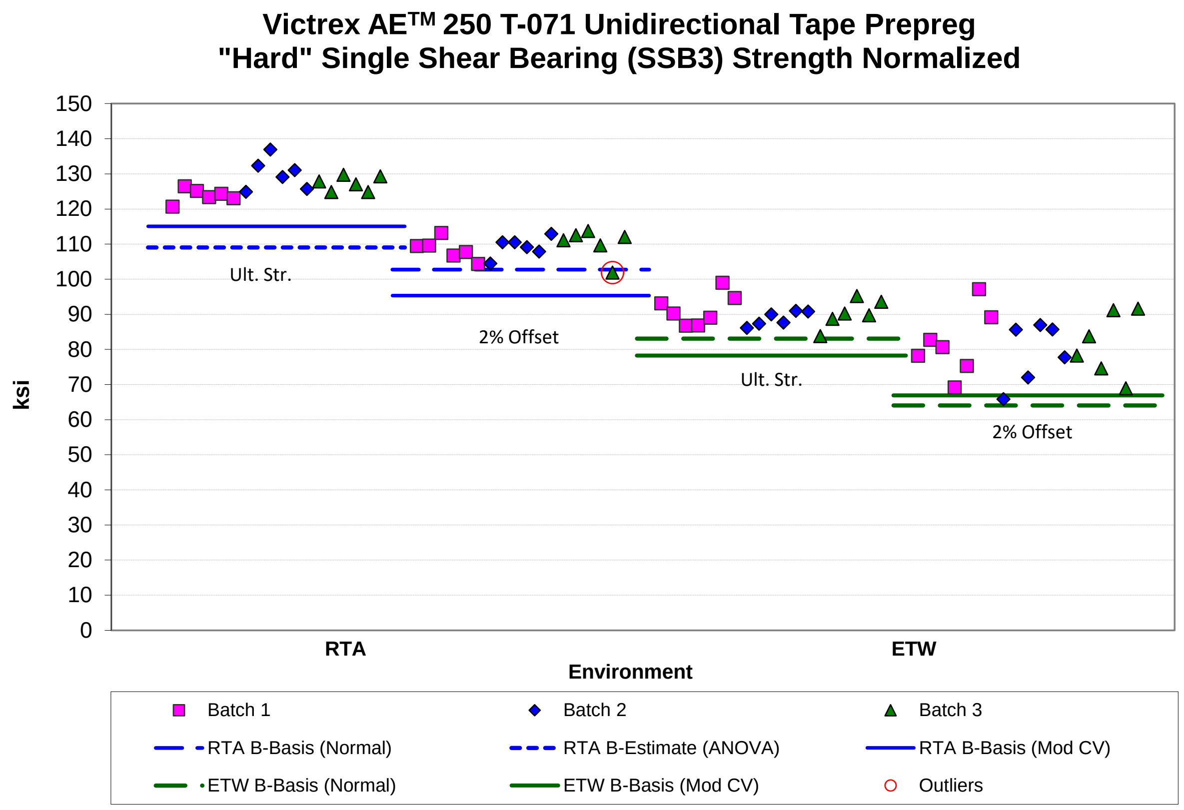

Figure 4-32: Batch plot for SSB3 strength normalized

Single Shear Bearing (SSB3) Strength Basis Values and Statistics								
	2% Offset Strength				Ultimate Strength			
	Normalized		As-measured		Normalized		As-measured	
Env	RTA	ETW	RTA	ETW	RTA	ETW	RTA	ETW
Mean	109.3	80.77	111.4	83.10	127.0	90.19	129.5	92.80
Stdev	3.308	8.583	3.504	8.983	3.878	3.662	4.133	4.121
CV	3.027	10.63	3.146	10.81	3.053	4.060	3.193	4.441
Modified CV	6.000	10.63	6.000	10.81	6.000	6.030	6.000	6.220
Min	101.9	65.87	104.1	67.69	120.7	83.82	122.4	86.39
Max	113.7	97.18	115.6	100.8	136.9	98.96	138.8	102.6
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	19	18	19	18	19	18	19
Basis Values and Estimates								
B-basis Value	102.8	64.04	104.5	65.59		83.06		84.77
B-estimate					109.1		111.9	
A-estimate	98.13	52.16	99.56	53.16	96.24	77.99	99.36	79.07
Method	Normal	Normal	Normal	Normal	ANOVA	Normal	ANOVA	Normal
Modified CV Basis Values and Estimates								
B-basis Value	95.36	66.90	96.93	68.73	115.1	78.28	117.1	80.48
A-estimate	85.90	57.43	87.12	58.90	106.9	70.13	108.7	72.05
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-46: Statistics and Basis Values for SSB3 Strength data

4.32 Quasi Isotropic Compression After Impact 1 (CAI1)

Basis values are not computed for this property. Data from only one batch of material is available. However the summary statistics are presented in Table 4-47 and the data are displayed graphically in Figure 4-33. The lowest value in the RTA condition was a statistical outlier.

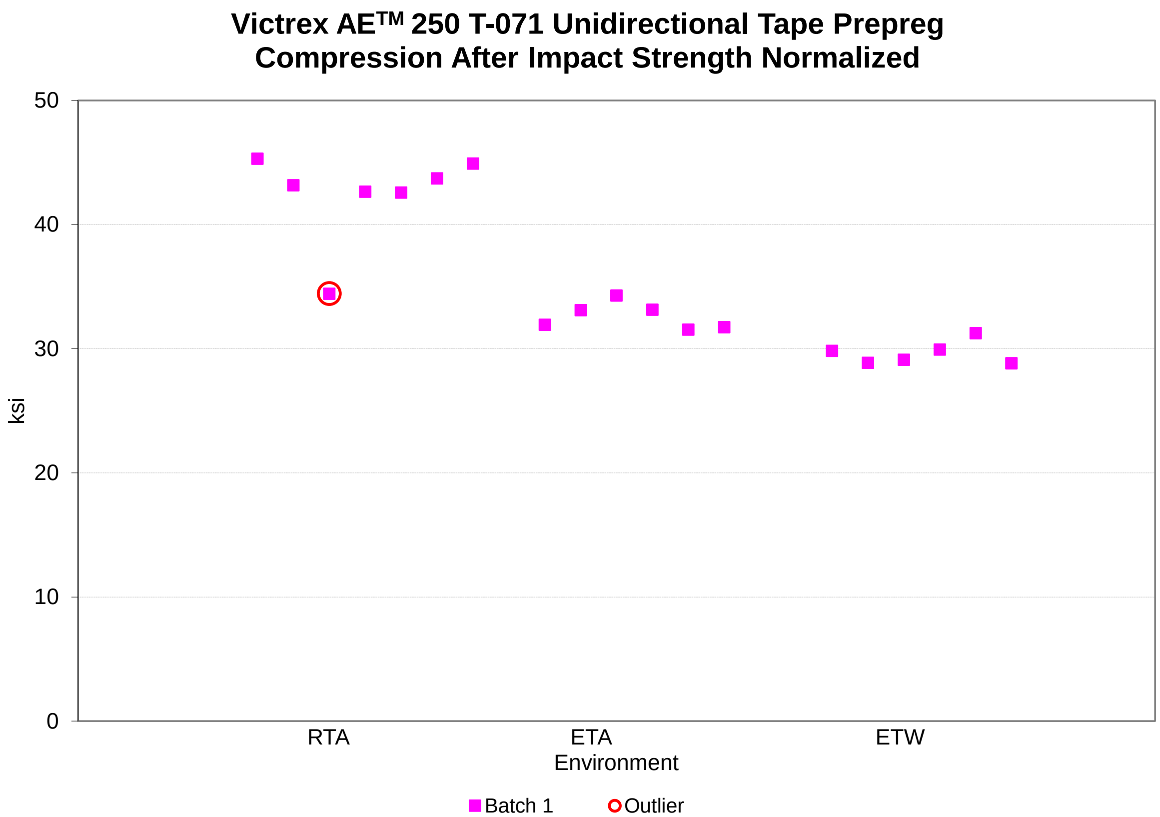

Figure 4-33: Plot for Compression After Impact strength normalized

Compression After Impact Strength (ksi)						
	Normalized			As-measured		
Env	ETW	RTA	ETW	RTA	ETA	ETW
Mean	42.40	32.63	29.63	42.29	32.86	29.68
Stdev	3.666	1.070	0.9236	3.566	1.011	0.9047
CV	8.647	3.278	3.117	8.430	3.077	3.048
Modified CV	8.647	8.000	8.000	8.430	8.000	8.000
Min	34.44	31.54	28.82	34.58	31.86	28.78
Max	45.31	34.29	31.25	45.07	34.52	31.20
No. Batches	1	1	1	1	1	1
No. Spec.	7	6	6	7	6	6

Table 4-47: Statistics for Compression After Impact Strength data

4.33 Interlaminar Tension and Curved Beam Strength (ILT and CBS)

The ILT and CBS data is not normalized. Basis values are not computed for these properties. Data from only one batch of material is available. However the summary statistics are presented in Table 4-48 and the data are displayed graphically in Figure 4-34. There were no statistical outliers.

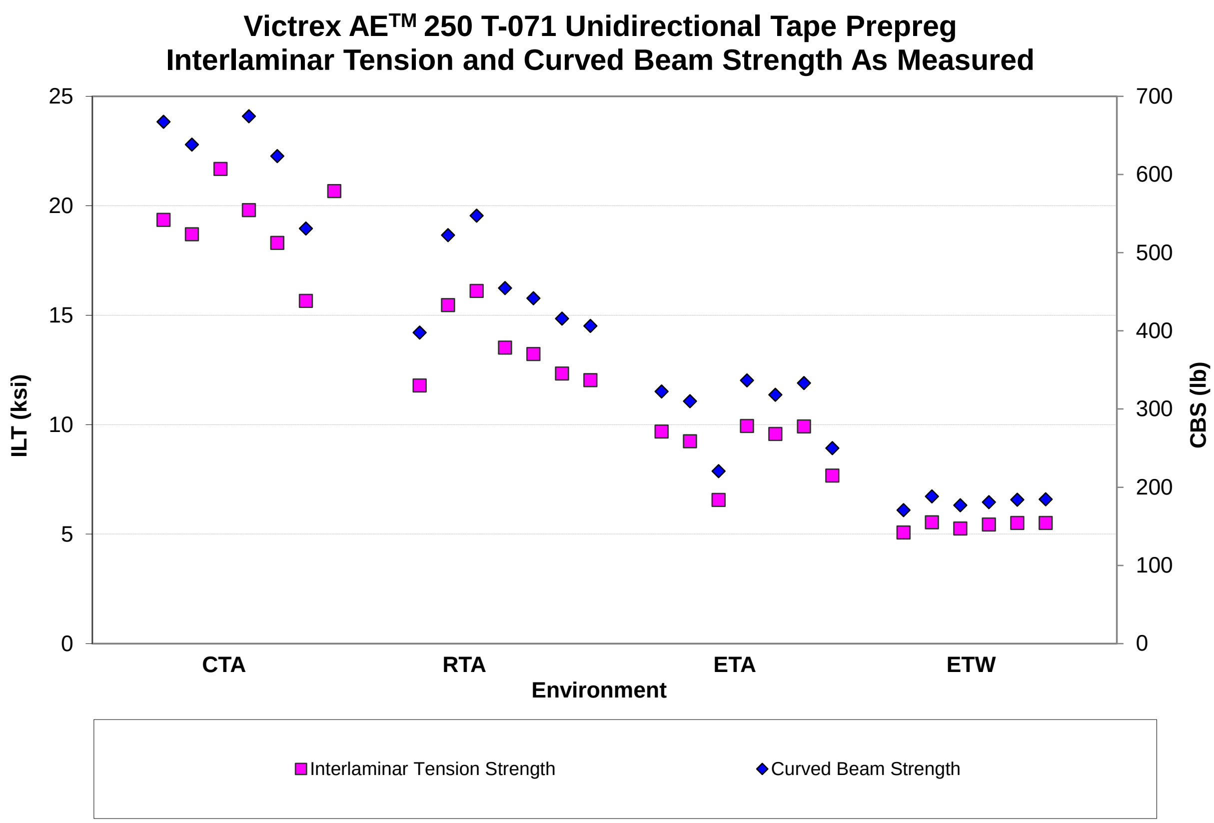

Figure 4-34: Plot for Interlaminar Tension (ILT) strength and Curved Beam Strength as-measured

Interlaminar Tension (ILT) Strength								
	Interlaminar Tension Strength [ksi]				Curved Beam Strength [lb]			
Env	CTA	RTA	ETA	ETW	CTA	RTA	ETA	ETW
Mean	19.16	13.50	8.944	5.387	652.3	455.1	298.8	180.9
Stdev	1.930	1.692	1.307	0.1847	64.47	58.31	45.10	6.226
CV	10.07	12.54	14.62	3.428	9.884	12.81	15.10	3.441
Modified CV	10.07	12.54	14.62	8.000	9.884	12.81	15.10	8.000
Min	15.65	11.79	6.566	5.076	531.0	397.8	220.6	170.8
Max	21.68	16.11	9.943	5.538	731.0	547.2	336.7	188.2
No. Batches	1	1	1	1	1	1	1	1
No. Spec.	7	7	7	7	7	7	7	7

Table 4-48: Statistics for ILT and CBS Strength 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 are typically more extreme and more likely to have a specific cause and be removed from the dataset than other outliers. Specimens that are outliers only for the batch, but not the condition and specimens that are identified as outliers only for the normalized data or the as-measured data but not both, are typical of normal random variation.

All outliers identified were investigated to determine if a cause could be found. Outliers with causes were removed from the dataset and the remaining specimens were analyzed for this report. Information about specimens that were removed from the dataset along with the cause for removal is documented in the material property data report, NCAMP Test Report CAM-RP-2021-025.

Outliers for which no causes could be identified are listed in Table 5-1. These outliers were included in the analysis for their respective test properties.

Test	Condition	Batch	Specimen Number	Normalized Strength	Strength As-measured	High/ Low	Batch Outlier	Condition Outlier
TC	CTA	1	TC-A-C1-CTA-1	NA	32.96	Low	No	Yes
TC	CTA	2	TC-B-C2-CTA-2	NA	36.98	Low	Yes	No
UNC0	RTA	2	UNC0-B-C2-RTA-1	Not an outlier	114.1	High	Yes	No
Backout LC					212.2			
UNC0	RTA	3	UNC0-C-C1-RTA-2	Not an outlier	100.3	Low	No	Yes
Backout LC					186.6			
UNC0	ETW	3	UNC0-C-C1-ETW-2	72.83	70.98	Low	Yes	Yes - as meas No-norm
Backout LC				143.6	140.0			
IPS - 5% Strain	ETA	1	IPS-A-C1-ETA-2	NA	4.038	Low	One Batch	
VNS - 0.2% Offset	ETW	3	VNS-C-C2-ETW-2	NA	2.479	High	Yes	Yes
VNS - 0.2% Offset	ETW	2	VNS-B-C1-ETW-3	NA	1.292	Low	Yes	No
VNS - 5% Strain					3.324			
VNS - 5% Strain	CTA	2	VNS-B-C2-CTA-1	NA	13.87	High	Yes	Yes
VNS1 - Ult. Str.	RTA	1	VNS1-A-C1-RTA-3	NA	50.19	High	Yes	No
CAI Strength	RTA	1	CAI1-A-C1-RTA-3	34.44	34.58	Low	One Batch	
FHC1	RTA	2	FHC1-B-C2-RTA-3	69.60	69.35	Low	Yes	No
FHC2	RTA	2	FHC2-B-C2-RTA-3	55.17	55.84	Low	Yes	No
FHC2	RTA	1	FHC2-A-C1-RTA-1	52.60	Not an outlier	Low	Yes	No
FHC3	ETW	3	FHC3-C-C1-ETW-2	57.93	58.75	Low	Yes	No
FHT1	RTA	2	FHT1-B-C2-RTA-3	Not an outlier	58.88	Low	Yes	No
FHT3	RTA	3	FHT3-C-C1-RTA-1	79.58	81.29	High	Yes	No
OHC1	ETW	3	OHC1-C-C1-ETW-3	33.69	34.39	High	Yes	Yes - as meas No-norm
OHC2	ETW	2	OHC2-B-C2-ETW-3	27.26	27.60	Low	Yes	No
OHT2	CTA	1	OHT1-A-C2-CTA-2	Not an outlier	48.96	High	Yes	No
OHT3	ETW	2	OHT3-B-C1-ETW-2	70.02	72.75	Low	Yes	No
UNT1	CTA	1	UNT1-A-C1-CTA-1	109.4	106.3	Low	Yes	No
UNT1	ETW	1	UNT1-A-C1-ETW-3	Not an outlier	95.42	Low	No	Yes
UNT3	RTA	2	UNT3-B-C1-RTA-2	155.0	Not an outlier	Low	Yes	No
UNC1	ETA	1	UNC1-A-C2-ETA-1	61.62	Not an outlier	Low	One Batch	
SSB1 - 2% Offset	ETW	1	SSB1-A-C1-ETW-2	99.26	97.88	High	Yes - as meas No-norm	Yes
SSB1 - 2% Offset	ETW	3	SSB1-C-C2-ETW-3	94.34	95.26	High	Yes	No
SSB1 - Ult. Str.				102.8	103.8			
SSB2 - Ult. Str.	RTA	1	SSB2-A-C1-RTA-3	128.4	128.5	Low	Yes	No
SSB2 - 2% Offset	RTA	3	SSB2-C-C2-RTA-1	114.9	Not an outlier	High	Yes	No
SSB3 - 2% Offset	RTA	3	SSB3-C-C2-RTA-2	101.9	104.7	Low	Yes	No
SSB3 - Initial Peak	ETW	3	SSB3-C-C2-ETW-1	NA	97.40	High	No	Yes

Table 5-1: List of Outliers

6. References

1. Snedecor, G.W. and Cochran, W.G., *Statistical Methods*, 7th ed., The Iowa State University Press, 1980, pp. 252-253.
2. Stefansky, W., "Rejecting Outliers in Factorial Designs," *Technometrics*, Vol. 14, 1972, pp. 469-479.
3. Scholz, F.W. and Stephens, M.A., "K-Sample Anderson-Darling Tests of Fit," *Journal of the American Statistical Association*, Vol. 82, 1987, pp. 918-924.
4. Lehmann, E.L., *Testing Statistical Hypotheses*, John Wiley & Sons, 1959, pp. 274-275.
5. Levene, H., "Robust Tests for Equality of Variances," in *Contributions to Probability and Statistics*, ed. I. Olkin, Palo, Alto, CA: Stanford University Press, 1960.
6. Lawless, J.F., *Statistical Models and Methods for Lifetime Data*, John Wiley & Sons, 1982, pp. 150, 452-460.
7. *Metallic Materials and Elements for Aerospace Vehicle Structures*, MIL-HDBK-5E, Naval Publications and Forms Center, Philadelphia, Pennsylvania, 1 June 1987, pp. 9-166,9-167.
8. Hanson, D.L. and Koopmans, L.H., "Tolerance Limits for the Class of Distribution with Increasing Hazard Rates," *Annals of Math. Stat.*, Vol 35, 1964, pp. 1561-1570.
9. Vangel, M.G., "One-Sided Nonparametric Tolerance Limits," *Communications in Statistics: Simulation and Computation*, Vol. 23, 1994, p. 1137.
10. Vangel, M.G., "New Methods for One-Sided Tolerance Limits for a One-Way Balanced Random Effects ANOVA Model," *Technometrics*, Vol 34, 1992, pp. 176-185.
11. Odeh, R.E. and Owen, D.B., *Tables of Normal Tolerance Limits, Sampling Plans and Screening*, Marcel Dekker, 1980.
12. Tomblin, John and Seneviratne, Waruna, *Laminate Statistical Allowable Generation for Fiber-Reinforced Composites Material: Lamina Variability Method*, U.S. Department of Transportation, Federal Aviation Administration, May 2006.
13. Tomblin, John, Ng, Yeow and Raju, K. Suresh, *Material Qualification and Equivalency for Polymer Matrix Composite Material Systems: Updated Procedure*, U.S. Department of Transportation, Federal Aviation Administration, September 2003.
14. CMH-17 Rev G, Volume 1, 2012. SAE International, 400 Commonwealth Drive, Warrendale, PA 15096