Solvay Cytec Cycom EP 2202 T650 3K-PW Fabric 38% RC Material Allowables Statistical Analysis Report

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1. Introduction

This report contains statistical analysis of the Solvay Cytec Cycom EP 2202 T650 3K-PW Fabric 38% RC material property data published in NCAMP Test Report CAM-RP-2014-022 N/C. The lamina and laminate material property data have been generated with NCAMP oversight in accordance with NSP 100 NCAMP Standard Operating Procedures; the test panels and test specimens have been inspected by NCAMP Authorized Inspection Representatives (AIR) and the testing has been witnessed by NCAMP Authorized Engineering Representatives (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 220/2 Rev Initial Release dated March 06, 2012. The qualification test panels were cured in accordance with NCAMP Process Specification NPS 82202 Revision - dated January 26, 2012 Baseline Cure Cycle “C”. The NCAMP Test Plan NTP 2202Q1 was used for this qualification program.

Basis numbers are labeled as ‘values’ when the data meets all the requirements of working draft CMH-17 Rev G. 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 (working draft 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 working draft CMH-17 Rev G. 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 working draft CMH-17 Rev G are adequate for the given program.

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 220/2. NMS 220/2 has additional requirements that are listed in its prepreg process control document (PCD), fiber specification, fiber PCD, and other raw material specifications and PCDs which impose essential quality controls on the raw materials and raw material manufacturing equipment and processes. *Aircraft companies and certifying agencies should assume that the material property data published in this report is not applicable when the material is not procured to NCAMP Material Specification NMS 220/2.* NMS 220/2 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
Warp Compression	WC
Warp Tension	WT
Fill Compression	FC
Fill Tension	FT
In-Plane Shear	IPS
Short Beam Strength	SBS
Unnotched Tension	UNT
Unnotched Compression	UNC
Laminate Short Beam Strength	SBS1
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
Warp Compression Strength	F_1^{cu}
Warp Compression Modulus	E_1^c
Warp Compression Poisson's Ratio	ν_{12}^c
Warp Tension Strength	F_1^{tu}
Warp Tension Modulus	E_1^t
Warp Tension Poisson's Ratio	ν_{12}^t
Fill Compression Strength	F_2^{cu}
Fill Compression Modulus	E_2^c
Fill Compression Poisson's Ratio	ν_{21}^c
Fill Tension Strength	F_2^{tu}
Fill Tension Modulus	E_2^t
In Plane Shear Strength at 5% strain	$F_{12}^{s5\%}$
In Plane Shear Strength at 0.2% offset	$F_{12}^{s0.2\%}$
In Plane Shear Modulus	G_{12}^s

Table 1-2: Test Property Symbols

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

Table 1-3: Environmental Conditions Abbreviations

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 40/20/40 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-2014-022.

1.2 Pooling Across Environments

When pooling across environments was allowable, the pooled co-efficient of variation was used. ASAP (**A**GATE **S**tatistical **A**nalysis **P**rogram) 2008 version 1.0 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 using Stat-17 version 5.

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 working draft CMH-17 Rev G. 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 AGATE Statistical Analysis Program (ASAP) when pooling across environments is permissible according to working draft CMH-17 Rev G guidelines. If pooling is not permissible, a single point analysis using STAT-17 is performed for each environmental condition with sufficient test results. If the data does not meet working draft CMH-17 Rev G 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 ASAP Statistical Formulas and Computations

This section contains the details of the specific formulas ASAP 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.: $$S_p = \sqrt{\frac{\sum_{i=1}^{k}\left(n_i - 1\right)S_i^2}{\sum_{i=1}^{k}\left(n_i - 1\right)}}$$ **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.

$$\textbf{Pooled Coefficient of Variation} = \frac{S_p}{1} = S_p \qquad \textbf{Equation 5}$$

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.

$$\textbf{Basis Values:} \quad \begin{aligned} A-basis &= \bar{X} - K_a S \\ B-basis &= \bar{X} - K_b S \end{aligned} \qquad \textbf{Equation 6}$$

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 working draft CMH-17 Rev G. The approximation formulas are given below:

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

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

Where

r = the number of environments being pooled together

n_j= number of data values for environment j

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

$$f = N - r$$

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

$$b_B(f) = \frac{1.1372}{\sqrt{f}} - \frac{0.49162}{f} + \frac{0.18612}{f\sqrt{f}}$$ **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 = $$CV^* = \begin{cases} .06 & \text{if } CV < .04 \\ \dfrac{CV}{2} + .04 & \text{if } .04 \le CV < .08 \\ CV & \text{if } CV \ge .08 \end{cases}$$ **Equation 14**

This is converted to percent by multiplying by 100%.

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

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

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

$$S_p^* = \sqrt{\frac{\sum_{i=1}^{k}\left((n_i - 1)\left(CV_i^* \cdot \bar{X}_i\right)^2\right)}{\sum_{i=1}^{k}(n_i - 1)}}$$ **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 working draft CMH-17 Rev G.

$$MNR = \frac{\max\limits_{all\ i}\left|X_i - \overline{X}\right|}{S},\ i = 1\ldots n \qquad \textbf{Equation 23}$$

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

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 $z_{(1)}, z_{(2)}, \dots z_{(L)}$, 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:

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

Where

n_i = the number of test specimens in each batch

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

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:

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

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:

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

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. ASAP 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.

2.2 STAT-17

This section contains the details of the specific formulas STAT-17 uses in its computations.

The basic descriptive statistics, the maximum normed residual (MNR) test for outliers, and the Anderson Darling K-sample test for batch variability are the same as with ASAP – see sections 2.1.1, 2.1.3.1, and 2.1.5.

Outliers must be dispositioned before checking any other test results. The results of the Anderson Darling k-Sample (ADK) Test for batch equivalency must be checked. If the data passes the ADK test, then the appropriate distribution is determined. If it does not pass the ADK test, then the ANOVA procedure is the only approach remaining that will result in basis values that meet the requirements of working draft CMH-17 Rev G.

2.2.1 Distribution Tests

In addition to testing for normality using the Anderson-Darling test (see 2.1.7); Stat17 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 $x_{(1)}, ..., x_{(n)}$.

2.2.2 Computing Normal Distribution Basis Values

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

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

Table 2-1: K factors for normal distribution

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

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

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

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

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

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

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

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

2.2.2.3 Two-parameter Weibull Distribution

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

$$e^{-\left(a/\alpha\right)^{\beta}} - e^{-\left(b/\alpha\right)^{\beta}}$$ **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 2.2.2.3.1). Calculations specific to the goodness-of-fit test for the Weibull distribution are provided in section 2.2.2.3.2.

2.2.2.3.1 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**

Stat17 solves these equations numerically for $\hat{\beta}$ and $\hat{\alpha}$ in order to compute basis values.

2.2.2.3.2 Goodness-of-fit test for the Weibull distribution

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

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

The Anderson-Darling test statistic is

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

and the observed significance level is

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

where

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

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

2.2.2.3.3 Basis value calculations for the Weibull distribution

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

$$B = \hat{q} e^{\left(-V / \hat{\beta} \sqrt{n} \right)}$$ **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 2-2. when the sample size is less than 16. For sample sizes of 16 or larger, a numerical approximation to the V values is given in the two equations immediately below.

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

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

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

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

Table 2-2: Weibull Distribution Basis Value Factors

2.2.2.4 Lognormal Distribution

A probability distribution for which the probability that an observation selected at random from this population falls between a and b $\left(0 < a < b < \infty\right)$ 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.

2.2.2.4.1 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 the linked equation above with linked equation below:

$$z_{(i)} = \frac{\ln\left(x_{(i)}\right) - \bar{x}_L}{s_L}, \quad \text{for } i = 1, \ldots, n$$ **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 the linked equation above and the observed significance level (OSL) is computed using the linked equation 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.

2.2.2.4.2 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.

2.2.3 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.

2.2.3.1 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:

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

For A-Basis values:

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

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_Bth lowest observation in the data set, while the A-basis values are the r_Ath 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.

2.2.3.2 Non-parametric Basis Values for small samples

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

$$B = x_{(r)} \left[\frac{x_{(1)}}{x_{(r)}} \right]^k \qquad \textbf{Equation 50}$$

The A-basis value is:

$$A = x_{(n)} \left[\frac{x_{(1)}}{x_{(n)}} \right]^k \qquad \textbf{Equation 51}$$

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 2-3. 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 2-4. For an A-basis value that meets all the requirements of working draft CMH-17 Rev G, 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 2-3: 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 2-4: A-Basis Hanson-Koopmans Table

2.2.4 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.

2.2.4.1 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 2.2.2 using a sample size of n (denoted k_0) and a sample size of k (denoted k_1). Whether this value is an A- or B-basis value depends only on whether k_0 and k_1 are computed for A or B-basis values.

Denote the ratio of mean squares by

$$u = \frac{MSB}{MSE} \qquad \textbf{Equation 59}$$

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

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

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.

2.3 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**

2.4 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 2-5

		N1													
		2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
N1+N2-2	**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 2-5: B-Basis factors for small datasets using variability of corresponding large dataset

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 working draft CMH-17 Rev G. 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 working draft CMH-17 Rev G 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 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 working draft CMH-17 Rev G 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 working draft CMH-17 Rev G 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 STAT17 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 CTD-RTD-ETW trend of the basis values are not consistent with the CTD-RTD-ETW trend of the average values), then the B-basis values will not be recommended.

NCAMP Recommended B-basis Values for
Cytec Cycom EP 2202 T650 3K-PW Fabric 38% 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 Tests

Environment	Statistic	WT	WC	FT	FC	SBS*	IPS* 0.2% Offset	IPS* 5% Strain
CTD (-65 F)	B-basis	103.837	105.578	NA:A	NA:A	12.165	8.223	15.719
	Mean	117.211	118.311	117.425	121.409	13.735	9.285	17.748
	CV	6.000	6.629	6.538	5.359	6.000	6.000	6.000
RTD (70 F)	B-basis	113.976	92.005	107.754	93.646	12.282	6.179	11.823
	Mean	127.349	104.851	122.865	105.150	12.783	6.977	13.349
	CV	6.000	6.000	6.580	6.000	2.871	6.000	6.000
ETW (180 F)	B-basis	116.824	72.373	NA:A	NA:A	7.724	3.850	7.164
	Mean	130.259	81.716	131.598	78.835	8.710	4.341	8.079
	CV	6.506	6.000	7.826	7.709	6.000	6.000	6.000

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 Stat17 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 Cytec Cycom EP 2202 T650 3K-PW Fabric 38% 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

Laminate Strength Tests

Lay-up	ENV	Statistic	OHT	OHC	FHT	FHC	UNT	UNC	SSB 2% Offset	SSB Ult.	SBS1*
25/50/25	CTD (-65 F)	B-basis	36.637		38.716		81.128				
		Mean	41.106		43.419		90.783				
		CV	6.000		6.000		6.000				
	RTD (70 F)	B-basis	37.962	41.007	40.070	NA:I	83.407	76.004	99.230	116.758	11.256
		Mean	42.431	45.332	44.772	74.266	93.063	84.041	110.604	129.422	12.692
		CV	6.000	6.000	6.000	8.778	6.000	6.024	6.081	6.000	6.000
	ETW (180 F)	B-basis	41.072	31.000	42.964	NA:I	85.588	53.405	82.917	95.989	7.197
		Mean	45.541	28.028	47.667	60.786	95.243	61.441	94.246	108.602	8.126
		CV	6.000	6.000	6.000	3.513	6.000	6.393	6.497	6.000	6.000
10/80/10	CTD (-65 F)	B-basis	40.312		41.998		NA:I				
		Mean	44.638		47.042		59.714				
		CV	6.000		6.000		1.856				
	RTD (70 F)	B-basis	40.447	37.542	42.706	NA:I	NA:I	54.072	96.157	113.680	
		Mean	44.774	41.486	47.750	54.699	57.377	59.541	106.607	125.921	
		CV	6.000	6.000	6.000	3.874	2.224	6.000	6.000	6.000	
	ETW (180 F)	B-basis	30.560	28.070	33.469	NA:I	NA:I	36.189	78.532	90.724	
		Mean	34.886	32.014	37.790	42.951	51.631	41.658	88.982	102.965	
		CV	6.000	6.000	6.000	4.526	2.680	6.000	6.000	6.000	
40/20/40	CTD (-65 F)	B-basis	42.448		43.470		91.521				
		Mean	48.321		49.163		103.406				
		CV	6.378		6.542		6.000				
	RTD (70 F)	B-basis	44.619	41.595	45.816	58.641	90.080	79.985	88.866	107.408	
		Mean	50.492	46.052	51.510	66.749	102.020	88.676	88.676	118.984	
		CV	6.558	6.000	6.523	7.414	7.078	6.278	6.278	6.000	
	ETW (180 F)	B-basis	49.306	32.776	49.283	53.963	107.174	60.504	60.504	85.904	
		Mean	55.179	37.233	54.977	62.184	119.059	69.230	69.230	97.480	
		CV	6.000	6.000	6.000	6.457	6.000	6.000	6.000	6.000	

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 Stat17 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

Prepreg Material: Cytec Cycom EP 2202 T650 3K-PW Fabric 38% RC
Material Specification: NMS 220/2
Process Specification: NPS 82202

Cytec Cycom EP 2202 T650 3K-PW Fabric 38% RC Lamina Properties Summary

Fiber: T650 3K PW **Resin: Cytec Cycom EP 2202**

Tg(dry): 365.41°F **Tg(wet):** 287.44°F **Tg METHOD:** ASTM D7028

Date of fiber manufacture	May 2012 - May 2013	**Date of testing**	Jan 2014 - Aug 2014
Date of resin manufacture	July 2012 - July 2013	**Date of data submittal**	20-Jan-15
Date of prepreg manufacture	Oct 2012 - July 2013	**Date of analysis**	Feb-15
Date of composite manufacture	May 2013 - Sept 2013		

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY
Data reported: As-measured followed by normalized values in parentheses, normalizing tply: 0.0081 in
Values shown in shaded boxes do not meet CMH-17G requirements and are estimates only
These values may not be used for certification unless specifically allowed by the certifying agency

	CTD			RTD			ETD			ETW		
	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}	109.808	104.899	118.458	102.249	115.189	128.748				118.349	117.744	131.366
(ksi)	(109.201)	(103.837)	(117.211)	(108.197)	(113.976)	(127.349)				(117.684)	(116.824)	(130.259)
E_1^t			9.349			9.232						9.346
(Msi)			(9.250)			(9.132)						(9.254)
ν_{12}^t			0.062			0.053						0.053
F_2^{tu}	82.055	101.349	118.352	112.649	109.051	123.999				90.914	113.287	132.776
(ksi)	(84.520)	(101.160)	(117.425)	(111.020)	(107.754)	(122.865)				(92.182)	(112.456)	(131.598)
E_2^t			9.590			9.344						9.472
(Msi)			(9.514)			(9.249)						(9.389)
F_1^{cu}	106.172	105.677	118.598	97.253	92.382	105.418	88.723	76.337	96.235	76.285	72.465	81.820
(ksi)	(106.458)	(105.578)	(118.311)	(97.443)	(92.005)	(104.851)	(88.501)	(75.981)	(95.787)	(76.539)	(72.373)	(81.716)
E_1^c			8.676			8.587			8.554			8.750
(Msi)			(8.656)			(8.538)			(8.530)			(8.727)
F_2^{cu}	86.964	107.110	122.259	99.514	94.347	105.937	84.679	73.264	94.019	50.284	67.717	79.342
(ksi)	(84.259)	(106.109)	(121.409)	(99.289)	(93.646)	(105.150)	82.674	73.421	(94.221)	(47.073)	67.035	(78.835)
E_2^c			8.592			8.595			8.453			8.681
(Msi)			(8.533)			(8.525)			(8.467)			(8.631)
$F_{12}^{s0.2\%}$ (ksi)	8.309	8.223	9.285	6.348	6.179	6.977				3.743	3.850	4.341
$F_{12}^{s5\%}$ (ksi)	15.384	15.719	17.748	10.680	11.823	13.349				6.596	7.164	8.079
G_{12}^s (Msi)			0.747			0.646						0.457
SBS (ksi)	12.915	12.165	13.735	12.282	NA	12.783	9.762	8.067	10.353	7.408	7.724	8.710

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

Prepreg Material: Cytec Cycom EP 2202 T650 3K-PW Fabric 38% RC
Material Specification: NMS 220/2
Process Specification: NPS 82202

Cytec Cycom EP 2202 T650 3K-PW Fabric 38% RC Laminate Properties Summary

Fiber: T650 3K PW **Resin: Cytec Cycom EP 2202**
Tg(dry): 365.41°F **Tg(wet):** 287.44°F **Tg METHOD:** ASTM D7028

Date of fiber manufacture	May 2012 - May 2013	**Date of testing**	Jan 2014 - Aug 2014
Date of resin manufacture	July 2012 - July 2013	**Date of data submittal**	20-Jan-15
Date of prepreg manufacture	Oct 2012 - July 2013	**Date of analysis**	Feb-15
Date of composite manufacture	May 2013 - Sept 2013		

LAMINATE MECHANICAL PROPERTY B-BASIS SUMMARY
Data reported as normalized used a normalizing t_{ply} of 0.0081 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	Layup:		Quasi Isotropic 25/50/25			"Soft" 10/80/10			"Hard" 40/20/40		
		Test Condition	Unit	B-value	Mod. CV B-value	Mean	B-value	Mod. CV B-value	Mean	B-value	Mod. CV B-value	Mean
OHT (normalized)	Strength	CTD	ksi	38.721	36.637	41.106	36.853	40.312	44.638	36.663	42.448	48.321
		RTD	ksi	40.047	37.962	42.431	35.117	40.447	44.774	46.521	44.619	50.492
		ETW	ksi	43.156	41.072	45.541	31.119	30.560	34.886	51.208	49.306	55.179
OHC (normalized)	Strength	RTD	ksi	43.068	41.007	45.332	39.610	37.542	41.486	44.231	41.595	46.052
		ETW	ksi	33.606	31.000	35.325	30.993	28.070	32.014	35.412	32.776	37.233
UNT (normalized)	Strength	CTD	ksi	85.425	81.128	90.783	57.374	52.156	59.714	81.053	91.521	103.406
	Modulus		msi	---	---	6.714	---	---	4.427	---	---	8.358
	Strength	RTD	ksi	86.326	83.407	93.063	54.682	50.115	57.377	89.924	90.080	102.020
	Modulus		msi	---	---	6.494	---	---	4.217	---	---	8.209
	Strength	ETW	ksi	91.908	85.588	95.243	27.919	45.096	51.631	112.596	107.174	119.059
	Modulus		msi	---	---	6.308	---	---	3.991	---	---	8.150
UNC (normalized)	Strength	RTD	ksi	78.401	76.004	84.041	50.046	54.072	59.541	81.058	79.985	88.676
	Modulus		msi	---	---	6.065	---	---	4.100	---	---	7.659
	Strength	ETW	ksi	55.802	53.405	61.441	39.540	36.189	41.658	65.084	60.504	69.230
	Modulus		msi	---	---	5.955	---	---	3.843	---	---	7.683
SBS1 (as-measured)	Strength	RTD	ksi	11.559	11.256	12.692	---	---	---	---	---	---
		ETW	ksi	7.370	7.197	8.126	---	---	---	---	---	---
FHT (normalized)	Strength	CTD	ksi	41.154	38.716	43.419	42.632	41.998	47.042	44.401	43.470	49.163
		RTD	ksi	42.508	40.070	44.772	44.483	42.706	47.750	38.595	45.816	51.510
		ETW	ksi	45.402	42.964	47.667	36.056	33.469	37.790	50.857	49.283	54.977
FHC (normalized)	Strength	RTD	ksi	61.003	NA	74.266	46.962	NA	54.699	58.067	58.641	66.749
		ETW	ksi	56.509	53.484	60.786	38.846	37.276	42.951	49.114	53.963	62.184
Single Shear Bearing (normalized)	Initial Peak Strength	RTD	ksi	92.124	87.748	109.719	NA	NA	109.096	93.173	79.129	99.545
		ETW	ksi	78.715	70.387	93.821	NA	NA	90.535	72.622	69.237	84.414
	2% Offset Strength	RTD	ksi	102.360	99.230	110.604	95.490	96.157	106.607	87.087	88.866	99.087
		ETW	ksi	86.035	82.917	94.246	82.597	78.532	88.982	76.119	74.259	84.480
	Ultimate Strength	RTD	ksi	122.760	116.758	129.422	109.398	113.680	125.921	112.508	107.408	118.984
		ETW	ksi	101.966	95.989	108.602	98.258	90.724	102.965	91.004	85.904	97.480
CAI (normalized)	Strength	RTD	ksi	28.461	NA	41.582	---	---	---	---	---	---
ILT (as-measured)	Strength	CTD	ksi	---	---	12.115	---	---	---	---	---	---
		RTD	ksi	---	---	7.603	---	---	---	---	---	---
		ETW	ksi	---	---	10.803	---	---	---	---	---	---
CBS (as-measured)	Strength	CTD	lbs	---	---	453.902	---	---	---	---	---	---
		RTD	lbs	---	---	292.539	---	---	---	---	---	---
		ETW	lbs	---	---	408.663	---	---	---	---	---	---

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

4. Individual Test Summaries, 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 of working draft CMH-17 Rev G section 8.3.10.

4.1 Warp Tension (WT)

Warp Tension data is normalized, so both normalized and as-measured data is provided. The RTD 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. When the RTD datasets were transformed according to the assumptions of the modified CV method, both the normalized and as-measured datasets passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable for computing the modified CV basis values.

There was one outlier. The lowest value in batch one of the as-measured CTD condition dataset was an outlier. It was an outlier only for batch one, not for the CTD condition and it was an outlier only in the as-measured dataset, not in the normalized dataset. It was retained for this analysis.

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

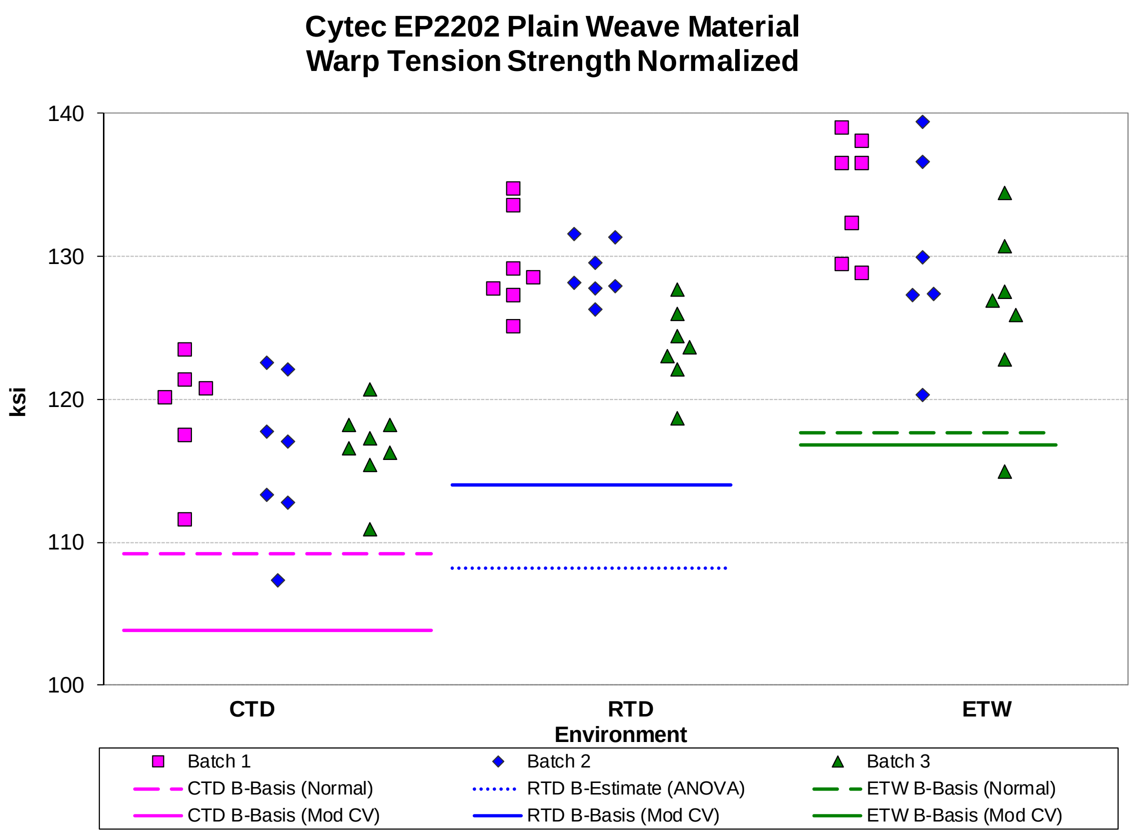

Figure 4-1: Batch plot for WT normalized strength

Warp Tension Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	117.211	127.349	130.259	118.458	128.748	131.366
Stdev	4.205	3.805	6.530	4.541	4.471	6.759
CV	3.587	2.988	5.013	3.833	3.473	5.145
Mod CV	6.000	6.000	6.506	6.000	6.000	6.573
Min	107.314	118.712	114.958	108.610	119.367	115.784
Max	123.521	134.741	139.436	125.661	136.236	141.671
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	20	21	21	20
Basis Values and/or Estimates						
B-basis Value	109.201		117.684	109.808		118.349
B-Estimate		108.197			102.249	
A-Estimate	103.490	94.526	108.736	103.640	83.332	109.087
Method	Normal	ANOVA	Normal	Normal	ANOVA	Normal
Modified CV Basis Values and/or Estimates						
B-basis Value	103.837	113.976	116.824	104.899	115.189	117.744
A-Estimate	94.803	104.942	107.802	95.739	106.030	108.596
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-1: Statistics and Basis values for WT Strength Data

Warp Tension Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	9.250	9.132	9.254	9.349	9.232	9.346
Stdev	0.113	0.109	0.142	0.156	0.153	0.145
CV	1.223	1.198	1.530	1.668	1.656	1.547
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	9.052	8.972	9.054	9.030	9.002	9.119
Max	9.543	9.359	9.541	9.670	9.551	9.618
No. Batches	3	3	3	3	3	3
No. Spec.	21	22	30	21	22	30

Table 4-2: Statistics from WT Modulus Data

4.2 Fill Tension (FT)

Fill Tension data is normalized, so both normalized and as-measured data is provided. The CTD and 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. When these datasets were transformed according to the assumptions of the modified CV method, none of them passed the ADK test, so the modified CV basis values could not provided. Estimates of modified CV basis values are provided for the CTD and ETW conditions. They are estimates due to the override of the ADK test for each of those datasets.

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

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

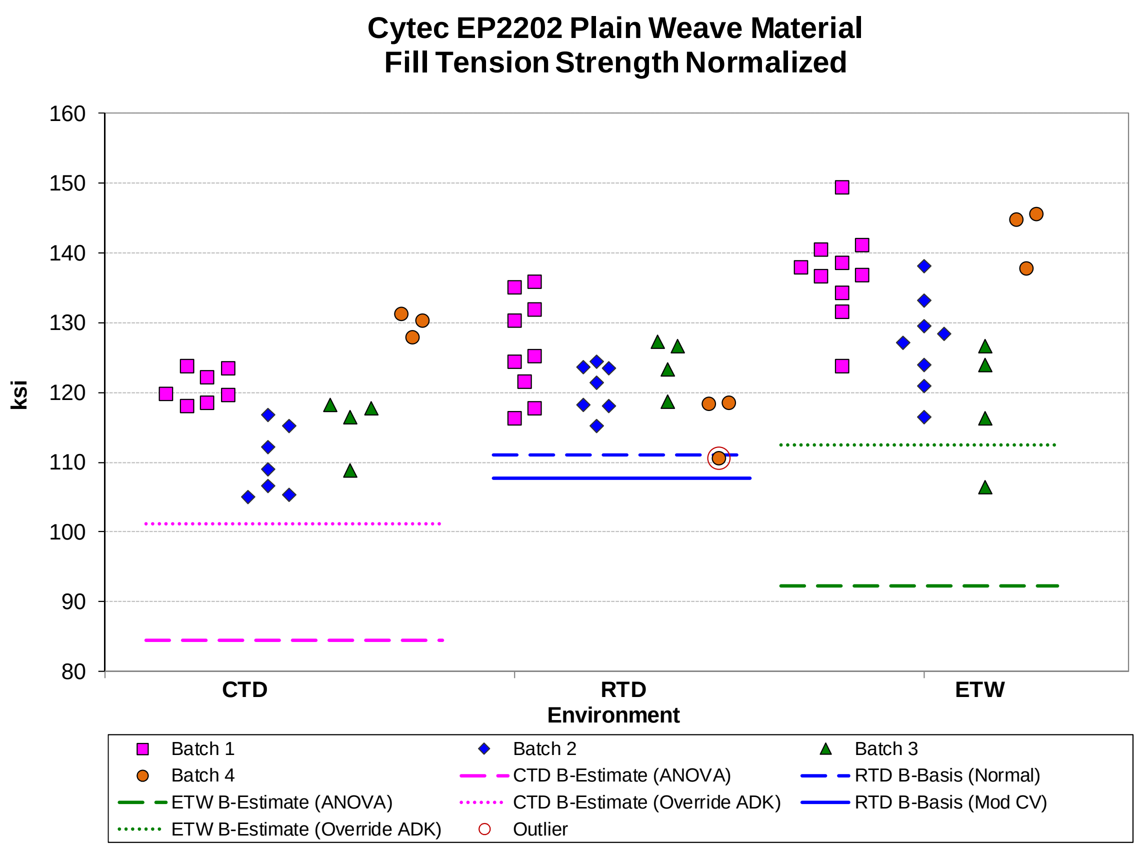

Figure 4-2: Batch Plot for FT normalized strength

Fill Tension Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	117.425	122.865	131.598	118.352	123.999	132.776
Stdev	7.677	6.340	10.299	8.377	6.075	10.583
CV	6.538	5.160	7.826	7.078	4.899	7.970
Mod CV	7.269	6.580	7.913	7.539	6.450	7.985
Min	104.917	110.539	106.342	105.832	114.529	106.679
Max	131.270	135.842	149.374	134.954	136.047	150.282
No. Batches	4	4	4	4	4	4
No. Spec.	21	23	25	21	23	25
Basis Values and Estimates						
B-basis Value		111.020			112.649	
B-Estimate	84.520		92.182	82.055		90.914
A-Estimate	61.714	102.544	64.762	56.904	104.526	61.820
Method	ANOVA	Normal	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value		107.754			109.051	
A-Estimate		96.945			98.358	
Method		Normal			Normal	
Mod CV Basis Value Estimates with override of ADK test result						
B-Estimate	101.160		112.456	101.349		113.287
A-Estimate	89.574		98.712	89.238		99.294
Method	Normal		Normal	Normal		Normal

Table 4-3: Statistics and Basis Values for FT Strength Data

Fill Tension Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	9.514	9.249	9.389	9.590	9.344	9.472
Stdev	0.188	0.170	0.223	0.225	0.181	0.244
CV	1.973	1.837	2.376	2.346	1.940	2.576
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	9.270	8.970	9.003	9.220	9.055	8.960
Max	9.790	9.582	9.770	9.953	9.692	9.872
No. Batches	4	4	4	4	4	4
No. Spec.	21	24	25	21	24	25

Table 4-4: Statistics from FT Modulus Data

4.3 Warp Compression (WC)

Warp Compression data is normalized, so both normalized and as-measured data is provided. The ETD dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

The pooled dataset failed Levene's test for equality of variation, so pooling across the environmental conditions was not appropriate. When the datasets were transformed according to the assumptions of the modified CV method, pooling was still not acceptable due to a failure of the normality test for the pooled dataset. However, the CTD and RTD conditions, both normalized and as-measured, could be pooled to compute modified CV basis values.

There was one outlier. The lowest value in batch two of the normalized RTD condition datatset dataset was an outlier. It was an outlier for the RTD condition but not for batch two. It was an outlier only for the normalized RTD dataset, not for the as-measured RTD dataset. It was 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 normalized data, B-estimates and B-basis values are shown graphically in Figure 4-3.

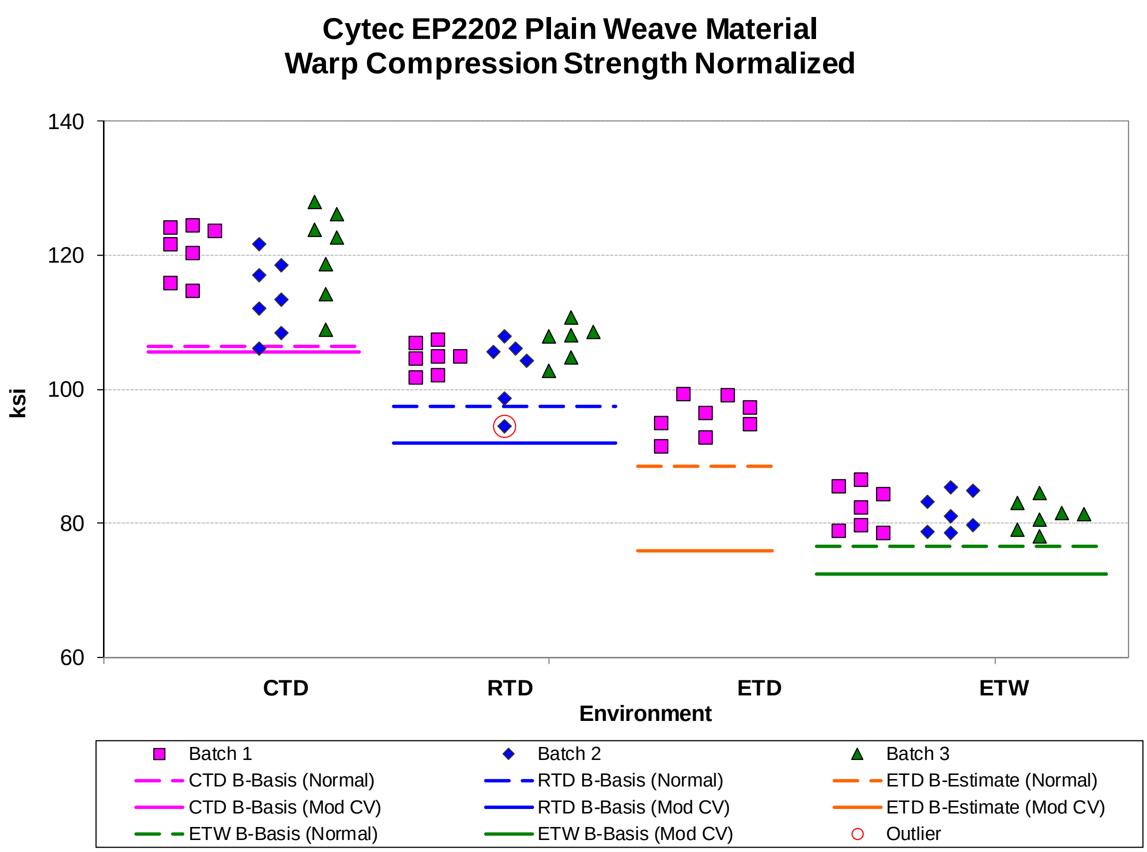

Figure 4-3: Batch plot for WC normalized strength

Warp Compression Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	118.311	104.851	95.787	81.716	118.598	105.418	96.235	81.820
Stdev	6.222	3.801	2.803	2.718	6.523	4.190	2.890	2.905
CV	5.259	3.625	2.927	3.326	5.500	3.974	3.003	3.551
Mod CV	6.629	6.000	8.000	6.000	6.750	6.000	8.000	6.000
Min	106.048	94.415	91.452	77.988	105.946	94.350	91.427	77.605
Max	128.005	110.692	99.322	86.576	128.836	112.638	100.022	87.090
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	19	8	21	21	19	8	21
Basis Values and/or Estimates								
B-basis Value	106.458	97.443		76.539	106.172	97.253		76.285
B-Estimate			88.501				88.723	
A-Estimate	98.008	92.183	83.401	72.849	97.313	91.455	83.465	72.339
Method	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Modified CV Basis Values and/or Estimates								
B-basis Value	105.578	92.005		72.373	105.677	92.382		72.465
B-Estimate			75.981				76.337	
A-Estimate	96.806	83.259	62.390	65.718	96.769	83.500	62.682	65.801
Method	pooled	pooled	Normal	Normal	pooled	pooled	Normal	Normal

Table 4-5: Statistics and Basis Values for WC Strength Data

Warp Compression Modulus Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	8.656	8.538	8.530	8.727	8.676	8.587	8.554	8.750
Stdev	0.228	0.154	0.127	0.185	0.236	0.158	0.132	0.206
CV	2.635	1.804	1.491	2.123	2.725	1.840	1.546	2.354
Mod CV	6.000	6.000	8.000	6.000	6.000	6.000	8.000	6.000
Min	8.372	8.287	8.284	8.347	8.391	8.304	8.296	8.341
Max	9.242	8.824	8.672	9.116	9.269	8.888	8.720	9.124
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	21	7	21	21	21	7	21

Table 4-6: Statistics from WC Modulus Data

4.4 Fill Compression (FC)

Fill Compression data is normalized, so both normalized and as-measured data is provided. The ETD dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

The CTD and 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. When these datasets were transformed according to the assumptions of the modified CV method, none of them passed the ADK test, so the modified CV basis values could not be provided and pooling was not acceptable. Estimates of modified CV basis values are provided for the CTD and ETW conditions, but they are estimates only due to the failure of the ADK test for those datasets.

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

Statistics, basis values and estimates are given for strength data in Table 4-7 and for the modulus data in Table 4-8. The normalized data and B-basis values are shown graphically in Figure 4-4.

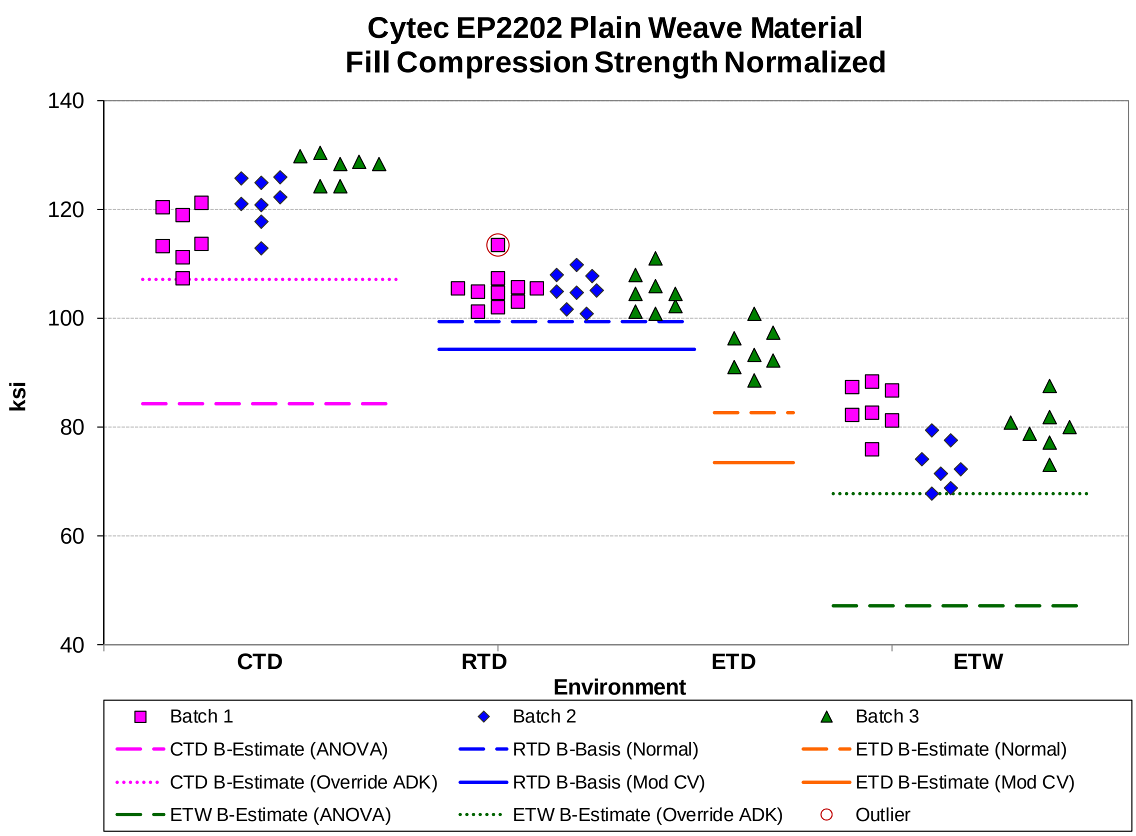

Figure 4-4: Batch Plot for FC normalized strength

Fill Compression Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	121.409	105.150	94.221	78.835	122.259	105.937	94.019	79.342
Stdev	6.507	3.214	4.158	6.078	6.278	3.523	3.364	5.853
CV	5.359	3.057	4.414	7.709	5.135	3.325	3.578	7.378
Mod CV	6.680	6.000	8.000	7.855	6.568	6.000	8.000	7.689
Min	107.260	100.723	88.582	67.725	108.195	99.542	89.342	68.993
Max	130.277	113.378	100.765	88.394	130.654	114.114	97.761	88.600
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	22	26	7	21	22	26	7	21
Basis Values and/or Estimates								
B-basis Value		99.289				99.514		
B-Estimate	84.259		82.674	47.073	86.964		84.679	50.284
A-Estimate	57.734	95.073	74.552	24.400	61.762	94.893	78.108	29.542
Method	ANOVA	Normal	Normal	ANOVA	ANOVA	Normal	Normal	ANOVA
Modified CV Basis Values and/or Estimates								
B-basis Value		93.646				94.347		
B-Estimate			73.421				73.264	
A-Estimate		85.371	59.182			86.010	59.055	
Method		Normal	Normal			Normal	Normal	
Modified CV Basis Values Estimates with override of ADK test result								
B-Estimate	106.109			67.035	107.110			67.717
A-Estimate	95.187			58.630	96.296			59.436
Method	Normal			Normal	Normal			Normal

Table 4-7: Statistics and Basis Values for FC Strength Data

Fill Compression Modulus Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	8.533	8.525	8.467	8.631	8.592	8.595	8.453	8.681
Stdev	0.332	0.138	0.130	0.250	0.327	0.163	0.207	0.271
CV	3.887	1.621	1.535	2.898	3.802	1.892	2.443	3.123
Mod CV	6.000	6.000	8.000	6.000	6.000	6.000	8.000	6.000
Min	7.674	8.244	8.335	8.236	7.741	8.240	8.087	8.220
Max	8.990	8.772	8.672	9.068	9.059	8.825	8.715	9.121
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	21	7	21	21	21	7	21

Table 4-8: Statistics from FC Modulus Data

4.5 In-Plane Shear (IPS)

In Plane Shear data is not normalized.

Datasets from all three conditions, both the 0.2% offset strength and the strength at 5% strain measurements, 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, all of them passed the ADK test, so the modified CV basis values are provided. However, pooling was not acceptable due to the failure of Levene's test for equality of variance. Modified CV B-basis values were computed for each individual dataset using the normal distribution.

There were two outliers in the strength at 5% datasets. The largest value in batch three of the CTD dataset was an outlier for batch three, but not for the CTD condition. The lowest value in batch two of the RTD dataset was an outlier for batch two, but not for the RTD condition. Both outliers were retained for this analysis.

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

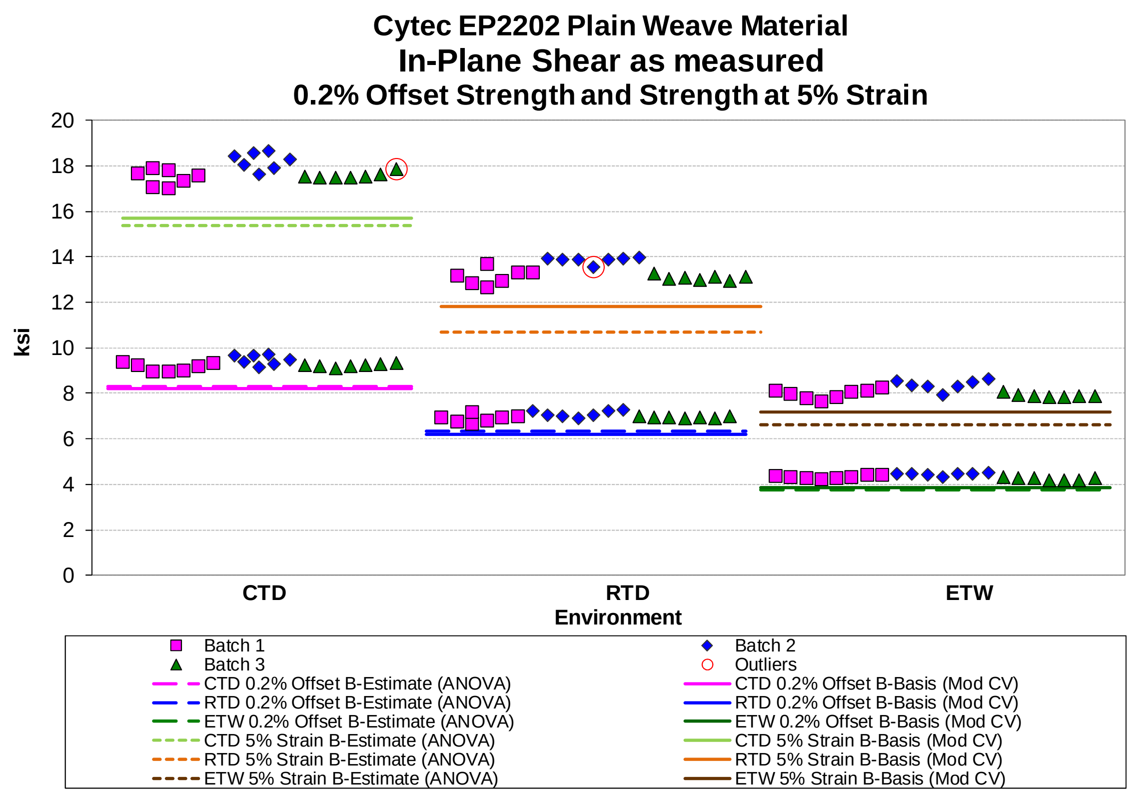

Figure 4-5: Batch plot for IPS strength as-measured

In Plane Shear Strength Basis Values and Statistics						
	0.2% Offset Strength			5% Strain		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	9.285	6.977	4.341	17.748	13.349	8.079
Stdev	0.205	0.149	0.106	0.439	0.424	0.269
CV	2.212	2.129	2.434	2.471	3.176	3.327
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	8.959	6.669	4.165	16.999	12.651	7.636
Max	9.689	7.254	4.528	18.631	13.952	8.625
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	22	21	21	22
Basis Values and Estimates						
B-Estimate	8.309	6.348	3.743	15.384	10.680	6.596
A-Estimate	7.613	5.900	3.316	13.696	8.774	5.538
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	8.223	6.179	3.850	15.719	11.823	7.164
A-Estimate	7.467	5.611	3.499	14.274	10.736	6.511
Method	Normal	Normal	Normal	Normal	Normal	Normal

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

In Plane Shear Modulus Statistics			
Env	CTD	RTD	ETW
Mean	0.747	0.646	0.457
Stdev	0.019	0.017	0.012
CV	2.554	2.593	2.693
Modified CV	6.000	6.000	6.000
Min	0.719	0.608	0.433
Max	0.785	0.672	0.476
No. Batches	3	3	3
No. Spec.	21	21	22

Table 4-10: Statistics for IPS Modulus Data

4.6 "25/50/25" Unnotched Tension 1 (UNT1)

Unnotched Tension data is normalized, so both normalized and as-measured data is provided. The pooled dataset failed Levene's test for equality of variance, so pooling was not appropriate. The single point method with the normal distribution was used for each condition. After transforming the data to meet the assumptions of the modified CV method, the pooled dataset passed Levene's test and pooling was appropriate to compute the modified CV basis values and estimates. There were no outliers.

Statistics, basis values and estimates are given for UNT1 strength data in Table 4-11 and for the modulus data in Table 4-12. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-6.

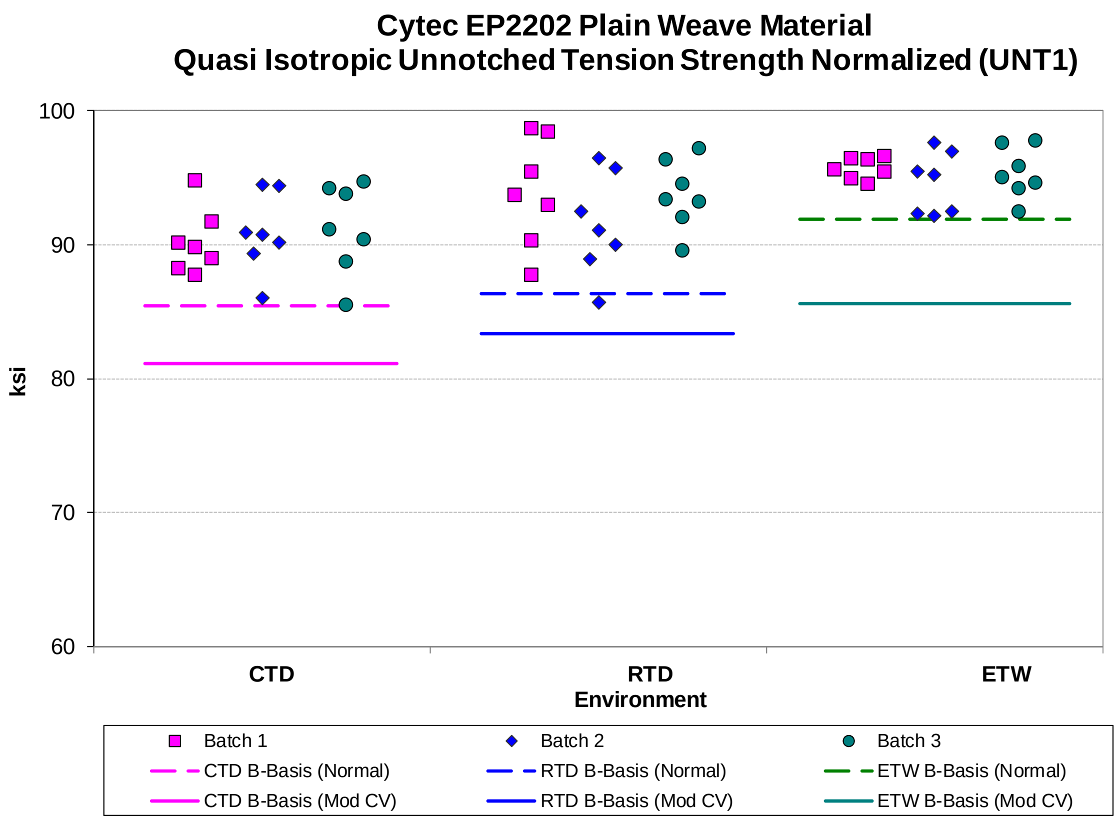

Figure 4-6: Batch Plot for UNT1 normalized strength

Unnotched Tension (UNT1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	90.783	93.063	95.243	91.588	94.140	95.741
Stdev	2.813	3.537	1.751	2.886	3.561	1.755
CV	3.098	3.800	1.838	3.151	3.782	1.833
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	85.525	85.684	92.153	85.879	86.846	92.184
Max	94.836	98.709	97.812	96.022	99.852	99.092
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	85.425	86.326	91.908	86.091	87.357	92.399
A-Estimate	81.605	81.523	89.531	82.172	82.521	90.016
Method	Normal	Normal	Normal	Normal	Normal	Normal
Modified CV Basis Values and Estimates						
B-basis Value	81.128	83.407	85.588	81.851	84.403	86.004
A-Estimate	74.609	76.889	79.070	75.277	77.829	79.430
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-11: Statistics and Basis Values for UNT1 Strength Data

Unnotched Tension (UNT1) Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	6.714	6.494	6.308	6.774	6.570	6.341
Stdev	0.082	0.082	0.085	0.091	0.105	0.087
CV	1.217	1.261	1.352	1.338	1.603	1.372
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	6.562	6.326	6.129	6.639	6.400	6.192
Max	6.867	6.637	6.453	6.950	6.743	6.550
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21

Table 4-12: Statistics from UNT1 Modulus Data

4.7 "10/80/10" Unnotched Tension 2 (UNT2)

Unnotched Tension data is normalized, so both normalized and as-measured data is provided. The UNT2 datasets have insufficient data to meet the requirements of the CMH17 Rev G, so only estimates can be provided for the UNT2 datasets.

The as-measured CTD dataset 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. When these datasets were transformed according to the assumptions of the modified CV method, all of them passed the ADK test, so the modified CV basis values are provided.

There were two outliers. The largest value in batch two of the RTD as-measured dataset was an outlier for the RTD condition but not for batch two alone. The smallest value in batch three of the ETW as-measured dataset was an outlier for batch three but not for the ETW condition. Neither were outliers in the normalized datasets. Both were retained for this analysis.

Statistics, basis values and estimates are given for UNT2 strength data in Table 4-13 and for the modulus data in Table 4-14. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-7.

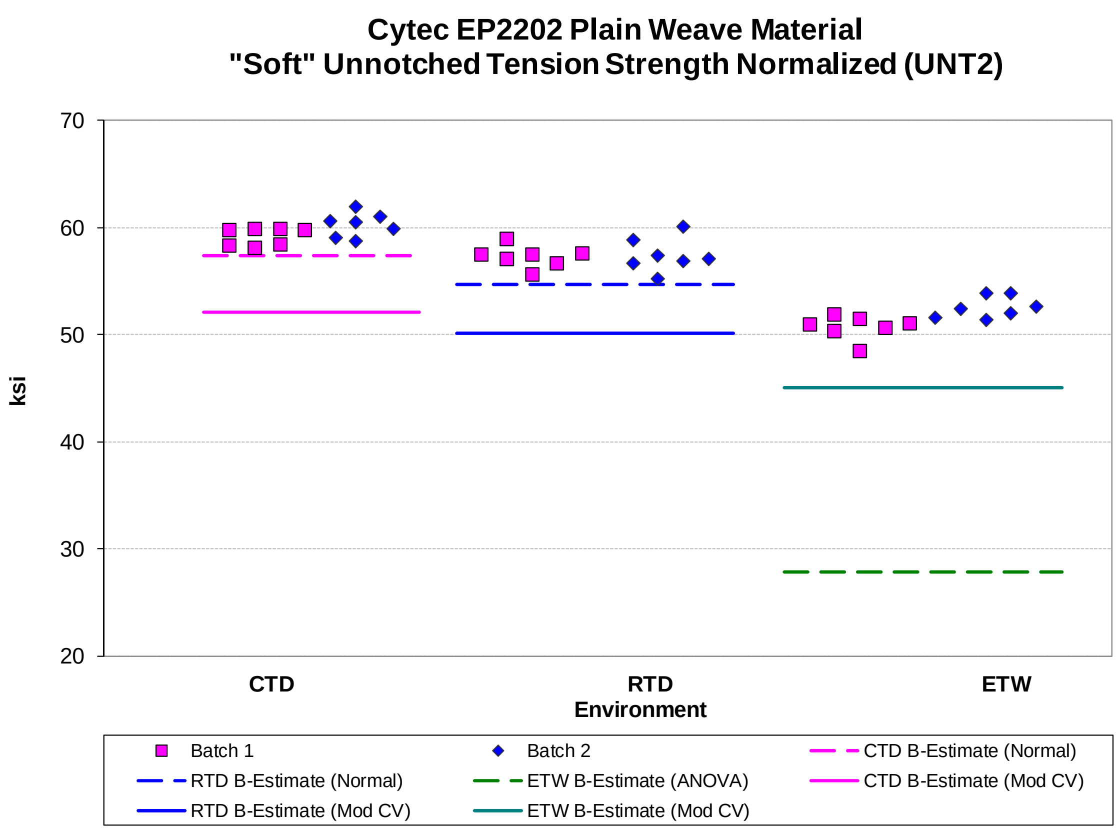

Figure 4-7: Batch Plot for UNT2 normalized strength

Unnotched Tension (UNT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	59.714	57.377	51.631	60.138	57.927	52.058
Stdev	1.108	1.276	1.384	1.411	1.544	1.624
CV	1.856	2.224	2.680	2.346	2.666	3.119
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	58.130	55.274	48.534	58.053	55.647	48.449
Max	61.988	60.129	53.904	62.861	61.841	54.898
No. Batches	2	2	2	2	2	2
No. Spec.	14	14	14	14	14	14
Basis Values and Estimates						
B-Estimate	57.374	54.682	27.919	30.391	54.666	19.444
A-Estimate	55.730	52.789	9.006	6.594	52.374	NA
Method	Normal	Normal	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and Estimates						
B-Estimate	52.156	50.115	45.096	52.526	50.595	45.469
A-Estimate	46.868	45.034	40.524	47.202	45.466	40.860
Method	Normal	Normal	Normal	Normal	Normal	Normal

Table 4-13: Statistics and Basis Values for UNT2 Strength Data

Unnotched Tension (UNT2) Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	4.427	4.217	3.991	4.458	4.258	4.024
Stdev	0.087	0.099	0.191	0.118	0.135	0.200
CV	1.969	2.350	4.785	2.644	3.163	4.964
Modified CV	6.000	6.000	6.393	6.000	6.000	6.482
Min	4.289	4.037	3.710	4.276	4.030	3.736
Max	4.546	4.379	4.474	4.610	4.444	4.529
No. Batches	2	2	2	2	2	2
No. Spec.	14	14	14	14	14	14

Table 4-14: Statistics from UNT2 Modulus Data

4.8 "40/20/40" Unnotched Tension 3 (UNT3)

Unnotched Tension data is normalized, so both normalized and as-measured data is provided. The CTD 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. When these datasets were transformed according to the assumptions of the modified CV method, both CTD datasets passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable for computing the mod CV B-basis value.

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

Statistics, basis values and estimates are given for UNT3 strength data in Table 4-15 and for the modulus data in Table 4-16. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-8.

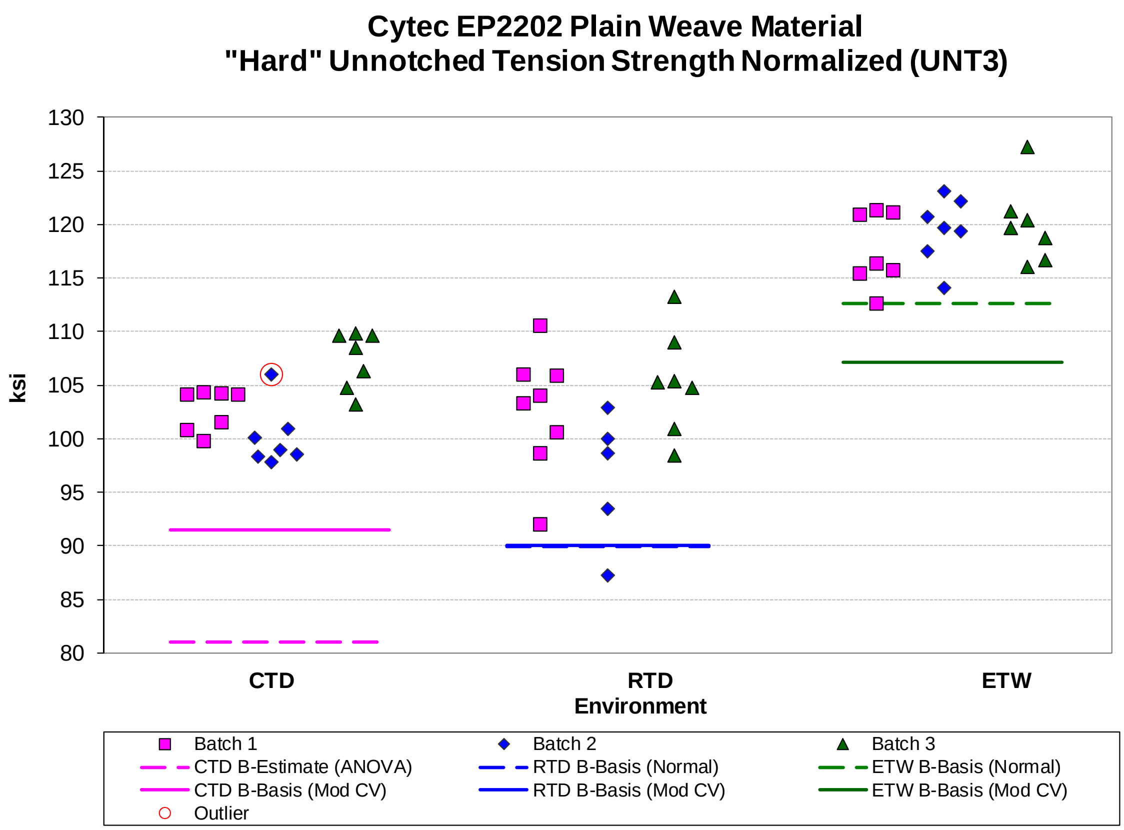

Figure 4-8: Batch Plot for UNT3 normalized strength

Unnotched Tension (UNT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	103.406	102.020	119.059	105.256	103.957	121.062
Stdev	3.903	6.280	3.393	4.235	6.444	3.822
CV	3.774	6.156	2.849	4.024	6.199	3.157
Modified CV	6.000	7.078	6.000	6.012	7.099	6.000
Min	97.860	87.299	112.689	99.277	89.283	113.577
Max	109.865	113.256	127.250	112.614	115.457	130.270
No. Batches	3	3	3	3	3	3
No. Spec.	21	20	21	21	20	21
Basis Values and Estimates						
B-basis Value		89.924	112.596		94.560	111.706
B-Estimate	81.053			80.025		
A-Estimate	65.095	81.318	107.989	62.012	88.131	105.267
Method	ANOVA	Normal	Normal	ANOVA	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	91.521	90.080	107.174	93.139	91.784	108.946
A-Estimate	83.493	82.062	99.146	84.954	83.609	100.760
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-15: Statistics and Basis Values for UNT3 Strength Data

Unnotched Tension (UNT3) Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	8.358	8.209	8.150	8.509	8.369	8.288
Stdev	0.124	0.130	0.144	0.168	0.176	0.206
CV	1.481	1.585	1.771	1.977	2.107	2.480
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	8.196	8.001	7.974	8.294	8.081	8.010
Max	8.705	8.477	8.543	8.907	8.700	8.805
No. Batches	3	3	3	3	3	3
No. Spec.	22	23	21	22	23	21

Table 4-16: Statistics from UNT3 Modulus Data

4.9 "25/50/25" Unnotched Compression 1 (UNC1)

Unnotched Compression data is normalized, so both normalized and as-measured data is provided. The Unnotched Compression strength datasets had no test failure or outliers. The two conditions could be pooled to compute basis values.

Statistics, basis values and estimates are given for UNC1 strength data in Table 4-17 and for the modulus data in Table 4-18. The normalized data and B-basis values are shown graphically in Figure 4-9.

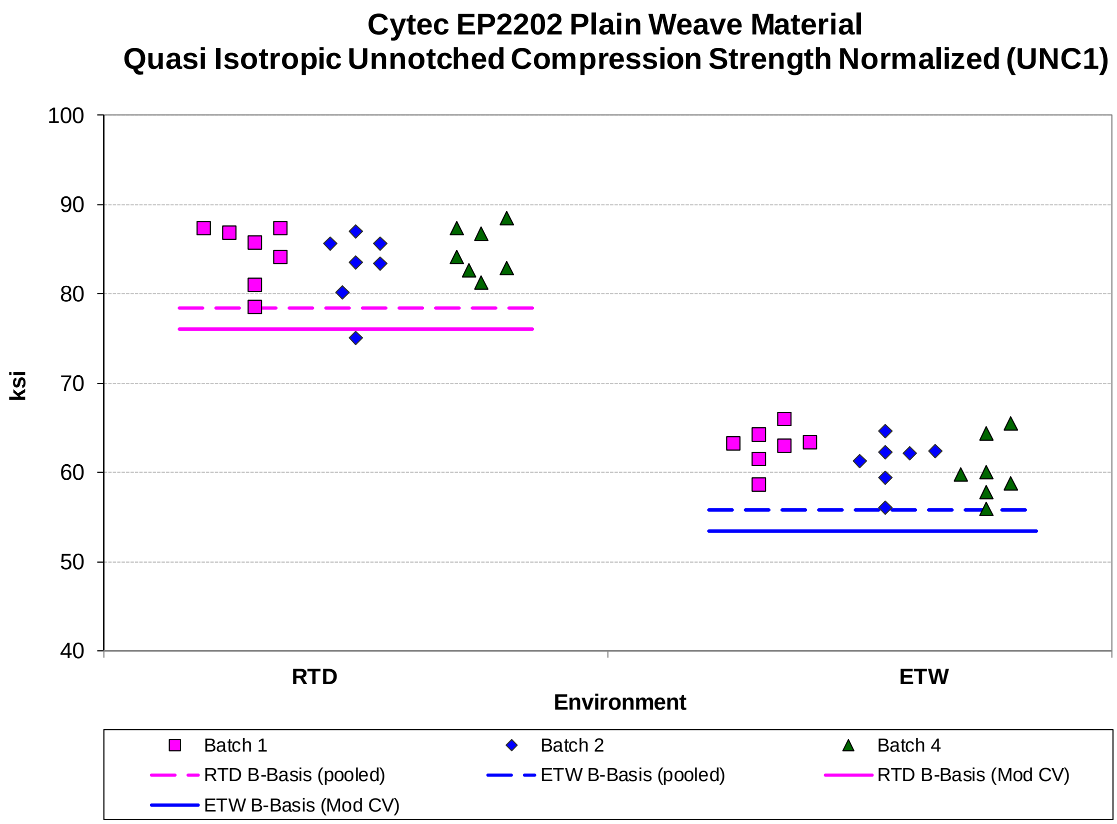

Figure 4-9: Batch plot for UNC1 normalized strength

Unnotched Compression (UNC1) Strength Basis Values and				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	84.041	61.441	84.332	61.874
Stdev	3.402	2.941	3.473	3.127
CV	4.048	4.786	4.119	5.053
Modified CV	6.024	6.393	6.059	6.527
Min	75.014	55.905	75.207	56.056
Max	88.518	66.017	88.336	67.289
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	78.401	55.802	78.471	56.012
A-Estimate	74.525	51.926	74.442	51.984
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	76.004	53.405	76.163	53.705
A-Estimate	70.481	47.881	70.549	48.091
Method	pooled	pooled	pooled	pooled

Table 4-17: Statistics and Basis Values for UNC1 Strength Data

Unnotched Compression (UNC1) Modulus Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	6.065	5.955	6.086	5.988
Stdev	0.088	0.090	0.109	0.111
CV	1.459	1.514	1.785	1.848
Modified CV	6.000	6.000	6.000	6.000
Min	5.906	5.744	5.885	5.756
Max	6.248	6.167	6.264	6.212
No. Batches	3	3	3	3
No. Spec.	21	21	21	21

Table 4-18: Statistics from UNC1 Modulus Data

4.10 "10/80/10" Unnotched Compression 2 (UNC2)

Unnotched Compression data is normalized, so both normalized and as-measured data is provided. The RTD 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. When these datasets were transformed according to the assumptions of the modified CV method, both RTD datasets passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable for computing the mod CV B-basis value.

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

Statistics, basis values and estimates are given for UNC2 strength data in Table 4-19 and for the modulus data in Table 4-20. The normalized data and B-basis values are shown graphically in Figure 4-10.

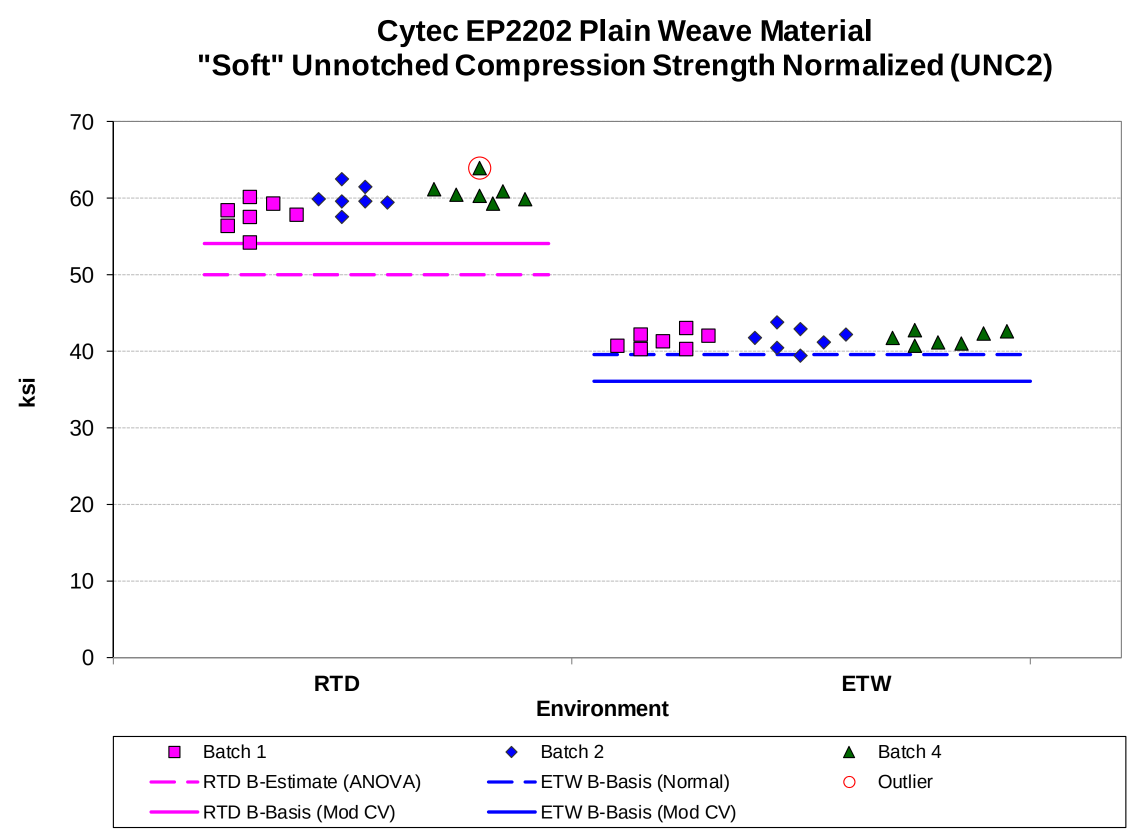

Figure 4-10: Batch plot for UNC2 normalized strength

Unnotched Compression (UNC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	59.541	41.658	60.427	42.198
Stdev	2.087	1.112	2.258	1.199
CV	3.505	2.669	3.737	2.841
Modified CV	6.000	6.000	6.000	6.000
Min	54.278	39.426	55.244	39.815
Max	63.938	43.846	65.515	44.196
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value		39.540		39.915
B-Estimate	50.046		49.239	
A-Estimate	43.270	38.030	41.254	38.286
Method	ANOVA	Normal	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-basis Value	54.072	36.189	54.880	36.652
A-Estimate	50.314	32.431	51.068	32.840
Method	pooled	pooled	pooled	pooled

Table 4-19: Statistics and Basis Values for UNC2 Strength Data

Unnotched Compression (UNC2) Modulus Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	4.100	3.843	4.162	3.890
Stdev	0.104	0.109	0.125	0.131
CV	2.541	2.834	3.000	3.376
Modified CV	6.000	6.000	6.000	6.000
Min	3.904	3.655	3.971	3.718
Max	4.269	4.109	4.434	4.212
No. Batches	3	3	3	3
No. Spec.	21	21	21	21

Table 4-20: Statistics from UNC2 Modulus Data

4.11 "40/20/40" Unnotched Compression 3 (UNC3)

Unnotched Compression data is normalized, so both normalized and as-measured data is provided. The pooled RTD and ETW datasets, both normalized and as-measured, failed Levene's test for equality of variance which means that pooling across environments was not acceptable. There were no other test failures, so the single point method was used to compute basis values. When these datasets were transformed according to the assumptions of the modified CV method, the pooled dataset passed Levene's test, so pooling was acceptable to compute the modified CV basis values.

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

Statistics, basis values and estimates are given for UNC3 strength data in Table 4-21 and for the modulus data in Table 4-22. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-11.

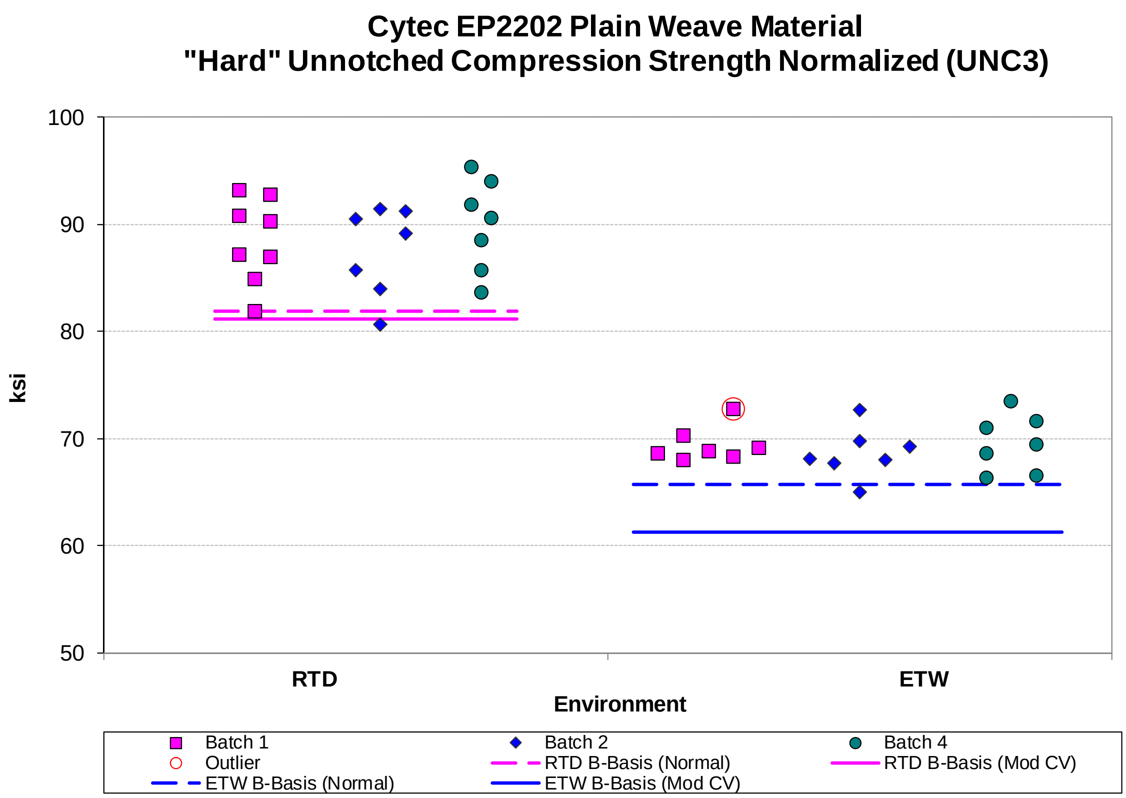

Figure 4-11: Batch plot for UNC3 normalized strength

Unnotched Compression (UNC3) Strength Basis Values				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	88.676	69.230	90.093	70.288
Stdev	4.039	2.176	4.347	2.357
CV	4.555	3.144	4.825	3.353
Modified CV	6.278	6.000	6.413	6.000
Min	80.696	65.005	81.552	65.538
Max	95.339	73.485	97.568	75.068
No. Batches	3	3	3	3
No. Spec.	22	21	22	21
Basis Values and Estimates				
B-basis Value	81.058	65.084	81.894	65.798
A-Estimate	75.617	62.129	76.038	62.597
Method	Normal	Normal	Normal	Normal
Modified CV Basis Values and Estimates				
B-basis Value	79.985	60.504	81.140	61.300
A-Estimate	73.987	54.514	74.962	55.129
Method	pooled	pooled	pooled	pooled

Table 4-21: Statistics and Basis Values for UNC3 Strength Data

Unnotched Compression (UNC3) Modulus Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	7.659	7.683	7.785	7.798
Stdev	0.170	0.121	0.223	0.159
CV	2.222	1.575	2.868	2.034
Modified CV	6.000	6.000	6.000	6.000
Min	7.426	7.489	7.466	7.511
Max	7.929	7.901	8.127	8.003
No. Batches	3	3	3	3
No. Spec.	21	21	21	21

Table 4-22: Statistics from UNC3 Modulus Data

4.12 Lamina Short-Beam Strength (SBS)

The Short Beam Strength data is not normalized. The ETD dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

The ETW dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. The RTD dataset failed the normality test, which means that CMH-17 Rev G guidelines required using the non-parametric distribution. Pooling across conditions was not acceptable due to the failure of Levene's test for equality of variance. Modified CV values could not be provided for the RTD condition due to the failure of the normality test even after the modified CV transformation was applied.

There were four outliers, two in the RTD condition and two in the ETW condition. In the RTD condition, the largest values from batches one and three were both considered outliers for their respective batches. The largest value from batch one was also an outlier for the RTD condition, but outlier in batch three was not an outlier for the condition. In the ETW condition, the lowest value in batch one and the largest value in batch three were outliers for their respective batches, but not for the ETW condition. All four outliers were retained for this analysis.

Statistics, basis values and estimates are given for SBS strength data in Table 4-23. The data, B-estimates and B-basis values are shown graphically in
Figure 4-12.

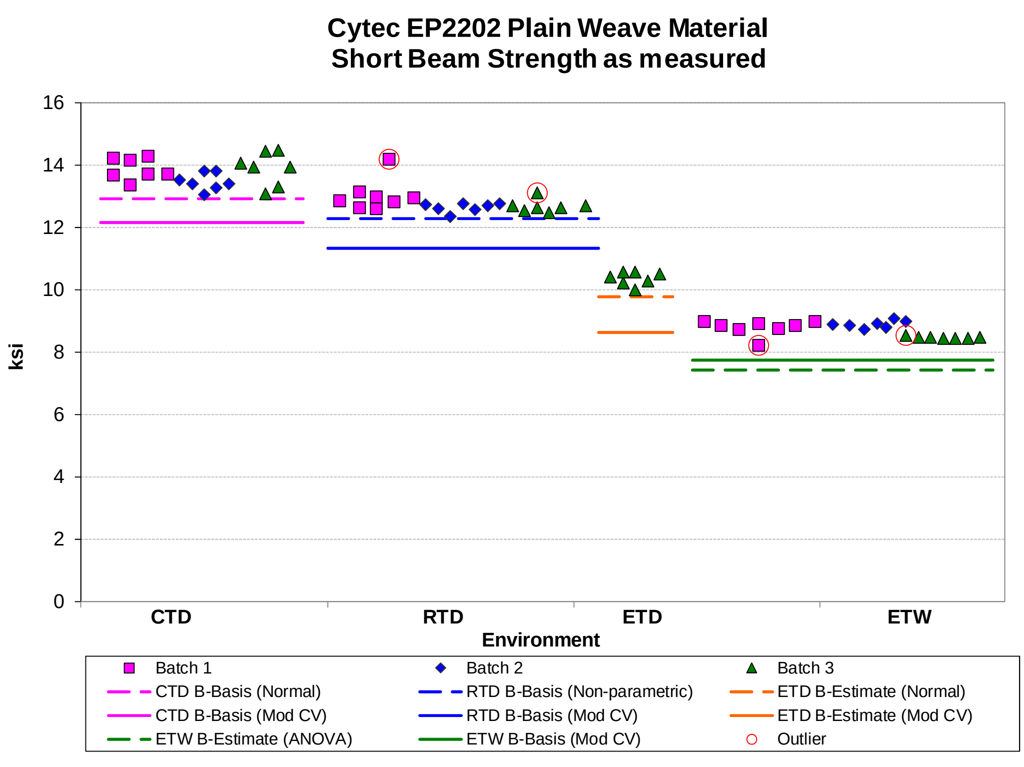

Figure 4-12: Batch plot for SBS strength as-measured

Short Beam Strength (SBS) As-measured				
Env	CTD	RTD	ETD	ETW
Mean	13.735	12.783	10.353	8.710
Stdev	0.430	0.367	0.213	0.238
CV	3.134	2.871	2.054	2.732
Mod CV	6.000	6.000	8.000	6.000
Min	13.028	12.343	9.978	8.213
Max	14.462	14.185	10.555	9.074
No. Batches	3	3	1	3
No. Spec.	21	22	7	22
Basis Values and Estimates				
B-basis Value	12.915	12.282		
B-Estimate			9.762	7.408
A-Estimate	12.331	10.359	9.347	6.479
Method	Normal	Non-Parametric	Normal	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	12.165	NA		7.724
B-Estimate			8.067	
A-Estimate	11.046		6.503	7.020
Method	Normal		Normal	Normal

Table 4-23: Statistics and Basis Values for SBS Strength Data

4.13 Laminate Short-Beam Strength (SBS1)

The Laminate Short Beam Strength data is not normalized. The data for both the RTD and ETW conditions failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that 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, both passed the ADK test, so the modified CV basis values could be provided. Pooling was acceptable for the modified CV basis values. There were no outliers.

Statistics, basis values and estimates are given for SBS1 strength data in Table 4-24. The data, B-estimates and B-basis values are shown graphically in Figure 4-13.

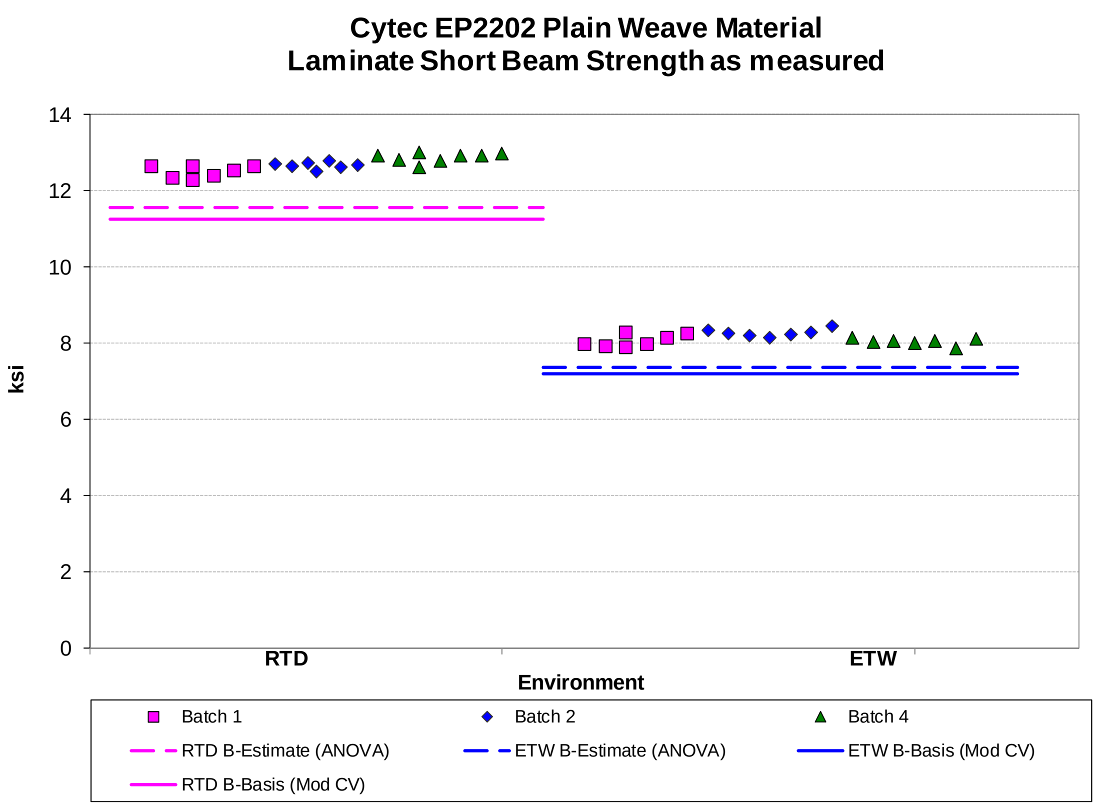

Figure 4-13: Batch plot for SBS1 strength as-measured

Laminate Short Beam Strength (SBS1)		
Env	RTD	ETW
Mean	12.692	8.126
Stdev	0.199	0.157
CV	1.565	1.937
Modified CV	6.000	6.000
Min	12.289	7.860
Max	13.001	8.455
No. Batches	3	3
No. Spec.	22	21
Basis Value Estimates		
B-Estimate	11.559	7.370
A-Estimate	10.749	6.831
Method	ANOVA	ANOVA
Modified CV Basis Values and Estimates		
B-basis Value	11.256	7.197
A-Estimate	10.230	6.535
Method	Normal	Normal

Table 4-24: Statistics and Basis Values for SBS1 Strength Data

4.14 "25/50/25" Open-Hole Tension 1 (OHT1)

Open-Hole Tension data is normalized, so both normalized and as-measured data is provided. The as-measured CTD and RTD 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 data from fewer than five batches available, these are considered estimates. When these datasets were transformed according to the assumptions of the modified CV method, both datasets passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable for computing the mod CV B-basis value. There were no outliers.

Statistics, basis values and estimates are given for OHT1 strength data in Table 4-25. The normalized data, B-basis values and B-estimates are shown graphically in Figure 4-14.

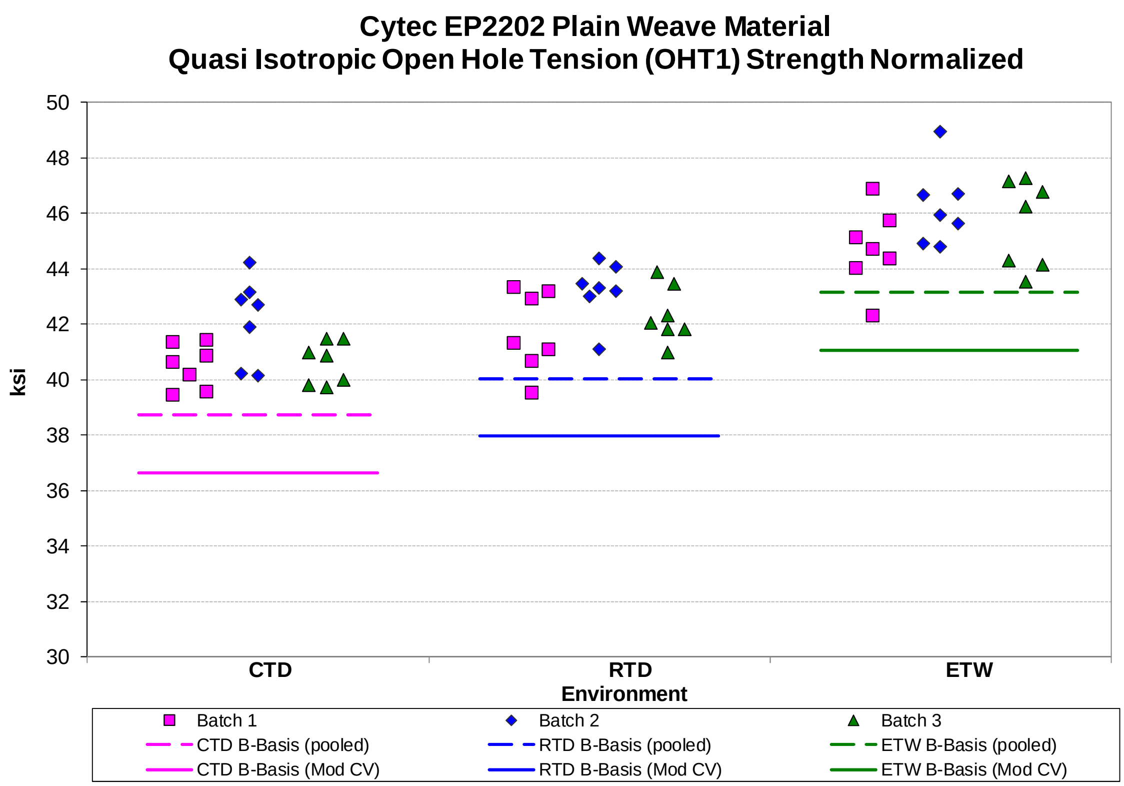

Figure 4-14: Batch Plot for OHT1 normalized strength

Open Hole Tension (OHT1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	41.106	42.431	45.541	41.575	42.908	45.925
Stdev	1.296	1.284	1.540	1.557	1.523	1.714
CV	3.152	3.027	3.382	3.746	3.549	3.732
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	39.474	39.555	42.311	39.792	39.760	42.629
Max	44.241	44.363	48.965	45.046	45.510	49.655
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	38.721	40.047	43.156			42.660
B-Estimate				32.990	35.966	
A-Estimate	37.112	38.438	41.547	26.862	31.010	40.333
Method	pooled	pooled	pooled	ANOVA	ANOVA	Normal
Modified CV Basis Values and/or Estimates						
B-basis Value	36.637	37.962	41.072	37.060	38.393	41.410
A-Estimate	33.620	34.946	38.055	34.013	35.345	38.363
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-25: Statistics and Basis Values for OHT1 Strength Data

4.15 "10/80/10" Open-Hole Tension 2 (OHT2)

Open-Hole Tension data is normalized, so both normalized and as-measured data is provided. All 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 data from fewer than five batches available, these are considered estimates. When these datasets were transformed according to the assumptions of the modified CV method, all datasets passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable for computing the modified CV B-basis value. There were no outliers.

Statistics, basis values and estimates are given for OHT2 strength data in Table 4-26. The normalized data and B-basis values are shown graphically in Figure 4-15.

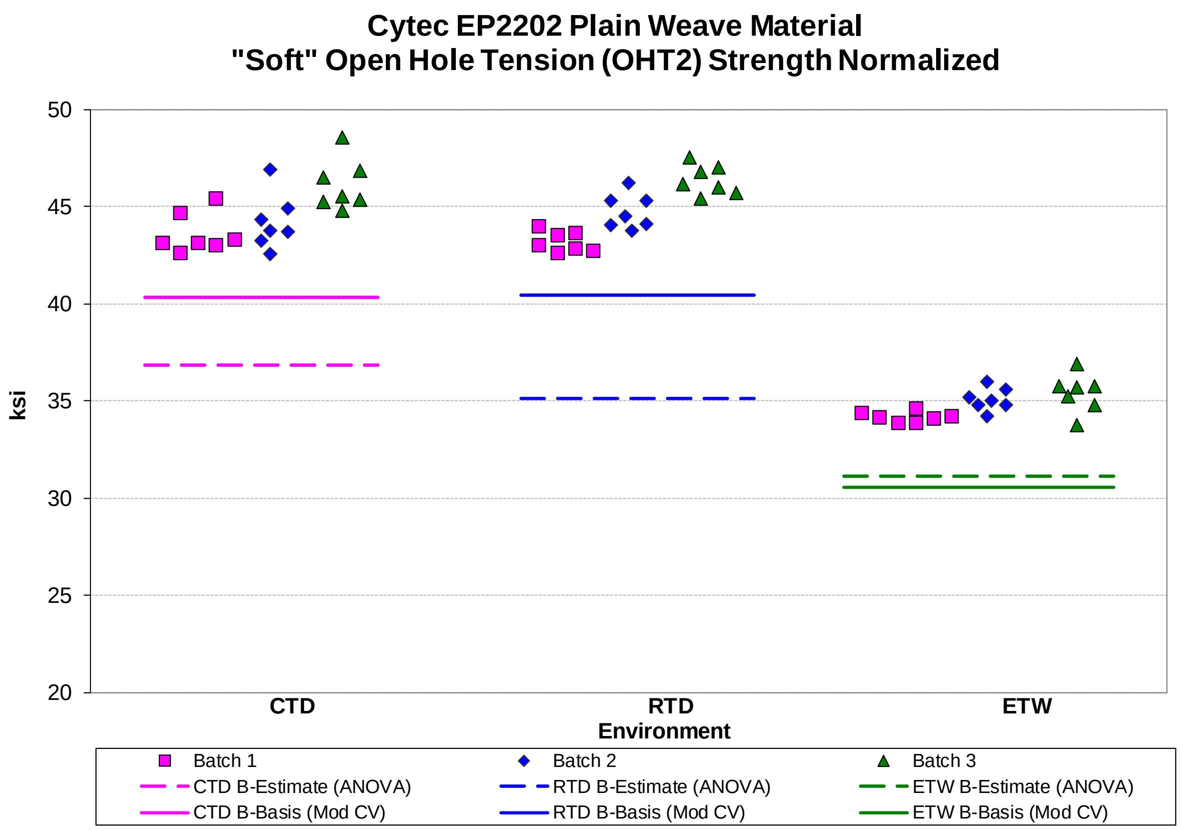

Figure 4-15: Batch Plot for OHT2 normalized strength

Open Hole Tension (OHT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	44.638	44.774	34.886	45.047	45.102	35.061
Stdev	1.620	1.501	0.837	1.477	1.581	0.935
CV	3.629	3.353	2.400	3.280	3.505	2.666
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	42.558	42.605	33.741	42.896	42.467	33.599
Max	48.585	47.519	36.911	47.798	47.446	36.602
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-Estimate	36.853	35.117	31.119	37.794	35.038	30.233
A-Estimate	31.296	28.224	28.429	32.617	27.853	26.786
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	40.312	40.447	30.560	40.689	40.743	30.703
A-Estimate	37.391	37.527	27.640	37.746	37.801	27.760
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-26: Statistics and Basis Values for OHT2 Strength Data

4.16 "40/20/40" Open-Hole Tension 3 (OHT3)

Open-Hole Tension data is normalized, so both normalized and as-measured data is provided. The as-measured CTD and RTD datasets and the normalized CTD dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that CMH-17 Rev G guidelines required using the ANOVA analysis. With data from fewer than five batches available, these are considered estimates. When these datasets were transformed according to the assumptions of the modified CV method, all but the CTD as-measured dataset passed the ADK test, so the modified CV basis values are provided for all datasets except CTD as-measured which has a modified CV B-estimate instead. Pooling the RTD and ETW conditions was acceptable for the normalized datasets and for the as-measured datasets when computing the mod CV basis values.

There were three outliers. The lowest value in batches one and four of the CTD data and batch four of the RTD data were outliers for their respective batches but not their respective conditions. The batch one outlier in the CTD condition was an outlier for the as-measured dataset but not the normalized dataset. The other two outliers were outliers for both the normalized and the as-measured datasets. All three outliers were retained for this analysis.

Statistics, basis values and estimates are given for OHT3 strength data in Table 4-27. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-16.

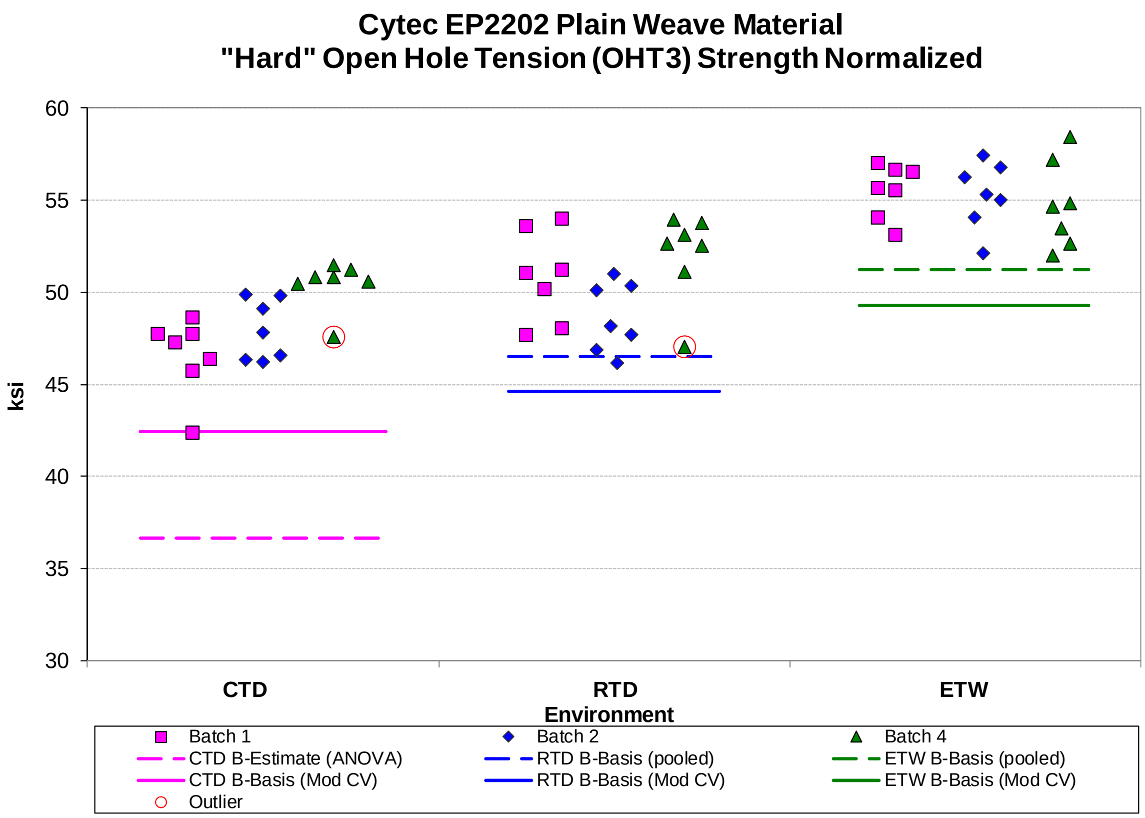

Figure 4-16: Batch Plot for OHT3 normalized strength

Open Hole Tension (OHT3) Strength (ksi) Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	48.321	50.492	55.179	49.124	51.501	55.982
Stdev	2.298	2.583	1.831	2.514	2.847	1.839
CV	4.755	5.116	3.318	5.117	5.527	3.285
Modified CV	6.378	6.558	6.000	6.559	6.764	6.000
Min	42.410	46.130	52.007	42.561	46.688	52.716
Max	51.499	53.991	58.419	53.026	55.509	60.109
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Value Estimates						
B-basis Value		46.521	51.208			
B-Estimate	36.663			35.503	39.386	52.479
A-Estimate	28.342	43.792	48.479	25.778	30.739	49.982
Method	ANOVA	pooled	pooled	ANOVA	ANOVA	Normal
Modified CV Basis Values and Estimates						
B-basis Value	42.448	44.619	49.306		45.432	49.913
B-Estimate				42.985		
A-Estimate	38.265	40.583	45.270	38.611	41.261	45.742
Method	Normal	pooled	pooled	Normal	pooled	pooled

Table 4-27: Statistics and Basis Values for OHT3 Strength Data

4.17 "25/50/25" Filled-Hole Tension 1 (FHT1)

Filled-Hole Tension data is normalized, so both normalized and as-measured data is provided. Pooling across the environmental conditions was acceptable. There were no outliers. Statistics, basis values and estimates are given for FHT1 strength data in Table 4-28. The normalized data and B-basis values are shown graphically in Figure 4-17.

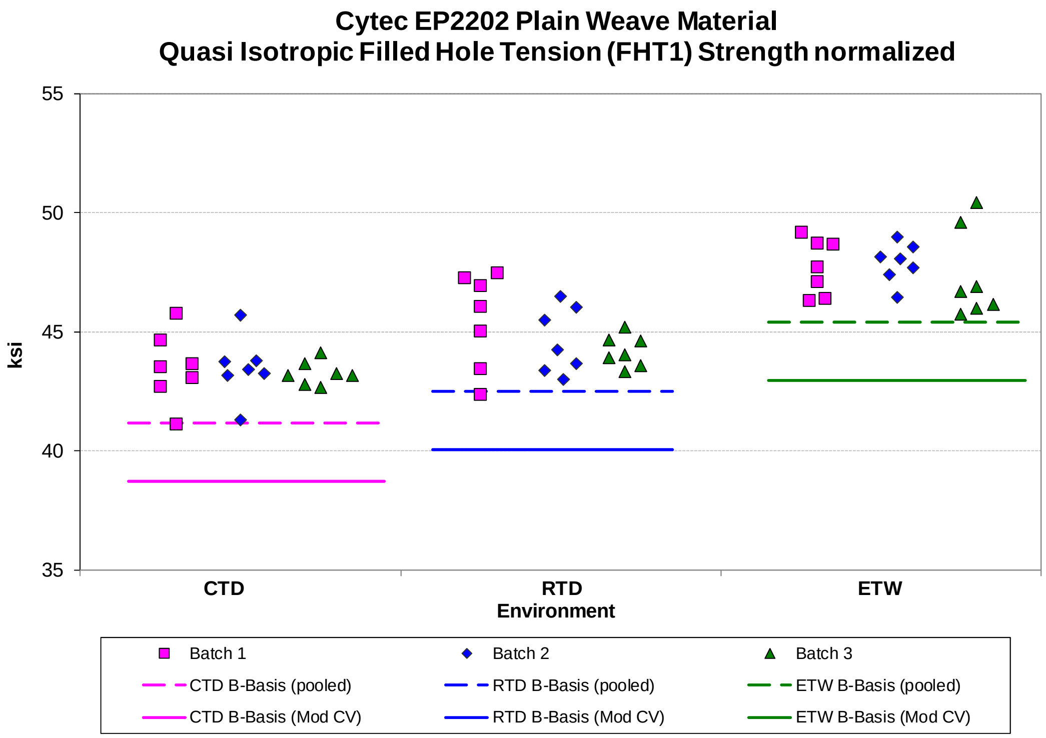

Figure 4-17: Batch plot for FHT1 normalized strength

Filled Hole Tension (FHT1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	43.419	44.772	47.667	43.752	45.166	47.923
Stdev	1.113	1.481	1.307	1.310	1.486	1.476
CV	2.564	3.308	2.743	2.993	3.290	3.079
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	41.150	42.389	45.749	41.214	42.697	45.567
Max	45.790	47.482	50.422	46.786	47.814	50.409
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	41.154	42.508	45.402	41.286	42.700	45.457
A-Estimate	39.625	40.979	43.873	39.621	41.035	43.792
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	38.716	40.070	42.964	39.015	40.429	43.187
A-Estimate	35.541	36.895	39.789	35.818	37.232	39.989
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-28: Statistics and Basis Values for FHT1 Strength Data

4.18 “10/80/10” Filled-Hole Tension 2 (FHT2)

Filled-Hole Tension data is normalized, so both normalized and as-measured data is provided. The CTD and RTD datasets, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that CMH-17 Rev G guidelines required using the ANOVA analysis. With data from fewer than five batches available, these are considered estimates. 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 CTD and RTD normalized datasets but the ETW normalized dataset could not be included due to the failure of the normality test for the pooled dataset. All three conditions could be pooled to compute the modified CV basis values for the as-measured datasets. There were no outliers.

Statistics, basis values and estimates are given for FHT2 strength data in Table 4-29. The normalized data and the B-basis values are shown graphically in Figure 4-18.

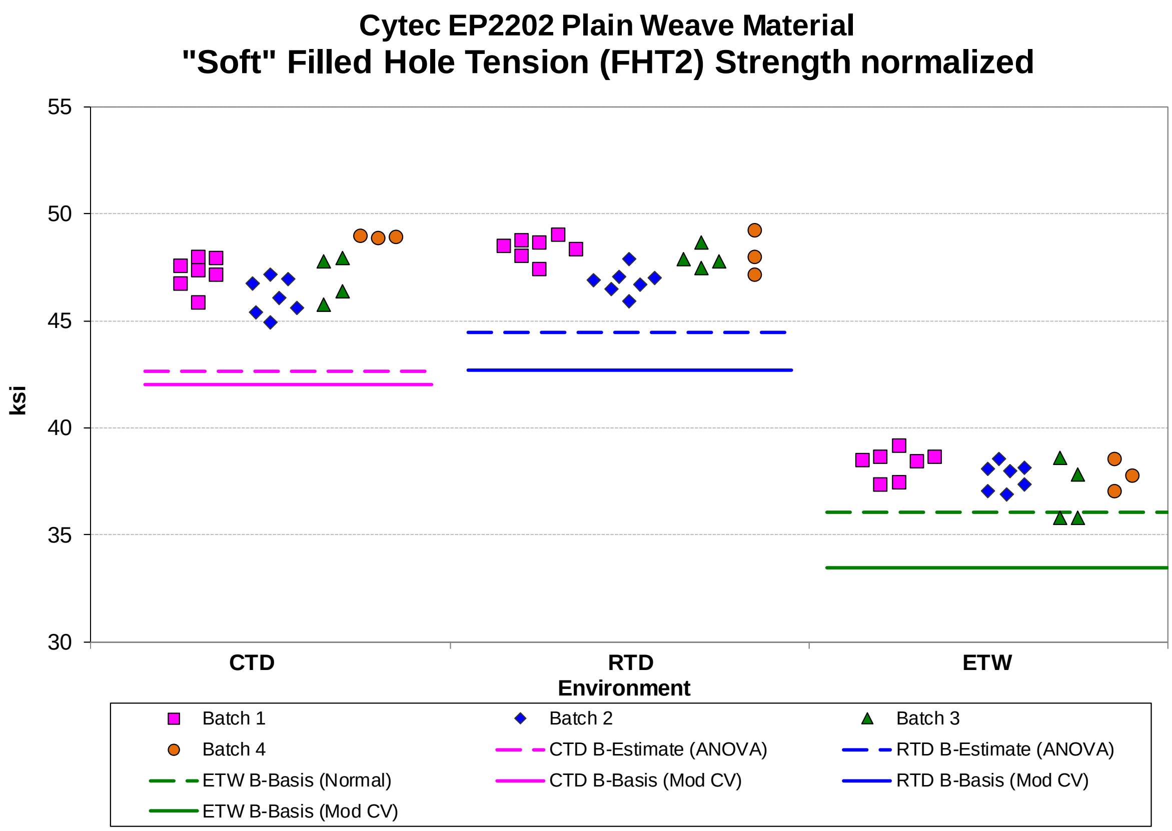

Figure 4-18: Batch plot for FHT2 normalized strength

Filled Hole Tension (FHT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	47.042	47.750	37.790	47.653	48.309	38.204
Stdev	1.183	0.893	0.910	1.331	0.896	1.006
CV	2.515	1.871	2.409	2.792	1.854	2.633
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	44.907	45.935	35.790	45.649	46.876	35.647
Max	48.944	49.221	39.152	50.335	50.521	39.422
No. Batches	4	4	4	4	4	4
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value			36.056			36.313
B-Estimate	42.632	44.483		42.580	45.056	
A-Estimate	39.566	42.209	34.819	39.054	42.792	34.208
Method	ANOVA	ANOVA	Normal	ANOVA	ANOVA	Weibull
Modified CV Basis Values and Estimates						
B-basis Value	41.998	42.706	33.469	42.987	43.644	33.539
A-Estimate	38.531	39.239	30.391	39.838	40.495	30.389
Method	pooled	pooled	Normal	pooled	pooled	pooled

Table 4-29: Statistics and Basis Values for FHT2 Strength Data

4.19 "40/20/40" Filled-Hole Tension 3 (FHT3)

Filled-Hole Tension data is normalized, so both normalized and as-measured data is provided. The RTD datasets, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that CMH-17 Rev G guidelines required using the ANOVA analysis. With data from fewer than five batches available, these are considered estimates. 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 both the normalized and as-measured datasets. There were no outliers.

Statistics, basis values and estimates are given for FHT3 strength data in Table 4-30. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-19.

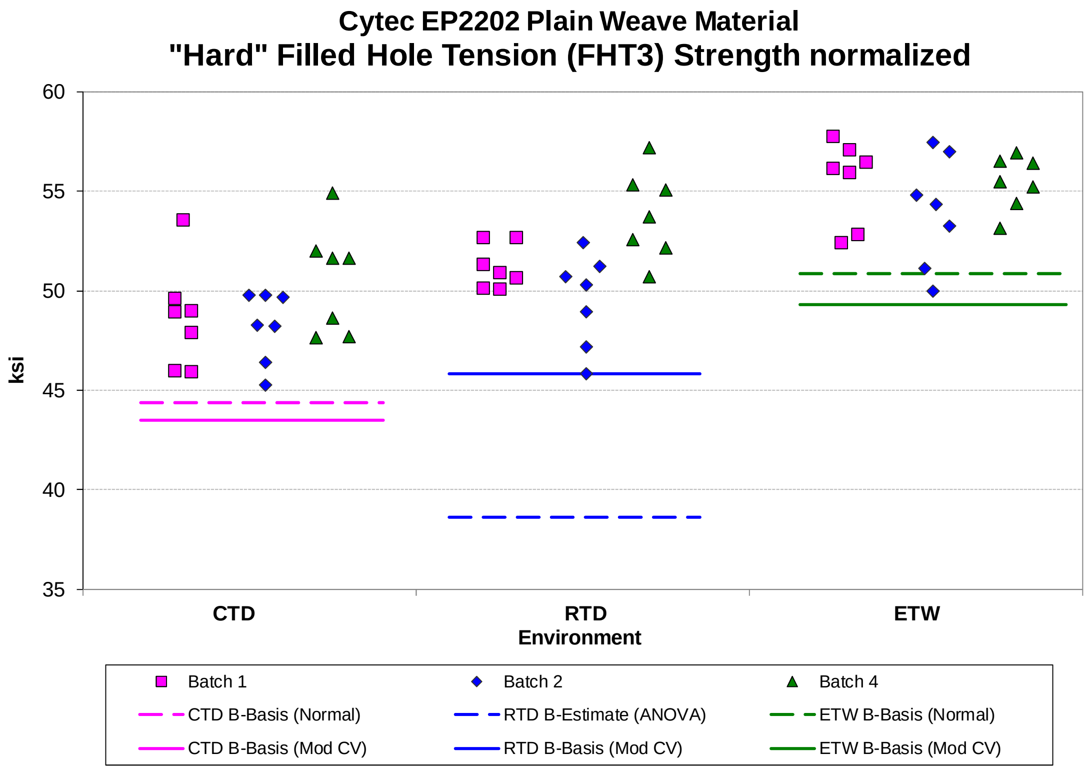

Figure 4-19: Batch plot for FHT3 normalized strength

Filled Hole Tension (FHT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	49.163	51.510	54.977	50.013	52.491	55.793
Stdev	2.500	2.599	2.163	2.609	2.863	2.157
CV	5.085	5.046	3.934	5.217	5.455	3.865
Modified CV	6.542	6.523	6.000	6.608	6.727	6.000
Min	45.264	45.829	49.985	46.131	46.850	50.829
Max	54.879	57.190	57.758	55.938	59.500	58.275
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	44.401		50.857	45.043		51.685
B-Estimate		38.595			37.883	
A-Estimate	41.006	29.375	47.920	41.499	27.455	48.756
Method	Normal	ANOVA	Normal	Normal	ANOVA	Normal
Modified CV Basis Values and Estimates						
B-basis Value	43.470	45.816	49.283	44.139	46.618	49.920
A-Estimate	39.626	41.972	45.440	40.174	42.653	45.955
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-30: Statistics and Basis Values for FHT3 Strength Data

4.20 "25/50/25" Open-Hole Compression 1 (OHC1)

Open-Hole Compression data is normalized, so both normalized and as-measured data is provided. The as-measured RTD dataset and 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 CMH-17 Rev G guidelines required using the ANOVA analysis. With data from fewer than five batches available, these are considered estimates. 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 not acceptable for the as-measured datasets due to the failure of the normality test for the pooled dataset, but the normalized datasets could be pooled to compute the modified CV basis values.

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

Statistics, B-basis values and estimates are given for OHC1 strength data in Table 4-31. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-20.

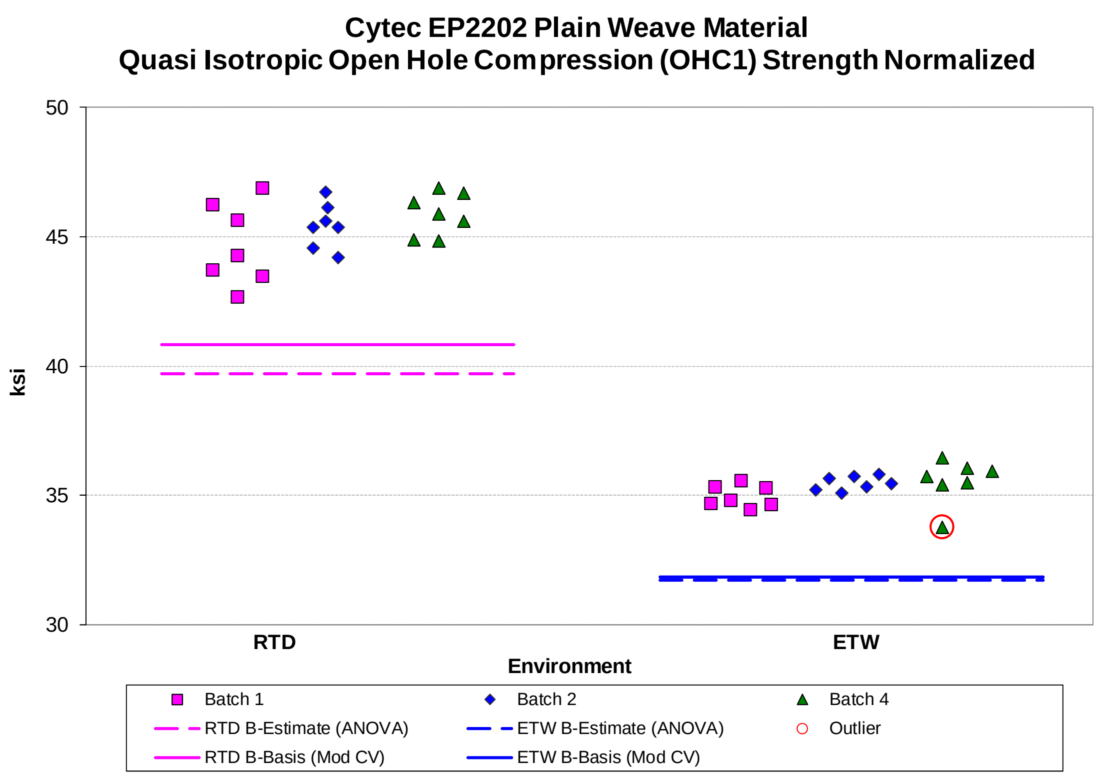

Figure 4-20: Batch plot for OHC1 normalized strength

Open Hole Compression (OHC1) Strength Basis Values				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	45.332	35.325	46.113	35.940
Stdev	1.188	0.609	1.534	0.893
CV	2.621	1.724	3.327	2.484
Modified CV	6.000	6.000	6.000	6.000
Min	42.668	33.750	42.712	34.455
Max	46.880	36.467	48.559	37.809
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	43.068			
B-Estimate		33.606	39.707	31.721
A-Estimate	41.455	32.380	35.135	28.710
Method	Normal	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	41.007	31.000	40.841	31.831
A-Estimate	38.035	28.028	37.085	28.904
Method	pooled	pooled	Normal	Normal

Table 4-31: Statistics and Basis Values for OHC1 Strength Data

4.21 “10/80/10” Open-Hole Compression 2 (OHC2)

Open-Hole Compression data is normalized, so both normalized and as-measured data is provided. The as-measured ETW dataset and the RTD datasets, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that CMH-17 Rev G guidelines required using the ANOVA analysis. With data from fewer than five batches available, these are considered estimates. 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 to compute the modified CV basis values.

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

Statistics, basis values and estimates are given for OHC2 strength data in Table 4-32. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-21.

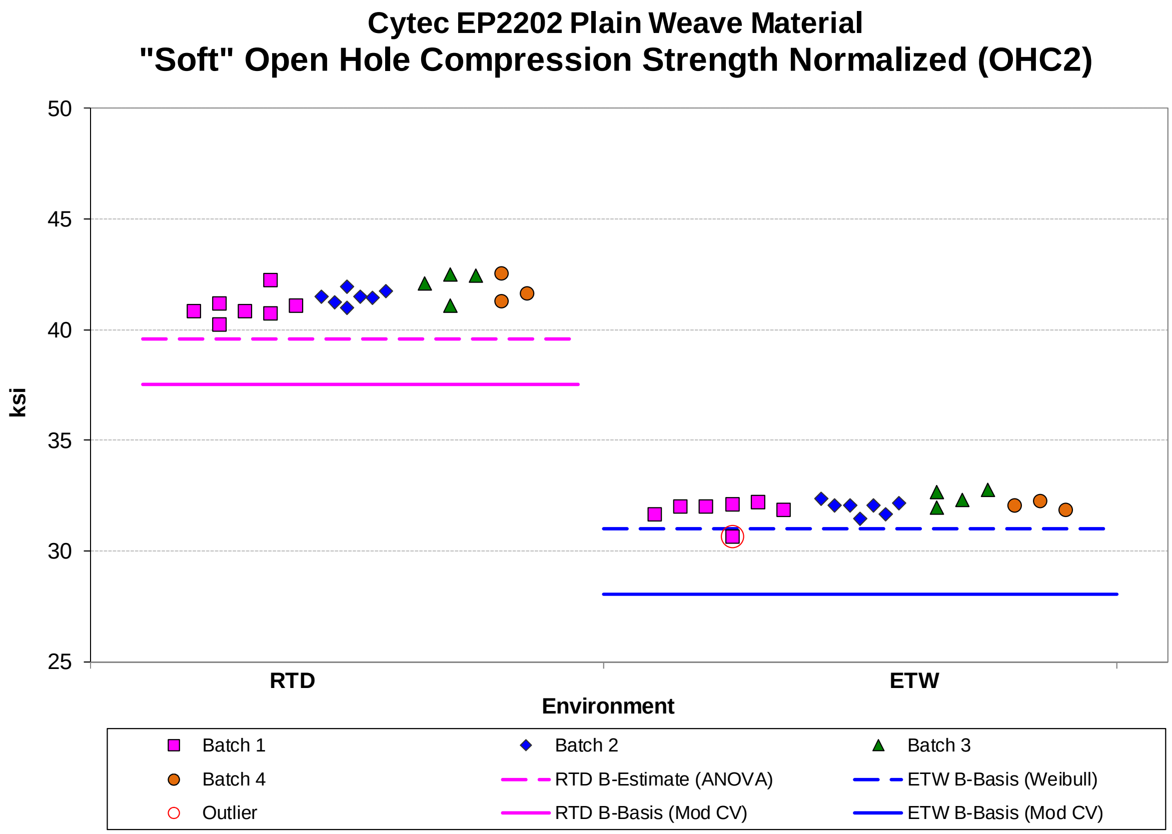

Figure 4-21: Batch plot for OHC2 normalized strength

Open Hole Compression (OHC2) Strength Basis Values and				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	41.486	32.014	41.837	32.277
Stdev	0.629	0.436	0.917	0.623
CV	1.517	1.362	2.192	1.930
Modified CV	6.000	6.000	6.000	6.000
Min	40.259	30.656	40.388	30.600
Max	42.536	32.778	44.158	33.590
No. Batches	4	4	4	4
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value		30.993		
B-Estimate	39.610		38.155	29.897
A-Estimate	38.297	29.861	35.599	28.243
Method	ANOVA	Weibull	ANOVA	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	37.542	28.070	37.861	28.300
A-Estimate	34.832	25.360	35.128	25.567
Method	pooled	pooled	pooled	pooled

Table 4-32: Statistics and Basis Values for OHC2 Strength Data

4.22 "40/20/40" Open-Hole Compression 3 (OHC3)

Open-Hole Compression data is normalized, so both normalized and as-measured data is provided. Pooling across the environmental conditions was acceptable. There was one outlier. It was the largest value in batch four of the RTD condition. It was an outlier only for batch four, not for the RTD condition. It was an outlier only for the normalized RTD dataset, not for the as-measured RTD dataset. It was retained for this analysis.

Statistics, basis values and estimates are given for OHC3 strength data in Table 4-33. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-22.

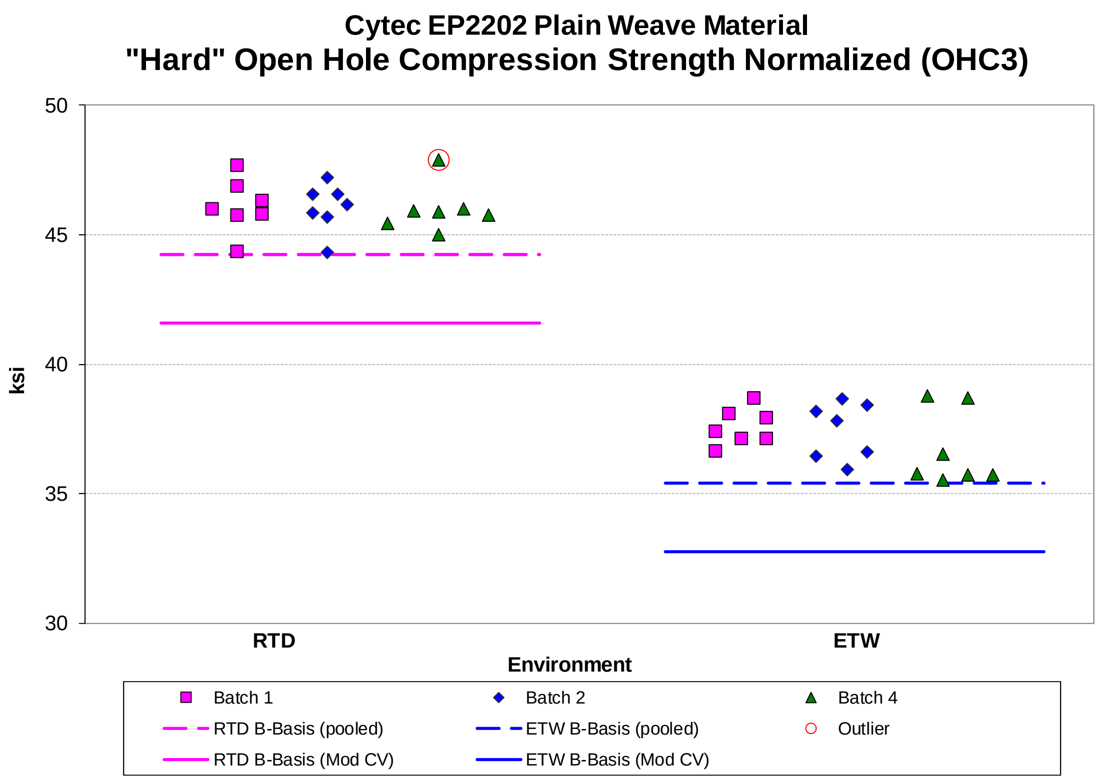

Figure 4-22: Batch plot for OHC3 normalized strength

Open Hole Compression (OHC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	46.052	37.233	46.796	37.846
Stdev	0.907	1.134	0.882	1.015
CV	1.969	3.045	1.884	2.681
Modified CV	6.000	6.000	6.000	6.000
Min	44.338	35.543	44.602	36.466
Max	47.876	38.775	48.465	40.038
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	44.231	35.412	45.110	36.160
A-Estimate	42.980	34.161	43.952	35.002
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	41.595	32.776	42.267	33.317
A-Estimate	38.532	29.713	39.154	30.204
Method	pooled	pooled	pooled	pooled

Table 4-33: Statistics and Basis Values for OHC3 Strength Data

4.23 "25/50/25" Filled-Hole Compression 1 (FHC1)

Filled-Hole Compression data is normalized, so both normalized and as-measured data is provided. There was insufficient data to meet the CMH17 Rev G requirements, so only estimates of B-basis values are provided. Pooling across the environmental conditions was not acceptable due to the failure of Levene's test of equality of variance. The RTD condition has a coefficient of variation greater than 8%, so modified CV basis values could not be provided.

There were three outliers. The lowest values in batches one and two and the largest value in batch four of the RTD condition. All three outliers were outliers for their respective batches but not the RTD condition and were outliers in both the normalized and as-measured datasets. All outliers were retained for this analysis.

Statistics, basis values and estimates are given for FHC1 strength data in Table 4-34. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-23.

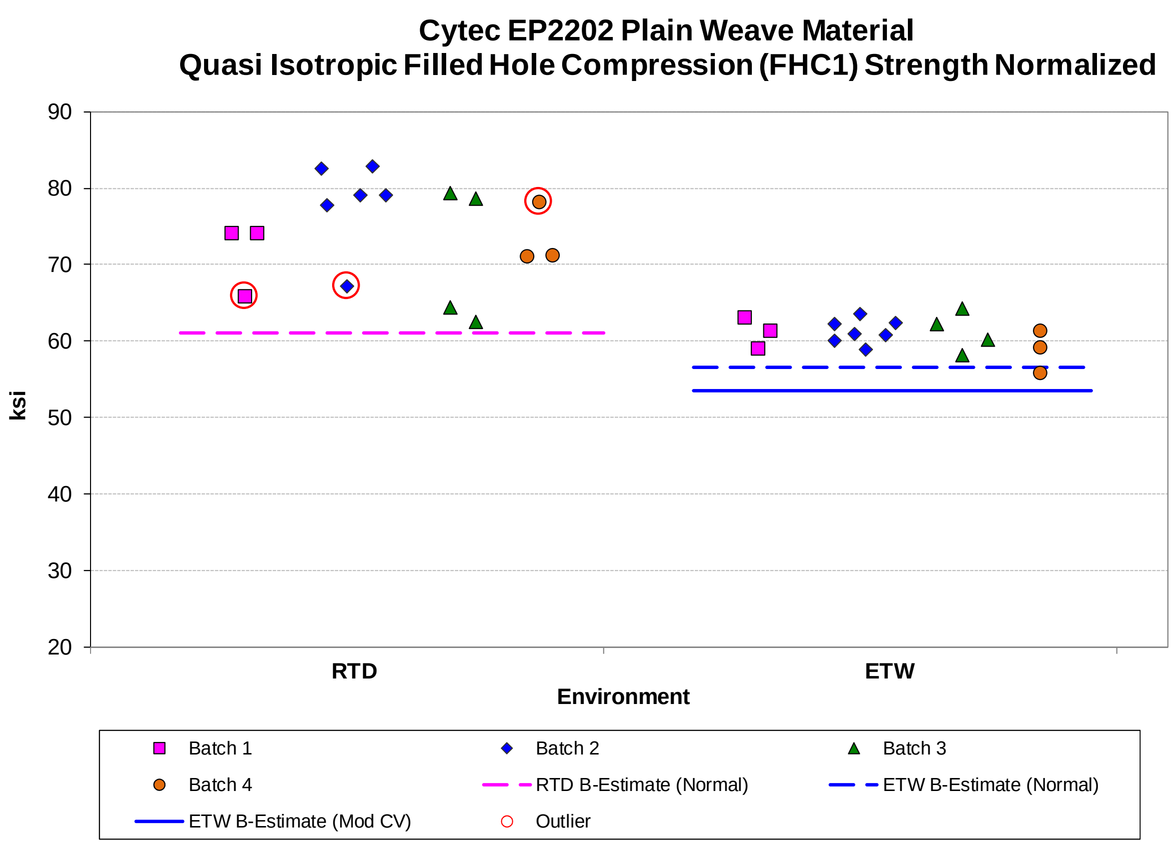

Figure 4-23: Batch plot for FHC1 normalized strength

Filled Hole Compression (FHC1) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	74.266	60.786	75.213	61.325
Stdev	6.519	2.136	6.825	2.201
CV	8.778	3.513	9.074	3.589
Modified CV	8.778	6.000	9.074	6.000
Min	62.569	55.848	62.965	56.688
Max	82.908	64.270	84.322	64.450
No. Batches	4	4	4	4
No. Spec.	16	17	16	17
Basis Values and Estimates				
B-Estimate	61.003	56.509	61.327	56.917
A-Estimate	51.643	53.485	51.529	53.800
Method	Normal	Normal	Normal	Normal
Modified CV Basis Values and Estimates				
B-Estimate	NA	53.484	NA	53.958
A-Estimate		48.331		48.760
Method		Normal		Normal

Table 4-34: Statistics and Basis Values for FHC1 Strength Data

4.24 "10/80/10" Filled-Hole Compression 2 (FHC2)

Filled-Hole Compression data is normalized, so both normalized and as-measured data is provided. There was insufficient data to meet the CMH17 Rev G requirements, so only estimates of B-basis values are provided. Pooling across the environmental conditions was not acceptable due to the non-normality of the data. The normalized RTD dataset failed normality even after the modified CV transformation was applied, so modified CV estimates of basis values could not be provided. There were no outliers.

Statistics, basis values and estimates are given for FHC2 strength data in Table 4-35. The normalized data and the B-basis values are shown graphically in Figure 4-24.

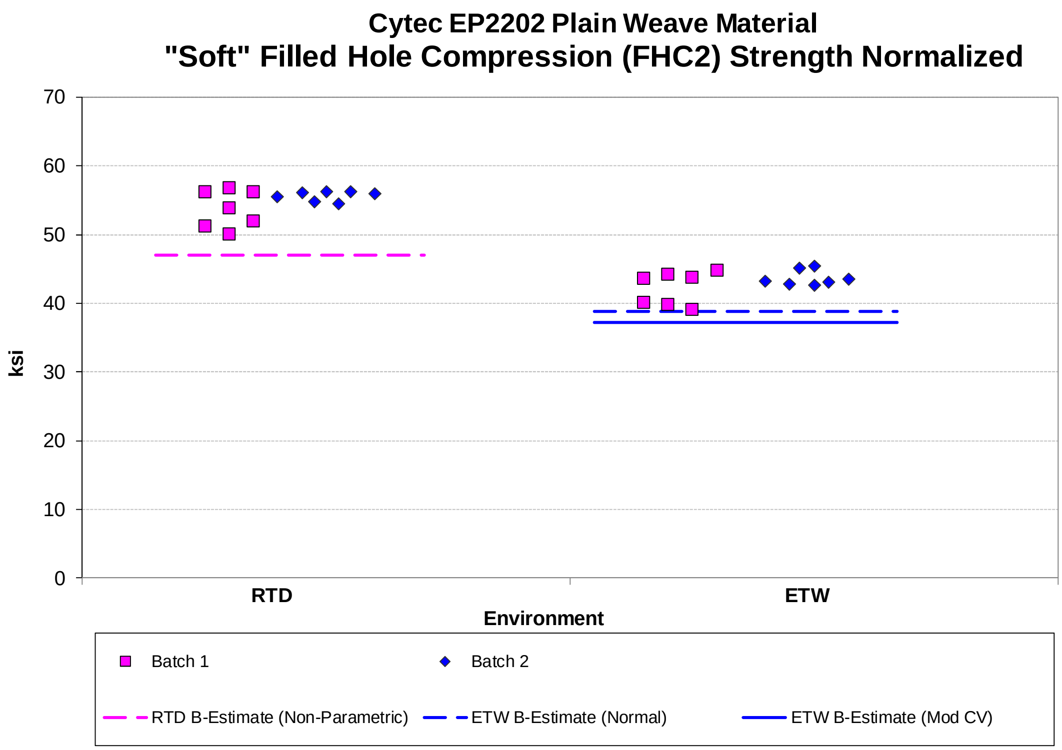

Figure 4-24: Batch plot for FHC2 normalized strength

Filled Hole Compression (FHC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	54.699	42.951	55.252	43.355
Stdev	2.119	1.944	2.499	2.244
CV	3.874	4.526	4.523	5.176
Modified CV	6.000	6.263	6.261	6.588
Min	50.146	39.133	49.992	38.952
Max	56.737	45.441	57.276	46.313
No. Batches	2	2	2	2
No. Spec.	14	14	14	14
Basis Values and Estimates				
B-Estimate	46.962	38.846	46.467	36.272
A-Estimate	39.810	35.962	38.769	28.185
Method	Non-Parametric	Normal	Non-Parametric	Non-Parametric
Modified CV Basis Values and Estimates				
B-Estimate	NA	37.276	47.954	37.330
A-Estimate		33.307	42.848	33.115
Method		Normal	Normal	Normal

Table 4-35: Statistics and Basis Values for FHC2 Strength Data

4.25 "40/20/40" Filled-Hole Compression 3 (FHC3)

Filled-Hole Compression data is normalized, so both normalized and as-measured data is provided. 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 CMH-17 Rev G guidelines required using the ANOVA analysis. With data from fewer than five batches available, these are considered estimates. 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 to compute the modified CV basis values.

There was one outlier. The largest value in batch one of the RTD datasets, both normalized and as measured, was an outlier for the RTD condition but not for batch one. It was retained for this analysis.

Statistics, basis values and estimates are given for FHC3 strength data in Table 4-36. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-25.

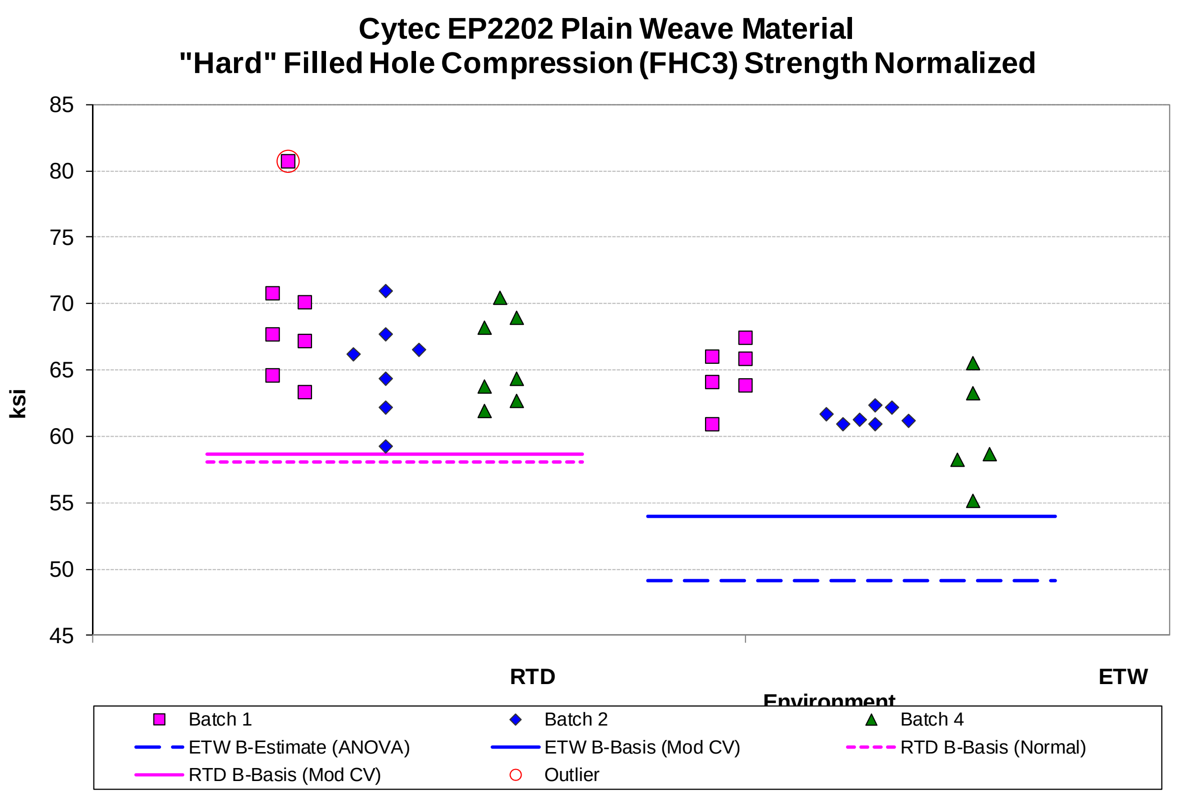

Figure 4-25: Batch plot for FHC3 normalized strength

Filled Hole Compression (FHC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	66.749	62.184	67.733	62.962
Stdev	4.558	3.056	4.487	3.071
CV	6.828	4.914	6.624	4.878
Modified CV	7.414	6.457	7.312	6.439
Min	59.278	55.155	59.895	56.284
Max	80.680	67.424	81.519	67.850
No. Batches	3	3	3	3
No. Spec.	21	18	21	18
Basis Values and Estimates				
B-basis Value	58.067		59.186	
B-Estimate		49.114		52.051
A-Estimate	51.877	39.799	53.092	44.283
Method	Normal	ANOVA	Normal	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	58.641	53.963	59.593	54.709
A-Estimate	53.048	48.395	53.977	49.119
Method	pooled	pooled	pooled	pooled

Table 4-36: Statistics and Basis Values for FHC3 Strength Data

4.26 "25/50/25" Single-Shear Bearing 1 (SSB1)

The Single-Shear Bearing data is normalized, so both normalized and as-measured data is provided. There was insufficient data for the initial peak strength property to meet the CMH17 Rev G requirements, so only estimates of B-basis values are provided for that property. Pooling across the two environmental conditions was acceptable for the 2% offset strength and ultimate strength properties.

There was one outlier. It was the largest value in batch one of the ETW ultimate strength property data. It was an outlier for the ETW condition, but not for batch one. It was an outlier for both the normalized and as-measured ETW ultimate strength datasets. It was retained for this analysis.

Statistics, basis values and estimates are given for the SSB1 normalized strength data in Table 4-37 and the as-measured strength data in Table 4-38. The normalized data, B-estimates and B-basis values are shown graphically for the initial peak strength and 2% offset strength in Figure 4-26 and for ultimate strength in Figure 4-27.

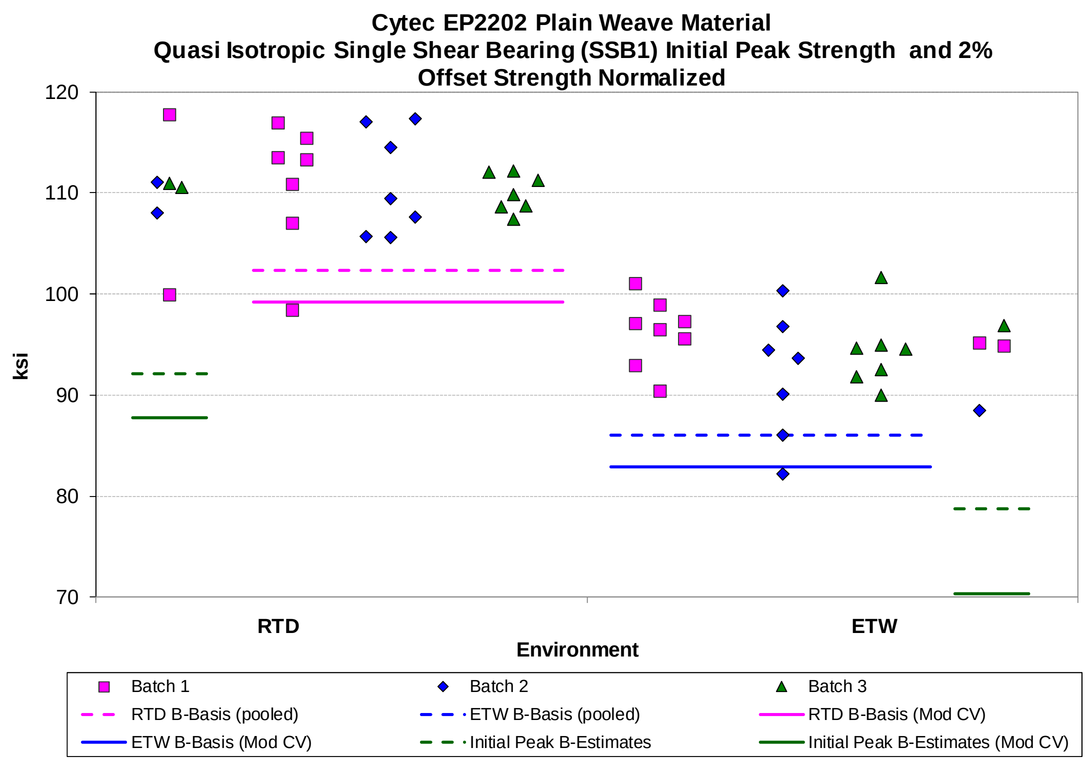

Figure 4-26: Batch plot for SSB1 normalized initial peak and 2% offset strength

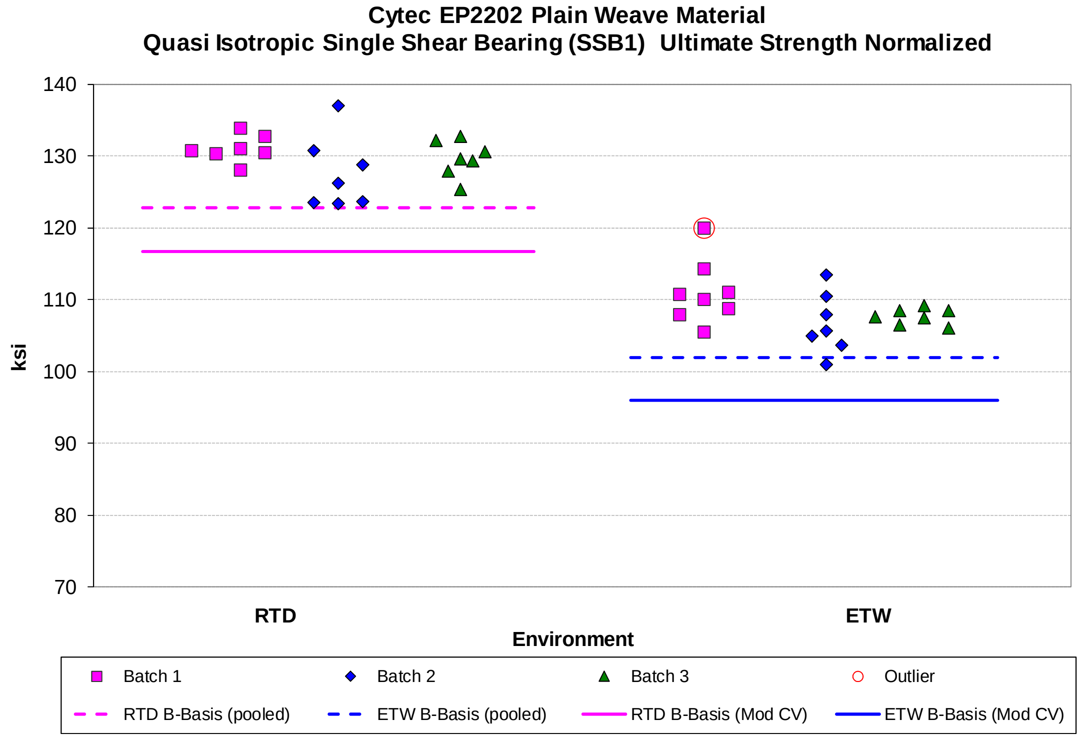

Figure 4-27: Batch plot for SSB1 ultimate normalized strength

Single Shear Bearing (SSB1) Normalized Strength Basis Values and Statistics						
Property	Initial Peak Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW
Mean	109.719	93.821	110.604	94.246	129.422	108.602
Stdev	5.809	3.688	4.603	4.707	3.547	3.958
CV	5.294	3.931	4.162	4.994	2.741	3.645
Modified CV	6.647	6.000	6.081	6.497	6.000	6.000
Min	99.878	88.448	98.420	82.200	123.348	101.033
Max	117.780	96.844	117.317	101.679	136.916	120.016
No. Batches	3	3	3	3	3	3
No. Spec.	6	4	21	22	21	22
Basis Values and Estimates						
B-basis Value			102.360	86.035	122.760	101.966
B-Estimate	92.124	78.715				
A-Estimate	79.614	67.269	96.700	80.368	118.186	97.386
Method	Normal	Normal	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value			99.230	82.917	116.758	95.989
B-Estimate	87.748	70.387				
A-Estimate	72.716	54.180	91.422	75.099	108.065	87.284
Method	Normal	Normal	pooled	pooled	pooled	pooled

Table 4-37: Statistics and Basis Values for SSB1 Normalized Strength Data

Single Shear Bearing (SSB1) As-measured Strength Basis Values and Statistics						
Property	Initial Peak Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW
Mean	111.074	94.539	112.033	94.970	131.081	109.443
Stdev	5.868	2.779	4.831	4.639	3.406	3.972
CV	5.283	2.940	4.312	4.885	2.599	3.630
Modified CV	6.641	6.000	6.156	6.442	6.000	6.000
Min	100.746	90.580	99.276	83.795	125.867	103.481
Max	118.604	96.994	120.685	102.770	139.719	120.465
No. Batches	3	3	3	3	3	3
No. Spec.	6	4	21	22	21	22
Basis Values and Estimates						
B-basis Value			103.652	86.623	124.518	102.906
B-Estimate	93.299	83.156				
A-Estimate	80.661	74.531	97.899	80.863	120.012	98.394
Method	Normal	Normal	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value			100.507	83.491	118.282	96.695
B-Estimate	88.850	70.925				
A-Estimate	73.645	54.594	92.596	75.569	109.496	87.897
Method	Normal	Normal	pooled	pooled	pooled	pooled

Table 4-38: Statistics and Basis Values for SSB1 As-measured Strength Data

4.27 "10/80/10" Single-Shear Bearing 2 (SSB2)

The Single-Shear Bearing data is normalized, so both normalized and as-measured data is provided. There were only two specimens that provided data for each condition in the initial peak strength property, which is insufficient to compute estimates of basis values.

The RTD datasets for 2% offset strength and ultimate strength, both normalized and as-measured, and the ETW dataset for ultimate strength as-measured failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that CMH-17 Rev G guidelines required using the ANOVA analysis. With data from fewer than five batches available, these are considered estimates. 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 to compute the modified CV basis values. There were no outliers.

Statistics, basis values and estimates are given for the SSB2 strength data in Table 4-40. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-28.

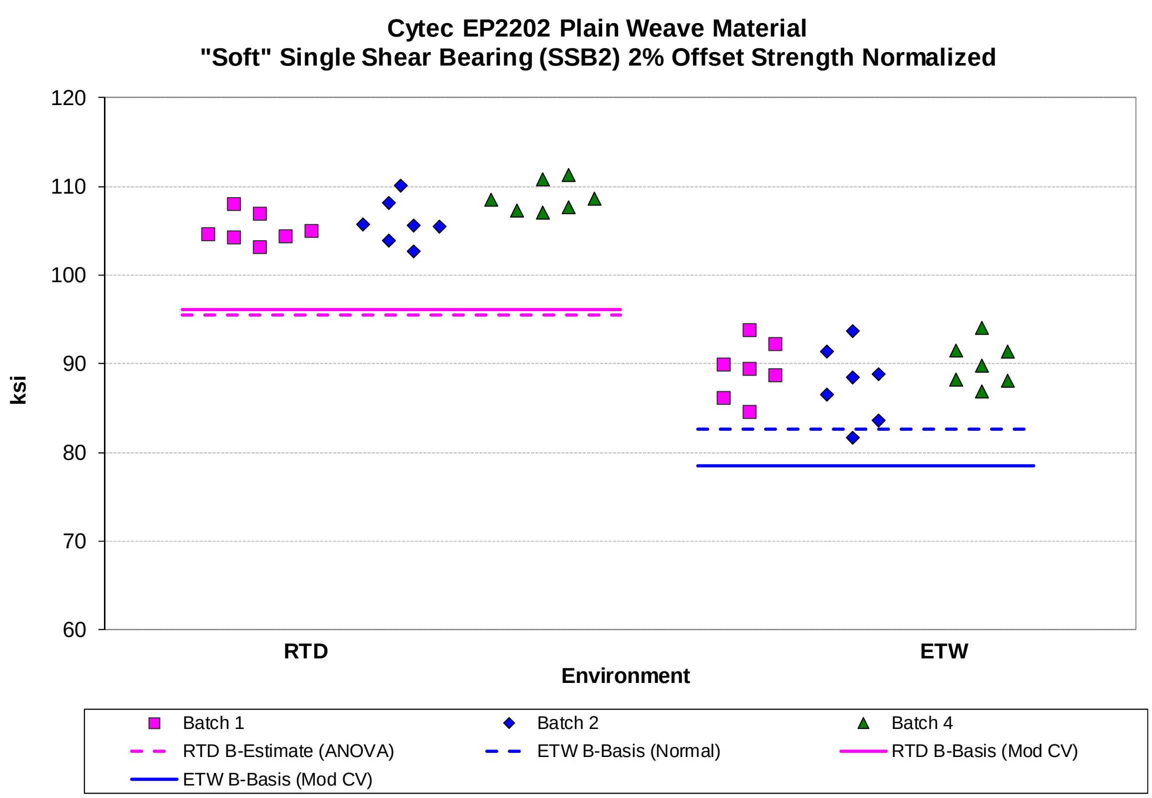

Figure 4-28: Batch plot for SSB2 2% offset normalized strength

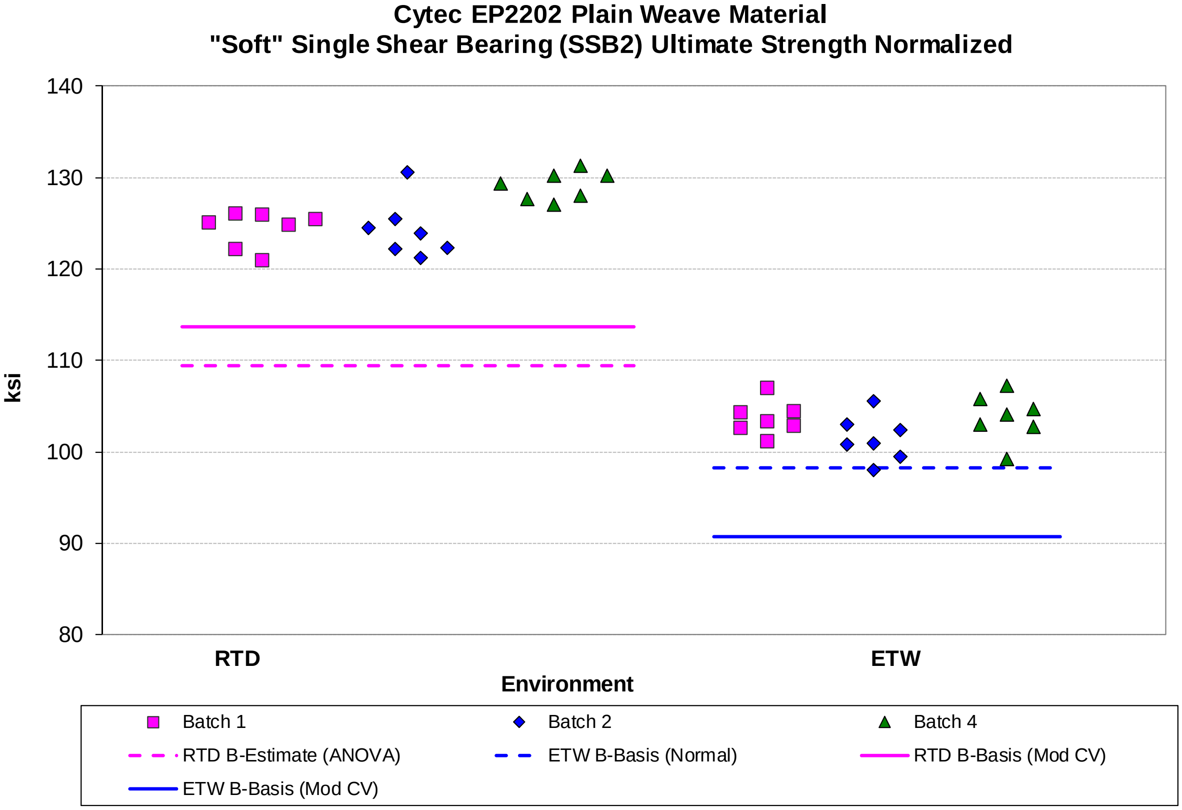

Figure 4-29: Batch plot for SSB2 normalized ultimate strength

Single Shear Bearing (SSB2) Normalized Strength Basis Values and Statistics						
Property	Initial Peak Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW
Mean	109.096	90.535	106.607	88.982	125.921	102.965
Stdev	0.601	6.186	2.476	3.352	3.188	2.471
CV	0.551	6.832	2.323	3.767	2.532	2.400
Modified CV	6.000	7.416	6.000	6.000	6.000	6.000
Min	108.670	86.161	102.617	81.600	121.000	97.941
Max	109.521	94.909	111.243	94.055	131.323	107.286
No. Batches	1	2	3	3	3	3
No. Spec.	2	2	21	21	21	21
Basis Values and Estimates						
B-basis Value	NA			82.597		98.258
B-Estimate			95.490		109.398	
A-Estimate			87.555	78.045	97.603	94.902
Method			ANOVA	Normal	ANOVA	Normal
Modified CV Basis Values and Estimates						
B-basis Value	NA		96.157	78.532	113.680	90.724
A-Estimate			88.975	71.350	105.267	82.312
Method			pooled	pooled	pooled	pooled

Table 4-39: Statistics and Basis Values for SSB2 Normalized Strength Data

Single Shear Bearing (SSB2) As-measured Strength Basis Values and Statistics						
Property	Initial Peak Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW
Mean	112.918	91.228	108.397	90.289	128.040	104.471
Stdev	0.809	5.746	3.169	3.721	4.130	2.829
CV	0.717	6.298	2.923	4.121	3.225	2.708
Modified CV	6.000	7.149	6.000	6.061	6.000	6.000
Min	112.346	87.165	103.275	81.466	121.932	99.232
Max	113.490	95.291	114.542	97.309	135.764	109.253
No. Batches	1	2	3	3	3	3
No. Spec.	2	2	21	21	21	21
Basis Values and Estimates						
B-basis Value	NA			83.201		
B-Estimate			90.955		103.969	93.331
A-Estimate			78.504	78.147	86.785	85.380
Method			ANOVA	Normal	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	NA		97.736	79.629	115.604	92.035
A-Estimate			90.410	72.302	107.057	83.488
Method			pooled	pooled	pooled	pooled

Table 4-40: Statistics and Basis Values for SSB2 As-measured Strength Data

4.28 "40/20/40" Single-Shear Bearing 3 (SSB3)

The Single-Shear Bearing data is normalized, so both normalized and as-measured data is provided. There was insufficient data for the initial peak strength property to meet the CMH17 Rev G requirements, so only estimates of B-basis values are provided for that property. Pooling across the two environmental conditions was acceptable for the 2% offset strength (modified CV values only) and ultimate strength properties.

The RTD datasets for 2% offset strength, both normalized and as-measured, and the ETW dataset for ultimate strength as-measured failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that CMH-17 Rev G guidelines required using the ANOVA analysis. With data from fewer than five batches available, these are considered estimates. 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 to compute the modified CV basis values.

There were three outliers. The smallest value in batch four of the RTD ultimate strength dataset was an outlier for batch four, but not for the RTD condition. It was an outlier for both the normalized and as-measured RTD datasets. The largest value in batch four of the ETW ultimate strength dataset was an outlier for both batch four and the ETW condition. It was an outlier for both the normalized and as-measured ETW datasets. The largest value in batch four of the ETW initial peak dataset was an outlier for batch four but not the ETW condition. It was an outlier for the as-measured dataset but not for the normalized dataset. All three outliers were retained for this analysis.

Statistics, basis values and estimates are given for the SSB3 normalized strength data in Table 4-41 and the as-measured strength data in Table 4-42. The normalized data, B-estimates and B-basis values are shown graphically for the initial peak strength and 2% offset strength in Figure 4-30 and for ultimate strength in Figure 4-31.

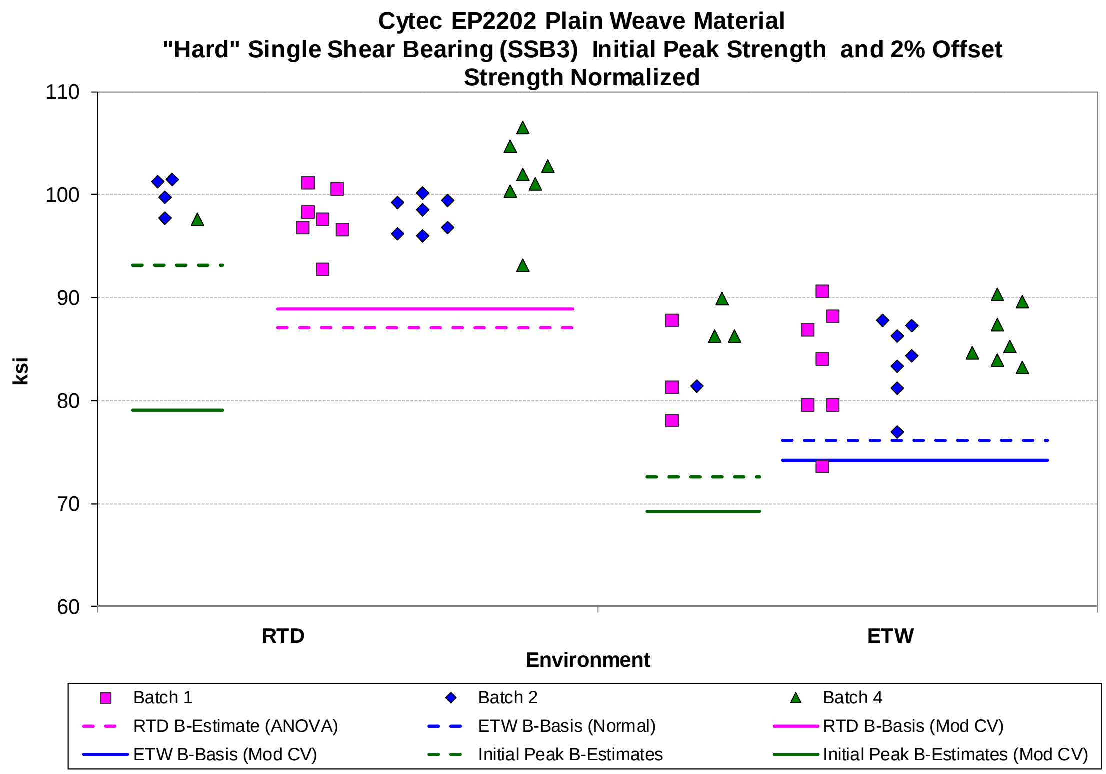

Figure 4-30: Batch plot for SSB3 normalized initial peak and 2% offset strength

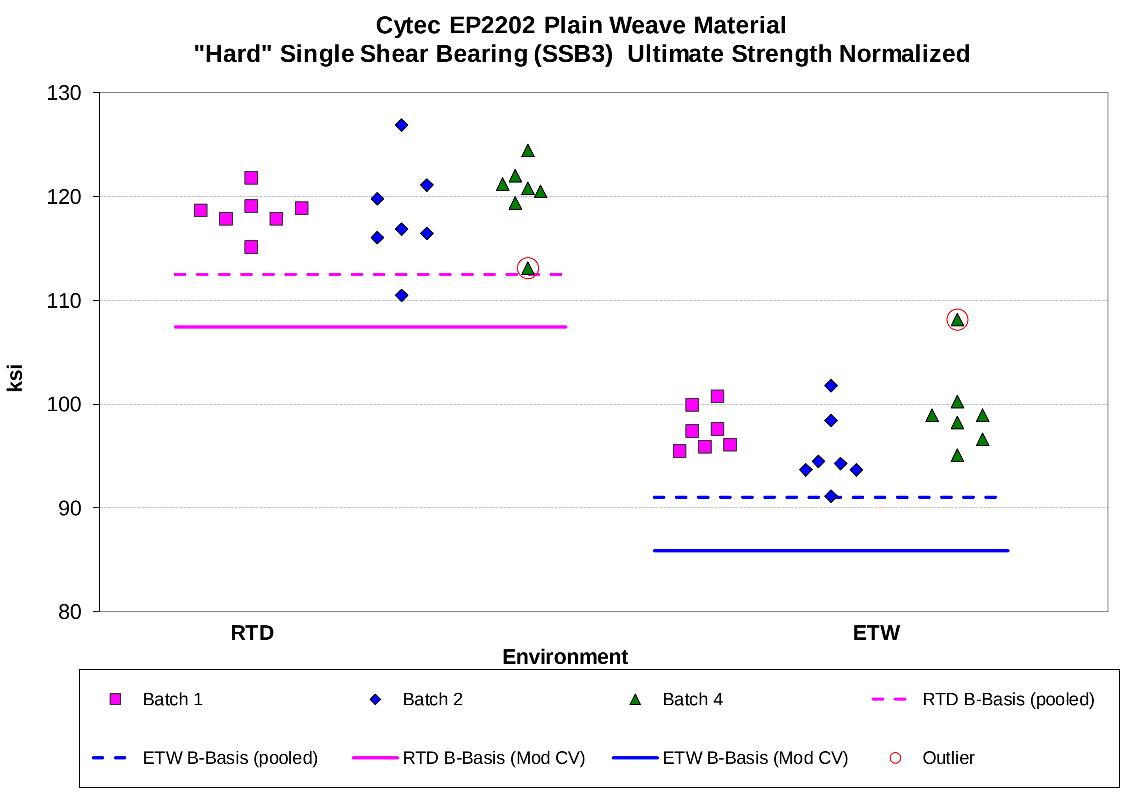

Figure 4-31: Batch plot for SSB3 normalized ultimate strength

Single Shear Bearing (SSB3) Normalized Strength Basis Values and Statistics						
Property	Initial Peak Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW
Mean	99.545	84.414	99.087	84.480	118.984	97.480
Stdev	1.864	4.247	3.427	4.389	3.667	3.634
CV	1.873	5.031	3.459	5.195	3.082	3.728
Modified CV	6.000	6.516	6.000	6.598	6.000	6.000
Min	97.621	78.030	92.765	73.630	110.490	91.198
Max	101.465	89.917	106.475	90.600	126.896	108.119
No. Batches	2	3	3	3	3	3
No. Spec.	5	7	21	21	21	21
Basis Values and Estimates						
B-basis Value				76.119	112.508	91.004
B-Estimate	93.173	72.622	87.087			
A-Estimate	88.545	64.326	78.523	70.159	108.057	86.553
Method	Normal	Normal	ANOVA	Normal	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value			88.866	74.259	107.408	85.904
B-Estimate	79.129	69.237				
A-Estimate	65.121	58.847	81.841	67.234	99.453	77.949
Method	Normal	Normal	pooled	pooled	pooled	pooled

Table 4-41: Statistics and Basis Values for SSB3 Normalized Strength Data

Single Shear Bearing (SSB3) As-measured Strength Basis Values and Statistics						
Property	Initial Peak Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW
Mean	101.600	85.157	100.931	85.572	121.192	98.735
Stdev	1.678	4.744	3.907	4.804	4.127	4.165
CV	1.652	5.571	3.871	5.614	3.406	4.218
Modified CV	6.000	6.785	6.000	6.807	6.000	6.109
Min	99.751	78.304	93.710	73.888	112.245	91.669
Max	103.578	92.116	109.240	92.535	129.794	110.810
No. Batches	2	3	3	3	3	3
No. Spec.	5	7	21	21	21	21
Basis Values and Estimates						
B-basis Value				76.421	113.330	
B-Estimate	95.863	71.986	83.238			84.124
A-Estimate	91.696	62.719	70.610	69.897	107.724	73.697
Method	Normal	Normal	ANOVA	Normal	Normal	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value			90.392	75.034	109.343	86.886
B-Estimate	80.762	69.213				
A-Estimate	66.466	58.297	83.149	67.791	101.199	78.742
Method	Normal	Normal	pooled	pooled	pooled	pooled

Table 4-42: Statistics and Basis Values for SSB3 As-measured Strength Data

4.29 Compression After Impact 1 (CAI1)

The CAI data is normalized, so both normalized and as-measured data is provided. Testing was done only in the RTD condition. The RTD datasets, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that CMH-17 Rev G guidelines required using the ANOVA analysis. With data from fewer than five batches available, these are considered estimates. When these datasets were transformed according to the assumptions of the modified CV method, they did not pass the ADK test, so only estimates can be provided for the modified CV basis values.

Summary statistics are presented in Table 4-43 and the data are displayed graphically in Figure 4-32. There were no outliers.

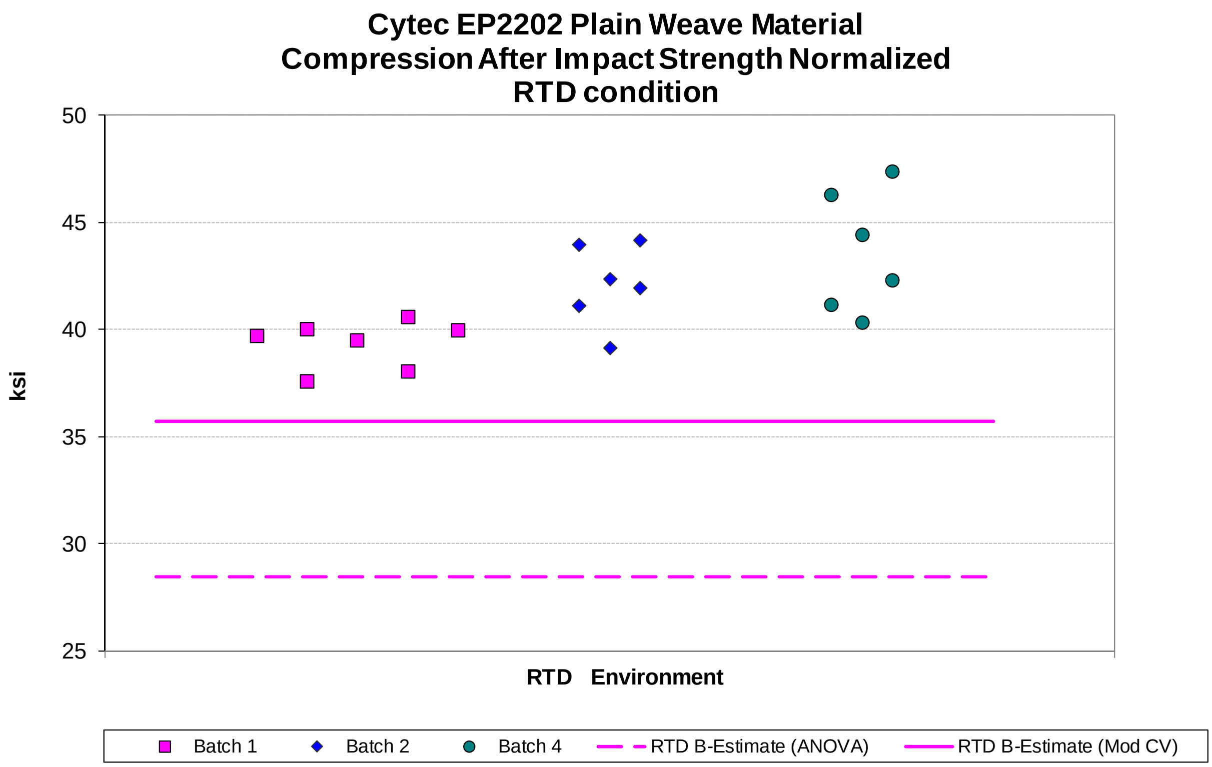

Figure 4-32: Plot for Compression After Impact normalized strength

Compression After Impact Strength (ksi)		
	Normalized	As-measured
Env	RTD	RTD
Mean	41.582	42.250
Stdev	2.666	2.854
CV	6.411	6.755
Modified CV	7.205	7.377
Min	37.609	37.889
Max	47.401	48.435
No. Batches	3	3
No. Spec.	19	19
Basis Value Estimates		
B-Estimate	28.461	27.349
A-Estimate	19.100	16.718
Method	ANOVA	ANOVA
Modified CV Basis Value Estimates		
B-Estimate	35.743	36.175
A-Estimate	31.602	31.867
Method	Normal	Normal

Table 4-43: Statistics for Compression After Impact Strength Data

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

The ILT and CBS data is not normalized. Basis values are not computed for these properties. However the summary statistics are presented in Table 4-44 and the data are displayed graphically in Figure 4-33. Only one batch of material was tested. There were no outliers.

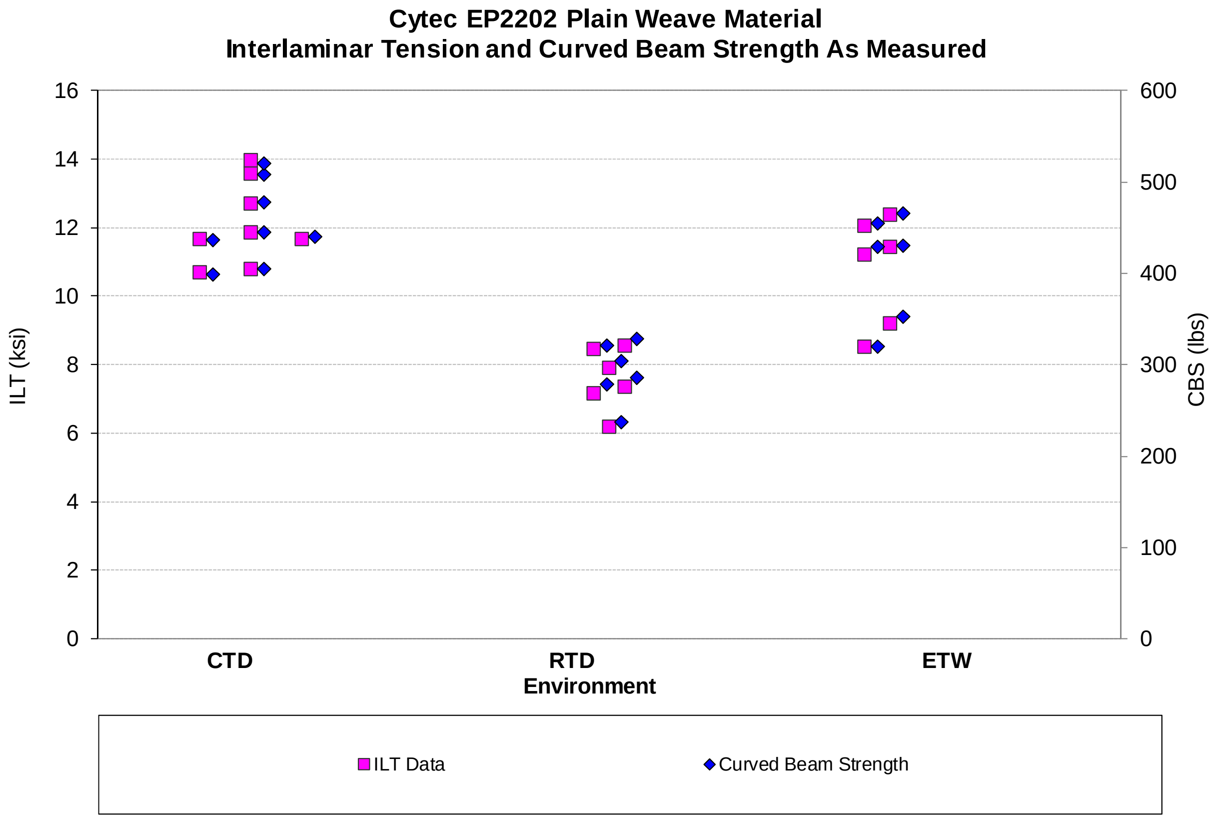

Figure 4-33: Plot for Interlaminar Tension and Curved Beam strength

Interlaminar Tension (ILT) and Curved Beam Strength (CBS) Statistics						
	ILT (ksi)			CBS (lb)		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	12.115	7.603	10.803	453.902	292.539	408.663
Stdev	1.207	0.889	1.565	44.553	33.354	58.715
CV	9.959	11.696	14.484	9.816	11.402	14.368
Modified CV	9.959	11.696	14.484	9.816	11.402	14.368
Min	10.691	6.200	8.536	399.216	237.177	320.086
Max	13.985	8.554	12.383	520.781	328.729	465.712
No. Batches	1	1	1	1	1	1
No. Spec.	8	6	6	8	6	6

Table 4-44: 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 working draft CMH-17 Rev G. 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-2014-022.

Outliers for which no causes could be identified are listed in Table 5-1

Test	Condition	Batch	Specimen Number	Normalized Strength	Strength As-measured	High/ Low	Batch Outlier	Condition Outlier
WC	RTD	2	EPBLB213A	94.415	Not an outlier	Low	No	Yes
WT	CTD	1	EPBJA117B	Not an outlier	112.499	Low	Yes	No
FC	RTD	1	EPBZA112A	113.378	Not an outlier	High	Yes	No
FT	RTD	4	EPBUD211A	110.539	114.529	Low	Yes	No
IPS - 5% Strain	CTD	3	EPBNC119B	NA	17.872	High	Yes	No
IPS - 5% Strain	RTD	2	EPBNB114A	NA	13.551	Low	Yes	No
SBS	RTD	1	EPBQA112A	NA	14.185	High	Yes	Yes
SBS	RTD	3	EPBQC212A	NA	13.095	High	Yes	No
SBS	ETW	1	EPBQA11BD	NA	8.213	Low	Yes	No
SBS	ETW	3	EPBQC21AD	NA	8.525	High	Yes	No
UNT2	RTD	2	EPBBB111A	Not an outlier	61.841	High	No	Yes
UNT2	ETW	1	EPBBA11ED	Not an outlier	48.449	Low	Yes	No
UNT3	CTD	2	EPBCB119B	105.959	108.125	High	Yes	No
UNC2	RTD	4	EPBXD112A	63.938	Not an outlier	High	Yes	No
UNC3	ETW	1	EPBYA11ED	72.824	73.436	High	Yes	No
OHT3	CTD	1	EPBFA119B	Not an outlier	42.561	Low	Yes	No
OHT3	CTD	4	EPBFD217B	47.558	48.632	Low	Yes	No
OHT3	RTD	4	EPBFD212A	47.054	48.009	Low	Yes	No
OHC1	ETW	4	EPBGD117D	33.750	34.605	Low	Yes	No
OHC2	ETW	1	EPBHA11AD	30.656	30.600	Low	Yes	Yes - Norm No - As-meas
OHC2	RTD	3	EPBHC114A	Not an outlier	40.938	Low	Yes	No
OHC3	RTD	4	EPBID211A	47.876	Not an outlier	High	Yes	No
FHC1	RTD	1	EPB7A214A	65.840	65.895	Low	Yes	No
FHC1	RTD	2	EPB7B215A	67.201	68.576	Low	Yes	No
FHC1	RTD	4	EPB7D211A	78.234	80.021	High	Yes	No
FHC3	RTD	1	EPB9A111A	80.680	81.519	High	No	Yes
SSB1-Ultimate Str.	ETW	1	EPB1A215D	120.016	120.465	High	No	Yes
SSB3-Ultimate Str.	RTD	4	EPB3D114A	113.082	116.363	Low	Yes	No
SSB3-Ultimate Str.	ETW	4	EPB3D217D	108.119	110.810	High	Yes	Yes
SSB3-Initial Peak	ETW	4	EPB3D116D	89.917	Not an outlier	High	Yes	No

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
WC	RTD	2	EPBLB213A	94.415	Not an outlier	Low	No	Yes
WT	CTD	1	EPBJA117B	Not an outlier	112.499	Low	Yes	No
FC	RTD	1	EPBZA112A	113.378	Not an outlier	High	Yes	No
FT	RTD	4	EPBUD211A	110.539	114.529	Low	Yes	No
IPS - 5% Strain	CTD	3	EPBNC119B	NA	17.872	High	Yes	No
IPS - 5% Strain	RTD	2	EPBNB114A	NA	13.551	Low	Yes	No
SBS	RTD	1	EPBQA112A	NA	14.185	High	Yes	Yes
SBS	RTD	3	EPBQC212A	NA	13.095	High	Yes	No
SBS	ETW	1	EPBQA11BD	NA	8.213	Low	Yes	No
SBS	ETW	3	EPBQC21AD	NA	8.525	High	Yes	No
UNT2	RTD	2	EPBBB111A	Not an outlier	61.841	High	No	Yes
UNT2	ETW	1	EPBBA11ED	Not an outlier	48.449	Low	Yes	No
UNT3	CTD	2	EPBCB119B	105.959	108.125	High	Yes	No
UNC2	RTD	4	EPBXD112A	63.938	Not an outlier	High	Yes	No
UNC3	ETW	1	EPBYA11ED	72.824	73.436	High	Yes	No
OHT3	CTD	1	EPBFA119B	Not an outlier	42.561	Low	Yes	No
OHT3	CTD	4	EPBFD217B	47.558	48.632	Low	Yes	No
OHT3	RTD	4	EPBFD212A	47.054	48.009	Low	Yes	No
OHC1	ETW	4	EPBGD117D	33.750	34.605	Low	Yes	No
OHC2	ETW	1	EPBHA11AD	30.656	30.600	Low	Yes	Yes - Norm No - As-meas
OHC2	RTD	3	EPBHC114A	Not an outlier	40.938	Low	Yes	No
OHC3	RTD	4	EPBID211A	47.876	Not an outlier	High	Yes	No
FHC1	RTD	1	EPB7A214A	65.840	65.895	Low	Yes	No
FHC1	RTD	2	EPB7B215A	67.201	68.576	Low	Yes	No
FHC1	RTD	4	EPB7D211A	78.234	80.021	High	Yes	No
FHC3	RTD	1	EPB9A111A	80.680	81.519	High	No	Yes
SSB1-Ultimate Str.	ETW	1	EPB1A215D	120.016	120.465	High	No	Yes
SSB3-Ultimate Str.	RTD	4	EPB3D114A	113.082	116.363	Low	Yes	No
SSB3-Ultimate Str.	ETW	4	EPB3D217D	108.119	110.810	High	Yes	Yes
SSB3-Initial Peak	ETW	4	EPB3D116D	89.917	Not an outlier	High	Yes	No

Table 5-1: List of Outliers

6. References

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