Cytec Cycom 5215 T650 3K70PW Fabric 38%RC Qualification Statistical Analysis Report

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1. Introduction

This report contains statistical analysis of the Cytec Cycom 5215 T650 3K70PW 38% RC Fabric material property data published in NCAMP Test Report CAM-RP-2010-067 N/C. The lamina and laminate material property data have been generated with FAA oversight through FAA Special Project Number SP4612WI-Q and also meet the requirements outlined in NCAMP Standard Operating Procedure NSP 100. The test panels, test specimens, and test setups have been conformed by the FAA and the testing has been witnessed by the FAA.

B-Basis values, A-estimates, and B-estimates were calculated using a variety of techniques that are detailed in section two. The qualification material was procured to NCAMP Material Specification NMS 323/3 Rev A dated July 16, 2007. The qualification test panels were fabricated per NCAMP Process Specification NPS 81323 Rev A dated July 16, 2007. The panels were fabricated by Cytec Engineered Materials at 1440 N. Kraemer Blvd, Anaheim, CA 92806. The NCAMP Test Plan NTP 3623Q1 Rev. A was used for this qualification program. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas.

Basis numbers are labeled as 'values' when the data meets all the requirements of 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 323/3. NMS 323/3 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 323/3. NMS 323/3* 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	Temperature	Abbreviation
Cold Temperature Dry	−65°±5°F	CTD
Room Temperature Dry	70°±10°F	RTD
Elevated Temperature Dry	180°±5°F	ETD
Elevated Temperature Wet	180°±5°F	ETW

Table 1-3: Environmental Conditions Abbreviations

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

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

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

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2010-067 N/C.

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: basis value = $\bar{X} - kS$ 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. $$S_p = \sqrt{\frac{\sum_{i=1}^{k} (n_i - 1) S_i^2}{\sum_{i=1}^{k} (n_i - 1)}}$$ **Equation 4**

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

2.1.2.2 Pooled Coefficient of Variation

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

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

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.

Basis Values:

$$A-basis = \bar{X} - K_a S$$
$$B-basis = \bar{X} - K_b S \qquad \textbf{Equation 6}$$

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

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

$$f = N - r$$

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

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

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

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

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

2.1.4 Modified Coefficient of Variation

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

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

This is converted to percent by multiplying by 100%.

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

$$S^* = CV^* \cdot \bar{X}$$ **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 $S_i^* = CV^* \cdot \bar{X}_i$ for each batch. Transform the individual data values (X_{ij}) in each batch as follows:

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

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

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.

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

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

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

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

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.

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

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

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

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

2.1.6 The k-Sample Anderson Darling Test for Batch Equivalency

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

The k-sample Anderson-Darling test statistic is:

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

Where

n_i = the number of test specimens in each batch
$n = n_1+n_2+\ldots+n_k$
h_j = the number of values in the combined samples equal to $z_{(j)}$
H_j = the number of values in the combined samples less than $z_{(j)}$ plus ½ the number of values in the combined samples equal to $z_{(j)}$
F_{ij} = the number of values in the i^{th} group which are less than $z_{(j)}$ plus ½ the number of values in this group which are equal to $z_{(j)}$.

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

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

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

$$\sigma_n^2 = VAR(ADK) = \frac{an^3 + bn^2 + cn + d}{(n-1)(n-2)(n-3)(k-1)^2}$$ **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:

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

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

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

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

The Anderson Darling test statistic (AD) is:

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

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

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

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

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

$$\hat{\alpha}\hat{\beta}\mathrm{n} - \frac{\hat{\beta}}{\hat{\alpha}^{\hat{\beta}-1}}\sum_{i=1}^{n} x_i^{\hat{\beta}} = 0$$ **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

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

The Anderson-Darling test statistic is

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

and the observed significance level is

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

where

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

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

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

where

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

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

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

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 $(0 < a < b < \infty)$ is given by the area under the normal distribution between ln(a) and ln(b).

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

2.2.2.4.1 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 ith 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:

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

For A-Basis values:

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

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

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

2.2.3.2 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:

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

The A-basis value is:

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

where $x_{(n)}$ is the largest data value, $x_{(1)}$ is the smallest, and $x_{(r)}$ is the r^{th} largest data value. The values of r and k depend on n and are listed in Table 2-3. 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 $\left(n_i, \bar{x}_i, s_i^2\right)$ 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:

$$SSB = \sum_{i=1}^{k} n_i \bar{x}_I^2 - n\bar{x}^2$$ **Equation 52**

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

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

$$SSE = SST - SSB$$ **Equation 54**

Next, the mean sums of squares are computed:

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

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

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

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

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

$$S = \sqrt{\frac{MSB}{n'} + \left(\frac{n'-1}{n'}\right) MSE}$$ **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.

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

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

Table 2-5: 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 tables Table 3-1and 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® 5215 T650 3K70PW

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	5% Strain
CTD (-65°F)	B-basis	99.618	99.680	101.382	90.696	9.612	7.637	NA:I
	Mean	111.867	110.386	113.390	102.150	10.518	8.623	12.729
	CV	6.000	6.927	6.046	7.586	6.000	6.000	8.000
RTD (70°F)	B-basis	107.263	85.319	105.511	83.329	9.050	5.426	
	Mean	119.511	96.306	117.519	94.783	9.948	6.127	
	CV	6.000	6.000	6.000	6.368	6.000	6.000	
ETD (180°F)	B-basis		69.704		67.526	7.262		
	Mean		80.509		79.089	8.168		
	CV		7.748		7.340	6.000		
ETW (180°F)	B-basis	110.324	44.561	103.422	NA:A	5.241	3.182	5.321
	Mean	122.572	55.223	115.430	55.836	6.143	3.607	6.013
	CV	6.000	9.372	6.000	9.568	6.000	6.187	6.037

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® 5215 T650 3K70PW

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	38.622		42.124		71.756				
		Mean	43.400		47.342		80.250				
		CV	6.000		6.482		6.000				
	RTD (70°F)	B-basis	40.100	35.776	43.486	58.049	75.886	59.073	83.738	97.614	8.314
		Mean	44.879	40.395	48.704	66.928	84.380	70.048	93.377	108.568	9.388
		CV	6.000	6.000	6.000	6.000	6.000	8.224	6.463	6.291	6.000
	ETW (180°F)	B-basis	44.890	28.263	45.804	42.966	72.464	45.818	65.032	79.826	5.559
		Mean	49.668	31.212	51.023	49.056	80.959	51.733	74.671	90.780	6.277
		CV	6.000	4.225	6.000	6.000	6.000	6.000	6.377	6.000	6.000
10/80/10	CTD (-65°F)	B-basis	35.911		39.775		48.192				
		Mean	39.744		43.975		53.463				
		CV	6.000		6.000		6.000				
	RTD (70°F)	B-basis	33.899	31.011	37.435	43.411	47.677	44.556	80.116	96.540	
		Mean	37.732	34.269	41.635	47.970	52.904	49.072	91.095	107.520	
		CV	6.000	6.000	6.000	6.000	6.000	6.013	7.408	6.185	
	ETW (180°F)	B-basis	29.204	23.218	31.149	31.947	40.468	29.916	65.147	83.984	
		Mean	33.036	26.476	35.348	36.466	45.739	34.433	76.126	94.965	
		CV	6.000	6.000	6.000	6.000	6.000	6.000	7.329	6.000	
40/20/40	CTD (-65°F)	B-basis	44.829		47.478		84.509				
		Mean	50.662		53.398		95.012				
		CV	6.335		6.000		6.127				
	RTD (70°F)	B-basis	47.998	38.587	49.566	58.568	91.625	63.320	73.655	88.018	
		Mean	53.832	42.650	55.486	66.623	102.084	70.603	84.027	98.749	
		CV	6.000	6.000	6.249	7.009	6.015	6.391	7.120	7.082	
	ETW (180°F)	B-basis	55.220	28.180	53.899	43.587	93.926	48.664	59.722	71.499	
		Mean	61.054	32.243	59.819	51.642	104.429	55.947	70.094	82.230	
		CV	6.000	6.165	6.000	8.062	6.000	6.536	8.150	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® 5215 T650 3K70PW
Prepreg Material Specification: NMS 323/3

CYTEC CYCOM® 5215 3K70PW
Lamina Properties Summary

Fabric: T650 3K70PW **Resin:** CYTEC CYCOM® 5215

Tg(dry): 330.82°F **Tg(wet):** 250.69°F **Tg METHOD:** DMA (SRM 18R-94)

PROCESSING: NPS 81323 Baseline "C" Cure Cycle

Date of fiber manufacture	3/2006 to 6/2006	**Date of testing**	Dec. 2010 to Sept. 2010
Date of resin manufacture	9/2006 to 12/2006	**Date of data submittal**	5/1/2011
Date of prepreg manufacture	12/1/2006	**Date of analysis**	Mar. 2012 to April 2012
Date of composite manufacture	February 2009		

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}	104.244	100.549	113.264	112.304	108.608	121.323				98.029	111.036	123.751
(ksi)	(104.705)	(99.618)	(111.867)	(112.349)	(107.263)	(119.511)				(115.410)	(110.324)	(122.572)
E_1^t			9.452			9.239						9.216
(Msi)			(9.334)			(9.096)						(9.144)
ν_{12}^t			0.057			0.052						0.047
F_2^{tu}	83.179	101.851	115.124	89.704	106.894	120.167				68.623	101.640	117.561
(ksi)	(93.508)	(101.382)	(113.390)	(110.126)	(105.511)	(117.519)				(96.485)	(103.422)	(115.430)
E_2^t			9.474			9.339						9.302
(Msi)			(9.330)			(9.131)						(9.138)
F_1^{cu}	83.495	101.725	112.827	89.447	87.525	98.917	73.234	71.349	82.553	47.099	45.244	56.299
(ksi)	(101.084)	(99.680)	(110.386)	(86.760)	(85.319)	(96.306)	(71.121)	(69.704)	(80.509)	(45.959)	(44.561)	(55.223)
E_1^c			9.230			8.546			8.521			8.663
(Msi)			(9.038)			(8.328)			(8.321)			(8.480)
ν_{12}^c			0.054			0.054			0.049			0.051
F_2^{cu}	92.550	91.244	102.837	85.572	84.266	95.859	69.972	68.653	80.357	31.872	NA	56.666
(ksi)	(92.033)	(90.696)	(102.150)	(84.665)	(83.329)	(94.783)	(68.875)	(67.526)	(79.089)	(32.101)	NA	(55.836)
E_2^c			8.493			8.311			8.196			8.508
(Msi)			(8.432)			(8.224)			(8.101)			(8.439)
ν_{21}^c			0.063			0.052			0.049			0.045
$F_{12}^{s0.2\%}$ (ksi)	7.815	7.637	8.623	5.710	5.426	6.127				3.323	3.182	3.607
$F_{12}^{s5\%}$ (ksi)	NA	6.459	12.729							5.546	5.321	6.013
G_{12}^s (Msi)			0.679			0.565						0.389
SBS (ksi)	9.894	9.612	10.518	9.329	9.050	9.948	7.822	7.262	8.168	4.987	5.241	6.143

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

Prepreg Material: CYTEC CYCOM® 5215 T650 3K70PW
Prepreg Material Specification: NMS 323/3

CYTEC CYCOM® 5215 3K70PW Laminate Properties Summary

Fabric: T650 3K70PW **Resin:** CYTEC CYCOM® 5215

Tg(dry): 330.82°F **Tg(wet):** 250.69°F **Tg METHOD:** DMA (SRM 18R-94)

PROCESSING: NPS 81323 Baseline "C" Cure Cycle

Date of fiber manufacture	3/2006 to 6/2006	**Date of testing**	Dec. 2010 to Sept. 2010
Date of resin manufacture	9/2006 to 12/2006	**Date of data submittal**	5/1/2011
Date of prepreg manufacture	12/1/2006	**Date of analysis**	Mar. 2012 to April 2012
Date of composite manufacture	February 2009		

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	Test Condition	Unit	Quasi Isotropic 25/50/25 B-value	Quasi Isotropic 25/50/25 Mod. CV B-value	Quasi Isotropic 25/50/25 Mean	"Soft" 10/80/10 B-value	"Soft" 10/80/10 Mod. CV B-value	"Soft" 10/80/10 Mean	"Hard" 40/20/40 B-value	"Hard" 40/20/40 Mod. CV B-value	"Hard" 40/20/40 Mean
OHT (normalized)	Strength	CTD	ksi	41.197	38.622	43.400	35.659	35.911	39.744	47.256	44.829	50.662
		RTD	ksi	42.675	40.100	44.879	33.290	33.899	37.732	50.425	47.998	53.832
		ETW	ksi	45.447	44.890	49.668	29.720	29.204	33.036	57.648	55.220	61.054
OHC (normalized)	Strength	RTD	ksi	38.535	35.776	40.395	28.635	31.011	34.269	40.077	38.587	42.650
		ETW	ksi	28.263	NA	31.212	22.085	23.218	26.476	29.670	28.180	32.243
UNT (normalized)	Strength	CTD	ksi	61.696	71.756	80.250	44.060	48.192	53.463	75.503	84.509	95.012
	Modulus		Msi	---	---	6.630	---	---	4.383	---	---	8.256
	Strength	RTD	ksi	68.632	75.886	84.380	46.413	47.677	52.904	84.533	91.625	102.084
	Modulus		Msi	---	---	6.457	---	---	4.226	---	---	8.205
	Strength	ETW	ksi	67.588	72.464	80.959	43.588	40.468	45.739	92.906	93.926	104.429
	Modulus		Msi	---	---	6.314	---	---	3.744	---	---	8.080
UNC (normalized)	Strength	RTD	ksi	59.073	NA	70.048	41.743	44.556	49.072	65.073	63.320	70.603
	Modulus		Msi	---	---	5.942	---	---	3.924	---	---	7.396
	Poisson's Ratio			---	---	0.317	---	---	0.550	---	---	0.141
	Strength	ETW	ksi	48.328	45.818	51.733	32.623	29.916	34.433	50.417	48.664	55.947
	Modulus		Msi	---	---	5.840	---	---	3.613	---	---	7.387
	Poisson's Ratio			---	---	0.325	---	---	0.572	---	---	0.139
SBS1 (as measured)	Strength	RTD	ksi	8.945	8.314	9.388	---	---	---	---	---	---
		ETW	ksi	5.877	5.559	6.277	---	---	---	---	---	---
FHT (normalized)	Strength	CTD	ksi	42.866	42.124	47.342	42.926	39.775	43.975	49.574	47.478	53.398
		RTD	ksi	39.780	43.486	48.704	40.586	37.435	41.635	51.662	49.566	55.486
		ETW	ksi	43.744	45.804	51.023	34.299	31.149	35.348	49.130	53.899	59.819
FHC (normalized)	Strength	RTD	ksi	64.003	58.049	66.928	42.238	43.411	47.970	59.181	58.568	66.623
		ETW	ksi	45.998	42.966	49.056	34.794	31.947	36.466	44.200	43.587	51.642
Single Shear Bearing (normalized)	2% Offset Strength	RTD	ksi	70.232	83.738	93.377	79.268	80.116	91.095	74.305	73.655	84.027
		ETW	ksi	66.962	65.032	74.671	54.608	65.147	76.126	60.371	59.722	70.094
	Ultimate Strength	RTD	ksi	100.937	97.614	108.568	100.252	96.540	107.520	67.471	88.018	98.749
		ETW	ksi	83.148	79.826	90.780	87.696	83.984	94.965	76.162	71.499	82.230
CAI (normalized)	Strength	RTD	ksi	---	---	27.140	---	---	---	---	---	---
ILT (as measured)	Strength	CTD	ksi	---	---	6.957	---	---	---	---	---	---
		RTD	ksi	---	---	8.050	---	---	---	---	---	---
		ETW	ksi	---	---	3.148	---	---	---	---	---	---
CBS (as measured)	Strength	CTD	lb	---	---	282.179	---	---	---	---	---	---
		RTD	lb	---	---	334.188	---	---	---	---	---	---
		ETW	lb	---	---	129.896	---	---	---	---	---	---

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 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 (0º) Tension (WT)

The Warp Tension data is normalized, so both normalized and as-measured statistics are provided. There were no test failures for the normalized data, so it was pooled across all three environmental conditions to compute basis values and estimates. The as-measured data for the ETW condition failed the ADK test, but passed with the use of the modified CV method. A B-estimate computed using the ANOVA method was computed for the as-measured ETW data while the other two environmental conditions were pooled to compute the basis values. All three conditions were pooled to compute the modified CV basis values. There were no outliers.

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.

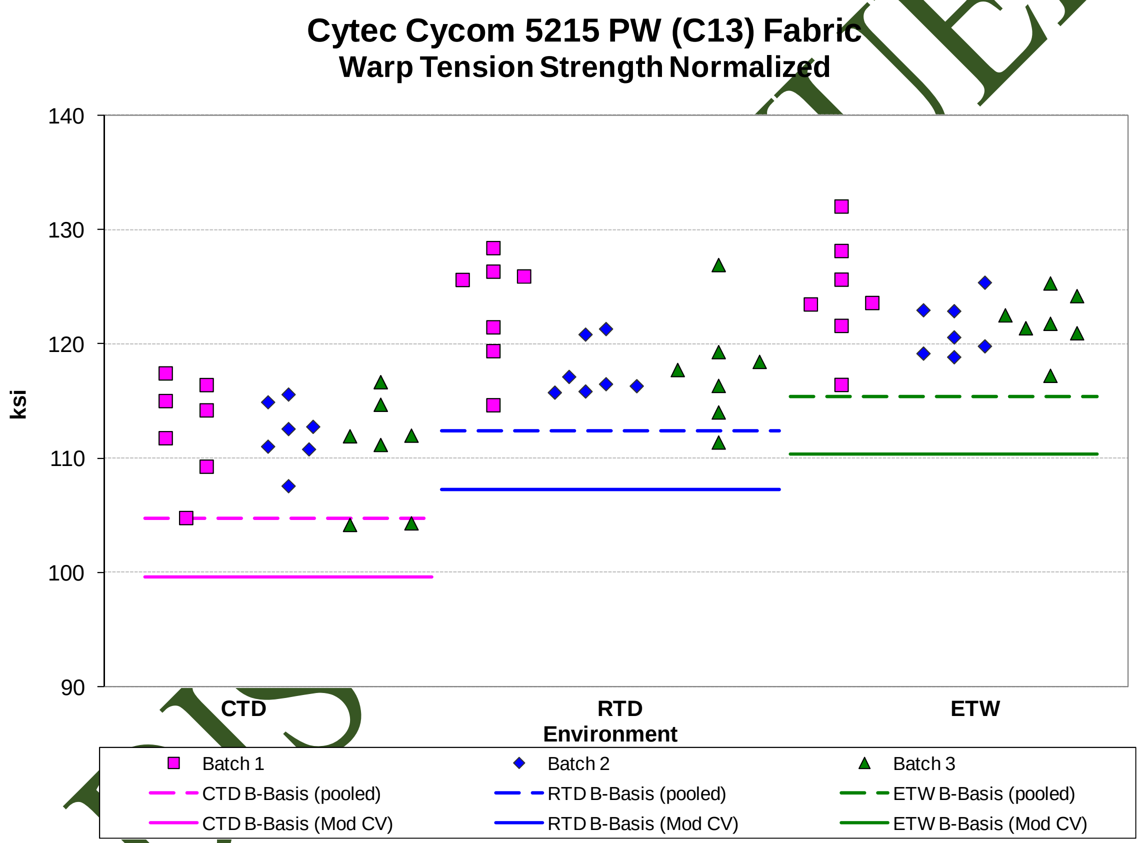

Figure 4-1 Batch plot for WT normalized strength

Warp Tension Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	111.867	119.511	122.572	113.264	121.323	123.751
Stdev	3.977	4.765	3.599	5.430	4.718	5.167
CV	3.555	3.987	2.937	4.794	3.889	4.175
Mod CV	6.000	6.000	6.000	6.397	6.000	6.088
Min	104.191	111.398	116.436	100.504	110.939	111.893
Max	117.442	128.405	132.047	123.031	132.298	134.108
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and/or Estimates						
B-basis Value	104.705	112.349	115.410	104.244	112.304	
B-Estimate						98.029
A-Estimate	99.867	107.511	110.572	98.040	106.100	79.668
Method	pooled	pooled	pooled	pooled	pooled	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	99.618	107.263	110.324	100.549	108.608	111.036
A-Estimate	91.344	98.989	102.050	91.959	100.019	102.447
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	9.334	9.096	9.144	9.452	9.239	9.216
Stdev	0.141	0.049	0.064	0.389	0.300	0.363
CV	1.511	0.534	0.697	4.111	3.244	3.944
Mod CV	6.000	6.000	6.000	6.055	6.000	6.000
Min	9.035	9.006	9.015	9.032	8.772	8.688
Max	9.539	9.192	9.266	10.141	9.675	9.916
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	22	21	21	22

Table 4-2: Statistics from WT Modulus Data

4.2 Fill (90º) Tension (FT)

The Fill Tension data is normalized, so both normalized and as-measured statistics are provided. The normalized data from CTD and ETW environmental conditions failed the ADK test, but passed with the use of the modified CV method. B-estimates were computed using the ANOVA method for the normalized CTD and ETW data. The normalized CTD data also failed Levene's test. Pooling all three environmental conditions was acceptable to compute modified CV basis values and estimates.

The as-measured data failed the ADK test for all three conditions; the as-measured data from the CTD and RTD conditions passed with the use of the modified CV method. The as-measured data from the CTD and ETW conditions also failed the normality test and the as-measured CTD data also failed Levene's test. B-estimates were computed using the ANOVA method. The CTD and RTD conditions could be pooled to compute the modified CV basis values. An estimate for the as-measured data from the ETW condition was prepared using the normal distribution. This estimate requires an override of both the ADK test result and the normality test. These failures were due to a large difference between the batch 1 and 2 results and the batch 3 results, which was largely eliminated by the normalization procedure. All strength values in batch 3 were higher than all strength values in batches 1 and 2, which were similar to each other. A check of the ADK and normality test results using only batches 1 and 2 showed that eliminating batch 3 eliminated those failures. An override of those tests results is therefore recommended and estimates of modified CV basis values were computed for the as-measured ETW data.

There were no outliers.

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.

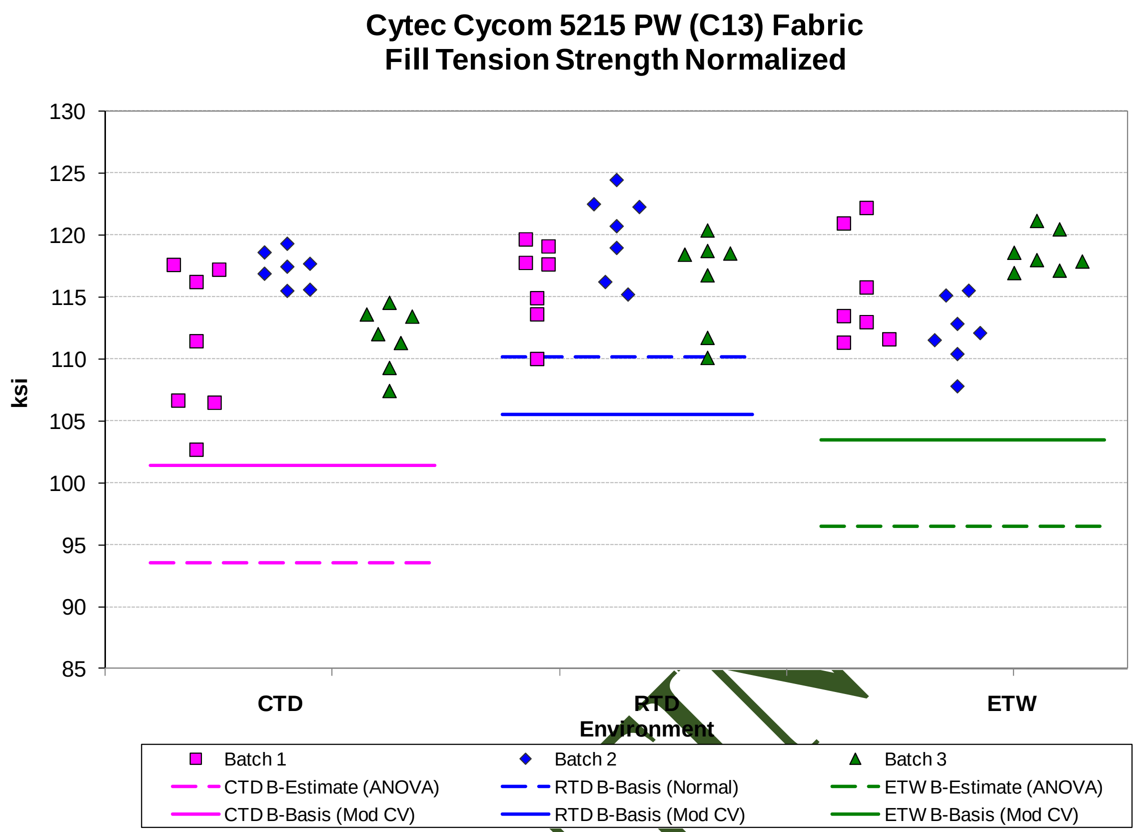

Figure 4-2: Batch Plot for FT normalized strength

Fill Tension Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	113.390	117.519	115.430	115.124	120.167	117.561
Stdev	4.641	3.881	3.998	5.663	5.453	7.304
CV	4.093	3.302	3.464	4.919	4.538	6.213
Mod CV	6.046	6.000	6.000	6.459	6.269	7.107
Min	102.702	110.025	107.817	101.560	108.566	108.441
Max	119.322	124.462	122.205	121.877	129.049	129.546
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value		110.126				
B-Estimate	93.508		96.485	83.179	89.704	68.623
A-Estimate	79.317	104.855	82.963	60.374	67.957	33.684
Method	ANOVA	Normal	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	101.382	105.511	103.422	101.851	106.894	
B-Estimate with override of ADK and normality Results						101.640
A-Estimate	93.271	97.400	95.311	92.723	97.766	90.300
Method	pooled	pooled	pooled	pooled	pooled	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	9.330	9.131	9.138	9.474	9.339	9.302
Stdev	0.180	0.148	0.134	0.367	0.383	0.406
CV	1.927	1.618	1.470	3.871	4.101	4.368
Mod CV	6.000	6.000	6.000	6.000	6.051	6.184
Min	9.034	8.801	8.894	8.960	8.702	8.770
Max	9.703	9.469	9.464	10.055	9.900	9.943
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21

Table 4-4: Statistics from FT Modulus Data

4.3 Warp (0º) Compression (WC)

The Warp Compression data is normalized, so both normalized and as-measured statistics are provided. There were no test failures for the normalized data, so it was pooled across all four environmental conditions to compute basis values and estimates. The as-measured data for the CTD condition failed the ADK test, but passed with the use of the modified CV method. A B-estimate computed using the ANOVA method for the as-measured CTD data while the other three environmental conditions were pooled to compute the basis values. All four conditions were pooled to compute the modified CV basis values. There were no outliers.

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.

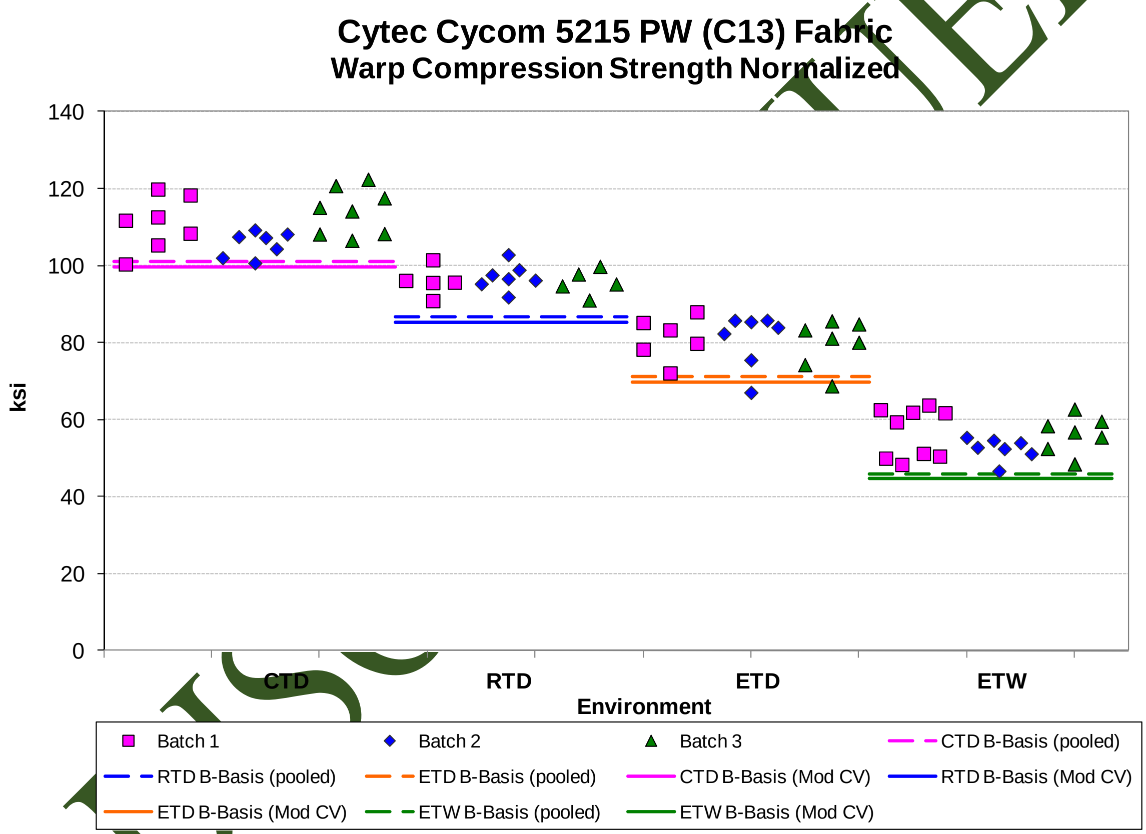

Figure 4-3 Batch plot for WC normalized strength

Warp Compression Strength Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	110.386	96.306	80.509	55.223	112.827	98.917	82.553	56.299
Stdev	6.461	3.307	6.035	5.176	6.888	3.791	6.379	5.347
CV	5.853	3.434	7.496	9.372	6.105	3.832	7.727	9.497
Mod CV	6.927	6.000	7.748	9.372	7.053	6.000	7.863	9.497
Min	100.375	90.872	67.049	46.652	100.665	92.470	68.544	47.110
Max	122.377	102.810	87.955	63.732	126.024	106.840	90.023	64.867
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	22	17	20	23	22	17	20	23
Basis Values and/or Estimates								
B-basis Value	101.084	86.760	71.121	45.959		89.447	73.234	47.099
B-Estimate					83.495			
A-Estimate	94.828	80.541	64.879	39.697	62.550	83.202	66.962	40.804
Method	pooled	pooled	pooled	pooled	ANOVA	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-basis Value	99.680	85.319	69.704	44.561	101.725	87.525	71.349	45.244
A-Estimate	92.480	78.161	62.520	37.354	94.260	80.103	63.900	37.771
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

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	9.038	8.328	8.321	8.480	9.230	8.546	8.521	8.663
Stdev	0.475	0.175	0.174	0.230	0.466	0.195	0.205	0.303
CV	5.254	2.101	2.088	2.717	5.051	2.281	2.406	3.497
Mod CV	6.627	6.000	6.000	6.000	6.525	6.000	6.000	6.000
Min	8.208	7.983	7.826	8.095	8.428	8.252	7.976	8.133
Max	9.761	8.608	8.551	8.961	10.010	8.886	8.906	9.263
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	24	26	21	21	24	26	21

Table 4-6: Statistics from WC Modulus Data

4.4 Fill (90º) Compression (FC)

The Fill Compression data is normalized, so both normalized and as-measured statistics are provided. The data from the CTD, RTD and ETD environmental conditions, both normalized and as-measured, met all requirements for pooling, so that method was used to compute basis values for those conditions. The data from the ETW environmental condition, both normalized and as-measured, failed the ADK test. The CV for the ETW data was over 8%, so the modified CV method could not be applied. Estimates of basis values for the ETW data were computed using the ANOVA method. In addition, estimates of basis values are provided for the ETW data with an override of the ADK test results. There were no outliers.

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.

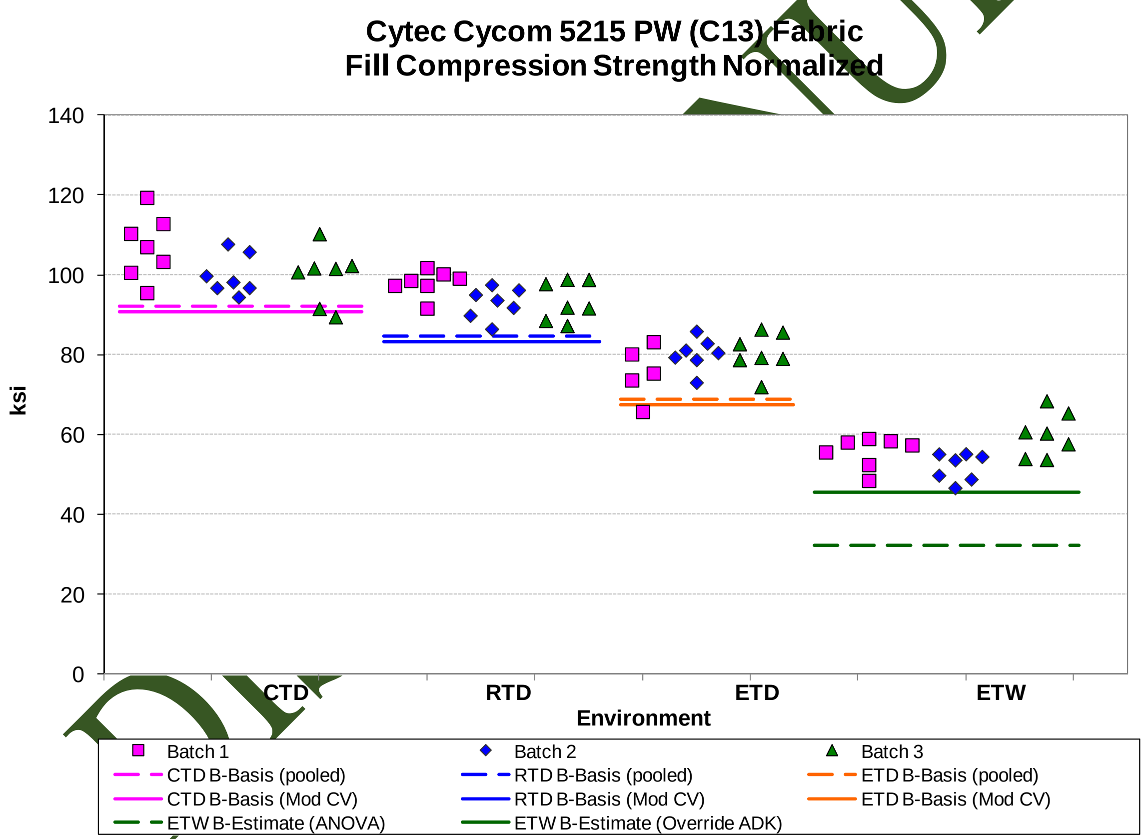

Figure 4-4: Batch Plot for FC normalized strength

Fill Compression Strength Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	102.150	94.783	79.089	55.836	102.837	95.859	80.357	56.666
Stdev	7.327	4.488	5.283	5.343	6.812	4.458	6.326	5.782
CV	7.173	4.736	6.680	9.568	6.624	4.651	7.872	10.204
Mod CV	7.586	6.368	7.340	9.568	7.312	6.325	7.936	10.204
Min	89.430	86.408	65.726	46.631	90.649	87.855	64.263	46.574
Max	119.332	101.731	86.332	68.386	116.239	103.040	89.845	70.216
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	21	19	21	21	21	19	21
Basis Values and/or Estimates								
B-basis Value	92.033	84.665	68.875		92.550	85.572	69.972	
B-Estimate				32.101				31.872
A-Estimate	85.189	77.821	62.049	15.161	85.592	78.614	63.031	14.175
Method	pooled	pooled	pooled	ANOVA	pooled	pooled	pooled	ANOVA
Modified CV Basis Values and/or Estimates								
B-basis Value	90.696	83.329	67.526		91.244	84.266	68.653	
A-Estimate	82.948	75.581	59.798		83.402	76.424	60.831	
Method	pooled	pooled	pooled		pooled	pooled	pooled	
Basis Value Estimates with override of ADK test result								
B-Estimate				45.658				45.651
A-Estimate				38.402				37.798
Method				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	8.432	8.224	8.101	8.439	8.493	8.311	8.196	8.508
Stdev	0.395	0.364	0.320	0.421	0.335	0.353	0.290	0.368
CV	4.690	4.422	3.949	4.986	3.941	4.253	3.542	4.326
Mod CV	6.345	6.211	6.000	6.493	6.000	6.126	6.000	6.163
Min	7.711	7.209	7.394	7.896	7.894	7.139	7.534	8.073
Max	9.041	8.733	8.482	9.367	8.930	8.790	8.650	9.309
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	23	24	20	21	23	24	20

Table 4-8: Statistics from FC Modulus Data

4.5 Short Beam Strength (SBS)

Short Beam Strength data is not normalized. The SBS data from the ETW environmental condition failed the ADK test, but passed with the modified CV transformation of the data. When the data from the CTD, RTD and ETD conditions was pooled, it failed Levene's test for equality of variance. The data from the CTD and RTD environmental conditions met all requirements for pooling, so that method was used to compute basis values for those conditions. The ETD basis values and estimates were computed separately using the single point method for the normal distribution. Estimates of basis values for the ETW data were computed using the ANOVA method. Pooling all four conditions was acceptable for computing the Mod CV basis values.

There was one outlier. It was the lowest value in batch three of the RTD data. It was an outlier for the RTD condition, but not for batch three. It was retained for this analysis.

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

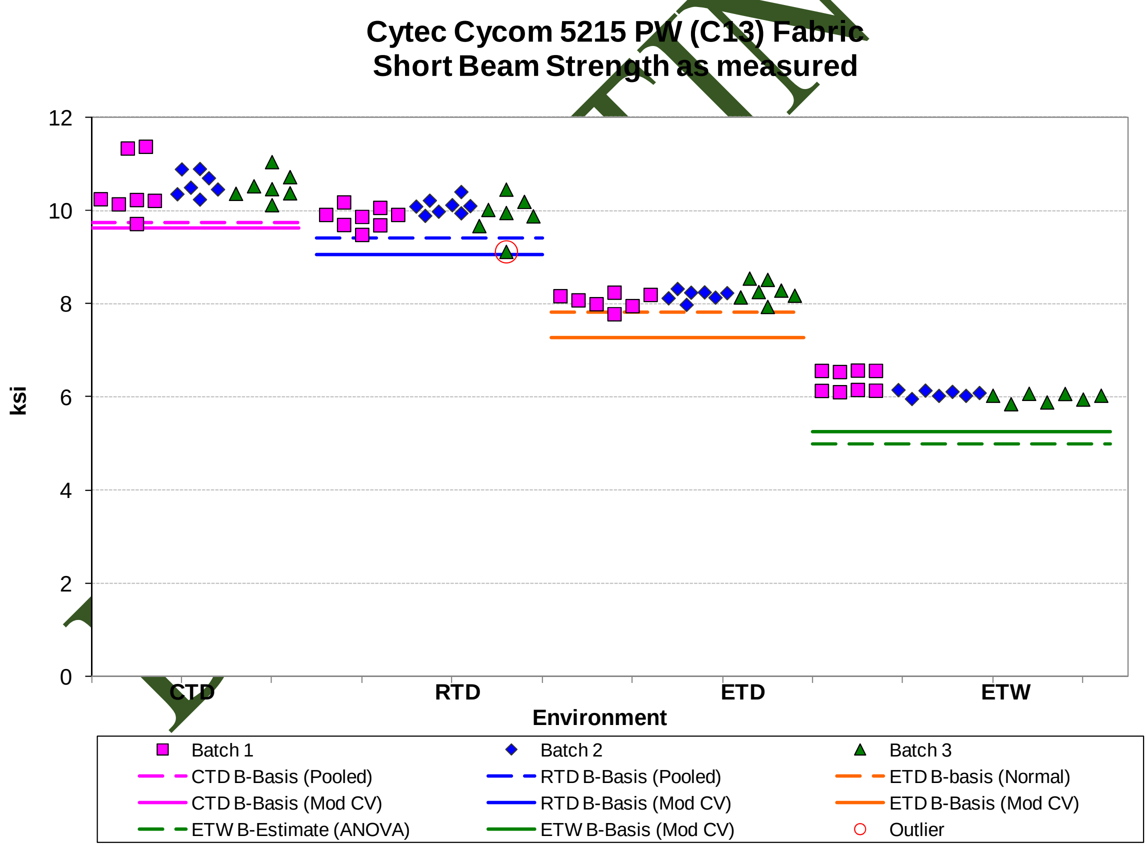

Figure 4-5: Batch plot for SBS as measured

Short Beam Strength (SBS) Basis Values and Statistics as measured				
Env	CTD	RTD	ETD	ETW
Mean	10.518	9.948	8.168	6.143
Stdev	0.411	0.292	0.182	0.217
CV	3.908	2.932	2.223	3.529
Mod CV	6.000	6.000	6.000	6.000
Min	9.716	9.118	7.779	5.848
Max	11.373	10.454	8.544	6.570
No. Batches	3	3	3	3
No. Spec.	21	23	21	22
Basis Values and Estimates				
B-basis Value	9.894	9.329	7.822	
B-Estimate				4.987
A-Estimate	9.465	8.899	7.576	4.162
Method	pooled	pooled	Normal	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	9.612	9.050	7.262	5.241
A-Estimate	9.008	8.444	6.657	4.636
Method	pooled	pooled	pooled	pooled

Table 4-9: Statistics and Basis Values for SBS

4.6 In-Plane Shear (IPS)

In-Plane Shear data is not normalized. Only the ETW condition had sufficient data to compute a B-basis value for strength at 5% strain. The CTD condition had values for only three specimens for strength at 5% strain while the RTD condition had no data for that property. Estimates of the basis values for the CTD condition were computed using the mean of the three specimens and the two batch method, which modifies the CV to 8%.

The 0.2% Offset Strength data for the CTD and RTD conditions failed the ADK test, but passed with the modified CV transformation of the data. The data from the ETW condition failed the normality test. The Weibull distribution provided the best fit and was used to compute the B-basis value and A-Estimate for the ETW condition. Estimates of basis values for the CTD and RTD data were computed using the ANOVA method. Pooling was not acceptable for computing the Mod CV basis values due to failure of Levene's test.

There are four outliers. The highest values of batches two and three of the 0.2% offset data for the RTD condition and the lowest values of batches one and three of the strength at 5% strain data for the ETW condition are outliers. All four are outliers only within their respective batches, not within their respective conditions. All outliers were retained for this analysis.

Statistics, basis values and estimates are given for the strength and modulus data in Table 4-10. The data, B-basis values and B-estimates are shown graphically for the 0.2% offset strength in Figure 4-6 and the strength at 5% strain in Figure 4-7.

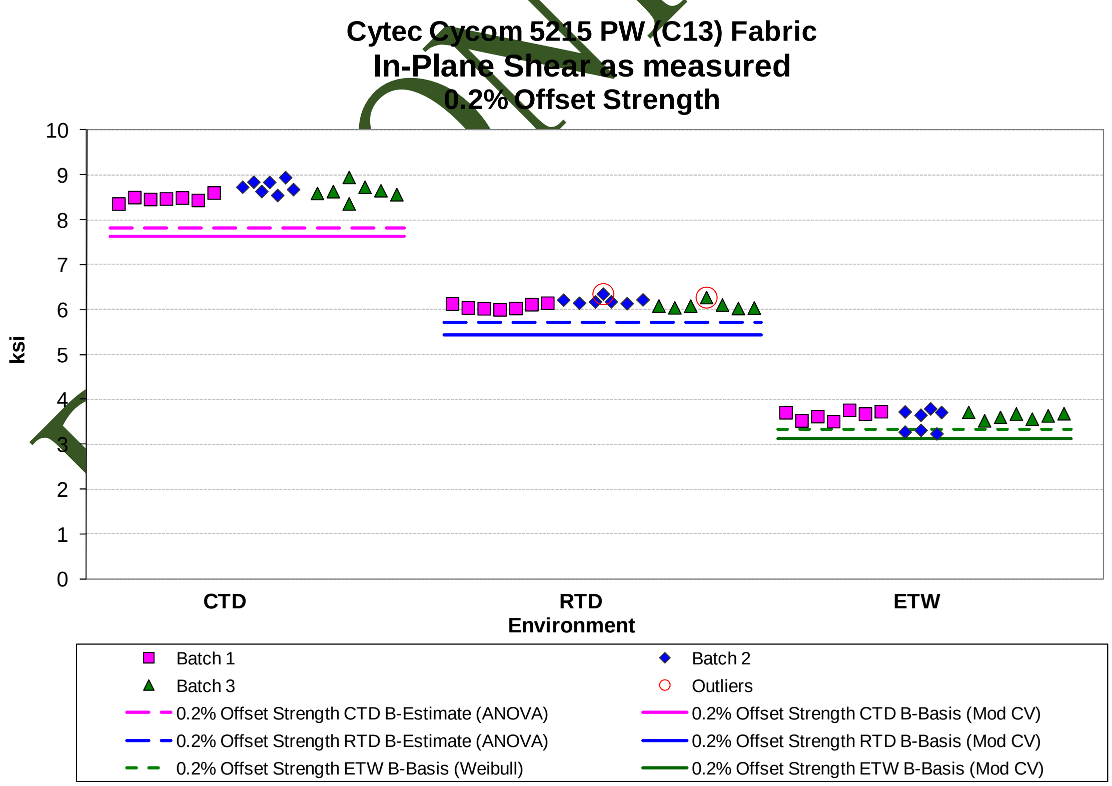

Figure 4-6: Batch plot for IPS 0.2% Offset Strength as measured

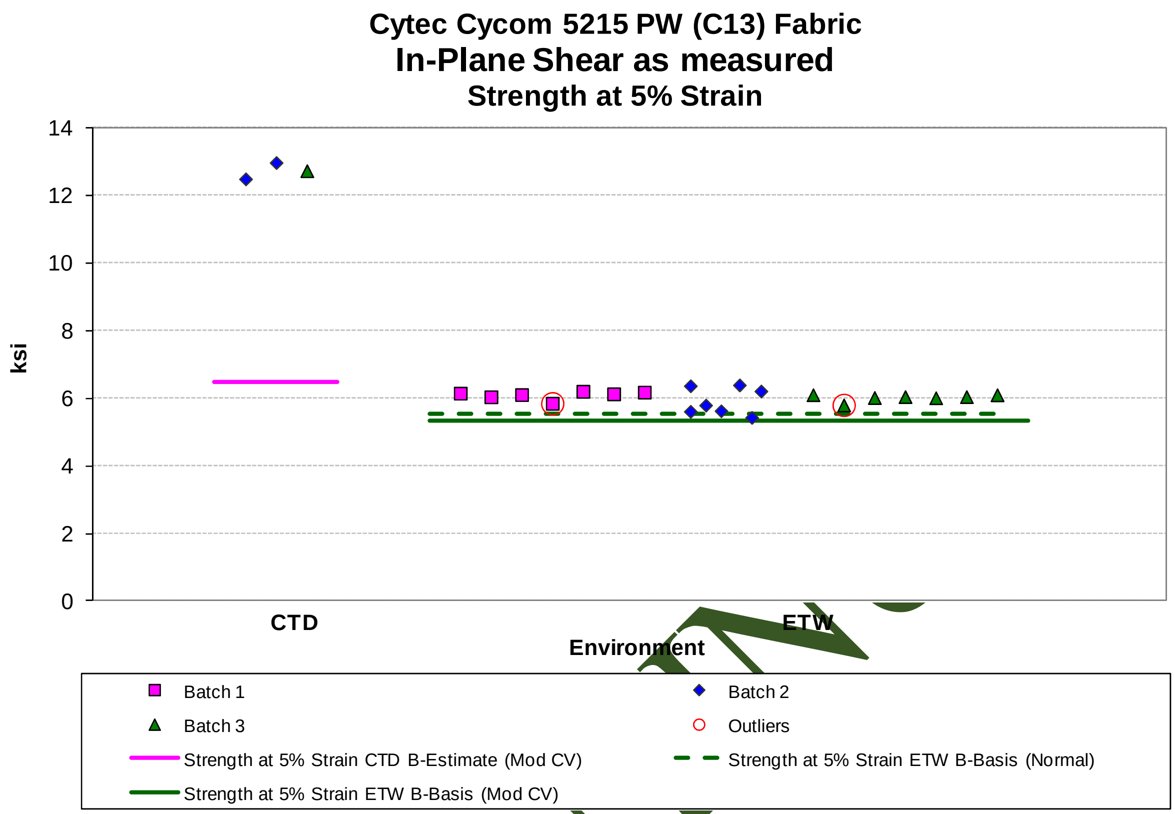

Figure 4-7: Batch plot for IPS Strength at 5% Strain as measured

In-Plane Shear Strength Basis Values and Statistics								
	0.2% Offset Strength			5% Strain		Modulus Statistics		
Env	CTD	RTD	ETW	CTD	ETW	CTD	RTD	ETW
Mean	8.623	6.127	3.607	12.729	6.013	0.679	0.565	0.389
Stdev	0.173	0.090	0.158	0.242	0.245	0.012	0.009	0.016
CV	2.007	1.476	4.375	1.901	4.073	1.713	1.580	4.098
Mod CV	6.000	6.000	6.187	8.000	6.037	6.000	6.000	6.049
Min	8.360	6.005	3.240	12.487	5.434	0.662	0.552	0.354
Max	8.951	6.354	3.799	12.971	6.395	0.703	0.586	0.411
No. Batches	3	3	3	2	3	3	3	3
No. Spec.	21	21	21	3	21	21	21	21
Basis Values and Estimates								
B-basis Value			3.323	NA	5.546			
B-Estimate	7.815	5.710						
A-Estimate	7.238	5.413	3.017	NA	5.214			
Method	ANOVA	ANOVA	Weibull	NA	Normal			
Modified CV Basis Values and Estimates								
B-basis Value	7.637	5.426	3.182	6.459	5.321			
A-Estimate	6.935	4.927	2.879	1.983	4.829			
Method	Normal	Normal	Normal	Two Batch	Normal			

Table 4-10: Statistics and Basis Values for IPS Strength and Modulus Data

4.7 Quasi Isotropic (25/50/25) Unnotched Tension (UNT1)

The Unnotched Tension data is normalized, so both normalized and as-measured statistics are provided. The data, both normalized and as-measured, from all three environmental conditions failed the ADK test, but passed with the modified CV transformation of the data. There were no other diagnostic test failures. B-estimates were computed using the ANOVA method. Pooling all three environmental conditions was acceptable to compute modified CV basis values and estimates.

There was one outlier. It was on the high side of batch 2 of the as-measured ETW data. It was an outlier only for batch 2, not for the ETW condition, and only in the as-measured data, not the normalized data. The outlier was retained for this analysis.

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 4-8.

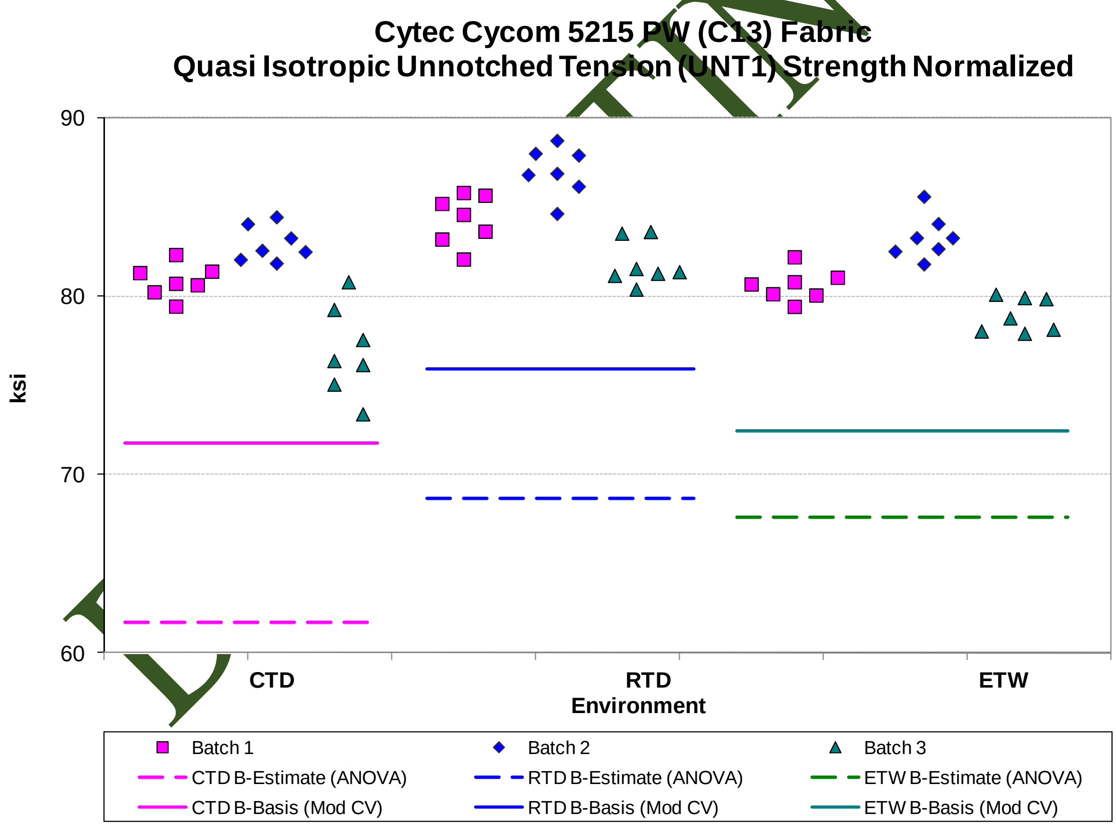

Figure 4-8: Batch Plot for UNT1 normalized strength

Unnotched Tension (UNT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	80.250	84.380	80.959	80.954	85.284	81.408
Stdev	2.992	2.507	2.084	2.102	1.786	1.780
CV	3.728	2.971	2.574	2.596	2.094	2.186
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	73.394	80.388	77.909	76.247	81.671	77.939
Max	84.435	88.721	85.581	84.578	88.295	84.947
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-Estimate	61.696	68.632	67.588	71.989	76.567	70.606
A-Estimate	48.450	57.389	58.041	65.591	70.345	62.894
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	71.756	75.886	72.464	72.388	76.718	72.842
A-Estimate	66.018	70.147	66.726	66.601	70.931	67.056
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	6.630	6.457	6.314	6.693	6.529	6.351
Stdev	0.078	0.071	0.128	0.197	0.152	0.211
CV	1.184	1.095	2.023	2.950	2.334	3.321
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	6.469	6.301	6.133	6.466	6.265	6.053
Max	6.772	6.581	6.640	7.089	6.792	6.812
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21

Table 4-12: Statistics from UNT1 Modulus Data

The UNT1 normalization results show an increase in both standard deviation and coefficient of variation after normalization, which is unusual. Looking a bit closer at the results, the batch three average specimen thickness is more than half a ply thinner than the batch one and batch two specimen thicknesses.

Batch 1 Average Spec. Thickness = 0.131
Batch 2 Average Spec. Thickness = 0.130
Batch 3 Average Spec. Thickness = 0.125

This leads to a significant decrease after normalization in the strength results for batch three as illustrated in Figure 4-9. Batch three is consistently lower than the other two batches but only for the normalized data. Pooling was acceptable for the modified CV basis values, which mitigates the change in results due to the specimen thickness.

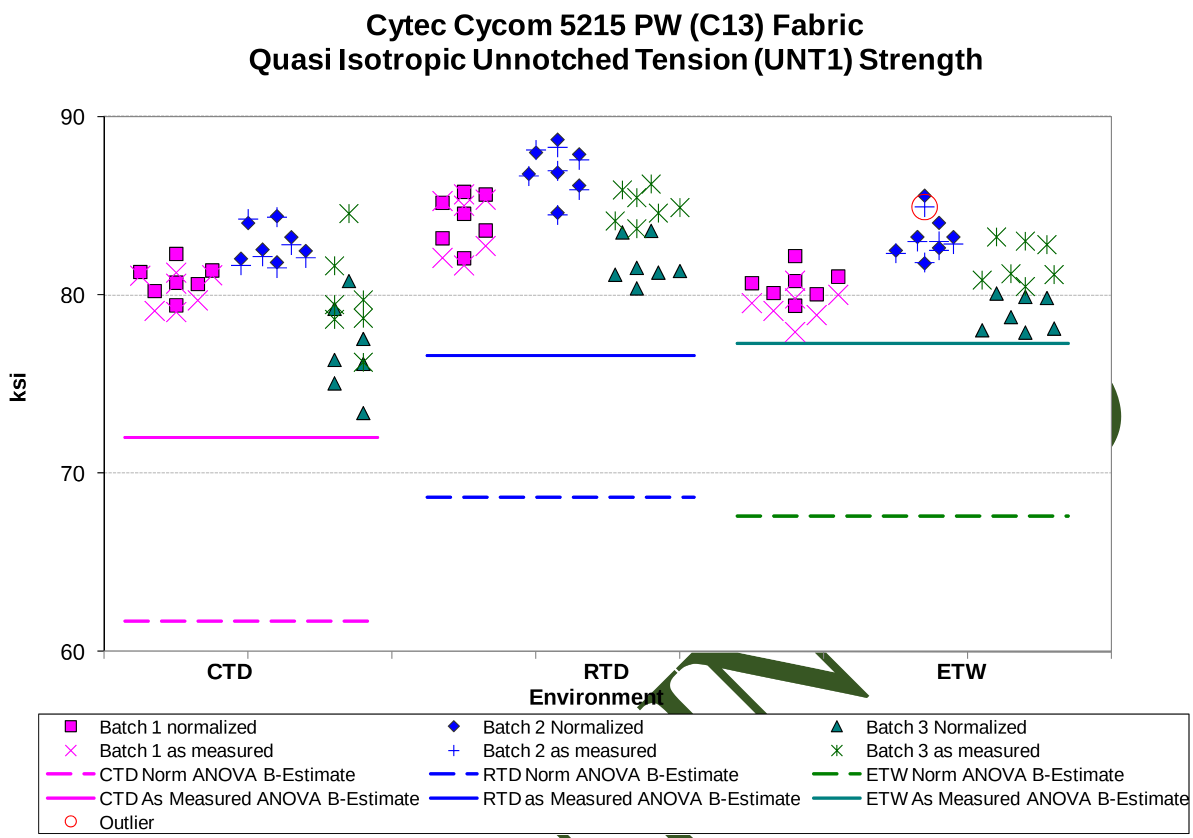

Figure 4-9: Batch Plot illustrated both normalized and as measured UNT1 strength

4.8 “Soft” (10/80/10) Unnotched Tension (UNT2)

The Unnotched Tension data is normalized, so both normalized and as-measured statistics are provided. There were no diagnostic test failures in the as-measured data and pooling was acceptable. The normalized data from the CTD and RTD environmental conditions failed the ADK test, but passed with the modified CV transformation of the data. B-estimates were computed using the ANOVA method. Pooling all three environmental conditions was acceptable to compute modified CV basis values and estimates.

There were two outliers. The highest value in the as-measured data from batch one of the CTD data was an outlier for batch one, but not for the CTD condition and not for the normalized data. The lowest value in the normalized data from batch three of the CTD data was an outlier for batch three, but not for the CTD condition and not for the as-measured data. Both outliers 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 4-10.

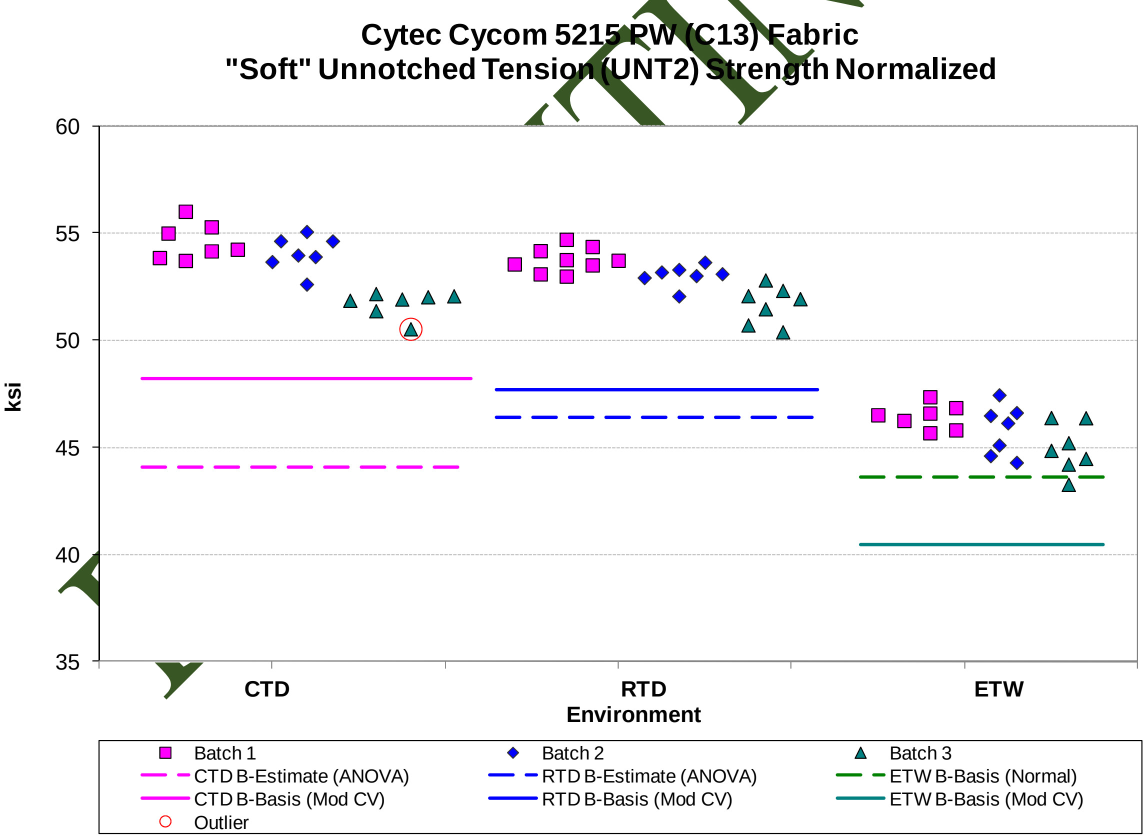

Figure 4-10: Batch Plot for UNT2 normalized strength

Unnotched Tension (UNT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	53.463	52.904	45.739	53.825	52.930	45.855
Stdev	1.477	1.087	1.129	0.980	0.840	1.046
CV	2.763	2.054	2.469	1.821	1.586	2.280
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	50.530	50.389	43.268	51.946	51.432	43.586
Max	56.016	54.708	47.446	55.981	54.579	47.886
No. Batches	3	3	3	3	3	3
No. Spec.	21	23	21	21	23	21
Basis Values and Estimates						
B-basis Value			43.588	52.176	51.294	44.206
B-Estimate	44.060	46.413				
A-Estimate	37.347	41.778	42.054	51.064	50.179	43.093
Method	ANOVA	ANOVA	Normal	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	48.192	47.677	40.468	48.537	47.685	40.567
A-Estimate	44.636	44.113	36.912	44.970	44.110	37.000
Method	pooled	pooled	pooled	pooled	pooled	pooled

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	4.383	4.226	3.744	4.414	4.229	3.755
Stdev	0.099	0.194	0.100	0.093	0.193	0.119
CV	2.264	4.588	2.658	2.118	4.570	3.160
Modified CV	6.000	6.294	6.000	6.000	6.285	6.000
Min	4.123	3.911	3.621	4.264	3.882	3.600
Max	4.533	4.556	3.952	4.596	4.649	3.985
No. Batches	3	3	3	3	3	3
No. Spec.	21	23	21	21	23	21

Table 4-14: Statistics from UNT2 Modulus Data

The UNT2 normalization results show an increase in both standard deviation and coefficient of variation after normalization, which is unusual. Looking a bit closer at the results, the batch three average specimen thickness is more than half a ply thinner than the batch one and batch two specimen thicknesses.

Batch 1 Average Spec. Thickness = 0.165
Batch 2 Average Spec. Thickness = 0.162
Batch 3 Average Spec. Thickness = 0.158

This leads to a decrease in the strength results for batch C as batch three is consistently lower than the other two batches but only for the normalized data. Pooling was acceptable for the modified CV basis values, which mitigates the change in results due to the specimen thickness.

4.9 "Hard" (40/20/40) Unnotched Tension (UNT3)

The Unnotched Tension data is normalized, so both normalized and as-measured statistics are provided. There were no diagnostic test failures in the as-measured data and pooling was acceptable. The normalized data from all three environmental conditions failed the ADK test, but passed with the modified CV transformation of the data. B-estimates were computed using the ANOVA method. Pooling all three environmental conditions was acceptable to compute modified CV basis values and estimates.

There was one outlier. The highest value in the as-measured data from batch one of the CTD data was an outlier for the CTD condition but not for batch one and not for the normalized data. This outlier 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 4-11.

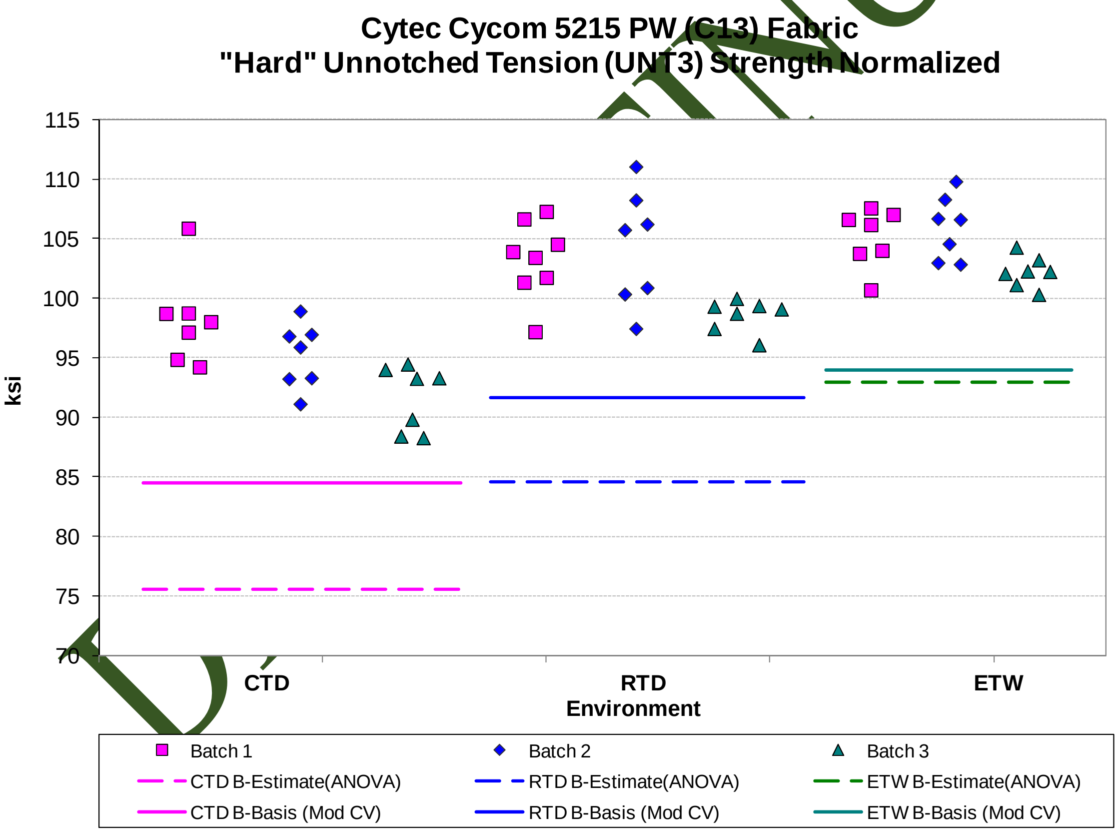

Figure 4-11: Batch Plot for UNT3 normalized strength

Unnotched Tension (UNT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	95.012	102.084	104.429	96.458	103.629	105.675
Stdev	4.042	4.114	2.662	2.952	3.452	2.632
CV	4.255	4.030	2.549	3.061	3.331	2.490
Modified CV	6.127	6.015	6.000	6.000	6.000	6.000
Min	88.277	96.078	100.302	92.074	96.213	100.295
Max	105.861	111.042	109.798	104.982	110.034	109.994
No. Batches	3	3	3	3	3	3
No. Spec.	21	22	21	21	22	21
Basis Values and Estimates						
B-basis Value				91.209	98.403	100.426
B-Estimate	75.503	84.533	92.906			
A-Estimate	61.578	72.002	84.682	87.666	94.856	96.883
Method	ANOVA	ANOVA	ANOVA	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	84.509	91.625	93.926	85.883	93.099	95.100
A-Estimate	77.419	84.527	86.836	78.744	85.952	87.961
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	8.256	8.205	8.080	8.388	8.334	8.180
Stdev	0.175	0.102	0.117	0.287	0.248	0.276
CV	2.115	1.243	1.443	3.422	2.970	3.376
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	7.787	7.948	7.849	7.694	7.959	7.869
Max	8.524	8.382	8.342	8.720	8.846	8.781
No. Batches	3	3	3	3	3	3
No. Spec.	21	22	21	21	22	21

Table 4-16: Statistics from UNT3 Modulus Data

The UNT3 normalization results show an increase in both standard deviation and coefficient of variation after normalization, which is unusual. Looking a bit closer at the results, the batch three average specimen thickness is more than half a ply thinner than the batch one and batch two specimen thicknesses.

Batch 1 Average Spec. Thickness = 0.122
Batch 2 Average Spec. Thickness = 0.121
Batch 3 Average Spec. Thickness = 0.116

This leads to a decrease in the strength results for batch C as batch three is consistently lower than the other two batches but only for the normalized data. Pooling was acceptable for the modified CV basis values, which mitigates the change in results due to the specimen thickness.

4.10 Quasi Isotropic (25/50/25) Unnotched Compression (UNC1)

The Unnotched Compression data is normalized, so both normalized and as-measured statistics are provided. The RTD and ETW data could not be pooled due to a failure of Levene's test. Basis values and estimates were computed using the single point method, normal distribution. Modified CV basis values were not provided for the RTD datasets because the coefficient of variation was over 8% for both the normalized and as-measured data, which means that that there is no change to the C.V. or basis values computed with the use of the modified CV approach.

There were two outliers. The highest value in batch three of the RTD data, both normalized and as-measured, was an outlier for batch three, but not for the RTD condition. The highest value in batch two of the normalized ETW data was an outlier for batch two, but not for the ETW condition and not for the as-measured data. Both outliers were retained for this analysis.

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 4-12.

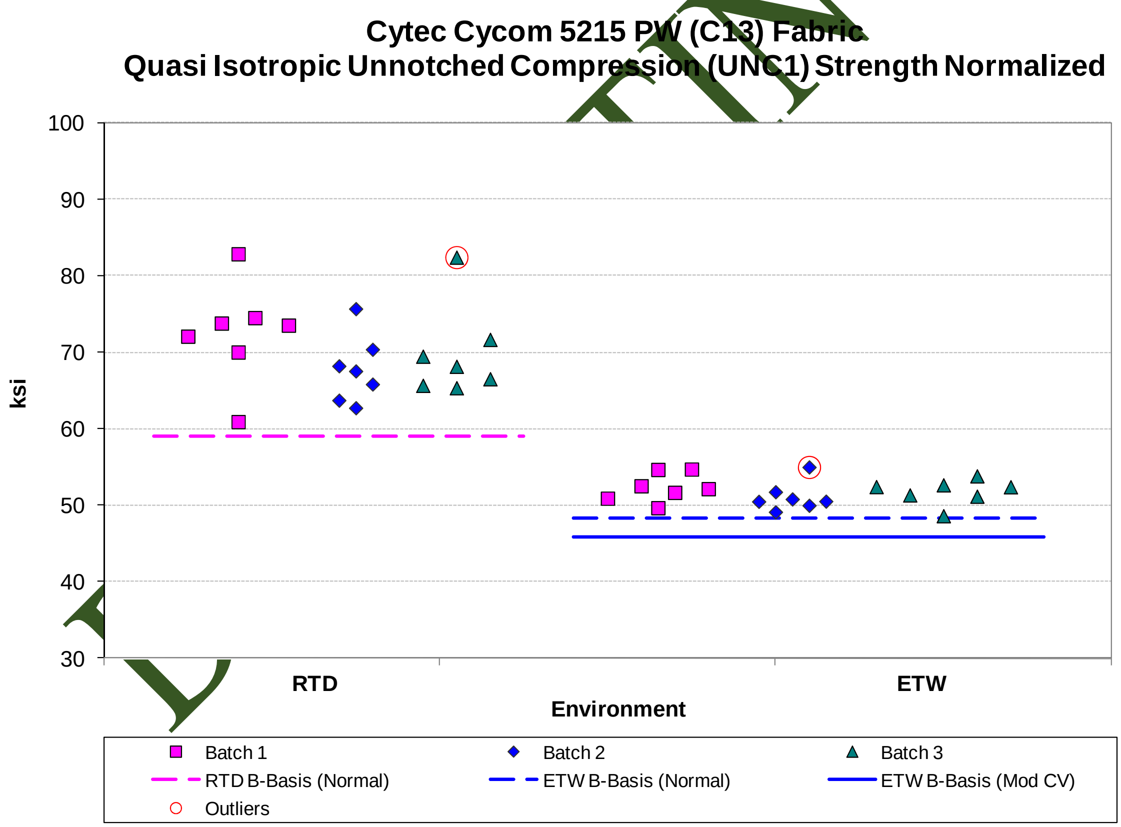

Figure 4-12: Batch plot for UNC1 normalized strength

Unnotched Compression (UNC1) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	70.048	51.733	70.704	52.515
Stdev	5.761	1.788	5.981	2.059
CV	8.224	3.456	8.460	3.920
Modified CV	8.224	6.000	8.460	6.000
Min	60.924	48.619	59.100	49.029
Max	82.849	54.992	86.327	56.392
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	59.073	48.328	59.309	48.594
A-Estimate	51.249	45.900	51.186	45.798
Method	Normal	Normal	Normal	Normal
Modified CV Basis Values and Estimates				
B-basis Value	NA	45.818	NA	46.511
A-Estimate	NA	41.605	NA	42.234
Method	NA	Normal	NA	Normal

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	5.942	5.840	5.997	5.853
Stdev	0.099	0.115	0.102	0.088
CV	1.660	1.976	1.707	1.499
Modified CV	6.000	6.000	6.000	6.000
Min	5.798	5.702	5.813	5.669
Max	6.199	6.142	6.186	5.971
No. Batches	3	3	3	3
No. Spec.	21	21	21	21

Table 4-18: Statistics from UNC1 Modulus Data

4.11 "Soft" (10/80/10) Unnotched Compression (UNC2)

The Unnotched Compression data is normalized, so both normalized and as-measured statistics are provided. The RTD and ETW as-measured data could not be pooled due to a failure of Levene's test. Basis values and estimates were computed using the single point method. However, after applying the modified CV transformation, pooling the RTD and ETW as-measured data was acceptable to compute the modified CV basis values and estimates.

The normalized data for the RTD condition failed the ADK test, but passed with the modified CV transformation of the data. A B-estimate was computed using the ANOVA method for the normalized RTD data. Pooling the RTD and ETW normalized data was acceptable to compute the modified CV basis values and estimates.

There was one outlier. The lowest value in batch two of the ETW data, both normalized and as-measured, was an outlier for batch two. It was also an outlier for the ETW condition in the as-measured dataset, but not for the ETW condition in the normalized dataset. This outlier 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 4-13.

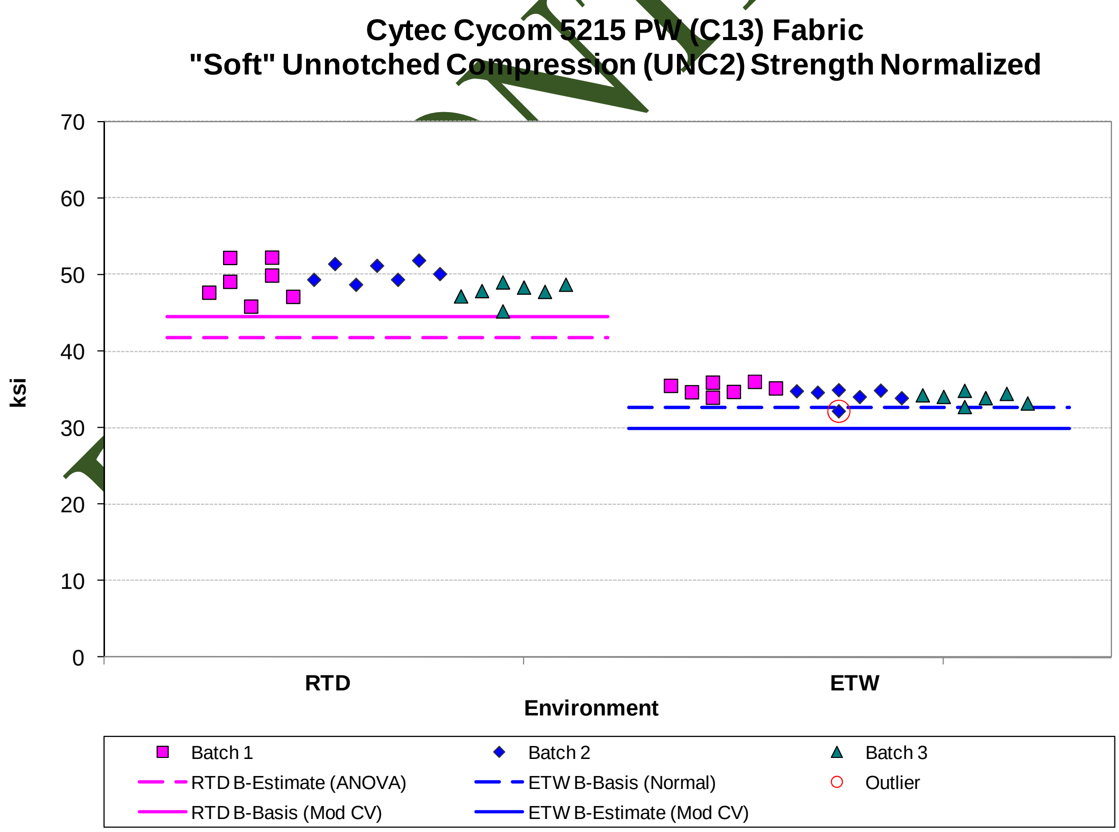

Figure 4-13: Batch plot for UNC2 normalized strength

Unnotched Compression (UNC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	49.072	34.433	49.590	34.796
Stdev	1.975	0.950	1.807	0.983
CV	4.025	2.759	3.645	2.825
Modified CV	6.013	6.000	6.000	6.000
Min	45.236	32.197	45.325	31.963
Max	52.264	36.049	52.273	36.034
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value		32.623	46.146	32.913
B-Estimate	41.743			
A-Estimate	36.512	31.333	43.692	30.834
Method	ANOVA	Normal	Normal	Weibull
Modified CV Basis Values and Estimates				
B-basis Value	44.556	29.916	45.032	30.238
A-Estimate	41.450	26.810	41.898	27.104
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	3.924	3.613	3.965	3.617
Stdev	0.101	0.085	0.073	0.082
CV	2.574	2.354	1.836	2.281
Modified CV	6.000	6.000	6.000	6.000
Min	3.697	3.503	3.831	3.483
Max	4.066	3.780	4.069	3.750
No. Batches	3	3	3	3
No. Spec.	21	21	21	21

Table 4-20: Statistics from UNC2 Modulus Data

4.12 "Hard" (40/20/40) Unnotched Compression (UNC3)

The Unnotched Compression data is normalized, so both normalized and as-measured statistics are provided. There were no diagnostic test failures, so the RTD and ETW data could be pooled to compute the basis values and estimates. There were no outliers.

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 4-14.

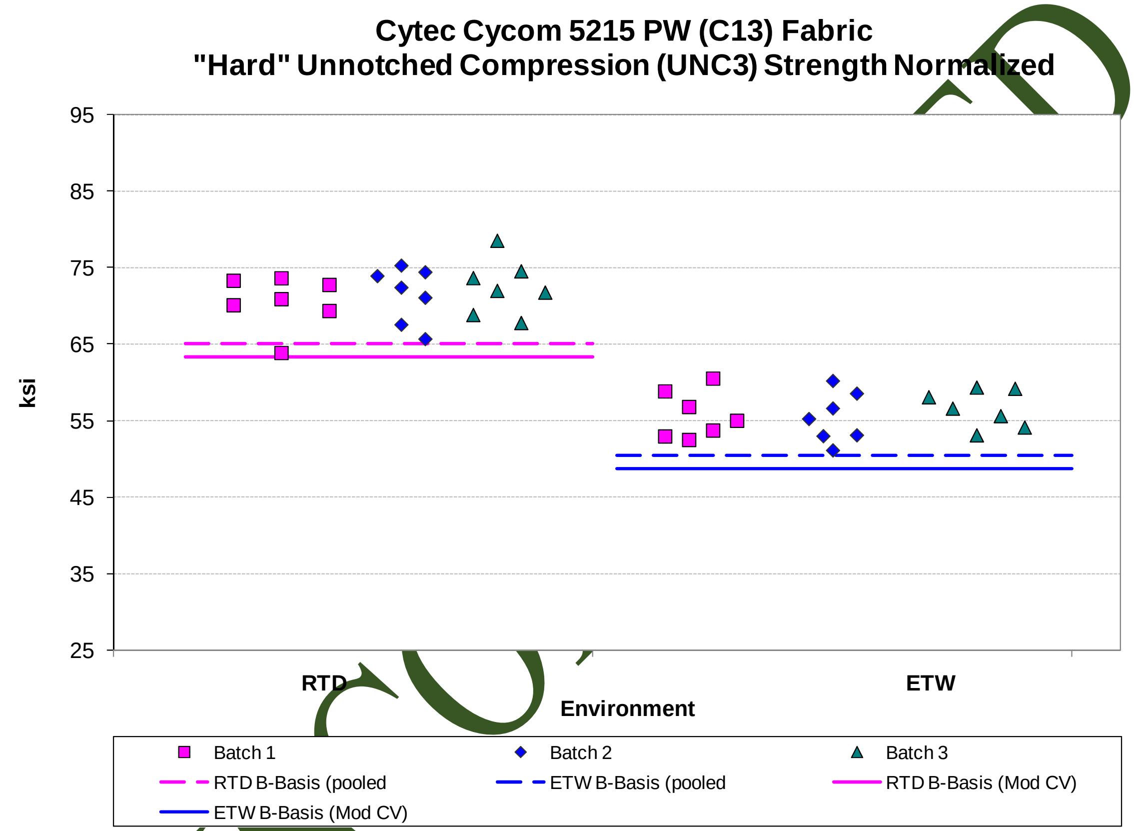

Figure 4-14: Batch plot for UNC3 normalized strength

Unnotched Compression (UNC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	70.603	55.947	71.521	56.881
Stdev	3.376	2.838	3.452	3.172
CV	4.782	5.072	4.826	5.577
Modified CV	6.391	6.536	6.413	6.789
Min	62.945	51.158	63.891	51.439
Max	75.187	60.545	78.562	62.102
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	65.073	50.417	65.643	51.002
A-Estimate	61.269	46.613	61.600	46.959
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	63.320	48.664	64.003	49.363
A-Estimate	58.312	43.656	58.833	44.193
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	7.396	7.387	7.492	7.434
Stdev	0.181	0.153	0.178	0.165
CV	2.450	2.073	2.381	2.226
Modified CV	6.000	6.000	6.000	6.000
Min	7.086	7.063	7.220	7.113
Max	7.859	7.626	7.855	7.817
No. Batches	3	3	3	3
No. Spec.	21	21	21	21

Table 4-22: Statistics from UNC3 Modulus Data

4.13 Quasi Isotropic (25/50/25) Open Hole Tension (OHT1)

The Open Hole Tension data is normalized, so both normalized and as-measured statistics are provided. The normalized data for the ETW condition failed the ADK test, but passed with the modified CV transformation of the data. A and B-estimates computed using the ANOVA method were computed for the normalized ETW data while the other two environmental conditions were pooled to compute the basis values.

For the as-measured data, all three environmental conditions could not be pooled due to a failure of Levene's test. However, the data from the CTD and RTD conditions could be pooled while using the single point method for the as-measured ETW data.

All three environmental conditions could be pooled after applying the modified CV transformation, so pooling was acceptable to compute the modified CV basis values and estimates for both the normalized and as-measured datasets.

There was one outlier. The highest value in batch three of the CTD data, both normalized and as-measured, was an outlier for batch three but not for the CTD condition. The outlier was retained for this analysis.

Statistics, basis values and estimates are given for OHT1 strength data in Table 4-23. The normalized data, B-basis values and B-estimates are shown graphically in Figure 4-15.

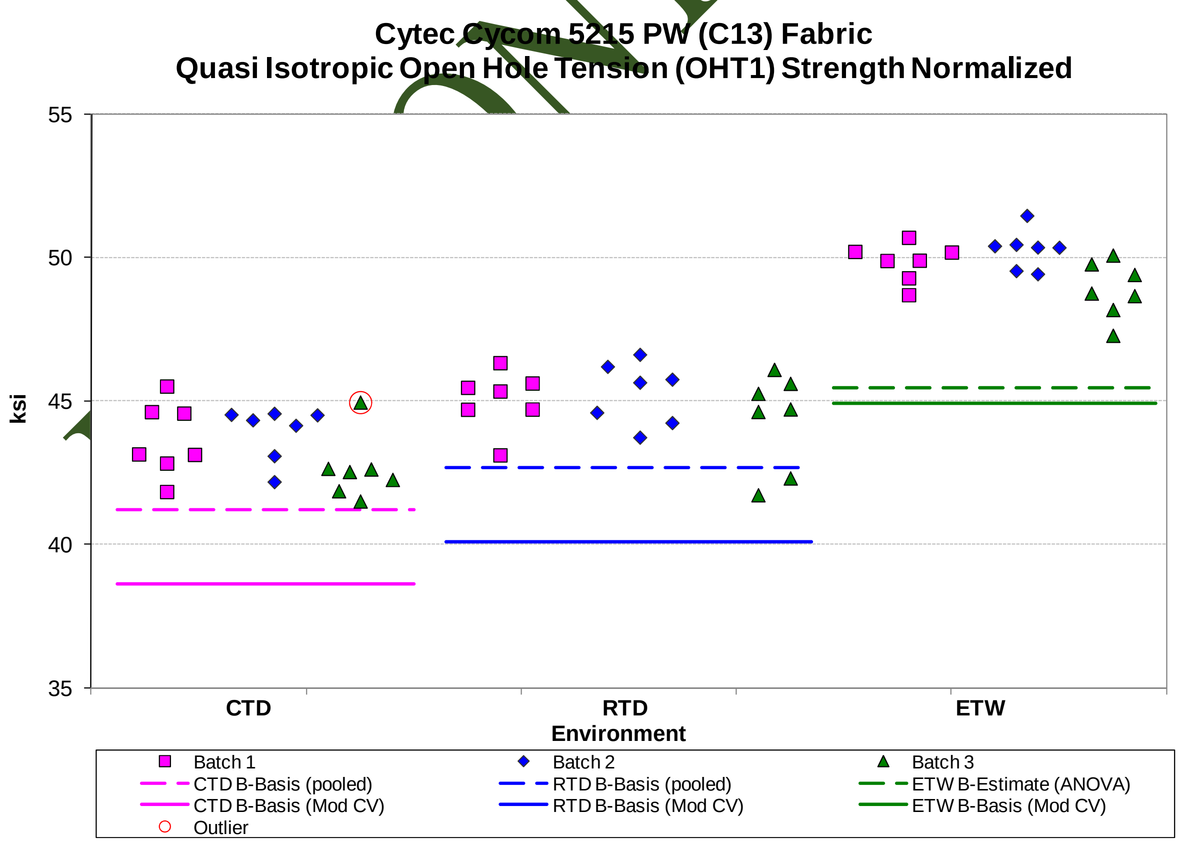

Figure 4-15: Batch Plot for OHT1 normalized strength

Open Hole Tension (OHT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	43.400	44.879	49.668	42.967	44.346	49.093
Stdev	1.198	1.286	0.953	1.048	1.577	0.946
CV	2.759	2.866	1.919	2.438	3.556	1.926
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	41.508	41.727	47.287	41.141	40.977	47.311
Max	45.514	46.620	51.464	44.978	47.224	50.548
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	41.197	42.675		40.593	41.972	47.291
B-Estimate			45.447			
A-Estimate	39.681	41.159	42.435	38.960	40.339	46.007
Method	pooled	pooled	ANOVA	pooled	pooled	Normal
Modified CV Basis Values and Estimates						
B-basis Value	38.622	40.100	44.890	38.242	39.621	44.368
A-Estimate	35.394	36.872	41.662	35.050	36.429	41.177
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-23: Statistics and Basis Values for OHT1 Strength Data

4.14 "Soft" (10/80/10) Open Hole Tension (OHT2)

The Open Hole Tension data is normalized, so both normalized and as-measured statistics are provided. The as-measured data for the ETW condition failed the ADK test, but passed with the modified CV transformation of the data. A and B-estimates computed using the ANOVA methodwere computed for the as-measured ETW data. The other two environmental conditions (CTD and RTD) could not be pooled to compute the basis values due to a failure of the normality test for the pooled dataset. The single point method was used to compute basis values, with the normal distribution being used for the CTD condition and the Weibull distribution for the RTD condition. All three environmental conditions could be pooled after applying the modified CV transformation, so pooling was acceptable to compute the modified CV basis values and estimates for the as-measured datasets.

For the normalized data, all three environmental conditions failed the ADK test, but passed with the modified CV transformation of the data. A and B-estimates computed using the ANOVA method were computed. All three environmental conditions could be pooled after applying the modified CV transformation, so pooling was acceptable to compute the modified CV basis values and estimates for the normalized datasets.

The OHT2 normalization results show an increase in both standard deviation and coefficient of variation after normalization, which is unusual. Looking a bit closer at the results, the batch three average specimen thickness is more than half a ply thinner than the batch one and batch two specimen thicknesses. This is likely to be the reason for the ADK test failures in the normalized data

There were two outliers. The highest value in batch three of the normalized CTD data was an outlier for batch three but not for the CTD condition. It was an outlier only for the normalized data, not for the as-measured data. The lowest value in batch two of the as-measured RTD data was an outlier for batch two but not for the RTD condition. It was an outlier only for the as-measured data, not for the normalized data. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for OHT2 strength data in Table 4-24. The normalized data and B-basis values are shown graphically in Figure 4-16.

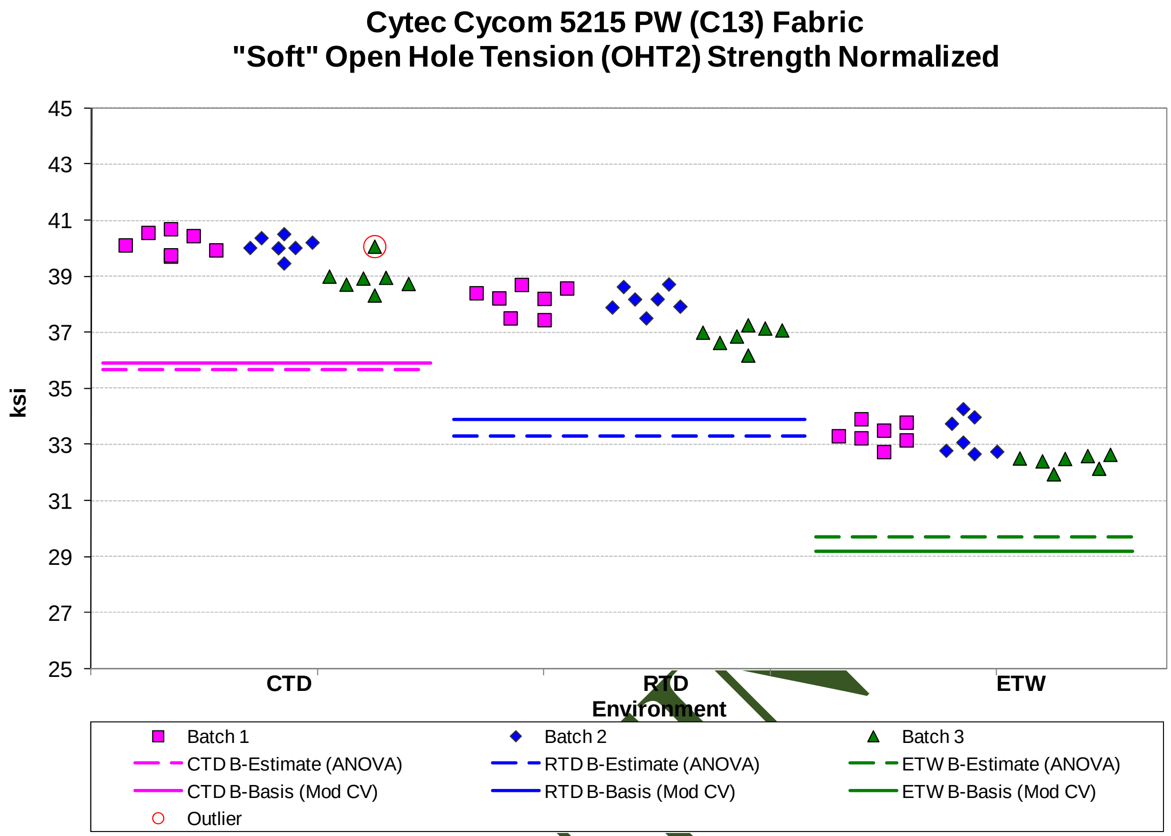

Figure 4-16: Batch Plot for OHT2 normalized strength

Open Hole Tension (OHT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	39.744	37.732	33.036	39.921	38.110	33.186
Stdev	0.698	0.737	0.643	0.607	0.505	0.570
CV	1.756	1.955	1.947	1.521	1.326	1.719
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	38.328	36.188	31.952	38.868	37.089	32.196
Max	40.693	38.724	34.278	41.362	38.739	34.274
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value				38.764	37.097	
B-Estimate	35.659	33.290	29.720			31.012
A-Estimate	32.742	30.118	27.353	37.939	35.935	29.461
Method	ANOVA	ANOVA	ANOVA	Normal	Weibull	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	35.911	33.899	29.204	36.064	34.253	29.329
A-Estimate	33.322	31.310	26.615	33.459	31.647	26.723
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-24: Statistics and Basis Values for OHT2 Strength Data

4.15 "Hard" (40/20/40) Open Hole Tension (OHT3)

The Open Hole Tension data is normalized, so both normalized and as-measured statistics are provided. There were no diagnostic test failures, so pooling was acceptable to compute basis values and estimates for both as-measured and normalized datasets.

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

Statistics, basis values and estimates are given for OHT3 strength data in Table 4-25. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-17.

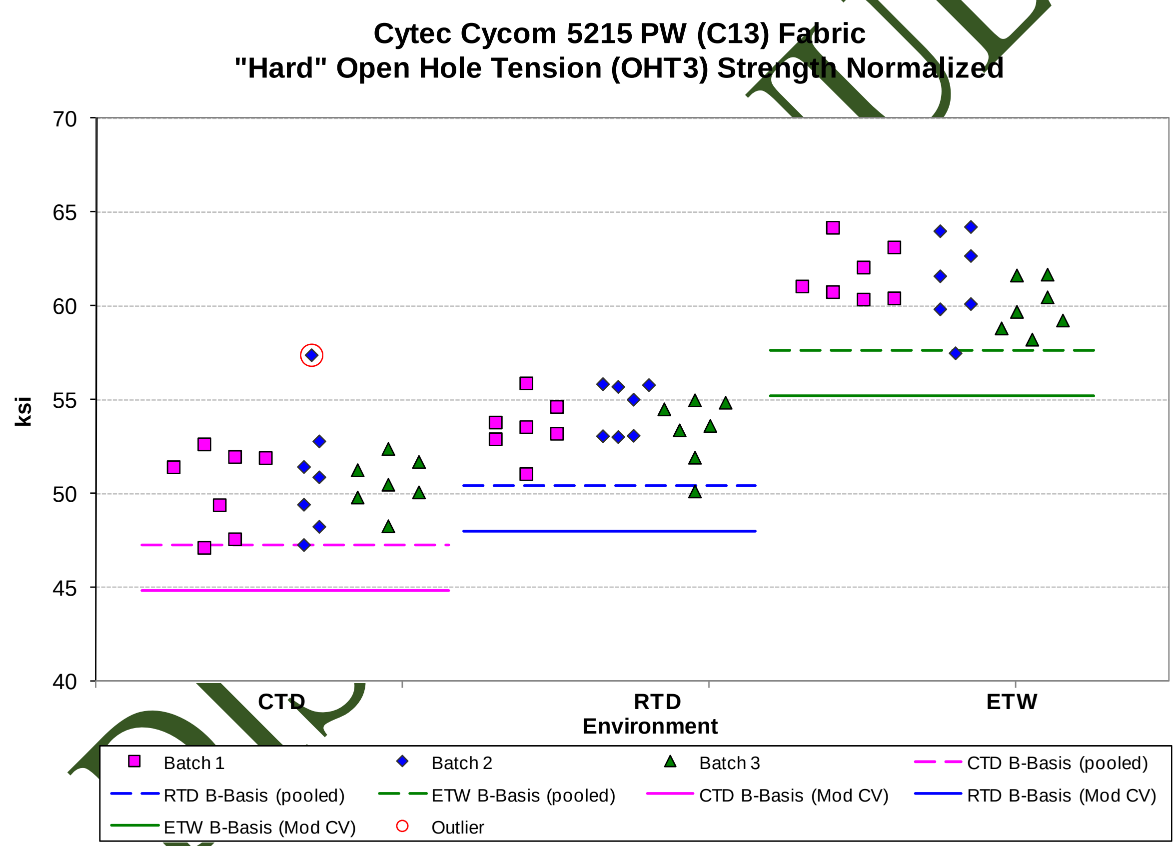

Figure 4-17: Batch Plot for OHT3 normalized strength

Open Hole Tension (OHT3) Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	50.662	53.832	61.054	50.534	53.790	60.675
Stdev	2.366	1.564	1.898	2.651	1.658	1.923
CV	4.670	2.905	3.108	5.246	3.082	3.170
Modified CV	6.335	6.000	6.000	6.623	6.000	6.000
Min	47.142	50.150	57.514	45.368	50.177	57.657
Max	57.410	55.911	64.243	57.489	56.324	63.797
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Value Estimates						
B-basis Value	47.256	50.425	57.648	46.869	50.125	57.010
A-Estimate	44.955	48.124	55.347	44.394	47.650	54.535
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	44.829	47.998	55.220	44.639	47.895	54.780
A-Estimate	40.888	44.057	51.279	40.657	43.913	50.798
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-25: Statistics and Basis Values for OHT3 Strength Data

4.16 Quasi Isotropic (25/50/25) Filled Hole Tension (FHT1)

The Filled Hole Tension data is normalized, so both normalized and as-measured statistics are provided.

Only the normalized data from the CTD condition passed the ADK test. A and B-estimates were computed for all other datasets using the ANOVA method. After applying the modified CV transformation, the as-measured CTD and ETW datasets and the normalized RTD and ETW datasets passed the ADK test, so modified CV basis values are provided for those conditions. The normalized data could be pooled after applying the modified CV transformation, so pooling was acceptable to compute the modified CV basis values and estimates. In addition, A-and B-estimates are provided for the as-measured RTD data with an override of the ADK test results.

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

Statistics, basis values and estimates are given for FHT1 strength data in Table 4-26. The normalized data and B-basis values are shown graphically in Figure 4-18.

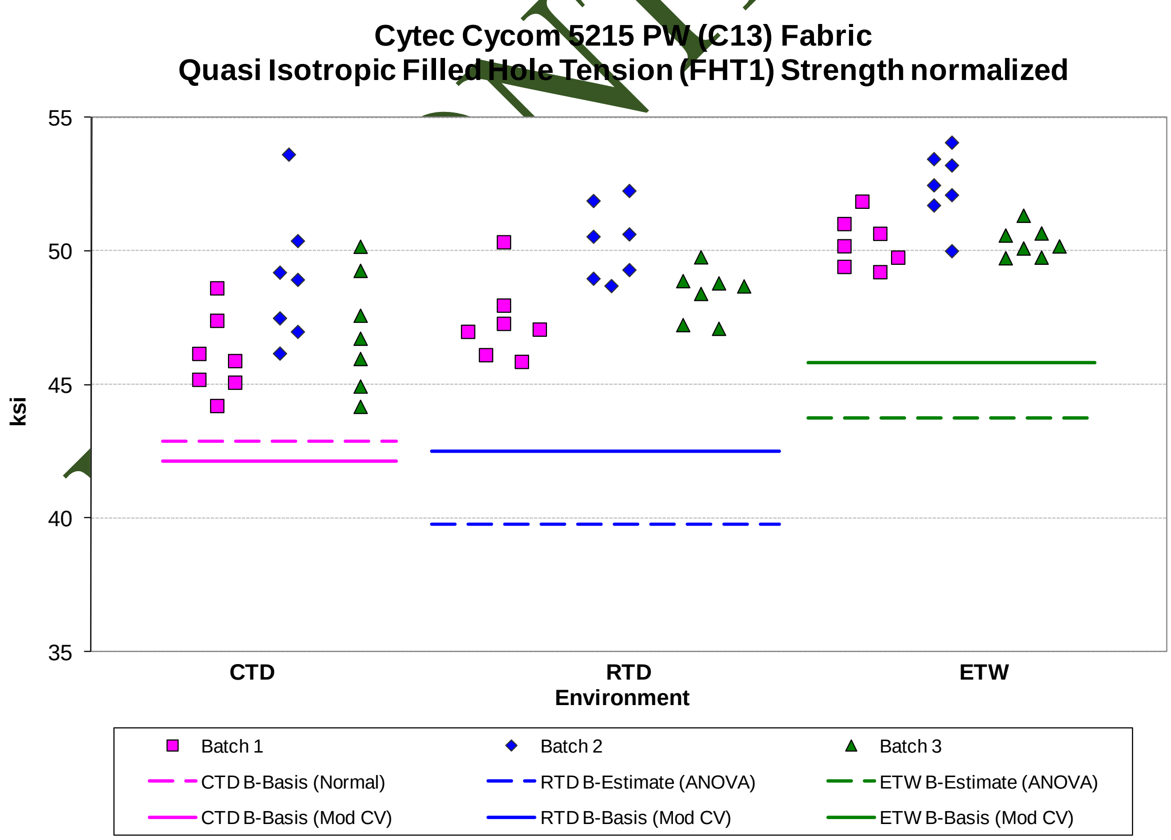

Figure 4-18: Batch plot for FHT1 normalized strength

Filled Hole Tension (FHT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	47.342	48.704	51.023	47.456	48.720	51.009
Stdev	2.350	1.758	1.392	2.633	2.219	1.781
CV	4.963	3.609	2.728	5.549	4.554	3.491
Modified CV	6.482	6.000	6.000	6.774	6.277	6.000
Min	44.183	45.866	49.220	43.769	44.981	48.257
Max	53.614	52.254	54.061	53.856	52.559	54.243
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	42.866					
B-Estimate		39.780	43.744	35.515	35.520	39.863
A-Estimate	39.675	33.410	38.548	26.991	26.096	31.906
Method	Normal	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	42.124	43.486	45.804	41.330		45.176
B-Estimate with override of ADK test result					42.892	
A-Estimate	38.599	39.961	42.279	36.966	38.741	41.022
Method	pooled	pooled	pooled	Normal	Normal	Normal

Table 4-26: Statistics and Basis Values for FHT1 Strength Data

4.17 “Soft” (10/80/10) Filled Hole Tension (FHT2)

The Filled Hole Tension data is normalized, so both normalized and as-measured statistics are provided. The normalized data had no diagnostic test failures, so pooling was acceptable to compute basis values and estimates.

For the as-measured data, all three environmental conditions failed the ADK test, but passed with the modified CV transformation of the data. A and B-estimates computed using the ANOVA method were computed. All three environmental conditions could be pooled after applying the modified CV transformation, so pooling was acceptable to compute the modified CV basis values and estimates for the normalized datasets.

There were no outliers.

Statistics, basis values and estimates are given for FHT2 strength data in Table 4-27. The normalized data and the B-basis values are shown graphically in Figure 4-19.

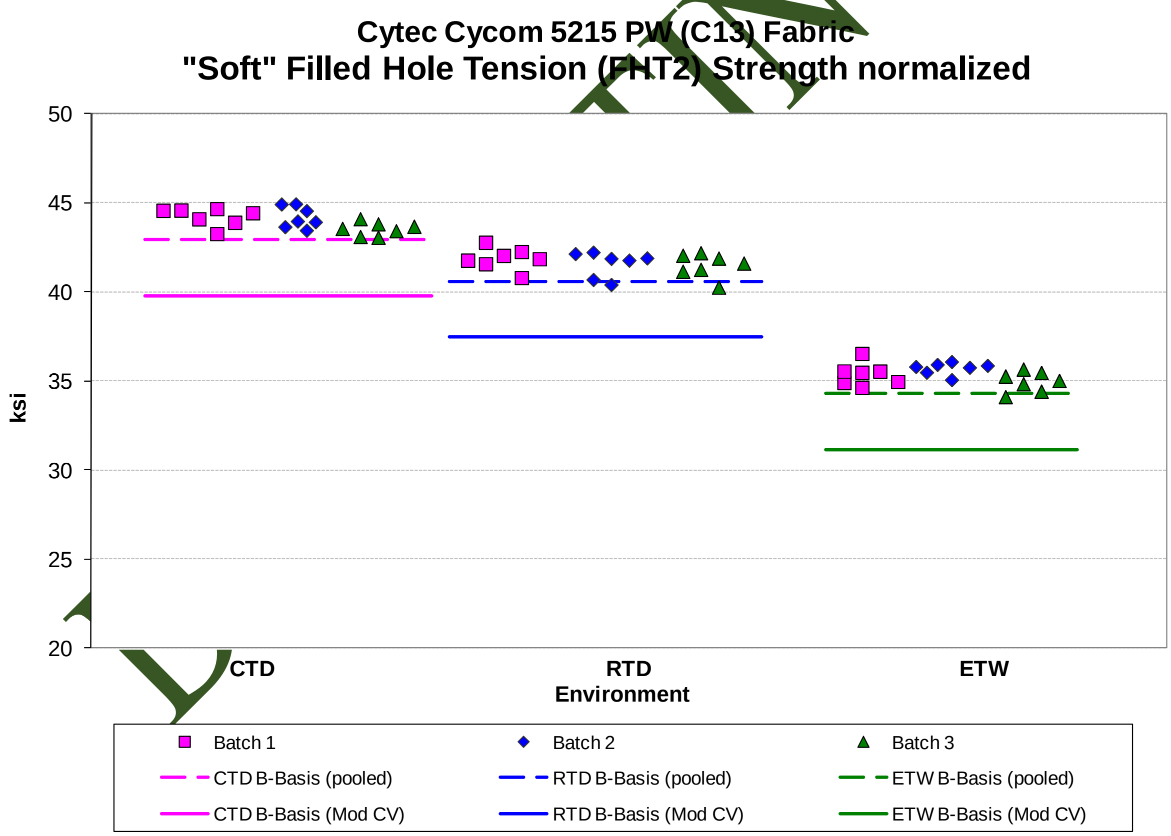

Figure 4-19: Batch plot for FHT2 normalized strength

Filled Hole Tension (FHT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	43.975	41.635	35.348	43.982	41.842	35.372
Stdev	0.576	0.655	0.585	0.798	1.071	0.823
CV	1.311	1.574	1.656	1.813	2.560	2.326
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	43.054	40.255	34.109	42.170	39.955	33.595
Max	44.926	42.772	36.537	45.107	44.145	36.662
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	42.926	40.586	34.299			
B-Estimate				39.508	37.051	30.540
A-Estimate	42.218	39.878	33.591	36.314	33.631	27.091
Method	pooled	pooled	pooled	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	39.775	37.435	31.149	39.773	37.634	31.164
A-Estimate	36.938	34.598	28.312	36.931	34.791	28.321
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-27: Statistics and Basis Values for FHT2 Strength Data

4.18 "Hard" (40/20/40) Filled Hole Tension (FHT3)

The Filled Hole Tension data is normalized, so both normalized and as-measured statistics are provided.

The data from the as-measured CTD and ETW environmental conditions and the normalized data from the ETW condition failed the ADK test, but passed with the modified CV transformation of the data. A and B-estimates computed using the ANOVA method were computed. All three environmental conditions could be pooled after applying the modified CV transformation, so pooling was acceptable to compute the modified CV basis values and estimates for both the normalized and as-measured datasets.

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

Statistics, basis values and estimates are given for FHT3 strength data in Table 4-28. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-20.

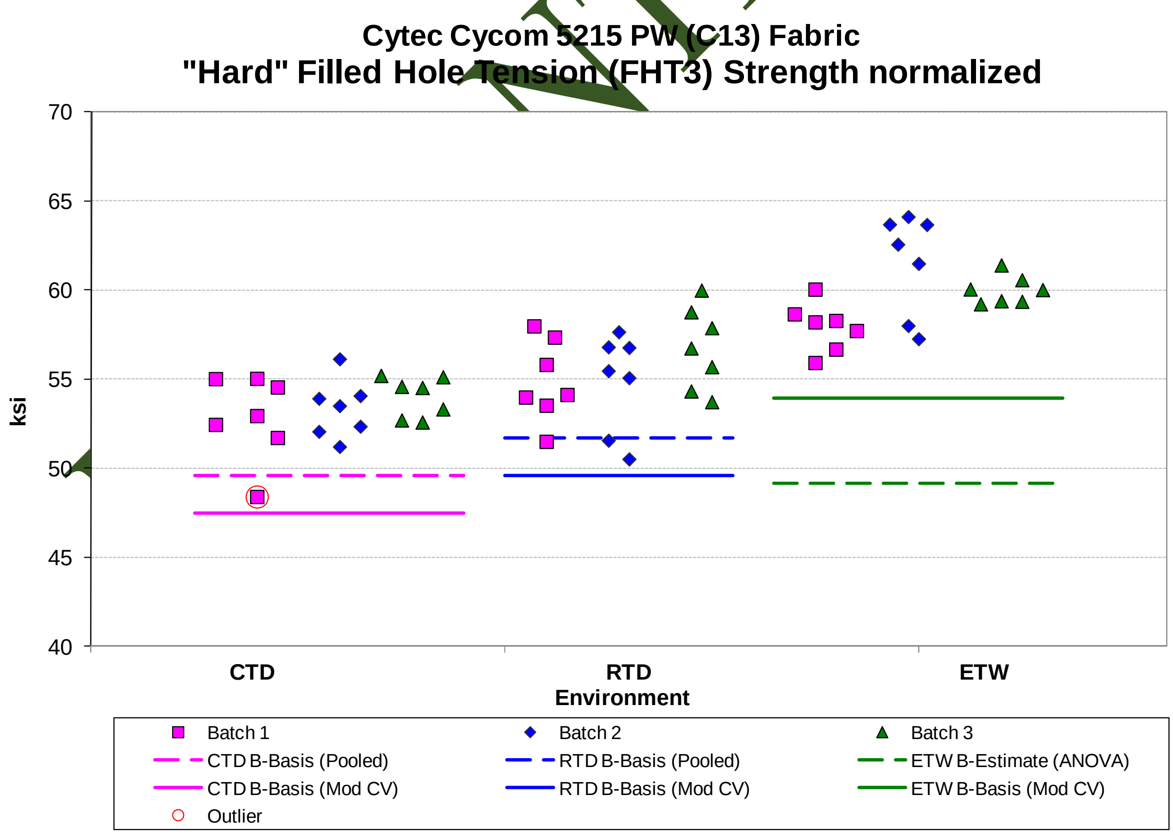

Figure 4-20: Batch plot for FHT3 normalized strength

Filled Hole Tension (FHT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	53.398	55.486	59.819	53.898	55.985	60.009
Stdev	1.752	2.496	2.324	2.253	3.312	2.677
CV	3.282	4.499	3.885	4.179	5.916	4.460
Modified CV	6.000	6.249	6.000	6.090	6.958	6.230
Min	48.404	50.515	55.921	48.444	50.336	55.553
Max	56.128	59.987	64.108	57.713	62.196	63.784
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value	49.574	51.662			49.675	
B-Estimate			49.130	42.272		45.230
A-Estimate	46.944	49.032	41.501	33.973	45.177	34.679
Method	pooled	pooled	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	47.478	49.566	53.899	47.590	49.677	53.702
A-Estimate	43.478	45.567	49.900	43.329	45.416	49.441
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-28: Statistics and Basis Values for FHT3 Strength Data

4.19 Quasi Isotropic (25/50/25) Open Hole Compression (OHC1)

The Open Hole Compression data is normalized, so both normalized and as-measured statistics are provided. There were no diagnostic test failures for the as-measured data, so pooling was acceptable to compute basis values and estimates. The normalized ETW and the normalized pooled datasets failed the normality test, so pooling was not appropriate. The single point method was used, with the Weibull distribution having the best fit for the normalized ETW data. Modified CV basis values cannot be provided for the normalized ETW data due to the lack of normality.

There was one outlier. It was the highest value in batch two of as-measured RTD data. It was an outlier for the batch two but not for the RTD condition or for the normalized dataset. The outlier was retained for this analysis.

Statistics, B-basis values and estimates are given for OHC1 strength data in Table 4-29. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-21.

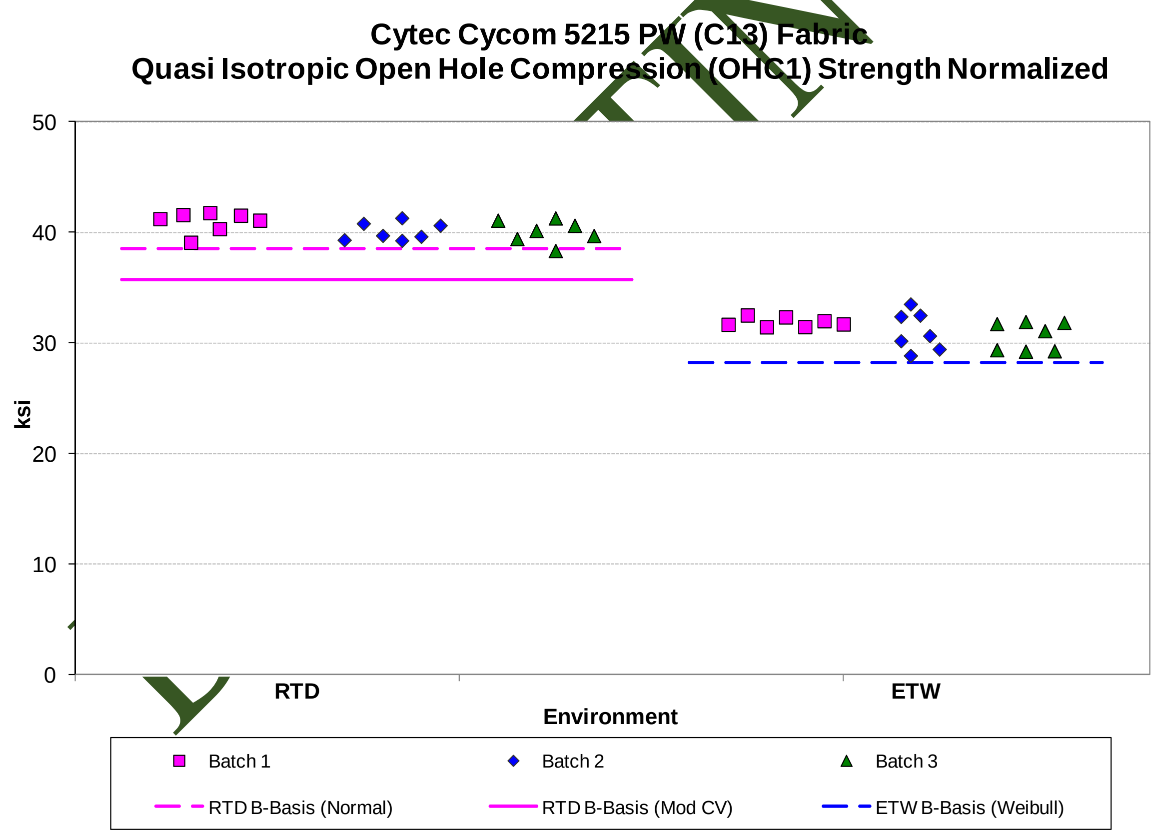

Figure 4-21: Batch plot for OHC1 normalized strength

Open Hole Compression (OHC1) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	40.395	31.212	40.588	31.395
Stdev	0.976	1.319	1.005	1.155
CV	2.417	4.225	2.475	3.680
Modified CV	6.000	6.113	6.000	6.000
Min	38.359	28.873	38.676	29.286
Max	41.792	33.530	42.403	33.482
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	38.535	28.263	38.668	29.476
A-Estimate	37.208	25.206	37.348	28.155
Method	Normal	Weibull	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	35.776	NA	36.727	27.535
A-Estimate	32.486	NA	34.072	24.880
Method	Normal	NA	pooled	pooled

Table 4-29: Statistics and Basis Values for OHC1 Strength Data

4.20 "Soft" (10/80/10) Open Hole Compression (OHC2)

The Open Hole Compression data is normalized, so both normalized and as-measured statistics are provided. The as-measured data had no diagnostic test failures, so pooling was acceptable to compute the basis values and estimates.

For the normalized data, both environmental conditions failed the ADK test, but passed with the modified CV transformation of the data. A and B-estimates computed using the ANOVA method were computed. The environmental conditions met all requirements for pooling after applying the modified CV transformation, so pooling was acceptable to compute the modified CV basis values and estimates for the normalized datasets.

The OHC2 normalization results show an increase in both standard deviation and coefficient of variation after normalization, which is unusual. Looking a bit closer at the results, the batch three average specimen thickness is more than half a ply thinner than the batch one and batch two specimen thicknesses. This is likely to be the reason for the ADK test failures in the normalized data.

There were no outliers. Statistics, basis values and estimates are given for OHC2 strength data in Table 4-30. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-22.

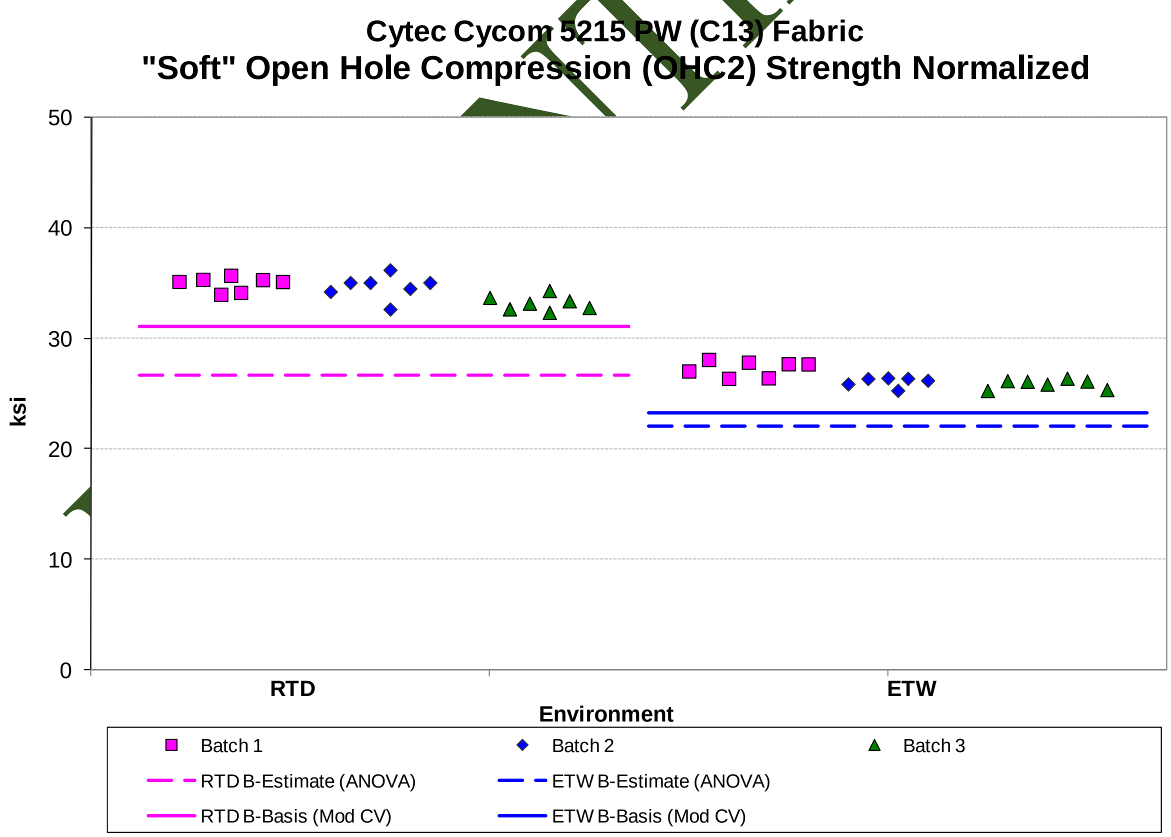

Figure 4-22: Batch plot for OHC2 normalized strength

Open Hole Compression (OHC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	34.269	26.476	34.521	26.746
Stdev	1.113	0.821	0.730	0.601
CV	3.247	3.100	2.115	2.247
Modified CV	6.000	6.000	6.000	6.000
Min	32.339	25.272	33.003	25.375
Max	36.182	28.073	35.801	27.638
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value			33.335	25.560
B-Estimate	28.635	22.085		
A-Estimate	24.613	18.951	32.520	24.745
Method	ANOVA	ANOVA	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	31.011	23.218	31.236	23.461
A-Estimate	28.770	20.978	28.976	21.201
Method	pooled	pooled	pooled	pooled

Table 4-30: Statistics and Basis Values for OHC2 Strength Data

4.21 “Hard” (40/20/40) Open Hole Compression (OHC3)

The Open Hole Compression data is normalized, so both normalized and as-measured statistics are provided. There were no diagnostic test failures, so pooling was acceptable to compute basis values and estimates for both the normalized and as-measured data. There were no outliers.

Statistics, basis values and estimates are given for OHC3 strength data in Table 4-31. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-23.

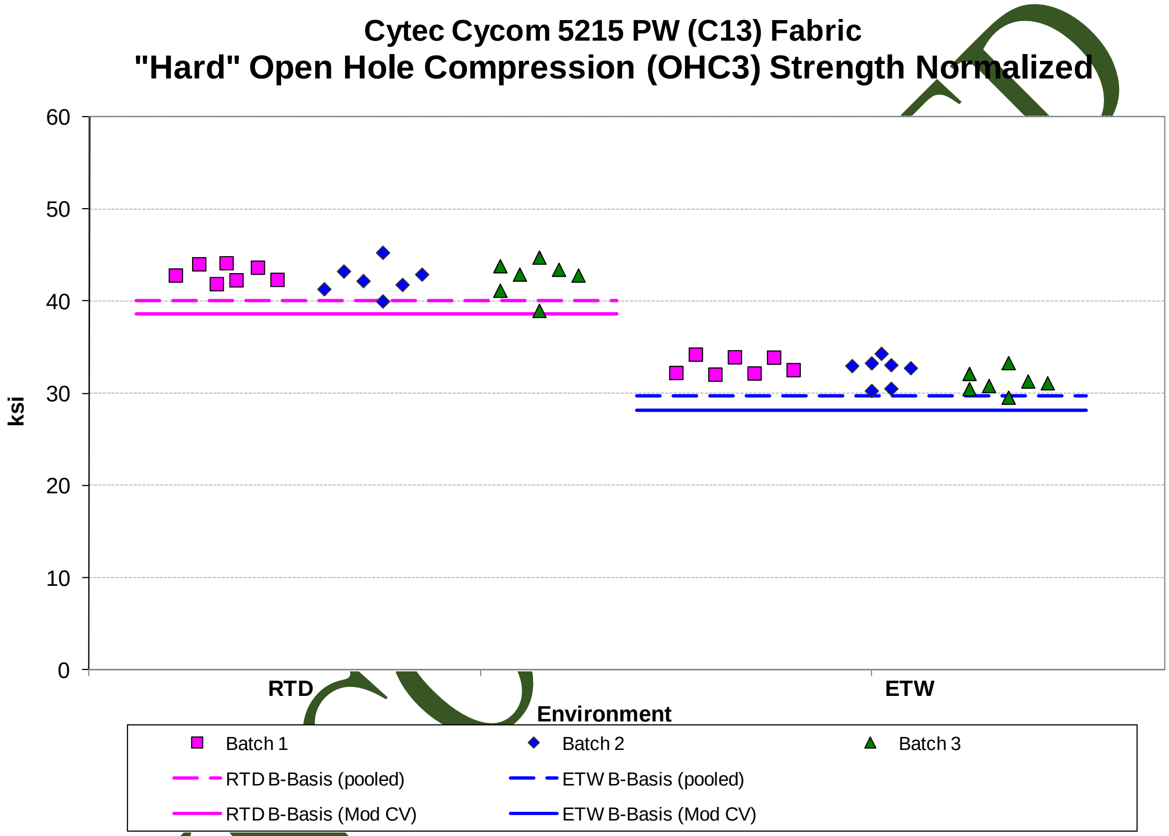

Figure 4-23: Batch plot for OHC3 normalized strength

Open Hole Compression (OHC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	42.650	32.243	42.725	32.278
Stdev	1.504	1.396	1.650	1.153
CV	3.526	4.329	3.862	3.571
Modified CV	6.000	6.165	6.000	6.000
Min	38.970	29.558	39.605	30.355
Max	45.266	34.316	45.769	33.960
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	40.077	29.670	40.201	29.755
A-Estimate	38.308	27.900	38.466	28.019
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	38.587	28.180	38.697	28.250
A-Estimate	35.793	25.386	35.926	25.479
Method	pooled	pooled	pooled	pooled

Table 4-31: Statistics and Basis Values for OHC3 Strength Data

4.22 Quasi Isotropic (25/50/25) Filled Hole Compression (FHC1)

The Filled Hole Compression data is normalized, so both normalized and as-measured statistics are provided. There was insufficient data to compute B-basis values due to unacceptable failure modes. Only estimates are provided.

The as-measured data from the RTD condition failed the ADK test, but passed with the modified CV transformation of the data. A and B-estimates for that dataset were computed using the ANOVA method.

There was one outlier. The highest value in batch two of the normalized RTD data was an outlier for the RTD condition. It was not an outlier for batch two or for the as-measured RTD data. The outlier was retained for this analysis.

Statistics, basis values and estimates are given for FHC1 strength data in Table 4-32. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-24.

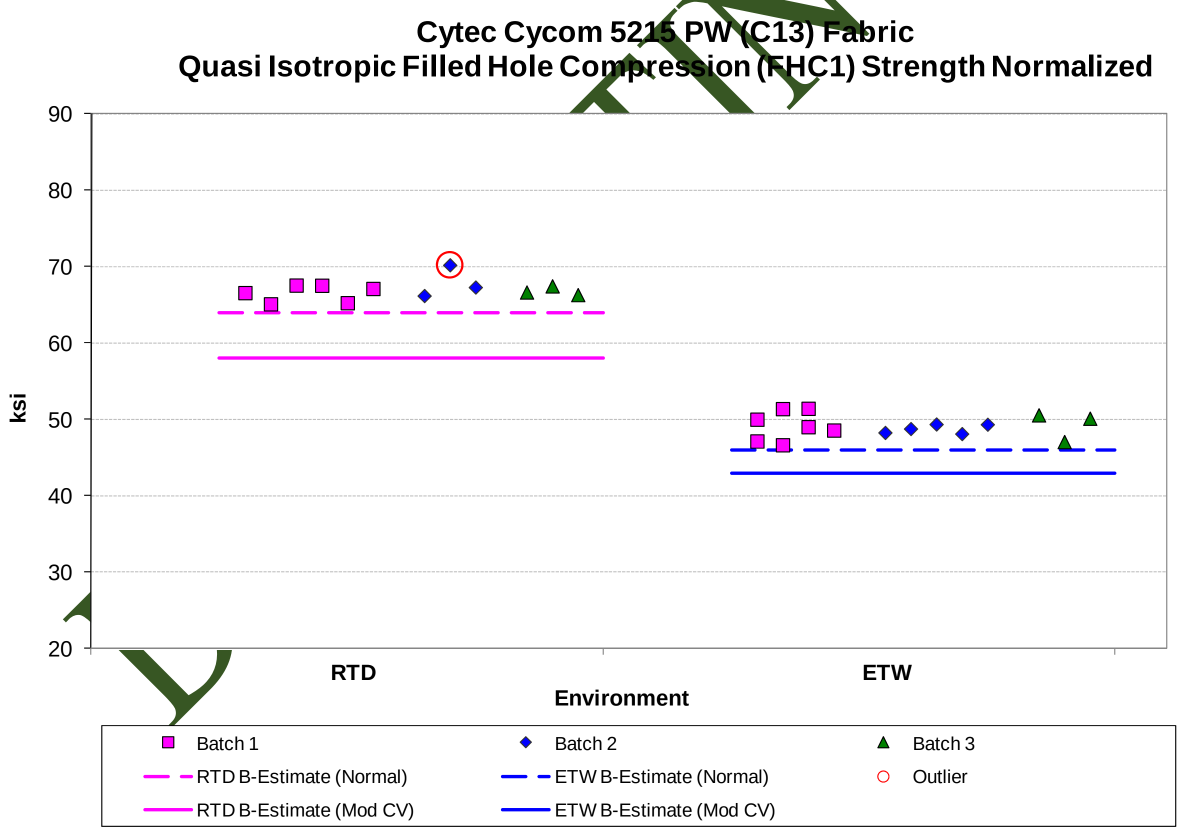

Figure 4-24: Batch plot for FHC1 normalized strength

Filled Hole Compression (FHC1) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	66.928	49.056	66.836	48.915
Stdev	1.323	1.478	1.950	1.684
CV	1.977	3.013	2.918	3.442
Modified CV	6.000	6.000	6.000	6.000
Min	65.093	46.658	63.866	46.253
Max	70.200	51.419	69.393	52.787
No. Batches	3	3	3	3
No. Spec.	12	15	12	15
Basis Values and Estimates				
B-Estimate	64.003	45.998	54.806	45.431
A-Estimate	61.970	43.854	46.235	42.988
Method	Normal	Normal	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-Estimate	58.049	42.966	57.968	42.842
A-Estimate	51.876	38.693	51.804	38.581
Method	Normal	Normal	Normal	Normal

Table 4-32: Statistics and Basis Values for FHC1 Strength Data

4.23 "Soft" (10/80/10) Filled Hole Compression (FHC2)

The Filled Hole Compression data is normalized, so both normalized and as-measured statistics are provided. The data from the RTD condition, both as-measured and normalized, failed the ADK test, but passed with the modified CV transformation of the data. The as-measured data from the ETW condition, failed the ADK test even with the use of the modified CV method. A and B-estimates for those datasets were computed using the ANOVA method. Modified CV basis values and estimates are provided for the RTD datasets. In addition, A-and B-estimates are provided for the as-measured ETW data with an override of the ADK test results.

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

Statistics, basis values and estimates are given for FHC2 strength data in Table 4-33. The normalized data and the B-basis values are shown graphically in Figure 4-25.

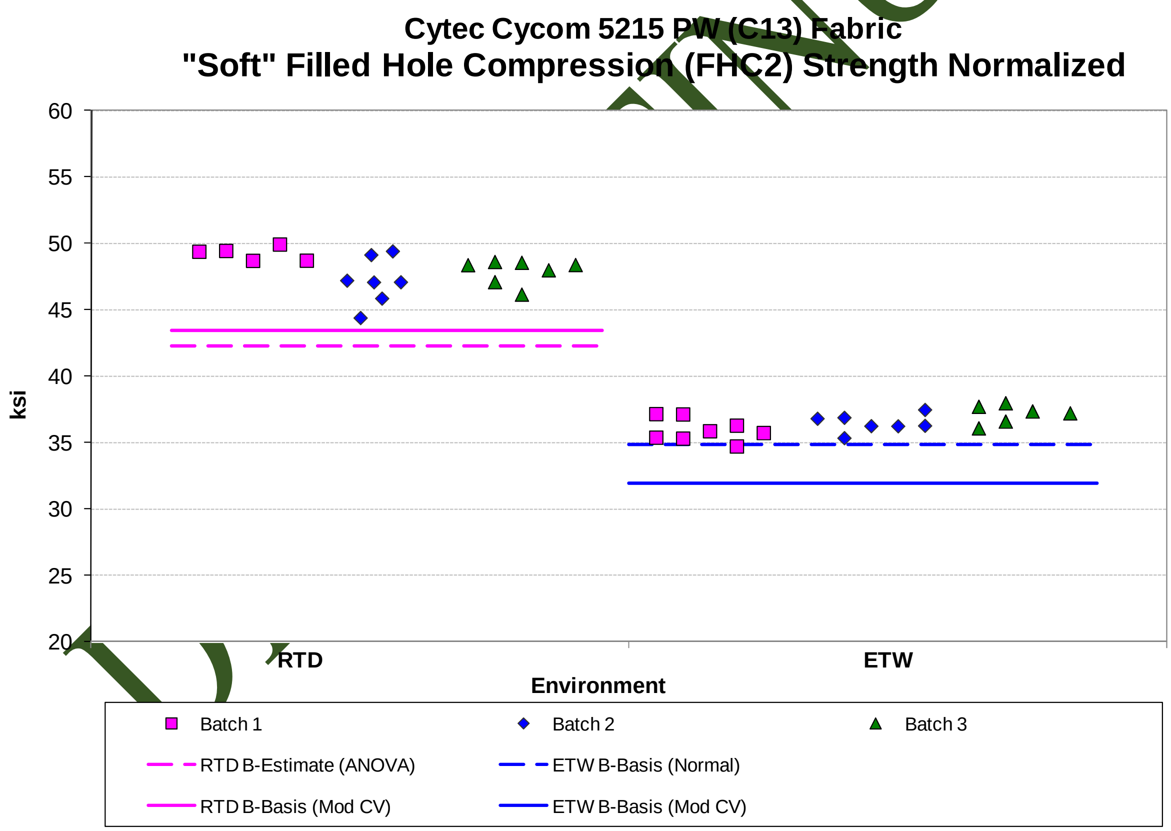

Figure 4-25: Batch plot for FHC2 normalized strength

Filled Hole Compression (FHC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	47.970	36.466	48.109	36.235
Stdev	1.435	0.878	1.531	1.434
CV	2.992	2.407	3.181	3.957
Modified CV	6.000	6.000	6.000	6.000
Min	44.389	34.720	43.529	34.166
Max	49.926	37.972	50.320	38.458
No. Batches	3	3	3	3
No. Spec.	19	21	19	21
Basis Values and Estimates				
B-basis Value		34.794		
B-Estimate	42.238		42.220	27.928
A-Estimate	38.153	33.601	38.022	21.997
Method	ANOVA	Normal	ANOVA	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	43.411	31.947	42.483	
B-Estimate with override of ADK test result				32.092
A-Estimate	40.304	28.832	38.494	29.141
Method	pooled	pooled	Normal	Normal

Table 4-33: Statistics and Basis Values for FHC2 Strength Data

4.24 “Hard” (40/20/40) Filled Hole Compression (FHC3)

The Filled Hole Compression data is normalized, so both normalized and as-measured statistics are provided. The normalized data had no diagnostic test failures, so pooling the RTD and ETW conditions was acceptable. The as-measured data from the ETW condition failed the ADK test, but passed with the modified CV transformation of the data. A and B-estimates for the ETW dataset were computed using the ANOVA method. Pooling the RTD and ETW conditions together was acceptable to compute the modified CV basis values for the as-measured data.

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

Statistics, basis values and estimates are given for FHC3 strength data in Table 4-34. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-26.

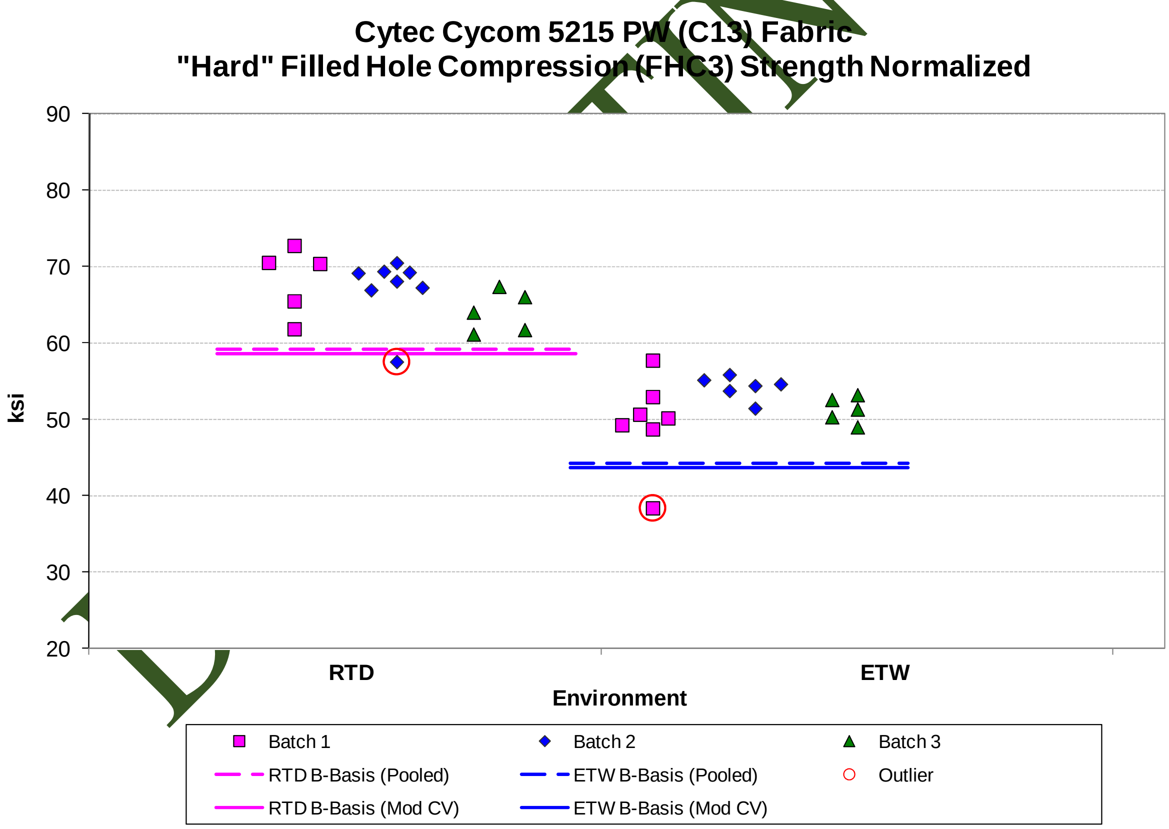

Figure 4-26: Batch plot for FHC3 normalized strength

Filled Hole Compression (FHC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	66.623	51.642	67.127	51.769
Stdev	4.009	4.163	3.563	4.137
CV	6.017	8.062	5.309	7.991
Modified CV	7.009	8.062	6.654	7.996
Min	57.539	38.399	58.380	38.379
Max	72.735	57.720	71.870	57.690
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and Estimates				
B-basis Value	59.181	44.200	60.091	
B-Estimate				38.005
A-Estimate	54.115	39.134	55.106	28.209
Method	pooled	pooled	Normal	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	58.568	43.587	59.285	43.927
A-Estimate	53.085	38.104	53.947	38.589
Method	pooled	pooled	pooled	pooled

Table 4-34: Statistics and Basis Values for FHC3 Strength Data

4.25 Laminate Short Beam Strength (SBS1)

The SBS1 data is not normalized. The data from the ETW condition failed the ADK test, but passed with the modified CV transformation of the data. A and B-estimates for the LSBS dataset were computed using the ANOVA method. Pooling was not appropriate for the modified CV basis values due to a failure of Levene's test. There were no outliers.

Statistics, basis values and estimates are given for the SBS1 data in Table 4-35. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-27.

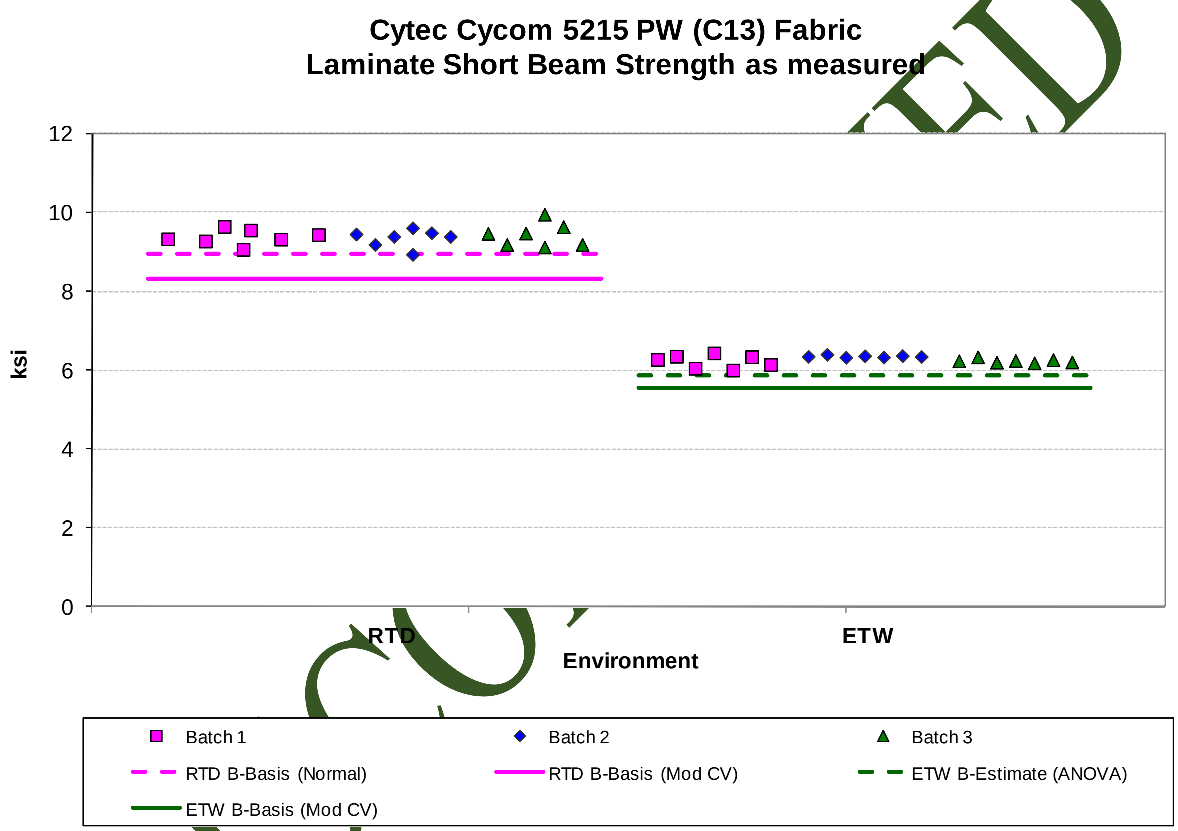

Figure 4-27: Batch plot for SBS1 as measured

Laminate Short Beam Strength (SBS1) Basis Values and Statistics as measured		
Env	RTD	ETW
Mean	9.388	6.277
Stdev	0.232	0.112
CV	2.473	1.791
Modified CV	6.000	6.000
Min	8.938	6.006
Max	9.956	6.439
No. Batches	3	3
No. Spec.	21	21
Basis Value Estimates		
B-basis Value	8.945	
B-Estimate		5.877
A-Estimate	8.630	5.591
Method	Normal	ANOVA
Modified CV Basis Values and Estimates		
B-basis Value	8.314	5.559
A-Estimate	7.550	5.048
Method	Normal	Normal

Table 4-35: Statistics and Basis Values for SBS1 Data

4.26 Quasi Isotropic (25/50/25) Single Shear Bearing (SSB1)

The Single Shear Bearing data is normalized, so both normalized and as-measured statistics are provided. The data from the 2% offset strength RTD condition, both as-measured and normalized, failed the ADK test. The normalized RTD data passed with the modified CV transformation of the data but the as-measured data did not. The as-measured ultimate strength data from the ETW condition failed the ADK but passed with the use of the modified CV method. A and B-estimates computed using the ANOVA method were used for those datasets. Pooling was acceptable for the modified CV basis values and estimates for the 2% offset strength data normalized and the ultimate strength data both normalized and as-measured. In addition, A- and B-estimates are provided for the as-measured 2% offset strength RTD condition data with an override of the ADK test results.

There was one outlier. The lowest value in batch three of the 2% offset strength ETW data was an outlier for batch three, but not for the ETW condition. It was an outlier for both the normalized and the as-measured ETW data. The outlier was retained for this analysis.

Statistics, basis values and estimates are given for the SSB1 strength data in Table 4-36. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-28.

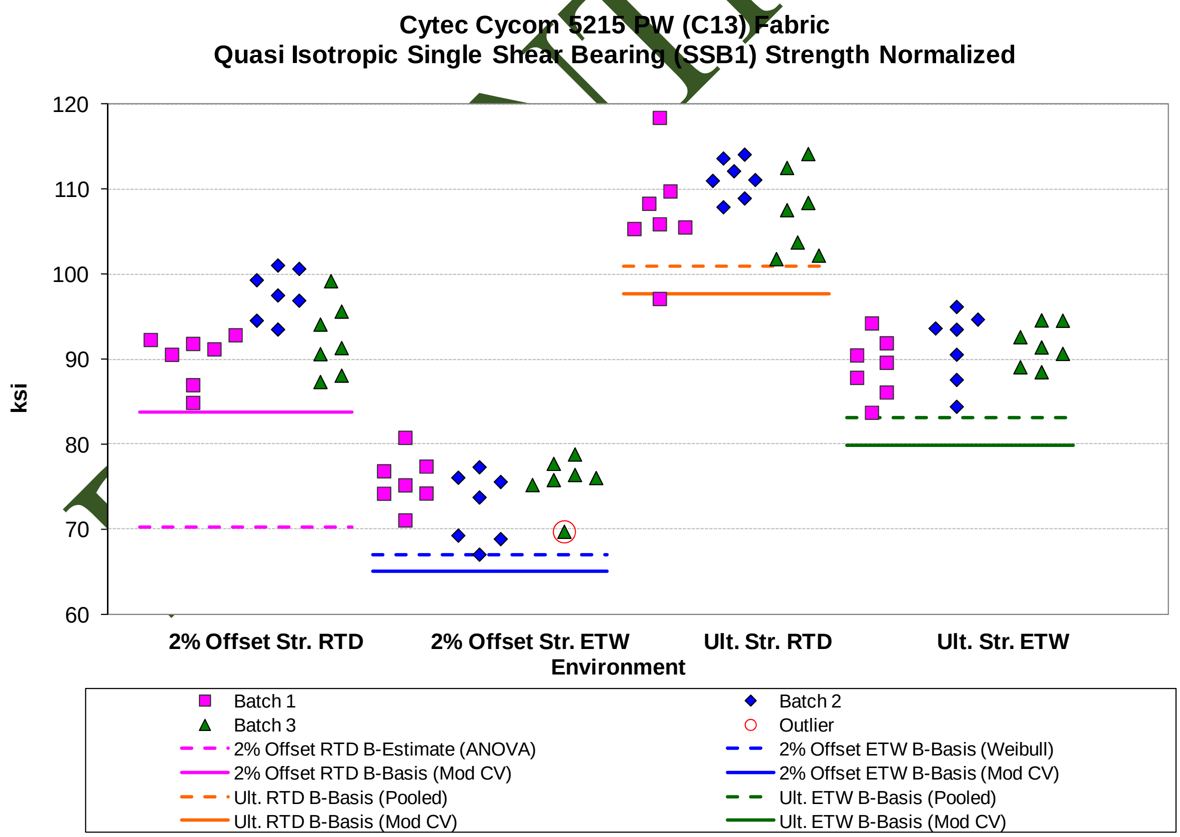

Figure 4-28: Batch plot for SSB1 normalized strength

Single Shear Bearing (SSB1) Strength Basis Values and Statistics								
	Normalized				As measured			
Property	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	93.377	74.671	108.568	90.780	95.539	75.121	111.067	91.351
Stdev	4.599	3.550	4.975	3.506	5.257	3.772	5.435	4.368
CV	4.926	4.754	4.583	3.862	5.503	5.021	4.893	4.782
Modified CV	6.463	6.377	6.291	6.000	6.751	6.511	6.447	6.391
Min	84.918	67.075	97.142	83.753	86.159	66.596	96.942	82.459
Max	101.069	80.802	118.423	96.198	104.546	79.553	120.297	96.921
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21	21	21
Basis Values and Estimates								
B-basis Value		66.962	100.937	83.148		67.935	100.714	
B-Estimate	70.232				66.613			71.627
A-Estimate	53.710	59.054	95.688	77.900	45.964	62.813	93.333	57.548
Method	ANOVA	Weibull	pooled	pooled	ANOVA	Normal	Normal	ANOVA
Modified CV Basis Values and Estimates								
B-basis Value	83.738	65.032	97.614	79.826		65.801	99.483	79.767
B-Estimate with override of ADK test result					83.247			
A-Estimate	77.109	58.403	90.081	72.292	74.492	59.162	91.516	71.801
Method	pooled	pooled	pooled	pooled	Normal	Normal	pooled	pooled

Table 4-36: Statistics and Basis Values for SSB1 Strength Data

4.27 "Soft" (10/80/10) Single Shear Bearing (SSB2)

The Single Shear Bearing data is normalized, so both normalized and as-measured statistics are provided. The as-measured data from the 2% offset strength ETW condition failed the ADK test even after applying the modified CV transformation of the data. The normalized data from the 2% offset strength ETW condition failed the ADK, but passed with the modified CV transformation of the data. A and B-estimates for those datasets were computed using the ANOVA method. Pooling was acceptable to compute the normalized modified CV basis values and estimates.

There were no diagnostic test failures for the ultimate strength datasets, so pooling was acceptable in all cases for those datasets.

There were two outliers, both in the RTD condition. The lowest value in batch two of the 2% offset strength RTD data was an outlier for the RTD condition, but not for batch two. It was an outlier for both the normalized and the as-measured RTD data. The highest value in batch three of the ultimate strength RTD as-measured data was an outlier for the RTD condition, but not for batch three. It was an outlier only for the as-measured data, not the normalized data. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for the SSB2 strength data in Table 4-37. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-29.

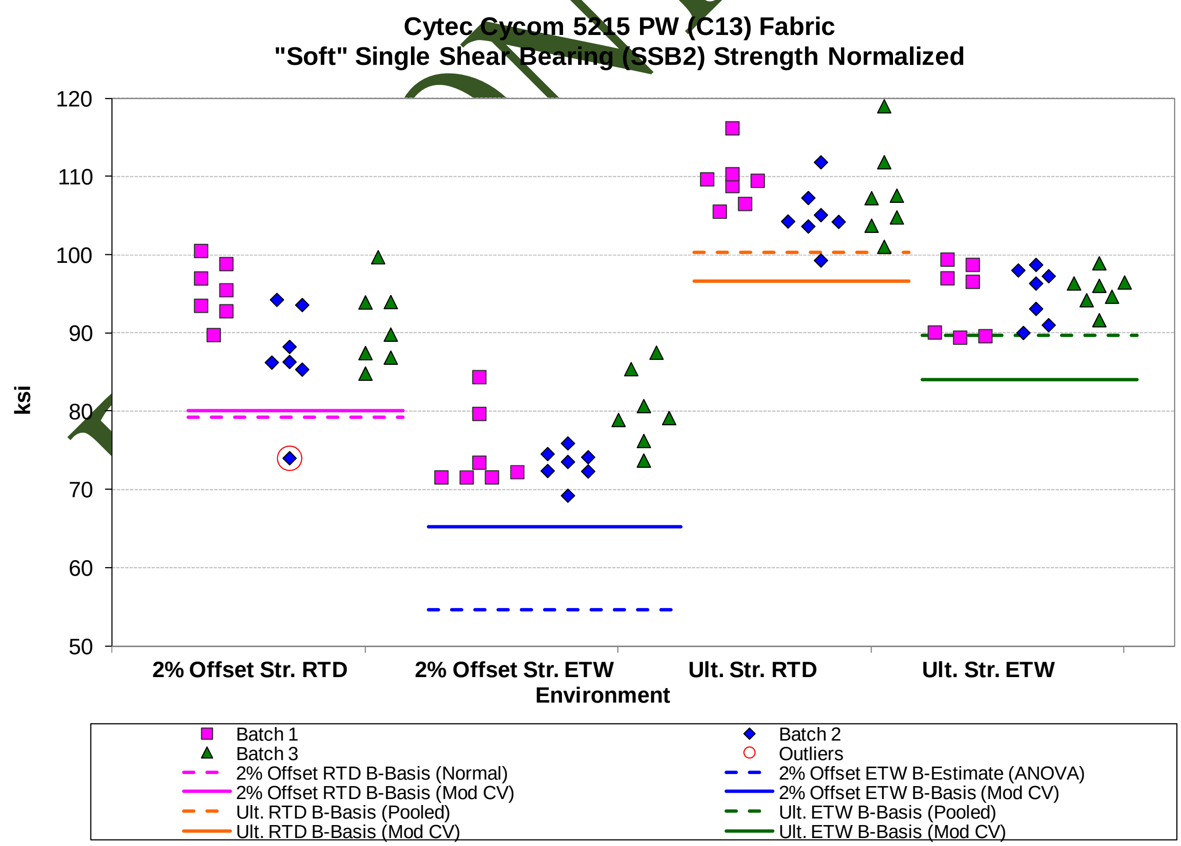

Figure 4-29: Batch plot for SSB2 normalized strength

Single Shear Bearing (SSB2) Strength Basis Values and Statistics								
	Normalized				As measured			
Property	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	91.095	76.126	107.520	94.965	92.393	76.511	109.059	95.408
Stdev	6.209	5.069	4.698	3.396	6.579	5.713	5.534	3.802
CV	6.816	6.659	4.369	3.576	7.121	7.468	5.075	3.985
Modified CV	7.408	7.329	6.185	6.000	7.560	7.734	6.537	6.000
Min	74.037	69.253	99.312	89.447	73.583	70.029	100.742	88.143
Max	100.534	87.541	119.033	99.432	104.626	90.138	124.865	102.728
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21	21	21
Basis Values and Estimates								
B-basis Value	79.268		100.252	87.696	79.860		100.640	86.989
B-Estimate		54.608				44.965		
A-Estimate	70.835	39.250	95.253	82.698	70.925	22.445	94.849	81.199
Method	Normal	ANOVA	pooled	pooled	Normal	ANOVA	pooled	pooled
Modified CV Basis Values and Estimates								
B-basis Value	80.116	65.147	96.540	83.984	79.082	65.235	97.594	83.943
A-Estimate	72.565	57.596	88.989	76.433	69.600	57.203	89.710	76.059
Method	pooled	pooled	pooled	pooled	Normal	Normal	pooled	pooled

Table 4-37: Statistics and Basis Values for SSB2 Strength Data

4.28 "Hard" (40/20/40) Single Shear Bearing (SSB3)

The Single Shear Bearing data is normalized, so both normalized and as-measured statistics are provided. The normalized data from the ultimate strength RTD condition failed the ADK, but passed with the modified CV transformation of the data. A and B-estimates for those datasets were computed using the ANOVA method. Pooling was acceptable for basis values and estimates for the 2% offset strength, both normalized and as-measured, for ultimate strength as-measured data. Pooling was acceptable for the normalized ultimate strength only for the modified CV method.

There were two outliers. The highest value in batch three of the ultimate strength ETW as-measured data was an outlier for the ETW condition, but not for batch three. The highest value in batch three of the 2% strength ETW as-measured data was an outlier for batch three but not for the ETW condition. Both were outliers only for the as-measured data, not the normalized data. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for the SSB3 strength data in Table 4-38. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-30.

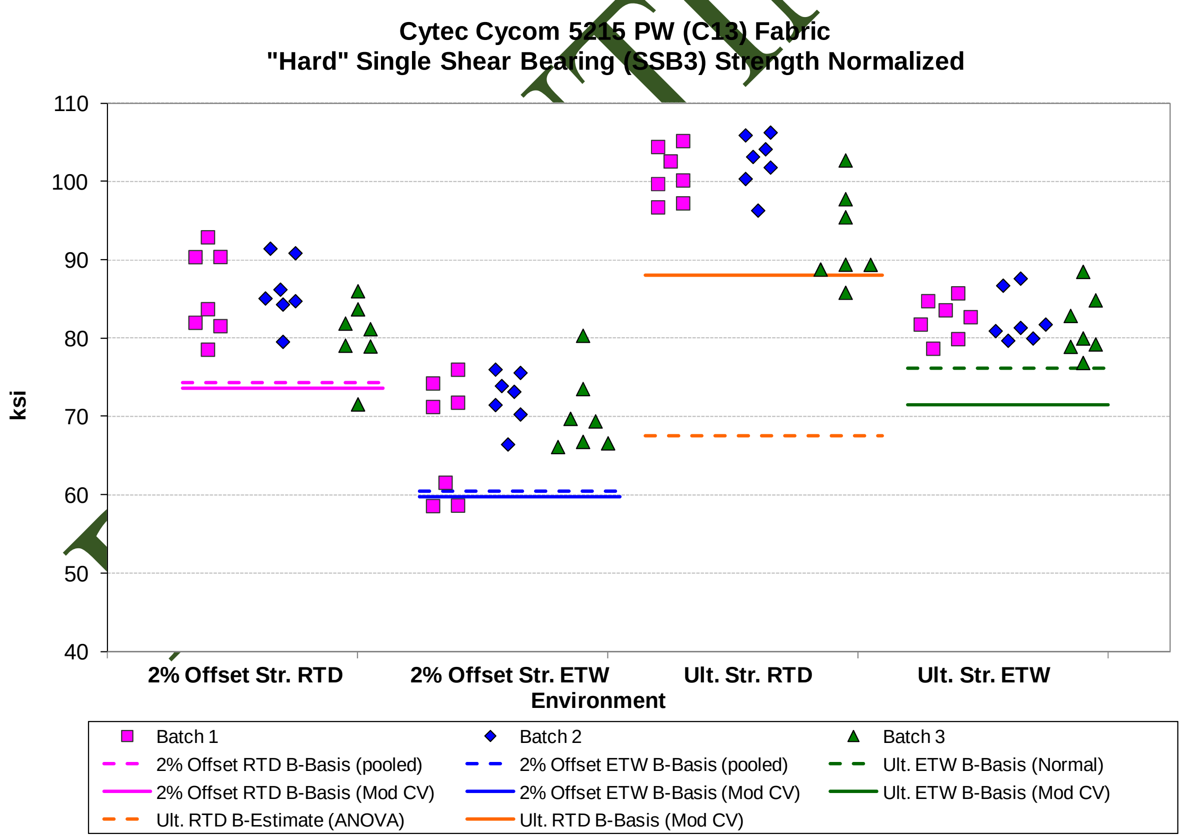

Figure 4-30: Batch plot for SSB3 normalized strength

Single Shear Bearing (SSB3) Strength Basis Values and Statistics								
	Normalized				As measured			
Property	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	84.027	70.094	98.749	82.230	85.966	70.249	101.021	82.405
Stdev	5.242	5.713	6.086	3.185	4.995	6.030	5.702	3.757
CV	6.239	8.150	6.163	3.874	5.810	8.583	5.644	4.559
Modified CV	7.120	8.150	7.082	6.000	6.905	8.583	6.822	6.279
Min	71.596	58.615	85.842	76.885	75.072	57.841	89.297	76.764
Max	92.920	80.355	106.289	88.513	94.562	83.090	108.844	92.809
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21	21	21
Basis Values and Estimates								
B-basis Value	74.305	60.371		76.162	76.148	60.432	92.459	73.843
B-Estimate			67.471					
A-Estimate	67.619	53.685	45.143	71.836	69.397	53.681	86.571	67.955
Method	pooled	pooled	ANOVA	Normal	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates								
B-basis Value	73.655	59.722	88.018	71.499	75.356	59.640	90.215	71.599
A-Estimate	66.522	52.588	80.638	64.119	68.060	52.344	82.783	64.167
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-38: Statistics and Basis Values for SSB3 Strength Data

4.29 Compression After Impact 1 (CAI1)

The Compression After Impact data was normalized, so statistics are provided for both normalized and as-measured datasets. Basis values are not computed for this property. Only one batch of material was tested. Testing is done only for the RTD condition. There were no outliers. Summary statistics are presented in Table 4-39 and the data are displayed graphically in Figure 4-31.

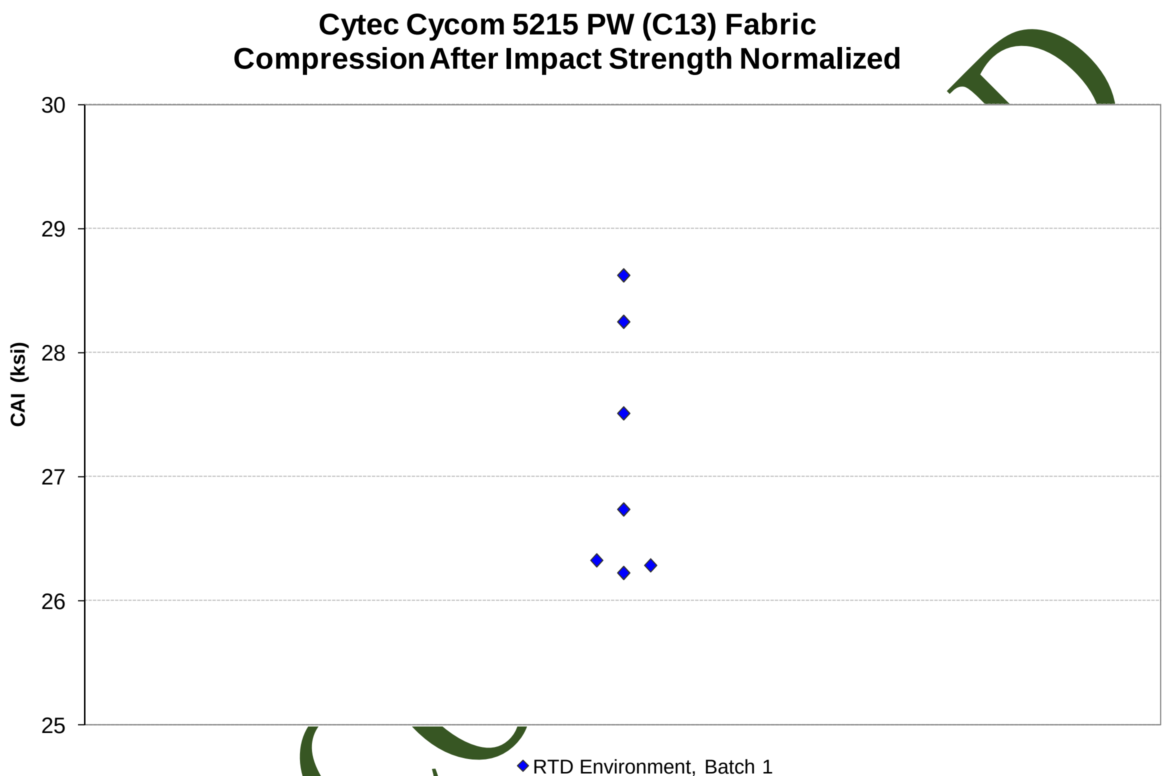

Figure 4-31: Plot for Compression After Impact normalized strength

Compression After Impact (CAI1) Strength Statistics		
	Normalized	As Measured
Env	RTD	RTD
Mean	27.140	26.561
Stdev	0.996	1.062
CV	3.672	3.999
Modified CV	6.000	6.000
Min	26.228	25.439
Max	28.626	27.990
No. Batches	1	1
No. Spec.	7	7

Table 4-39: 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 this property. Only one batch of material was tested. There were no outliers. The summary statistics are presented in Table 4-40 and the data are displayed graphically in Figure 4-32.

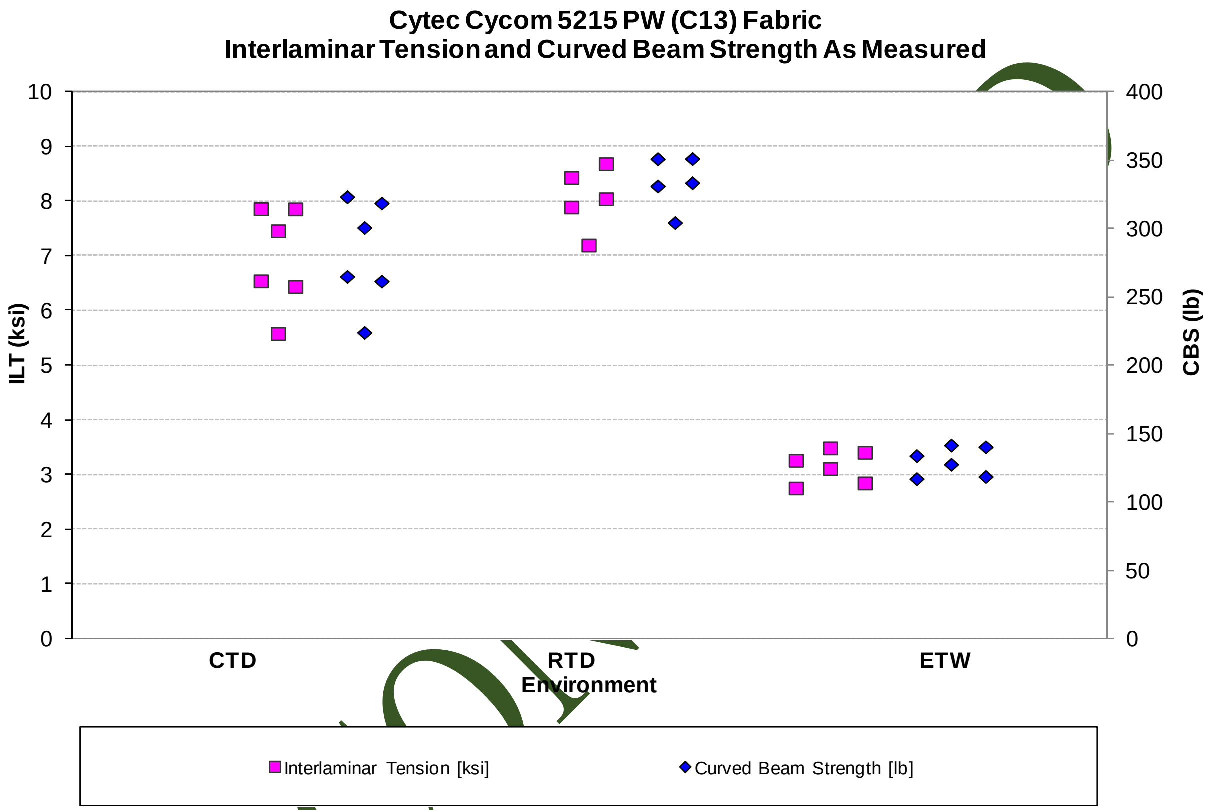

Figure 4-32: Plot for Interlaminar Tension and Curved Beam Strength as measured

Interlaminar Tension (ILT) and Curved Beam Strength (CBS) Statistics as measured						
	ILT [ksi]			CBS [lb]		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	6.957	8.050	3.148	282.179	334.188	129.896
Stdev	0.918	0.570	0.297	38.635	19.165	10.573
CV	13.195	7.077	9.441	13.692	5.735	8.140
Modified CV	13.195	7.538	9.441	13.692	6.867	8.140
Min	5.581	7.198	2.758	224.027	304.324	117.106
Max	7.862	8.683	3.489	323.230	351.095	141.641
No. Batches	1	1	1	1	1	1
No. Spec.	6	5	6	6	5	6

Table 4-40: 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-2010-067 N/C.

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

Test	Condition	Batch	Specimen Number	Normalized Strength	Strength As Measured	High/ Low	Batch Outlier	Condition Outlier
SBS	RTD	3	C0FQC211A	NA	9.118	Low	No	Yes
UNT1	ETW	2	C0FAB119M	Not an Outlier	84.947	High	Yes	No
UNT2	CTD	1	C0FBA217B	Not an Outlier	55.981	High	Yes	No
	CTD	3	C0FBC118B	50.530	Not an Outlier	Low	Yes	No
UNT3	CTD	1	C0FCA216B	Not an Outlier	104.982	High	No	Yes
UNC1	RTD	3	C0FWC111A	82.419	86.327	High	Yes	No
	ETW	2	C0FWB11CM	54.992	Not an Outlier	High	Yes	No
UNC2	ETW	2	C0FXB218M	32.197	31.963	Low	Yes	Yes - As meas, No - Norm
OHT1	CTD	3	C0FDC117B	44.955	44.978	High	Yes	No
OHT2	CTD	3	C0FEC217B	40.072	Not an Outlier	High	Yes	No
	RTD	2	C0FEB213A	Not an Outlier	37.176	Low	Yes	No
OHT3	CTD	2	C0FFB215B	57.410	Not an Outlier	High	No	Yes
OHC1	RTD	2	C0FGB113A	Not an Outlier	41.698	High	Yes	No
FHT1	RTD	1	C0F4A212A	Not an Outlier	49.345	High	Yes	No
FHT3	CTD	1	C0F6A119B	48.404	Not an Outlier	Low	No	Yes
	ETW	3	C0F6C21BM	Not an Outlier	62.998	High	Yes	No
FHC1	RTD	2	C0F7B113A	70.200	Not an Outlier	High	No	Yes
FHC2	RTD	2	C0F8B213A	Not an Outlier	43.529	Low	No	Yes
FHC3	RTD	2	C0F9B111A	57.539	58.380	Low	Yes	No
	ETW	1	C0F9A118M	38.399	38.379	Low	No	Yes
IPS - Strength at 5% Strain	ETW	1	C0FNA21BM	NA	5.852	Low	Yes	No
		3	C0FNC21BM	NA	5.803	Low	Yes	No
IPS - 0.2% Offset Strength	RTD	2	C0FNB111A	NA	6.354	High	Yes	No
		3	C0FNC111A	NA	6.277	High	Yes	No
SSB1 - 2% Offset Strength	ETW	3	C0F1C117M	69.759	71.600	Low	Yes	No
SSB2 - 2% Offset Strength	RTD	2	C0F2B112A	74.037	73.583	Low	No	Yes
SSB2 - Ultimate Strength	RTD	3	C0F2C114A	Not an Outlier	124.865	High	No	Yes
SSB3 - 2% Offset Strength	ETW	3	C0F3C217M	Not an Outlier	83.090	High	Yes	No
SSB3 - Ultimate Strength	ETW	3	C0F3C216M	Not an Outlier	92.809	High	No	Yes

Table 5-1: List of outliers

6. References

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