Hexcel Hexply® 8552S AS4 GP 3K 8HS fabric with 38% RC Material Allowables Statistical Analysis Report

NCAMP Project Number: NPN 021801

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1. Introduction

This report contains statistical analysis of the Hexcel Hexply® 8552S AS4 3K 8HS weave fabric prepreg material property data published in NCAMP Test Report CAM-RP-2019-057 Rev -. The lamina and laminate material property data have been generated with NCAMP oversight through NCAMP Special Project Number NPN 021801 and also meet the requirements outlined in NCAMP Standard Operating Procedure NSP 100. The test panels and test specimens have been inspected by NCAMP Authorized Inspection Representatives (AIR) and the testing has been witnessed by NCAMP Authorized Engineering Representatives (AER).

B-Basis values, A-estimates, and B-estimates were calculated using a variety of techniques that are detailed in section two. The qualification material was procured to NCAMP Material Specification NMS 128/4 Rev - dated May 7, 2018. The qualification test panels were cured in accordance with NCAMP Process Specification NPS 81228 Rev B dated April 14, 2011 with Baseline “M” Cure Cycle. The panels were fabricated at Spirit AeroSystems, 3800 Oliver St., Wichita, KS 67210. The NCAMP Test Plan NTP 1528Q1 was used for this qualification program. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas.

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

The material property data acquisition process is designed to generate basic material property data with sufficient pedigree for submission to Complete Documentation sections of the Composite Materials Handbook (CMH-17-1G).

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

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

The applicability and accuracy of NCAMP material property data, material allowables, and specifications must be evaluated on case-by-case basis by aircraft companies and certifying agencies. NCAMP assumes no liability whatsoever, expressed or implied, related to the use of the material property data, material allowables, and specifications.

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

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 128/4. NMS 128/4 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 128/4. NMS 128/4* 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
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 Peak Strength before 5% strain	F_{12}^{smax}
In Plane Shear Modulus	G_{12}^s

Table 1-2: Test Property Symbols

Environmental Condition	Abbreviation	Temperature
Cold Temperature Dry	CTD	−65 ± 5˚F
Room Temperature Dry	RTD	70 ± 10˚F
Elevated Temperature Dry	ETD	250 ± 5˚F
Elevated Temperature Wet	ETW	250 ± 5˚F

Table 1-3: Environmental Conditions Abbreviations

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

1 refers to a 25/50/25 layup. This is also referred to as "Quasi-Isotropic"
2 refers to a 10/80/10 layup. This is also referred to as “Soft”
3 refers to a 40/20/40 layup. This is also referred to as “Hard”

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

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2019-057 Rev -.

1.2 Pooling Across Environments

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

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

1.3 Basis Value Computational Process

The general form to compute engineering basis values is: $\text{basis value} = \bar{X} - kS$ 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.

1.4 Modified Coefficient of Variation (CV) Method

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

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

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

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

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

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

2. Background

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

2.1 CMH17 STATS Statistical Formulas and Computations

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

2.1.1 Basic Descriptive Statistics

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

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

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

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

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

2.1.2 Statistics for Pooled Data

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

2.1.2.1 Pooled Standard Deviation

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

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

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

2.1.2.2 Pooled Coefficient of Variation

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

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

2.1.3 Basis Value Computations

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

Basis Values:
$$A - basis = \bar{X} - K_a S$$
$$B - basis = \bar{X} - K_b S$$
Equation 6

2.1.3.1 K-factor computations

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

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

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

Where

r = the number of environments being pooled together

n_j = number of data values for environment j

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

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

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

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

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

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

2.1.4 Modified Coefficient of Variation

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

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

This is converted to percent by multiplying by 100%.

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

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

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

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

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

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

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

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

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

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

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

2.1.5 Determination of Outliers

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

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

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

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

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

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:

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

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

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

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

$$z_{(i)} = \frac{x_{(i)} - \bar{x}}{s}, \quad \text{for i = 1,…,n}$$ **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:

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

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

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

This OSL measures the probability of observing an Anderson-Darling statistic at least as extreme as the value calculated if, in fact, the data are a sample from a normal population. If OSL > 0.05, the data is considered sufficiently close to a normal distribution.

2.1.8 Levene's Test for Equality of Coefficient of Variation

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

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

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

2.1.9 Distribution Tests

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

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

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

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

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

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

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

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

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

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

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

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

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

2.1.9.3 Two-parameter Weibull Distribution

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

$$e^{-\left(a/\alpha\right)^{\beta}} - e^{-\left(b/\alpha\right)^{\beta}}$$ **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 2.1.9.3.1). Calculations specific to the goodness-of-fit test for the Weibull distribution are provided in section 2.1.9.3.2.

2.1.9.3.1 Estimating Weibull Parameters

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

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

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

2.1.9.3.2 Goodness-of-fit test for the Weibull distribution

The two-parameter Weibull distribution is considered by comparing the cumulative Weibull distribution function that best fits the data with the cumulative distribution function of the data. Using the shape and scale parameter estimates from section 2.1.9.3.1, let

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

The Anderson-Darling test statistic is

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

and the observed significance level is

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

where

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

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

2.1.9.3.3 Basis value calculations for the Weibull distribution

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

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

where

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

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

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

V is the value in Table 2-1 when the sample size is less than 16. For sample sizes of 16 or larger, a numerical approximation to the V values is given in the two equations immediately below.

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

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

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

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

Table 2-1: Weibull Distribution Basis Value Factors

2.1.9.4 Lognormal Distribution

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

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

2.1.9.4.1 Goodness-of-fit test for the Lognormal distribution

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

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

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

The Anderson-Darling statistic is then computed using Equation 30 above and the observed significance level (OSL) is computed using Equation 31 above. This OSL measures the probability of observing an Anderson-Darling statistic at least as extreme as the value calculated if in fact the data are a sample from a lognormal distribution. If OSL ≤ 0.05, one may conclude (at a five percent risk of being in error) that the population is not lognormally distributed. Otherwise, the hypothesis that the population is lognormally distributed is not rejected. For further information on these procedures, see reference 6.

2.1.9.4.2 Basis value calculations for the Lognormal distribution

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

2.1.10 Non-parametric Basis Values

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

2.1.10.1 Non-parametric Basis Values for large samples

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

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

For B-basis values:

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

For A-Basis values:

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

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

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

2.1.10.2 Non-parametric Basis Values for small samples

The Hanson-Koopmans method (references 8 and 9) is used for obtaining a B-basis value for sample sizes not exceeding 28 and A-basis values for sample sizes less than 299. This procedure requires the assumption that the observations are a random sample from a population for which the logarithm of the cumulative distribution function is concave, an assumption satisfied by a large class of probability distributions. There is substantial empirical evidence that suggests that composite strength data satisfies this assumption.

The Hanson-Koopmans B-basis value is:

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

The A-basis value is:

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

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

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

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

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

A-Basis Hanson-Koopmans Table					
n	k	n	k	n	k
2	80.00380	38	1.79301	96	1.32324
3	16.91220	39	1.77546	98	1.31553
4	9.49579	40	1.75868	100	1.30806
5	6.89049	41	1.74260	105	1.29036
6	5.57681	42	1.72718	110	1.27392
7	4.78352	43	1.71239	115	1.25859
8	4.25011	44	1.69817	120	1.24425
9	3.86502	45	1.68449	125	1.23080
10	3.57267	46	1.67132	130	1.21814
11	3.34227	47	1.65862	135	1.20620
12	3.15540	48	1.64638	140	1.19491
13	3.00033	49	1.63456	145	1.18421
14	2.86924	50	1.62313	150	1.17406
15	2.75672	52	1.60139	155	1.16440
16	2.65889	54	1.58101	160	1.15519
17	2.57290	56	1.56184	165	1.14640
18	2.49660	58	1.54377	170	1.13801
19	2.42833	60	1.52670	175	1.12997
20	2.36683	62	1.51053	180	1.12226
21	2.31106	64	1.49520	185	1.11486
22	2.26020	66	1.48063	190	1.10776
23	2.21359	68	1.46675	195	1.10092
24	2.17067	70	1.45352	200	1.09434
25	2.13100	72	1.44089	205	1.08799
26	2.09419	74	1.42881	210	1.08187
27	2.05991	76	1.41724	215	1.07595
28	2.02790	78	1.40614	220	1.07024
29	1.99791	80	1.39549	225	1.06471
30	1.96975	82	1.38525	230	1.05935
31	1.94324	84	1.37541	235	1.05417
32	1.91822	86	1.36592	240	1.04914
33	1.89457	88	1.35678	245	1.04426
34	1.87215	90	1.34796	250	1.03952
35	1.85088	92	1.33944	275	1.01773
36	1.83065	94	1.33120	299	1.00000
37	1.81139				

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

2.1.11 Analysis of Variance (ANOVA) Basis Values

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

2.1.11.1 Calculation of basis values using ANOVA

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

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

First, statistics are computed for each batch, which are indicated with a subscript $\left(n_i, \bar{x}_i, s_i^2\right)$ 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:

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

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

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

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

Next, the mean sums of squares are computed:

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

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

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

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

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

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

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

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

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

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

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

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

2.2 Single Batch and Two Batch Estimates using Modified CV

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

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

2.3 Lamina Variability Method (LVM)

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

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

The LVM B-basis value is then computed as:

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

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

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

With:

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

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

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

3. Summary of Results

The basis values for all tests are summarized in the following tables. The NCAMP recommended B-basis values meet all requirements of CMH-17-1G. However, not all test data meets those requirements. The summary tables provide a complete listing of all computed basis values and estimates of basis values. Data that does not meet the requirements of CMH-17-1G are shown in shaded boxes and labeled as estimates. Basis values computed with the modified coefficient of variation (CV) are presented whenever possible. Basis values and estimates computed without that modification are presented for all tests.

3.1 NCAMP Recommended B-basis Values

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

1. Recommended values are NEVER estimates. Only B-basis values that meet all requirements of CMH-17-1G are recommended.
2. Modified CV basis values are preferred. Recommended values will be the modified CV basis value when available. The CV provided with the recommended basis value will be the one used in the computation of the basis value.
3. Only normalized basis values are given for properties that are normalized.
4. ANOVA B-basis values are not recommended since only three batches of material are available and CMH-17-1G recommends that no less than five batches be used when computing basis values with the ANOVA method.
5. Basis values of 90% or more of the mean value imply that the CV is unusually low and may not be conservative. Caution is recommended with B-Basis values calculated from CMH-17 STATS when the B-basis value is 90% or more of the average value. Such values will be indicated.
6. If the data appear questionable (e.g. when the CTD-RTD-ETW trend of the basis values is 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 Hexcel Hexply® 8552S AS4 GP 3K 8HS fabric with 38% RC

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

Lamina Strength Tests

Environment	Statistic	WT	WC	FT	FC	SBS*	IPS*		
							0.2% Offset	5% Strain	Maximum
CTD (-65˚ F)	B-basis	106.3	132.5	95.92	108.4	NA: A	10.45**		14.26
	Mean	120.8	145.2	109.5	121.6	14.02	11.09		16.18
	CV	6.000	6.000	7.436	6.501	7.947	4.114		6.000
RTD (70˚ F)	B-basis	124.9	108.5	108.0	96.61	10.51	7.137	11.77	
	Mean	139.4	120.9	121.7	109.9	11.97	8.083	13.33	
	CV	6.000	6.000	6.164	6.000	6.184	6.000	6.000	
ETD (250˚ F)	B-basis		NA: I		NA: I	NA: I			
	Mean		91.25		86.16	8.210			
	CV		5.133		2.476	3.264			
ETW (250˚ F)	B-basis	125.6	57.35	105.2	NA: A	NA: A	2.669	4.539	
	Mean	140.1	69.61	119.0	64.24	5.901	3.028	5.149	
	CV	6.462	8.234	6.444	8.192	6.506	6.000	6.000	

Notes: The modified CV B-basis value is recommended when available.
The CV provided corresponds with the B-basis value given.
NA implies that tests were run but data did not meet NCAMP recommended requirements.
"NA: A" indicates ANOVA with 3 batches, "NA: I" indicates insufficient data,
Shaded empty boxes indicate that no test data is available for that property and condition.
* Data is as-measured rather than normalized
** indicates the Single Point B-basis value is greater than 90% of the mean value.

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

NCAMP Recommended B-basis Values for
Hexcel Hexply® 8552S AS4 GP 3K 8HS fabric with 38% RC

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

Laminate Strength Tests

Lay-up	ENV	Statistic	OHT	OHC	FHT	FHC**	UNT	UNC	SSB 2% Offset	SSB Ult.	SBS1*
25/50/25	CTD (-65˚ F)	B-basis	36.40		38.73		73.30				
		Mean	41.38		44.06		82.56				
		CV	6.389		6.950		6.000				
	RTD (70˚ F)	B-basis	40.67	44.11	42.69	73.38	81.67	82.18	91.55	114.3	8.639
		Mean	45.65	50.04	48.02	85.23	90.93	91.68	105.4	128.0	9.953
		CV	6.000	6.000	6.132	7.043	6.000	7.230	7.790	6.176	6.685
	ETW (250˚ F)	B-basis	45.72	28.07	45.06	43.17	78.49	43.75	72.79	81.49	4.446
		Mean	50.70	31.85	50.39	49.74	87.75	53.12	86.84	94.99	5.043
		CV	6.000	6.000	6.000	6.689	6.000	6.967	7.849	7.393	6.000
10/80/10	CTD (-65˚ F)	B-basis	36.51		39.78		45.51				
		Mean	40.45		44.05		51.94				
		CV	6.000		6.000		6.269				
	RTD (70˚ F)	B-basis	36.12	34.19	38.90		NA: A	49.16	93.79	119.3	
		Mean	40.06	38.78	43.17		53.58	55.76	108.6	132.3	
		CV	6.000	6.000	6.000		3.297	6.000	6.892	6.214	
	ETW (250˚ F)	B-basis	25.82	19.96	27.94		39.21	26.18	75.66	84.73	
		Mean	29.76	22.89	32.21		44.48	30.11	86.86	97.75	
		CV	6.000	6.482	6.000		6.000	6.852	6.531	6.000	
40/20/40	CTD (-65˚ F)	B-basis	43.54		44.06		NA: A				
		Mean	50.12		50.11		100.9				
		CV	6.933		6.206		6.130				
	RTD (70˚ F)	B-basis	52.27	52.15	49.81	79.31	103.5	82.89	91.09	NA: A	
		Mean	58.85	57.57	55.85	88.69	117.2	93.71	101.6	119.7	
		CV	6.304	6.429	6.371	6.971	6.000	6.281	6.435	5.187	
	ETW (250˚ F)	B-basis	59.31	27.96	52.19	46.91	103.0	49.27	65.42	76.36	
		Mean	65.89	33.38	58.24	56.34	116.8	59.85	75.91	86.62	
		CV	6.000	6.000	6.101	6.857	6.757	10.175	6.400	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
** Values for FHC data is not reported because FHC values are greater than or equal to UNC values. In such scenarios, NCAMP and CMH17 do not recommend the use of FHC values for design. UNC values are recommended for use instead.

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

3.2 Lamina and Laminate Summary Tables

Prepreg Material:	Hexcel Hexply® 8552S AS4 GP 3k 8HS		**Hexcel Hexply® 8552S AS4 GP 3K 8HS fabric with 38% RC Lamina Properties Summary**
Material Specification:	NMS 128/4		
Process Specification:	NPS 81228		
Fabric:	Hexcel AS4 GP 3k 8HS	**Resin:** Hexcel 8552S	
Tg(dry): 384.1 ˚F		**Tg(wet):** 301.6 ˚F	**Tg METHOD:** DMA (ASTM D7028)

Date of fiber manufacture	Sep-17 to Dec-17	**Date of testing:**	Dec-18 to Dec-19
Date of resin manufacture	Feb-18	**Date of data submittal**	Jan-20
Date of prepreg manufacture	Feb-18	**Date of analysis**	Oct-19 to Dec-19
Date of composite manufacture	Jun-18 to Sep-18		

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported: As-measured followed by normalized values in parentheses, normalizing tply: 0.015 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

Test Condition	CTD			RTD			ETD			ETW		
Property	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean
F_1^{tu}	109.1	106.6	122.9	131.0	128.5	144.8				120.2	117.6	134.0
(ksi)	(110.8)	(106.3)	(120.8)	(129.4)	(124.9)	(139.4)				(130.1)	(125.6)	(140.1)
E_1^t			9.861			9.833						9.047
(Msi)			(9.699)			(9.431)						(9.461)
ν_{12}^t			0.060			0.052						0.047
F_2^{tu}	95.27	94.46	110.7	115.4	109.1	123.6				102.7	101.4	116.0
(ksi)	(95.05)	(95.92)	(109.5)	(115.2)	(108.0)	(121.7)				(107.5)	(105.2)	(119.0)
E_2^t			9.201			9.006						8.699
(Msi)			(9.088)			(8.865)						(8.931)
F_1^{cu}	131.8	127.8	140.4	117.7	113.7	126.1	81.35	76.84	91.09	60.01	56.16	68.34
(ksi)	(136.0)	(132.5)	(145.2)	(111.9)	(108.5)	(120.9)	(80.84)	(76.91)	(91.25)	(60.71)	(57.35)	(69.61)
E_1^c			8.603			9.324			8.752			8.878
(Msi)			(8.905)			(8.888)			(8.767)			(8.628)
F_2^{cu}	107.9	104.4	117.6	101.8	98.30	111.5	74.00	64.67	85.21	35.46	NA	62.52
(ksi)	(112.2)	(108.4)	(121.6)	(100.5)	(96.61)	(109.9)	(79.70)	(65.39)	(86.16)	(38.45)	NA	(64.24)
E_2^c			8.260			8.561			8.159			8.002
(Msi)			(8.542)			(8.340)			(8.251)			(8.154)
$F_{12}^{s0.2\%}$ (ksi)	10.45	NA	11.09	7.465	7.137	8.083				2.426	2.669	3.028
$F_{12}^{s5\%}$ (ksi)				12.90	11.77	13.33				4.176	4.539	5.149
F_{12}^{smax} (ksi)	15.16	14.26	16.18									
G_{12}^s (Msi)			0.855			0.730						0.288
SBS (ksi)	9.232	NA	14.024	8.835	10.51	11.97	7.398	6.231	8.210	3.936	NA	5.901

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

Prepreg Material:	Hexcel Hexply® 8552S AS4 GP 3k 8HS		
Material Specification:	NMS 128/4		
Process Specification:	NPS 81228		
Fabric:	Hexcel AS4 GP 3k 8HS	**Resin:** Hexcel 8552S	
Tg(dry): 384.1˚F	**Tg(wet):** 301.6˚F	**Tg METHOD:** DMA (ASTM D7028)	

Hexcel Hexply® 8552S AS4 GP 3K 8HS fabric with 38% RC Properties Summary

Date of fiber manufacture	Sep-17 to Dec-17	**Date of testing:**	Dec-18 to Dec-19
Date of resin manufacture	Feb-18	**Date of data submittal**	Jan-20
Date of prepreg manufacture	Feb-18	**Date of analysis**	Oct-19 to Dec-19
Date of composite manufacture	Jun-18 to Sep-18		

LAMINATE MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported as normalized used a normalizing t_{ply} of 0.015 in

Values shown in shaded boxes do not meet CMH17 Rev G requirements and are estimates only

These values may not be used for certification unless specifically allowed by the certifying agency

Test	Property		Layup:	Quasi Isotropic 25/50/25			"Soft" 10/80/10			"Hard" 40/20/40		
		Test Condition	Unit	B-value	Mod. CV B-value	Mean	B-value	Mod. CV B-value	Mean	B-value	Mod. CV B-value	Mean
OHT (normalized)	Strength	CTD	ksi	38.13	36.40	41.38	32.72	36.51	40.45	44.97	43.54	50.12
		RTD	ksi	42.40	40.67	45.65	37.85	36.12	40.06	53.70	52.27	58.85
		ETW	ksi	40.33	45.72	50.70	26.49	25.82	29.76	57.18	59.31	65.89
OHC (normalized)	Strength	RTD	ksi	46.55	44.11	50.04	36.39	34.19	38.78	52.05	52.15	57.57
		ETW	ksi	27.78	28.07	31.85	20.49	19.96	22.89	30.78	27.96	33.38
UNT (normalized)	Strength	CTD	ksi	70.14	73.30	82.56	37.80	45.51	51.94	58.36	NA	100.9
	Modulus		Msi	---	---	6.924	---	---	4.736	---	---	8.535
	Strength	RTD	ksi	71.21	81.67	90.93	43.46	NA	53.58	93.16	103.5	117.2
	Modulus		Msi	---	---	6.643	---	---	4.394	---	---	8.303
	Strength	ETW	ksi	70.01	78.49	87.75	38.66	39.21	44.48	84.86	103.0	116.8
	Modulus		Msi	---	---	6.157	---	---	3.448	---	---	8.062
UNC (normalized)	Strength	RTD	ksi	83.29	82.18	91.68	46.41	49.16	55.76	84.02	82.89	93.71
	Modulus		Msi	---	---	6.328	---	---	4.226	---	---	7.867
	Strength	ETW	ksi	44.85	43.75	53.12	26.84	26.18	30.11	50.37	49.27	59.85
	Modulus		Msi	---	---	5.705	---	---	3.382	---	---	7.627
SBS1 (as-measured)	Strength	RTD	ksi	8.897	8.639	9.953	---	---	---	---	---	---
		ETW	ksi	4.003	4.446	5.043	---	---	---	---	---	---
FHT (normalized)	Strength	CTD	ksi	39.80	38.73	44.06	39.27	39.78	44.05	45.78	44.06	50.11
		RTD	ksi	43.75	42.69	48.02	41.71	38.90	43.17	51.53	49.81	55.85
		ETW	ksi	38.19	45.06	50.39	30.75	27.94	32.21	53.91	52.19	58.24
FHC* (normalized)	Strength	RTD	ksi	74.99	73.38	85.23	---	---	---	80.74	79.31	88.69
		ETW	ksi	44.46	43.17	49.74	---	---	---	48.35	46.91	56.34
Single Shear Bearing (normalized)	2% Offset Strength	RTD	ksi	91.88	91.55	105.4	82.85	93.79	108.6	93.67	91.09	101.6
		ETW	ksi	73.12	72.79	86.84	78.17	75.66	86.86	68.00	65.42	75.91
	Ultimate Strength	RTD	ksi	116.9	114.3	128.0	123.5	119.3	132.3	85.61	NA	119.7
		ETW	ksi	84.03	81.49	94.99	88.86	84.73	97.75	81.57	76.36	86.62
CAI (normalized)	Strength	RTD	ksi	---	---	34.01	---	---	---	---	---	---
ILT (as-measured)	Strength	CTD	ksi	---	---	11.84	---	---	---	---	---	---
		RTD	ksi	---	---	11.96	---	---	---	---	---	---
		ETW	ksi	---	---	3.876	---	---	---	---	---	---
CBS (as-measured)	Strength	CTD	lb	---	---	346.5	---	---	---	---	---	---
		RTD	lb	---	---	352.3	---	---	---	---	---	---
		ETW	lb	---	---	115.7	---	---	---	---	---	---

* Values for FHC data is not reported because FHC values are greater than or equal to UNC values. In such scenarios, NCAMP and CMH17 do not recommend the use of FHC values for design. UNC values are recommended for use instead.

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

4. Individual Test Summaries, Statistics, Basis Values and Graphs

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

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

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

4.1 Warp Tension (WT)

Warp Tension data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in three environmental conditions. The normalized RTD dataset did not pass the normality test, but the pooled dataset passed the normality test and there were no other diagnostic test failures. Hence, the data could be pooled across all three conditions to compute the basis values.

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

Statistics, estimates and basis values are given for the WT 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.

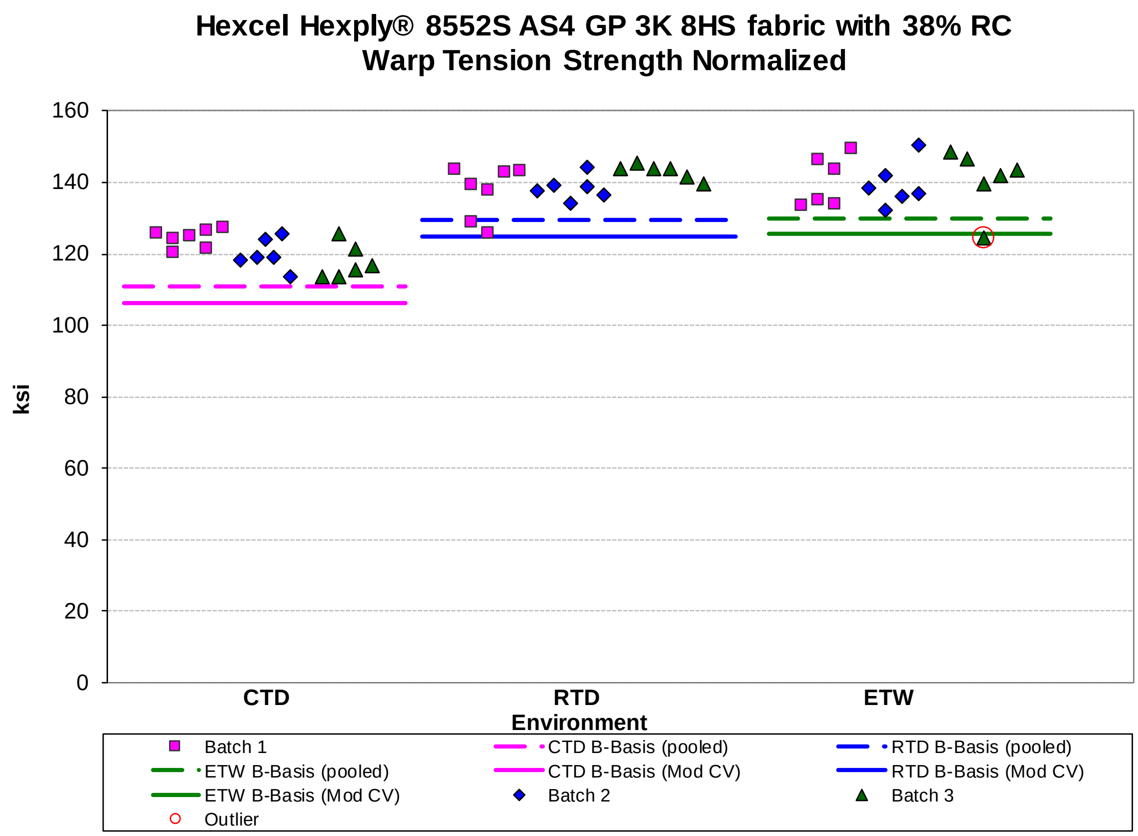

Figure 4-1: Batch plot for WT normalized strength

Warp Tension Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	120.8	139.4	140.1	122.9	144.8	134.0
Stdev	4.658	5.309	6.899	7.708	7.945	7.800
CV	3.856	3.808	4.923	6.274	5.488	5.820
Mod CV	6.000	6.000	6.462	7.137	6.744	6.910
Min	113.5	125.5	124.6	111.0	130.0	119.6
Max	127.2	145.2	150.4	138.0	155.7	145.0
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	18	19	19	18
Basis Value Estimates						
B-Basis	110.8	129.4	130.1	109.1	131.0	120.2
A-Estimate	104.1	122.8	123.4	99.9	121.8	111.0
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Value Estimates						
B-Basis	106.3	124.9	125.6	106.6	128.5	117.6
A-Estimate	96.60	115.2	115.9	95.63	117.5	106.7
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	9.699	9.431	9.461	9.861	9.833	9.047
Stdev	0.1357	0.09168	0.08430	0.3996	0.4020	0.1878
CV	1.399	0.9721	0.8910	4.052	4.089	2.076
Mod CV	6.000	6.000	6.000	6.026	6.044	6.000
Min	9.487	9.322	9.295	9.354	9.115	8.521
Max	9.985	9.694	9.598	10.55	10.42	9.341
No. Batches	3	3	3	3	3	3
No. Spec.	19	18	18	19	18	18

Table 4-2: Statistics from WT Modulus Data

4.2 Fill Tension (FT)

Fill Tension data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in three environmental conditions. The RTD datasets, both normalized and as-measured, did not pass the normality test, and the pooled dataset also failed normality. The RTD datasets and the normalized pooled data passed normality with the use of the modified CV transformation, so modified CV basis values are provided for the RTD condition and the pooled approach could be used for normalized modified CV basis values. Pooling was acceptable for as-measured RTD and ETW conditions for modified CV.

There were no statistical outliers.

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

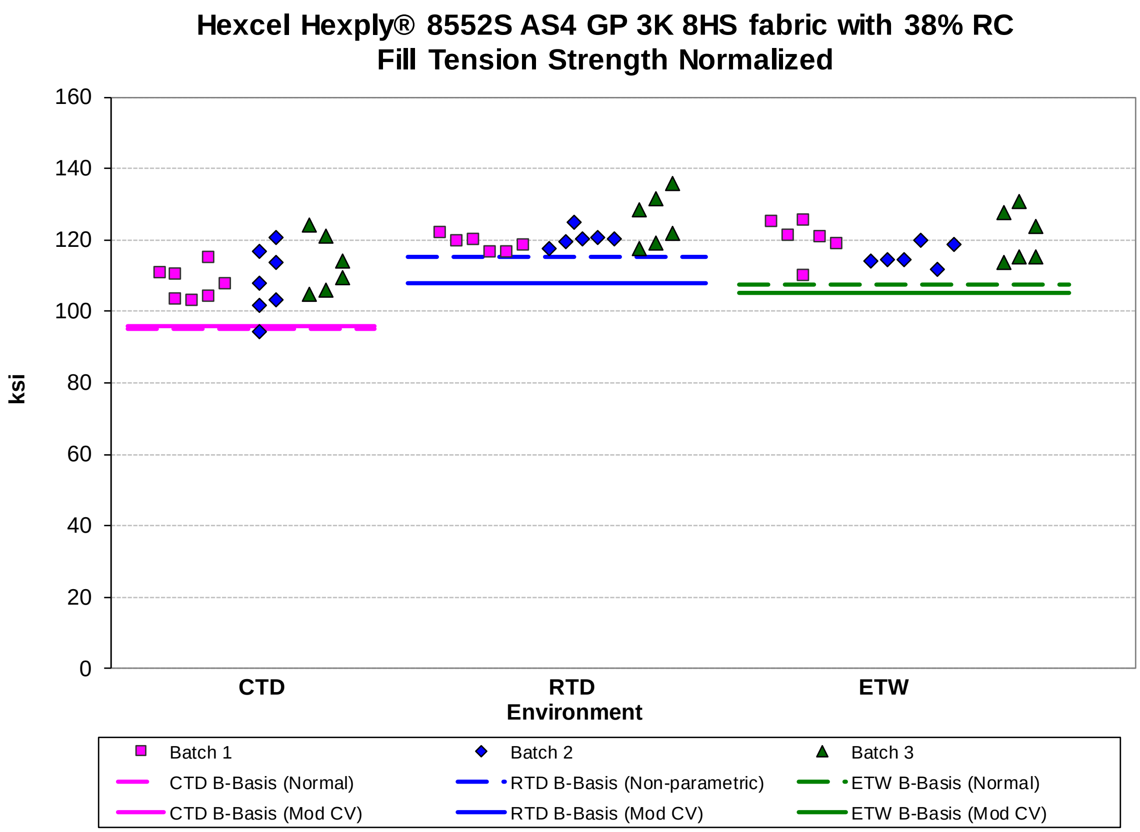

Figure 4-2: Batch Plot for FT normalized strength

Fill Tension Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	109.5	121.7	119.0	110.7	123.6	116.0
Stdev	7.527	5.269	5.815	8.019	6.077	6.766
CV	6.871	4.328	4.889	7.243	4.916	5.832
Mod CV	7.436	6.164	6.444	7.622	6.458	6.916
Min	94.30	116.5	109.8	93.27	116.9	107.1
Max	124.1	135.7	130.8	124.5	135.5	129.2
No. Batches	3	3	3	3	3	3
No. Spec.	20	18	18	20	18	18
Basis Value Estimates						
B-Basis	95.05	115.2	107.5	95.27	115.4	102.7
A-Estimate	84.74	92.66	99.34	84.28	93.74	93.19
Method	Normal	Non-Parametric	Normal	Normal	Non-Parametric	Normal
Modified CV Basis Value Estimates						
B-Basis	95.92	108.0	105.2	94.46	109.1	101.4
A-Estimate	86.73	98.80	96.02	82.90	99.14	91.52
Method	pooled	pooled	pooled	Normal	pooled	pooled

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	9.088	8.865	8.931	9.201	9.006	8.699
Stdev	0.1063	0.09781	0.1042	0.2165	0.3146	0.1687
CV	1.170	1.103	1.166	2.353	3.494	1.940
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	8.856	8.586	8.698	8.934	8.451	8.432
Max	9.291	8.968	9.115	9.640	9.509	8.980
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	19	18	18	19

Table 4-4: Statistics from FT Modulus Data

4.3 Warp Compression (WC)

Warp Compression data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in four environmental conditions, but the ETD condition had data available from only one batch, so only B-estimates can be provided for that condition. The normalized RTD dataset did not pass the normality test, but the pooled dataset passed the normality test and there were no other diagnostic test failures. Hence, the data could be pooled across all four conditions. While the CTD condition had only 15 specimens, this is adequate to meet CMH17 requirements when pooling across environments.

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

Statistics, basis values and estimates are given for the WC 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.

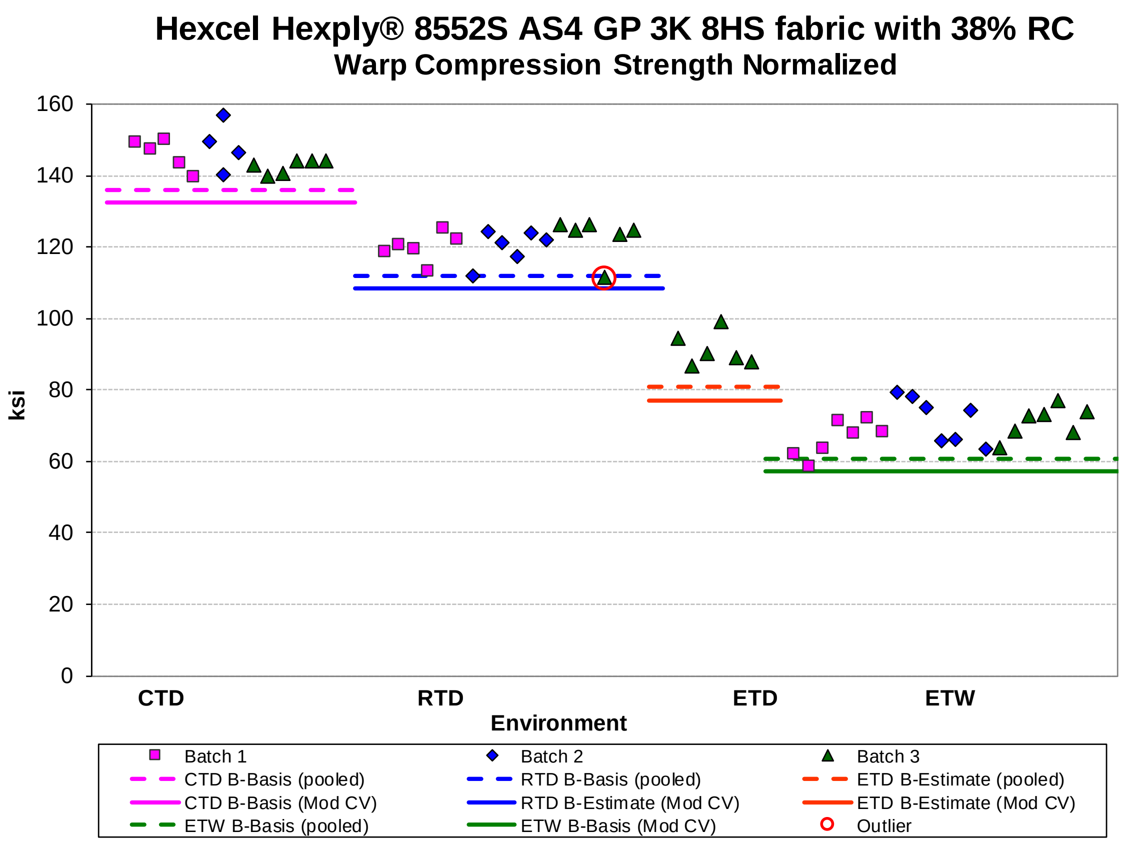

Figure 4-3: Batch plot for WC normalized strength

Warp Compression Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	145.2	120.9	91.25	69.61	140.4	126.1	91.09	68.34
Stdev	4.797	4.751	4.684	5.732	4.152	4.307	5.438	5.403
CV	3.303	3.929	5.133	8.234	2.958	3.415	5.970	7.906
Mod CV	6.000	6.000	8.000	8.234	6.000	6.000	8.000	7.953
Min	139.4	111.4	86.76	58.46	133.1	120.2	84.21	57.66
Max	157.0	126.5	99.08	79.41	145.9	134.5	96.47	77.81
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	15	18	6	21	15	18	6	21
Basis Values and Estimates								
B-Basis	136.0	111.9		60.71	131.8	117.7		60.01
B-Estimate			80.84				81.35	
A-Estimate	130.0	105.9	75.00	54.68	126.2	112.0	75.89	54.38
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates								
B-Basis	132.5	108.5		57.35	127.8	113.7		56.16
B-Estimate			76.91				76.84	
A-Estimate	124.3	100.2	68.86	49.04	119.6	105.5	68.84	47.90
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	8.905	8.888	8.767	8.628	8.603	9.324	8.752	8.878
Stdev	0.1309	0.1725	0.1094	0.1159	0.2075	0.5880	0.3044	0.5721
CV	1.470	1.941	1.248	1.343	2.412	6.306	3.478	6.445
Mod CV	6.000	6.000	8.000	6.000	6.000	7.153	8.000	7.222
Min	8.744	8.631	8.623	8.463	8.119	8.445	8.420	7.732
Max	9.204	9.230	8.902	8.988	9.116	10.485	9.208	9.789
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	18	18	18	6	18

Table 4-6: Statistics from WC Modulus Data

4.4 Fill Compression (FC)

Fill Compression data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in four environmental conditions, but the ETD condition had data available from only one batch, so only B-estimates can be provided for that condition. The CTD and RTD datasets met all requirements for pooling.

The ETW datasets, both normalized and as-measured, did not pass the Anderson Darling k-sample test (ADK test), even after applying the modified CV transformation to the data. This diagnostic test failure means that the ANOVA method must be used to compute basis values, and with test results from only 3 batches of data available, these are considered estimates. Modified CV basis values could not be computed due to the failure of ADK test after the modified CV transformation was applied.

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

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

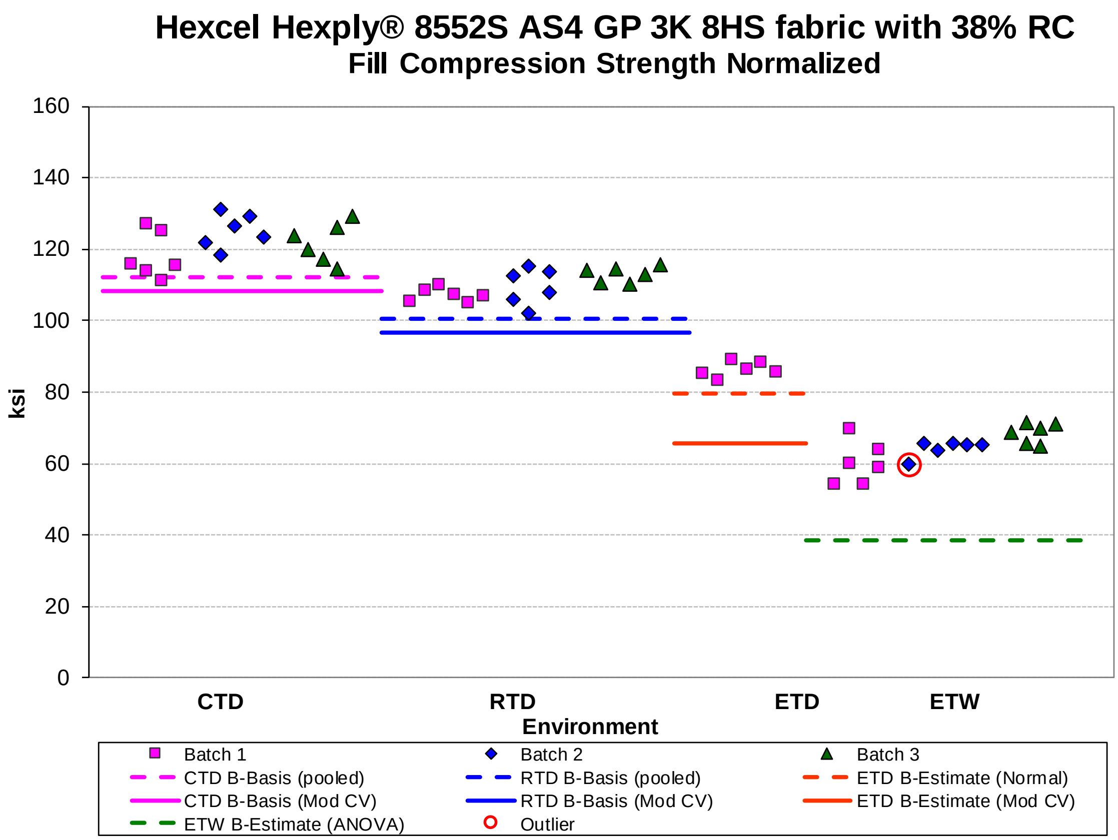

Figure 4-4: Batch Plot for FC normalized strength

Fill Compression Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	121.6	109.9	86.16	64.24	117.6	111.5	85.21	62.52
Stdev	6.085	4.055	2.133	5.262	5.492	5.116	3.700	5.288
CV	5.003	3.691	2.476	8.192	4.671	4.589	4.343	8.459
Mod CV	6.501	6.000	8.000	8.192	6.335	6.295	8.000	8.459
Min	111.1	102.0	83.15	53.93	108.0	103.2	80.97	52.03
Max	131.2	115.7	89.01	71.33	126.6	121.6	91.44	69.94
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	18	18	18	6	18
Basis Values and Estimates								
B-Basis	112.2	100.5			107.9	101.8		
B-Estimate			79.70	38.45			74.00	35.46
A-Estimate	105.8	94.05	75.10	20.07	101.3	95.24	66.03	16.16
Method	pooled	pooled	Normal	ANOVA	pooled	pooled	Normal	ANOVA
Modified CV Basis Values and Estimates								
B-Basis	108.4	96.61		NA	104.4	98.30		NA
B-Estimate			65.39				64.67	
A-Estimate	99.35	87.59	51.19		95.42	89.33	50.62	
Method	pooled	pooled	Normal		pooled	pooled	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	8.542	8.340	8.251	8.154	8.260	8.561	8.159	8.002
Stdev	0.1224	0.09343	0.04756	0.1570	0.1742	0.3694	0.2971	0.1874
CV	1.433	1.120	0.576	1.926	2.109	4.315	3.641	2.342
Mod CV	6.000	6.000	8.000	6.000	6.000	6.157	8.000	6.000
Min	8.281	8.219	8.199	7.808	7.928	8.084	7.988	7.665
Max	8.746	8.579	8.327	8.401	8.518	9.318	8.763	8.284
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	18	18	18	6	18

Table 4-8: Statistics from FC Modulus Data

4.5 In-Plane Shear (IPS)

In Plane Shear data is not normalized. Test results were available for 0.2% Offset Strength for all three conditions (CTD, RTD and ETW), but the Strength at 5% Strain property data was available only for the RTD and ETW conditions, not for the CTD condition while Maximum Strength is available only for the CTD condition.

The ETW datasets for all two properties, failed the Anderson Darling k-sample test (ADK test), so the ANOVA method was required and with test results from only 3 batches of data available, these are considered estimate basis values for those properties. All these datasets passed the ADK test after the modified CV transformation of data was applied, so modified CV basis values could be provided.

The CTD dataset for 0.2% Offset Strength failed all distribution tests and also failed the normality test after the modified CV transformation. The non-parametric method was used to compute the basis values for the property and the modified CV approach could not be used.

There were two outliers. The largest value in batch one of the RTD dataset was an outlier for batch one, but not the RTD condition, for both 0.2% Offset Strength and Strength at 5% Strain. The largest value in batch one of the CTD dataset was an outlier for batch one, but not the CTD condition, for the Maximum Strength property. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for the IPS strength data in Table 4-9 and for the modulus data in Table 4-10. The as-measured data, B-basis values and B-estimates are shown graphically for Maximum Strength and Strength at 5% Strain in Figure 4-5 and for 0.2% Offset Strength in Figure 4-6.

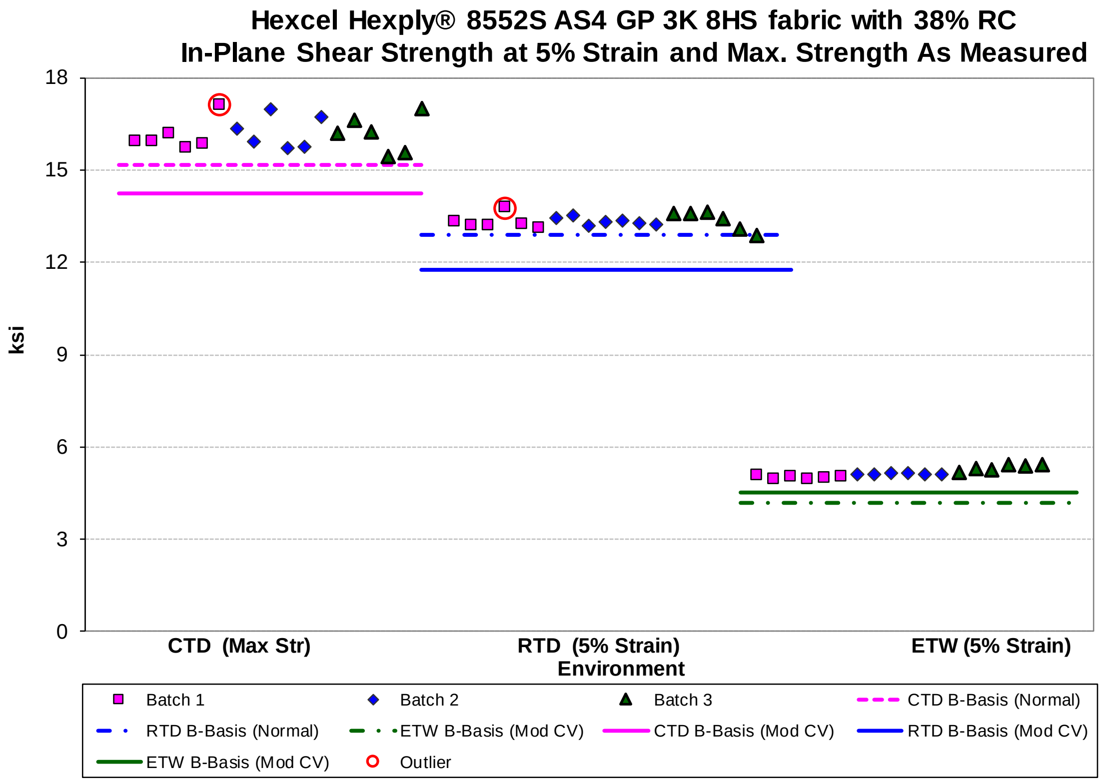

Figure 4-5: Batch plot for IPS Maximum Strength and Strength at 5% Strain as-measured

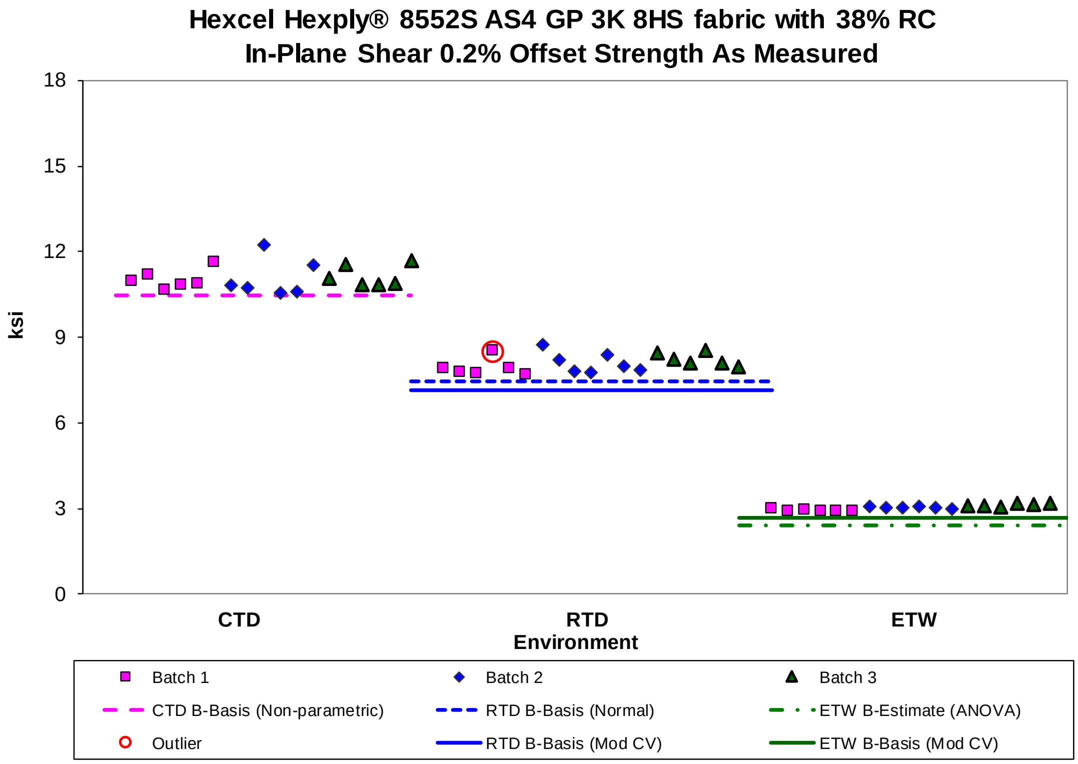

Figure 4-6: Batch plot for IPS 0.2% Offset Strength as-measured

In Plane Shear Strength Basis Values and Statistics						
	0.2% Offset Strength			Strength at 5% Strain		Max Str
Env	CTD	RTD	ETW	RTD	ETW	CTD
Mean	11.09	8.083	3.028	13.33	5.149	16.18
Stdev	0.4561	0.3169	0.09163	0.2204	0.1491	0.5173
CV	4.114	3.921	3.026	1.653	2.896	3.198
Mod CV	6.057	6.000	6.000	6.000	6.000	6.000
Min	10.57	7.697	2.895	12.88	4.940	15.43
Max	12.22	8.728	3.181	13.76	5.443	17.10
No. Batches	3	3	3	3	3	3
No. Spec.	18	19	18	19	18	18
Basis Values and Estimates						
B-basis Value	10.45	7.465		12.90		15.16
B-Estimate			2.426		4.176	
A-Estimate	8.495	7.026	1.996	12.60	3.482	14.43
Method	Non-Parametric	Normal	ANOVA	Normal	ANOVA	Normal
Modified CV Basis Values and Estimates						
B-basis Value	NA	7.137	2.669	11.77	4.539	14.26
A-Estimate		6.467	2.415	10.67	4.108	12.91
Method		Normal	Normal	Normal	Normal	Normal

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

IPS Modulus Statistics			
Env	CTD	RTD	ETW
Mean	0.8552	0.7296	0.2885
Stdev	0.04971	0.03916	0.007742
CV	5.813	5.368	2.684
Mod CV	6.907	6.684	6.000
Min	0.8039	0.6832	0.2777
Max	0.9776	0.8130	0.3030
No. Batches	3	3	3
No. Spec.	18	19	18

Table 4-10: Statistics from IPS Modulus Data

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

The UNT1 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in three environmental conditions.

The normalized datasets from all three conditions and the as-measured RTD and ETW datasets did not pass the Anderson Darling k-sample test (ADK test). This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only 3 batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, all datasets passed the ADK test and modified CV basis values are provided. Pooling all three conditions was appropriate for both the normalized and as-measured modified CV basis values computations.

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

Statistics, basis values and estimates are given for the 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 4-7.

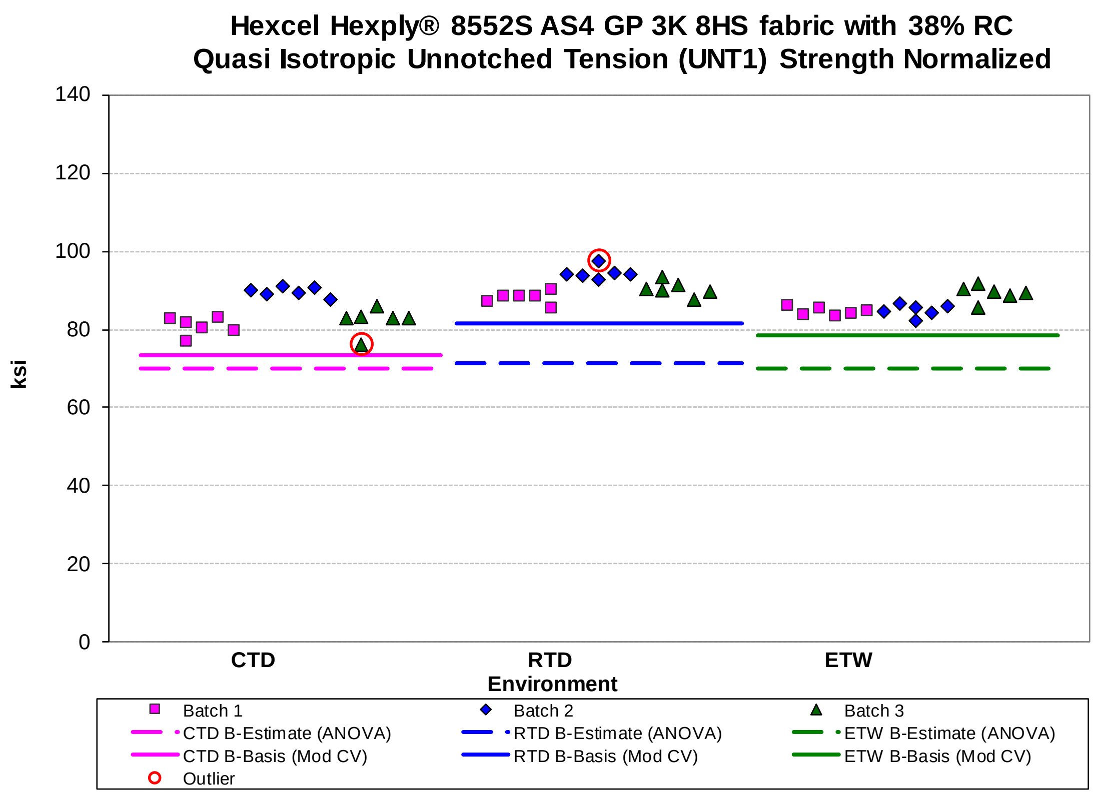

Figure 4-7: Batch Plot for UNT1 normalized strength

Unnotched Tension (UNT1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	82.56	90.93	87.75	84.21	95.56	84.47
Stdev	2.921	3.176	2.851	4.220	4.944	2.680
CV	3.538	3.493	3.249	5.011	5.174	3.173
Modified CV	6.000	6.000	6.000	6.506	6.587	6.000
Min	76.18	85.37	83.12	74.68	86.95	80.71
Max	86.59	97.53	91.85	92.91	105.8	89.20
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and Estimates						
B-Basis				75.88		
B-Estimate	70.14	71.21	70.01		71.44	69.95
A-Estimate	61.28	57.13	57.35	69.97	54.25	59.60
Method	ANOVA	ANOVA	ANOVA	Normal	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-Basis	73.30	81.67	78.49	74.23	85.58	74.48
A-Estimate	67.13	75.49	72.31	67.57	78.92	67.83
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	6.924	6.643	6.157	7.063	6.982	5.928
Stdev	0.09688	0.08429	0.06413	0.3058	0.2847	0.1275
CV	1.399	1.269	1.042	4.329	4.078	2.151
Modified CV	6.000	6.000	6.000	6.164	6.039	6.000
Min	6.711	6.490	5.999	6.801	6.575	5.682
Max	7.157	6.760	6.284	7.790	7.412	6.174
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18

Table 4-12: Statistics from UNT1 Modulus Data

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

The UNT2 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in three environmental conditions.

The normalized datasets from all three conditions and the as-measured CTD and ETW datasets did not pass the Anderson Darling k-sample test (ADK test). This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only 3 batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, the normalized CTD and ETW datasets and the as-measured ETW dataset passed the ADK test and modified CV basis values are provided. Pooling the as-measured RTD and ETW conditions was appropriate for computing modified CV basis values, but the normalized datasets could not be pooled across conditions.

There were six outliers, three in the normalized datasets and three in the as-measured datasets. The largest value in batch one of the as-measured CTD dataset was an outlier for batch one, but not for the CTD condition and not for the normalized dataset. The largest value in batch two of the as-measured RTD dataset was an outlier for batch two and for the RTD condition, but not for the normalized dataset. The largest value in batch two of the as-measured ETW dataset was an outlier for batch two, but not for the ETW condition and not for the normalized dataset. The lowest value in batch two of the normalized RTD dataset was an outlier for batch two, but not for the RTD condition and not for the as-measured dataset. The largest value in batch one of the normalized RTD dataset was an outlier for batch one, but not for the RTD condition and not for the as-measured dataset. The largest value in batch one of the normalized ETW dataset was an outlier for batch one, but not for the ETW condition and not for the as-measured dataset. All outliers were retained for this analysis.

Statistics, basis values and estimates are given for the 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 4-8.

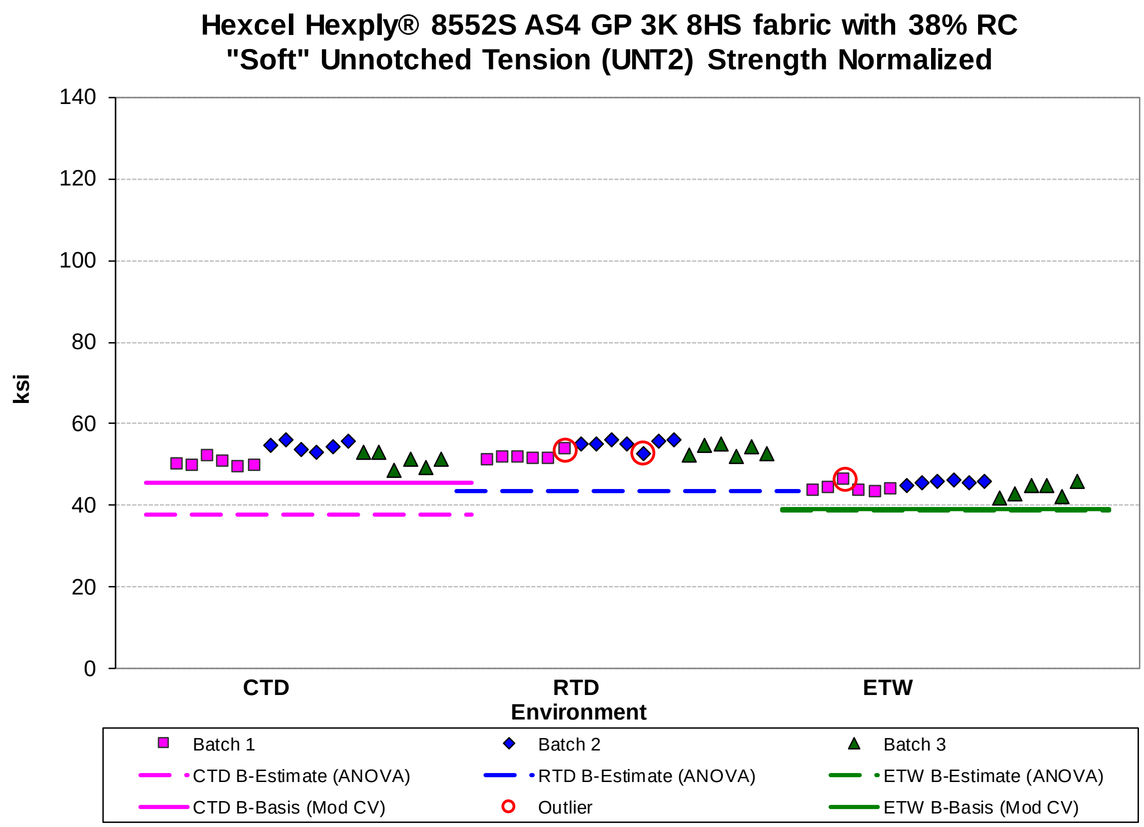

Figure 4-8: Batch Plot for UNT2 normalized strength

Unnotched Tension (UNT2) Strength Basis Values and Statistics							
	Normalized			As-measured			
Env	CTD	RTD	ETW	CTD	RTD	ETW	
Mean	51.94	53.58	44.48	52.68	55.89	43.18
Stdev	2.357	1.767	1.410	3.759	2.041	1.652
CV	4.538	3.297	3.170	7.135	3.652	3.825
Modified CV	6.269	6.000	6.000	7.567	6.000	6.000
Min	48.63	51.11	41.87	47.89	53.15	40.11
Max	56.22	55.95	46.33	59.32	61.82	46.50
No. Batches	3	3	3	3	3	3
No. Spec.	18	19	18	18	19	18
Basis Values and Estimates						
B-Basis					51.91	
B-Estimate	37.80	43.46	38.66	35.67		34.76
A-Estimate	27.71	36.24	34.51	23.55	49.09	28.74
Method	ANOVA	ANOVA	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and Estimates						
B-Basis	45.51	NA	39.21	NA	50.45	37.72
A-Estimate	40.96		35.48		46.73	34.01
Method	Normal		Normal		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	4.736	4.394	3.448	4.802	4.588	3.349
Stdev	0.08503	0.1165	0.07199	0.2478	0.2588	0.1430
CV	1.796	2.651	2.088	5.160	5.640	4.271
Modified CV	6.000	6.000	6.000	6.580	6.820	6.135
Min	4.569	4.071	3.339	4.463	4.113	3.170
Max	4.863	4.630	3.589	5.348	5.208	3.765
No. Batches	3	3	3	3	3	3
No. Spec.	18	19	18	18	19	18

Table 4-14: Statistics from UNT2 Modulus Data

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

The UNT3 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in three environmental conditions.

The normalized datasets from all three conditions and the as-measured CTD and ETW datasets did not pass the Anderson Darling k-sample test (ADK test). This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only 3 batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, the RTD and ETW datasets passed the ADK test but the CTD datasets did not. Pooling the RTD and ETW conditions was appropriate for both the normalized and as-measured modified CV basis values. The ETW condition datasets have only sixteen specimens. When pooling across environments, sixteen is considered adequate for a publishable B-basis value.

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

Statistics, basis values and estimates are given for the 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 4-9.

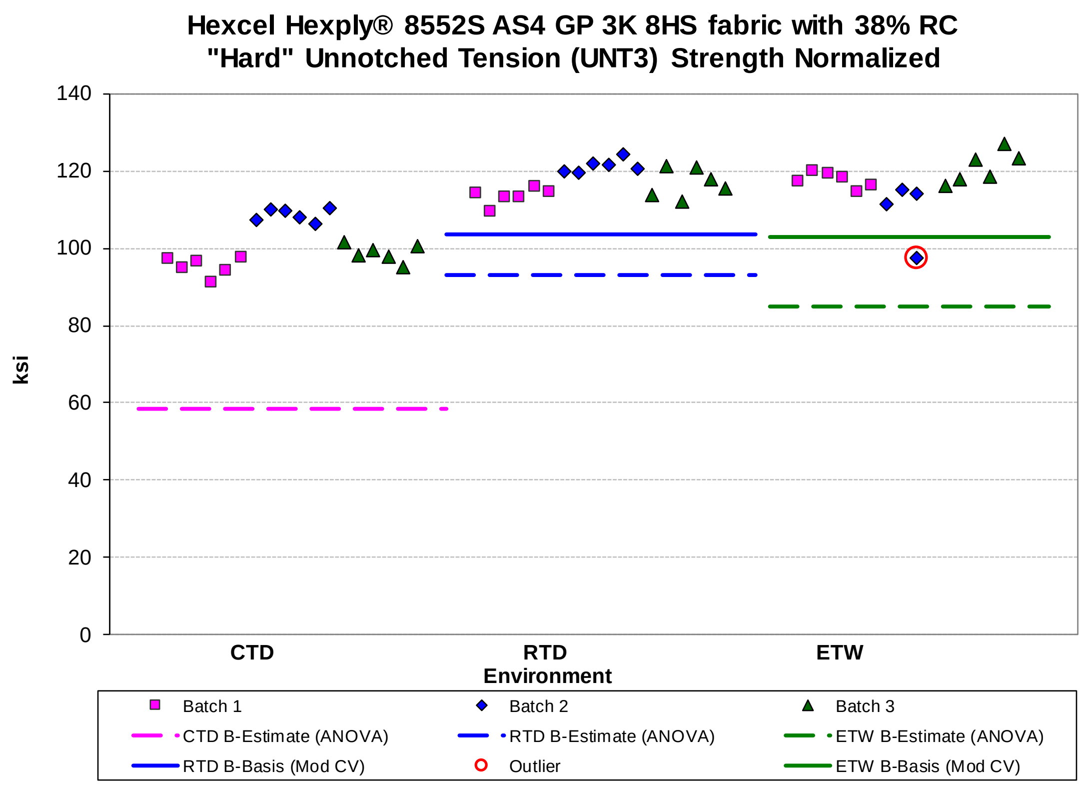

Figure 4-9: Batch Plot for UNT3 normalized strength

Unnotched Tension (UNT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	100.9	117.2	116.8	100.8	122.0	113.4
Stdev	6.183	4.219	6.442	8.177	6.141	6.271
CV	6.130	3.600	5.515	8.112	5.036	5.528
Modified CV	7.065	6.000	6.757	8.112	6.518	6.764
Min	90.91	109.4	97.49	88.82	110.6	93.95
Max	110.3	124.5	127.1	114.8	132.0	121.6
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	16	18	18	16
Basis Values and Estimates						
B-Basis					109.8	
B-Estimate	58.36	93.16	84.86	55.39		83.68
A-Estimate	28.02	76.02	62.09	23.00	101.2	62.48
Method	ANOVA	ANOVA	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and Estimates						
B-Basis	NA	103.5	103.0	NA	107.6	98.96
A-Estimate		94.24	93.74		97.86	89.22
Method		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	8.535	8.303	8.062	8.525	8.642	7.817
Stdev	0.1136	0.1171	0.1089	0.3666	0.3468	0.1625
CV	1.331	1.410	1.351	4.301	4.013	2.078
Modified CV	6.000	6.000	6.000	6.150	6.006	6.000
Min	8.331	8.112	7.847	8.079	8.143	7.416
Max	8.791	8.485	8.242	9.310	9.391	7.998
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	20	18	18	20

Table 4-16: Statistics from UNT3 Modulus Data

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

The UNC1 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in two environmental conditions.

There were no diagnostic test failures. Pooling the two conditions was acceptable.

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

Statistics, basis values and estimates are given for the 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 4-10.

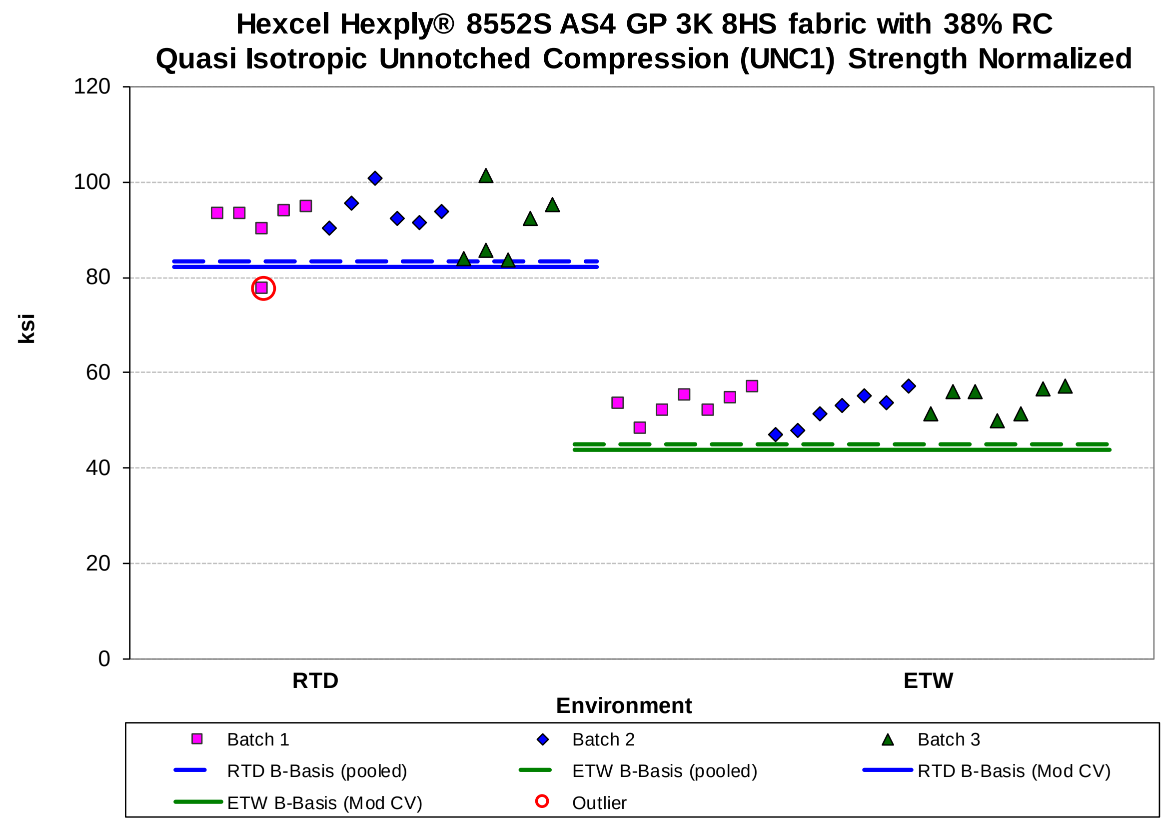

Figure 4-10: Batch plot for UNC1 normalized strength

Unnotched Compression (UNC1) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	91.68	53.12	96.48	55.21
Stdev	5.922	3.152	4.144	3.048
CV	6.459	5.934	4.295	5.520
Modified CV	7.230	6.967	6.148	6.760
Min	77.59	46.89	86.99	49.38
Max	101.3	57.06	106.22	59.80
No. Batches	3	3	3	3
No. Spec.	18	21	18	21
Basis Values and Estimates				
B-Basis	83.29	44.85	89.97	48.80
A-Estimate	77.61	39.14	85.57	44.38
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-Basis	82.18	43.75	87.67	46.53
A-Estimate	75.74	37.28	81.70	40.53
Method	pooled	pooled	pooled	pooled

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

Unnotched Compression (UNC1) Modulus Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	6.328	5.705	6.673	5.460
Stdev	0.1068	0.1887	0.3384	0.2528
CV	1.688	3.307	5.072	4.630
Modified CV	6.000	6.000	6.536	6.315
Min	6.162	5.408	6.155	5.034
Max	6.474	5.984	7.513	5.839
No. Batches	3	3	3	3
No. Spec.	18	18	18	18

Table 4-18: Statistics from UNC1 Modulus Data

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

The UNC2 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in two environmental conditions.

There were no diagnostic test failures for the as-measured datasets. Pooling the two conditions was acceptable. The normalized RTD dataset failed the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only 3 batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, the normalized RTD dataset passed the ADK test and modified CV basis values are provided. The normalized datasets for the two conditions could not be pooled due to a failure of Levene's test for equality of variance.

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

Statistics, basis values and estimates are given for the 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 4-11.

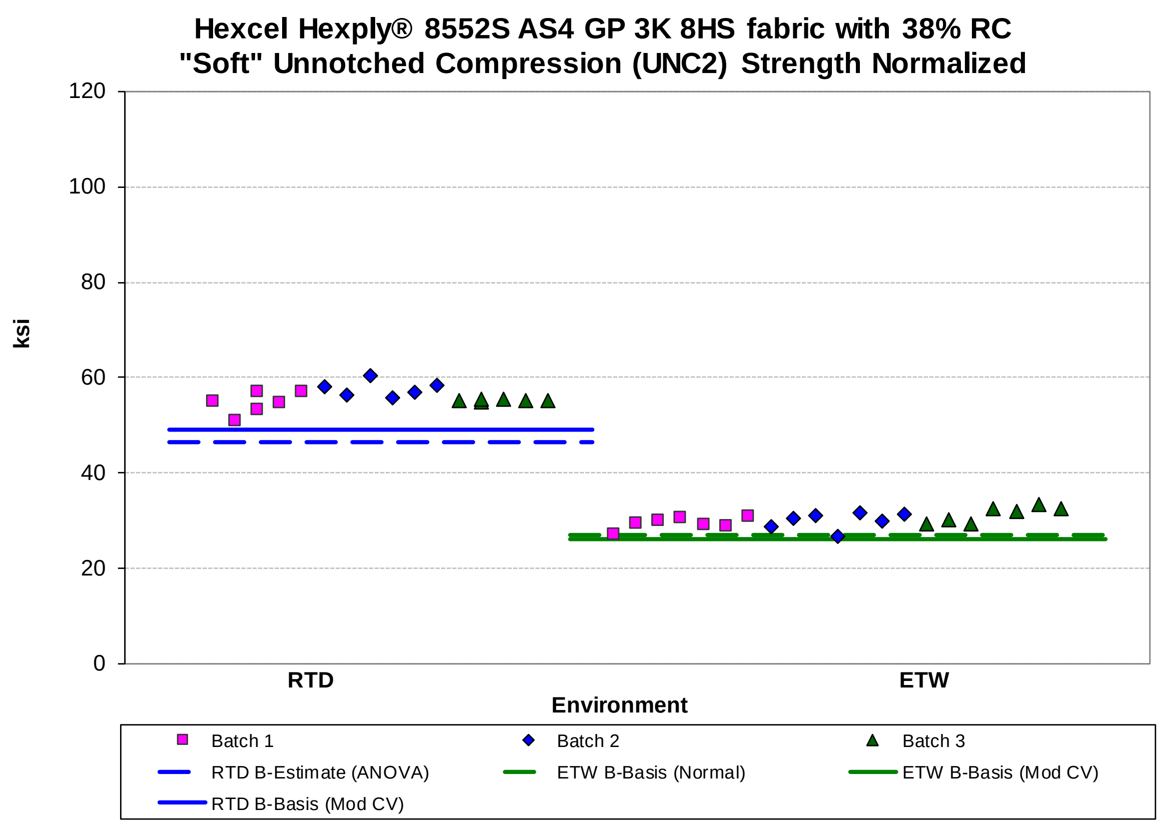

Figure 4-11: Batch plot for UNC2 normalized strength

Unnotched Compression (UNC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	55.76	30.11	59.51	31.59
Stdev	2.102	1.718	2.330	1.484
CV	3.769	5.704	3.915	4.696
Modified CV	6.000	6.852	6.000	6.348
Min	50.70	26.58	53.11	29.21
Max	60.39	33.34	63.23	34.35
No. Batches	3	3	3	3
No. Spec.	18	21	18	21
Basis Values and Estimates				
B-Basis		26.84	56.04	28.17
B-Estimate	46.41			
A-Estimate	39.74	24.51	53.69	25.80
Method	ANOVA	Normal	pooled	pooled
Modified CV Basis Values and Estimates				
B-Basis	49.16	26.18	54.39	26.53
A-Estimate	44.48	23.38	50.91	23.04
Method	Normal	Normal	pooled	pooled

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

Unnotched Compression (UNC2) Modulus Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	4.226	3.382	4.511	3.306
Stdev	0.1126	0.1566	0.1604	0.2039
CV	2.664	4.631	3.556	6.166
Modified CV	6.000	6.316	6.000	7.083
Min	4.023	3.154	4.116	3.008
Max	4.383	3.706	4.754	3.692
No. Batches	3	3	3	3
No. Spec.	18	18	18	18

Table 4-20: Statistics from UNC2 Modulus Data

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

The UNC3 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in two environmental conditions.

There were no diagnostic test failures for the normalized datasets. Pooling the two conditions was acceptable. The pooled as-measured dataset failed Levene's test for equality of variance after the modified CV transformation, so pooling was not appropriate for the as-measured modified CV basis values.

There were no statistical outliers.

Statistics, basis values and estimates are given for the 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 4-12.

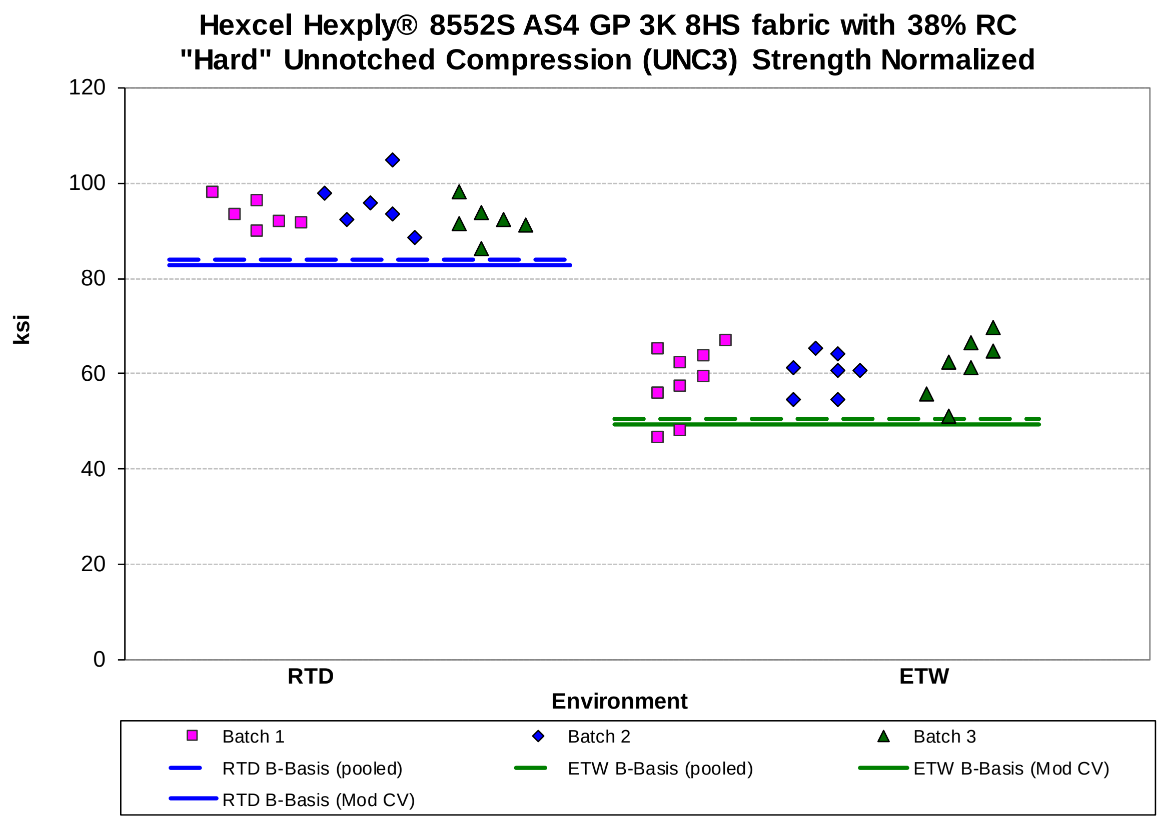

Figure 4-12: Batch plot for UNC3 normalized strength

Unnotched Compression (UNC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	93.71	59.85	98.40	61.77
Stdev	4.275	6.090	6.471	4.076
CV	4.562	10.18	6.576	6.599
Modified CV	6.281	10.18	7.288	7.299
Min	86.29	46.38	89.59	52.83
Max	104.9	69.82	113.6	67.90
No. Batches	3	3	3	3
No. Spec.	18	23	18	23
Basis Values and Estimates				
B-Basis	84.02	50.37	88.93	52.50
A-Estimate	77.48	43.78	82.53	46.05
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-Basis	82.89	49.27	84.24	53.34
A-Estimate	75.59	41.91	74.23	47.31
Method	pooled	pooled	Normal	Normal

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	7.867	7.627	8.262	7.289
Stdev	0.1773	0.1265	0.4386	0.2690
CV	2.253	1.658	5.309	3.690
Modified CV	6.000	6.000	6.654	6.000
Min	7.394	7.348	7.587	6.863
Max	8.095	7.823	9.116	7.747
No. Batches	3	3	3	3
No. Spec.	18	18	18	18

Table 4-22: Statistics from UNC3 Modulus Data

4.12 Lamina Short-Beam Strength (SBS)

The Short Beam Strength data is not normalized. Tests were conducted in four environmental conditions, but the ETD condition had data available from only one batch, so only B-estimates can be provided for that condition.

The datasets from all three conditions with three batches did not pass the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only three batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, only the RTD dataset passed the ADK test and modified CV basis values are provided only for RTD.

There were two outliers. The lowest value in batch one of the RTD dataset was an outlier for the RTD condition but not for batch one. The lowest value in batch two of the ETW dataset was an outlier for batch two but not for the ETW condition. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for the SBS data in Table 4-23. The as-measured data, B-estimates and B-basis values are shown graphically in Figure 4-13.

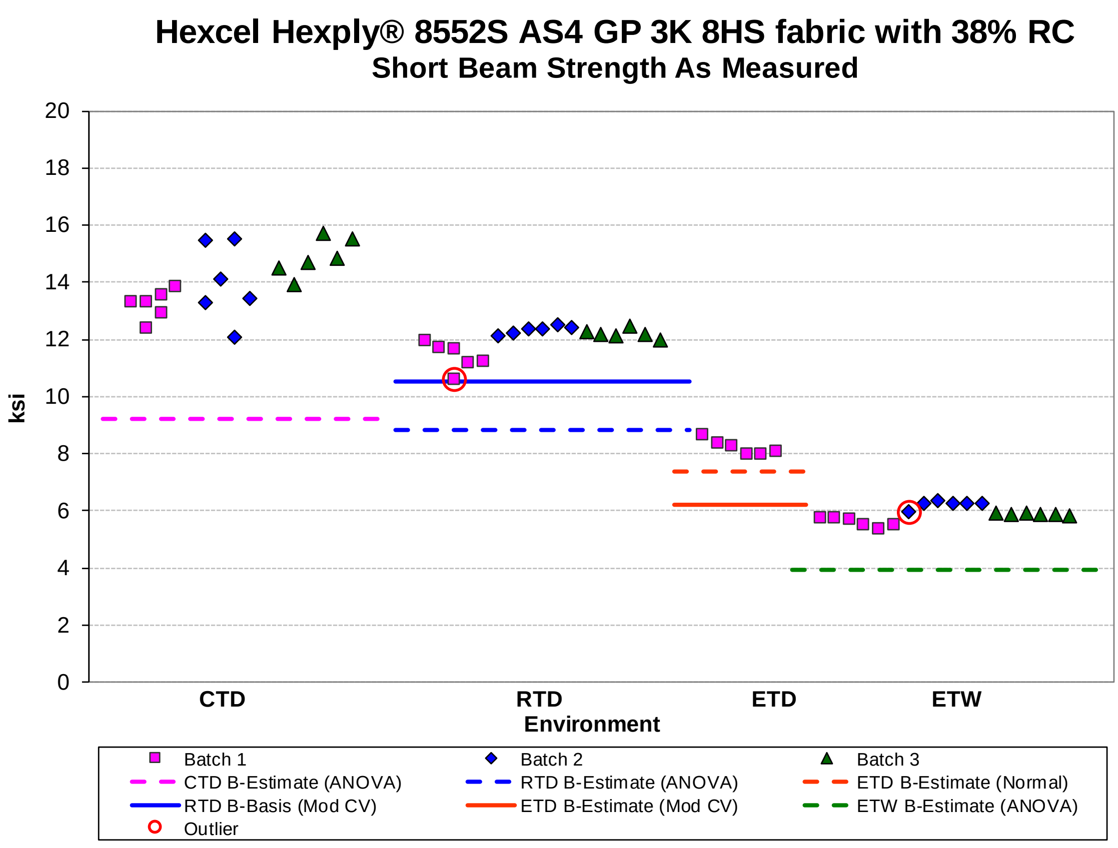

Figure 4-13: Batch plot for SBS as-measured

Short Beam Strength (SBS) As-measured Basis Values and Statistics				
Env	CTD	RTD	ETD	ETW
Mean	14.02	11.97	8.210	5.901
Stdev	1.107	0.5227	0.2680	0.2958
CV	7.894	4.367	3.264	5.012
Mod CV	7.947	6.184	8.000	6.506
Min	12.07	10.58	7.959	5.330
Max	15.71	12.50	8.643	6.370
No. Batches	3	3	1	3
No. Spec.	18	18	6	18
Basis Values and Estimates				
B-Estimate	9.232	8.835	7.398	3.936
A-Estimate	5.816	6.599	6.821	2.534
Method	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and Estimates				
B-Basis	NA	10.51		NA
B-Estimate			6.231	
A-Estimate		9.474	4.878	
Method		Normal	Normal	

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

4.13 Laminate Short-Beam Strength (SBS1)

The Laminate Short Beam Strength data is not normalized. Tests were conducted in two environmental conditions.

The ETW dataset failed the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only three batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, the ETW dataset passed the ADK test and modified CV basis values are provided. The datasets for the two conditions could not be pooled due to a failure of Levene's test for equality of variance. There were no statistical outliers.

Statistics, basis values and estimates are given for the SBS1 data in Table 4-24. The as-measured data, B-estimates and B-basis values are shown graphically in Figure 4-14.

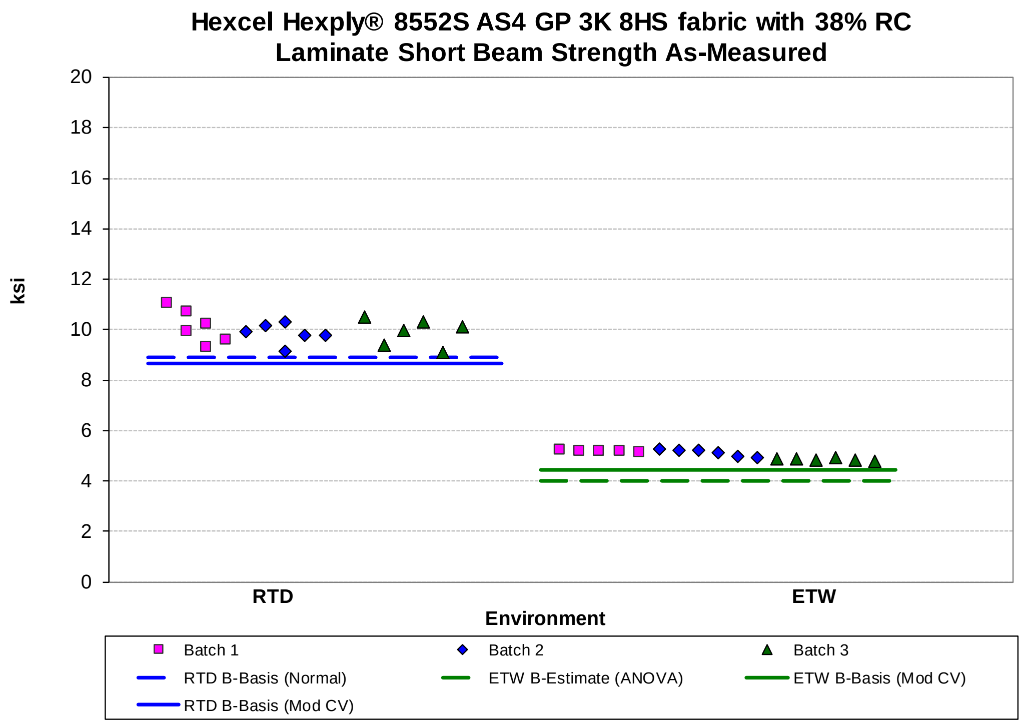

Figure 4-14: Batch plot for SBS1 as-measured

Laminate Short Beam Strength (SBS1) Basis Values and Statistics		
Env	RTD	ETW
Mean	9.953	5.043
Stdev	0.5344	0.1654
CV	5.370	3.279
Modified CV	6.685	6.000
Min	9.073	4.774
Max	11.03	5.261
No. Batches	3	3
No. Spec.	18	18
Basis Values and Estimates		
B-Basis	8.897	
B-Estimate		4.003
A-Estimate	8.150	3.261
Method	Normal	ANOVA
Modified CV Basis Values and Estimates		
B-Basis	8.639	4.446
A-Estimate	7.710	4.023
Method	Normal	Normal

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

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

The OHT1 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in three environmental conditions.

There were no diagnostic test failures in the as-measured datasets. When pooling the three conditions together the pooled dataset failed the normality test, so only the RTD and ETW conditions could be pooled to compute basis values. All three conditions could be pooled for computing the modified CV basis values.

The normalized CTD and RTD datasets could be pooled, but the normalized ETW dataset did not pass the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only three batches of data available, these are considered estimates. After applying the modified CV transformation, the ETW dataset passed the ADK test and pooling the datasets from all three conditions was appropriate for computing the modified CV basis values.

There were no statistical outliers.

Statistics, basis values and estimates are given for the OHT1 strength data in Table 4-25. The normalized data, B-basis values and B-estimates are shown graphically in Figure 4-15.

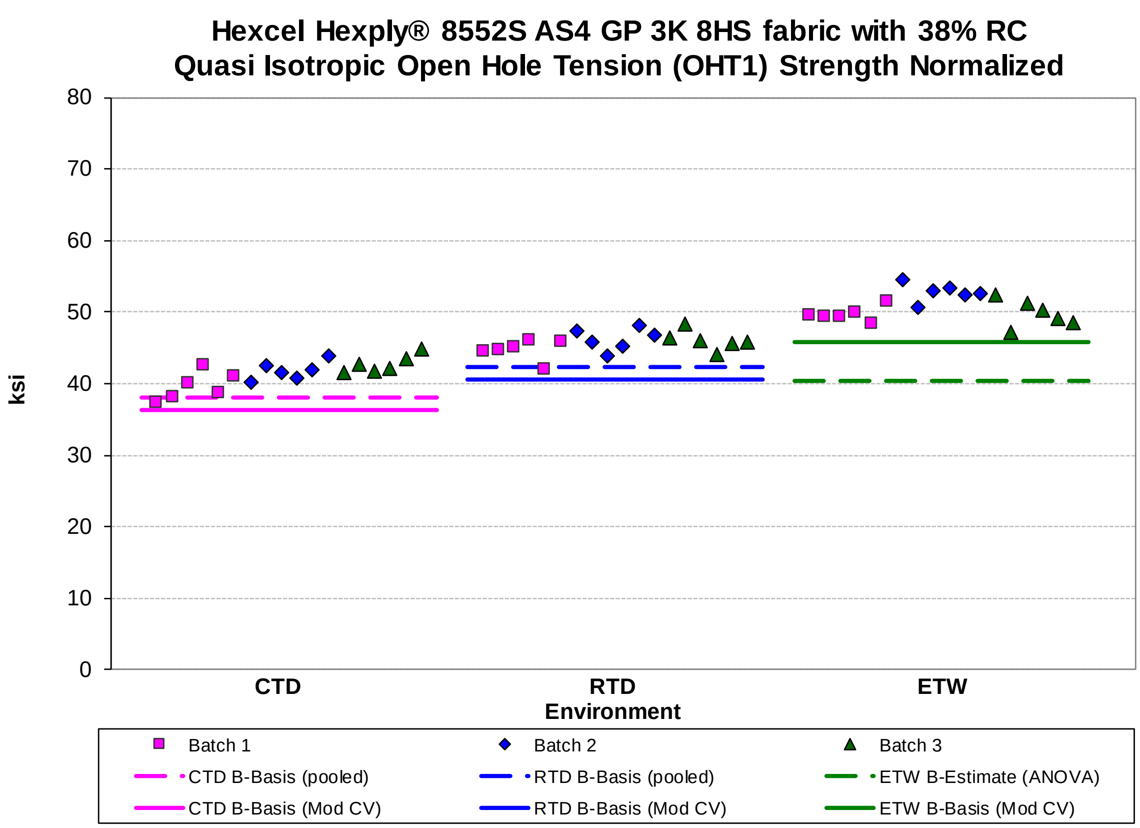

Figure 4-15: Batch Plot for OHT1 normalized strength

Open Hole Tension (OHT1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	41.38	45.65	50.70	40.94	45.38	48.92
Stdev	1.977	1.571	1.994	3.296	2.746	1.863
CV	4.777	3.442	3.934	8.050	6.051	3.808
Modified CV	6.389	6.000	6.000	8.050	7.026	6.000
Min	37.36	41.92	47.15	36.83	40.47	45.47
Max	44.82	48.36	54.51	48.30	50.85	52.23
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and Estimates						
B-Basis	38.13	42.40		34.43	41.11	44.65
B-Estimate			40.33			
A-Estimate	35.91	40.18	32.94	29.82	38.20	41.74
Method	pooled	pooled	ANOVA	Normal	pooled	pooled
Modified CV Basis Values and Estimates						
B-Basis	36.40	40.67	45.72	35.38	39.82	43.36
A-Estimate	33.07	37.34	42.40	31.66	36.10	39.64
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

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

The OHT2 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in three environmental conditions.

The normalized CTD and ETW datasets did not pass the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only three batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, both the CTD and ETW datasets passed the ADK test and modified CV basis values are provided. Pooling was acceptable for the modified CV basis values. The as-measured RTD dataset failed all distribution tests requiring the use of the non-parametric method to compute basis values. It failed the normality test even after the modified CV transformation of the data, so modified CV basis values are not provided for that dataset. Pooling was unacceptable due to the lack of normality.

There were no statistical outliers.

Statistics, basis values and estimates are given for the OHT2 strength data in Table 4-26. The normalized data and B-basis values are shown graphically in Figure 4-16.

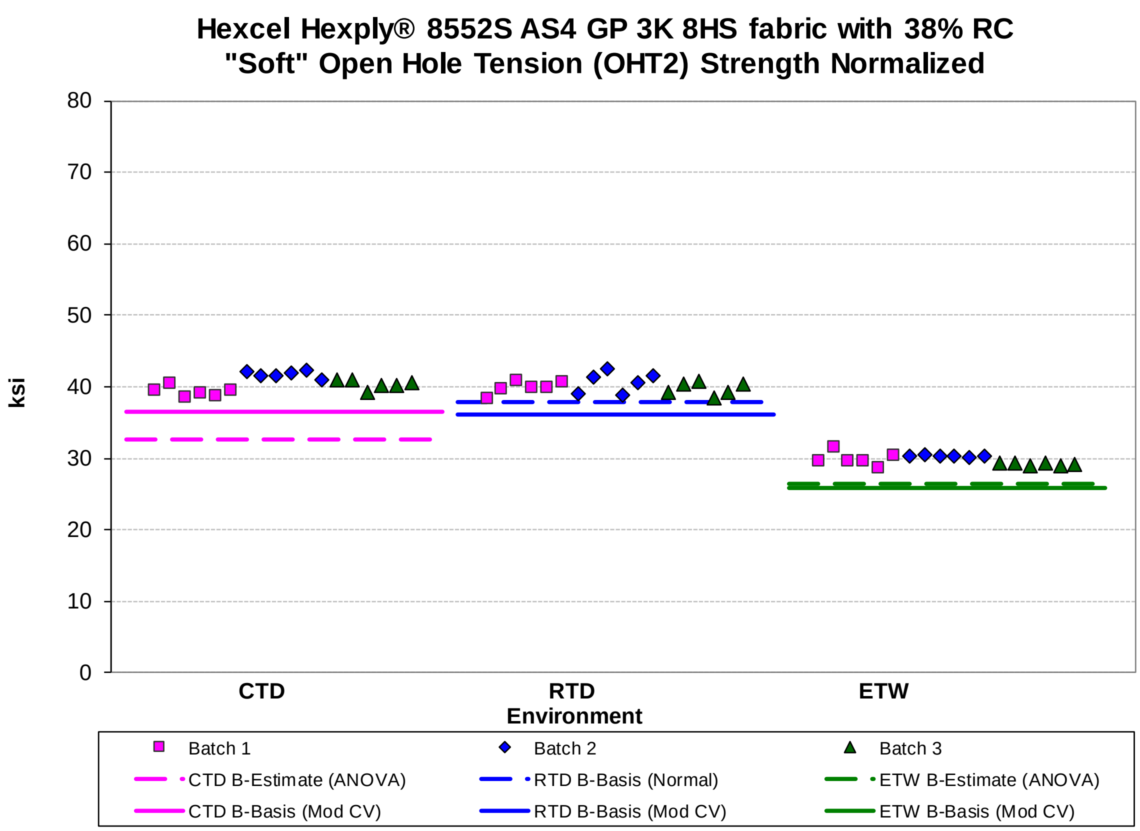

Figure 4-16: Batch Plot for OHT2 normalized strength

Open Hole Tension (OHT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	40.45	40.06	29.76	39.57	40.18	28.48
Stdev	1.214	1.122	0.720	1.733	1.244	0.707
CV	3.001	2.801	2.420	4.379	3.096	2.482
Modified CV	6.000	6.000	6.000	6.189	6.000	6.000
Min	38.40	38.30	28.59	36.99	38.53	27.13
Max	42.41	42.47	31.45	43.89	42.07	29.98
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and Estimates						
B-Basis		37.85		36.15	38.08	27.09
B-Estimate	32.72		26.49			
A-Estimate	27.20	36.28	24.17	33.73	33.78	26.10
Method	ANOVA	Normal	ANOVA	Normal	Non-Parametric	Normal
Modified CV Basis Values and Estimates						
B-Basis	36.51	36.12	25.82	34.74	NA	25.11
A-Estimate	33.88	33.49	23.19	31.32		22.72
Method	pooled	pooled	pooled	Normal		Normal

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

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

The OHT3 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in three environmental conditions.

Pooling the CTD and RTD conditions was acceptable for the normalized datasets. The normalized ETW dataset did not pass the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only three batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, the ETW dataset pass the ADK test and modified CV basis values are provided. The as-measured ETW fits Weibull much better than normal distribution and that method was used to compute the as-measured basis values for that dataset. Pooling all three conditions was acceptable for modified CV for both normalized and as-measured datasets.

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

Statistics, basis values and estimates are given for the OHT3 strength data in Table 4-27. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-17.

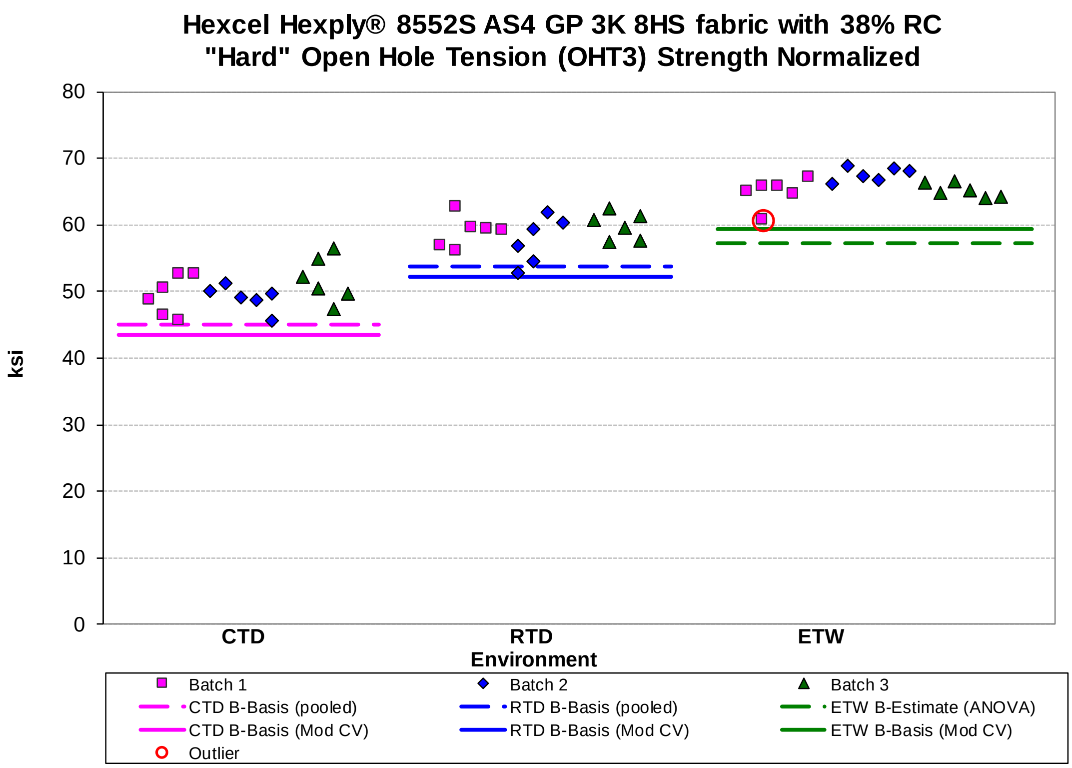

Figure 4-17: Batch Plot for OHT3 normalized strength

Open Hole Tension (OHT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	50.12	58.85	65.89	49.27	58.61	63.19
Stdev	2.940	2.712	1.923	4.554	5.273	2.052
CV	5.866	4.609	2.918	9.243	8.996	3.248
Modified CV	6.933	6.304	6.000	9.243	8.996	6.000
Min	45.56	52.80	60.66	42.85	49.72	56.96
Max	56.43	62.67	68.80	61.03	67.53	66.21
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and Estimates						
B-Basis	44.97	53.70		40.28	48.20	58.93
B-Estimate			57.18			
A-Estimate	41.47	50.19	50.96	33.91	40.83	54.40
Method	pooled	pooled	ANOVA	Normal	Normal	Weibull
Modified CV Basis Values and Estimates						
B-Basis	43.54	52.27	59.31	41.16	50.50	55.08
A-Estimate	39.15	47.88	54.92	35.75	45.09	49.67
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

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

The FHT1 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in three environmental conditions.

Pooling the CTD and RTD conditions was acceptable for both the as-measured and normalized datasets. The ETW datasets, both normalized and as-measured, did not pass the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only three batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, the ETW datasets passed the ADK test and modified CV basis values are provided. Pooling all three conditions was acceptable for modified CV for both normalized and as-measured datasets.

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

Statistics, basis values and estimates are given for the FHT1 strength data in Table 4-28. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-18.

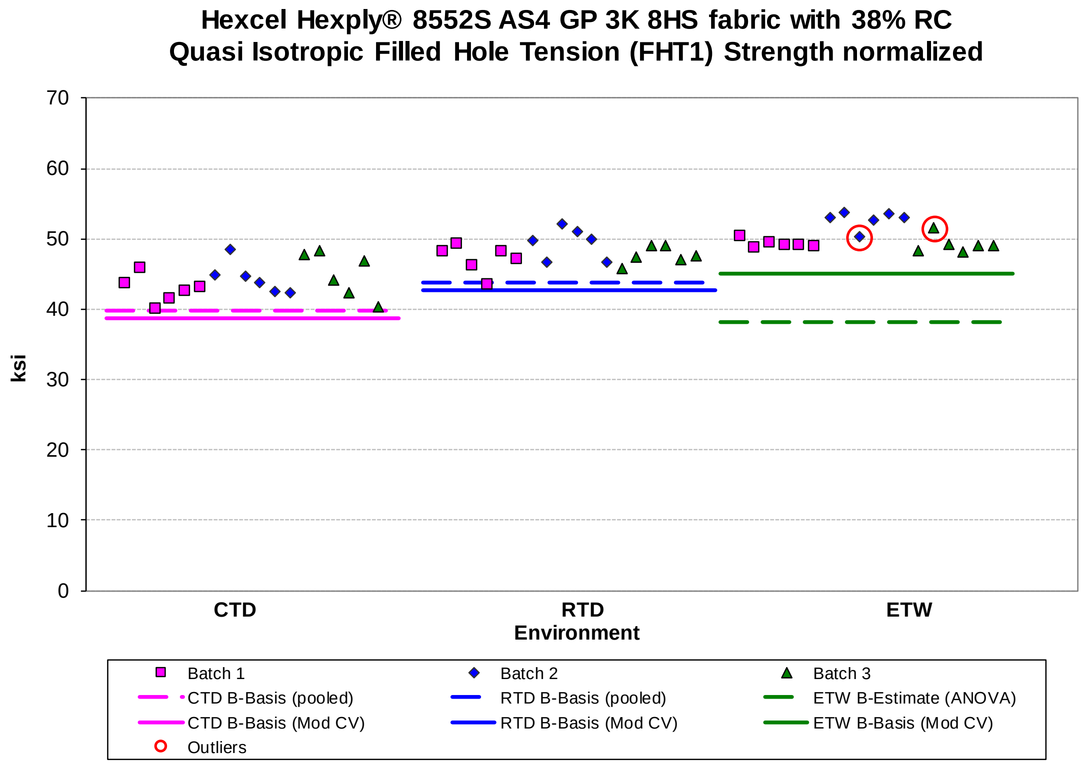

Figure 4-18: Batch plot for FHT1 normalized strength

Filled Hole Tension (FHT1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	44.06	48.02	50.39	43.58	47.81	48.06
Stdev	2.600	2.048	1.961	2.361	2.811	1.548
CV	5.901	4.264	3.891	5.417	5.879	3.220
Modified CV	6.950	6.132	6.000	6.709	6.940	6.000
Min	40.02	43.46	48.18	40.26	43.55	45.91
Max	48.56	52.04	53.68	47.78	53.48	50.77
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and Estimates						
B-basis	39.80	43.75		38.85	43.08	
B-Estimate			38.19			38.69
A-Estimate	36.90	40.85	29.49	35.63	39.87	32.00
Method	pooled	pooled	ANOVA	pooled	pooled	ANOVA
Modified CV Basis Values and Estimates						
B-basis	38.73	42.69	45.06	38.18	42.42	42.67
A-Estimate	35.18	39.13	41.50	34.58	38.81	39.07
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

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

The FHT2 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in three environmental conditions.

Pooling the RTD and ETW conditions was acceptable for the normalized datasets. The normalized CTD dataset did not pass the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only three batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, the normalized CTD dataset passed the ADK test and modified CV basis values are provided. Pooling all three conditions was acceptable for modified CV for the normalized datasets.

The as-measured CTD dataset passed the ADK test, but did not pass any of the distribution tests. The non-parametric method was used to compute the basis values. The RTD and ETW datasets failed Levene’s test for equality of variance prior to the modified CV transformation of data but passed this diagnostic test afterwards, so the pooling method was acceptable for those modified CV datasets. The CTD dataset could not be included due to a failure of the normality of the pooled dataset.

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

Statistics, basis values and estimates are given for the FHT2 strength data in Table 4-29. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-19.

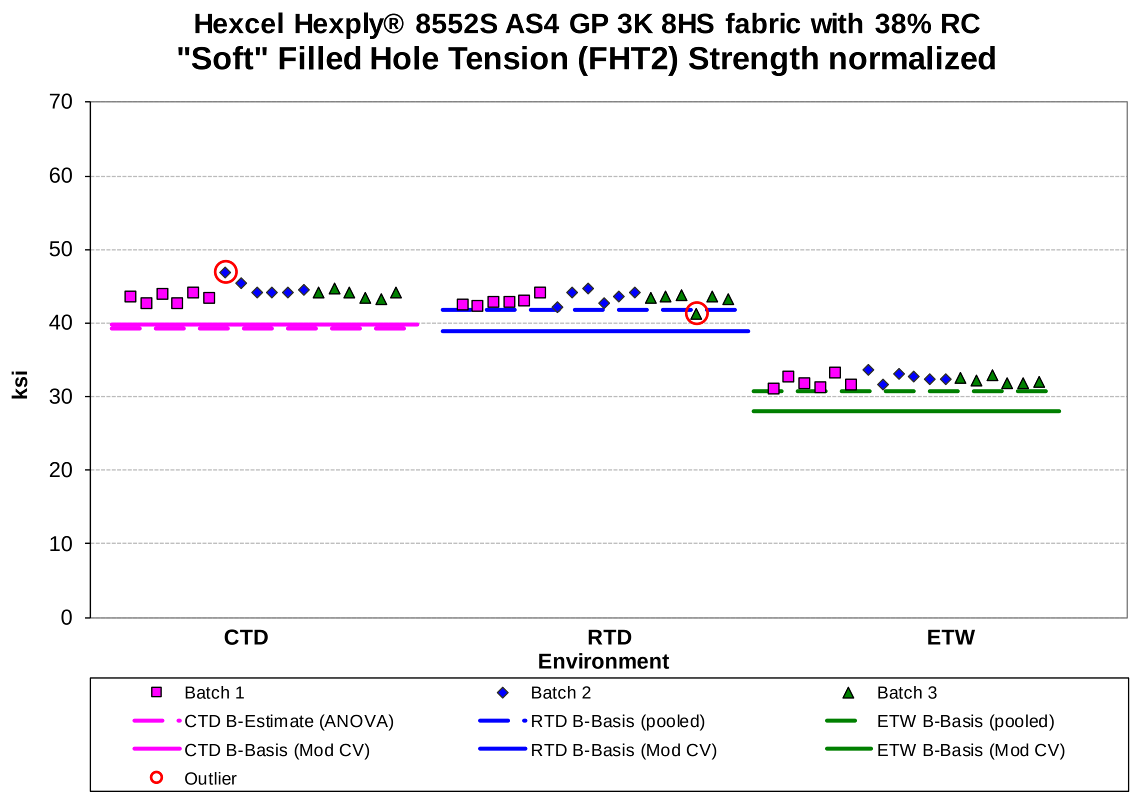

Figure 4-19: Batch plot for FHT2 normalized strength

Filled Hole Tension (FHT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	44.05	43.17	32.21	42.88	43.24	30.80
Stdev	1.023	0.8536	0.7466	2.087	1.635	0.7287
CV	2.322	1.977	2.318	4.867	3.781	2.366
Modified CV	6.000	6.000	6.000	6.433	6.000	6.000
Min	42.52	41.33	30.87	39.81	40.49	29.24
Max	46.95	44.66	33.63	47.23	46.00	32.19
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and Estimates						
B-basis		41.71	30.75	39.06	40.01	29.36
B-Estimate	39.27					
A-Estimate	35.86	40.72	29.76	30.84	37.72	28.34
Method	ANOVA	pooled	pooled	Non-Parametric	Normal	Normal
Modified CV Basis Values and Estimates						
B-basis	39.78	38.90	27.94	37.44	39.14	26.69
A-Estimate	36.93	36.06	25.10	33.58	36.35	23.90
Method	pooled	pooled	pooled	Normal	pooled	pooled

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

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

The FHT3 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in three environmental conditions.

There were no diagnostic test failures. The three conditions could be pooled to compute basis values.

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

Statistics, basis values and estimates are given for the FHT3 strength data in Table 4-30. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-20.

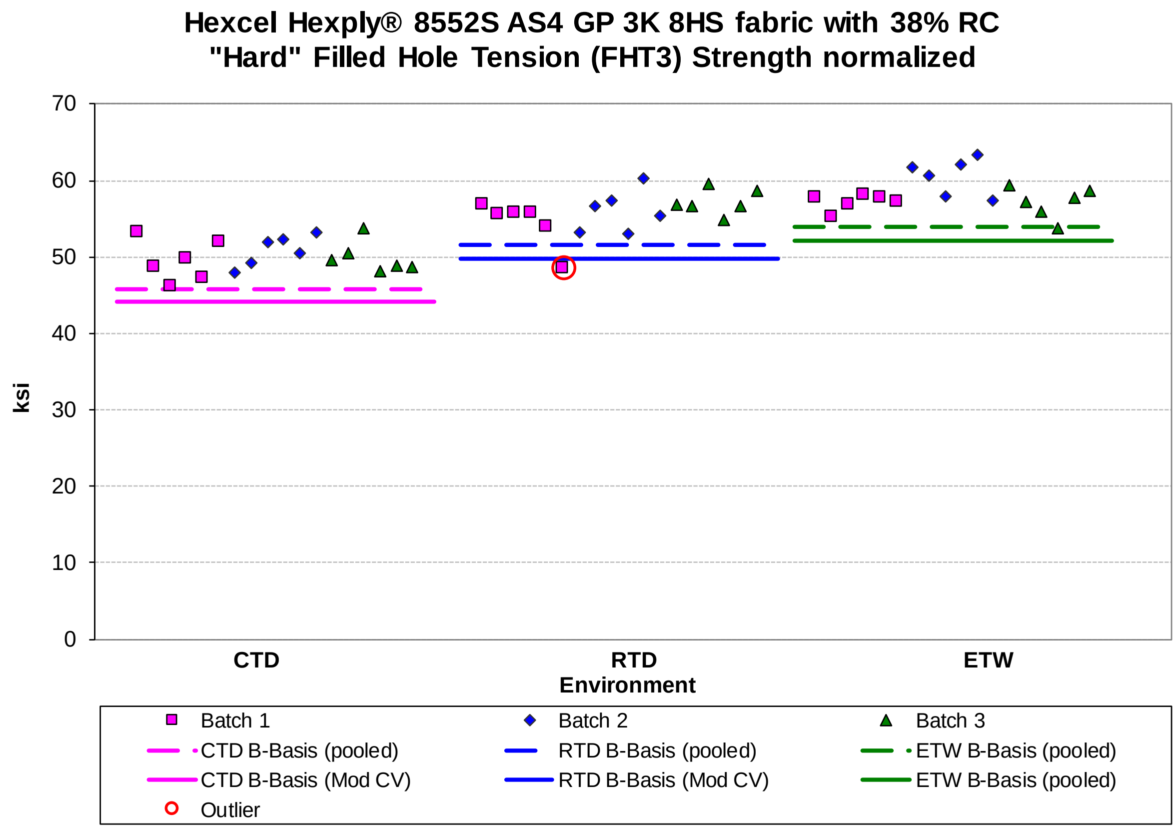

Figure 4-20: Batch plot for FHT3 normalized strength

Filled Hole Tension (FHT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	50.11	55.85	58.24	49.23	55.41	55.50
Stdev	2.211	2.649	2.447	3.108	3.220	2.393
CV	4.413	4.743	4.202	6.313	5.811	4.312
Modified CV	6.206	6.371	6.101	7.157	6.906	6.156
Min	46.22	48.59	53.74	45.07	46.07	51.86
Max	53.85	60.25	63.40	56.86	59.66	60.04
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and Estimates						
B-basis	45.78	51.53	53.91	44.04	50.22	50.31
A-Estimate	42.90	48.64	51.03	40.58	46.76	46.85
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis	44.06	49.81	52.19	42.86	49.04	49.13
A-Estimate	40.03	45.78	48.16	38.62	44.80	44.89
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

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

The OHC1 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in the RTD and ETW environmental conditions.

The two conditions could be pooled to compute the as-measured basis values. The normalized ETW dataset did not pass the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only three batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, the normalized ETW dataset passed the ADK test and modified CV basis values are provided, but pooling was not appropriate due to failures of both normality and Levene's test.

There was one outlier. The largest 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 in the normalized dataset. It was retained for this analysis.

Statistics, basis values and estimates are given for the OHC1 strength data in Table 4-31. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-21.

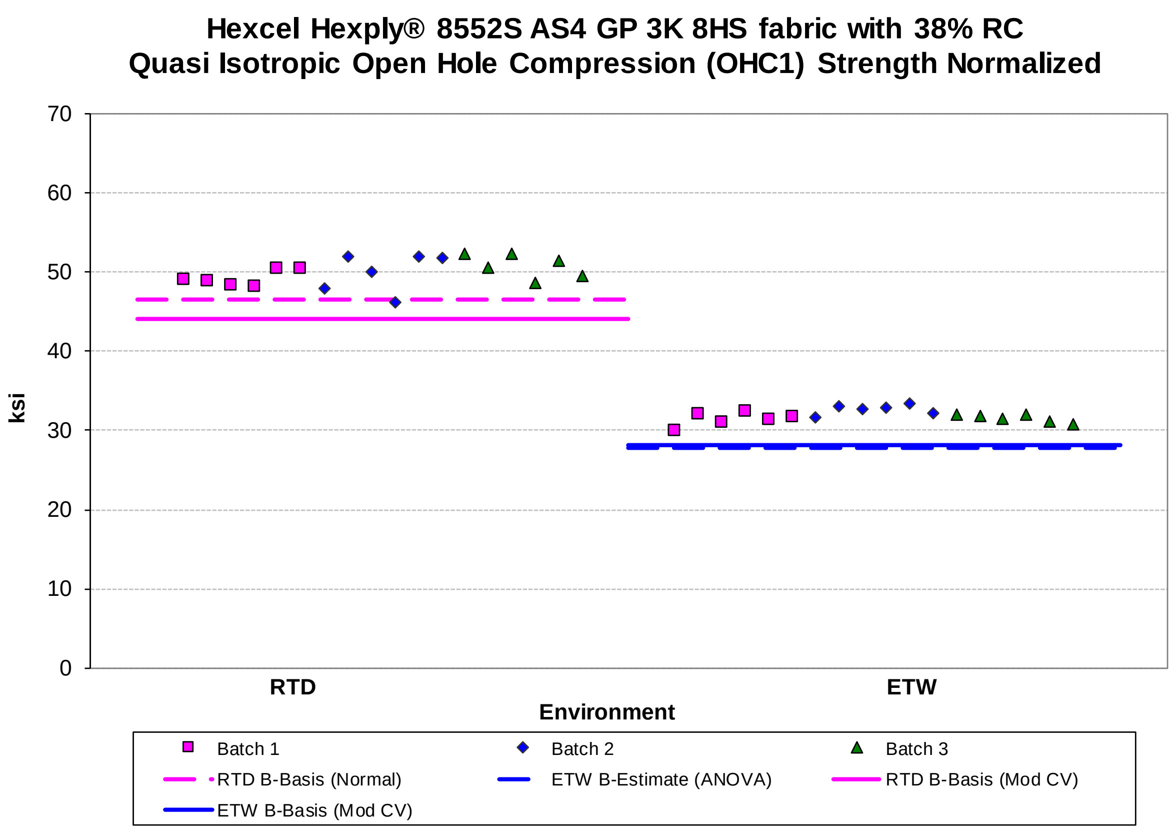

Figure 4-21: Batch plot for OHC1 normalized strength

Open Hole Compression (OHC1) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	50.04	31.85	50.19	31.36
Stdev	1.766	0.8597	1.972	1.071
CV	3.530	2.699	3.930	3.415
Modified CV	6.000	6.000	6.000	6.000
Min	46.29	29.97	47.43	29.85
Max	52.32	33.37	55.35	33.53
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and Estimates				
B-basis	46.55		47.30	28.47
B-Estimate		27.78		
A-Estimate	44.08	24.88	45.33	26.50
Method	Normal	ANOVA	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	44.11	28.07	45.61	26.79
A-Estimate	39.92	25.41	42.50	23.68
Method	Normal	Normal	pooled	pooled

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

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

The OHC2 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in the RTD and ETW environmental conditions.

The two conditions could be pooled to compute the basis values. After applying the modified CV transformation to the normalized datasets, the normalized pooled dataset failed Levene's test for equality of variance and could not be pooled to compute the modified CV basis values.

There were no statistical outliers.

Statistics, basis values and estimates are given for the OHC2 strength data in Table 4-32. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-22.

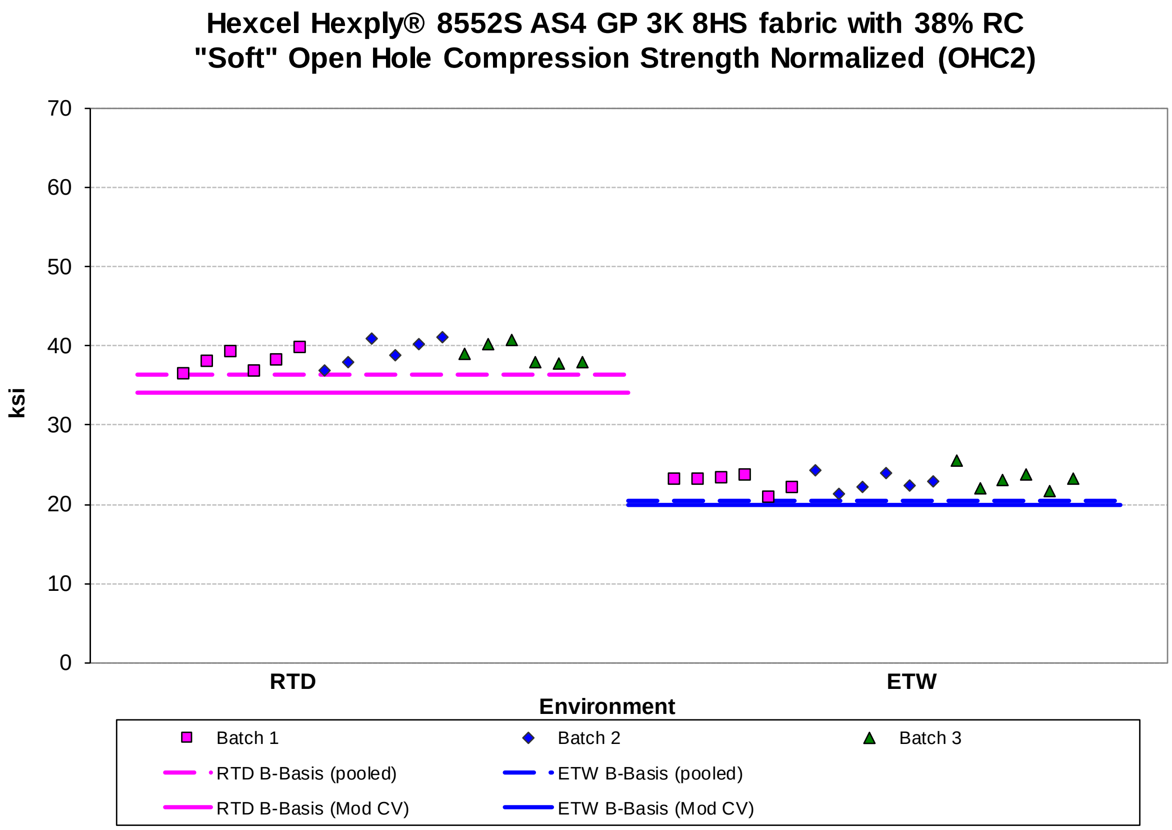

Figure 4-22: Batch plot for OHC2 normalized strength

Open Hole Compression (OHC2) Strength Basis Values				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	38.78	22.89	39.15	22.56
Stdev	1.473	1.136	1.272	1.132
CV	3.799	4.964	3.249	5.019
Modified CV	6.000	6.482	6.000	6.509
Min	36.46	20.76	37.33	21.23
Max	41.08	25.53	41.56	25.55
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and Estimates				
B-basis	36.39	20.49	36.96	20.36
A-Estimate	34.76	18.86	35.47	18.87
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis	34.19	19.96	35.59	18.99
A-Estimate	30.94	17.89	33.16	16.56
Method	Normal	Normal	pooled	pooled

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

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

The OHC3 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in the RTD and ETW environmental conditions.

The as-measured ETW dataset did not pass the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only three batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, the as-measured ETW dataset passed the ADK test and modified CV basis values are provided but pooling was not appropriate due to a failure of Levene's test for equality of variance. The two conditions failed Levene's test for the normalized values prior to the transformation of data for the modified CV approach, but passed that test and could be pooled for the normalized modified CV basis values.

There were no statistical outliers.

Statistics, basis values and estimates are given for the OHC3 strength data in Table 4-33. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-23.

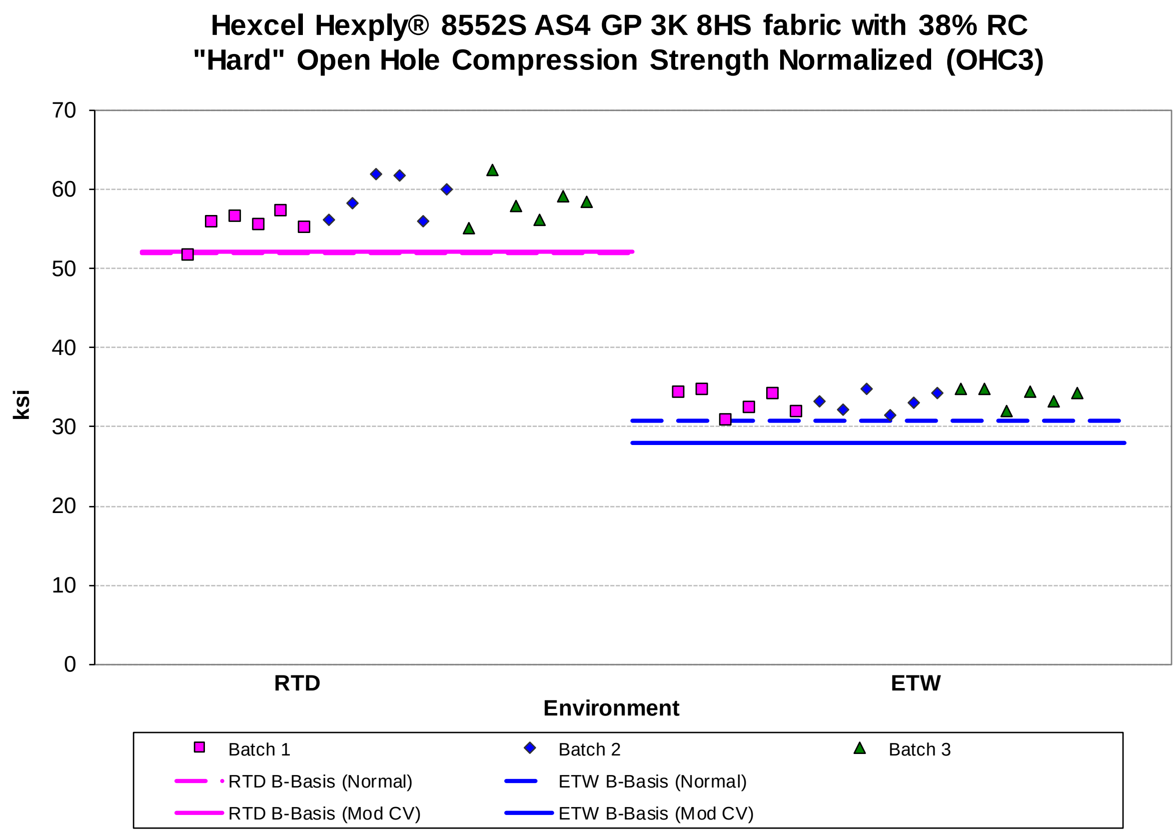

Figure 4-23: Batch plot for OHC3 normalized strength

Open Hole Compression (OHC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	57.57	33.38	57.58	33.27
Stdev	2.796	1.316	2.956	1.899
CV	4.857	3.942	5.134	5.708
Modified CV	6.429	6.000	6.567	6.854
Min	51.68	30.75	52.56	29.65
Max	62.55	34.86	62.81	36.97
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and Estimates				
B-basis	52.05	30.78	51.74	
B-Estimate				24.26
A-Estimate	48.14	28.94	47.61	17.84
Method	Normal	Normal	Normal	ANOVA
Modified CV Basis Values and Estimates				
B-basis	52.15	27.96	50.11	28.76
A-Estimate	48.46	24.28	44.83	25.58
Method	pooled	pooled	Normal	Normal

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

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

The FHC1 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in the RTD and ETW environmental conditions.

The two conditions failed Levene's test prior to the transformation of data for the modified CV approach. After that transformation of data, the as-measured datasets passed Levene's test and could be pooled for the as-measured modified CV basis values.

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

Statistics, basis values and estimates are given for the FHC1 strength data in Table 4-34. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-24.

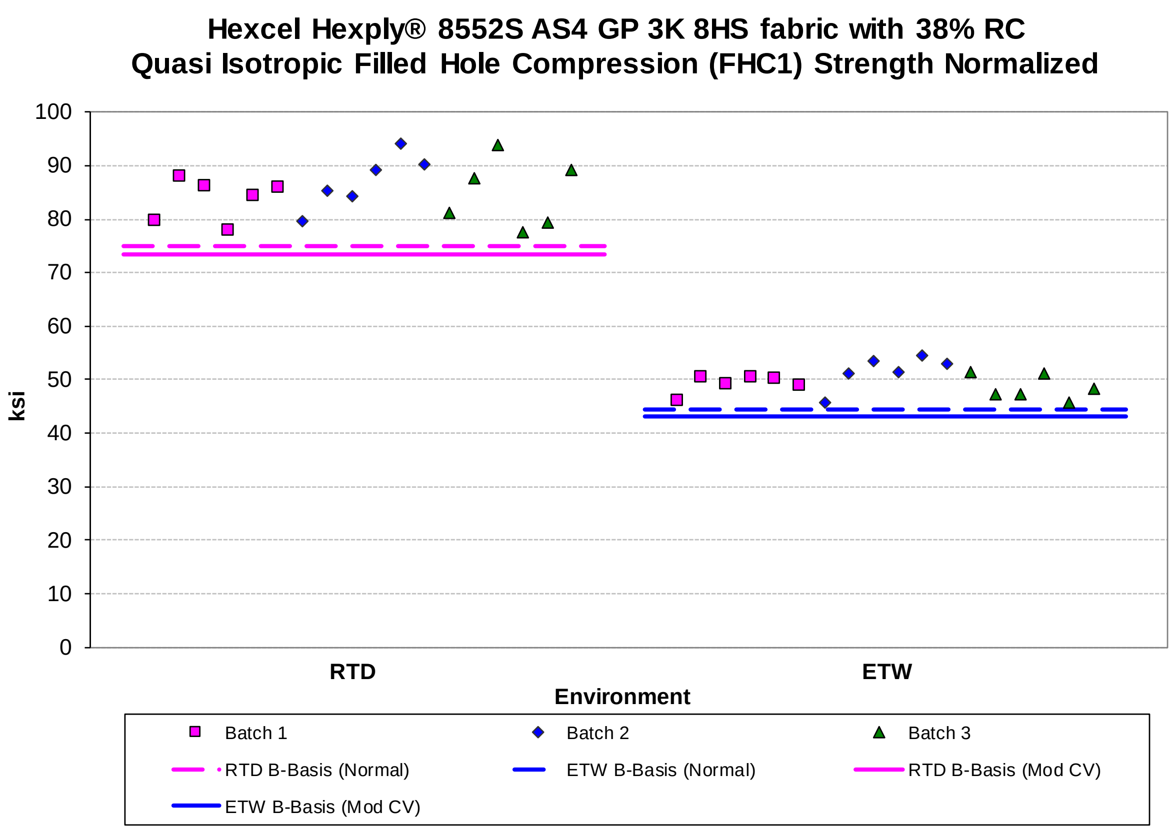

Figure 4-24: Batch plot for FHC1 normalized strength

Filled Hole Compression (FHC1) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	85.23	49.74	85.41	49.31
Stdev	5.186	2.675	3.196	1.323
CV	6.086	5.378	3.742	2.684
Modified CV	7.043	6.689	6.000	6.000
Min	77.51	45.67	79.38	46.88
Max	94.19	54.64	90.93	52.02
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and Estimates				
B-basis	74.99	44.46	79.10	46.70
A-Estimate	67.73	40.72	74.63	44.85
Method	Normal	Normal	Normal	Normal
Modified CV Basis Values and Estimates				
B-basis	73.38	43.17	77.79	41.69
A-Estimate	64.99	38.52	72.60	36.50
Method	Normal	Normal	pooled	pooled

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

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

The FHC2 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in the RTD and ETW environmental conditions. ***Data reported for reference only. FHC2 values are equal to or greater than UNC2 values, therefore CMH17 and NCAMP recommend the use of UNC2 values for design purposes.***

There was one outlier. The largest value in batch two of the as-measured ETW dataset was an outlier for batch two and for the ETW condition, but not for the normalized dataset.

Statistics are given for the FHC2 strength data in Table 4-35. The normalized specimen data are shown graphically in Figure 4-25.

Hexcel Hexply® 8552S AS4 GP 3K 8HS fabric with 38% RC
"Soft" Filled Hole Compression (FHC2) Strength Normalized

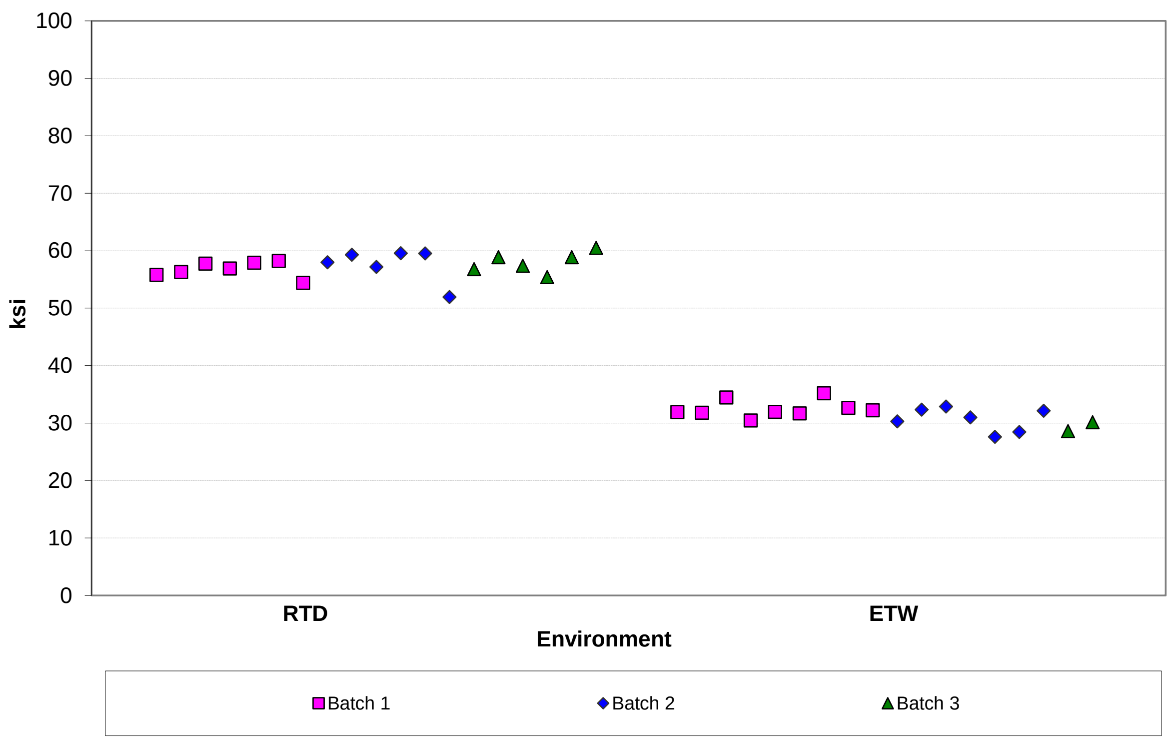

Figure 4-25: Batch plot for FHC2 normalized strength

Filled Hole Compression (FHC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	57.39	31.44	57.77	31.34
Stdev	2.044	1.958	1.341	1.612
CV	3.561	6.230	2.320	5.145
Modified CV	6.000	7.115	6.000	6.572
Min	51.93	27.62	55.31	28.48
Max	60.48	35.20	60.22	35.80
No. Batches	3	3	3	3
No. Spec.	19	18	19	18

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

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

The FHC3 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in the RTD and ETW environmental conditions.

The normalized datasets passed all diagnostic tests and could be pooled to compute basis values. The as-measured RTD dataset did not pass the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only three batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, the RTD datasets passed the ADK test and modified CV basis values are provided. After that transformation of data, the pooled as-measured dataset did not pass the normality test and could not be pooled for the modified CV basis values.

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

Statistics, basis values and estimates are given for the FHC3 strength data in Table 4-36. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-26.

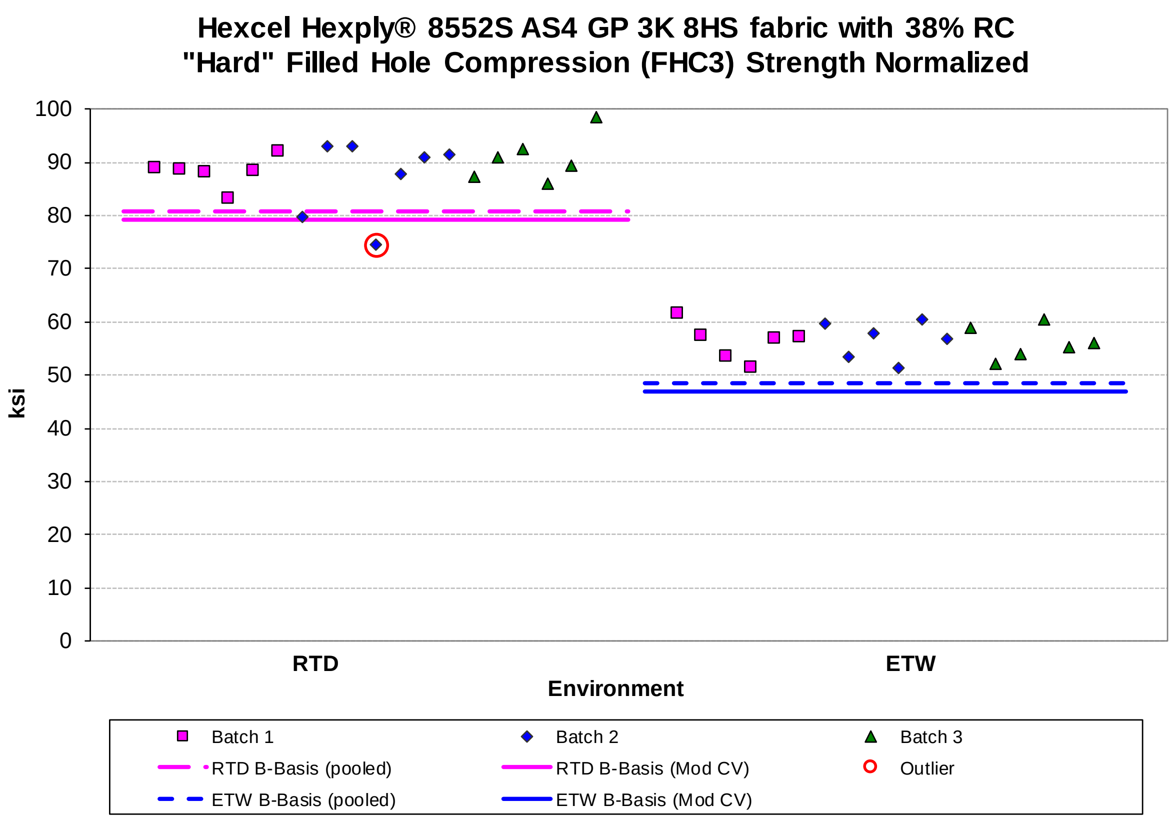

Figure 4-26: Batch plot for FHC3 normalized strength

Filled Hole Compression (FHC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	88.69	56.34	89.30	56.55
Stdev	5.270	3.219	3.666	1.928
CV	5.942	5.714	4.105	3.409
Modified CV	6.971	6.857	6.052	6.000
Min	74.45	51.25	79.87	52.62
Max	98.45	61.42	95.96	60.32
No. Batches	3	3	3	3
No. Spec.	19	18	19	18
Basis Values and Estimates				
B-basis	80.74	48.35		52.74
B-Estimate			73.97	
A-Estimate	75.31	42.92	63.04	50.04
Method	pooled	pooled	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-basis	79.31	46.91	78.77	49.85
A-Estimate	72.90	40.51	71.30	45.11
Method	pooled	pooled	Normal	Normal

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

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

The SSB1 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in the RTD and ETW environmental conditions.

The Ultimate Strength datasets met all requirement for pooling across the two conditions. The ETW datasets for 2% Offset Strength, both normalized and as-measured, failed the normality test. When the datasets for the two conditions were pooled together, the normalized datasets passed the normality test and pooling was appropriate. However, the as-measured pooled dataset did not pass normality and pooling was not appropriate. The Weibull distribution was used to compute single point design values for the as-measured 2% Offset Strength ETW condition. This dataset had only sixteen test values available for this property, which is acceptable for pooled computations but not for the single point approach. Thus the ETW 2% Offset Strength is labeled B-basis for the normalized pooled result and B-estimate for the as-measured single point Weibull result. The as-measured ETW 2% Offset Strength dataset failed normality after the transformation of data for the modified CV method, so modified CV basis value estimates could not be provided for that dataset.

There were three outliers. The lowest value in batch two of the as-measured ETW 2% Offset Strength dataset was an outlier for batch two, but not for the ETW condition and not for the normalized dataset. The lowest value in batch one of the normalized ETW 2% Offset Strength dataset was an outlier for batch one, but not for the ETW condition and not for the as-measured dataset. Both outliers were retained for this analysis.

The largest value in batch two of the normalized RTD Ultimate Strength dataset was an outlier for the RTD condition but not for batch two and not for the as-measured dataset. It was excluded from this analysis. High outliers are permitted to be removed in order to reduce the variance of the dataset, which can result in higher basis values. That was the case for this outlier.

Statistics, basis values and estimates are given for the SSB1 strength data in Table 4-37. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-27.

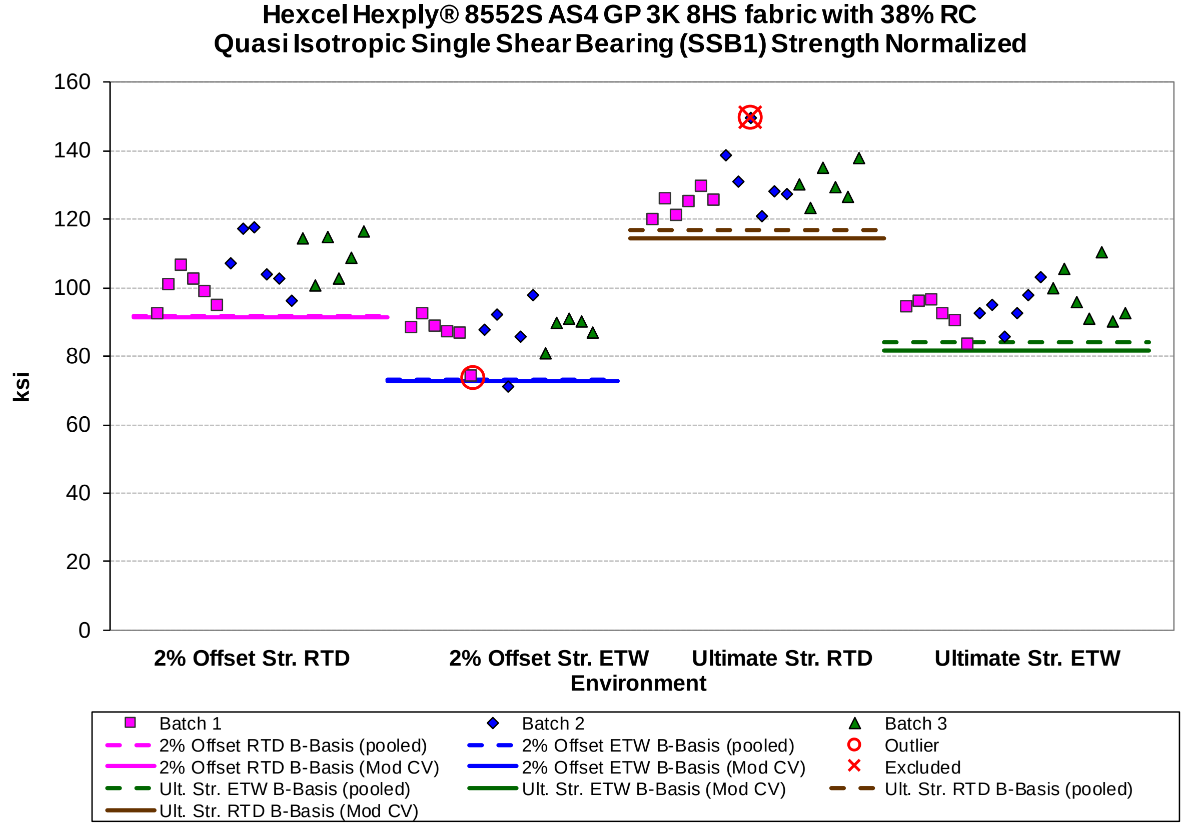

Figure 4-27: Batch plot for SSB1 normalized strength

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	105.4	86.84	128.0	94.99	111.0	87.60	136.0	95.17
Stdev	7.993	6.685	5.568	6.445	7.726	8.175	7.647	7.994
CV	7.580	7.698	4.352	6.785	6.959	9.332	5.622	8.400
Modified CV	7.790	7.849	6.176	7.393	7.480	9.332	6.811	8.400
Min	92.35	71.15	119.6	83.26	91.30	68.76	121.0	78.97
Max	117.5	97.81	138.7	110.2	123.7	97.97	149.8	109.3
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	16	17	19	18	16	18	19
Basis Values and Estimates								
B-basis	91.88	73.12	116.9	84.03	95.76		121.8	81.01
B-Estimate						71.67		
A-Estimate	82.63	63.90	109.4	76.52	84.96	57.07	112.1	71.34
Method	pooled	pooled	pooled	pooled	Normal	Weibull	pooled	pooled
Modified CV Basis Values and Estimates								
B-basis	91.55	72.79	114.3	81.49	94.62	NA	120.3	79.55
A-Estimate	82.06	63.34	105.1	72.24	83.03		109.7	68.88
Method	pooled	pooled	pooled	pooled	Normal		pooled	pooled

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

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

The SSB2 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in the RTD and ETW environmental conditions.

The Ultimate Strength datasets and the as-measured 2% Offset Strength datasets met all requirement for pooling across the two conditions. The normalized RTD dataset for 2% Offset Strength did not pass the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only three batches of data available, these are considered estimates. After applying the modified CV transformation to the datasets, this dataset passed the ADK test and modified CV basis values are provided, but after that transformation of data, the pooled normalized 2% Offset Strength datasets did not pass the normality test and could not be pooled for the modified CV basis values.

There were two outliers. The lowest value in batch three of the normalized 2% Offset Strength RTD dataset was an outlier for batch three, but not for the RTD condition and not for the as-measured dataset. The lowest value in batch two of the as-measured Ultimate Strength ETW dataset was an outlier the ETW dataset, but not for batch two and not for the normalized dataset. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for the SSB2 strength data in Table 4-38. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-28.

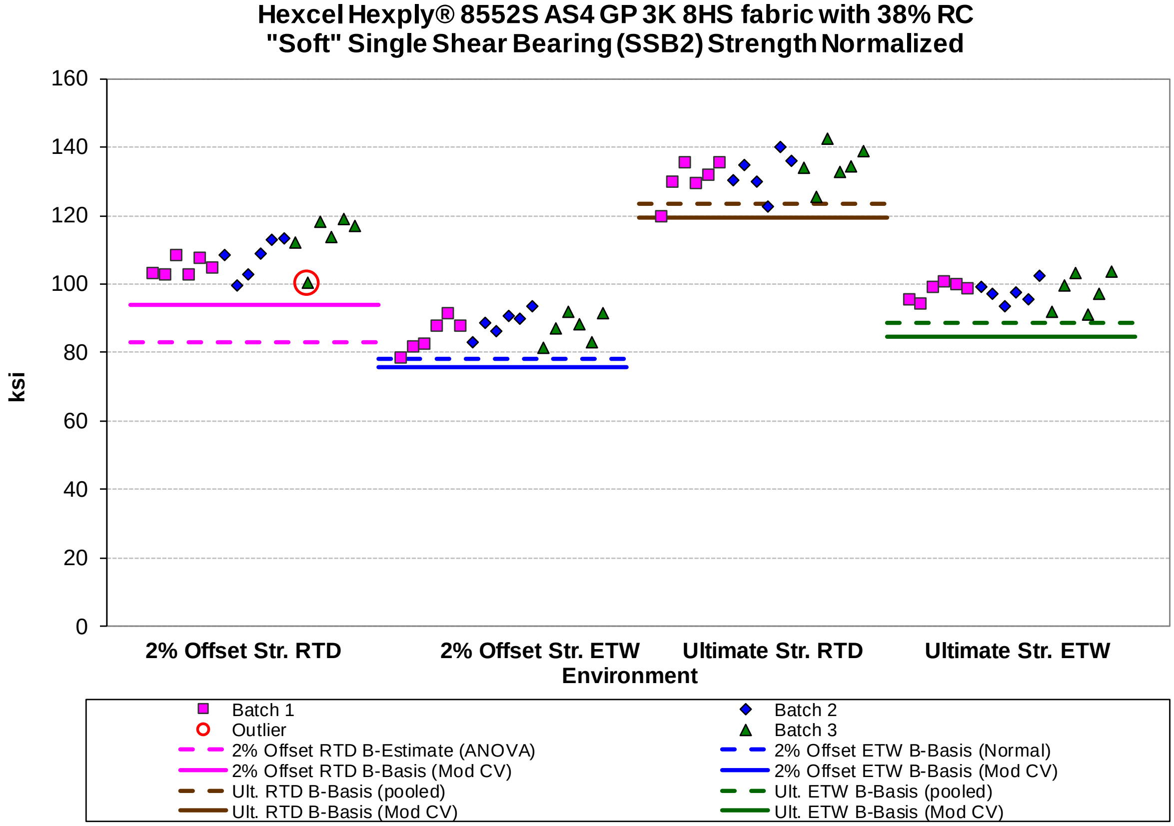

Figure 4-28: Batch plot for SSB2 normalized strength

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	108.6	86.86	132.3	97.75	113.7	87.84	138.6	98.89
Stdev	6.279	4.397	5.862	3.641	5.206	3.957	5.562	3.957
CV	5.784	5.063	4.429	3.725	4.579	4.505	4.012	4.002
Modified CV	6.892	6.531	6.214	6.000	6.290	6.252	6.006	6.001
Min	99.59	78.01	119.6	91.27	102.2	80.99	129.4	88.09
Max	119.1	93.53	142.5	103.7	122.0	97.63	146.3	104.5
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18	18	18
Basis Values and Estimates								
B-basis		78.17	123.5	88.86	105.3	79.41	129.9	90.09
B-Estimate	82.85							
A-Estimate	64.53	72.02	117.4	82.81	99.53	73.68	123.9	84.11
Method	ANOVA	Normal	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates								
B-basis	93.79	75.66	119.3	84.73	102.1	76.22	125.5	85.72
A-Estimate	83.34	67.73	110.5	75.88	94.17	68.32	116.5	76.76
Method	Normal	Normal	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-38: Statistics and Basis Values for SSB2 Strength Data

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

The SSB3 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in the RTD and ETW environmental conditions.

The normalized 2% Offset Strength datasets and the as-measured Ultimate Strength datasets passed all diagnostic tests and pooling the two environments was appropriate.

The normalized RTD dataset for Ultimate Strength did not pass the Anderson Darling k-sample (ADK) test. This diagnostic test failure means that the ANOVA method must be used to compute basis values and with test results from only three batches of data available, these are considered estimates. After applying the modified CV transformation to the dataset, it still did not pass the ADK test and modified CV basis values could not be provided.

The as-measured RTD dataset for 2% Offset Strength did not pass the normality test. The lognormal distribution provided the best fit to the data and was used to compute the basis values. It did not pass the normality test after applying the modified CV transformation to the datasets, so modified CV basis values could not be provided.

There were no statistical outliers.

Statistics, basis values and estimates are given for the SSB3 strength data in Table 4-39. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-29.

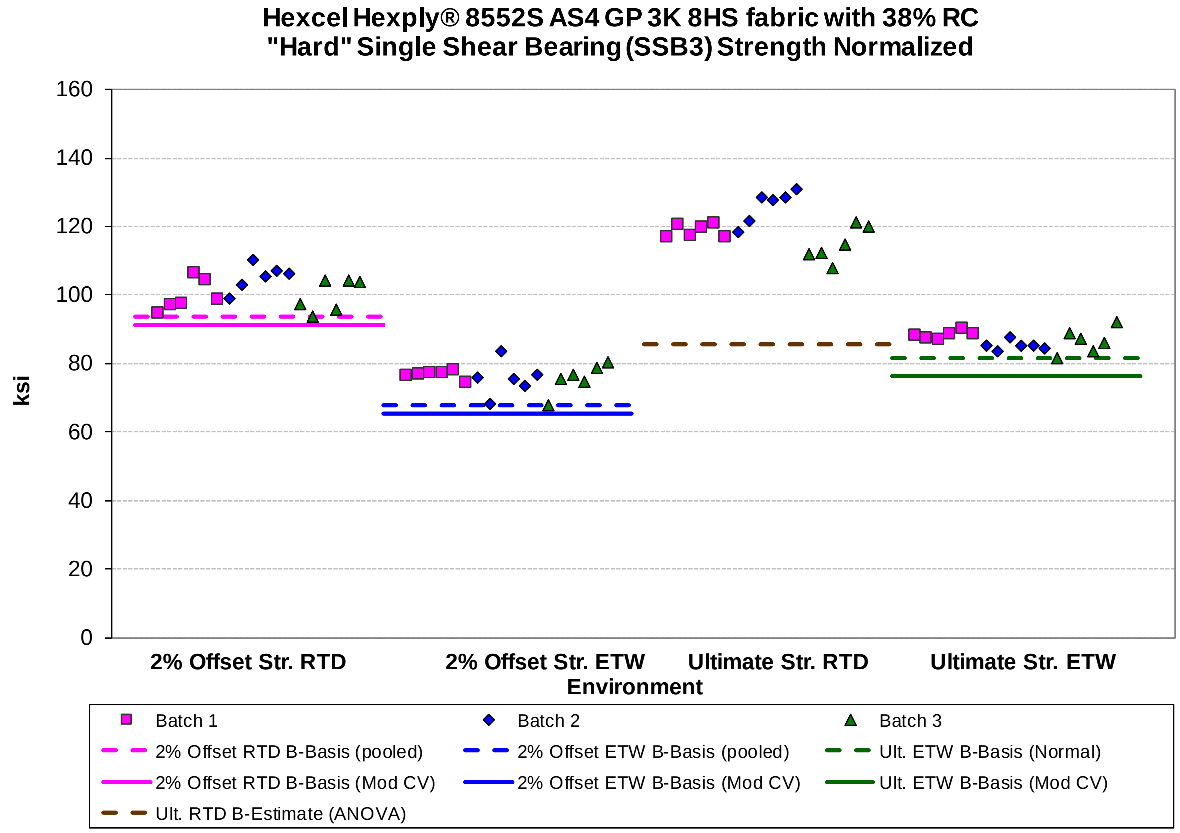

Figure 4-29: Batch plot for SSB3 normalized strength

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	101.6	75.91	119.7	86.62	107.2	75.78	126.3	86.52
Stdev	4.948	3.643	6.210	2.562	4.582	3.565	4.305	3.535
CV	4.871	4.800	5.187	2.957	4.274	4.704	3.408	4.086
Modified CV	6.435	6.400	6.593	6.000	6.137	6.352	6.000	6.043
Min	93.60	67.76	107.9	81.62	101.5	70.21	119.8	81.04
Max	110.2	83.41	130.9	91.98	118.7	82.87	133.5	93.45
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18	18	18
Basis Values and Estimates								
B-basis	93.67	68.00		81.57	98.64	68.74	119.1	79.34
B-Estimate			85.61					
A-Estimate	88.28	62.61	61.29	77.98	93.03	63.76	114.2	74.46
Method	pooled	pooled	ANOVA	Normal	Lognormal	Normal	pooled	pooled
Modified CV Basis Values and Estimates								
B-basis	91.09	65.42	NA	76.36	NA	66.28	114.4	74.66
A-Estimate	83.95	58.28		69.10		59.56	106.4	66.59
Method	pooled	pooled		Normal		Normal	pooled	pooled

Table 4-39: Statistics and Basis Values for SSB3 Strength Data

4.29 "25/50/25" Compression After Impact 1 (CAI1)

The CAI1 data is normalized by cured ply thickness. Basis values are not computed for this property. Testing is done only for the RTD condition. Only one batch of material was tested. There were no statistical analysis. Basis values are not computed for these properties. Summary statistics are presented in Table 4-40 and the data are displayed graphically in Figure 4-30.

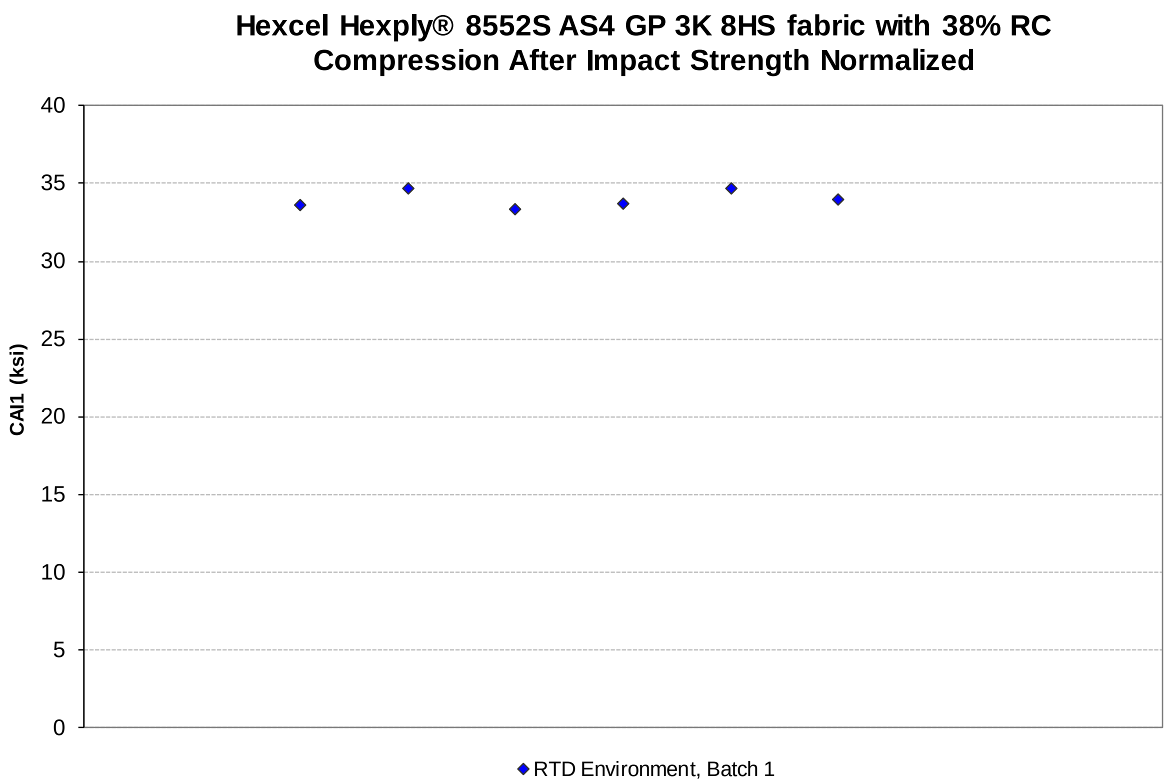

Figure 4-30: Plot for Compression After Impact normalized strength

Compression After Impact (CAI1) Strength (ksi) Statistics		
	Normalized	As-measured
Env	RTD	RTD
Mean	34.01	34.19
Stdev	0.5751	0.9037
CV	1.691	2.643
Modified CV	8.000	8.000
Min	33.37	33.17
Max	34.72	35.70
No. Batches	1	1
No. Spec.	6	6

Table 4-40: Statistics for Compression After Impact Strength Data

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

The ILT data is not normalized. Data is reported on two properties: Interlaminar Tension Strength and Curved Beam Strength. Testing was done in the CTD, RTD and ETW conditions. Only one batch of material was tested. There were no statistical analysis. Basis values are not computed for these properties. However the summary statistics are presented in Table 4-41 and the as-measured data are displayed graphically in Figure 4-31.

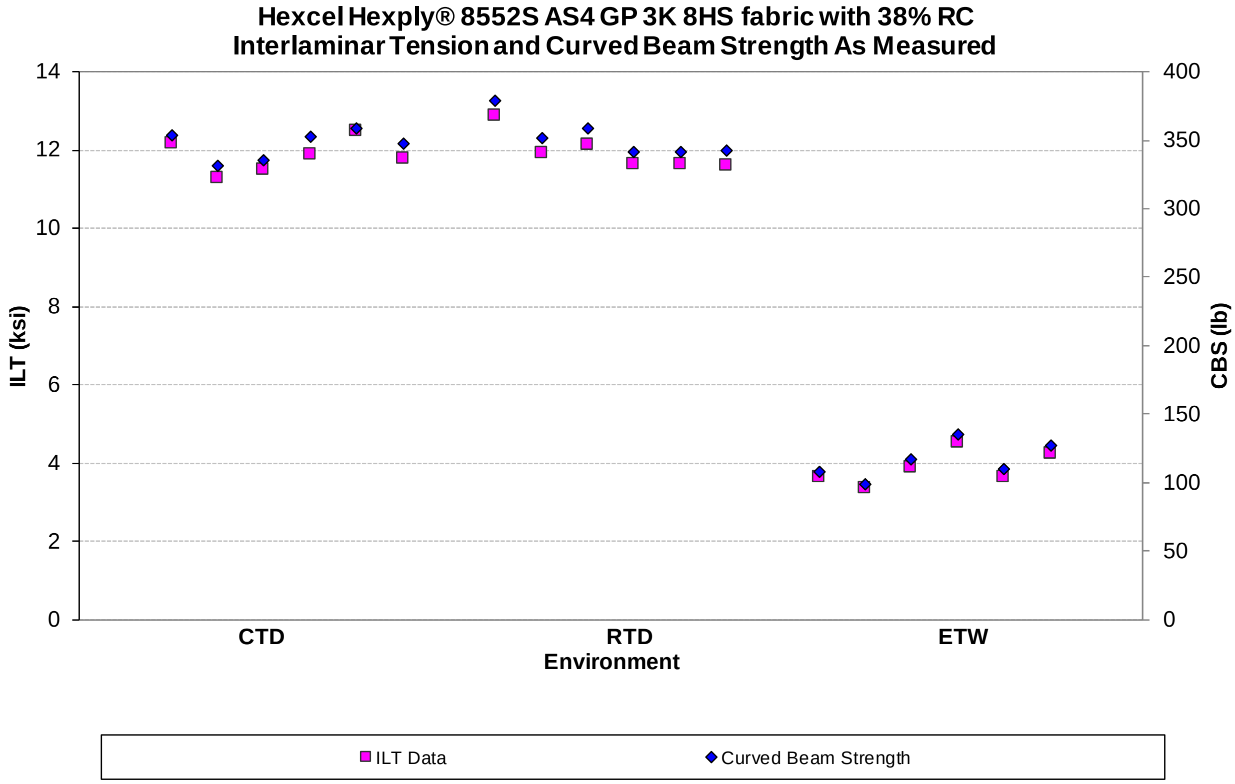

Figure 4-31: Plot for Interlaminar Tension and Curved Beam Strength

Interlaminar Tension (ILT) and Curved Beam Strength (CBS) Statistics						
	ILT (ksi)			CBS (lb)		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	11.84	11.96	3.876	346.5	352.3	115.7
Stdev	0.4328	0.4889	0.4356	10.92	14.59	13.33
CV	3.655	4.087	11.24	3.151	4.141	11.52
Modified CV	8.000	8.000	11.24	8.000	8.000	11.52
Min	11.28	11.61	3.340	330.9	341.5	98.55
Max	12.46	12.86	4.520	358.3	378.7	134.6
No. Batches	1	1	1	1	1	1
No. Spec.	6	6	6	6	6	6

Table 4-41: Statistics for ILT and CBS Data

5. Outliers

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

Approximately 5 out of 100 specimens will be identified as outliers due to the expected random variation of the data. This test is used only to identify specimens to be investigated for a cause of the extreme observation. Outliers that have an identifiable cause are removed from the dataset as they inject bias into the computation of statistics and basis values. Specimens that are outliers for the condition and in both the normalized and as-measured data are typically more extreme and more likely to have a specific cause and be removed from the dataset than other outliers. Specimens that are outliers only for the batch, but not the condition and specimens that are identified as outliers only for the normalized data or the as-measured data but not both, are typical of normal random variation.

All outliers identified were investigated to determine if a cause could be found. Outliers with causes were removed from the dataset and the remaining specimens were analyzed for this report. Information about specimens that were removed from the dataset along with the cause for removal is documented in the material property data report, NCAMP Test Report CAM-RP-2019-057.

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
WC	RTD	3	HPALC211A	111.4	Not an Outlier	Low	Yes	No
WT	ETW	3	HPAJC112D	124.6	Not an Outlier	Low	Yes	No
IPS-0.2% Offset	RTD	1	HPANA211A	NA	8.506	High	Yes	No
IPS-5% Strain					13.76			
IPS - Max Str.	CTD	1	HPANA213B	NA	17.10	High	Yes	No
FC	ETW	2	HPAZB1R4D	59.69	58.06	Low	Yes	No
SBS	RTD	1	HPAQA211A	NA	10.58	Low	No	Yes
SBS	ETW	2	HPAQB111D (Redo)	NA	5.955	Low	Yes	No
UNT1	CTD	3	HPAAC112B	76.18	Not an Outlier	Low	Yes	No
UNT1	RTD	2	HPAAB113A	97.53	Not an Outlier	High	Yes	No
UNT1	ETW	1	HPAAA111D	Not an Outlier	85.08	High	Yes	No
UNT2	CTD	1	HPABA113B	Not an Outlier	57.48	High	Yes	No
UNT2	RTD	2	HPABB111A	Not an Outlier	61.82	High	Yes	Yes
UNT2	ETW	2	HPABB211D	Not an Outlier	44.74	High	Yes	No
UNT2	RTD	1	HPABA213A	53.67	Not an Outlier	High	Yes	No
UNT2	RTD	2	HPABB211A	52.75	Not an Outlier	Low	Yes	No
UNT2	ETW	1	HPABA113D	46.26	Not an Outlier	High	Yes	No
UNT3	CTD	1	HPACA213B	Not an Outlier	106.0	High	Yes	No
UNT3	ETW	2	HPACB2R2D	97.49	93.95	Low	No	Yes
UNC1	RTD	1	HPAWA211A	77.59	Not an Outlier	Low	Yes	No
UNC1	RTD	3	HPAWC113A	Not an Outlier	106.2	High	Yes	No
UNC2	RTD	1	HPAXA112A	Not an Outlier	53.11	Low	No	Yes
UNC2	ETW	1	HPAXA214D	Not an Outlier	33.81	High	Yes	No
OHT3	ETW	1	HPAFA112D	60.66	56.96	Low	No	Yes
OHT3	CTD	3	HPAFC213B	Not an Outlier	61.03	High	Yes	No
FHT1	ETW	2	HPA4B113D	50.28	Not an Outlier	Low	Yes	No
FHT1	ETW	3	HPA4C112D	51.51	Not an Outlier	High	Yes	No
FHT2	CTD	2	HPA5B111B	46.95	Not an Outlier	High	No	Yes
FHT2	RTD	3	HPA5C211A	41.33	Not an Outlier	Low	Yes	No
FHT3	RTD	1	HPA6A213A	48.59	46.07	Low	No - as meas Yes - norm	Yes
OHC1	ETW	3	HPAGC211D	Not an Outlier	33.53	High	Yes	No
FHC1	RTD	1	HPA7A112A	Not an Outlier	89.23	High	Yes	No
FHC2	ETW	2	HPA8B112D	Not an Outlier	35.80	High	Yes	Yes
FHC3	RTD	2	HPA9B211A	74.45	Not an Outlier	Low	No	Yes
SSB1 - 2% Offset	ETW	1	HPA1A213D	73.88	Not an Outlier	Low	Yes	No
SSB1 - 2% Offset	ETW	2	HPA1B113D	Not an Outlier	68.76	Low	Yes	No
SSB1 - Ult. Str.	**RTD**	**2**	**HPA1B113A**	**149.7**	**Not an Outlier**	**High**	**No**	**Yes**
SSB2 - 2% Offset	RTD	3	HPA2C112A	100.3	Not an Outlier	Low	Yes	No
SSB2 - Ult. Str.	ETW	2	HPA2B113D	Not an Outlier	88.09	Low	No	Yes

SSB1 - Ult Str. RTD outlier was excluded from the analysis

Table 5-1: List of Outliers

6. References

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