Hexcel 8552S AS4 Plain Weave Fabric Qualification Statistical Analysis Report

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1. Introduction

This report contains statistical analysis of the Hexcel 8552S AS4 Plain Weave Fabric Prepreg 193 gsm & 38% RC fabric material property data published in NCAMP Test Report CAM-RP-2010-006 N/C. The lamina and laminate material property data have been generated with FAA oversight through FAA Special Project Number SP4614WI-Q and also meet the requirements outlined in NCAMP Standard Operating Procedure NSP 100. The test panels, test specimens, and test setups have been conformed by the FAA and the testing has been witnessed by the FAA.

B-Basis values, A-estimates, and B-estimates were calculated using a variety of techniques that are detailed in section two. The qualification material was procured to NCAMP Material Specification NMS 128/3 Rev Initial Release dated June 7, 2007. The qualification test panels were cured in accordance with NCAMP Process Specification 81228 Cure "M," June 7, 2007. The NCAMP Test Plan NTP 1628Q1 Rev. B was used for this qualification program. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas.

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

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

The 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 Rev G. The applicability of equivalency process must be evaluated on program-by-program basis by the applicant and certifying agency. The applicant and certifying agency must agree that the equivalency test plan along with the equivalency process described in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17 Rev G are adequate for the given program.

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 128/3. NMS 128/3 has additional requirements that are listed in its prepreg process control document (PCD), fiber specification, fiber PCD, and other raw material specifications and PCDs which impose essential quality controls on the raw materials and raw material manufacturing equipment and processes. *Aircraft companies and certifying agencies should assume that the material property data published in this report is not applicable when the material is not procured to NCAMP Material Specification NMS 128/3*. NMS 128/3 is a free, publicly available, non-proprietary aerospace industry material specification.

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

1.1 Symbols and Abbreviations

Test Property	**Abbreviation**
Warp Compression	WC
Warp Tension	WT
Fill Compression	FC
Fill Tension	FT
In Plane Shear	IPS
Short Beam Strength	SBS
Unnotched Tension	UNT
Unnotched Compression	UNC
Laminate Short Beam Strength	SBS1
Filled Hole Tension	FHT
Filled Hole Compression	FHC
Open Hole Tension	OHT
Open Hole Compression	OHC
Single Shear Bearing	SSB
Interlaminar Tension	ILT
Curved Beam Strength	CBS
Compression After Impact	CAI

Table 1-1: Test Property Abbreviations

Test Property	**Symbol**
Warp Compression Strength	F_1^{cu}
Warp Compression Modulus	E_1^{c}
Warp Compression Poisson's Ratio	ν_{12}^{c}
Warp Tension Strength	F_1^{tu}
Warp Tension Modulus	E_1^{t}
Warp Tension Poisson's Ratio	ν_{12}^{t}
Fill Compression Strength	F_2^{cu}
Fill Compression Modulus	E_2^{c}
Fill Compression Poisson's Ratio	ν_{21}^{c}
Fill Tension Strength	F_2^{tu}
Fill Tension Modulus	E_2^{t}
In Plane Shear Strength at 5% strain	$F_{12}^{s5\%}$
In Plane Shear Strength at 0.2% offset	$F_{12}^{s0.2\%}$
In Plane Shear Modulus	G_{12}^{s}

Table 1-2: Test Property Symbols

Environmental Condition	**Abbreviation**
Cold Temperature Dry (−65°)	CTD
Room Temperature Dry (70°)	RTD
Elevated Temperature Dry (250°)	ETD
Elevated Temperature Wet (250°)	ETW

Table 1-3: Environmental Conditions Abbreviations

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

1 = "Quasi-Isotropic"
2 = "Soft"
3 = "Hard"

EX: OHT1 is an open hole tension test with a "Quasi-Isotropic" layup

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2010-006 N/C.

1.2 Pooling Across Environments

When pooling across environments was allowable, the pooled co-efficient of variation was used. ASAP (**A**GATE **S**tatistical **A**nalysis **P**rogram) 2008 version 1.0 was used to determine if pooling was allowable and to compute the pooled coefficient of variation for those tests. In these cases, the modified coefficient of variation based on the pooled data was used to compute the basis values.

When pooling across environments was not advisable because the data was not eligible for pooling and engineering judgment indicated there was no justification for overriding the result, then B-Basis values were computed for each environmental condition separately using Stat17 version 5.

1.3 Basis Value Computational Process

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

1.4 Modified Coefficient of Variation (CV) Method

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

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

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

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

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

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

2. Background

Statistical computations are performed with AGATE Statistical Analysis Program (ASAP) when pooling across environments is permissible according to CMH-17 Rev G guidelines. If pooling is not permissible, a single point analysis using STAT-17 is performed for each environmental condition with sufficient test results. If the data does not meet CMH-17 Rev G requirements for a single point analysis, estimates are created by a variety of methods depending on which is most appropriate for the dataset available. Specific procedures used are presented in the individual sections where the data is presented.

2.1 ASAP Statistical Formulas and Computations

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

2.1.1 Basic Descriptive Statistics

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

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

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

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

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

2.1.2 Statistics for Pooled Data

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

2.1.2.1 Pooled Standard Deviation

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

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

Where k refers to the number of batches 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 Rev G. The approximation formulas are given below:

$$K_a = \frac{2.3263}{\sqrt{q(f)}} + \sqrt{\frac{1}{c_A(f)\cdot n_j} + \left(\frac{b_A(f)}{2c_A(f)}\right)^2} - \frac{b_A(f)}{2c_A(f)}$$ **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 = $$CV^* = \begin{cases} .06 & \text{if } CV < .04 \\ \frac{CV}{2} + .04 & \text{if } .04 \le CV < .08 \\ CV & \text{if } CV \ge .08 \end{cases}$$ **Equation 14**

This is converted to percent by multiplying by 100%.

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

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

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

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

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

2.1.4.1 Transformation of data based on Modified CV

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

To accomplish this requires a transformation in two steps:

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

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

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

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

Step 2: Another transformation is needed as applying the modified CV to each batch leads to a larger CV for the combined data than when applying the modified CV rules to the combined data (due to the addition of between batch variation when combining data from multiple batches). In order to alter the data to match S^*, the transformed data is transformed again, this time setting using the same value of C′ for all batches.

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

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

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

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

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

2.1.5 Determination of Outliers

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

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

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

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

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

2.1.6 The k-Sample Anderson Darling Test for batch equivalency

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

The k-sample Anderson-Darling test statistic is:

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

Where

n_i = the number of test specimens in each batch

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

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

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

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

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

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

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

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

With

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

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

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

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

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

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

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

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

2.1.7 The Anderson Darling Test for Normality

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

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

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

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

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

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

The Anderson Darling test statistic (AD) is:

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

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

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

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

2.1.8 Levene's test for Equality of Coefficient of Variation

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

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

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

2.2 STAT-17

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

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

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

2.2.1 Distribution tests

In addition to testing for normality using the Anderson-Darling test (see 2.1.7); Stat17 also tests to see if the Weibull or Lognormal distribution is a good fit for the data.

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

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

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

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

2.2.2 Computing Normal Distribution Basis values

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

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

Table 2-1: K factors for normal distribution

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

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

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

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

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

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

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

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

2.2.2.3 Two-parameter Weibull Distribution

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

$$e^{-\left(a/\alpha\right)^{\beta}} - e^{-\left(b/\alpha\right)^{\beta}}$$ **Equation 35**

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

In order to compute a check of the fit of a data set to the Weibull distribution and compute basis values assuming Weibull, it is first necessary to obtain estimates of the population shape and scale parameters (Section 2.2.2.3.1). Calculations specific to the goodness-of-fit test for the Weibull distribution are provided in section 2.2.2.3.2.

2.2.2.3.1 Estimating Weibull Parameters

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

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

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

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

2.2.2.3.2 Goodness-of-fit test for the Weibull distribution

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

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

The Anderson-Darling test statistic is

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

and the observed significance level is

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

where

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

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

2.2.2.3.3 Basis value calculations for the Weibull distribution

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

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

where

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

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

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

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

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

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

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

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

Table 2-2: Weibull Distribution Basis Value Factors

2.2.2.4 Lognormal Distribution

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

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

2.2.2.4.1 Goodness-of-fit test for the Lognormal distribution

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

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

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

2.2.2.4.2 Basis value calculations for the Lognormal distribution

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

2.2.3 Non-parametric Basis Values

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

2.2.3.1 Non-parametric Basis Values for large samples

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

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

For B-basis values:

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

For A-Basis values:

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

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

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

2.2.4 Non-parametric Basis Values for small samples

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

The Hanson-Koopmans B-basis value is:

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

The A-basis value is:

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

where $x_{(n)}$ is the largest data value, $x_{(1)}$ is the smallest, and $x_{(r)}$ is the r^{th} largest data value. The values of r and k depend on n and are listed in Table 2-3. This method is not used for the B-basis value when $x_{(r)} = x_{(1)}$.

The Hanson-Koopmans method can be used to calculate A-basis values for n less than 299. Find the value k_A corresponding to the sample size n in Table 2-4. For an A-basis value publishable according to CMH-17 Rev G, there must be at least five batches represented in the data and at least 55 data points. For a B-basis value, there must be at least three batches represented in the data and at least 18 data points.

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

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

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

Table 2-4: A-Basis Hanson-Koopmans Table

2.2.5 Analysis of Variance (ANOVA) Basis Values

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

2.2.5.1 Calculation of basis values using ANOVA

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

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

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

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

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

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

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

Next, the mean sums of squares are computed:

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

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

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

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

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

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

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

Denote the ratio of mean squares by

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

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

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

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

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

2.3 Single Batch and Two Batch estimates using modified CV

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

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

2.4 Lamina Variability Method (LVM)

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

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

The LVM B-basis value is then computed as:

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

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

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

With:

$\bar{X}_1$ the mean of the laminate (small dataset)
N_1 the sample size of the laminate (small dataset)
N_2 the sample size of the lamina (large dataset)
CV_1 is the coefficient of variation of the laminate (small dataset)
CV_2 is the coefficient of variation of the lamina (large dataset)
$K_{(N_1,N_2)}$ is given in Table 2-5

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

Table 2-5: B-Basis factors for small datasets using variability of corresponding large dataset

3. Summary of Results

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

3.1 NCAMP Recommended B-basis Values

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

1. Recommended values are NEVER estimates. Only B-basis values that meet all requirements of CMH-17 Rev G are recommended.
2. Modified CV basis values are preferred. Recommended values will be the modified CV basis value when available. The CV provided with the recommended basis value will be the one used in the computation of the basis value.
3. Only normalized basis values are given for properties that are normalized.
4. ANOVA B-basis values are not recommended since only three batches of material are available and the CMH-17 Rev G recommends that no less than five batches be used when computing basis values with the ANOVA method.
5. B-Basis values calculated from STAT17 are not included if the basis values are 90% or more of the average values. Basis values of 90% or more of the mean value imply that the CV is unusually low and may not be conservative.
6. If the data appear questionable (e.g. when the CTD-RTD-ETW trend of the basis values are not consistent with the CTD-RTD-ETW trend of the average values), then the B-basis values will not be recommended.

NCAMP Recommended B-basis Values for
Hexcel 8552S AS4 3K Plain Weave Fabric

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

Lamina Strength Tests

Environment	Statistic	WT	WC	FT	FC	SBS*	IPS* 0.2% Offset	IPS* 5% Strain
CTD (-65 F)	B-basis	85.30	110.12	NA: A	105.54	NA: I	9.97	
	Mean	95.97	129.16	93.22	120.83	13.45	11.01	
	CV	6.00	7.56	4.99	7.84	4.47	6.00	
RTD (70 F)	B-basis	96.27	103.12	94.89	93.75	11.49	7.06	
	Mean	109.02	115.13	107.62	109.12	13.36	8.11	
	CV	6.00	6.34	6.16	9.27	8.44	6.00	
ETD (250 F)	B-basis		88.17		71.65	8.34		
	Mean		100.23		87.33	9.41		
	CV		6.00		8.47	6.00		
ETW (250 F)	B-basis	NA: A	NA: A	108.96	49.51	6.71**	2.82	NA: A
	Mean	130.29	72.78	121.74	64.89	7.07	3.21	5.43
	CV	6.45	11.28	6.22	11.75	2.56	6.49	4.43

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

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

NCAMP Recommended B-basis Values for
Hexcel 8552S AS4 3K Plain Weave Fabric

All B-basis values in this table meet the standards for publication in CMH-17 Rev G 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 Ultimate Strength	SBS1*
25/50/25	CTD (-65 F)	B-basis	34.46		38.02		NA: A				
		Mean	38.97		43.17		74.21				
		CV	6.14		6.12		4.79				
	RTD (70 F)	B-basis	38.21	41.94	44.01	74.92	74.43	82.09	NA: A	120.96	11.90
		Mean	42.72	47.49	49.10	85.00	83.82	90.57	106.95	135.32	12.99
		CV	6.10	6.00	6.45	5.07	6.00	6.10	8.97	6.62	6.00
	ETW (250 F)	B-basis	NA:A	27.71	46.43	NA: I	80.92	45.75	65.09	82.20	5.18
		Mean	48.62	31.77	51.58	54.87	90.19	54.16	79.01	96.37	6.27
		CV	4.22	6.78	6.00	8.53	6.00	7.12	9.34	7.36	6.02
10/80/10	CTD (-65 F)	B-basis	36.74		39.08		48.01				
		Mean	40.85		44.07		53.33				
		CV	6.00		6.00		6.00				
	RTD (70 F)	B-basis	39.10	38.43	42.08	55.47	48.73	56.15	88.86	113.89	
		Mean	43.21	42.19	46.47	61.20	54.12	61.60	102.14	132.73	
		CV	6.00	6.00	6.00	6.00	6.00	6.00	6.67	7.28	
	ETW (250 F)	B-basis	29.18	22.95	30.86	31.72	42.51	30.58	NA: A	85.25	
		Mean	33.25	26.67	35.25	37.51	47.85	35.98	78.44	96.26	
		CV	6.00	6.00	6.00	7.01	6.00	6.35	8.43	6.00	
40/20/40	CTD (-65 F)	B-basis	38.46		42.15		75.52				
		Mean	43.88		48.35		85.46				
		CV	6.67		6.85		6.00				
	RTD (70 F)	B-basis	44.94	45.37	48.59	74.41	88.09	77.84	NA: A	112.33	
		Mean	50.36	49.99	54.84	84.27	97.95	90.60	96.40	125.02	
		CV	6.11	6.00	6.88	6.00	6.00	7.23	9.11	6.59	
	ETW (250 F)	B-basis	53.61	27.75	NA: A	NA: I	NA: A	NA: A	NA: A	75.10	
		Mean	60.55	32.35	59.44	58.50	115.02	63.78	70.69	87.68	
		CV	6.02	6.72	5.09	12.30	4.03	6.16	9.21	6.64	

Notes: The modified CV B-basis value is recommended when available.
The CV provided corresponds with the B-basis value given.
NA indicates that tests were run but data did not meet NCAMP recommended rqmts
"NA: A" indicates ANOVA with 3 batches, "NA: I" indicates insufficient data,
"NA: 90%" indicates the Stat17 Basis value is greater than 90% of the mean value.
Modified CV values are given with all Mod CV recommended values and for NA:90%
Shaded empty boxes indicate that no test data is available for that property and condition.
* Data is as measured rather than normalized

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

3.2 Lamina and Laminate Summary Tables

Prepreg Material:	Hexcel 8552S AS4 3k Plain Weave NMS 128/3 Material Specification			**Hexcel 8552S AS4 3K Plain Weave Lamina Properties Summary**
Fiber:	3K Plain Weave AS4	**Resin:**	Hexcel 8552	
	Tg(dry): 396.75 °F	**Tg(wet):** 332.02°F		**Tg METHOD: DMA (SRM 18R-94)**
PROCESSING:	NPS 81228 "M" Cure Cycle			

	1	2	3		
Date of fiber manufacture	11/6/07	11/21/06	10/20/06	**Date of testing**	4/30/09 to 8/16/10
Date of resin manufacture	1/23/07	2/9/07	2/11/07	**Date of data submittal**	9/1/2010
Date of prepreg manufacture	1/23/07	2/9/07	2/11/07	**Date of analysis**	8/10/2010 to 9/1/2010
Date of composite manufacture	11/1/2008 to 1/1/2009				

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported: As measured followed by normalized values in parentheses, normalizing tply: 0.0078 in

Values shown in shaded boxes do not meet CMH-17G requirements and are estimates only

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

	CTD			RTD			ETD			ETW		
	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean
F_1^{tu}	86.73	85.20	96.17	102.20	100.33	111.52				83.05	113.60	132.15
(ksi)	(81.33)	(85.30)	(95.97)	(103.60)	(96.27)	(109.02)				(78.20)	(112.16)	(130.29)
E_1^t			9.30			9.58						9.47
(Msi)			(9.28)			(9.36)						(9.33)
ν_{12}^t			0.031			0.046						0.054
F_2^{tu}	65.05	81.52	92.97	98.00	95.26	109.19				112.09	109.35	123.34
(ksi)	(62.91)	(81.41)	(93.22)	(89.79)	(94.89)	(107.62)				(111.22)	(108.96)	(121.74)
E_2^t			9.28			9.66						9.60
(Msi)			(9.30)			(9.51)						(9.45)
F_1^{cu}	116.10	115.66	129.76	108.77	108.33	122.37	82.37	86.77	100.88	27.53	59.66	76.84
(ksi)	(111.22)	(110.12)	(129.16)	(106.61)	(103.12)	(115.13)	(91.68)	(88.17)	(100.23)	(27.45)	(56.77)	(72.78)
E_1^c			8.57			9.20			8.51			8.98
(Msi)			(8.53)			(8.65)			(8.45)			(8.57)
ν_{12}^c			0.054			0.046			0.054			0.053
F_2^{cu}	106.33	106.28	122.55	97.00	96.95	113.31	74.93	74.88	91.57	48.23	48.18	64.54
(ksi)	(105.64)	(105.54)	(120.83)	(93.85)	(93.75)	(109.12)	(71.75)	(71.65)	(87.33)	(49.61)	(49.51)	(64.89)
E_2^c			8.70			9.01			8.87			8.53
(Msi)			(8.58)			(8.67)			(8.41)			(8.46)
ν_{21}^c			0.062			0.054			0.046			0.053
$F_{12}^{s0.2\%}$ (ksi)	10.68	9.97	11.01	7.78	7.06	8.11				2.82	NA	3.21
$F_{12}^{s5\%}$ (ksi)										4.20	NA	5.43
G_{12}^s (Msi)			0.83			0.72						0.32
SBS (ksi)	11.79	11.14	13.45	11.49	NA	13.36	8.06	8.34	9.41	6.71	NA	7.07

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

Prepreg Material:	Hexcel 8552S AS4 3k Plain Weave NMS 128/3 Material Specification		**Hexcel 8552S AS4 3K Plain Weave Laminate Properties Summary**
Fiber:	3K Plain Weave AS4	**Resin:**	Hexcel 8552
Tg(dry): 396.75 °F	**Tg(wet):** 332.02°F	**Tg METHOD:**	**DMA (SRM 18R-94)**
PROCESSING: NPS 81228 "M" Cure Cycle			

	1	2	3		
Date of fiber manufacture	11/6/07	11/21/06	10/20/06	**Date of testing**	4/30/09 to 8/16/10
Date of resin manufacture	1/23/07	2/9/07	2/11/07	**Date of data submittal**	9/1/2010
Date of prepreg manufacture	1/23/07	2/9/07	2/11/07	**Date of analysis**	8/10/2010 to 9/1/2010
Date of composite manufacture	11/1/2008 to 1/1/2009				

LAMINATE MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported as normalized used a normalizing t_{ply} of 0.0078 in

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

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

Test	Property	Test Condition	Layup: Unit	Quasi Isotropic 25/50/25 B-value	Quasi Isotropic 25/50/25 Mod. CV B-value	Quasi Isotropic 25/50/25 Mean	"Soft" 10/80/10 B-value	"Soft" 10/80/10 Mod. CV B-value	"Soft" 10/80/10 Mean	"Hard" 40/20/40 B-value	"Hard" 40/20/40 Mod. CV B-value	"Hard" 40/20/40 Mean
OHT (normalized)	Strength	CTD	ksi	35.84	34.46	38.97	39.17	36.74	40.85	39.84	38.46	43.88
		RTD	ksi	39.59	38.21	42.72	41.53	39.10	43.21	46.32	44.94	50.36
		ETW	ksi	35.64	42.96	48.62	31.59	29.18	33.25	47.60	53.61	60.55
OHC (normalized)	Strength	RTD	ksi	45.02	41.94	47.49	39.74	38.43	42.19	47.49	45.37	49.99
		ETW	ksi	25.13	27.71	31.77	21.54	22.95	26.67	22.80	27.75	32.35
UNT (normalized)	Strength	CTD	ksi	51.49	65.41	74.21	45.29	48.01	53.33	69.25	75.52	85.46
	Modulus		Msi	---	---	7.01	---	---	4.82	---	---	8.69
	Strength	RTD	ksi	77.80	74.43	83.82	49.01	48.73	54.12	78.96	88.09	97.95
	Modulus		Msi	---	---	6.75	---	---	4.46	---	---	8.40
	Strength	ETW	ksi	69.67	80.92	90.19	43.09	42.51	47.85	87.11	101.84	115.02
	Modulus		Msi	---	---	6.37	---	---	3.57	---	---	8.25
UNC (normalized)	Strength	RTD	ksi	84.12	82.09	90.57	58.02	56.15	61.60	79.20	77.84	90.60
	Modulus		Msi	---	---	6.30	---	---	4.37	---	---	7.72
	Poisson's Ratio			---	---	0.320	---	---	0.526	---	---	0.135
	Strength	ETW	ksi	47.77	45.75	54.16	32.43	30.58	35.98	40.98	55.26	63.78
	Modulus		Msi	---	---	5.87	---	---	3.56	---	---	7.62
	Poisson's Ratio			---	---	0.347	---	---	0.606	---	---	0.141
FHT (normalized)	Strength	CTD	ksi	39.70	38.02	43.17	40.91	39.08	44.07	43.17	42.15	48.35
		RTD	ksi	45.67	44.01	49.10	45.08	42.08	46.47	49.62	48.59	54.84
		ETW	ksi	48.11	46.43	51.58	33.86	30.86	35.25	40.77	52.03	59.44
FHC (normalized)	Strength	RTD	ksi	74.92	NA	85.00	57.35	55.47	61.20	78.29	74.41	84.27
		ETW	ksi	43.85	NA	54.87	33.62	31.72	37.51	18.47	42.98	58.50
SSB (normalized)	2% Offset Strength	RTD	ksi	62.48	88.25	106.95	75.95	88.86	102.14	51.34	82.63	96.40
		ETW	ksi	65.09	NA	79.01	43.84	65.84	78.44	45.16	57.03	70.69
	Ultimate Strength	RTD	ksi	123.19	120.96	135.32	115.74	113.89	132.73	92.59	112.33	125.02
		ETW	ksi	84.40	82.20	96.37	89.98	85.25	96.26	63.01	75.10	87.68
SBS1 (as measured)	Strength	RTD	ksi	12.03	11.90	12.99	---	---	---	---	---	---
		ETW	ksi	5.22	5.18	6.27	---	---	---	---	---	---
CAI (normalized)	Strength	RTD	ksi	---	---	31.22	---	---	---	---	---	---
ILT (as measured)	Strength	CTD	ksi	---	---	12.12	---	---	---	---	---	---
		RTD	ksi	---	---	10.72	---	---	---	---	---	---
		ETW	ksi	---	---	3.97	---	---	---	---	---	---
CBS (as measured)	Strength	CTD	lbs	---	---	402.44	---	---	---	---	---	---
		RTD	lbs	---	---	361.18	---	---	---	---	---	---
		ETW	lbs	---	---	134.63	---	---	---	---	---	---

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 of there was of the data within and between batches. When there was little variation, the batches were graphed from left to right and the environmental conditions were identified by the shape and color of the symbol used to plot the data. Otherwise, the environmental conditions were graphed from left to right and the batches were identified by the shape and color of the symbol.

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

4.1 Warp (0º) Tension Properties (WT)

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

Both the normalized and the as measured WT data for the CTD and ETW environmental conditions fail the ADK test, which indicates substantial batch to batch variability. This means that the ANOVA method was required for analysis of those datasets. The CTD data passes the ADK test with the transform for the modified CV method, but the ETW data does not. The as measured CTD and RTD data could be pooled together, but the normalized CTD and RTD data could not due to non-normality of the pooled dataset after the transform for the modified CV method was applied.

Modified CV B-basis values are provided for the CTD and RTD data. Estimates computed using the modified CV method are provided for the ETW environment. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method.

There was one outlier. It was in batch one of the normalized RTD data. It was on the low side and was an outlier both before and after pooling the data from the three batches together. The outlier was retained for this analysis.

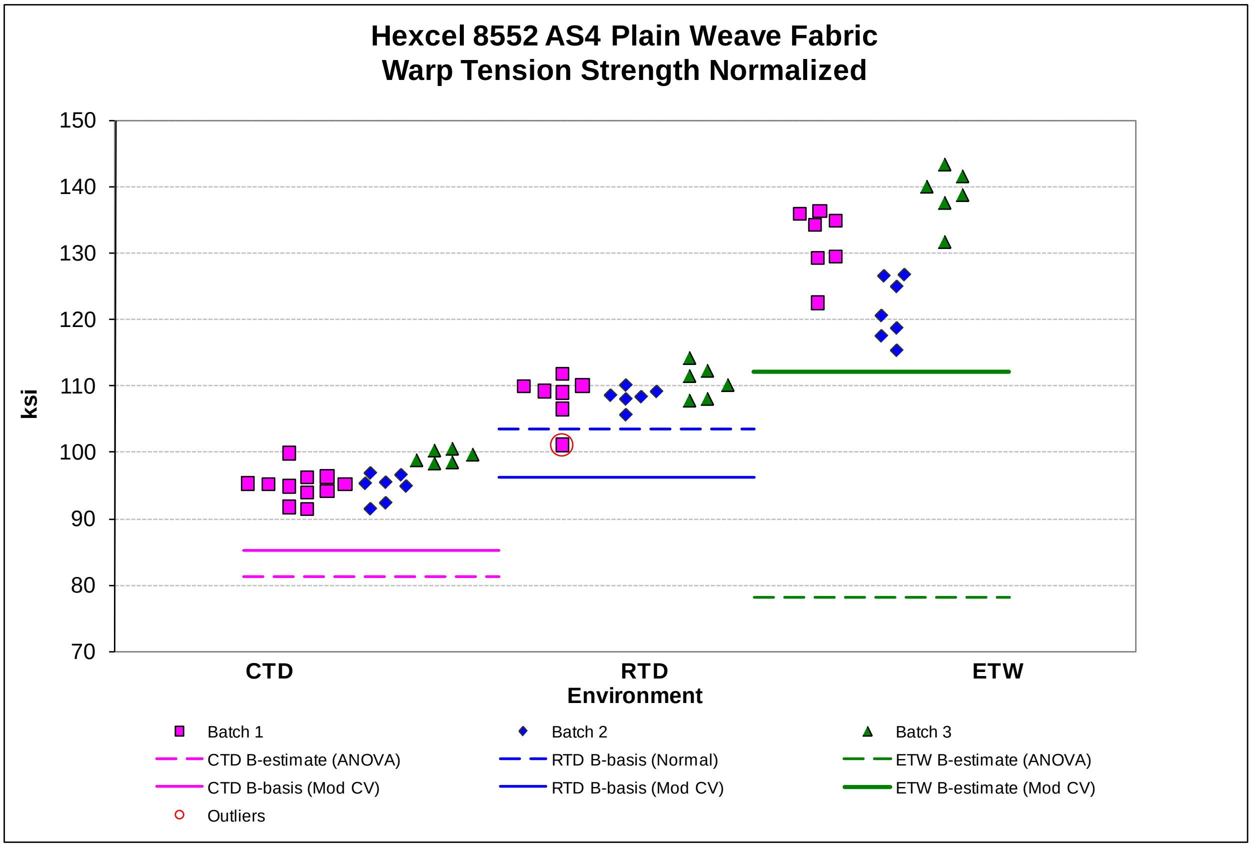

Figure 4-1 Batch plot for WT normalized strength

Warp Tension Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	95.97	109.02	130.29	96.17	111.52	132.15
Stdev	2.74	2.78	8.40	2.84	4.78	8.68
CV	2.86	2.55	6.45	2.95	4.29	6.57
Mod CV	6.00	6.00	7.22	6.00	6.14	7.29
Min	91.45	101.12	115.39	91.15	103.37	114.05
Max	100.54	114.18	143.25	103.19	119.24	148.58
No. Batches	3	3	3	3	3	3
No. Spec.	24	19	20	24	19	20
Basis Values and/or Estimates						
B-basis Value		103.60			102.20	
B-Estimate	81.33		78.20	86.73		83.05
A-Estimate	70.86	99.76	41.02	79.98	95.58	48.00
Method	ANOVA	Normal	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	85.30	96.27		85.20	100.33	
B-Estimate			112.16			113.60
A-Estimate	77.66	87.23	99.28	77.55	92.73	100.42
Method	Normal	Normal	Normal	pooled	pooled	Normal

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	9.28	9.36	9.33	9.30	9.58	9.47
Stdev	0.08	0.07	0.13	0.14	0.29	0.31
CV	0.90	0.80	1.34	1.50	3.04	3.32
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	9.16	9.27	9.13	9.17	9.28	9.08
Max	9.45	9.50	9.52	9.75	10.10	10.14
No. Batches	3	3	3	3	3	3
No. Spec.	23	19	20	23	19	20

Table 4-2: Statistics from WT Modulus Data

4.2 Fill (90º) Tension Properties (FT)

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

The data from the CTD environmental condition fails the ADK test, both as measured and normalized, and even after the transform for the modified CV method. The normalized RTD data also fails the ADK test, but passes with the transform for the modified CV method. The CTD data can only by analyzed using the ANOVA method. The as measured RTD and ETW data can be pooled. The normalized RTD data can be pooled with the ETW data to compute modified CV basis values.

Estimates computed using the modified CV method are provided for the CTD environment. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method.

There were three outliers, all in the normalized data only. The lowest value in batch two of the ETW data was an outlier after, but not before, pooling the three batches together. The highest value in batch one and the lowest value in batch three of the RTD data were outliers before, but not after, pooling the three batches together. All outliers were retained for this analysis.

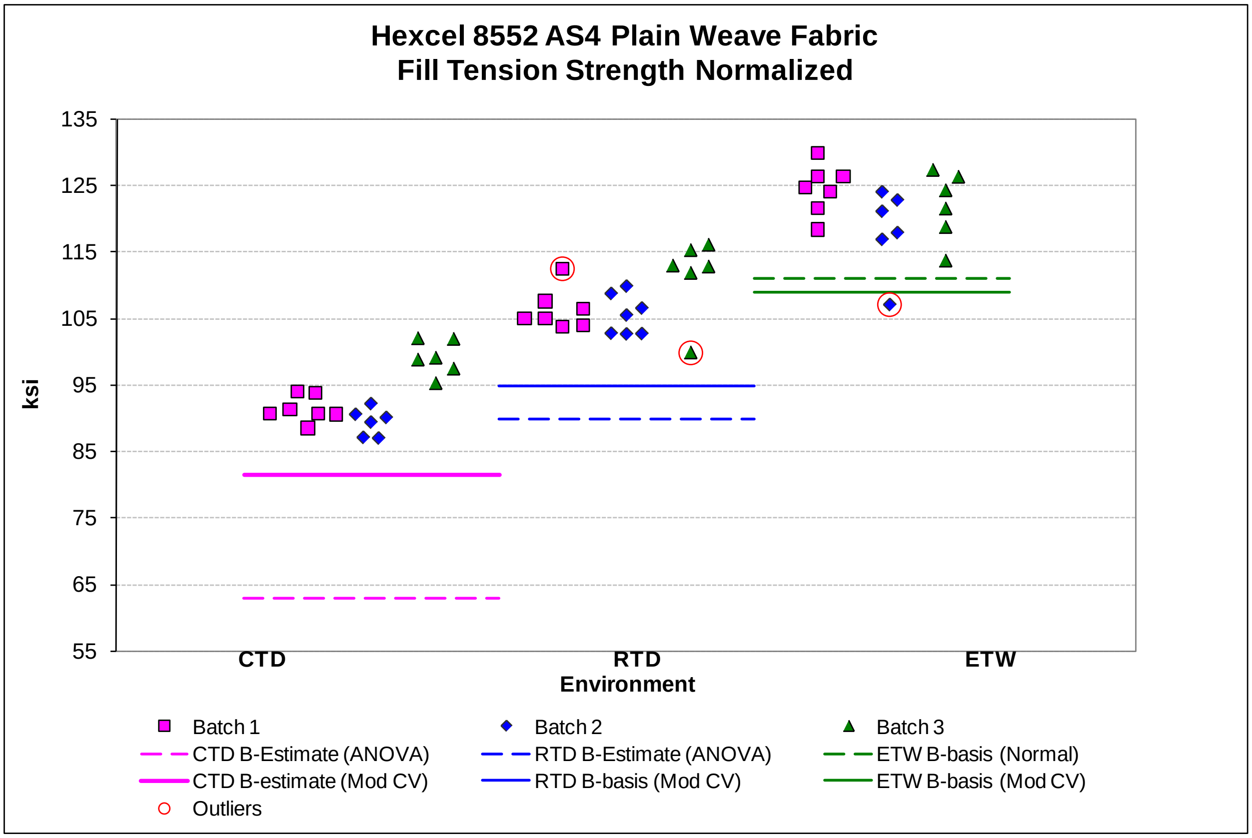

Figure 4-2: Batch Plot for FT normalized strength

Fill Tension Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	93.22	107.62	121.74	92.97	109.19	123.34
Stdev	4.65	4.65	5.40	4.31	5.95	6.55
CV	4.99	4.32	4.43	4.64	5.45	5.31
Mod CV	6.50	6.16	6.22	6.32	6.72	6.66
Min	87.10	99.86	107.13	85.16	98.53	112.39
Max	102.01	116.07	129.89	99.93	121.37	133.40
No. Batches	3	3	3	3	3	3
No. Spec.	19	20	19	19	20	19
Basis Values and/or Estimates						
B-basis Value			111.22		98.00	112.09
B-Estimate	62.91	89.79		65.05		
A-Estimate	41.28	77.07	103.75	45.12	90.31	104.42
Method	ANOVA	ANOVA	Normal	ANOVA	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value		94.89	108.96		95.26	109.35
B-Estimate	81.41			81.52		
A-Estimate	73.05	86.16	100.24	73.40	85.70	99.80
Method	Normal	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	9.30	9.51	9.45	9.28	9.66	9.60
Stdev	0.15	0.27	0.62	0.23	0.40	0.61
CV	1.64	2.82	6.56	2.48	4.19	6.31
Mod CV	6.00	6.00	7.28	6.00	6.09	7.15
Min	8.93	9.16	8.39	8.94	9.04	8.85
Max	9.56	10.22	10.95	9.79	10.58	10.76
No. Batches	3	3	3	3	3	3
No. Spec.	19	22	21	19	22	21

Table 4-4: Statistics from FT Modulus Data

4.3 Warp (0º) Compression Properties (WC)

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

The as measured CTD and RTD data can be pooled. The as measured ETD data fails the ADK test, but passes with the transform for the modified CV method. The as measured ETD data requires the ANOVA method, but can be pooled with the CTD and RTD data to compute modified CV basis values. The data from the ETW environmental condition fails the ADK test, both as measured and normalized, and even after the transform for the modified CV method. This means that the ETW data requires ANOVA method for analysis. The normalized CTD, RTD, and ETD data cannot be pooled due to failure of Levene's test, but the RTD and ETD normalized data can be pooled together.

Estimates computed using the modified CV method are provided for the ETW environment. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method.

There was one outlier. It was on the low side of batch two of the normalized ETD data. It was an outlier only after pooling the three batches. It was retained for this analysis.

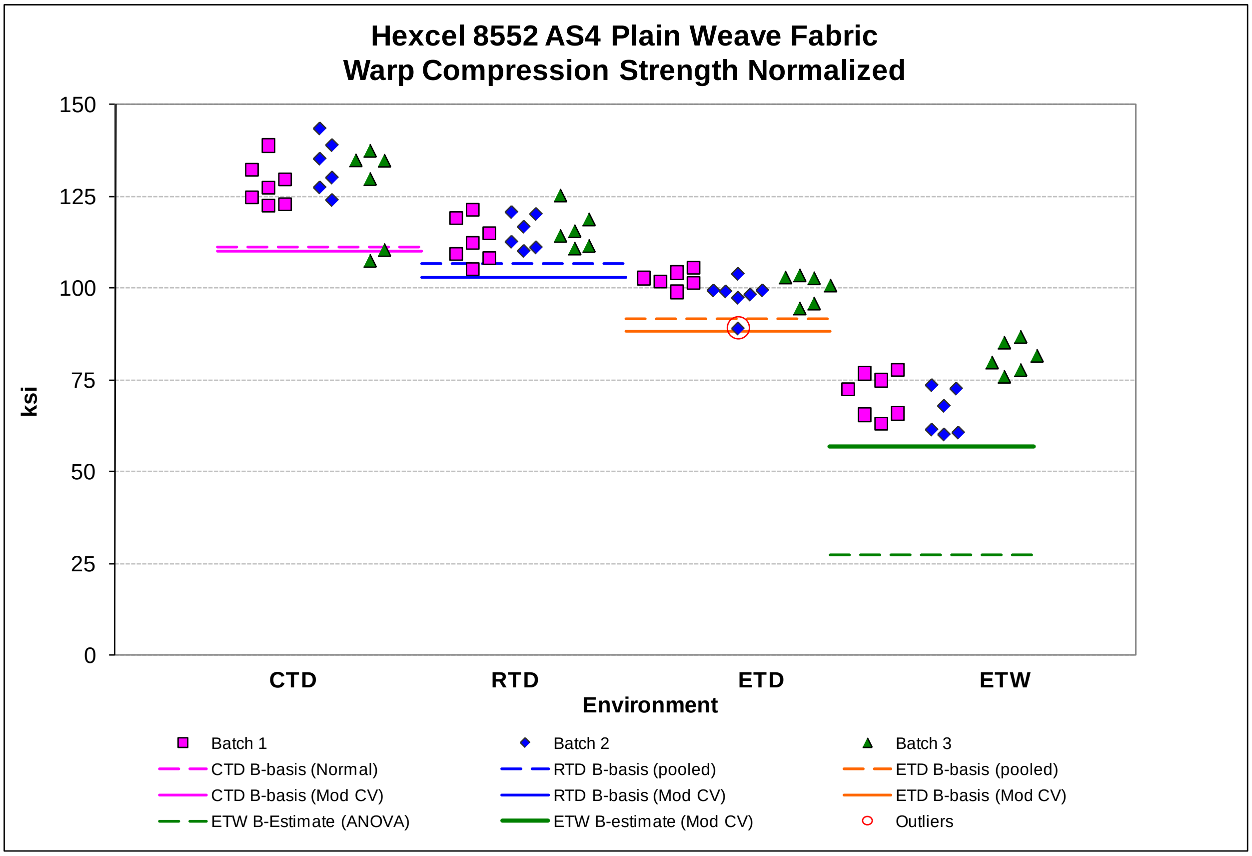

Figure 4-3 Batch plot for WC normalized strength

Warp Compression Strength Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	129.16	115.13	100.23	72.78	129.76	122.37	100.88	76.84
Stdev	9.21	5.38	3.99	8.21	9.17	5.71	4.39	8.81
CV	7.13	4.67	3.98	11.28	7.06	4.67	4.35	11.47
Mod CV	7.56	6.34	6.00	11.28	7.53	6.33	6.18	11.47
Min	107.68	105.21	89.15	60.34	107.01	110.42	90.49	61.12
Max	143.51	125.50	105.75	86.99	142.87	134.40	107.08	93.43
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	20	19	19	19	20	19	19
Basis Values and/or Estimates								
B-basis Value	111.22	106.61	91.68		116.10	108.77		
B-Estimate				27.45			82.37	27.53
A-Estimate	98.48	100.77	85.84	0.00	106.78	99.43	69.18	0.00
Method	Normal	pooled	pooled	ANOVA	pooled	pooled	ANOVA	ANOVA
Modified CV Basis Values and/or Estimates								
B-basis Value	110.12	103.12	88.17		115.66	108.33	86.77	
B-Estimate				56.77				59.66
A-Estimate	96.62	94.88	79.94	45.42	106.21	98.87	77.32	47.48
Method	Normal	pooled	pooled	Normal	pooled	pooled	pooled	Normal

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

Warp Compression Modulus Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	8.53	8.65	8.45	8.57	8.57	9.20	8.51	8.98
Stdev	0.43	0.38	0.19	0.26	0.46	0.52	0.23	0.27
CV	5.10	4.39	2.30	3.00	5.41	5.63	2.73	3.01
Mod CV	6.55	6.20	6.00	6.00	6.71	6.81	6.00	6.00
Min	7.43	8.19	8.01	8.21	7.39	8.32	8.08	8.59
Max	9.37	9.36	8.80	9.09	9.51	10.16	8.92	9.64
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	20	24	19	21	20	24	19

Table 4-6: Statistics from WC Modulus Data

4.4 Fill (90º) Compression Properties (FC)

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

There were no diagnostic test failures, so pooling across all test environments was acceptable for both the normalized and the as measured data. There were two outliers. One outlier was in the RTD data, both normalized and as measured, on the low side of batch one. Another outlier was in the ETW normalized data on the low side of batch two. Both outliers were outliers only before pooling the data from the three batches together. Both outliers were retained for this analysis.

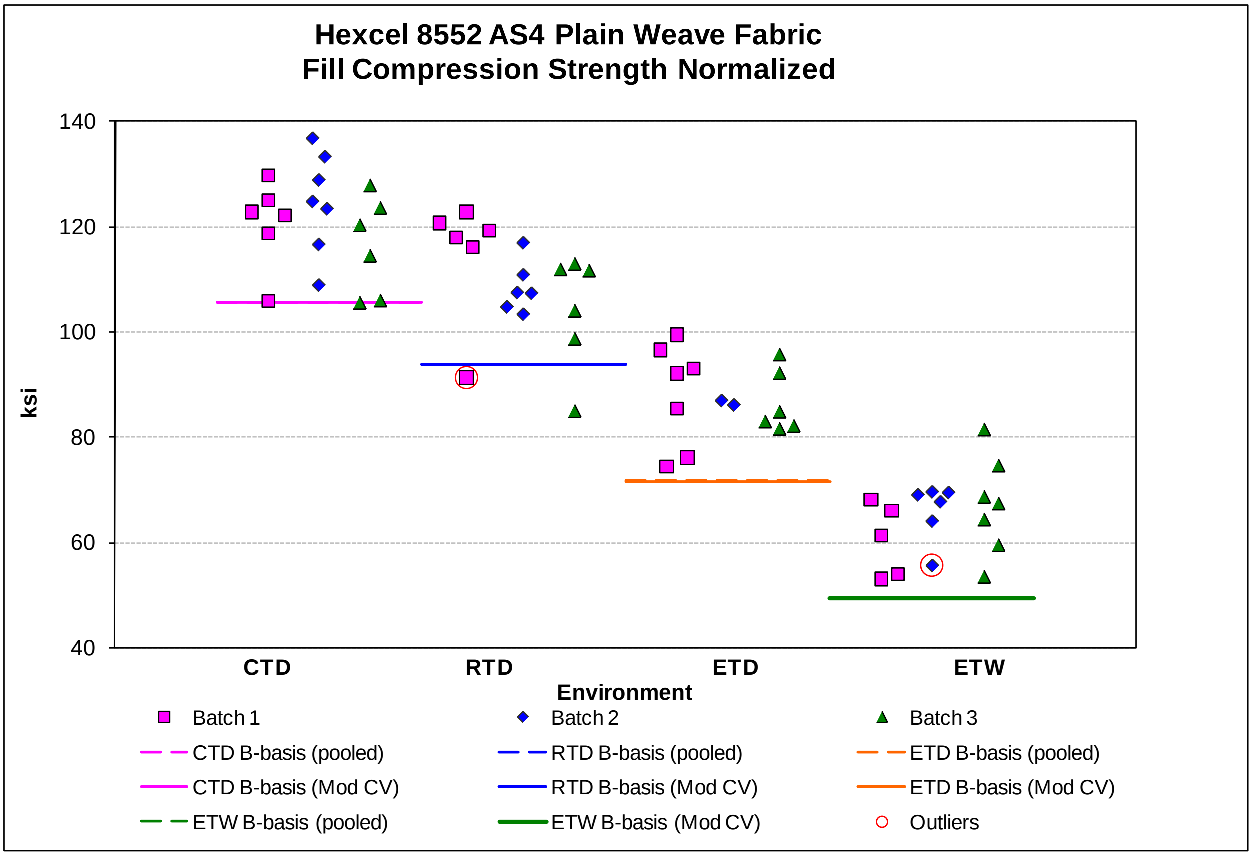

Figure 4-4: Batch Plot for FC normalized strength

Fill Compression Strength Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	120.83	109.12	87.33	64.89	122.55	113.31	91.57	64.54
Stdev	9.28	10.12	7.40	7.62	9.59	11.96	7.42	7.25
CV	7.68	9.27	8.47	11.75	7.83	10.56	8.11	11.23
Mod CV	7.84	9.27	8.47	11.75	7.91	10.56	8.11	11.23
Min	105.55	84.94	74.40	53.09	104.52	86.33	74.08	51.90
Max	136.91	122.84	99.52	81.44	137.84	130.16	102.01	79.87
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	18	15	18	19	18	15	18
Basis Values and/or Estimates								
B-basis Value	105.64	93.85	71.75	49.61	106.33	97.00	74.93	48.23
A-Estimate	95.54	83.76	61.71	39.53	95.54	86.23	64.21	37.46
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-basis Value	105.54	93.75	71.65	49.51	106.28	96.95	74.88	48.18
A-Estimate	95.38	83.59	61.55	39.36	95.46	86.14	64.12	37.37
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

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

Fill Compression Modulus Statistics (Estimates only)								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	8.58	8.67	8.41	8.46	8.70	9.01	8.87	8.53
Stdev	0.19	0.23	0.25	0.42	0.32	0.36	0.44	0.52
CV	2.17	2.70	2.95	5.01	3.64	4.03	5.00	6.15
Mod CV	6.00	6.00	6.00	6.51	6.00	6.02	6.50	7.08
Min	8.22	8.07	7.80	7.60	8.18	8.08	8.09	7.44
Max	8.88	9.11	8.79	8.87	9.52	9.52	9.68	9.13
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	19	19	19	21	19	19	19

Table 4-8: Statistics from FC Modulus Data

Fill compression modulus is reported as estimate only because the specification limit in NMS 128/3 is not derived per DOT/FAA/AR-03/19. The acceptance range based on alpha=1% and mod CV is 8.0-9.3msi. However, Hexcel is only willing to certify to 7.8-9.3msi (based on their historical data). So, this modulus value is reported as an estimate only until additional data can be generated.

4.5 In-Plane Shear Properties (IPS)

In Plane Shear data is not normalized. Statistics, basis values and estimates are given for the strength and modulus data in Table 4-9. The data, B-basis values and B-estimates are shown graphically for the 0.2% offset strength and the strength at 5% strain in Figure 4-5.

The 0.2% offset strength had data available from all three environments tested. Pooling the three environments together was not appropriate due to non-normality. However, two of the environments, CTD and RTD, could be pooled. The 2% offset strength data for the ETW environment did not fit any distribution tested and the non-parametric method was used to determine basis values. Since it did not fit the normal distribution, modified CV basis values are not provided.

The strength at 5% strain had data available only from the ETW environmental condition. It did not pass the ADK test, so an ANOVA analysis was required. It did not pass the ADK test even with the modified CV transform, so modified CV basis values are not provided.

There was one outlier. It was on the high side of batch one in the ETW data. It was an outlier both before and after pooling the three batches together for the 0.2% offset strength data. It was retained for this analysis.

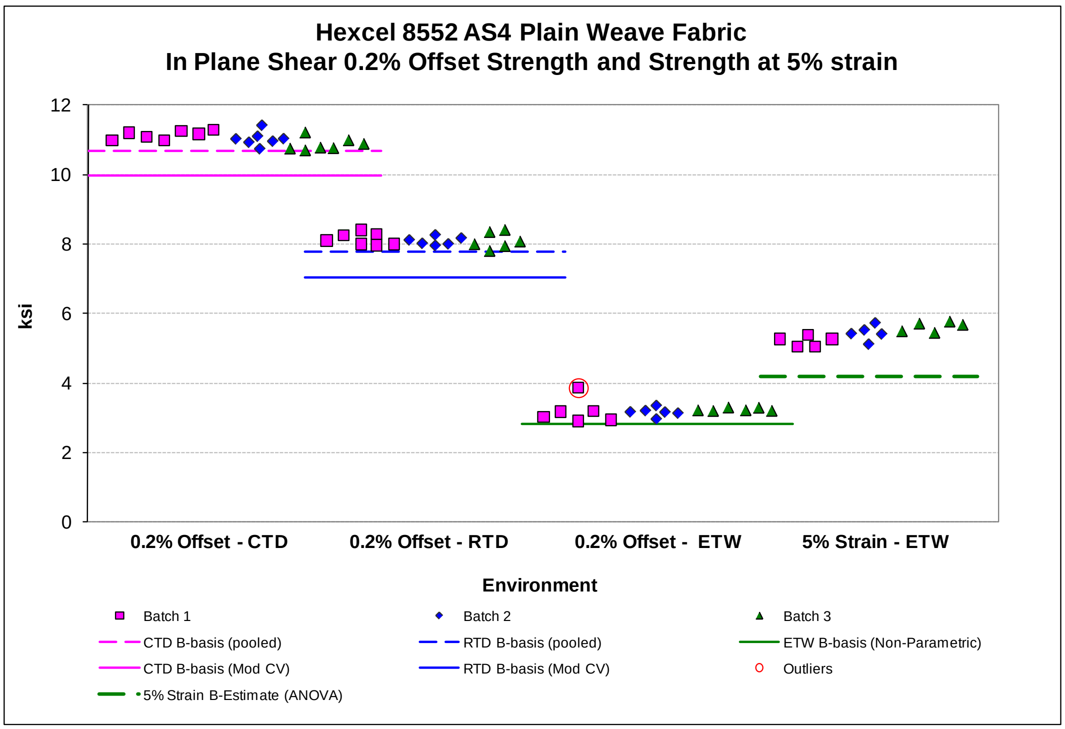

Figure 4-5: Batch plot for IPS strength

In Plane Shear Strength Basis Values and Statistics							
	0.2% Offset Strength			Strength at 5% Strain	Modulus Statistics		
Env	CTD	RTD	ETW	ETW	CTD	RTD	ETW
Mean	11.01	8.11	3.21	5.43	0.83	0.72	0.32
Stdev	0.20	0.17	0.21	0.24	0.02	0.02	0.02
CV	1.82	2.13	6.49	4.43	2.57	2.89	6.29
Mod CV	6.00	6.00	7.25	6.21	6.00	6.00	7.14
Min	10.70	7.81	2.92	5.05	0.79	0.69	0.29
Max	11.41	8.41	3.88	5.78	0.87	0.77	0.38
No. Batches	3	3	3	3	3	3	3
No. Spec.	21	19	18	15	21	19	18
Basis Values and/or Estimates							
B-basis Value	10.68	7.78	2.82				
B-Estimate				4.20			
A-Estimate	10.45	7.55	1.91	3.33			
Method	pooled	pooled	Non-Parametric	ANOVA			
Modified CV Basis Values and/or Estimates							
B-basis Value	9.97	7.06	NA	NA			
A-Estimate	9.25	6.35	NA	NA			
Method	pooled	pooled	NA	NA			

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

4.6 Unnotched Tension Properties

4.6.1 Quasi Isotropic Unnotched Tension Properties (UNT1)

Statistics, basis values and estimates are given for UNT1 strength data in Table 4-10 and for the modulus data in Table 4-11. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-6.

The data from the CTD and ETW environmental conditions fail the ADK test, both as measured and normalized. Using the modified CV transform, only the normalized ETW data passes that test. The CTD data must be analyzed using the ANOVA method. The ETW data also requires the ANOVA method, but the normalized ETW data can be pooled with the normalized RTD data to compute modified CV basis values.

Estimates computed using the modified CV method are provided for the CTD environment. These are termed estimates due to the failure of the ADK test after the transformation of the modified CV method. The as measured data from the ETW environment does not pass the normality test, so modified CV estimates are not provided for that data.

There was one outlier. It was on the high side of batch three in the RTD data. It was an outlier only before pooling the three batches for the as measured data, but it was an outlier both before and after pooling the data for the normalized data. It was retained for this analysis.

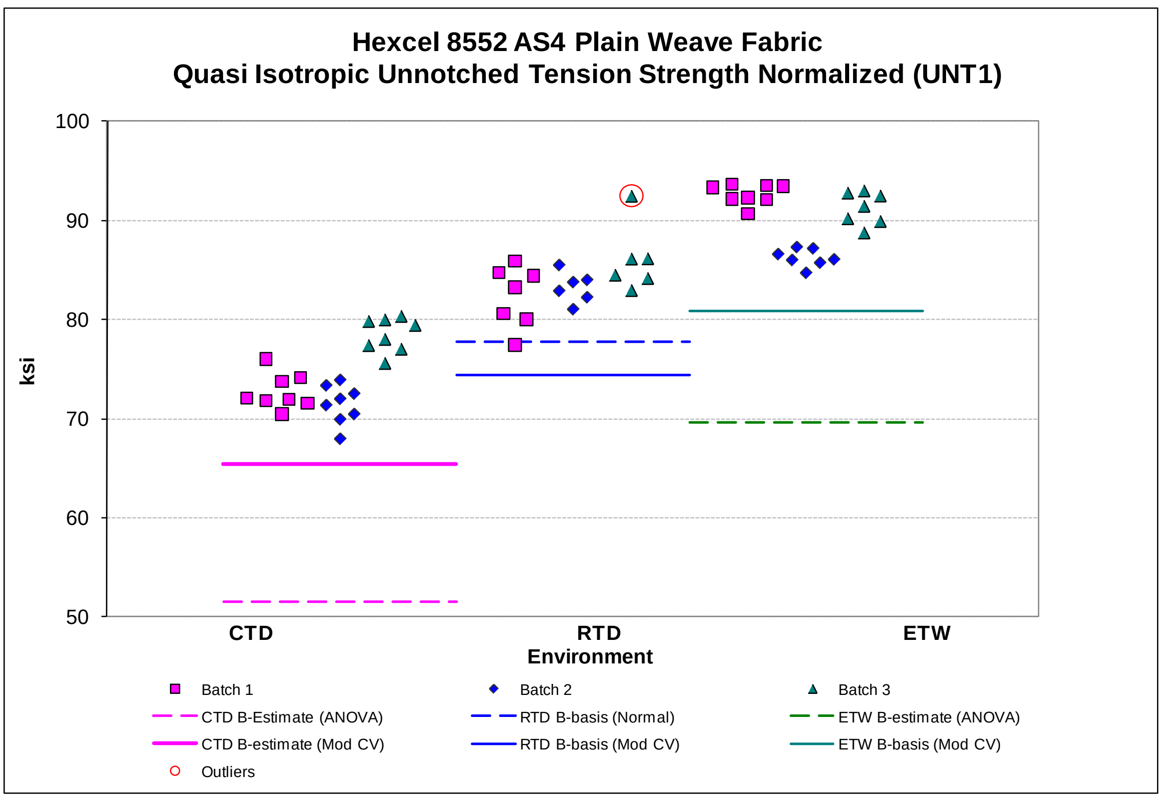

Figure 4-6: Batch Plot for UNT1 normalized strength

Quasi Isotropic Unnotched Tension (UNT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	74.21	83.82	90.19	74.16	84.62	89.63
Stdev	3.56	3.09	3.03	3.58	3.83	4.25
CV	4.79	3.69	3.36	4.83	4.53	4.74
Mod CV	6.40	6.00	6.00	6.42	6.26	6.37
Min	67.97	77.45	84.75	68.96	77.46	82.77
Max	80.33	92.48	93.65	83.22	94.32	95.11
No. Batches	3	3	3	3	3	3
No. Spec.	24	19	22	24	19	22
Basis Values and/or Estimates						
B-basis Value		77.80			77.16	
B-Estimate	51.49		69.67	52.68		62.05
A-Estimate	35.27	73.52	55.03	37.34	71.86	42.36
Method	ANOVA	Normal	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value		74.43	80.92		74.29	
B-Estimate	65.41			65.34		NA
A-Estimate	59.11	68.04	74.50	59.02	66.97	NA
Method	Normal	pooled	pooled	Normal	Normal	NA

Table 4-10: Statistics and Basis Values for UNT1 Strength Data

Quasi Isotropic Unnotched Tension (UNT1) Modulus Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	7.01	6.75	6.37	7.01	6.81	6.32
Stdev	0.15	0.16	0.16	0.19	0.26	0.20
CV	2.07	2.32	2.45	2.69	3.81	3.13
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	6.77	6.27	6.07	6.64	6.13	6.03
Max	7.35	6.94	6.79	7.37	7.26	6.87
No. Batches	3	3	3	3	3	3
No. Spec.	24	19	22	24	19	22

Table 4-11: Statistics from UNT1 Modulus Data

4.6.2 "Soft" Unnotched Tension Properties (UNT2)

Statistics, basis values and estimates are given for UNT2 strength data in Table 4-12 and for the modulus data in Table 4-13. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-7.

The as measured data from the CTD and ETW environmental conditions fail the ADK test so those environments require the use of the ANOVA method to set basis values. Both the CTD and ETW data pass the ADK test with the transform for the modified CV method, so modified CV basis values are computed for all environments. The pooled dataset after the modified CV transform fails the normality test, so pooling all three environments is not appropriate. However the RTD and ETW data can be pooled to compute the modified CV basis values.

The normalized data fails the ADK test for all three environments tested, requiring the use of ANOVA analysis to compute basis values. However, all three environments pass the ADK test with the modified CV transform, so pooling the three environments is acceptable for computing the modified CV basis values.

There were no outliers.

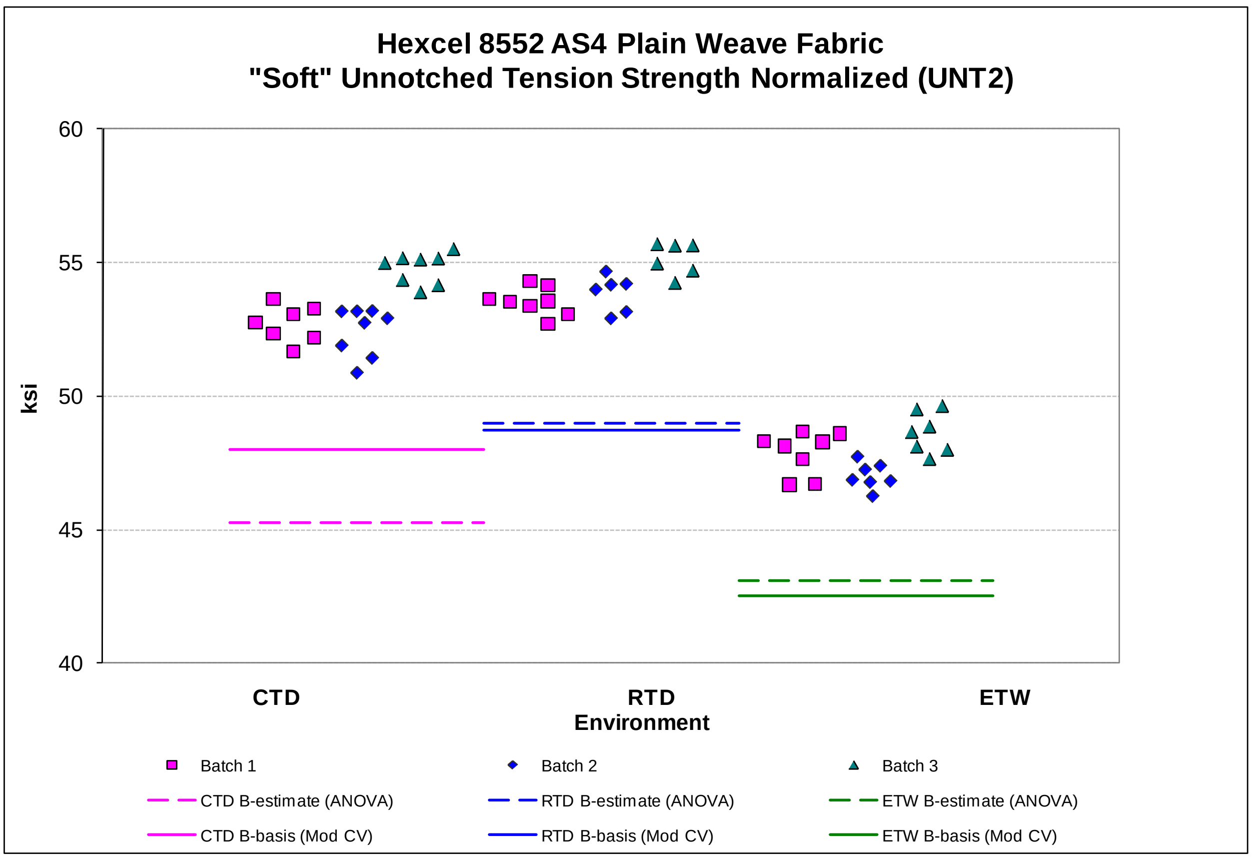

Figure 4-7: Batch Plot for UNT2 normalized strength

"Soft" Unnotched Tension (UNT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	53.33	54.12	47.85	53.28	54.91	47.36
Stdev	1.31	0.90	0.94	1.46	2.07	1.67
CV	2.45	1.67	1.96	2.73	3.77	3.52
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	50.87	52.71	46.26	50.65	51.52	44.02
Max	55.51	55.70	49.64	57.32	60.00	50.31
No. Batches	3	3	3	3	3	3
No. Spec.	23	20	22	23	20	22
Basis Values and/or Estimates						
B-basis Value					50.92	
B-Estimate	45.29	49.01	43.09	46.53		40.45
A-Estimate	39.55	45.36	39.70	41.71	48.08	35.52
Method	ANOVA	ANOVA	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	48.01	48.73	42.51	47.31	49.45	41.94
A-Estimate	44.39	45.11	38.89	43.03	45.72	38.20
Method	pooled	pooled	pooled	Normal	pooled	pooled

Table 4-12: Statistics and Basis Values for UNT2 Strength Data

"Soft" Unnotched Tension (UNT2) Modulus Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	4.82	4.46	3.57	4.82	4.53	3.53
Stdev	0.11	0.24	0.19	0.18	0.33	0.21
CV	2.38	5.32	5.32	3.68	7.21	6.06
Mod CV	6.00	6.66	6.66	6.00	7.60	7.03
Min	4.63	4.04	3.17	4.49	3.99	2.97
Max	5.10	5.14	3.80	5.12	5.17	3.82
No. Batches	3	3	3	3	3	3
No. Spec.	23	20	21	23	20	21

Table 4-13: Statistics from UNT2 Modulus Data

4.6.3 "Hard" Unnotched Tension Properties (UNT3)

Statistics, basis values and estimates are given for UNT3 strength data in Table 4-14 and for the modulus data in Table 4-15. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-8.

The normalized data fails the ADK test for all three environments tested, requiring the use of ANOVA analysis to compute basis values. However, the CTD and RTD environments pass the ADK test with the modified CV transform and pooling those two environments was acceptable for computing the modified CV basis values.

The data from the as measured CTD and RTD conditions could be pooled. The as measured data from the ETW environmental condition failed the ADK test so the ANOVA analysis method was required.

Estimates computed using the modified CV method are also provided for the data from the ETW environment, both normalized and as measured. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method. There were no outliers.

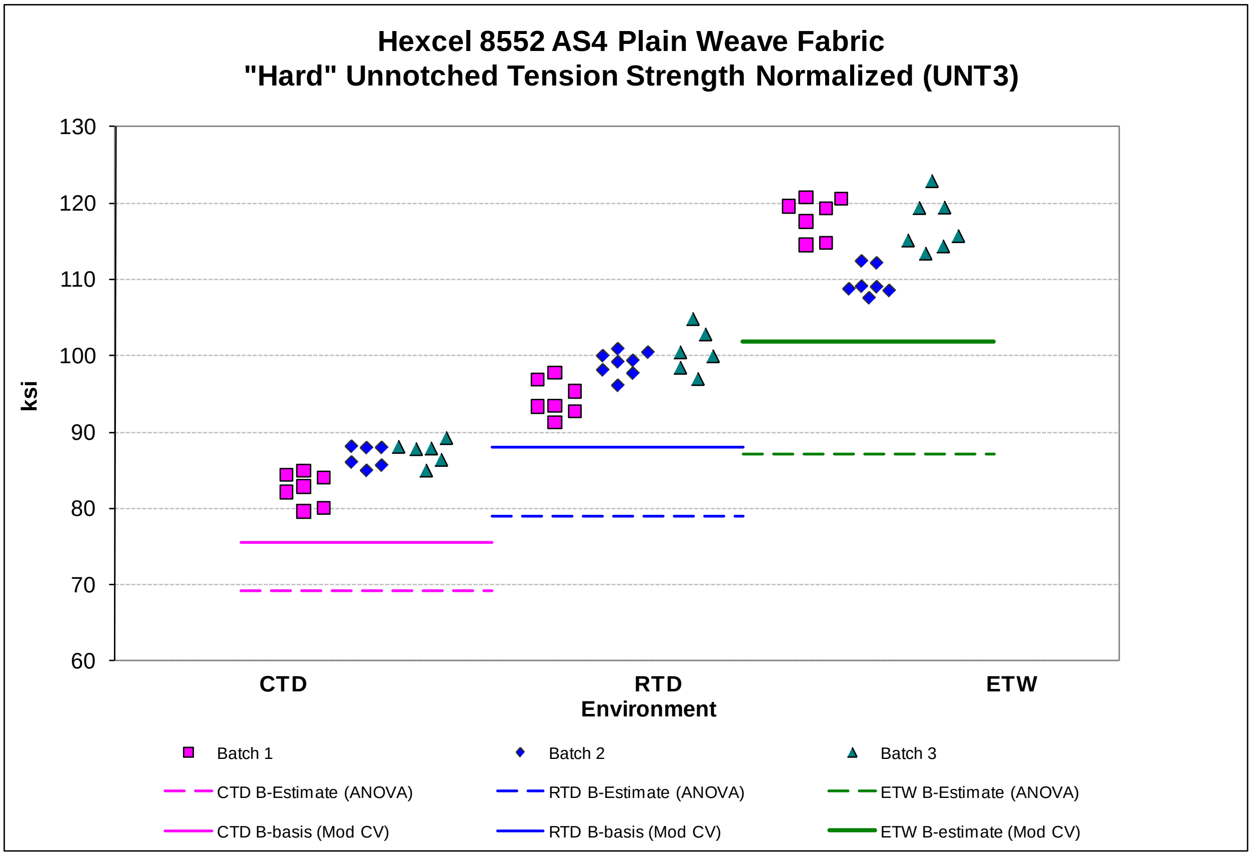

Figure 4-8: Batch Plot for UNT3 normalized strength

"Hard" Unnotched Tension (UNT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	85.46	97.95	115.02	85.63	99.44	114.55
Stdev	2.78	3.39	4.63	2.40	3.58	5.23
CV	3.25	3.46	4.03	2.80	3.60	4.57
Mod CV	6.00	6.00	6.01	6.00	6.00	6.28
Min	79.63	91.35	107.66	81.04	93.36	106.67
Max	89.30	104.84	122.84	90.54	106.83	122.92
No. Batches	3	3	3	3	3	3
No. Spec.	19	21	21	19	21	21
Basis Values and/or Estimates						
B-basis Value				80.10	93.96	
B-Estimate	69.25	78.96	87.11			80.85
A-Estimate	57.67	65.40	67.19	76.34	90.19	56.79
Method	ANOVA	ANOVA	ANOVA	pooled	pooled	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	75.52	88.09		75.59	89.49	
B-Estimate			101.84			100.84
A-Estimate	68.75	81.30	92.45	68.75	82.63	91.06
Method	pooled	pooled	Normal	pooled	pooled	Normal

Table 4-14: Statistics and Basis Values for UNT3 Strength Data

"Hard" Unnotched Tension (UNT3) Modulus Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	8.69	8.40	8.25	8.71	8.53	8.21
Stdev	0.11	0.23	0.11	0.29	0.26	0.16
CV	1.30	2.79	1.30	3.30	2.99	1.94
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	8.43	8.08	7.95	8.25	8.08	7.83
Max	8.89	9.13	8.38	9.43	8.99	8.47
No. Batches	3	3	3	3	3	3
No. Spec.	19	21	21	19	21	21

Table 4-15: Statistics from UNT3 Modulus Data

4.7 Unnotched Compression

4.7.1 Quasi Isotropic Unnotched Compression (UNC1)

Statistics, basis values and estimates are given for UNC1 strength data in Table 4-16 and for the modulus data in Table 4-17. The normalized data and B-basis values are shown graphically in Figure 4-9.

The as measured data from the RTD condition failed the ADK test, but passed the test with the modified CV transform, so modified CV basis values are provided for the RTD data. Pooling was acceptable for the normalized data and for the modified CV basis values for the as measured data. There were no outliers.

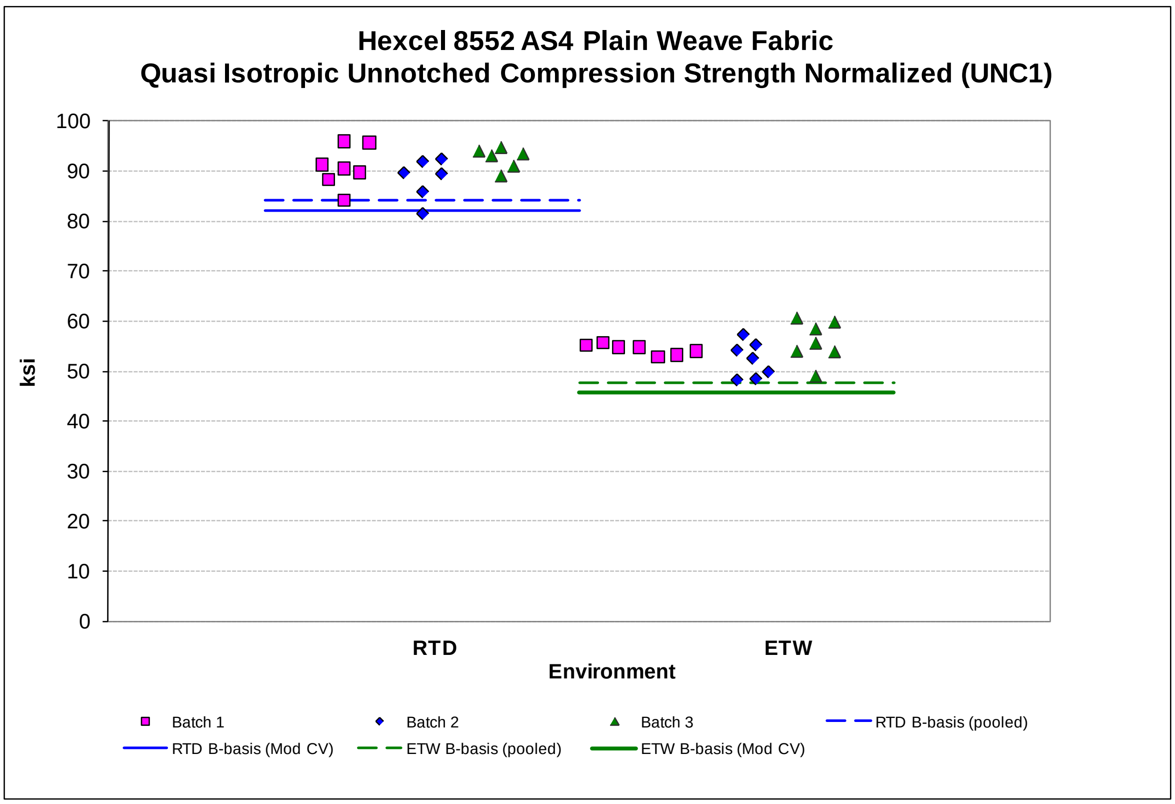

Figure 4-9: Batch plot for UNC1 normalized strength

Quasi Isotropic Unnotched Compression (UNC1) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	90.57	54.16	92.36	54.44
Stdev	3.81	3.38	4.17	3.44
CV	4.20	6.25	4.51	6.32
Mod CV	6.10	7.12	6.26	7.16
Min	81.43	48.17	82.55	48.38
Max	95.95	60.63	98.78	61.08
No. Batches	3	3	3	3
No. Spec.	19	21	19	21
Basis Values and/or Estimates				
B-basis Value	84.12	47.77		47.88
B-Estimate			74.25	
A-Estimate	79.73	43.36	61.33	43.20
Method	pooled	pooled	ANOVA	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value	82.09	45.75	83.60	45.75
A-Estimate	76.31	39.95	77.62	39.76
Method	pooled	pooled	pooled	pooled

Table 4-16: Statistics and Basis Values for UNC1 Strength Data

Quasi Isotropic Unnotched Compression (UNC1) Modulus Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	6.31	5.87	6.43	5.91
Stdev	0.15	0.13	0.20	0.13
CV	2.30	2.18	3.10	2.14
Mod CV	19.00	6.00	19.00	6.00
Min	6.00	5.63	6.12	5.66
Max	6.68	6.13	6.87	6.13
No. Batches	3	3	3	3
No. Spec.	19	21	19	21

Table 4-17: Statistics from UNC1 Modulus Data

4.7.2 "Soft" Unnotched Compression (UNC2)

Statistics, basis values and estimates are given for UNC2 strength data in Table 4-18 and for the modulus data in Table 4-19. The normalized data and B-basis values are shown graphically in Figure 4-10. There were no test failures or outliers.

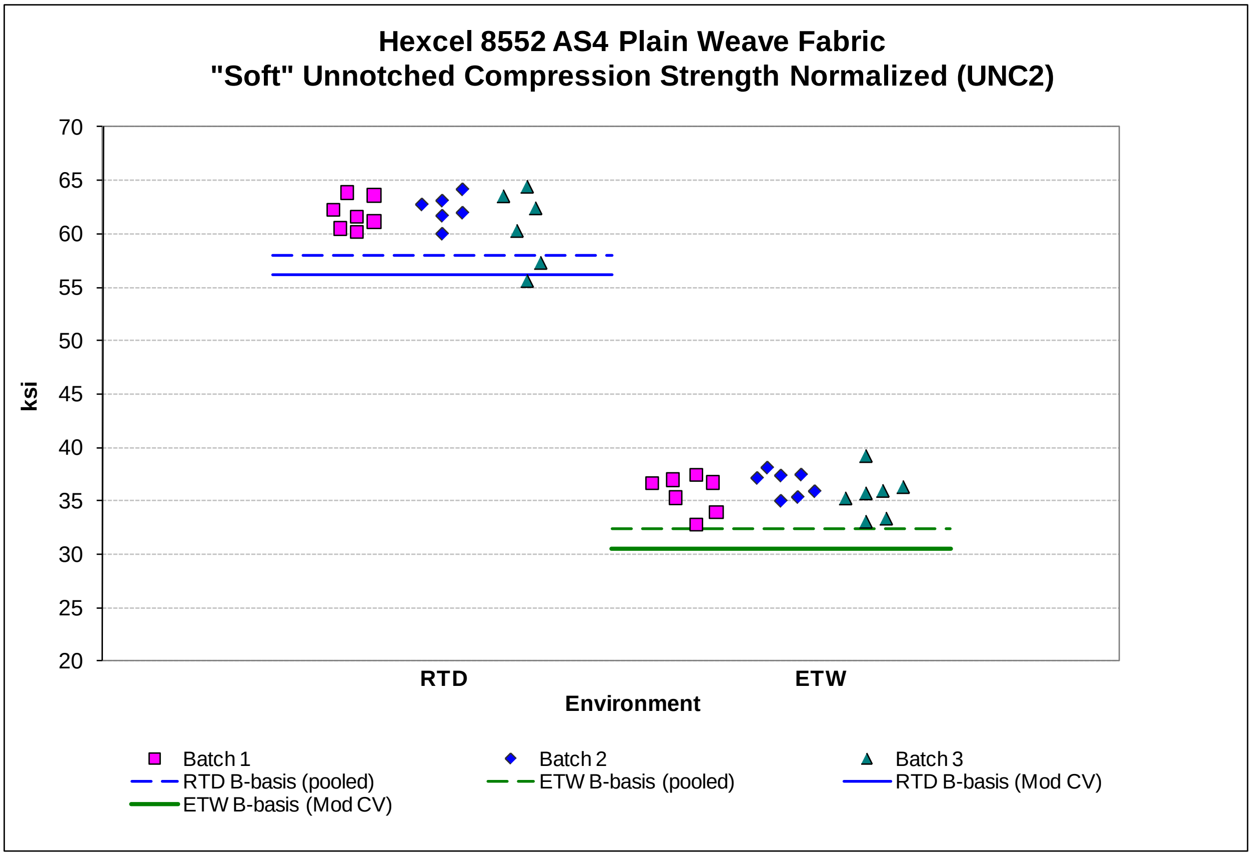

Figure 4-10: Batch plot for UNC2 normalized strength

"Soft" Unnotched Compression (UNC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	61.60	35.98	63.52	35.91
Stdev	2.29	1.69	2.23	1.77
CV	3.71	4.70	3.52	4.93
Mod CV	6.00	6.35	6.00	6.46
Min	55.62	32.80	57.61	32.53
Max	64.45	39.23	66.79	39.14
No. Batches	3	3	3	3
No. Spec.	19	21	19	21
Basis Values and/or Estimates				
B-basis Value	58.02	32.43	59.92	32.34
A-Estimate	55.58	29.98	57.47	29.89
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates				
B-basis Value	56.15	30.58	57.92	30.36
A-Estimate	52.43	26.85	54.11	26.54
Method	pooled	pooled	pooled	pooled

Table 4-18: Statistics and Basis Values for UNC2 Strength Data

"Soft" Unnotched Compression (UNC2) Modulus Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	4.37	3.56	4.50	3.56
Stdev	0.11	0.20	0.16	0.18
CV	2.62	5.65	3.48	5.01
Mod CV	6.00	6.82	6.00	6.50
Min	4.15	3.20	4.17	3.28
Max	4.56	4.04	4.78	4.04
No. Batches	3	3	3	3
No. Spec.	19	21	19	21

Table 4-19: Statistics from UNC2 Modulus Data

4.7.3 "Hard" Unnotched Compression (UNC3)

Statistics, basis values and estimates are given for UNC3 strength data in Table 4-20 and for the modulus data in Table 4-21. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-11.

Both the as measured and the normalized data from the ETW environmental condition failed the ADK test even with the modified CV transform, so that environmental condition required the ANOVA method of analysis.

Estimates computed using the modified CV method are also provided for the data from the ETW environment, both normalized and as measured. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method. There were no outliers.

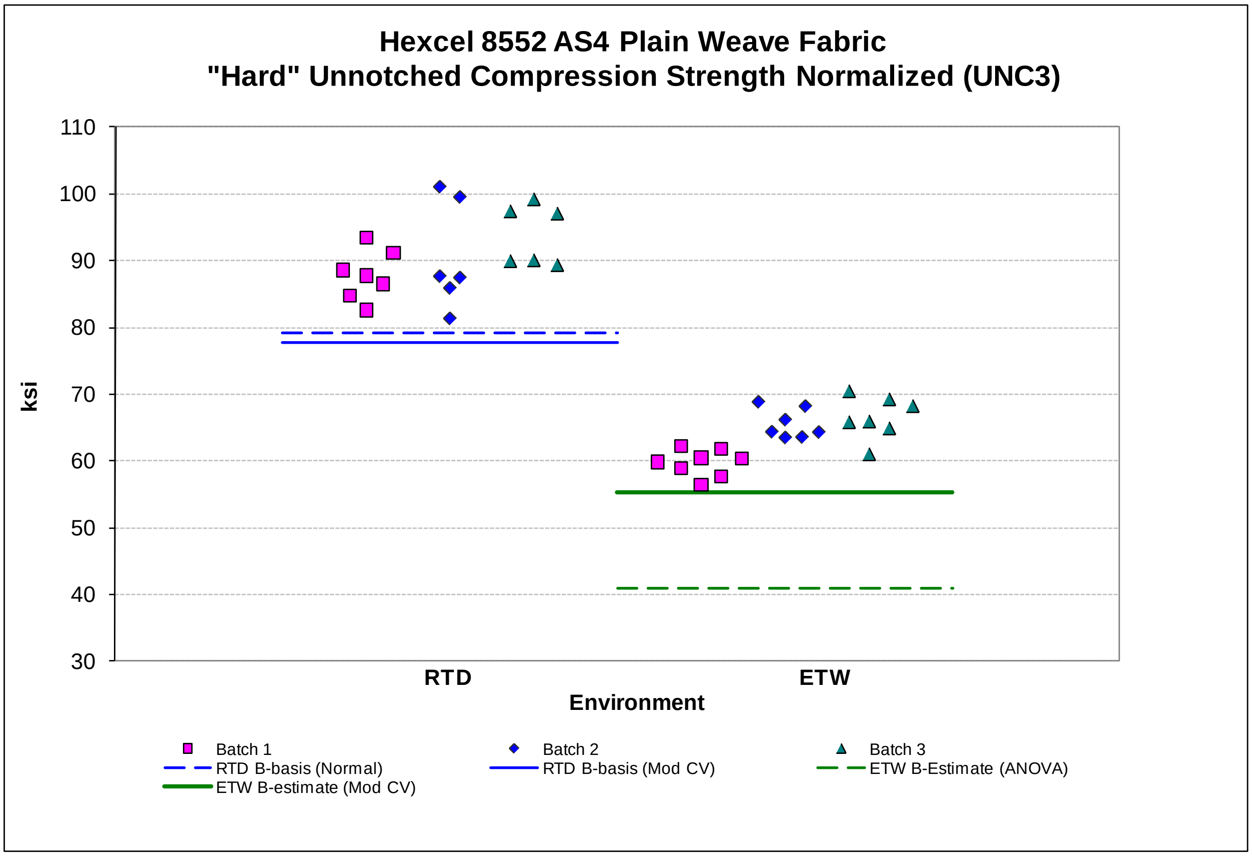

Figure 4-11: Batch plot for UNC3 normalized strength

"Hard" Unnotched Compression (UNC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	90.60	63.78	92.63	63.50
Stdev	5.85	3.93	5.77	3.20
CV	6.46	6.16	6.23	5.03
Mod CV	7.23	7.08	7.11	6.52
Min	81.39	56.41	82.68	57.56
Max	101.07	70.48	102.00	68.92
No. Batches	3	3	3	3
No. Spec.	19	22	19	22
Basis Values and/or Estimates				
B-basis Value	79.20		81.39	
B-Estimate		40.98		47.30
A-Estimate	71.11	24.70	73.41	35.73
Method	Normal	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates				
B-basis Value	77.84		79.79	
B-Estimate		55.26		55.70
A-Estimate	68.79	49.18	70.68	50.12
Method	Normal	Normal	Normal	Normal

Table 4-20: Statistics and Basis Values for UNC3 Strength Data

"Hard" Unnotched Compression (UNC3) Modulus Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	7.72	7.62	7.89	7.58
Stdev	0.14	0.14	0.24	0.15
CV	1.80	1.85	3.05	2.01
Mod CV	6.00	6.00	6.00	6.00
Min	7.53	7.33	7.53	7.17
Max	7.96	7.83	8.47	7.86
No. Batches	3	3	3	3
No. Spec.	19	21	19	21

Table 4-21: Statistics from UNC3 Modulus Data

4.8 Short Beam Strength (SBS) Data

The Short Beam Strength data is not normalized. Statistics, basis values and estimates are given for SBS strength data in Table 4-22. The data, B-estimates and B-basis values are shown graphically in Figure 4-12.

The data from the ETD environmental condition failed the ADK test but passed with the modified CV transform so modified CV basis values are provided. The pooled dataset failed both the normality test and Levene's test, so pooling was not appropriate. The CTD environment had insufficient data (seven specimens), so only estimates are provided.

There were three outliers. Two outliers were in the RTD environment, one in batch two and one in batch three, both on the low side of their respective batches. The outlier on the low side of batch two which was an outlier only after pooling the three batches together. The outlier on the low side of batch three was an outlier for batch three only and not after pooling the three batches together. The third outlier was on the high side of batch one in the ETW environment. It was an outlier both before and after pooling the three batches together. These outliers were retained for this analysis.

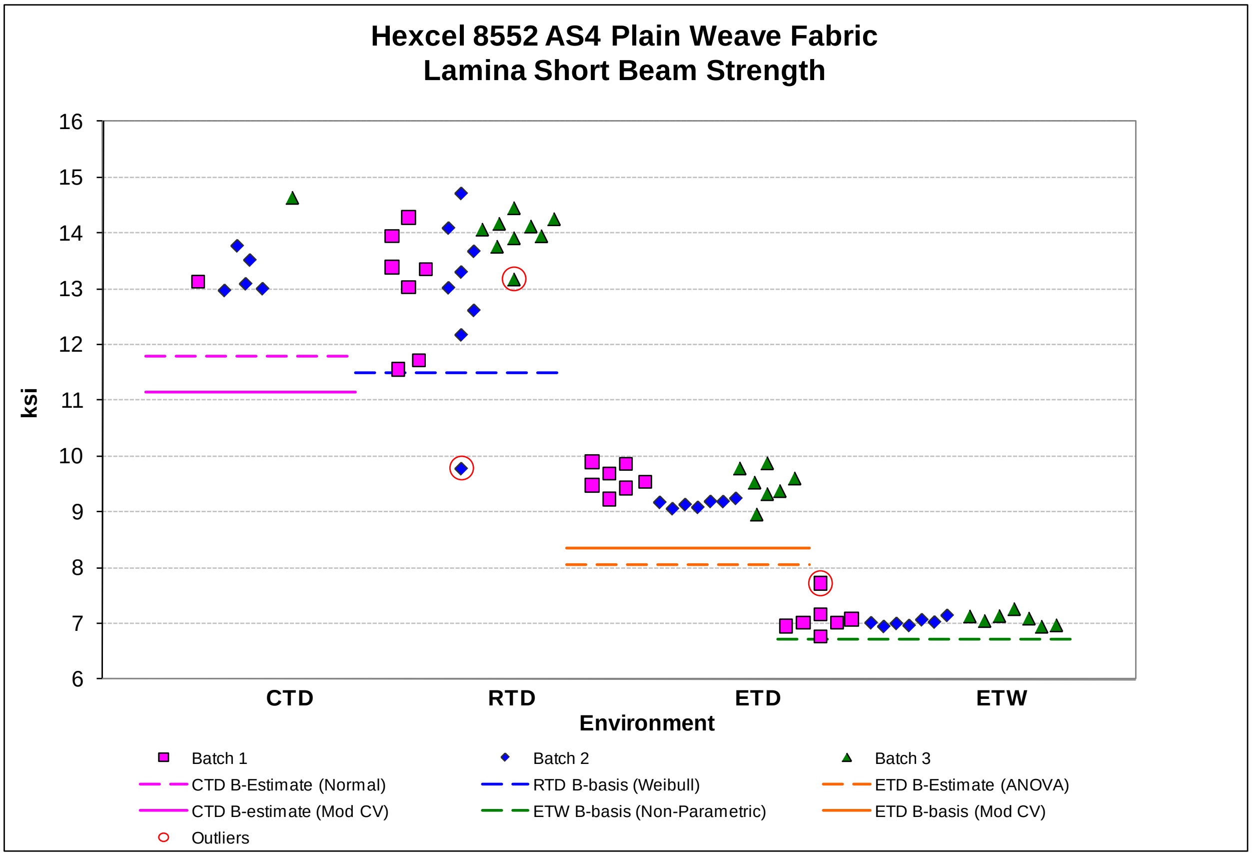

Figure 4-12: Batch plot for SBS strength

Short Beam Strength (SBS) as measured				
Env	CTD	RTD	ETD	ETW
Mean	13.45	13.36	9.41	7.07
Stdev	0.60	1.13	0.29	0.18
CV	4.47	8.44	3.08	2.56
Mod CV	6.24	8.44	6.00	6.00
Min	12.98	9.78	8.96	6.76
Max	14.64	14.72	9.90	7.72
No. Batches	3	3	3	3
No. Spec.	7	24	21	21
Basis Values and/or Estimates				
B-basis Value		11.49		6.71
B-Estimate	11.79		8.06	
A-Estimate	10.66	9.62	7.09	5.69
Method	Normal	Weibull	ANOVA	Non-Parametric
Modified CV Basis Values and/or Estimates				
B-basis Value		NA	8.34	NA
B-Estimate	11.14			
A-Estimate	9.55	NA	7.57	NA
Method	Normal	NA	Normal	NA

Table 4-22: Statistics and Basis Values for SBS Strength Data

4.8.1 Laminate Short Beam Strength (SBS1) Data

The Laminate Short Beam Strength data is not normalized. Statistics, basis values and estimates are given for LSBS strength data in Table 4-23. The data, B-estimates and B-basis values are shown graphically in Figure 4-13.

The data from the ETW environmental condition fails the ADK test, but passes with the transform for the modified CV method. The RTD and ETW data can be pooled to compute the modified CV basis values. There were no outliers.

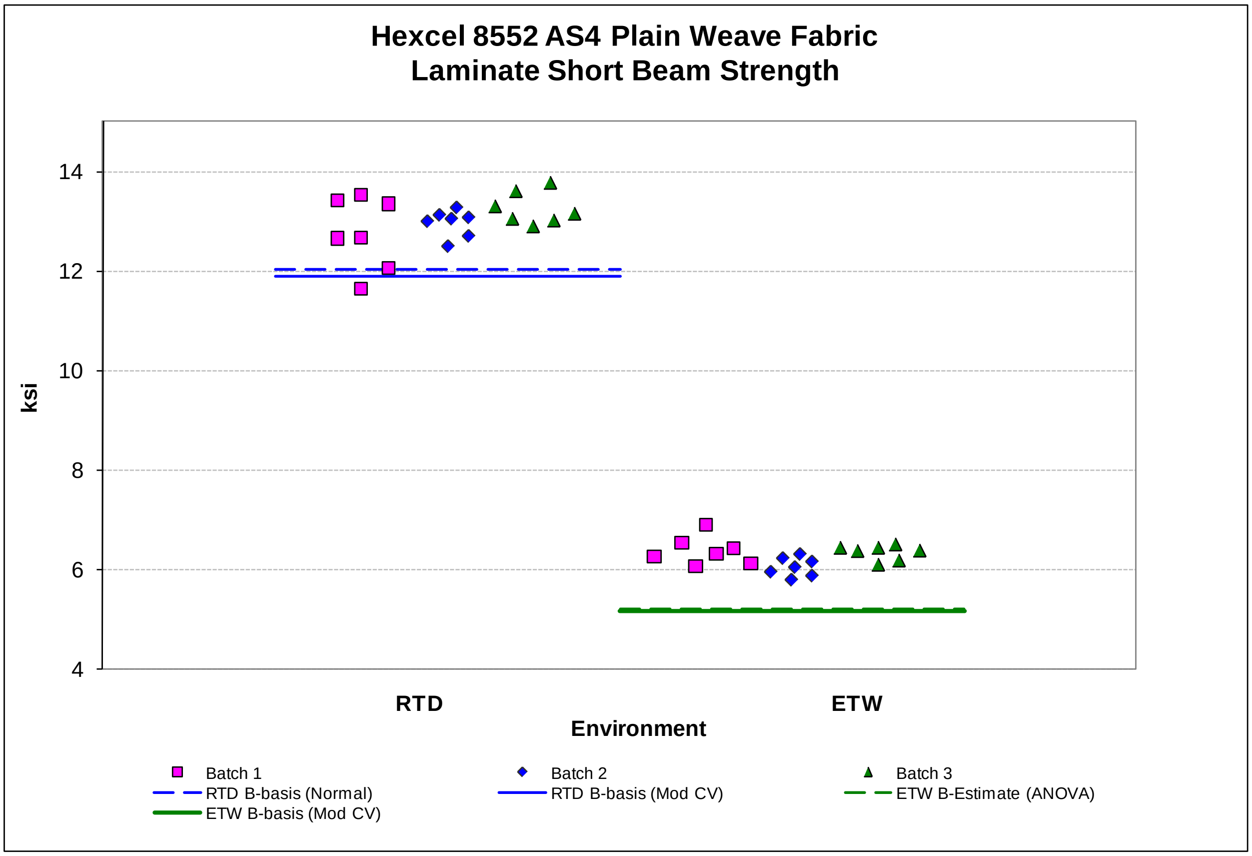

Figure 4-13: Batch plot for SBS1 strength

Laminate Short Beam Strength Properties (SBS1)		
Env	RTD	ETW
Mean	12.99	6.27
Stdev	0.50	0.25
CV	3.86	4.05
Mod CV	6.00	6.02
Min	11.64	5.80
Max	13.77	6.92
No. Batches	3	3
No. Spec.	21	21
Basis Values and/or Estimates		
B-basis Value	12.03	
B-Estimate		5.22
A-Estimate	11.35	4.47
Method	Normal	ANOVA
Modified CV Basis Values and/or Estimates		
B-basis Value	11.90	5.18
A-Estimate	11.16	4.44
Method	pooled	pooled

Table 4-23: Statistics and Basis Values for SBS1 Strength Data

4.9 Open Hole Tension Properties

4.9.1 Quasi Isotropic Open Hole Tension Properties (OHT1)

Statistics, basis values and estimates are given for OHT1 strength data in Table 4-24. The normalized data, B-basis values and B-estimates are shown graphically in Figure 4-14.

The CTD and RTD data could be pooled to compute basis values. The data from the ETW environmental condition failed the ADK test for both normalized and as measured data. It failed the ADK test even after the modified CV transform, so modified CV basis values are not provided for that environment. Estimates computed using the modified CV method are provided instead. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method.

There were two outliers. One outlier was on the low side of batch three in the normalized CTD data. The other outlier was on the low side of batch two of the ETW data. It was an outlier in both the normalized and as measured ETW data. Both outliers were outliers only within their batch, not after pooling the data from the three batches together. The outliers were retained for this analysis.

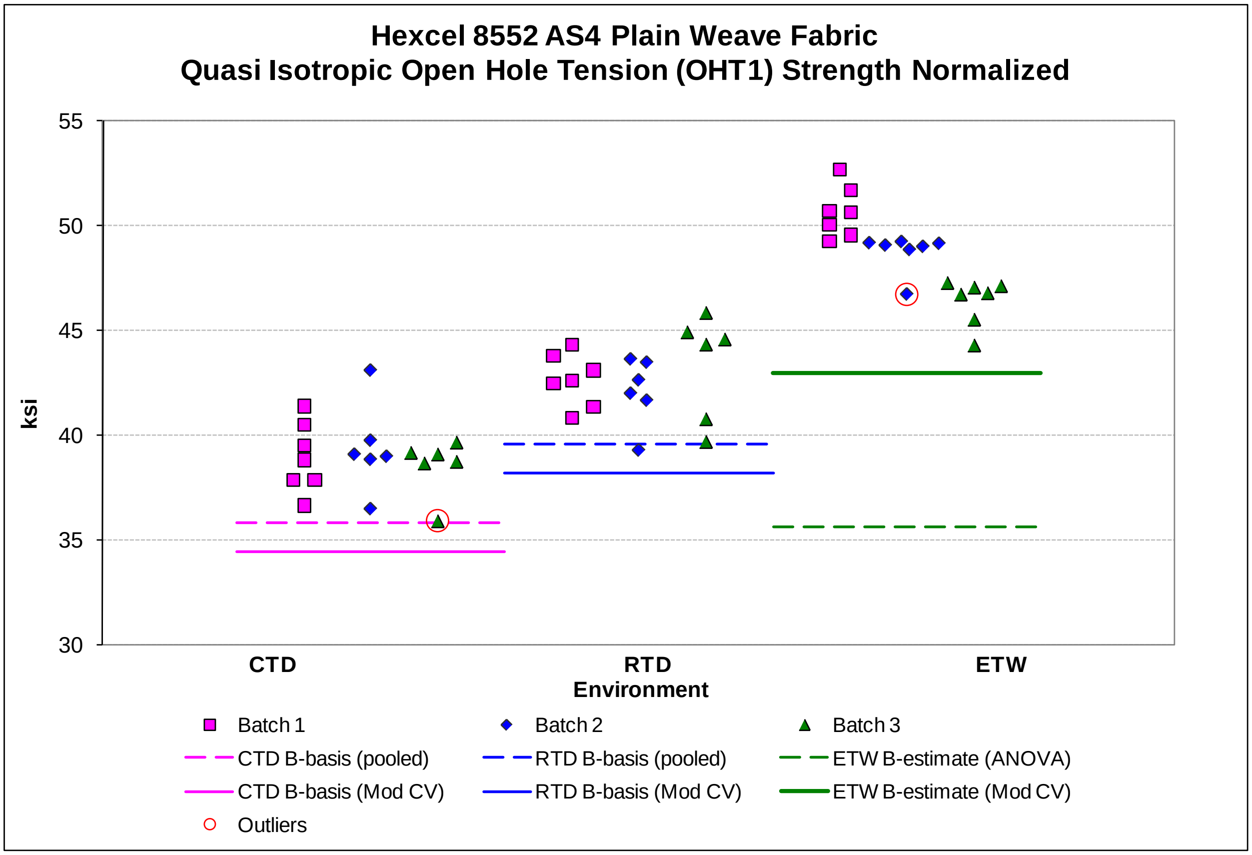

Figure 4-14: Batch Plot for OHT1 normalized strength

Quasi Isotropic Open Hole Tension (OHT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	38.97	42.72	48.62	38.97	43.13	48.04
Stdev	1.67	1.79	2.05	2.09	2.68	2.49
CV	4.29	4.20	4.22	5.37	6.21	5.19
Mod CV	6.14	6.10	6.11	6.68	7.11	6.60
Min	35.92	39.31	44.31	34.41	38.35	43.26
Max	43.12	45.87	52.69	42.48	48.81	53.06
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	21	19	19	21
Basis Values and/or Estimates						
B-basis Value	35.84	39.59		34.63	38.79	
B-Estimate			35.64			31.68
A-Estimate	33.71	37.46	26.38	31.67	35.83	20.00
Method	pooled	pooled	ANOVA	pooled	pooled	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	34.46	38.21		33.84	38.00	
B-Estimate			42.96			42.00
A-Estimate	31.37	35.12	38.92	30.33	34.50	37.70
Method	pooled	pooled	Normal	pooled	pooled	Normal

Table 4-24: Statistics and Basis Values for OHT1 Strength Data

4.9.2 "Soft" Open Hole Tension Properties (OHT2)

Statistics, basis values and estimates are given for OHT2 strength data in Table 4-25. The normalized data and B-basis values are shown graphically in Figure 4-15.

The as measured data from the RTD and ETW environmental conditions failed the ADK test, but they both passed the ADK test after the modified CV transform, so modified CV basis values are provided. The three environments could not be pooled together due to a failure of Levene's test, but the CTD and RTD as measured data could be pooled to compute the modified CV basis values. The normalized data had no diagnostic test failures and could be pooled across all three environments. There were no outliers.

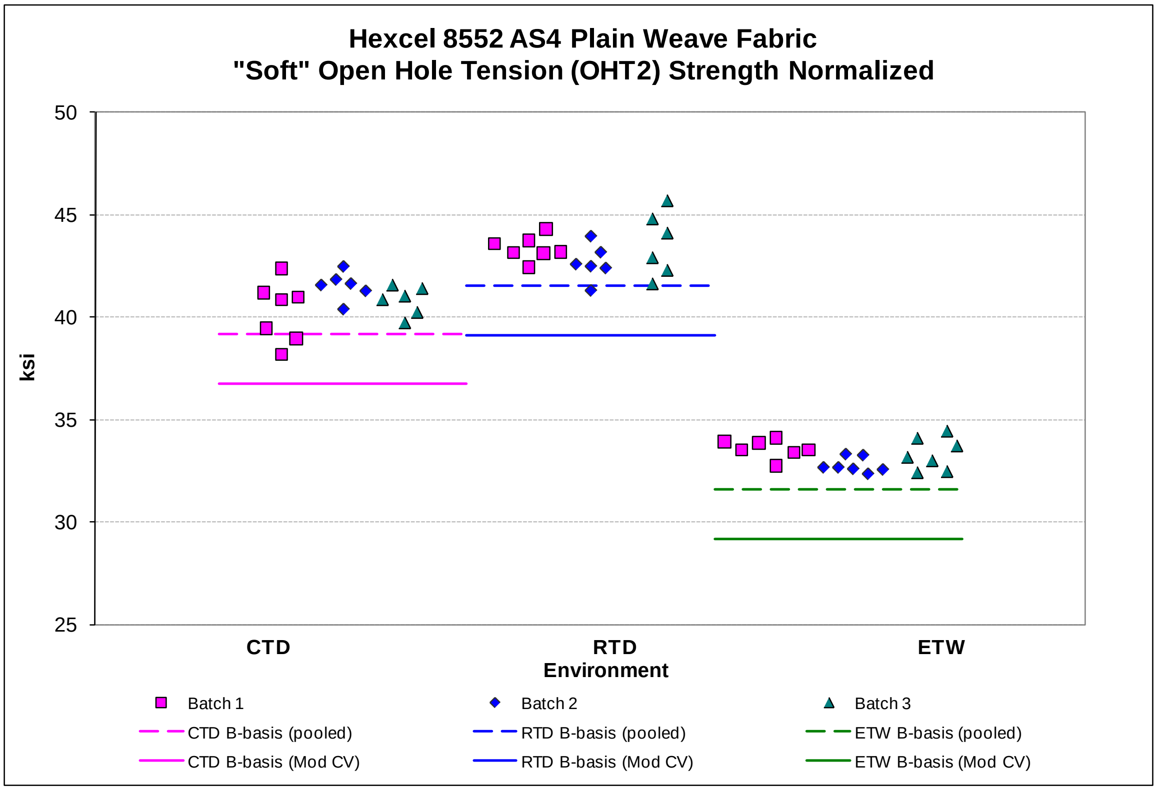

Figure 4-15: Batch Plot for OHT2 normalized strength

"Soft" Open Hole Tension (OHT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	40.85	43.21	33.25	41.10	43.89	32.83
Stdev	1.12	1.07	0.63	1.48	1.54	0.89
CV	2.75	2.48	1.90	3.61	3.50	2.70
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	38.19	41.31	32.39	38.02	40.53	31.65
Max	42.48	45.68	34.47	44.18	46.53	34.88
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	21	19	19	21
Basis Values and/or Estimates						
B-basis Value	39.17	41.53	31.59	38.21		
B-Estimate					35.84	28.24
A-Estimate	38.05	40.41	30.46	36.16	30.09	24.97
Method	pooled	pooled	pooled	Normal	ANOVA	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	36.74	39.10	29.18	36.50	39.29	29.08
A-Estimate	33.99	36.34	26.42	33.36	36.14	26.40
Method	pooled	pooled	pooled	pooled	pooled	Normal

Table 4-25: Statistics and Basis Values for OHT2 Strength Data

4.9.3 "Hard" Open Hole Tension Properties (OHT3)

Statistics, basis values and estimates are given for OHT3 strength data in Table 4-26. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-16.

Both the as measured and the normalized data from the ETW environmental condition failed the ADK test, but both passed the ADK test after the modified CV transform, so modified CV basis values are provided. Pooling the CTD and RTD datasets together was acceptable for both the as measured and the normalized data, and the ETW dataset can be included for the computation of the modified CV basis values for the as measured data. The three environments could not be pooled together for the normalized data due to a failure of Levene's test.

There were three outliers. One outlier was on the high side of batch two in the as measured RTD data. Another outlier was on the high side of batch three in the as measured ETW data. Both of these outliers were only outliers before pooling the data from the three batches together. The third outlier was on the low side of batch two in the normalized CTD data. It was an outlier only after pooling the data from the three batches together. These outliers were retained for this analysis.

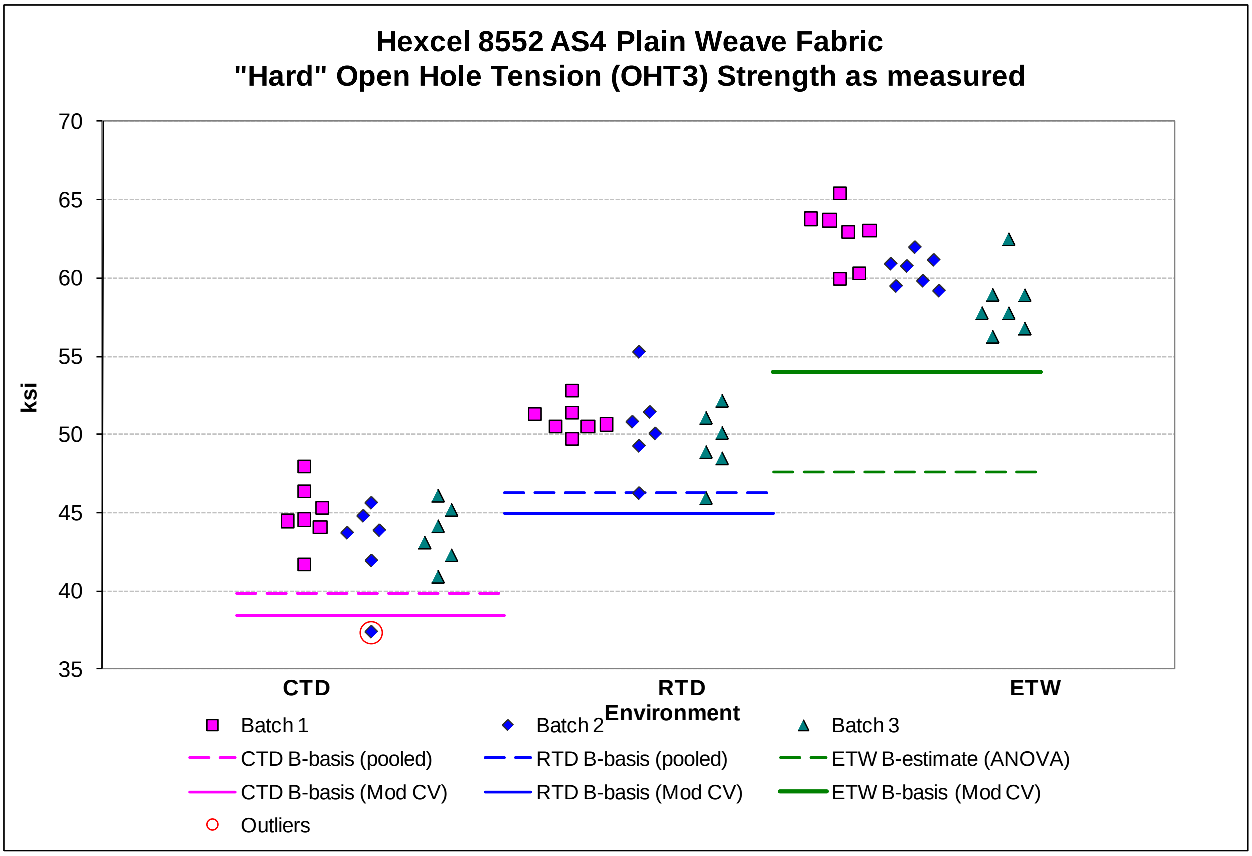

Figure 4-16: Batch Plot for OHT3 normalized strength

"Hard" Open Hole Tension (OHT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	43.88	50.36	60.55	44.63	50.67	60.08
Stdev	2.35	2.13	2.44	3.04	2.86	2.67
CV	5.34	4.22	4.04	6.80	5.64	4.44
Mod CV	6.67	6.11	6.02	7.40	6.82	6.22
Min	37.37	45.96	56.26	37.33	45.26	56.01
Max	47.95	55.30	65.40	50.03	56.05	65.54
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	21	19	19	21
Basis Values and/or Estimates						
B-basis Value	39.84	46.32		39.31	45.35	
B-Estimate			47.60			47.61
A-Estimate	37.08	43.56	38.36	35.68	41.72	38.72
Method	pooled	pooled	ANOVA	pooled	pooled	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	38.46	44.94	53.61	38.48	44.52	53.98
A-Estimate	34.76	41.24	48.66	34.36	40.40	49.85
Method	pooled	pooled	Normal	pooled	pooled	pooled

Table 4-26: Statistics and Basis Values for OHT3 Strength Data

4.10 Filled Hole Tension

4.10.1 Quasi Isotropic Filled Hole Tension (FHT1)

Statistics, basis values and estimates are given for FHT1 strength data in Table 4-27. The normalized data and B-basis values are shown graphically in Figure 4-17.

The as measured data from the ETW environmental condition failed the ADK test, but passed the ADK test with the modified CV transform. Pooling was appropriate for the as measured data for the CTD and RTD environments and for all three environments for the modified CV basis values. The normalized FHT1 data had no diagnostic test failures, so pooling was appropriate. There were no outliers.

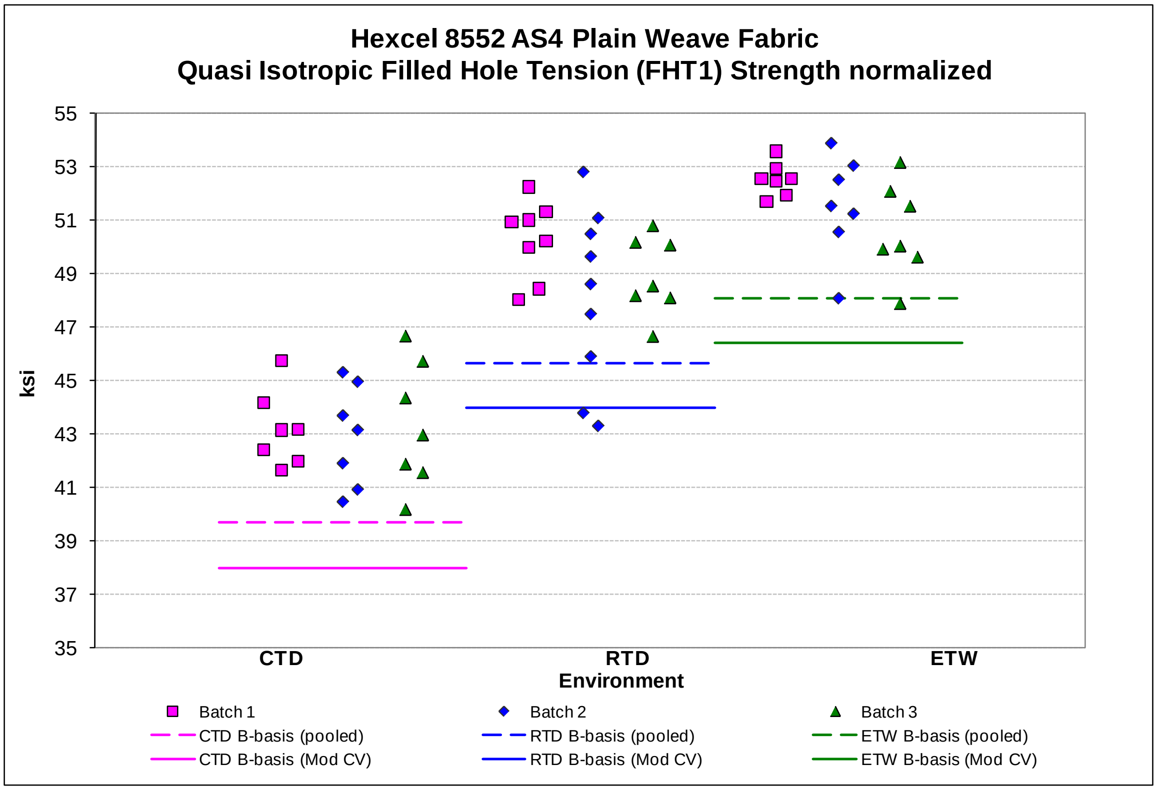

Figure 4-17: Batch plot for FHT1 normalized strength

Quasi Isotropic Filled Hole Tension (FHT1) Strength Basis Values and						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	43.17	49.10	51.58	43.70	49.49	51.14
Stdev	1.83	2.40	1.67	2.50	2.75	1.98
CV	4.24	4.89	3.23	5.72	5.56	3.86
Mod CV	6.12	6.45	6.00	6.86	6.78	6.00
Min	40.21	43.34	47.90	40.09	44.74	46.94
Max	46.69	52.84	53.92	49.35	55.13	53.74
No. Batches	3	3	3	3	3	3
No. Spec.	21	24	21	21	24	21
Basis Values and/or Estimates						
B-basis Value	39.70	45.67	48.11	39.05	44.89	
B-Estimate						41.22
A-Estimate	37.36	43.32	45.77	35.86	41.69	34.14
Method	pooled	pooled	pooled	pooled	pooled	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	38.02	44.01	46.43	38.26	44.11	45.70
A-Estimate	34.55	40.53	42.96	34.59	40.43	42.04
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-27: Statistics and Basis Values for FHT1 Strength Data

4.10.2 “Soft” Filled Hole Tension (FHT2)

Statistics, basis values and estimates are given for FHT2 strength data in Table 4-28. The normalized data and the B-basis values are shown graphically in Figure 4-18.

The data for the as measured ETW environmental condition failed the ADK test, which indicates substantial batch to batch variability. This means that the ANOVA analysis is the only method appropriate for use with that dataset. The ETW data passes the ADK test with the transform for the modified CV method, so the modified CV method can be used with the ETW data.

The as measured CTD and RTD data can be pooled and with the modified CV transform, the as measured data can be pooled across all three. The normalized RTD and ETW data were pooled to compute the modified CV basis values, but the CTD data could not be included because when the CTD data was included, the pooled dataset failed Levene’s test. The normalized CTD basis values and estimates were computed using the single point method.

There were three outliers. In the as measured data, the highest value in batch three of the RTD dataset is an outlier before pooling the three batches together. In the normalized data, the lowest value in batch three is an outlier in the CTD dataset after pooling the three batches together and the highest value in batch one of the ETW dataset is an outlier before pooling the three batches together. These outliers were retained for this analysis.

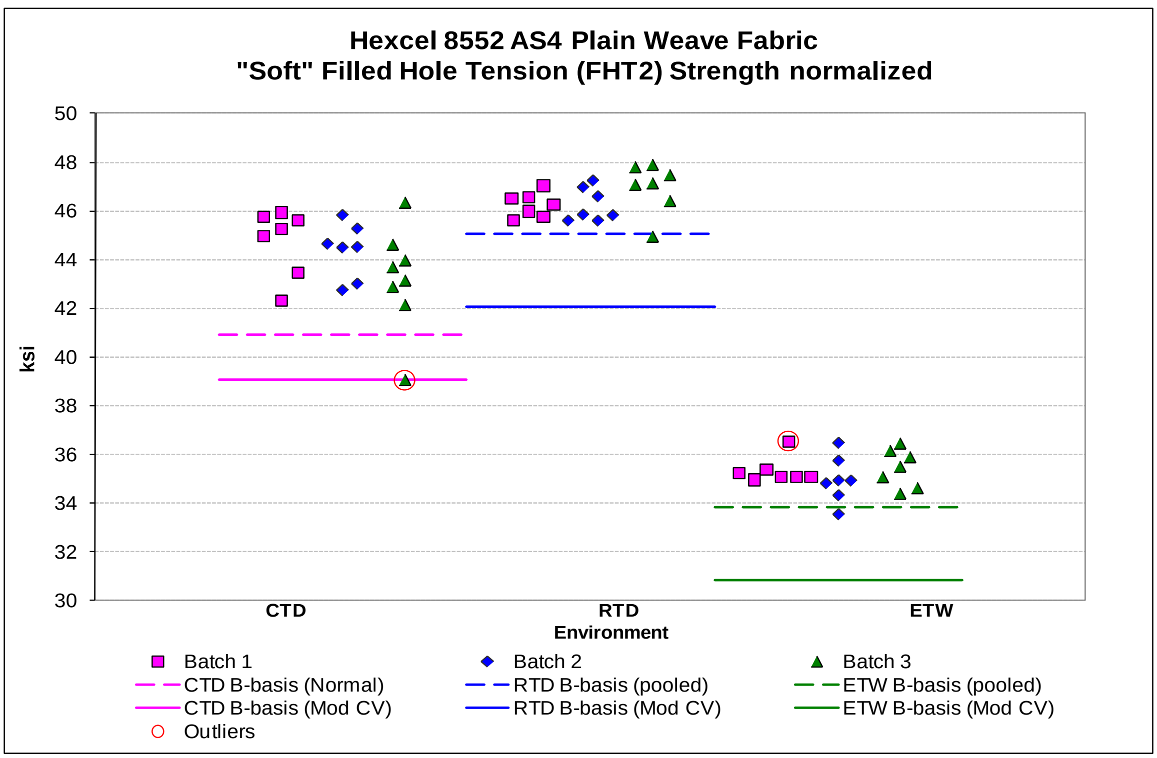

Figure 4-18: Batch plot for FHT2 normalized strength

"Soft" Filled Hole Tension (FHT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	44.07	46.47	35.25	44.48	46.23	34.71
Stdev	1.68	0.80	0.76	2.18	1.54	0.96
CV	3.81	1.73	2.17	4.90	3.33	2.77
Mod CV	6.00	6.00	6.00	6.45	6.00	6.00
Min	39.06	44.94	33.54	40.90	43.67	32.59
Max	46.33	47.88	36.53	49.26	49.85	36.17
No. Batches	3	3	3	3	3	3
No. Spec.	22	21	21	22	21	21
Basis Values and/or Estimates						
B-basis Value	40.91	45.08	33.86	41.14	42.88	
B-Estimate						29.56
A-Estimate	38.65	44.13	32.90	38.83	40.58	25.88
Method	Normal	pooled	pooled	pooled	pooled	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	39.08	42.08	30.86	40.00	41.73	30.21
A-Estimate	35.52	39.07	27.84	36.96	38.70	27.17
Method	Normal	pooled	pooled	pooled	pooled	pooled

Table 4-28: Statistics and Basis Values for FHT2 Strength Data

4.10.3 "Hard" Filled Hole Tension (FHT3)

Statistics, basis values and estimates are given for FHT3 strength data in Table 4-29. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-19.

The CTD and RTD datasets could be pooled together. The data for the ETW environmental condition, both as measured and normalized, failed the ADK test, which indicates substantial batch to batch variability, so the ANOVA method was required for analysis.

Estimates computed using the modified CV method are also provided for the normalized data from the ETW environment. This is termed an estimate due to the failure of the ADK test after the transformation for the modified CV method. The as measured data from the ETW environment did not pass the normality test, so modified CV estimates are not provided for that data.

There was one outlier. It was on the high side of batch two in the ETW data. It was an outlier only before pooling the data from all three batches together. It was an outlier in both the normalized and as measured datasets. This outlier was retained for this analysis.

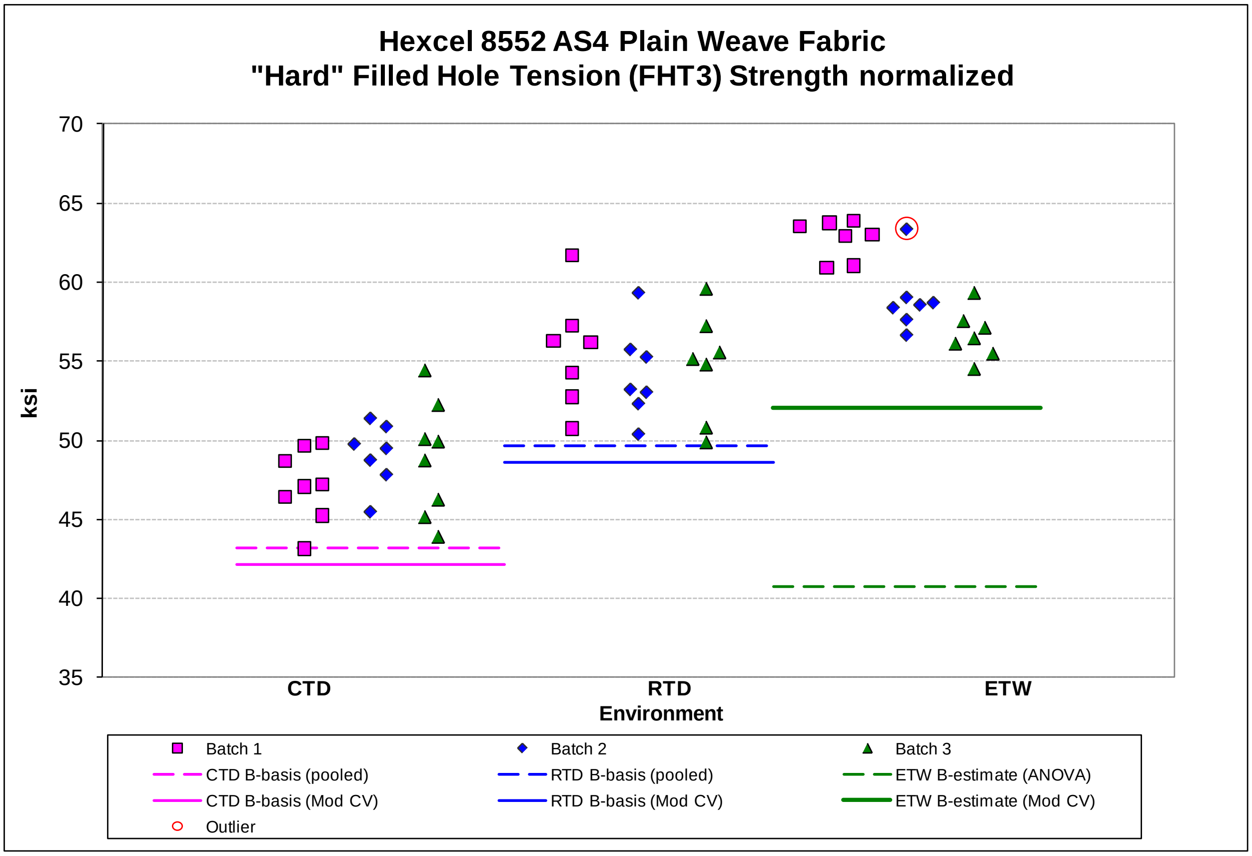

Figure 4-19: Batch plot for FHT3 normalized strength

"Hard" Filled Hole Tension (FHT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	48.35	54.84	59.44	49.64	54.63	59.16
Stdev	2.75	3.16	3.02	3.03	3.51	3.55
CV	5.69	5.76	5.09	6.11	6.42	6.00
Mod CV	6.85	6.88	6.54	7.06	7.21	7.00
Min	43.15	49.90	54.52	44.56	48.71	53.83
Max	54.43	61.68	63.92	53.73	62.35	64.72
No. Batches	3	3	3	3	3	3
No. Spec.	23	21	21	23	21	21
Basis Values and/or Estimates						
B-basis Value	43.17	49.62		43.91	48.86	
B-Estimate			40.77			37.43
A-Estimate	39.58	46.04	27.44	39.94	44.89	21.92
Method	pooled	pooled	ANOVA	pooled	pooled	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	42.15	48.59		43.12	48.06	
B-Estimate			52.03			NA
A-Estimate	37.84	44.30	46.75	38.60	43.56	NA
Method	pooled	pooled	Normal	pooled	pooled	NA

Table 4-29: Statistics and Basis Values for FHT3 Strength Data

4.11 Open Hole Compression

4.11.1 Quasi Isotropic Open Hole Compression (OHC1)

Statistics, B-basis values and estimates are given for OHC1 strength data in Table 4-30. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-20.

The data for the ETW environmental condition, both as measured and normalized, failed the ADK test, which indicates substantial batch to batch variability. This means that the ANOVA analysis is the only method appropriate for use with that dataset. The normalized ETW data passed the ADK test with the transform for the modified CV method, but the as measured ETW data did not, so modified CV basis values are provided for normalized ETW environmental condition, but not for the as measured ETW data.

There were two outliers. One outlier was on the high side of batch two in the as measured RTD data. It was an outlier only before pooling the data from all three batches together. The highest value in batch one of the ETW was an outlier in both the normalized and as measured datasets and an outlier both before and after pooling the data from the three batches together. These outliers were retained for this analysis.

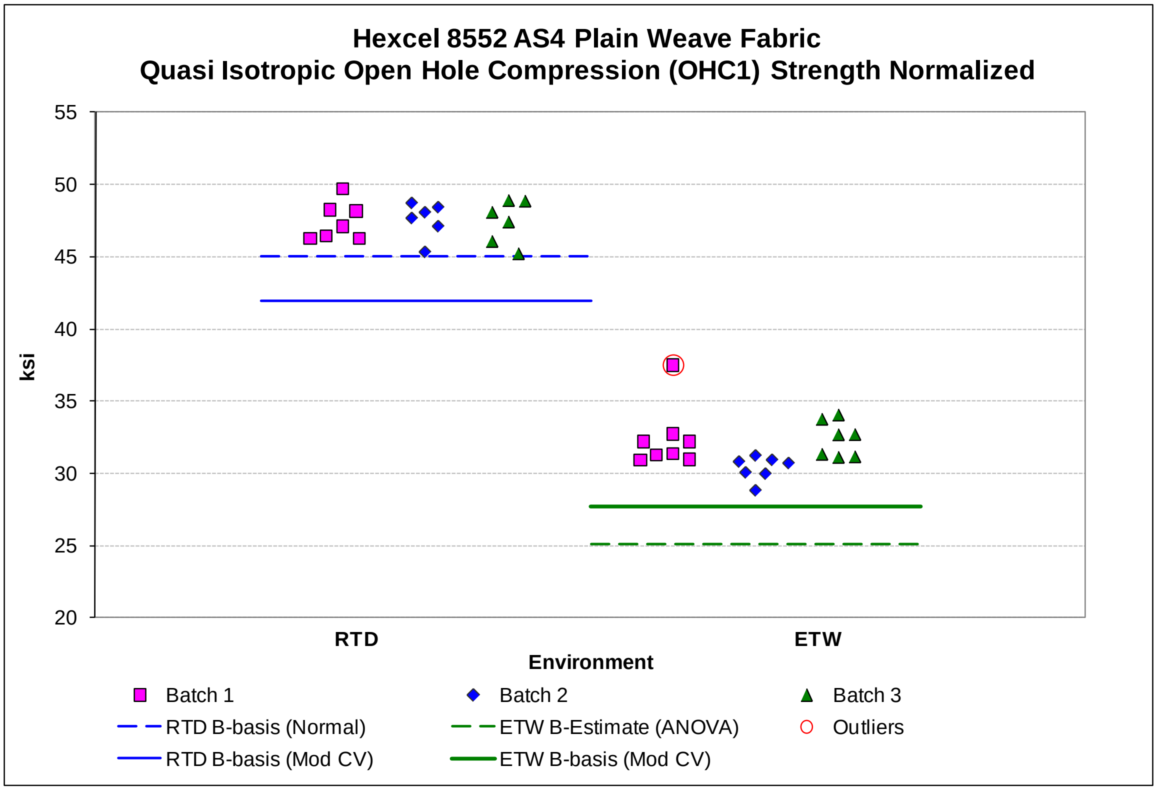

Figure 4-20: Batch plot for OHC1 normalized strength

Quasi Isotropic Open Hole Compression (OHC1)				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	47.49	31.77	47.70	31.72
Stdev	1.27	1.76	1.23	1.91
CV	2.67	5.56	2.58	6.04
Mod CV	6.00	6.78	6.00	7.02
Min	45.24	28.86	45.88	28.59
Max	49.72	37.51	50.36	37.61
No. Batches	3	3	3	3
No. Spec.	19	22	19	22
Basis Values and/or Estimates				
B-basis Value	45.02		45.31	
B-Estimate		25.13		22.58
A-Estimate	43.26	20.39	43.60	16.06
Method	Normal	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates				
B-basis Value	41.94	27.71	42.13	NA
A-Estimate	38.00	24.81	38.17	NA
Method	Normal	Normal	Normal	NA

Table 4-30: Statistics and Basis Values for OHC1 Strength Data

4.11.2 "Soft" Open Hole Compression (OHC2)

Statistics, basis values and estimates are given for OHC2 strength data in Table 4-31. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-21.

The data for the ETW environmental condition, both as measured and normalized, failed the ADK test, which indicates substantial batch to batch variability. This means that the ANOVA analysis is the only method appropriate for use with that dataset. The ETW data, both as measured and normalized, passed the ADK test with the transform for the modified CV method, so modified CV basis values are provided for that environmental condition. The normalized data could be pooled across the two environments to compute the modified CV basis values, but the pooled as measured data failed the normality test, so pooling was not appropriate for the as measured data.

There were two outliers. The highest value in batch one of the as measured data from the ETW condition was an outlier before pooling the data from all three batches together. The lowest value in batch one of the normalized data from the ETW condition was also an outlier before pooling the data from all three batches together. These outliers were retained for this analysis.

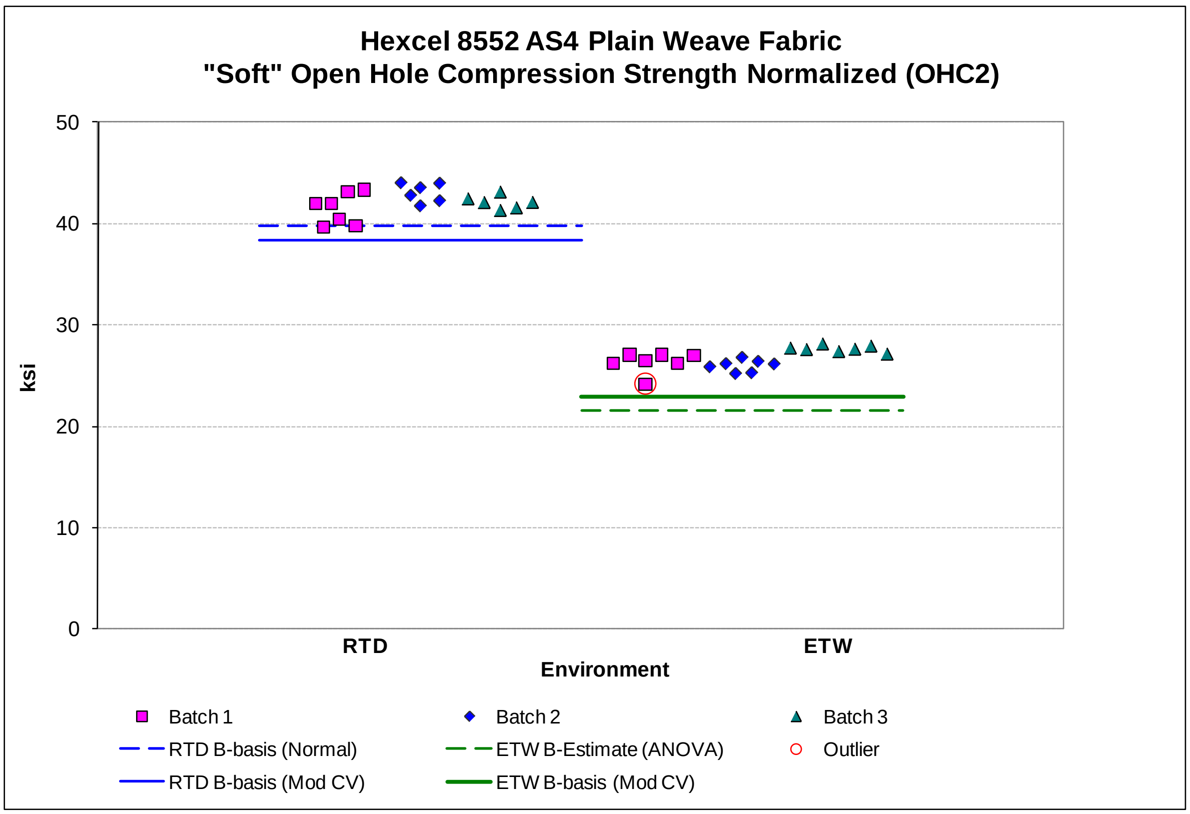

Figure 4-21: Batch plot for OHC2 normalized strength

"Soft" Open Hole Compression (OHC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	42.19	26.67	42.42	26.61
Stdev	1.26	0.98	1.09	0.97
CV	2.98	3.67	2.56	3.65
Mod CV	6.00	6.00	6.00	6.00
Min	39.70	24.17	39.65	24.25
Max	44.05	28.14	44.41	28.65
No. Batches	3	3	3	3
No. Spec.	19	21	19	21
Basis Values and/or Estimates				
B-basis Value	39.74		40.30	
B-Estimate		21.54		22.10
A-Estimate	37.99	17.88	38.80	18.89
Method	Normal	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates				
B-basis Value	38.43	22.95	37.46	23.57
A-Estimate	35.87	20.38	33.94	21.40
Method	pooled	pooled	Normal	Normal

Table 4-31: Statistics and Basis Values for OHC2 Strength Data

4.11.3 "Hard" Open Hole Compression (OHC3)

Statistics, basis values and estimates are given for OHC3 strength data in Table 4-32. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-22.

The data for the ETW environmental condition, both as measured and normalized, failed the ADK test, which indicates substantial batch to batch variability. This means that the ANOVA analysis is the only method appropriate for use with that dataset. The normalized ETW data passed the ADK test with the transform for the modified CV method, but the as measured ETW data did not, so modified CV basis values are provided for normalized ETW environmental condition. The normalized RTD and ETW data could be pooled to compute the modified CV basis values.

Estimates computed using the modified CV method are also provided for the as measured data from the ETW environment. This is termed an estimate due to the failure of the ADK test after the transformation for the modified CV method.

There were no outliers.

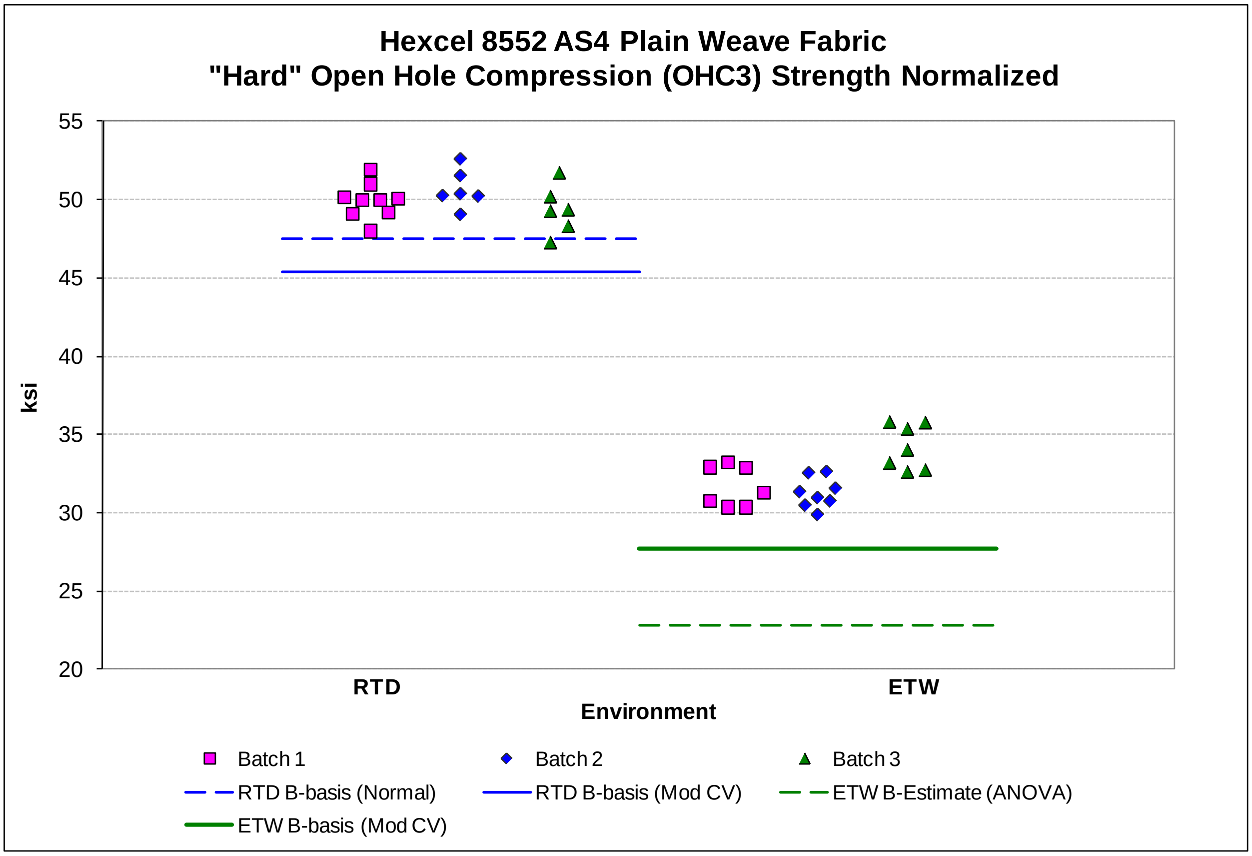

Figure 4-22: Batch plot for OHC3 normalized strength

"Hard" Open Hole Compression (OHC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	49.99	32.35	50.31	32.16
Stdev	1.31	1.76	1.16	1.78
CV	2.62	5.45	2.30	5.53
Mod CV	6.00	6.72	6.00	6.76
Min	47.30	29.90	48.65	29.13
Max	52.60	35.82	52.70	35.46
No. Batches	3	3	3	3
No. Spec.	21	22	21	22
Basis Values and/or Estimates				
B-basis Value	47.49		48.10	
B-Estimate		22.80		22.95
A-Estimate	45.71	15.99	46.53	16.37
Method	Normal	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates				
B-basis Value	45.37	27.75	44.55	
B-Estimate				28.06
A-Estimate	42.20	24.57	40.46	25.13
Method	pooled	pooled	Normal	Normal

Table 4-32: Statistics and Basis Values for OHC3 Strength Data

4.12 Filled Hole Compression

4.12.1 Quasi Isotropic Filled Hole Compression (FHC1)

Statistics, basis values and estimates are given for FHC1 strength data in Table 4-33. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-23.

Pooling the data from the two environmental conditions together was not acceptable due to the difference in their variances. There were no outliers.

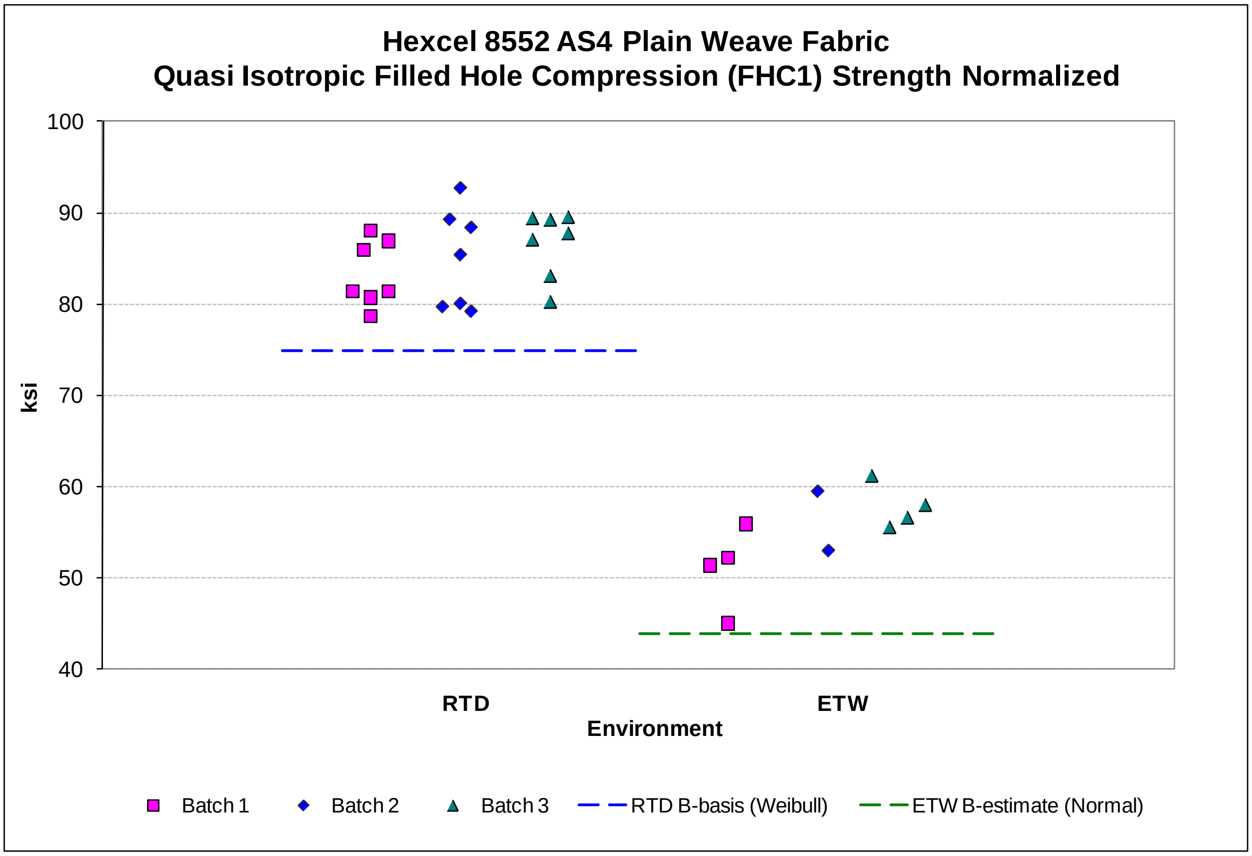

Figure 4-23: Batch plot for FHC1 normalized strength

Quasi Isotropic Filled-Hole Compression (FHC1)				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	85.00	54.87	84.51	53.46
Stdev	4.31	4.68	3.78	4.04
CV	5.07	8.53	4.47	7.56
Mod CV	6.53	8.53	6.24	7.78
Min	78.72	45.04	77.35	44.41
Max	92.72	61.28	89.34	57.86
No. Batches	3	3	3	3
No. Spec.	21	10	21	10
Basis Values and/or Estimates				
B-basis Value	74.92		75.73	
B-Estimate		43.85		43.95
A-Estimate	64.82	36.25	64.03	37.38
Method	Weibull	Normal	Non-Parametric	Normal
Modified CV Basis Values and/or Estimates				
B-Estimate	NA	NA	NA	43.66
A-Estimate	NA	NA	NA	36.90
Method	NA	NA	NA	Normal

Table 4-33: Statistics and Basis Values for FHC1 Strength Data

4.12.2 “Soft” Filled Hole Compression (FHC2)

Statistics, basis values and estimates are given for FHC2 strength data in Table 4-34. The normalized data and the B-basis values are shown graphically in Figure 4-24.

The as measured ETW data failed the ADK test even after the modified CV transform, so no modified CV basis values are provided for that condition. It also failed the normality tests, so modified CV estimates are not provided either. Pooling the data from the two environmental conditions together was acceptable for the normalized data.

There were four outliers. Three were in the as measured ETW data and one was in the normalized RTD data. In the ETW as measured data, the largest value in batch one and the largest value in batch two were both outliers only before pooling the three batches together. The largest value in batch three of the as measured ETW data was an outlier only after pooling the three batches together.

The normalized data outlier was the lowest value in batch two of the normalized RTD data. It was an outlier only before pooling the three batches of data together. All outliers were retained for this analysis.

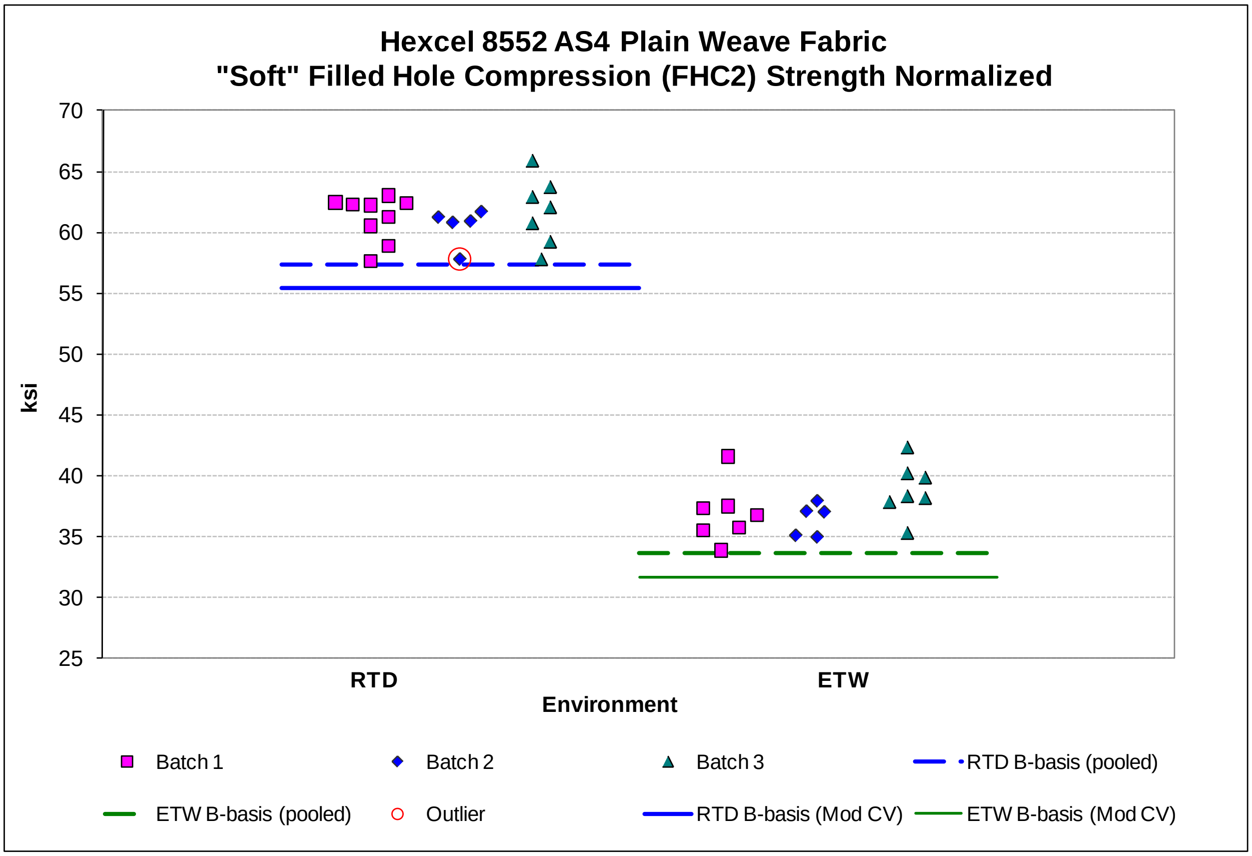

Figure 4-24: Batch plot for FHC2 normalized strength

"Soft" Filled-Hole Compression (FHC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	61.20	37.51	61.29	37.54
Stdev	2.08	2.26	1.54	2.52
CV	3.40	6.02	2.50	6.72
Mod CV	6.00	7.01	6.00	7.36
Min	57.66	33.90	58.55	35.19
Max	65.85	42.32	64.72	44.40
No. Batches	3	3	3	3
No. Spec.	21	19	21	19
Basis Values and/or Estimates				
B-basis Value	57.35	33.62	58.36	
B-Estimate				26.18
A-Estimate	54.69	30.97	56.28	18.08
Method	pooled	pooled	Normal	ANOVA
Modified CV Basis Values and/or Estimates				
B-basis Value	55.47	31.72	54.28	NA
A-Estimate	51.52	27.78	49.29	NA
Method	pooled	pooled	Normal	NA

Table 4-34: Statistics and Basis Values for FHC2 Strength Data

4.12.3 “Hard” Filled Hole Compression (FHC3)

Statistics, basis values and estimates are given for FHC3 strength data in Table 4-35. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-25.

The ETW condition had data from only thirteen specimens which is insufficient for computing basis values. In addition, the data for the ETW environmental condition, both as measured and normalized, did not pass the ADK test even with the transform for the modified CV method so the ANOVA method was required. Estimates computed using the modified CV method are also provided for the ETW environment. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method.

There was one outlier. It was the lowest value in batch one of the as measured RTD data. It was an outlier both before and after pooling the three batches of data together. The outlier was retained for this analysis.

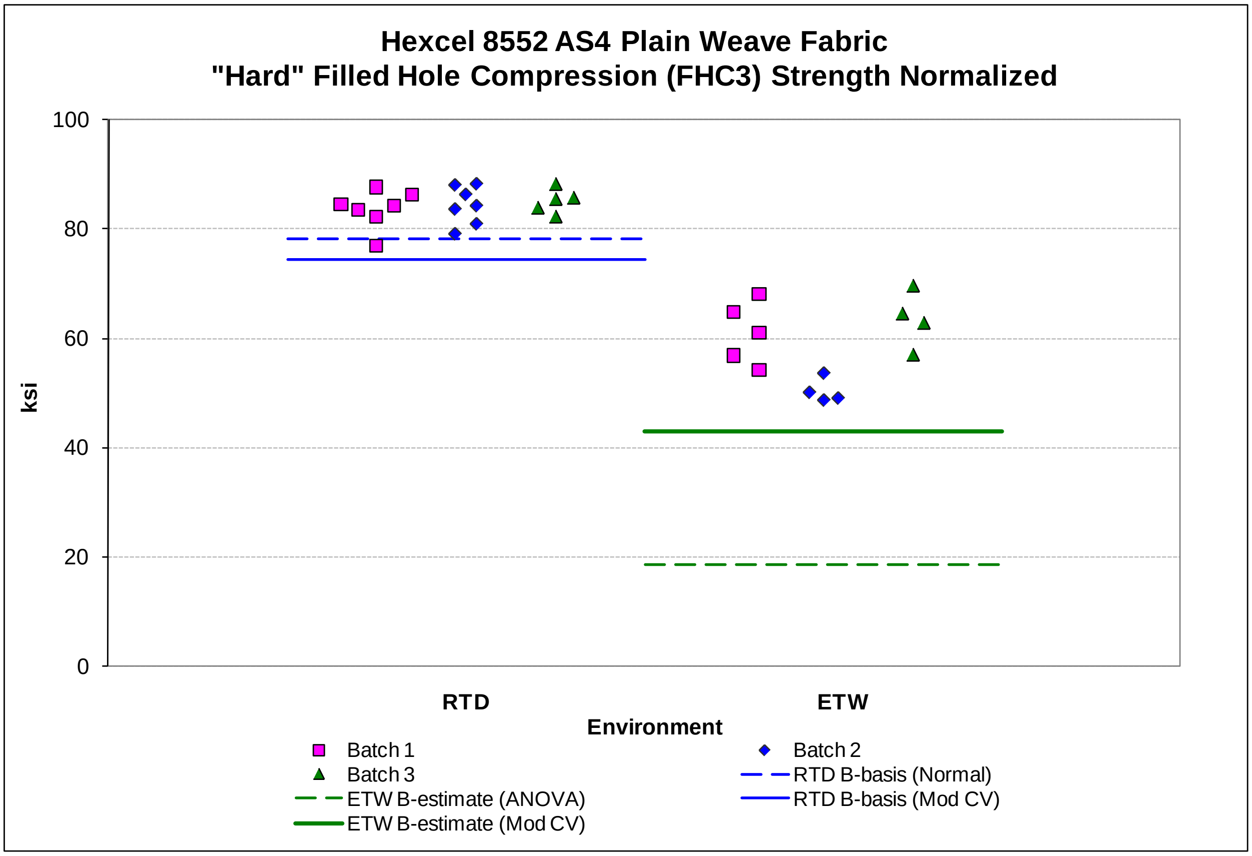

Figure 4-25: Batch plot for FHC3 normalized strength

"Hard" Filled-Hole Compression (FHC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	84.27	58.50	84.87	58.19
Stdev	3.07	7.20	2.76	7.36
CV	3.64	12.30	3.25	12.65
Mod CV	6.00	12.30	6.00	12.65
Min	76.99	48.67	77.17	47.63
Max	88.23	69.65	88.62	69.17
No. Batches	3	3	3	3
No. Spec.	19	13	19	13
Basis Values and/or Estimates				
B-basis Value	78.29		79.49	
B-Estimate		18.47		18.25
A-Estimate	74.05	0.00	75.67	0.00
Method	Normal	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates				
B-basis Value	74.41		74.94	
B-Estimate		42.98		42.32
A-Estimate	67.43	32.16	67.90	31.25
Method	Normal	Normal	Normal	Normal

Table 4-35: Statistics and Basis Values for FHC3 Strength Data

4.13 Single Shear Bearing

4.13.1 Quasi Isotropic Single Shear Bearing (SSB1)

Statistics, basis values and estimates are given for the SSB1 strength data in Table 4-36. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-26.

The 2% offset strength data from the RTD environmental condition, both as measured and normalized, failed the ADK test, which indicates substantial batch to batch variability. This means that the ANOVA analysis required with that dataset. Estimates computed using the modified CV method are also provided for the RTD environment. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method.

The ETW 2% Offset Strength data had a large CV, so modified CV basis values are unchanged from the basis values computed using the single point method. There were no diagnostic test failures for the ultimate strength data, so it could be pooled across the two environmental conditions.

There were three outliers in the SSB1 data, all three outliers were outliers only within their batch, not after pooling the three batches together and only for 2% offset strength. There were no outliers in the ultimate strength data. The lowest value in batch two of the 2% offset strength RTD data was an outlier in both the normalized and the as measured data. The lowest value in batch three of the 2% offset strength RTD data was an outlier for the as measured data only. The lowest value in batch two of the 2% offset strength ETW data was an outlier for both the normalized and as measured data. All three outliers were retained for this analysis.

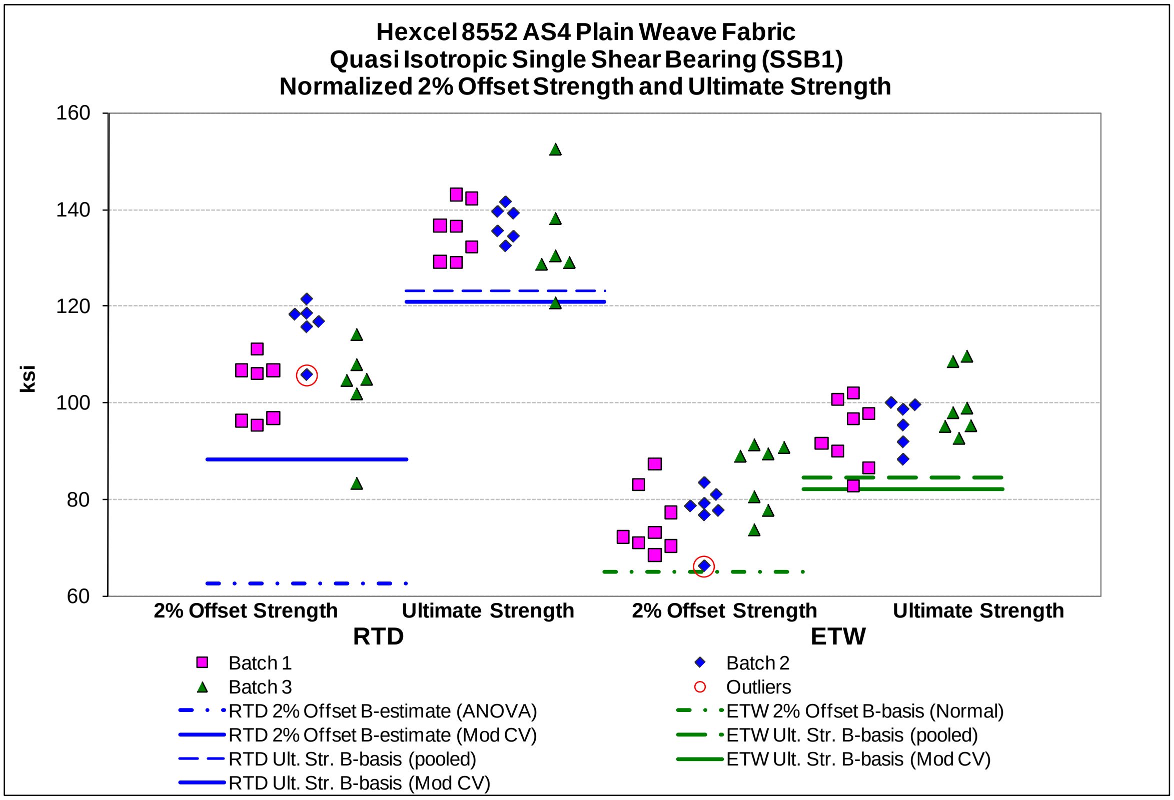

Figure 4-26: Batch plot for SSB1 normalized strength

Quasi Isotropic Single Shear Bearing (SSB1) Strength Basis Values and Statistics								
Property	Normalized				As measured			
	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	106.95	79.01	135.32	96.37	108.25	83.55	137.09	101.97
Stdev	9.59	7.38	7.08	6.48	7.91	6.86	5.95	6.57
CV	8.97	9.34	5.23	6.73	7.30	8.22	4.34	6.44
Mod CV	8.97	9.34	6.62	7.36	7.65	8.22	6.17	7.22
Min	83.37	66.13	120.67	82.75	88.37	67.37	127.91	89.86
Max	121.43	91.33	152.41	109.63	118.30	96.70	149.54	116.08
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	22	19	22	19	22	19	22
Basis Values and/or Estimates								
B-basis Value		65.09	123.19	84.40		70.60	125.81	90.84
B-Estimate	62.48				77.55			
A-Estimate	30.77	55.16	114.94	76.11	55.66	61.36	118.14	83.14
Method	ANOVA	Normal	pooled	pooled	ANOVA	Normal	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-basis Value		NA	120.96	82.20		NA	122.95	88.02
B-Estimate	88.25				92.11			
A-Estimate	74.99	NA	111.20	72.39	80.66	NA	113.33	78.35
Method	Normal	NA	pooled	pooled	Normal	NA	pooled	pooled

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

4.13.2 "Soft" Single Shear Bearing (SSB2)

Statistics, basis values and estimates are given for the SSB2 strength data in Table 4-37. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-27.

The 2% offset strength normalized data from the RTD environmental condition, and the 2% offset strength from the ETW environmental condition, both as measured and normalized, failed the ADK test, which indicates substantial batch to batch variability. This means that the ANOVA analysis is required with those datasets. The normalized RTD 2% offset strength data passed the ADK test with the transform for the modified CV method, so modified CV basis values are provided for that dataset. Estimates computed using the modified CV method are provided for the ETW environment. There are termed estimates due to the failure of the ADK test after the transformation for the modified CV method.

Pooling the ultimate strength data was not appropriate due to the difference in variances of the two environmental conditions.

There was one outlier in the SSB2 data. It was the highest value in batch three of the 2% offset strength data for the as measured ETW environmental condition. It was an outlier only for that batch, not after the three batches were pooled together. It was retained for this analysis.

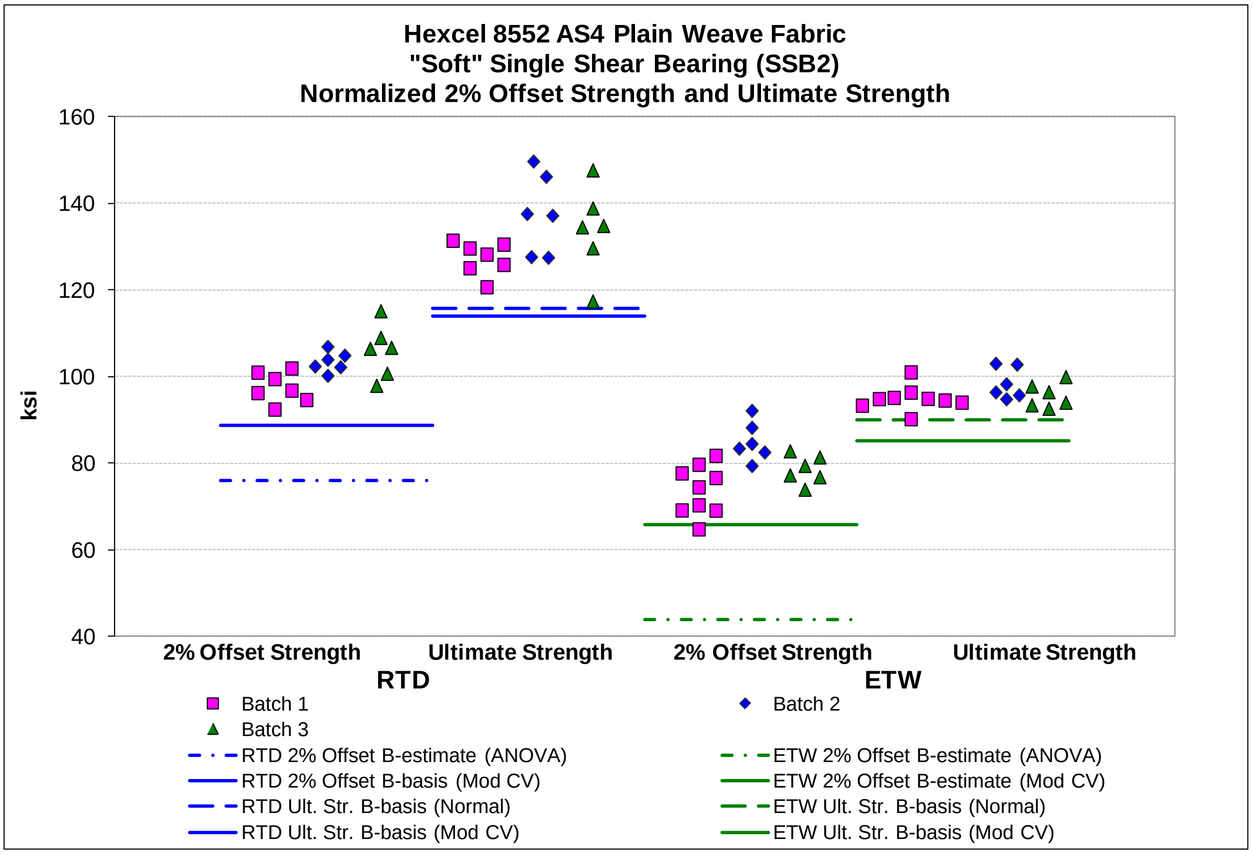

Figure 4-27: Batch plot for SSB2 normalized strength

"Soft" Single Shear Bearing (SSB2) Strength Basis Values and Statistics								
Property	Normalized				As measured			
	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	102.14	78.44	132.73	96.26	104.13	84.57	135.29	103.86
Stdev	5.45	6.61	8.72	3.30	3.89	6.32	6.68	3.39
CV	5.34	8.43	6.57	3.43	3.74	7.47	4.94	3.26
Mod CV	6.67	8.43	7.28	6.00	6.00	7.73	6.47	6.00
Min	92.52	64.86	117.48	90.30	98.17	73.27	124.73	96.07
Max	115.23	92.22	149.80	103.10	114.50	98.27	150.25	110.62
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	21	19	21	19	21	19	21
Basis Values and/or Estimates								
B-basis Value			115.74	89.98	96.55		122.26	97.40
B-Estimate	75.95	43.84				53.10		
A-Estimate	57.27	19.14	103.68	85.50	91.16	30.63	113.01	92.79
Method	ANOVA	ANOVA	Normal	Normal	Normal	ANOVA	Normal	Normal
Modified CV Basis Values and/or Estimates								
B-basis Value	88.86		113.89	85.25	91.95		118.23	91.98
B-Estimate		65.84				72.11		
A-Estimate	79.45	56.87	100.53	77.41	83.32	63.23	106.13	83.53
Method	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal

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

4.13.3 "Hard" Single Shear Bearing (SSB3)

Statistics, basis values and estimates are given for the SSB3 strength data in Table 4-38. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-28.

Only the as measured 2% offset strength and ultimate strength data from the RTD environmental condition passed the ADK test. All other datasets for the SSB3 test failed the ADK test which means that the ANOVA analysis is required with those datasets. The normalized RTD and ETW ultimate strength data passed the ADK test with the transform for the modified CV method and met all the requirements for pooling, so modified CV basis values were computed by pooling the two environments together.

Estimates computed using the modified CV method are provided for the 2% offset strength normalized data, both RTD and ETW, and the as measured data from the ETW environment for both the 2% offset strength and ultimate strength. There are termed estimates due to the failure of the ADK test after the transformation for the modified CV method. The 2% offset strength normalized data could be pooled across the two environments for computing the modified CV estimates.

There was one outlier. It was the lowest value in batch two of the ultimate strength normalized data for the RTD environmental condition. It was an outlier only for that batch, not after pooling the data from the three batches together. It was retained for this analysis.

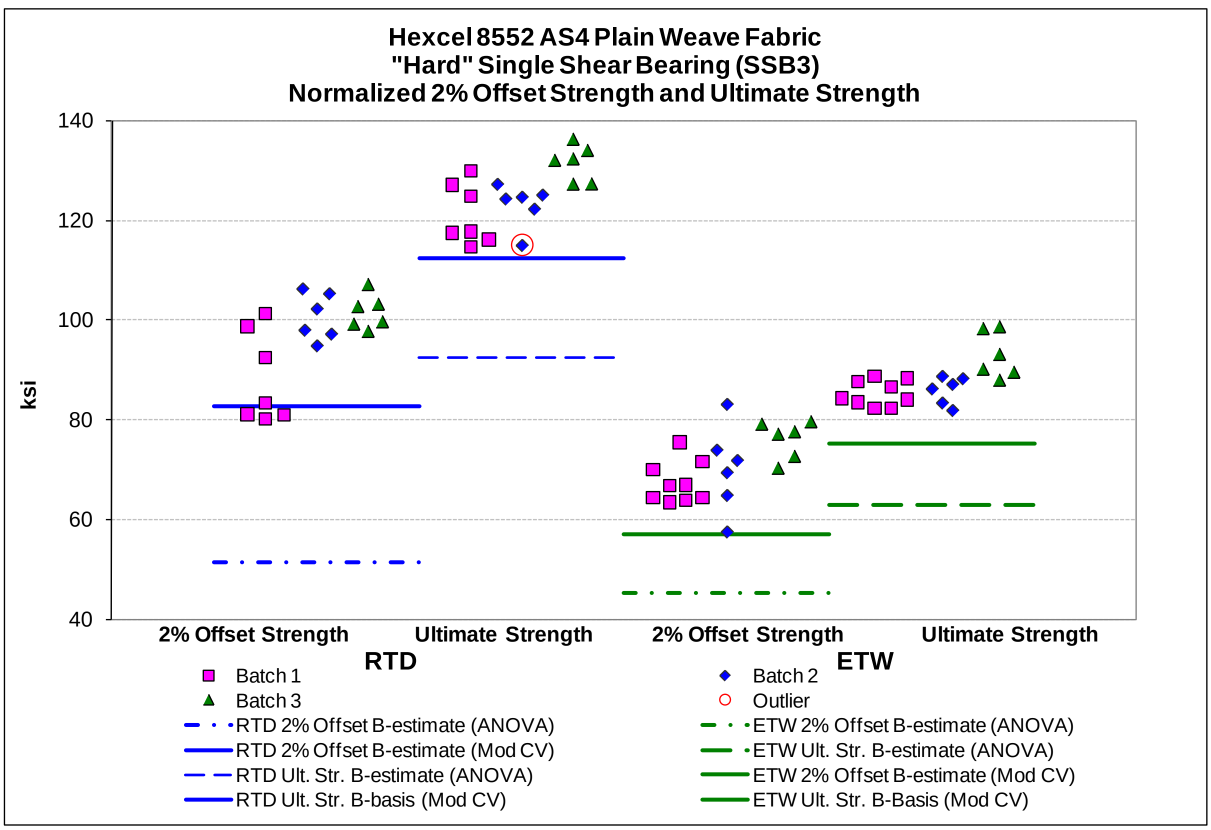

Figure 4-28: Batch plot for SSB3 normalized strength

"Hard" Single Shear Bearing (SSB3) Strength Basis Values and Statistics								
Property	Normalized				As measured			
	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	96.40	70.69	125.02	87.68	95.11	75.40	123.39	93.57
Stdev	8.78	6.51	6.47	4.62	7.83	7.22	5.39	6.17
CV	9.11	9.21	5.17	5.27	8.24	9.58	4.37	6.59
Mod CV	9.11	9.21	6.59	6.64	8.24	9.58	6.18	7.30
Min	80.24	57.55	114.72	81.92	81.29	60.88	113.53	83.69
Max	107.11	83.13	136.20	98.63	104.84	89.35	131.81	104.80
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	21	19	21	19	21	19	21
Basis Values and/or Estimates								
B-basis Value					79.31		112.89	
B-Estimate	51.34	45.16	92.59	63.01		40.32		57.26
A-Estimate	19.20	26.94	69.45	45.40	64.37	15.27	105.44	31.34
Method	ANOVA	ANOVA	ANOVA	ANOVA	Weibull	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates								
B-basis Value			112.33	75.10			108.52	
B-Estimate	82.63	57.03			79.84	61.64		80.56
A-Estimate	73.24	47.62	103.68	66.43	69.01	51.84	97.98	71.30
Method	pooled	pooled	pooled	pooled	Normal	Normal	Normal	Normal

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

4.14 Compression After Impact (CAI)

Basis values are not computed for this property. Testing is done only for the RTD condition. Summary statistics are presented in Table 4-39 and the data are displayed graphically in Figure 4-29. There were no outliers. Only one batch of material was tested.

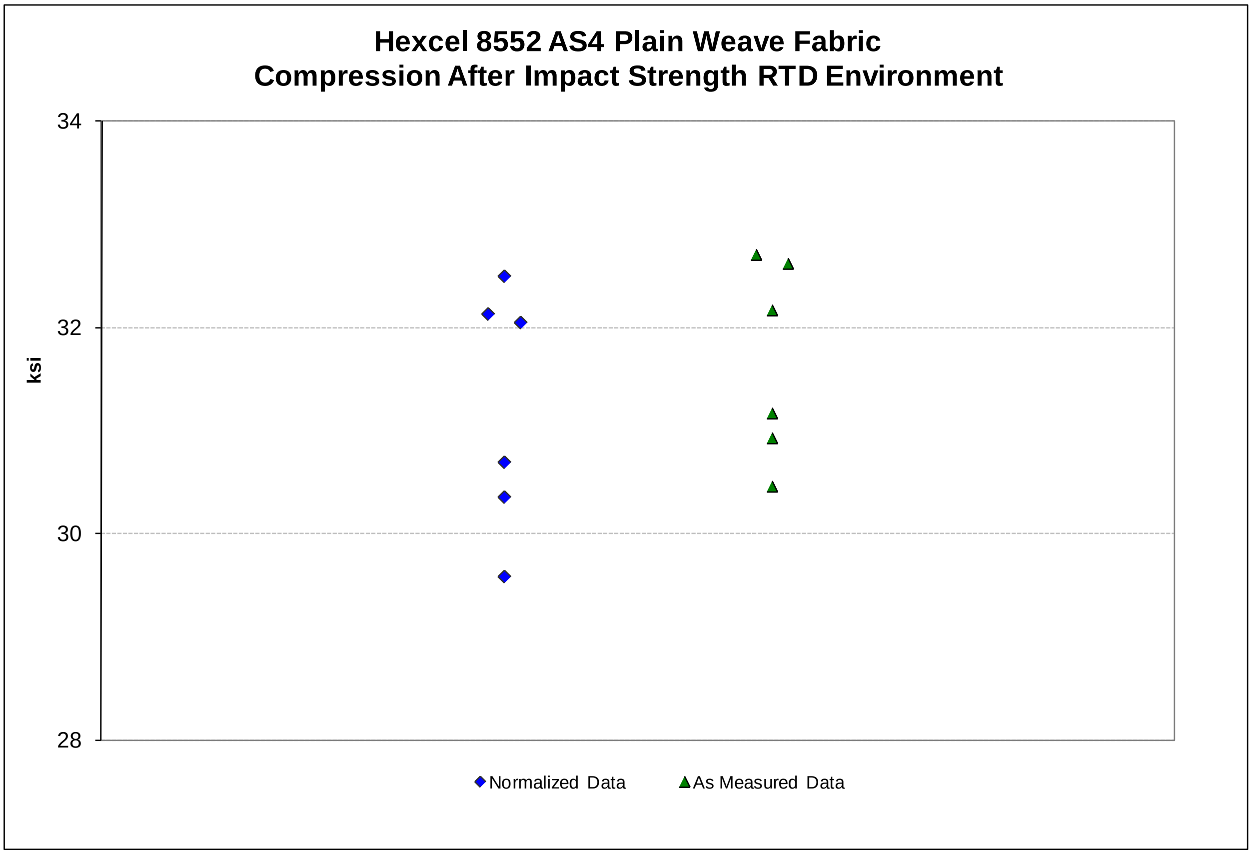

Figure 4-29: Plot for Compression After Impact normalized strength

Compression After Impact Strength		
RTD	Normalized	As Measured
Mean	31.22	31.67
Stdev	1.17	0.94
CV	3.76	2.98
Mod CV	6.00	6.00
Min	29.58	30.46
Max	32.50	32.70
No. Batches	1	1
No. Spec.	6	6

Table 4-39: Statistics for Compression After Impact Strength Data

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

The ILT and CBS data is not normalized. Basis values are not computed for these properties. However the summary statistics are presented in Table 4-40 and the data are displayed graphically in Figure 4-30. The lowest value of the CTD data is identified as an outlier. Only one batch of material was tested.

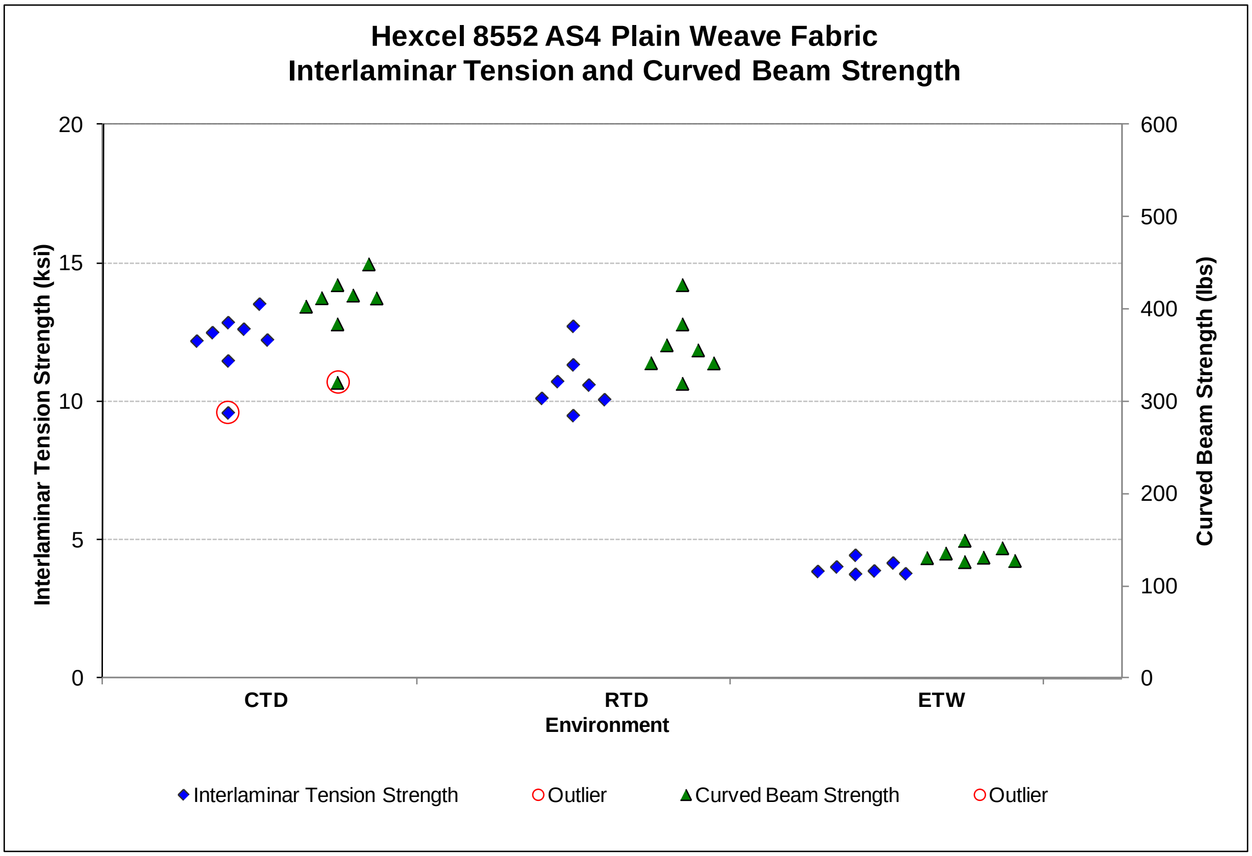

Figure 4-30: Plot for Interlaminar Tension and Curved Beam Strength as measured

Property	Interlaminar Strength (ksi)			Curved Beam Strength (lbs)		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	12.12	10.72	3.97	402.44	361.18	134.63
Stdev	1.18	1.06	0.25	37.98	34.82	8.27
CV	9.75	9.87	6.25	9.44	9.64	6.15
Min	9.58	9.49	3.74	320.35	319.30	126.40
Max	13.52	12.72	4.43	448.50	426.07	149.48
No. Batches	1	1	1	1	1	1
No. Spec.	8	7	7	8	7	7

Table 4-40: Statistics for ILT and CBS Strength Data

5. Outliers

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

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

All outliers identified were investigated to determine if a cause could be found. Outliers with causes were removed from the dataset and the remaining specimens were analyzed for this report. Information about specimens that were removed from the dataset along with the cause for removal is documented in the material property data report, NCAMP Test Report CAM-RP-2010-006 N/C.

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

Test	Condition	Batch	Specimen Number	Normalized Strength	Strength As Measured	High/ Low	Batch Outlier	Condition Outlier
FC	RTD	1	HFPZA215A	91.37	94.21	Low	Yes	No
FC	ETW	2	HFPZB21CD	55.72	Not an Outlier	Low	Yes	No
FHC2	RTD	2	HFP8B111A	57.78	Not an Outlier	Low	Yes	No
FHC3	**RTD**	**1**	**HFP9A115A**	Not an Outlier	**77.17**	**Low**	**Yes**	**Yes**
FHT2	CTD	3	HFP5C219B	39.06	Not an Outlier	Low	No	Yes
FHT2	ETW	1	HFP5A11DD	36.53	Not an Outlier	High	Yes	No
FHT2	RTD	3	HFP5C211A	Not an Outlier	49.85	High	Yes	No
FHT3	ETW	2	HFP6B21AD	63.39	63.61	High	Yes	No
FT	ETW	2	HFPUB21AD	107.13	Not an Outlier	Low	No	Yes
FT	RTD	1	HFPUA213A	112.43	Not an Outlier	High	Yes	No
ILT	CTD	1	HFPMA11FB	NA	9.58	Low	Yes	NA
CBS					320.35			
IPS 0.2% Offset	**ETW**	**1**	**HFPNA11FD**	**NA**	**3.88**	**High**	**Yes**	**Yes**
OHC1	**ETW**	**1**	**HFPGA118D**	**37.51**	**37.61**	**High**	**Yes**	**Yes**
OHC1	RTD	2	HFPGB111A	Not an Outlier	49.61	High	Yes	No
OHC2	ETW	1	HFPHA216D	24.17	Not an Outlier	Low	Yes	No
OHC2	ETW	1	HFPHA117D	Not an Outlier	28.65	High	Yes	No
OHT1	CTD	3	HFPDC218B	35.92	Not an Outlier	Low	Yes	No
OHT1	ETW	2	HFPDB11DD	46.75	45.79	Low	Yes	No
OHT3	CTD	2	HFPFB217B	37.37	Not an Outlier	Low	No	Yes
OHT3	ETW	3	HFPFC11AD	Not an Outlier	63.61	High	Yes	No
OHT3	RTD	2	HFPFB212A	Not an Outlier	55.23	High	Yes	No
SBS	**ETW**	**1**	**HFPQA11PD**	**NA**	**7.72**	**High**	**Yes**	**Yes**
SBS	RTD	2	HFPQB111A	NA	9.78	Low	No	Yes
SBS	RTD	3	HFPQC113A	NA	13.17	Low	Yes	No
SSB1 2% Offset	RTD	2	HFP1B113A	105.76	104.92	Low	Yes	No
SSB1 2% Offset	RTD	3	HFP1C113A	Not an Outlier	88.37	Low	Yes	No
SSB2 2% Offset	ETW	3	HFP2C217D	Not an Outlier	91.97	High	Yes	No
SSB3 Ultimate	RTD	2	HFP3B211A	115.01	Not an Outlier	Low	Yes	No
UNT1	**RTD**	**3**	**HFPAC211A**	**92.48**	**94.32**	**High**	**Yes**	**Yes**
WC	ETD	2	HFPLB11DC	89.15	Not an Outlier	Low	No	Yes
WT	**RTD**	**1**	**HFPJA112A**	**101.12**	**Not an Outlier**	**Low**	**Yes**	**Yes**

Table 5-1: List of outliers

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