Advanced Composites Group MTM45-1 CF0526A-36%RW 3K Plain Weave G30-500 Fabric, 193 gsm Qualification Statistical Analysis Report

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A	Elizabeth Clarkson	05/02/2013	Increase decimals for G_{12}^{S} in table 3-3 on page 35. Removed 'working draft' from all references to CMH17 Rev G. Decimals increased to 3 digits in all tables. ETW2 modulus values added for WC, FC, and UNC test results. WC B-basis values computed with as-measured CV and override of ADK test results changed to B-estimates.

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1. Introduction

This report contains statistical analysis of the Advanced Composite Group (ACG) MTM45-1/CF0526A-36%RW 3K Plain Weave G30-500 fabric material property data published in NCAMP Test Report NCP-RP-2008-003 Rev D. The lamina and laminate material property data have been generated with FAA oversight through FAA Special Project Number SP3505WI-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 and estimates were calculated using a variety of techniques that are detailed in section two. Qualification material was procured to ACG Material Specification ACGM Material Specification ACGM 1001–13 Revision A dated November 14, 2007. An equivalent NCAMP Material Specification NMS 451/13 which contains specification limits that are derived from guidelines in DOT/FAA/AR-03/19 has been created. The qualification test panels were cured in accordance with ACG process specification ACGP 1001-02 Revision E “MH” cure cycle. An equivalent NCAMP Process Specification, NPS 81451 baseline “MH” Cure Cycle, has been created. The panels were fabricated at Advanced Composites Group, 5350 S 129th E. Ave, Tulsa, OK 74134. The ACG Test Plan AI/TR/1392 Revision E was used for this qualification program. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas.

Basis numbers are labeled as ‘values’ when the data meets all the requirements of CMH-17 Revision 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 along with the specific requirement(s) the data fails to meet. The method used to compute the basis value is noted for each basis value provided. When appropriate, in addition to the traditional computational methods, values computed using the modified coefficient of variation method is also provided.

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

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

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

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

Part fabricators that wish to utilize the material property data, allowables, and specifications may be able to do so by demonstrating the capability to reproduce the original material properties; a process known as equivalency. More information about this equivalency process including the test statistics and its limitations can be found in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17 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 451/13. NMS 451/13 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 451/13.* NMS 451/13 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	LSBS
Open Hole Tension	OHT
Open Hole Compression	OHC
Filled Hole Tension	FHT
Filled Hole Compression	FHC
Pin Bearing Strength	PB
Compression After Impact	CAI
Interlaminar Tension	ILT
Curved Beam Strength	CBS

Table 1-1: Test Property Abbreviations

Test Property	Symbol
Warp (0°) Compression Strength	F_1^{cu}
Warp (0°) Compression Modulus	E_1^{c}
Warp (0°) Compression Poisson's Ratio	ν_{12}^{cu}
Warp (0°) Tension Strength	F_1^{tu}
Warp (0°) Tension Modulus	E_1^{t}
Warp (0°) Tension Poisson's Ratio	ν_{12}^{tu}
Fill (90°) Compression Strength	F_2^{cu}
Fill (90°) Compression Modulus	E_2^{c}
Fill (90°) Compression Poisson's Ratio	ν_{21}^{cu}
Fill (90°) Tension Strength	F_2^{tu}
Fill (90°) Tension Modulus	E_2^{t}
Fill (90°) Tension Poisson's Ratio	ν_{21}^{tu}
In-Plane Shear Strength at 5% strain	$F_{12}^{s5\%}$
In-Plane Shear Strength at 0.2% offset	$F_{12}^{s0.2\%}$
In-Plane Shear Modulus	G_{12}^{s}

Table 1-2: Test Property Symbols

Environmental Condition	Temperature	Abbreviation
Cold Temperature Dry	−65° F	CTD
Room Temperature Dry	75° F	RTD
Elevated Temperature Dry	200° F	ETD
Elevated Temperature Wet	200° F	ETW
Elevated Temperature Wet 2	250° F	ETW2

Table 1-3: Environmental Conditions Abbreviations

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

1 = "Quasi-Isotropic" 25/50/25
2 = "Soft" 10/80/10
3 = "Hard" 40/20/40

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

Detailed information about the test methods and conditions used is given in NCAMP Test Report NCP-RP-2008-003 Rev D.

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 (section 1.4) based on the pooled data was used to compute the basis values.

When pooling across environments was not allowable, (i.e. the data failed the Anderson-Darling test or normality tests and engineering judgment indicated there was no justification for overriding the result), B-Basis values were computed for each environment separately using Stat-17 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

Experience has shown that material qualification and allowables generation programs often fail to capture the true material property variability. 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 CV method is designed to account for the variability not typically present in qualification materials so that the material allowables will not be overly optimistic, which will lead to un-conservative designs. 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 modified CV method has been approved for inclusion in CMH-17 Rev G (formerly MIL-HDBK-17) section 8.4.4. While this revision has not yet been approved for publication in its entirety, this section has been approved by the statistics working group. 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.

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 will be provided in addition to the ANOVA estimate.

In a few cases (TC, SBS, and UNT1), 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 is permissible according to CMH-17 Rev G guidelines. If pooling is not permissible, a single point analysis using STAT-17 is performed. If the data does not meet the 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.: $$S = \sqrt{\tfrac{1}{n-1}\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2}$$ **Equation 2**

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

Where *n* refers to the number of specimens in the sample

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.

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: $$A - basis = \overline{X} - K_a S$$ $$B - basis = \overline{X} - K_b S$$ **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

Outliers are identified using the Maximum Normed Residual Test for Outliers as specified in CMH-17 Rev G section 8.3.3.

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

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

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

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:

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

Where

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

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

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

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

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

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

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

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 Graphical Test for Normality and Pearson's Coefficient

2.1.8.1 Normal Plots

2.1.8.1.1 Distribution of Data at Individual Test Conditions

The distribution for each environment data is graphed by taking the data, sorting it into ascending order and computing the percent of data that survived beyond that point.

$$x_{i(1)} \le x_{i(2)} \le \cdots \le x_{i(n_i)}$$

The probability of survival for $x_{i(j)}$ is computed:

$$\frac{n_i - j + 1}{n_i + 1}, \; j = 1, \cdots, n_i \qquad \textbf{Equation 32}$$

2.1.8.1.2 Distribution of Pooled Data

The distribution of pooled data is graphed by dividing each value by the mean for that environment, thus adjusting all environments to have a mean of 1: $\left(y_{ij} = \frac{x_{ij}}{\bar{x}_i} \Rightarrow \bar{y}_i = 1, i = 1, \ldots, k\right)$. Then the data is sorting into ascending order and the probability of survival is computed for each point.

$$y_{(1)} \le y_{(2)} \le \cdots \le y_{(n)}, n = \sum_{i=1}^{k} n_i$$

The probability of survival is computed:

$$\frac{n - j + 1}{n + 1}, \; j = 1, \cdots, n \qquad \textbf{Equation 33}$$

The normal curve and its ±10% bounds are computed as follows. A total of n points are computed and plotted for the normal curve and the +/− 10% normal curves.

S* = the standard deviation of the transformed data

Normal curves x-value:

$u_{(1)} = z_{(1)} - 0.05$, $u_{(n)} = z_{(n)} + 0.05$

$u_{(i)} = ((u_{(n)} - u_{(1)})/(n-1) + u_{(i-1)}$ for i = 2, …, n−1

Normal curve y-value: $v_{(i)} = \text{Prob}(t > u_{(i)})$, $u_{(i)} \sim N(1, S^*)$

+10% Normal curve y-value: $\max(v_{(i)} + 0.1, 0.1)$

−10% Normal curve y-value: $\max(v_{(i)} - 0.1, -.1)$

2.1.8.2 Normal Pearson's r

The Normal Pearson's r statistic is the correlation coefficient of the actual data values with the predicted values computed assuming a normal distribution with the same mean and standard deviation as the original data and using the probability of survival as the percentile of the normal distribution.

Correlation Formula: $$r = \frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{x_i - \overline{x}}{S_x}\right)\left(\frac{y_i - \overline{y}}{S_y}\right)$$ **Equation 34**

2.1.9 Levene's test for Equality of Coefficient of Variation

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

$$F = \frac{\sum_{i=1}^{k} n_i \left(\overline{w}_i - \overline{w}\right)^2 /(k-1)}{\sum_{i=1}^{k}\sum_{j=1}^{n_i} {}_i\left(w_{ij} - \overline{w}_i\right)^2 /(n-k)}$$ **Equation 35**

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); Stat-17 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

Stat-17 uses a table of values for the k-factors (shown in Table 2-1) and a slightly different formula than ASAP to compute approximate k-values for the normal distribution when the sample size is larger than 15.

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 36**

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 37**

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

2.2.2.3 Two-parameter Weibull Distribution

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

$$e^{-(a/\alpha)^{\beta}} - e^{-(b/\alpha)^{\beta}}$$ **Equation 38**

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:

$$\hat{\alpha}\hat{\beta}n - \frac{\hat{\beta}}{\hat{\alpha}^{\hat{\beta}-1}}\sum_{i=1}^{n} x_i^{\hat{\beta}} = 0 \qquad \textbf{Equation 39}$$

$$\frac{n}{\hat{\beta}} - n\ln\hat{\alpha} + \sum_{i=1}^{n}\ln x_i - \sum_{i=1}^{n}\left[\frac{x_i}{\hat{\alpha}}\right]^{\hat{\beta}}(\ln x_i - \ln\hat{\alpha}) = 0 \qquad \textbf{Equation 40}$$

Stat-17 solves these equations numerically for $\hat{\beta}$ and $\hat{\alpha}$ in order to compute basis values.

2.2.2.3.2 Goodness-of-fit test for the Weibull distribution

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

$$z_{(i)} = \left[x_{(i)}/\hat{\alpha}\right]^{\hat{\beta}}, \quad for\ i = 1,\ldots,n \qquad \textbf{Equation 41}$$

The Anderson-Darling test statistic is

$$AD = \sum_{i=1}^{n}\frac{1-2i}{n}\left[\ln\left[1-\exp(-z_{(i)})\right] - z_{(n+1-i)}\right] - n \qquad \textbf{Equation 42}$$

and the observed significance level is

$$OSL = 1/\left\{1+\exp[-0.10+1.24\ln(AD^{*})+4.48AD^{*}]\right\} \qquad \textbf{Equation 43}$$

where

$$AD^{*} = \left(1+\frac{0.2}{\sqrt{n}}\right)AD \qquad \textbf{Equation 44}$$

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

$$B = \hat{q}\exp\left\{\frac{-V}{\hat{\beta}\sqrt{n}}\right\}$$ **Equation 45**

where

$$\hat{q} = \hat{\alpha}(0.10536)^{1/\hat{\beta}}$$ **Equation 46**

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

$$\hat{q} = \hat{\alpha}(0.01005)^{1/\beta}$$ **Equation 47**

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

$$V_B \approx 3.803 + \exp\left[1.79 - 0.516\ln(n) + \frac{5.1}{n-1}\right]$$ **Equation 48**

$$V_A \approx 6.649 + \exp\left[2.55 - 0.526\ln(n) + \frac{4.76}{n}\right]$$ **Equation 49**

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

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

Table 2-2: Weibull Distribution Basis Value Factors

2.2.2.4 Lognormal Distribution

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

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

2.2.2.4.1 Goodness-of-fit test for the Lognormal distribution

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

$$z_{(i)} = \frac{\ln(\overline{x}_{(i)}) - \overline{x}_L}{s_L}, \quad \text{for } i = 1,\ldots,n \qquad \textbf{Equation 50}$$

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 be transformed back to the original units by applying the inverse of the log transformation.

2.2.3 Non-parametric Basis Values

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

2.2.3.1 Non-parametric Basis Values for large samples

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

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

For B-basis values:

$$r_B = \frac{n}{10} - 1.645\sqrt{\frac{9n}{100}} + 0.23 \qquad \textbf{Equation 51}$$

For A-Basis values:

$$r_A = \frac{n}{100} - 1.645\sqrt{\frac{99n}{10,000}} + 0.29 + \frac{19.1}{n} \qquad \textbf{Equation 52}$$

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:

$$B = x_{(r)}\left[\frac{x_{(1)}}{x_{(r)}}\right]^k \qquad \textbf{Equation 53}$$

The A-basis value is:

$$A = x_{(n)}\left[\frac{x_{(1)}}{x_{(n)}}\right]^k \qquad \textbf{Equation 54}$$

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 listed in Table 2-3. This method is not used for the B-basis value when $x_{(r)} = x_{(1)}$.

The Hanson-Koopmans method can be used to calculate A-basis values for n less than 299. Find the value k_A corresponding to the sample size n in Table 2-4. For an A-basis value that meets the requirements of 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 2.1.9). 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 $\left(n_i, \overline{x}_i, s_i^2\right)$ while statistics that were computed with the entire dataset do not have a subscript. Individual data values are represented with a double subscript, the first number indicated the batch and the second distinguishing between the individual data values within the batch. k stands for the number of batches in the analysis. With these statistics, the Sum of Squares Between batches (SSB) and the Total Sum of Squares (SST) are computed:

$$SSB = \sum_{i=1}^{k} n_i \overline{x}_I^2 - n\overline{x}^2 \quad \textbf{Equation 55}$$

$$SST = \sum_{i=1}^{k} \sum_{j=1}^{n_i} x_{ij}^2 - n\overline{x}^2 \quad \textbf{Equation 56}$$

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

$$SSE = SST - SSB \quad \textbf{Equation 57}$$

Next, the mean sums of squares are computed:

$$MSB = \frac{SSB}{k-1} \quad \textbf{Equation 58}$$

$$MSE = \frac{SSE}{n-k} \quad \textbf{Equation 59}$$

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

$$n' = \frac{n - \frac{1}{n}\sum_{i=1}^{k} n_i^2}{k-1} \quad \textbf{Equation 60}$$

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

$$S = \sqrt{\frac{MSB}{n'} + \left(\frac{n'-1}{n'}\right) MSE} \quad \textbf{Equation 61}$$

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

$$u = \frac{MSB}{MSE} \quad \textbf{Equation 62}$$

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

$$T = \frac{k_0 - \frac{k_1}{\sqrt{n'}} + \left(k_1 - k_0\right)\sqrt{\frac{u}{u+n'-1}}}{1 - \frac{1}{\sqrt{n'}}} \quad \textbf{Equation 63}$$

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 64**

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 0^{o}

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-estimate value is then computed as:

LVM B-estimate = $\bar{X}_1 - K_{(N_1,N_2)} \cdot \bar{X}_1 \cdot \max\left(CV_1, CV_2\right)$ **Equation 65**

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

Mod CV LVM B-estimate = $\bar{X}_1 - K_{(N_1,N_2)} \cdot \bar{X}_1 \cdot Max\left(8\%, CV_1, CV_2\right)$ **Equation 66**

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_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 Tables

The basis values for all tests are summarized in the following tables. The NCAMP recommended B-basis values meet all requirements of 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 for publication in 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 CMH-17 Rev G recommends that no less than five batches be used when computing basis values with the ANOVA method.
5. Caution is recommended with B-Basis values calculated from STAT-17 when the B-basis value is 90% or more of the average value. Basis values of 90% or more of the mean value imply that the CV is unusually low and may not be conservative. Such values will be indicated.
6. If the data appear questionable (e.g. when the CTD-RTD-ETW trend of the basis values are not consistent with the CTD-RTD-ETW trend of the average values), then the B-basis values will not be recommended.

NCAMP Recommended B-basis Values for
ACG - MTM45-1 PWC2 3K PW G30-500 Fabric

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

Lamina Strength Tests

Environment	Statistic	WT	WC	FT	FC	SBS*	IPS* 0.2% Offset	IPS* 5% Strain
CTD (-65 F)	B-basis	122.849	92.325	111.689	86.591	11.881	7.222	NA:I
	Mean	137.389	104.845	125.639	96.406	12.863	8.267	14.077
	CV	6.415	9.326	6.082	7.962	6.723	6.399	3.229
RTD (75 F)	B-basis	127.278	86.968	114.307	78.862	9.312	5.375	9.573
	Mean	141.306	99.431	128.257	88.677	10.293	6.119	10.772
	CV	6.269	6.821	6.924	7.501	6.000	6.670	6.105
ETD (200 F)	B-basis				65.610	6.989		
	Mean				75.424	7.970		
	CV				7.302	6.000		
ETW (200 F)	B-basis	119.906	53.074	103.311	48.493	5.540	3.429	NA:I
	Mean	134.528	65.303	117.184	58.307	6.532	3.877	6.804
	CV	6.000	7.567	6.706	6.000	6.000	6.000	6.123
ETW2 (250 F)	B-basis	115.841	42.396	96.493	42.094	4.249	2.852	4.865
	Mean	130.237	58.451	110.443	51.854	5.241	3.248	5.671
	CV	6.000	8.392	6.844	7.797	6.000	6.392	7.294

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 ACG - MTM45-1 PWC2 3K PW G30-500 Fabric

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

Laminate Strength Tests

Lay-up	ENV	Statistic	OHT	OHC	FHT	FHC	UNT	UNC	PB 2% Offset	LSBS*
25/50/25	CTD (-65 F)	B-basis	45.640		47.713		84.420			
		Mean	51.269		54.124		94.449			
		CV	6.000		6.000		6.000			
	RTD (75 F)	B-basis	46.535	37.853	NA:I	NA:I	86.339	65.341	78.309	9.155
		Mean	52.164	41.707	52.466	59.800	96.419	74.048	88.263	9.992
		CV	6.000	6.000	2.309	2.986	6.000	6.033	6.015	6.000
	ETW2 (250 F)	B-basis	45.586	25.061		NA:I	NA:I	43.007	64.048	4.424
		Mean	51.214	28.915		44.299	78.128	48.786	73.856	5.261
		CV	6.705	6.179		6.916	2.146	6.000	7.536	6.000
10/80/10	CTD (-65 F)	B-basis	39.876		NA:I		NA:I			
		Mean	45.234		46.523		59.186			
		CV	6.000		0.698		2.397			
	RTD (75 F)	B-basis	NA:I	NA:I	NA:I	NA:I	NA:I	NA:I	NA:I	
		Mean	40.061	36.941	41.251	50.047	58.233	50.881	86.800	
		CV	1.491	1.693	1.616	1.621	1.598	5.710	5.583	
	ETW2 (250 F)	B-basis	NA:I	23.622	NA:I	26.514	NA:I	NA:I	56.897	
		Mean	31.175	26.396	33.428	31.647	45.638	32.157	66.362	
		CV	1.096	5.202	1.693	8.215	2.103	3.612	7.486	
40/20/40	CTD (-65 F)	B-basis	55.619		NA:I		NA:I			
		Mean	65.309		64.398		122.052			
		CV	7.515		3.161		1.796			
	RTD (75 F)	B-basis	NA:I	NA:I	NA:I	NA:I	NA:I	NA:I	NA:I	
		Mean	62.558	48.776	60.951	66.297	124.202	84.843	82.130	
		CV	2.734	4.877	3.954	2.733	1.114	4.307	6.381	
	ETW2 (250 F)	B-basis	NA:I	26.548		40.026	NA:I	NA:I	45.561	
		Mean	64.131	30.741		48.011	113.656	52.640	70.181	
		CV	2.384	7.080		7.717	4.668	6.485	11.460	

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

Table 3-2 : Recommended B-basis values for laminate test data

3.2 Lamina and Laminate Summary Tables

Material: Advanced Composites Group - MTM45-1/CF0526A-36%RW 3K Plain Weave G30-500 fabric
Material Specificaton: NCAMP Material Specification NMS 451/13
Fiber: Tenax-J HTS40 E13 3K 200TEX
Resin: MTM45-1

Process Specification: NCAMP Process Specification NPS 81451 with baseline "MH" cure cycle

Tg(dry): 360.36°F **Tg(wet):** 320.42°F **Tg METHOD: DMA (SRM 18-94)**

ACG - MTM45-1/3K Plain Weave G30-500 Fabric Lamina Properties Summary

Date of fiber manufacture	10/2003; 7/2004; 6/2005	**Date of testing**	02/2006 - 07/2006
Date of resin manufacture	11/2005 -12/2005	**Date of data submittal**	03/2008 - 08/2008
Date of prepreg manufacture	11/2005-12/2005; 4/2006	**Date of analysis**	10/2006 - 2/2011
Date of composite manufacture	12/2005 -3/2006; 4/2006		

LAMINA MECHANICAL PROPERTY SUMMARY FOR MTM45-1/ 3K PLAIN WEAVE G30-500 FABRIC
Data reported: As measured followed by normalized values in parentheses, normalizing tply: 0.0079 in
Values shown in shaded boxes do not meet all CMH17 Rev G requirements and are estimates only
These values may NOT be used for certification unless specifically allowed by the certifying agency.

	CTD			RTD			ETD			ETW			ETW2		
	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	B-Basis	Modified CV B-basis	Mean
F_1^{cu} (ksi)	87.313	92.552	105.083	73.204	87.387	99.860				57.878	54.224	66.463	50.282		59.702
	(93.014)	(92.325)	(104.845)	(87.654)	(86.968)	(99.431)				(53.748)	(53.074)	(65.303)	(42.396)		(58.451)
E_1^c (Msi)			8.823			8.357						8.478			8.402
			(8.801)			(8.321)						(8.329)			(8.227)
ν_{12}^{cu}			0.048			0.057						0.048			0.054
F_1^{tu} (ksi)	125.071	120.725	135.472	129.592	125.398	139.626				123.642	119.272	134.101	119.857	115.553	130.154
	(127.862)	(122.849)	(137.389)	(132.114)	(127.278)	(141.306)				(124.947)	(119.906)	(134.528)	(120.804)	(115.841)	(130.237)
E_1^t (Msi)			9.234			9.131						8.951			NA
			(9.367)			(9.241)						(8.981)			NA
F_2^{cu} (ksi)	89.226	88.641	98.597	80.065	79.480	89.436	66.561	65.975	75.931	48.534	47.949	57.905	42.269	41.686	51.587
	(87.197)	(86.591)	(96.406)	(79.468)	(78.862)	(88.677)	(66.215)	(65.610)	(75.424)	(49.099)	(48.493)	(58.307)	(42.697)	(42.094)	(51.854)
E_2^c (Msi)			8.595			8.277			8.274			7.840			7.943
			(8.398)			(8.204)			(8.215)			(7.894)			(7.981)
ν_{21}^{cu}			0.051			0.056			0.050			0.047			0.053
F_2^{tu} (ksi)	114.771	112.484	127.062	116.923	114.637	129.215				105.054	102.779	117.278	97.418	95.131	109.709
	(114.498)	(111.689)	(125.639)	(117.116)	(114.307)	(128.257)				(106.105)	(103.311)	(117.184)	(99.302)	(96.493)	(110.443)
E_2^t (Msi)			9.175			8.948						8.643			NA
			(9.071)			(8.883)						(8.636)			NA
$F_{12}^{s5\%}$ (ksi)	13.097	12.256	14.077	9.945	9.573	10.772				4.177	5.842	6.804	3.661	4.865	5.671
$F_{12}^{s0.2\%}$ (ksi)	6.186	7.222	8.267	5.637	5.375	6.119				3.150	3.429	3.877	2.593	2.852	3.248
G_{12}^s (Msi)			0.661			0.557						0.401			0.340
SBS (ksi)	12.257	11.881	12.863	9.687	9.312	10.293	7.365	6.989	7.970	5.920	5.540	6.532	4.628	4.249	5.241

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

Material: Advanced Composites Group - MTM45-1/CF0526A-36%RW 3K Plain Weave G30-500 fabric
Material Specificaton: NCAMP Material Specification NMS 451/13
Fiber: Tenax-J HTS40 E13 3K 200TEX
Resin: MTM45-1

ACG - MTM45-1/ 3K Plain Weave G30-500 Fabric Laminate Properties Summary

Process Specification: NCAMP Process Specification NPS 81451 with baseline “MH” cure cycle

Tg(dry): 360.36°F **Tg(wet):** 320.42°F **Tg METHOD: DMA (SRM 18-94)**

Date of fiber manufacture 10/2003; 7/2004; 6/2005
Date of resin manufacture 11/2005 -12/2005
Date of prepreg manufacture 11/2005-12/2005; 4/2006
Date of composite manufacture 12/2005 -3/2006; 4/2006
Date of testing 02/2006 - 07/2006
Date of data submittal 03/2006 - 08/2006
Date of analysis 10/2006 - 2/2011

LAMINATE MECHANICAL PROPERTY SUMMARY for MTM45-1/3K PLAIN WEAVE G30-500 FABRIC
Data reported as normalized used a normalizing t_{ply} of 0.0079 in
Values shown in shaded boxes do not meet all CMH17 Rev G requirements and are estimates only
These values may NOT be used for certification unless specifically allowed by the certifying agency.

Test	Property	Test Condition	Unit	Quasi Isotropic 25/50/25 B-value	Quasi Isotropic 25/50/25 Mod. CV B-value	Quasi Isotropic 25/50/25 Mean	"Soft" 10/80/10 B-value	"Soft" 10/80/10 Mod. CV B-value	"Soft" 10/80/10 Mean	"Hard" 40/20/40 B-value	"Hard" 40/20/40 Mod. CV B-value	"Hard" 40/20/40 Mean
OHT (normalized)	Strength	CTD	ksi	42.944	45.640	51.269	42.713	39.876	45.234	44.631	55.619	65.309
		RTD	ksi	42.497	46.535	52.164	36.327	33.478	40.061	56.594	52.043	62.558
		ETW	ksi	45.709	43.027	49.516	---	---	---	---	---	---
		ETW2	ksi	33.191	45.586	51.214	29.498	25.858	31.175	60.996	54.194	64.131
OHC (normalized)	Strength	RTD	ksi	39.594	37.853	41.707	32.498	30.640	36.941	42.910	40.457	48.776
		ETW	ksi	29.037	27.041	31.460	---	---	---	---	---	---
		ETW2	ksi	26.802	25.061	28.915	23.622	---	26.396	27.094	26.548	30.741
UNT (normalized)	Strength	CTD	ksi	77.703	84.420	94.449	53.045	49.016	59.186	109.388	101.079	122.052
	Modulus		Msi	---	---	6.611	---	---	4.327	---	---	8.324
	Strength	RTD	ksi	78.317	86.339	96.419	52.681	48.445	58.233	112.626	103.793	124.202
	Modulus		Msi	---	---	6.455	---	---	4.121	---	---	8.159
	Strength	ETW2	ksi	73.924	66.565	78.128	43.244	38.051	45.638	102.345	94.271	113.656
UNC (normalized)	Strength	RTD	ksi	68.181	65.341	74.048	44.687	42.203	50.881	74.639	70.372	84.843
	Modulus		Msi	---	---	5.938	---	---	3.880	---	---	7.516
	Poisson's Ratio			---	---	0.322	---	---	0.554	---	---	0.144
	Strength	ETW	ksi	44.982	44.020	52.914	---	---	---	---	---	---
	Modulus		Msi	---	---	5.608	---	---	---	---	---	---
	Poisson's Ratio			---	---	0.304	---	---	---	---	---	---
	Strength	ETW2	ksi	46.062	43.007	48.786	26.336	NA	32.157	43.359	NA	52.640
	Modulus		Msi	---	---	5.584	---	---	3.457	---	---	7.670
	Poisson's Ratio			---	---	0.313	---	---	0.564	---	---	0.149
FHT (normalized)	Strength	CTD	ksi	43.261	47.713	54.124	41.696	38.529	46.523	57.716	53.332	64.398
		RTD	ksi	47.576	43.844	52.466	37.318	34.318	41.251	55.140	50.706	60.951
		ETW2	ksi	---	---	---	31.629	27.727	33.428	---	---	---
FHC (normalized)	Strength	RTD	ksi	52.608	49.600	59.800	44.028	41.511	50.047	58.065	54.623	66.297
		ETW2	ksi	38.163	37.684	44.299	19.500	26.514	31.647	40.026	---	48.011
Pin Bearing (normalized)	2% Offset	RTD	ksi	79.975	78.309	88.263	76.360	71.995	86.800	70.957	68.122	82.130
	2% Offset	ETW2	ksi	65.689	64.048	73.856	56.897	---	66.362	45.561	---	70.181
LSBS (as meas)	Strength	RTD	ksi	9.616	9.155	9.992	---	---	---	---	---	---
		ETW	ksi	5.407	5.390	6.328	---	---	---	---	---	---
		ETW2	ksi	5.134	4.424	5.261	---	---	---	---	---	---
ILT (as meas)	Strength	RTD	ksi	---	---	6.596	---	---	---	---	---	---
		ETW2	ksi	---	---	2.699	---	---	---	---	---	---
CBS (as meas)	Strength	RTD	lbs	---	---	259.361	---	---	---	---	---	---
		ETW2	lbs	---	---	110.697	---	---	---	---	---	---
CAI (normalized)	Strength	RTD	ksi	---	---	33.844	---	---	---	---	---	---

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

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

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

All individual specimen results are graphed for each test by batch and environmental condition with a line indicating the recommended basis values for each environmental condition. The data is jittered (moved slightly to the left or right) in order for all specimen values to be clearly visible. The strength values are always graphed on the vertical axis with the scale adjusted to include all data values and their corresponding basis values. The vertical axis may not include zero. The environmental conditions were graphed from left to right and the batches were identified by the shape and color of the symbol.

4.1 Warp (0º) Tension Properties (WT)

The CTD and RTD environments did not pass the Anderson-Darling k-sample test (ADK) for batch-to-batch variation for both the normalized and as measured data. The ETW2 environment fails the ADK test for the as measured data only. Overrides of the ADK test results are recommended for this data, both the normalized and as measured. For the RTD data, the batch averages are similar while the variances differ and only a few points in the batches with higher scatter fall outside the overlap region. For the CTD data, the batch CV's are uncharacteristically low for batches two and three (2.1 and 2.3 respectively), while batch one is barely within the expected range (4.1). These are situations described in CMH-17 Rev G section 8.3.10 as permissible to override the ADK test results and pool batches.

While ASAP shows a failure of Levene's test for the normalized data with the modified CV transform, when the data from all of the environments is transformed (ASAP only transforms those that fail the ADK test) to fit the assumptions of the modified CV method, the data passes Levene's test and can be pooled.

While the ETW data fails the Anderson Darling test for normality, the pooled dataset does not. Pooled CV basis values are provided, both with and without using the modified CV approach in Table 4-1. There is one outlier on the high side of batch two of the CTD environment, normalized data only. It is an outlier before, but not after, pooling the three batches. It was retained for this analysis.

Statistics, estimates and basis values are given for WT strength data in Table 4-1. Single point (no override of any test results), pooled CV and pooled with modified CV basis values (with overrides of test results) are provided. Statistics for the modulus data are given in Table 4-2. The normalized data, B-estimates and B-basis values are shown graphically in Figure 1.

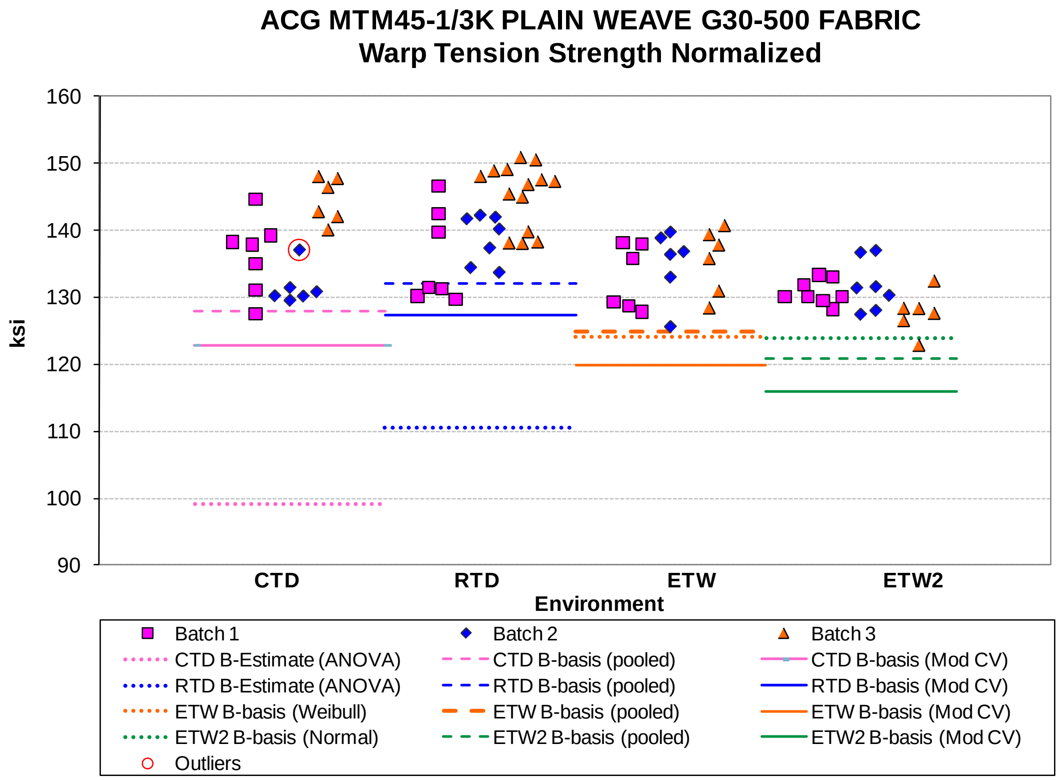

Figure 1: Batch Plot for WT Strength normalized

Warp Tension Strength (ksi) Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	137.389	141.306	134.528	130.237	135.472	139.626	134.101	130.154
Stdev	6.637	6.412	4.795	3.287	7.377	6.716	5.659	3.531
CV	4.831	4.538	3.564	2.524	5.445	4.810	4.220	2.713
Mod CV	6.415	6.269	6.000	6.000	6.723	6.405	6.110	6.000
Min	127.615	129.722	125.704	122.830	125.145	127.286	124.954	122.682
Max	147.996	150.835	140.679	137.018	146.911	150.242	141.759	136.463
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	28	18	21	19	28	18	21
Basis values and/or estimates without overrides								
B-basis Value			124.141	123.976			121.220	
B-estimate	99.107	110.552			91.353	106.597		112.443
A-estimate	71.788	88.555	113.140	119.512	59.865	82.975	103.452	99.800
Method	ANOVA	ANOVA	Weibull	Normal	ANOVA	ANOVA	Non-Para	ANOVA
Pooled basis values and/or estimates with recommended override of ADK test results								
B-basis Value	127.862	132.114	124.947	120.804	125.071	129.592	123.642	119.857
A-estimate	121.578	125.776	118.671	114.506	118.212	122.673	116.791	112.982
Pooled modified CV basis values and/or estimates with recommended override of ADK test results								
B-basis Value	122.849	127.278	119.906	115.841	120.725	125.398	119.272	115.553
A-estimate	113.259	117.605	110.328	106.230	110.999	115.588	109.557	105.805

Table 4-1: Statistics and Basis Values for WT Strength data

Warp Tension Modulus (msi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	9.367	9.241	8.981	9.234	9.131	8.951
Stdev	0.113	0.162	0.313	0.121	0.208	0.327
CV	1.202	1.754	3.480	1.313	2.283	3.648
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	9.162	8.890	8.213	9.002	8.733	8.056
Max	9.582	9.534	9.349	9.426	9.463	9.337
No. Batches	3	3	3	3	3	3
No. Spec.	19	28	18	19	28	18

ETW2 Modulus data not reported due to suspected improper strain gage instrumentations.

Table 4-2: Statistics for WT modulus data

4.2 Fill (90º) Tension Properties (FT)

Only the CTD environment passed ADK test. This means the remaining environments (RTD, ETW, ETW2) datasets require the ANOVA method to compute basis values which may result in overly conservative basis values. Overrides of the ADK test results are recommended for this data. For these datasets, the batch CV's are uncharacteristically low (they all fall below 4%) while being similar across all the environments. This situation is described in CMH-17 Rev G section 8.3.10.1 as permissible to override the ADK test results and pool batches. There were no outliers.

Statistics, estimates and basis values are given for fill tension strength data in Table 4-3. Single point (no override of any test results), estimates computed by pooling across conditions after override of ADK test results and modified CV basis values with a recommended override of ADK test results are all provided. Statistics for the modulus data are given in Table 4-4. The normalized data, B-estimates and B-basis values are shown graphically in Figure 2.

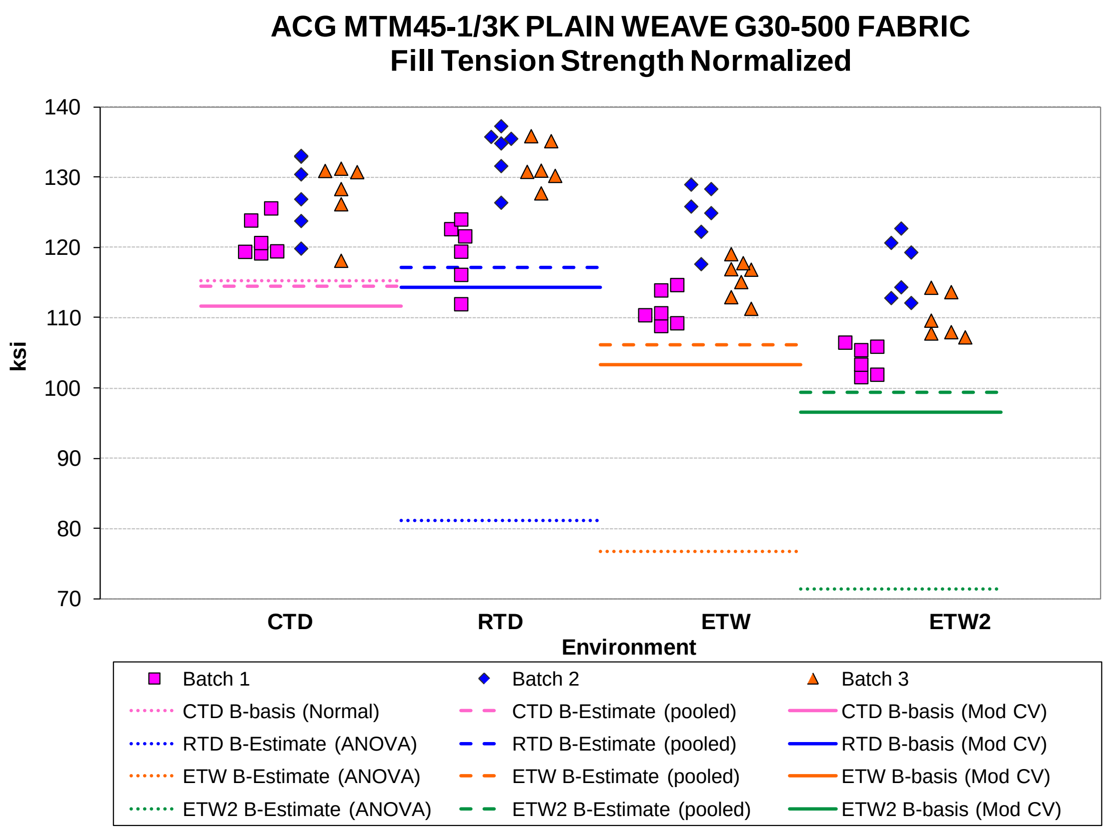

Figure 2: Batch Plot for FT Strength normalized

Fill Tension Strength (ksi) Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	125.639	128.257	117.184	110.443	127.062	129.215	117.278	109.709
Stdev	5.232	7.500	6.342	6.282	6.605	7.876	7.214	6.396
CV	4.165	5.848	5.412	5.688	5.198	6.096	6.151	5.830
Mod CV	6.082	6.924	6.706	6.844	6.599	7.048	7.076	6.915
Min	118.178	111.989	108.885	101.609	117.189	110.360	106.729	99.745
Max	133.107	137.325	129.016	122.766	140.898	138.979	130.128	120.627
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	19	18	18	18	19	18
Basis values and/or estimates without overrides								
B-basis Value	115.309				114.022			
B-estimate		81.088	76.711	71.335		79.542	68.095	70.272
A-estimate	107.988	47.424	47.822	43.426	104.781	44.090	32.983	42.128
Method	Normal	ANOVA	ANOVA	ANOVA	Normal	ANOVA	ANOVA	ANOVA
Estimates computed with override of ADK test results								
B-estimate	114.498	117.116	106.105	99.302	114.771	116.923	105.054	97.418
A-estimate	107.154	109.772	98.751	91.958	106.668	108.820	96.940	89.315
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV basis values and/or estimates with recommended override of ADK test results								
B-basis Value	111.689	114.307	103.311	96.493	112.484	114.637	102.779	95.131
A-estimate	102.493	105.111	94.102	87.296	102.874	105.026	93.156	85.521
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

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

Fill Tension Modulus (msi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	9.071	8.883	8.636	9.175	8.948	8.643
Stdev	0.272	0.284	0.192	0.407	0.306	0.300
CV	2.996	3.194	2.225	4.441	3.416	3.469
Mod CV	6.000	6.000	6.000	6.220	6.000	6.000
Min	8.599	8.035	8.258	8.528	8.096	8.116
Max	9.395	9.178	8.868	10.023	9.634	9.310
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	19	18	18	19

ETW2 Modulus data not reported due to suspected improper strain gage instrumentations.

Table 4-4: Statistics for FT Modulus data

4.3 Warp (0º) Compression Properties (WC)

The as measured data from the RTD environment and the normalized data from the ETW environment did not pass the Anderson-Darling k-sample (ADK) test for batch-to-batch variation. An override of the ADK test for the normalized ETW data is recommended. The batch averages are similar while the variances differ and only a few points in the batches with higher scatter fall outside the overlap region. This is a situation described in CMH-17 Rev G section 8.3.10.1 as permissible to override the ADK test results and pool batches. Pooling is appropriate for the CTD, RTD and ETW environments only as the ETW2 environment does not pass the normality test and neither does the pooled dataset with the ETW2 data included.

Both the as measured RTD and normalized ETW datasets pass the ADK test under the modified CV transformation, so no override is needed to compute the pooled modified CV values. The pooled data from all four environments does not pass the normality test, but with the ETW2 data excluded, pooling the other three environments is acceptable with an override of the Levene's test result. The Weibull distribution is recommended for the as measured ETW2 data and non-parametric methods for the normalized ETW2 data. There were no outliers.

Statistics, estimates and basis values are given for warp compression strength data in Table 4-5. Single point (no override of any test results) basis values, pooled basis values with override of the ADK test for the ETW data, and modified CV basis values are all provided. Statistics for the modulus data are given in Table 4-6. The normalized data, B-estimates and B-basis values are shown graphically in Figure 3.

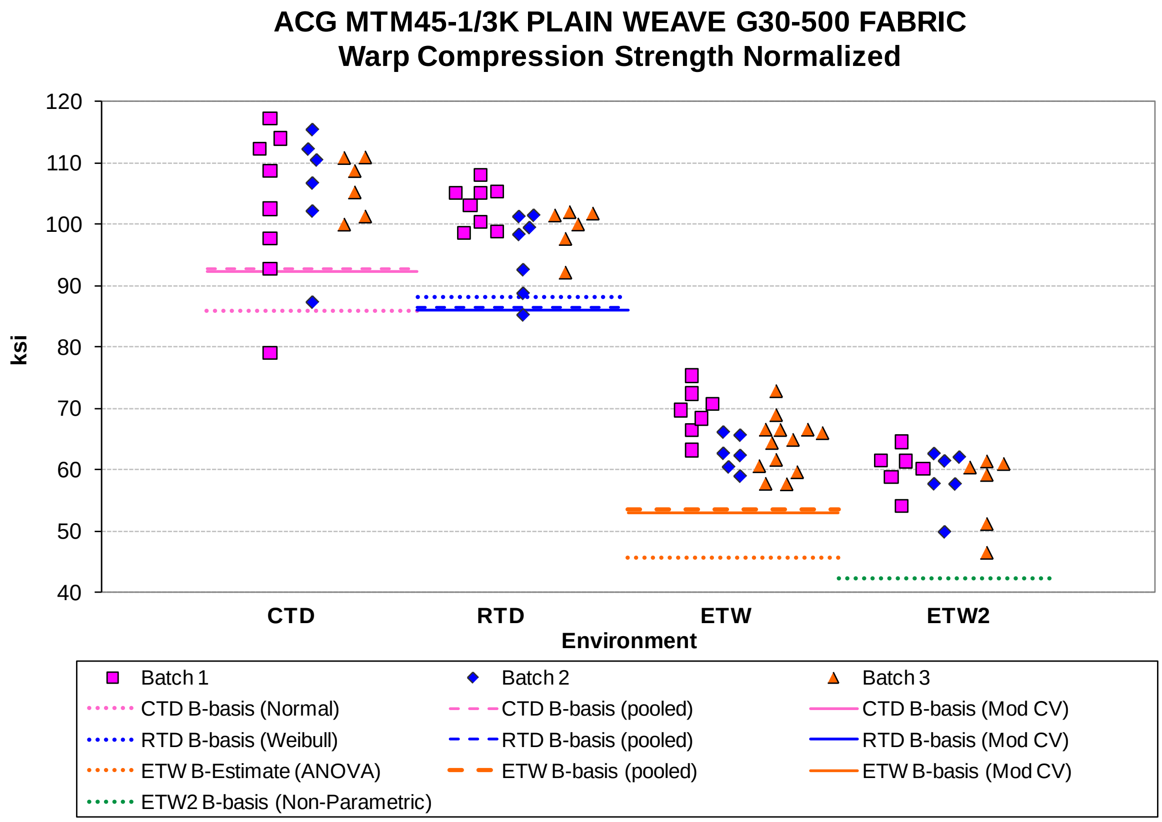

Figure 3: Batch Plot for WC Strength normalized

Warp Compression Strength (ksi) Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	104.845	99.431	65.303	58.451	105.083	99.860	66.463	59.702
Stdev	9.777	5.609	4.659	4.905	9.689	5.724	4.708	5.263
CV	9.326	5.641	7.135	8.392	9.220	5.732	7.084	8.816
Mod CV	9.326	6.821	7.567	8.392	9.220	6.866	7.542	8.816
Min	79.045	85.323	57.655	46.474	81.255	84.678	58.243	46.781
Max	117.218	108.069	75.378	64.558	116.224	107.003	75.795	65.339
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	20	21	26	18	20	21	26	18
Basis values and/or estimates without overrides								
B-basis Value	86.015	88.123		42.396	87.313		57.878	50.282
B-estimate			45.828			73.204		
A-estimate	72.617	76.620	31.899	28.417	70.422	54.178	51.703	41.211
Method	Normal	Weibull	ANOVA	Non-Parametric	Weibull	ANOVA	Normal	Weibull
Pooled basis values and/or estimates with recommended override of ADK test results								
B-basis Value	93.014	87.654	53.748					
A-estimate	85.089	79.719	45.771					
Modified CV Basis values and/or estimates								
B-basis Value	92.325	86.968	53.074		92.552	87.387	54.224	
A-estimate	83.937	78.571	44.633		84.159	78.983	45.776	
Method	pooled	pooled	pooled		pooled	pooled	pooled	

Table 4-5: Statistics and B-Basis values for WC Strength data

Warp Compression Modulus (msi) Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	8.801	8.321	8.329	8.227	8.823	8.357	8.478	8.402
Stdev	0.520	0.183	0.356	0.374	0.529	0.226	0.377	0.431
CV	5.904	2.196	4.280	4.550	5.995	2.703	4.447	5.132
Mod CV	6.952	6.000	6.140	6.275	6.997	6.000	6.223	6.566
Min	7.914	8.018	7.505	7.488	7.846	7.984	7.502	7.537
Max	9.992	8.671	9.220	8.824	9.895	8.827	9.158	9.154
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	20	21	26	18	20	21	26	18

Table 4-6: Statistics for WC modulus data

4.4 Fill (90º) Compression Properties (FC)

This data meets all CMH-17 Rev G requirements for B-basis values. There was one outlier in the as measured data. It was on the low side of batch one in the ETW2 condition. It was an outlier before but not after pooling the three batches together. Statistics, estimates and basis values are given for fill compression strength data in Table 4-7. Statistics for the modulus data are given in Table 4-8. The normalized data and B-basis values are shown graphically in Figure 4.

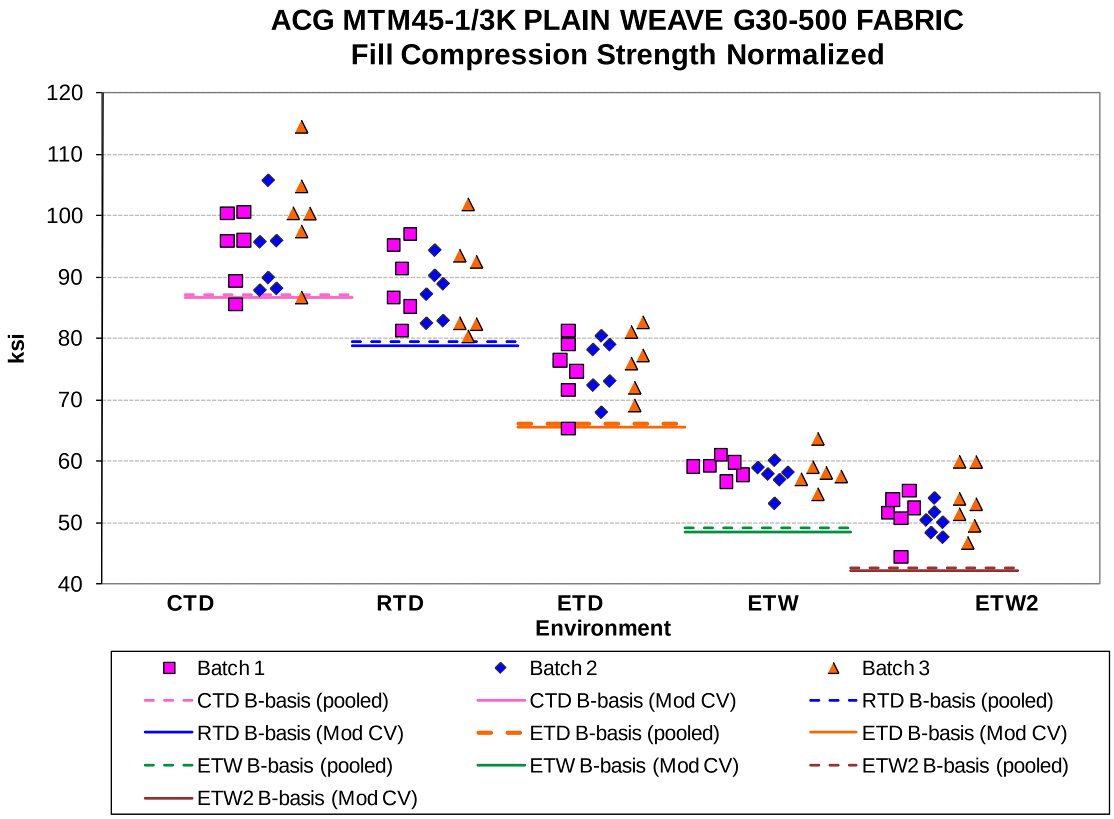

Figure 4: Batch Plot for FC Strength normalized

Fill Compression Strength (ksi) Statistics										
	Normalized					As Measured				
Env	CTD	RTD	ETD	ETW	ETW2	CTD	RTD	ETD	ETW	ETW2
Mean	96.406	88.677	75.424	58.307	51.854	98.597	89.436	75.931	57.905	51.587
Stdev	7.639	6.210	4.981	2.323	3.938	7.614	6.361	5.261	2.562	3.882
CV	7.924	7.003	6.604	3.984	7.594	7.723	7.112	6.929	4.424	7.524
Mod CV	7.962	7.501	7.302	6.000	7.797	7.861	7.556	7.465	6.212	7.762
Min	85.519	80.354	65.296	53.132	44.472	83.755	79.173	65.751	52.844	44.260
Max	114.411	101.805	82.640	63.701	59.977	113.957	101.931	85.673	63.007	58.879
No. Batches	3	3	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	18	19	18	18	18	18	19
Basis Values and/or Estimates										
B-basis Value	87.197	79.468	66.215	49.099	42.697	89.226	80.065	66.561	48.534	42.269
A-estimate	81.175	73.446	60.193	43.076	36.667	83.098	73.937	60.432	42.405	36.133
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV basis values and/or estimates										
B-basis Value	86.591	78.862	65.610	48.493	42.094	88.641	79.480	65.975	47.949	41.686
A-estimate	80.173	72.444	59.191	42.074	35.668	82.130	72.969	59.464	41.437	35.167
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

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

Fill Compression Modulus (msi) Statistics										
	Normalized					As Measured				
Env	CTD	RTD	ETD	ETW	ETW2	CTD	RTD	ETD	ETW	ETW2
Mean	8.398	8.204	8.215	7.894	7.981	8.595	8.277	8.274	7.840	7.943
Stdev	0.245	0.160	0.340	0.277	0.313	0.395	0.293	0.469	0.320	0.369
CV	2.918	1.944	4.142	3.512	3.920	4.591	3.543	5.669	4.081	4.641
Mod CV	6.000	6.000	6.071	6.000	6.000	6.295	6.000	6.835	6.041	6.321
Min	8.000	7.933	7.659	7.455	7.497	7.968	7.811	7.652	7.177	7.529
Max	8.936	8.578	8.792	8.465	8.739	9.357	8.886	9.115	8.425	8.827
No. Batches	3	3	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	18	19	18	18	18	18	19

Table 4-8: Statistics and Basis Values for FC Modulus data

4.5 In-Plane Shear Properties (IPS)

The IPS data is not normalized. Pooling is not recommended for the IPS data. The pooled dataset does not pass Levene's test for equality of variation and the pooled dataset does not pass either Levene's test or the Anderson-Darling normality test after the modified CV transformation.

For the 0.2% offset strength data, three environments did not pass the Anderson-Darling k-sample test for batch-to-batch variation: CTD, ETW and ETW2. This means those datasets require the ANOVA method to compute basis values which may result in overly conservative basis values. However, all environments pass the ADK test under the modified CV transformation, so the modified CV values are provided.

For the 5% strain strength data, the ETW and ETW2 environments did not pass the Anderson-Darling k-sample test for batch-to-batch variation which means those datasets require the ANOVA method to compute basis values which may result in overly conservative basis values. While these environments did not pass the ADK test even after the modified CV transform, an override of the ADK results is recommended. The reasons for these recommendations are as follows:

- For the ETW data, the individual batch CV's were 3.3%, 3.2% and 4.3% respectively with an overall CV of 6.1%. This fits the second situation described in section 8.3.10.1 as permissible to override the ADK test results

- For the ETW2 data, batch three has a much higher coefficient of variation (6.8%) than batches one and two (1.8% and 2.3% respectively) which fits the first situation described in section 8.3.10.1 as permissible to override the ADK test results.

There is insufficient data to produce B-basis values that meet the requirements of CMH-17 Rev G for the CTD (13 specimens) and ETW (17 specimens) environments, so only estimates are provided for those conditions.

There were two outliers in the IPS data, both on the high side of batch one, one in the RTD data and the other in the ETW2 dataset. The outlier in the RTD data was an outlier for both the 0.2% offset strength and the strength at 5% strain data. The outlier in the ETW2 data was an outlier only for the 0.2% offset strength. Both were outliers before, but not after, pooling the three batches together. Both were retained for this analysis.

Statistics, estimates and basis values are given for the 0.2% offset strength data in Table 4-9 and for the 5% strain strength data in Table 4-10. Statistics for the modulus data are given in Table 4-11. The data, B-estimates and B-basis values are shown graphically for the 0.2% offset strength data in Figure 5 and for the 5% strain strength data in Figure 6.

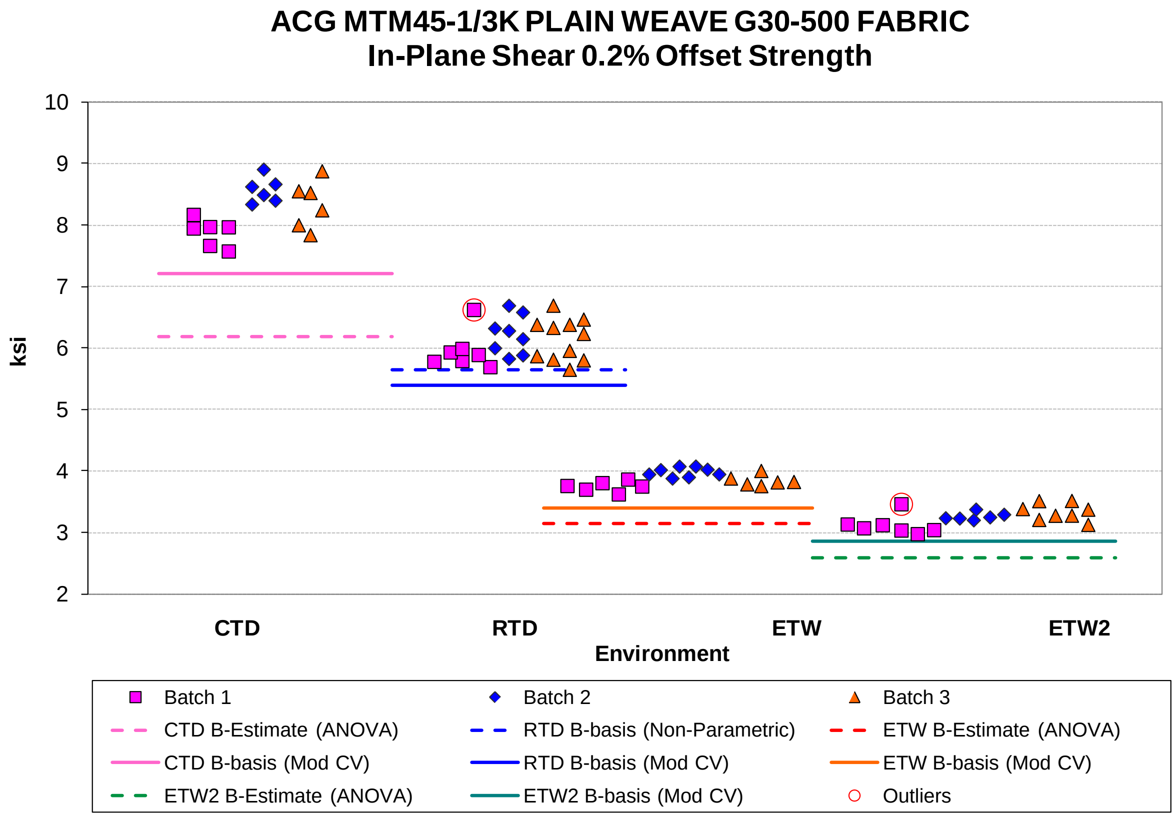

Figure 5: Batch plot for IPS 0.2% Offset Strength as measured

In-Plane Shear Properties (IPS) - 0.2% Offset Strength (ksi) Statistics				
Env	CTD	RTD	ETW	ETW2
Mean	8.267	6.119	3.877	3.248
Stdev	0.397	0.327	0.127	0.155
CV	4.799	5.341	3.275	4.784
Mod CV	6.399	6.670	6.000	6.392
Min	7.577	5.654	3.627	2.981
Max	8.908	6.695	4.081	3.521
No. Batches	3	3	3	3
No. Spec.	18	26	20	21
Basis values and/or estimates				
B-basis Value		5.637		
B-estimate	6.186		3.150	2.593
A-estimate	4.702	4.699	2.632	2.126
Method	ANOVA	Non-Para	ANOVA	ANOVA
Modified CV basis values and/or estimates				
B-basis Value	7.222	5.375	3.429	2.852
A-estimate	6.483	4.840	3.110	2.571
Method	Normal	Normal	Normal	Normal

Table 4-9: Statistics and Basis Values for IPS 0.2% Offset Strength data

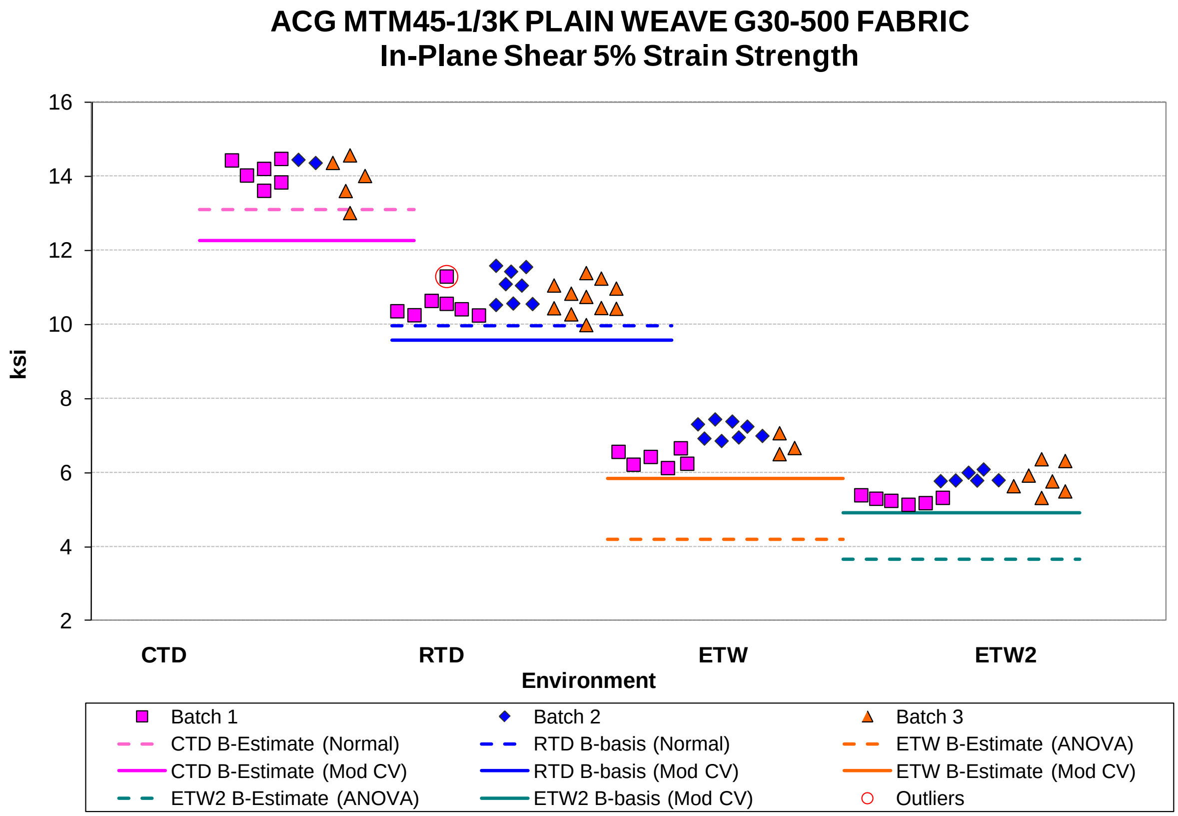

Figure 6: Batch plot for IPS 5% Shear Strain as measured

In-Plane Shear Properties (IPS) - Strength at 5% Strain (ksi) Statistics				
Env	CTD	RTD	ETW	ETW2
Mean	14.077	10.772	6.804	5.671
Stdev	0.455	0.454	0.417	0.374
CV	3.229	4.210	6.123	6.588
Mod CV	6.000	6.105	7.061	7.294
Min	13.015	9.991	6.132	5.142
Max	14.571	11.591	7.446	6.370
No. Batches	3	3	3	3
No. Spec.	13	26	17	19
Basis values and/or estimates				
B-basis Value		9.945		
B-estimate	13.097		4.177	3.661
A-estimate	12.414	9.350	2.302	2.227
Method	Normal	Normal	ANOVA	ANOVA
Modified CV basis values and/or estimates with recommended overrides of ADK test results				
B-basis Value		9.573		4.865
B-estimate	12.256		5.842	
A-estimate	10.986	8.710	5.164	4.293
Method	Normal	Normal	Normal	Normal

Table 4-10: Statistics and Basis Values for IPS 5% Shear Strain Strength data

In-Plane Shear Modulus (msi) Statistics				
Env	CTD	RTD	ETW	ETW2
Mean	0.661	0.557	0.401	0.340
Stdev	0.027	0.020	0.013	0.018
CV	4.016	3.669	3.150	5.162
Mod CV	6.008	6.000	6.000	6.581
Min	0.622	0.525	0.382	0.318
Max	0.713	0.602	0.421	0.377
No. Batches	3	3	3	3
No. Spec.	18	26	20	21

Table 4-11: Statistics for IPS Modulus data

4.6 Short Beam Strength (SBS)

The Short Beam strength data is not normalized. This dataset has one outlier. It is in the CTD environment, batch two on the low side, and is an outlier both before and after pooling batches. Due to this outlier, the pooled data fails both the normality test and Levene's test. With this outlier removed, the pooled data fails only the normality test. This outlier was retained for analysis, as no cause could be determined for the anomalous result. However an override is recommended for the pooled normality test and Levene's test. Statistics, estimates and basis values are given for the SBS data in Table 4-12. The data and B-basis values are shown graphically in Figure 7.

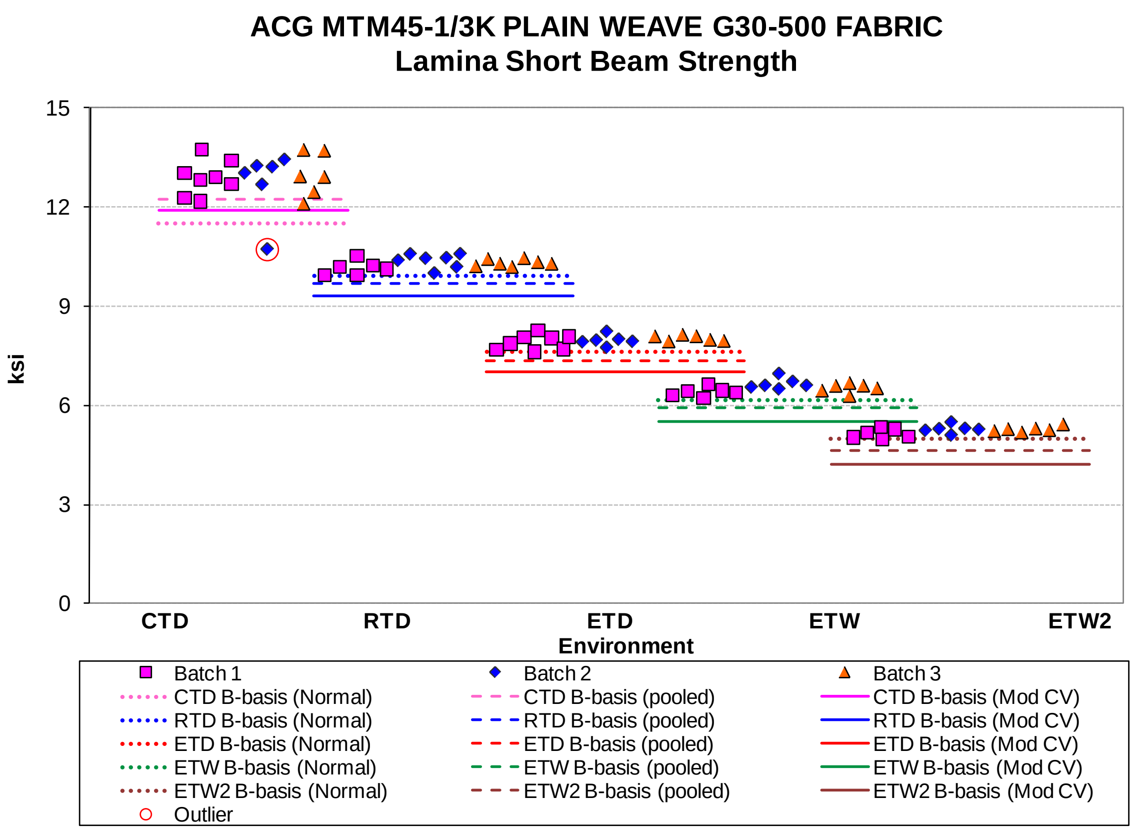

Figure 7: Batch plot for Short Beam Strength as measured

Short Beam Strength (ksi) Statistics					
Env	CTD	RTD	ETD	ETW	ETW2
Mean	12.863	10.293	7.970	6.532	5.241
Stdev	0.701	0.194	0.175	0.178	0.132
CV	5.447	1.888	2.199	2.729	2.515
Mod CV	6.723	6.000	6.000	6.000	6.000
Min	10.727	9.957	7.627	6.219	4.995
Max	13.736	10.583	8.281	6.973	5.510
No. Batches	3	3	3	3	3
No. Spec.	20	20	20	18	18
Basis values and/or estimates without overrides					
B-basis Value	11.514	9.919	7.633	6.180	4.980
A-estimate	10.554	9.653	7.393	5.931	4.796
Method	Normal	Normal	Normal	Normal	Normal
Pooled basis values and/or estimates with recommended overrides					
B-basis Value	12.257	9.687	7.365	5.920	4.628
A-estimate	11.857	9.287	6.964	5.520	4.229
Mod. CV basis values and/or estimates with recommended overrides					
B-basis Value	11.881	9.312	6.989	5.540	4.249
A-estimate	11.232	8.662	6.340	4.892	3.601
Method	pooled	pooled	pooled	pooled	pooled

Table 4-12: Statistics and Basis Values for SBS Strength data

5. Laminate Test Results, Statistics and Basis Values

Many of the laminate tests were performed with one batch only. This is insufficient data to produce basis values that meet the requirements of CMH-17 Rev G, so only estimates are provided. Estimates were prepared using the lamina variability method documented in section 2.4 or by pooling with the other environments when appropriate.

5.1 Unnotched Tension (UNT1, UNT2, UNT3) Properties

5.1.1 Quasi Isotropic Un-notched Tension (UNT1) Properties

The normalized UNT1 CTD and RTD data did not pass the Anderson-Darling k-sample test for batch-to-batch variation. This means those datasets require the ANOVA method to compute basis values which may result in overly conservative basis values. However, they both pass the ADK test under the modified CV transformation. Pooling was appropriate for the modified CV basis value computations. The as measured data did not fail any tests and pooling across all environments was acceptable. There was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G for the ETW2 environment, which had tested specimens from batch one only. Estimates are provided for that condition.

There were two outliers in the normalized data, one of which was also an outlier for the as measured data. Both outliers were in the RTD data and both were outliers before but not after pooling the three batches. One is on the low side of batch one (this was an outlier in both the normalized and the as measured data), the other is on the high side of batch three (this was an outlier in the normalized data only). Both were retained for this analysis. Statistics, estimates and basis values are given for the UNT1 strength data in Table 4-13. Statistics for the modulus data are given in Table 4-14. The normalized data, B-estimates and B-basis values are shown graphically in Figure 8.

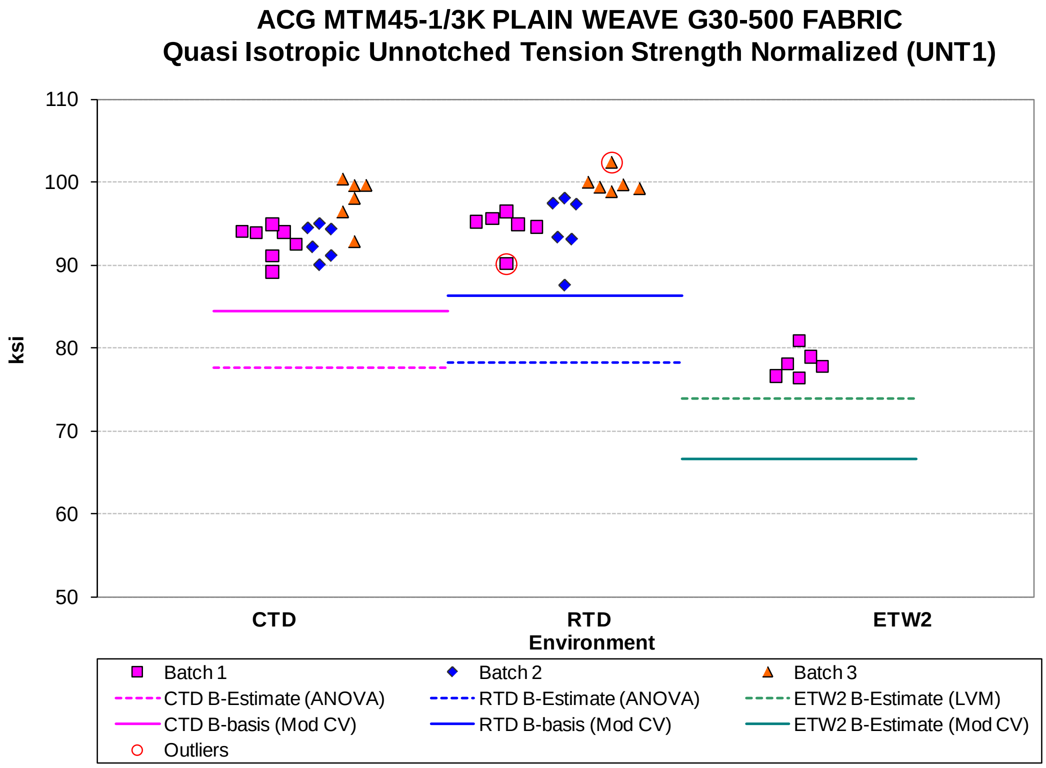

Figure 8: Batch plot for UNT1 Strength normalized

Unnotched Tension Properties (UNT1) Strength (ksi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	94.449	96.419	78.128	92.957	94.785	77.486
Stdev	3.211	3.495	1.677	2.579	3.038	1.519
CV	3.400	3.625	2.146	2.774	3.205	1.960
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	89.185	89.092	76.368	89.079	87.727	76.167
Max	100.389	102.414	80.946	97.408	99.680	80.300
No. Batches	3	3	1	3	3	1
No. Spec.	19	18	6	19	18	6
Basis values and/or estimates						
B-basis Value				88.155	89.959	
B-estimate	77.703	78.317	73.924			71.950
A-estimate	65.756	65.406	NA	84.892	86.701	68.797
Method	ANOVA	ANOVA	LVM	pooled	pooled	pooled
Modified CV basis values and/or estimates						
B-basis Value	84.420	86.339		83.085	84.863	
B-estimate			66.565			66.104
A-estimate	77.604	79.534	59.981	76.375	78.164	59.623
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-13: Statistics and Basis Values for UNT1 Strength data

Unnotched Tension Properties (UNT1) Modulus (msi)				
	Normalized		As Measured	
Env	CTD	RTD	CTD	RTD
Mean	6.611	6.455	6.509	6.347
Stdev	0.107	0.097	0.132	0.131
CV	1.621	1.508	2.028	2.068
Modified CV	6.000	6.000	6.000	6.000
Min	6.464	6.277	6.258	6.121
Max	6.798	6.667	6.671	6.574
No. Batches	3	3	3	3
No. Spec.	19	18	19	18

ETW2 Modulus data not reported due to suspected improper strain gage instrumentations.

Table 4-14: Statistics for UNT1 Modulus Data

5.1.2 “Soft” Unnotched Tension (UNT2) Properties

This property had data from only one batch available, so there was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G. B-estimates were prepared using the LVM method. There were no outliers. Statistics and A- and B-estimates are given for UNT2 normalized strength data in Table 4-15. Statistics for the modulus data are given in Table 4-16. The data and B-estimates are shown graphically in Figure 9.

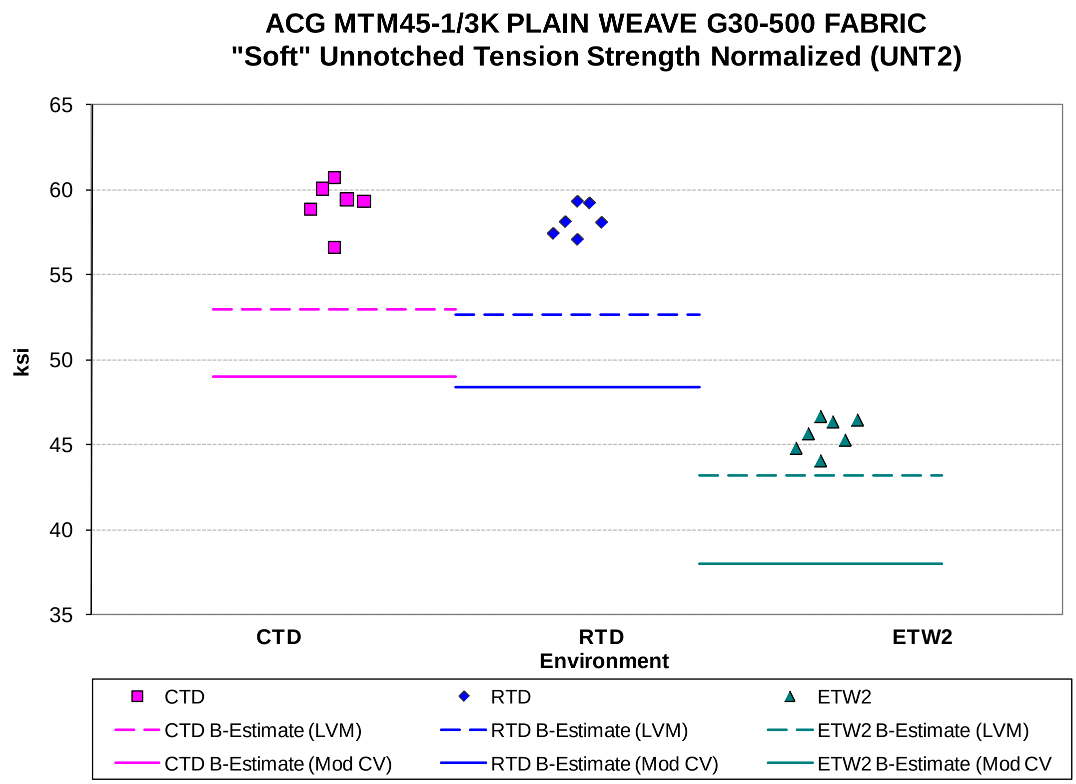

Figure 9: Batch plot for UNT2 Strength normalized

Unnotched Tension Properties (UNT2) Strength (ksi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	59.186	58.233	45.638	58.283	56.838	44.472
Stdev	1.419	0.931	0.960	1.680	0.878	0.860
CV	2.397	1.598	2.103	2.882	1.544	1.933
Modified CV	8.000	8.000	8.000	8.000	8.000	8.000
Min	56.623	57.080	44.094	55.196	55.653	43.241
Max	60.761	59.364	46.692	60.348	57.970	45.395
No. Batches	1	1	1	1	1	1
No. Spec.	6	6	7	6	6	7
LVM B-estimates						
B-estimate	53.045	52.681	43.244	51.466	51.094	41.965
Modified CV LVM B-estimates						
B-estimate	49.016	48.445	38.051	48.268	47.285	37.079

Table 4-15: Statistics and Basis Values for UNT2 Strength data

Unnotched Tension Properties (UNT2) Modulus (msi)				
	Normalized		As Measured	
Env	CTD	RTD	CTD	RTD
Mean	4.327	4.121	4.260	4.023
Stdev	0.073	0.068	0.065	0.065
CV	1.683	1.646	1.519	1.607
Modified CV	6.000	6.000	6.000	6.000
Min	4.237	4.023	4.188	3.922
Max	4.421	4.218	4.346	4.111
No. Batches	1	1	1	1
No. Spec.	6	6	6	6

ETW2 Modulus data not reported due to suspected improper strain gage instrumentations.

Table 4-16: Statistics for UNT2 Modulus Data

5.1.3 "Hard" Unnotched Tension (UNT3) Properties

This property had data from only one batch available, so there was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G. B-estimates were prepared using the LVM method. There were no outliers. Statistics and A- and B-estimates are given for UNT3 strength data Table 4-17. Statistics for the modulus data are given in Table 4-18. The normalized data and B-estimates are shown graphically in Figure 10.

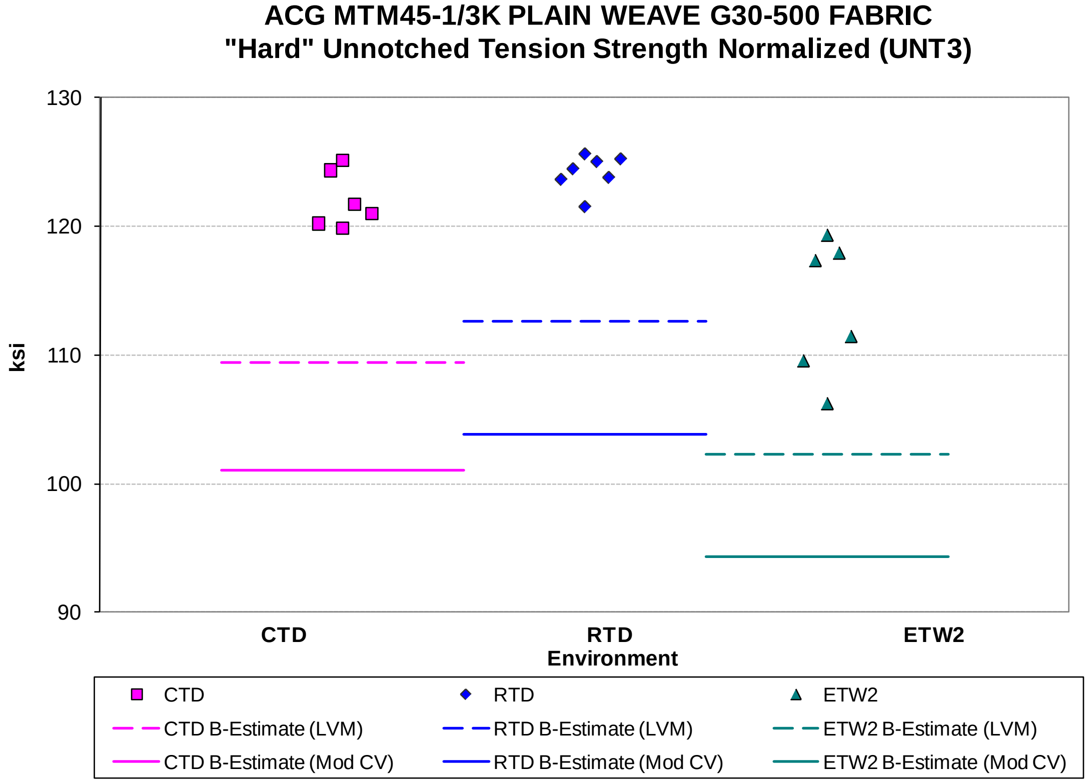

Figure 10: Batch plot for UNT3 Strength normalized

Unnotched Tension Properties (UNT3) Strength (ksi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	122.052	124.202	113.656	121.112	122.671	112.316
Stdev	2.193	1.383	5.305	1.793	1.075	4.916
CV	1.796	1.114	4.668	1.481	0.876	4.377
Modified CV	8.000	8.000	8.000	8.000	8.000	8.000
Min	119.865	121.539	106.249	118.416	121.353	105.272
Max	125.129	125.636	119.335	123.145	124.290	118.419
No. Batches	1	1	1	1	1	1
No. Spec.	6	7	6	6	7	6
LVM B-estimates						
B-estimate	109.388	112.626	102.345	106.946	110.551	101.834
Modified CV LVM B-estimates						
B-estimate	101.079	103.793	94.271	100.300	102.514	93.159

Table 4-17: Statistics and Basis Values for UNT3 Strength data

Unnotched Tension Properties (UNT3) Modulus (msi)				
	Normalized		As Measured	
Env	CTD	RTD	CTD	RTD
Mean	8.324	8.159	8.261	8.058
Stdev	0.126	0.139	0.172	0.121
CV	1.516	1.708	2.077	1.498
Modified CV	6.000	6.000	6.000	6.000
Min	8.156	7.946	8.076	7.942
Max	8.472	8.389	8.543	8.280
No. Batches	1	1	1	1
No. Spec.	6	7	6	7

ETW2 Modulus data not reported due to suspected improper strain gage instrumentations.

Table 4-18: Statistics for UNT3 Modulus Data

5.2 Unnotched Compression (UNC1, UNC2, UNC3) Properties

5.2.1 Quasi Isotropic Unnotched Compression (UNC1) Properties

There was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G for the ETW environment, which had tested specimens from batch one only. Estimates are provided for that condition. The as measured RTD data failed the Anderson-Darling normality test. The Weibull distribution provided the best fit to this data. Both the normalized and the as measured ETW data also failed the Anderson-Darling normality test.

There were three outliers in the UNC1 data. One outlier was on the low side of batch three of the RTD data. It was an outlier for both the as measured and normalized data. The second outlier was on the high side of batch one in the ETW environment. It was an outlier for both the as measured and normalized data. The third outlier was on the low side of batch one in the ETW2 environment. It was an outlier only for the as measured data. All three outliers were outliers only for the batch, not the three batches pooled together. All three outliers were retained for this analysis.

Statistics, estimates and basis values are given for the UNC1 normalized strength data in Table 4-19. Statistics for the modulus data are given in Table 4-20. The normalized data, B-estimates and B-basis values are shown graphically in Figure 11.

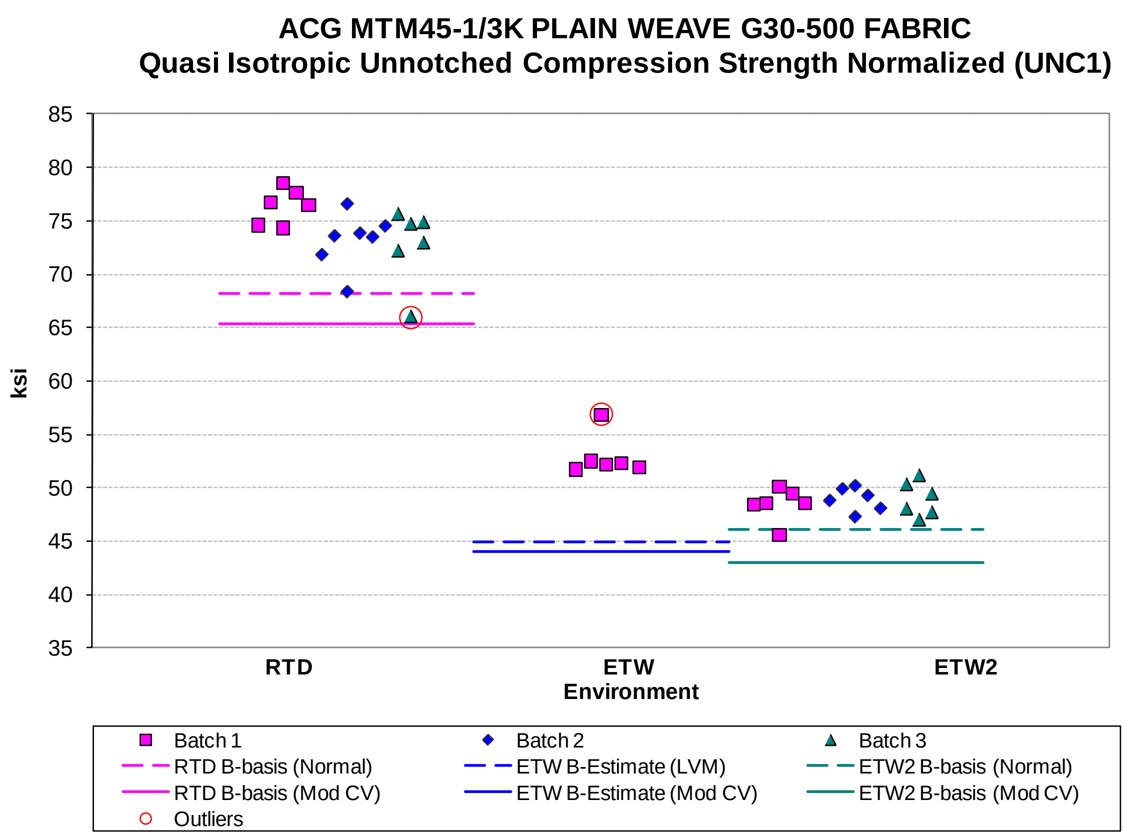

Figure 11: Batch plot for UNC1 Strength normalized

Unnotched Compression Properties (UNC1) Strength (ksi) Statistics						
	Normalized			As Measured		
Env	RTD	ETW	ETW2	RTD	ETW	ETW2
Mean	74.048	52.914	48.786	74.697	53.050	48.763
Stdev	3.010	1.956	1.380	3.153	1.833	1.407
CV	4.065	3.697	2.828	4.221	3.455	2.885
Modified CV	6.033	8.000	6.000	6.110	8.000	6.000
Min	66.078	51.746	45.568	66.587	51.823	45.488
Max	78.552	56.871	51.224	79.944	56.692	51.660
No. Batches	3	1	3	3	1	3
No. Spec.	19	6	18	19	6	18
Basis values and/or estimates						
B-basis Value	68.181		46.062	67.910		45.986
B-estimate		44.982			45.155	
A-estimate	64.015	NA	44.132	60.889	NA	44.017
Method	Normal	LVM	Normal	Weibull	LVM	Normal
Modified CV basis values and/or estimates						
B-basis Value	65.341		43.007	NA		42.987
B-estimate		44.020			44.133	
A-estimate	59.168	NA	38.920	NA	NA	38.901
Method	Normal	LVM	Normal	NA	LVM	Normal

Table 4-19: Statistics and Basis Values for UNC1 Strength data

Unnotched Compression Properties (UNC1) Modulus (msi) Statistics						
	Normalized			As Measured		
Env	RTD	ETW	ETW2	RTD	ETW	ETW2
Mean	5.938	5.608	5.584	5.984	5.624	5.581
Stdev	0.180	0.331	0.198	0.168	0.363	0.186
CV	3.026	5.894	3.543	2.803	6.447	3.326
Modified CV	6.000	6.947	6.000	6.000	7.224	6.000
Min	5.585	5.079	5.027	5.689	5.046	5.070
Max	6.342	5.961	5.848	6.404	6.055	5.842
No. Batches	3	1	3	3	1	3
No. Spec.	18	6	18	18	6	18

Table 4-20: Statistics for UNC1 Modulus data

5.2.2 "Soft" Unnotched Compression (UNC2) Properties

This property had data from only one batch available, so there was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G, so only estimates are provided. The only test failure was the normality test for the RTD data. This failure was due to an outlier on the low side in the single batch available. If that outlier was removed, the remaining data values pass the normality test, so normality of the underlying population is a reasonable assumption.

There was one outlier in the UNC2 data. It was in batch one of the RTD data. It was an outlier for both the normalized and the as measured data. The outlier was retained for this analysis. Statistics and A- and B-estimates are given for UNC2 strength data in Table 4-21. Statistics for the modulus data are given in Table 4-22. The data and B-estimates are shown graphically in Figure 12.

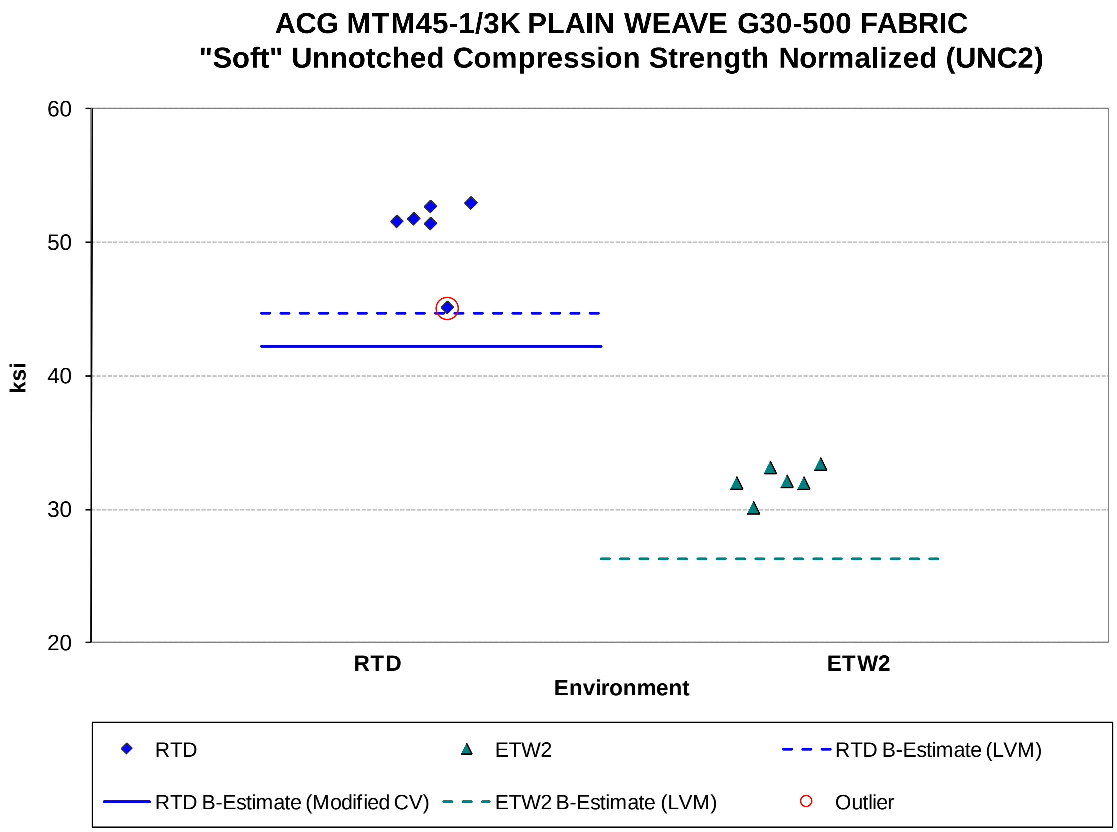

Figure 12: Batch plot for UNC2 Strength normalized

Unnotched Compression Properties (UNC2) Strength (ksi) Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	50.881	32.157	51.017	31.883
Stdev	2.905	1.161	2.416	1.207
CV	5.710	3.612	4.736	3.786
Modified CV	8.000	8.000	8.000	8.000
Min	45.089	30.158	46.220	30.269
Max	52.915	33.443	52.654	33.785
No. Batches	1	1	1	1
No. Spec.	6	6	6	6
LVM B-estimates				
B-estimate	44.687	26.336	44.782	25.820
Modified CV LVM B-estimates				
B-estimate	42.203	NA	42.315	NA

Table 4-21: Statistics and Basis Values for UNC2 Strength data normalized

Unnotched Compression Properties (UNC2) Modulus (msi) Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	3.880	3.457	3.893	3.429
Stdev	0.214	0.164	0.231	0.195
CV	5.511	4.748	5.923	5.691
Modified CV	6.756	6.374	6.961	6.846
Min	3.663	3.222	3.749	3.136
Max	4.230	3.646	4.291	3.660
No. Batches	1	1	1	1
No. Spec.	6	6	6	6

Table 4-22: Statistics for UNC2 Modulus data

5.2.3 “Hard” Unnotched Compression (UNC3) Properties

This property had data from only one batch available, so there was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G. Thus only estimates are provided. The only test failure was the normality test for the normalized ETW2 data. This failure was due to an outlier on the low side in the single batch available. It was an outlier in both the as measured and normalized datasets. It was retained for this analysis. If that outlier was removed, the remaining data values pass the normality test, so normality of the underlying population is a reasonable assumption. Statistics and A- and B-estimates are given for UNC3 strength data Table 4-23. Statistics for the modulus data are given in Table 4-24. The normalized data and B-estimates are shown graphically in Figure 13.

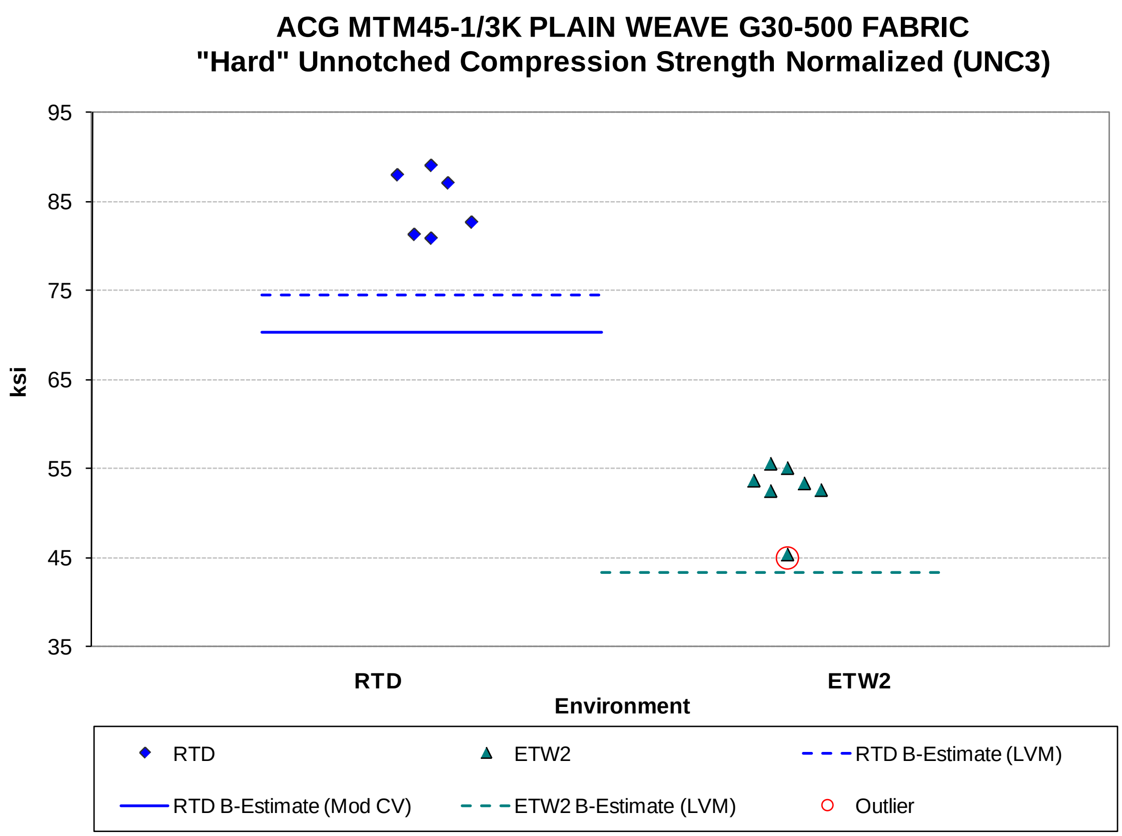

Figure 13: Batch plot for UNC3 Strength normalized

Unnotched Compression Properties (UNC3) Strength (ksi) Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	84.843	52.640	85.575	52.833
Stdev	3.654	3.414	3.999	3.348
CV	4.307	6.485	4.673	6.336
Modified CV	8.000	8.000	8.000	8.000
Min	80.854	45.367	81.102	45.738
Max	89.100	55.635	89.402	55.912
No. Batches	1	1	1	1
No. Spec.	6	7	6	7
LVM B-estimates				
B-estimate	74.639	43.359	75.116	43.047
Modified CV LVM B-estimates				
B-estimate	70.372	NA	70.979	NA

Table 4-23: Statistics and Basis Values for UNC3 Strength data

Unnotched Compression Properties (UNC3) Modulus (msi) Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	7.516	7.670	7.582	7.699
Stdev	0.093	0.157	0.116	0.136
CV	1.242	2.053	1.530	1.763
Modified CV	6.000	6.000	6.000	6.000
Min	7.392	7.476	7.404	7.513
Max	7.654	7.884	7.738	7.834
No. Batches	1	1	1	1
No. Spec.	7	7	7	7

Table 4-24: Statistics for UNC3 Modulus data

5.3 Laminate Short Beam Strength (LSBS)

The Laminate Short Beam Strength data is not normalized. The data could not be pooled across environments due to a failure of Levene's test. However, an override is recommended for Levene's test for the modified CV basis values.

There was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G for the ETW environment, which had tested seven specimens from batch one only. That data was included in computing the pooled basis values. Estimates from the LVM approach and the ASAP modified CV method are provided for the ETW condition.

There were no outliers. Statistics, estimates and basis values are given for the LSBS strength data in Table 4-25. The data, B-estimates and B-basis values are shown graphically in Figure 14.

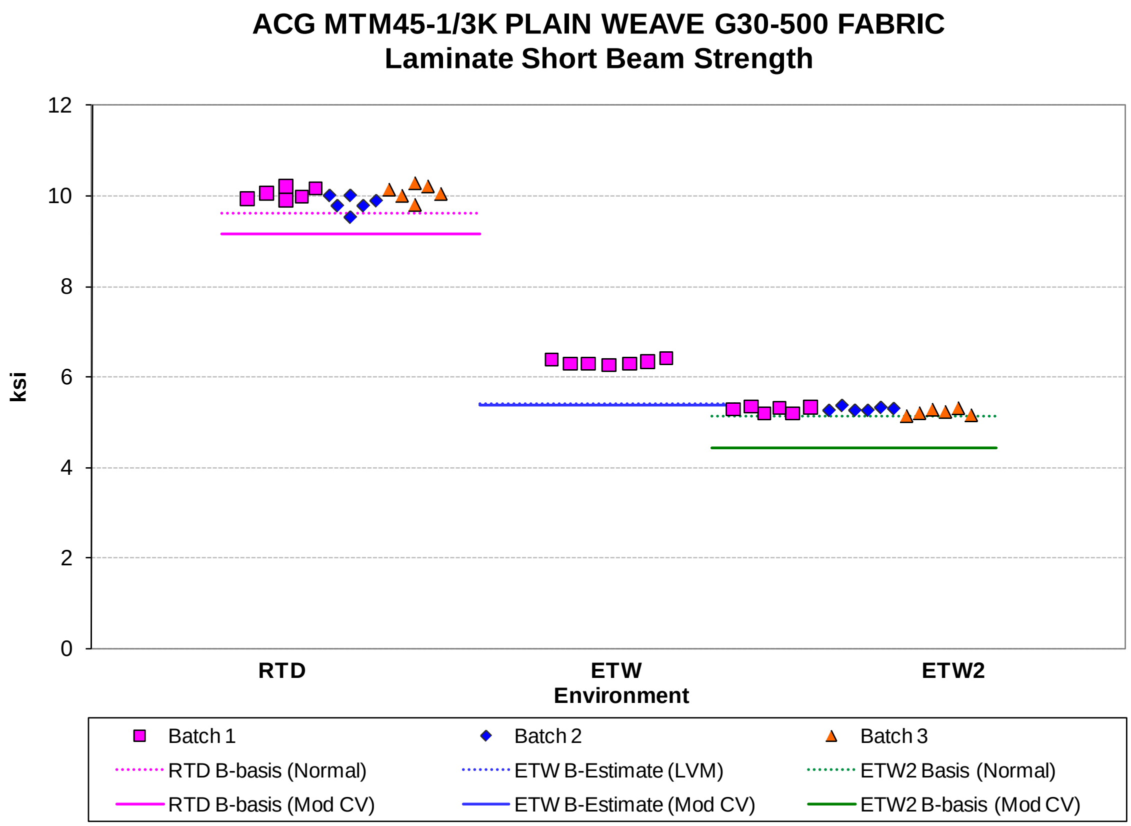

Figure 14: Batch plot for LSBS Strength as measured

Laminate Short Beam Strength (ksi) Statistics			
Env	RTD	ETW	ETW2
Mean	9.992	6.328	5.261
Stdev	0.191	0.059	0.064
CV	1.907	0.933	1.223
Modified CV	6.000	6.000	6.000
Min	9.530	6.264	5.142
Max	10.296	6.421	5.356
No. Batches	3	1	3
No. Spec.	18	7	18
Basis values and/or estimates			
B-basis Value	9.616		5.134
B-estimate		5.407	
A-estimate	9.349	NA	5.044
Method	Normal	LVM	Normal
Modified CV Basis values and/or estimates with recommended override			
B-basis Value	9.155		4.424
B-estimate		5.390	
A-estimate	8.590	4.840	3.859
Method	pooled	pooled	pooled

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

5.4 Open Hole Tension (OHT1, OHT2, OHT3) Properties

5.4.1 Quasi Isotropic Open Hole Tension (OHT1)

None of the normalized OHT1 data passed the Anderson-Darling k-sample test for batch-to-batch variation. Only the as measured RTD environment passed the ADK test. This means that the ANOVA method is used to compute basis values which may result in overly conservative basis values. However, the CTD and RTD environments, both normalized and as measured, pass the ADK test under the modified CV transformation and the pooled dataset passes the normality test.

An override of the ADK test is recommended for both the normalized and as measured ETW2 data with the modified CV method. For the ETW2 data, the batch CV's are uncharacteristically low for batches one and two (1.35 and 0.74 respectively for the normalized data), while batch three is barely within the expected range (4.25). This is a situation described in CMH-17 Rev G section 8.3.10.1 as permissible to override the ADK test results and pool batches. Overriding this ADK test result allows pooling across environments and provides more realistic basis values for the ETW and ETW2 environments. There is insufficient data to produce CMH-17 Rev G publishable B-basis values for the ETW environment, so only estimates are provided for that condition. Estimates were computed using the LVM approach and including the data in ASAP for pooling across environments.

There were two outliers in the normalized data and none in the as measured data. The outliers were both from batch two. One outlier was in the CTD data on the high side, the other was in the ETW2 data on the low side. Both are outliers before, but not after, pooling the three batches for their respective environments. Both were retained for this analysis. Statistics, estimates and basis values are given for the OHT1 strength data in Table 4-26. The data, B-estimates and the B-basis values are shown graphically in Figure 15.

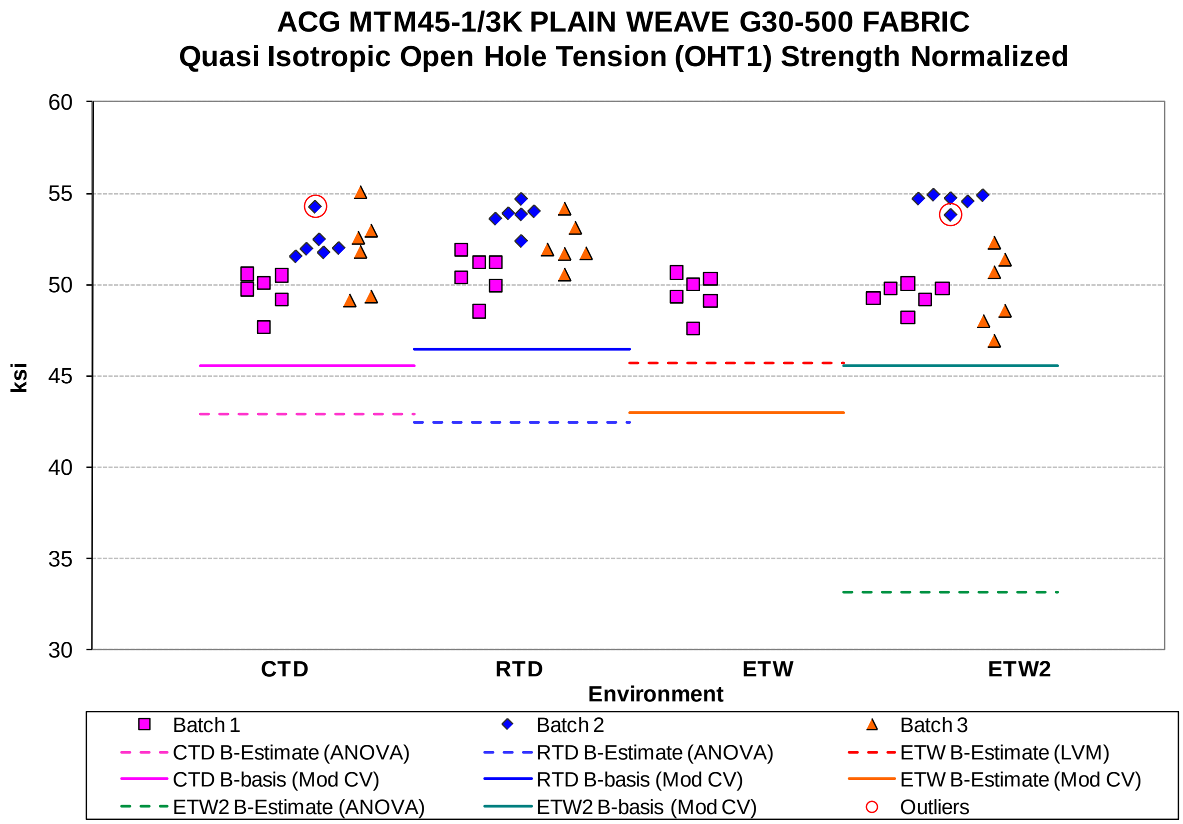

Figure 15: Batch plot for OHT1 Strength normalized

Open Hole Tension (OHT1) Strength (ksi) Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	51.269	52.164	49.516	51.214	50.809	51.951	48.735	50.741
Stdev	1.897	1.701	1.108	2.770	1.509	1.810	0.651	2.226
CV	3.700	3.260	2.237	5.410	2.971	3.485	1.336	4.387
Modified CV	6.000	6.000	6.000	6.705	6.000	6.000	6.000	6.194
Min	47.691	48.549	47.593	46.921	48.426	48.796	47.915	47.939
Max	55.038	54.717	50.674	54.947	53.647	54.974	49.616	53.970
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	18	6	18	18	18	6	18
Basis values and/or estimates without overrides								
B-basis Value						48.377		
B-estimate	42.944	42.497	45.709	33.191	42.600		44.299	35.498
A-estimate	37.011	35.600	NA	20.326	36.744	45.845	NA	24.617
Method	ANOVA	ANOVA	LVM	ANOVA	ANOVA	Normal	LVM	ANOVA
Modified CV basis values and/or estimates with recommended overrides								
B-basis Value	45.640	46.535		45.586	45.372	46.514		45.304
B-estimate			43.027				42.466	
A-estimate	41.898	42.793	39.388	41.844	41.757	42.898	38.950	41.689
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-26: Statistics and Basis Values for OHT1 Strength data

5.4.2 "Soft" Open Hole Tension (OHT2)

Only the as measured data from the CTD environment meets the requirements of CMH-17 Rev G. There was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G for the RTD and ETW2 environments, so only estimates are provided for those conditions. The normalized CTD data did not pass the Anderson-Darling k-sample test for batch-to-batch variation. This means that dataset requires the ANOVA method to compute basis values which may result in overly conservative basis values. However, the CTD data does pass the normality test and it passes the ADK test under the modified CV transformation, so modified CV values are provided based on pooling the data across environments.

There were no outliers. Statistics, estimates and basis values are given for the OHT2 strength data in Table 4-27. The data, B-estimates and B-basis values are shown graphically in Figure 16.

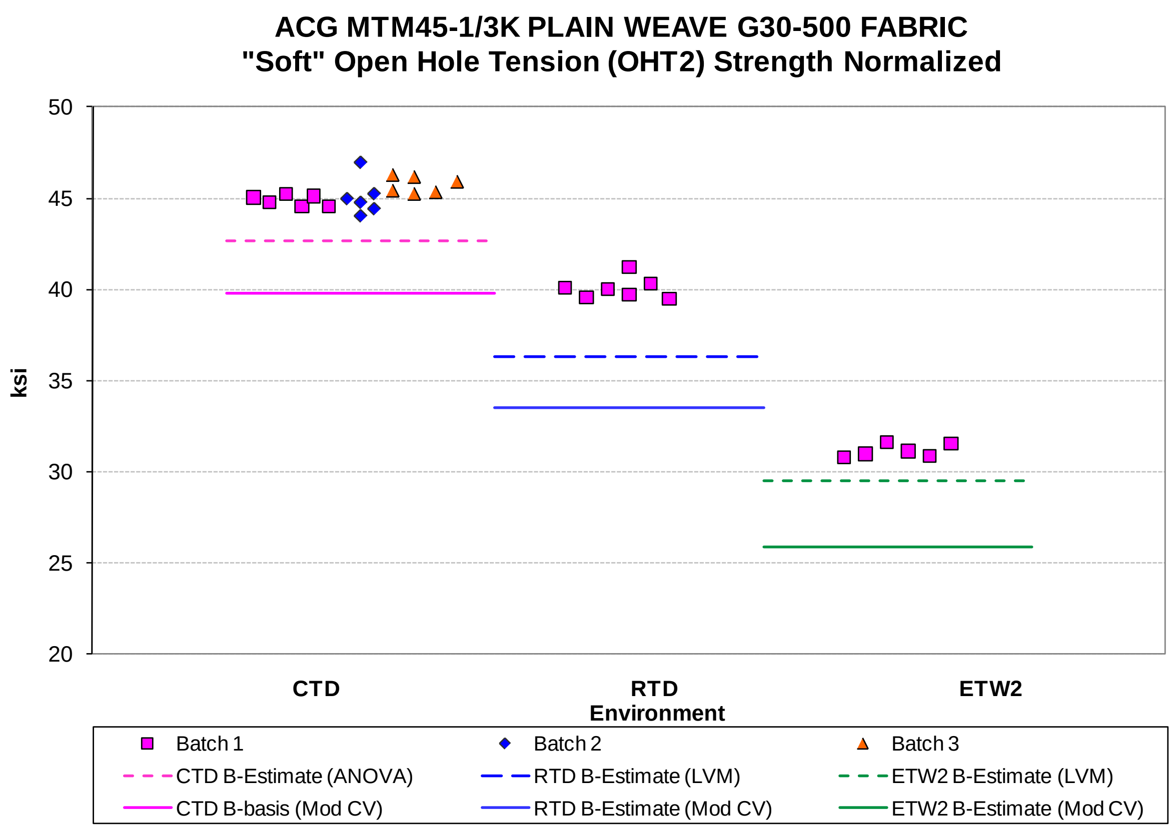

Figure 16: Batch plot for OHT2 Strength normalized

Open Hole Tension (OHT2) Strength (ksi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	45.234	40.061	31.175	44.224	39.256	30.481
Stdev	0.739	0.597	0.342	0.683	0.675	0.574
CV	1.633	1.491	1.096	1.545	1.719	1.884
Modified CV	6.000	8.000	8.000	6.000	8.000	8.000
Min	44.018	39.483	30.820	43.314	38.568	29.905
Max	46.987	41.226	31.620	45.983	40.559	31.346
No. Batches	3	1	1	3	1	1
No. Spec.	18	7	6	18	7	6
Basis values and/or estimates						
B-basis Value				42.875		
B-estimate	42.713	36.327	29.498		35.378	28.719
A-estimate	40.918	NA	NA	41.919	NA	NA
Method	ANOVA	LVM	LVM	Normal	LVM	LVM
Modified CV basis values and/or estimates						
B-basis Value	39.876			38.985		
B-estimate		33.478	25.858		32.806	25.283
A-estimate	36.086	NA	NA	35.280	NA	NA
Method	Normal	LVM	LVM	Normal	LVM	LVM

Table 4-27: Statistics and Basis Values for OHT2 Strength data

5.4.3 "Hard" Open Hole Tension (OHT3)

Only the CTD data meets the requirements for publication in CMH-17 Rev G. There was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G for the RTD and ETW2 environments, so only estimates are provided for those conditions. The CTD data, both normalized and as measured, did not pass the Anderson-Darling k-sample test for batch-to-batch variation. This means that dataset requires the ANOVA method to compute basis values which may result in overly conservative basis values. However, the CTD data does pass the normality test, and it passes the ADK test under the modified CV transformation so modified CV values can be provided.

There were no outliers. Statistics, estimates and basis values are given for the OHT3 strength data in Table 4-28. The data, B-estimates and B-basis values are shown graphically in Figure 17.

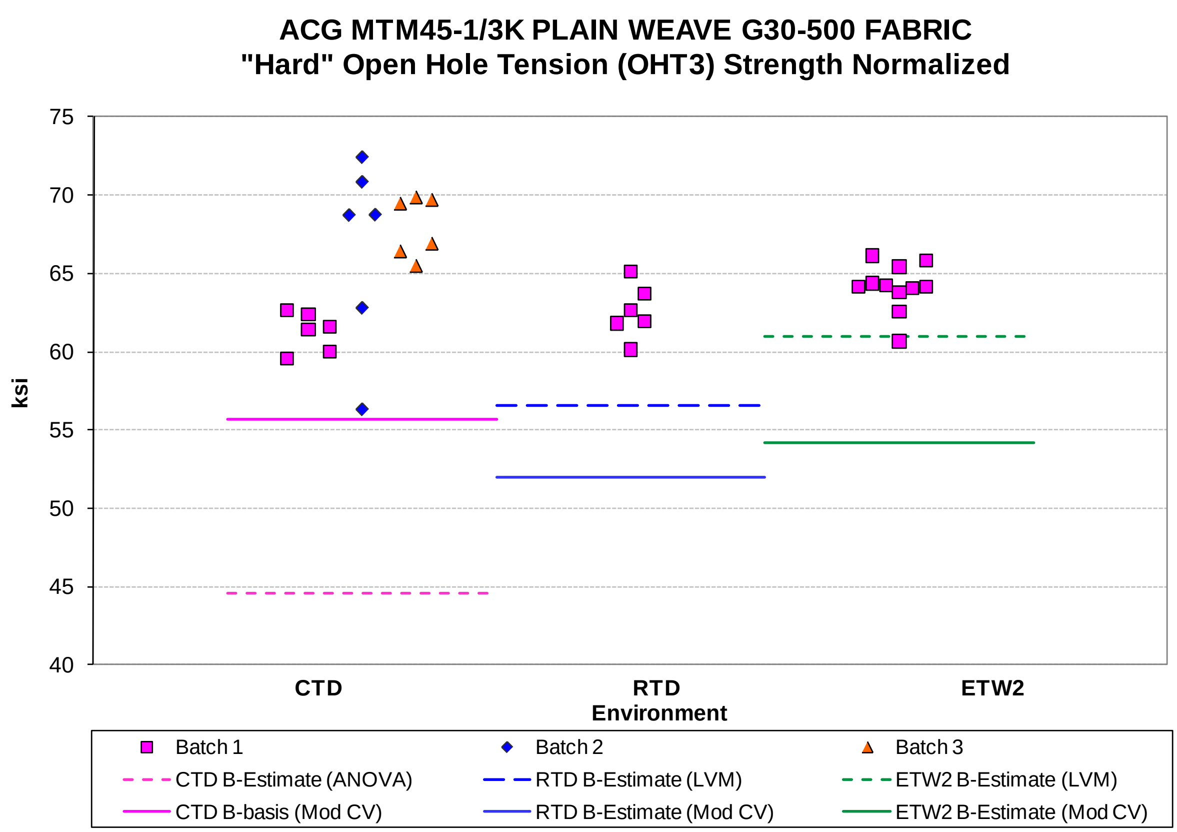

Figure 17: Batch plot for OHT3 Strength normalized

Open Hole Tension (OHT3) Strength (ksi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	65.309	62.558	64.131	64.402	62.511	63.527
Stdev	4.591	1.710	1.529	4.504	1.608	1.711
CV	7.030	2.734	2.384	6.993	2.572	2.694
Modified CV	7.515	8.000	8.000	7.497	8.000	8.000
Min	56.359	60.143	60.662	56.550	60.160	59.954
Max	72.426	65.110	66.147	72.590	64.682	66.147
No. Batches	3	1	1	3	1	1
No. Spec.	18	6	11	18	6	11
Basis values and/or estimates						
B-estimate	44.631	56.594	60.996	45.242	56.194	60.189
A-estimate	29.892	NA	NA	31.587	NA	NA
Method	ANOVA	LVM	LVM	ANOVA	LVM	LVM
Modified CV basis values and/or estimates						
B-basis Value	55.619			54.871		
B-estimate		52.043	54.194		52.005	53.683
A-estimate	48.765	NA	NA	48.128	NA	NA
Method	Normal	LVM	LVM	Normal	LVM	LVM

Table 4-28: Statistics and Basis Values for OHT3 Strength data

5.5 Open Hole Compression (OHC1, OHC2, OHC3) Properties

5.5.1 Quasi Isotropic Open Hole Compression 1 (OHC1)

The OHC1 strength data is able to be pooled and meets all requirements of CMH-17 Rev G with the exception of the ETW environment which lacks sufficient data, so only estimates are provided for that condition. The data meets all requirements for pooling across environments.

There is one outlier on the high side of batch three of the normalized RTD data. It is an outlier both before and after pooling the three batches. It was retained for this analysis. Statistics, estimates and basis values are given for the OHC1 strength data in Table 4-29. The normalized data, B-estimates and B-basis values are shown graphically in Figure 18.

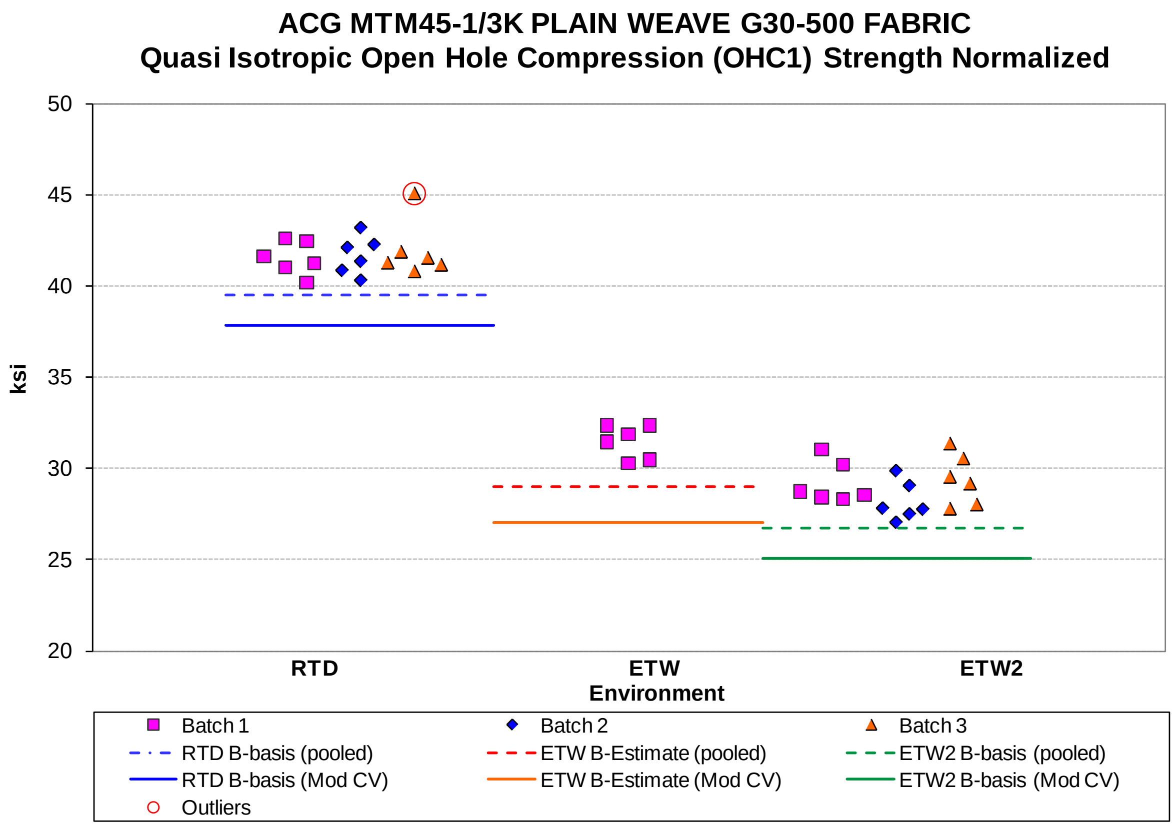

Figure 18: Batch plot for OHC1 Strength normalized

Open Hole Compression (OHC1) Strength (ksi) Statistics						
	Normalized			As Measured		
Env	RTD	ETW	ETW2	RTD	ETW	ETW2
Mean	41.707	31.460	28.915	40.714	30.584	28.003
Stdev	1.151	0.915	1.260	1.095	1.131	1.097
CV	2.759	2.908	4.357	2.690	3.698	3.919
Modified CV	6.000	6.000	6.179	6.000	6.000	6.000
Min	40.200	30.259	27.028	39.179	29.000	26.531
Max	45.064	32.364	31.343	43.327	31.979	29.774
No. Batches	3	1	3	3	1	3
No. Spec.	18	6	18	18	6	18
Basis values and/or estimates						
B-basis Value	39.594		26.802	38.731		26.020
B-estimate		29.037			28.311	
A-estimate	38.165	27.655	25.373	37.390	27.014	24.679
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV basis values and/or estimates						
B-basis Value	37.853		25.061	36.994		24.283
B-estimate		27.041			26.319	
A-estimate	35.247	24.520	22.455	34.480	23.887	21.769
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

5.5.2 "Soft" Open Hole Compression (OHC2)

The ETW2 data meets the requirements of CMH-17 Rev G. There was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G for the RTD environment, so only estimates are provided. The normalized ETW2 data failed the Anderson Darling test for normality; the Weibull distribution provided the best fit to the data. Modified CV basis values are not provided for the normalized ETW2 data due to the non-normality of the dataset. There were no outliers. Statistics, estimates and basis values are given for the OHC2 strength data in Table 4-30. The normalized data, B-estimates and B-basis values are shown graphically in Figure 19.

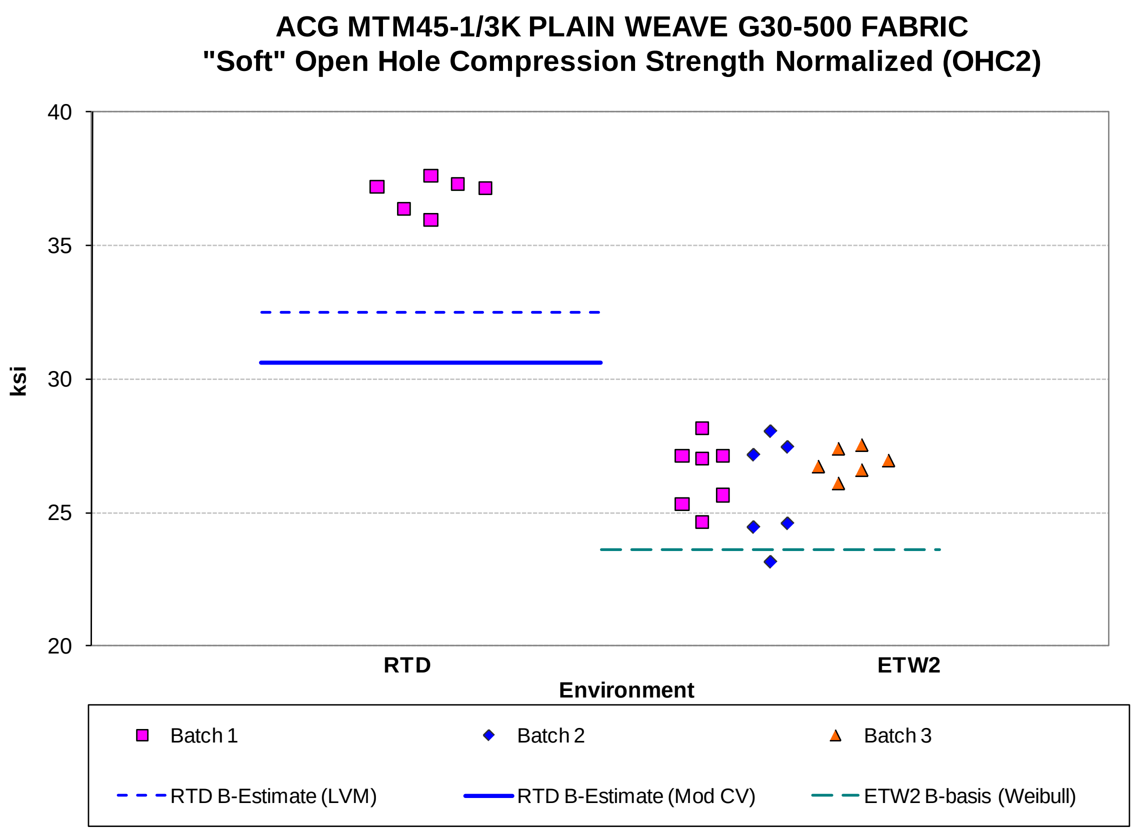

Figure 19: Batch plot for OHC2 Strength normalized

Open Hole Compression Properties (OHC2) Strength (ksi) Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	36.941	26.396	36.468	25.685
Stdev	0.626	1.373	0.420	1.305
CV	1.693	5.202	1.151	5.080
Modified CV	8.000	6.601	8.000	6.540
Min	35.968	23.182	35.761	22.659
Max	37.627	28.158	36.860	27.342
No. Batches	1	3	1	3
No. Spec.	6	19	6	19
Basis values and/or estimates				
B-basis Value		23.622		23.142
B-estimate	32.498		32.011	
A-estimate	NA	20.770	NA	21.337
Method	LVM	Weibull	LVM	Normal
Modified CV basis values and/or estimates				
B-basis Value		NA		22.411
B-estimate	30.640		30.248	
A-estimate	NA	NA	NA	20.090
Method	LVM	NA	LVM	Normal

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

5.5.3 “Hard” Open Hole Compression (OHC3)

The ETW2 data meets the requirements of CMH-17 Rev G. There was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G for the RTD environment, so only estimates are provided. There were no outliers. Statistics, estimates and basis values are given for the OHC3 strength data in Table 4-31. The normalized data, B-estimates and B-basis values are shown graphically in Figure 20.

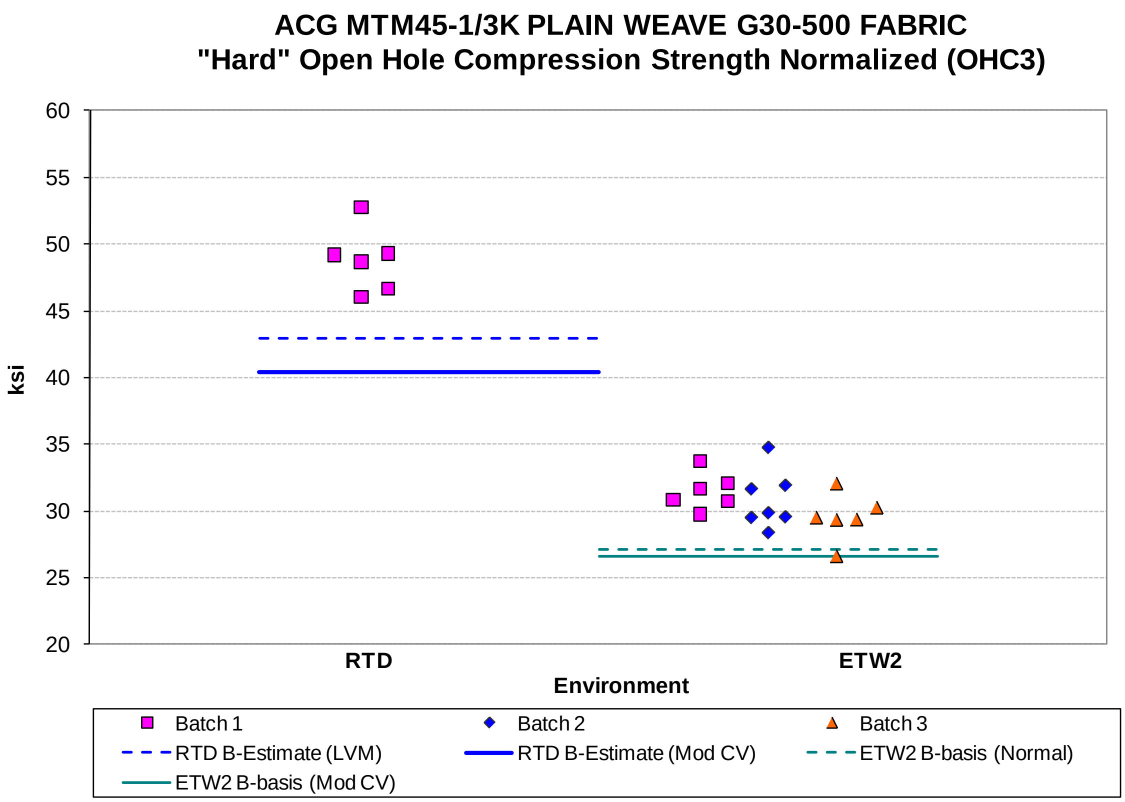

Figure 20: Batch plot for OHC3 Strength normalized

Open Hole Compression Properties (OHC3) Strength (ksi) Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	48.776	30.741	47.062	29.758
Stdev	2.379	1.894	2.397	1.960
CV	4.877	6.160	5.094	6.588
Modified CV	8.000	7.080	8.000	7.294
Min	46.048	26.682	44.065	25.623
Max	52.758	34.803	50.959	34.108
No. Batches	1	3	1	3
No. Spec.	6	20	6	20
Basis values and/or estimates				
B-basis Value		27.094		25.982
B-estimate	42.910		41.310	
A-estimate	NA	24.499	NA	23.296
Method	LVM	Normal	LVM	Normal
Modified CV basis values and/or estimates				
B-basis Value		26.548		25.577
B-estimate	40.457		39.035	
A-estimate	NA	23.569	NA	22.605
Method	LVM	Normal	LVM	Normal

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

5.6 Filled Hole Tension (FHT1, FHT2, FHT3) Properties

5.6.1 Quasi Isotropic Filled Hole Tension (FHT1)

The CTD data meets the requirements of CMH-17 Rev G. There was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G for the RTD environment, so only estimates are provided. The CTD data failed the Anderson Darling k-sample test for batch to batch variation. However, that data does pass the normality test, and passes the ADK test under the modified CV transformation, so the modified CV values are provided for that dataset.

There were no outliers. Statistics, estimates and basis values are given for the FHT1 strength data in Table 4-32. The data, B-estimates, and B-basis values are shown graphically in Figure 21.

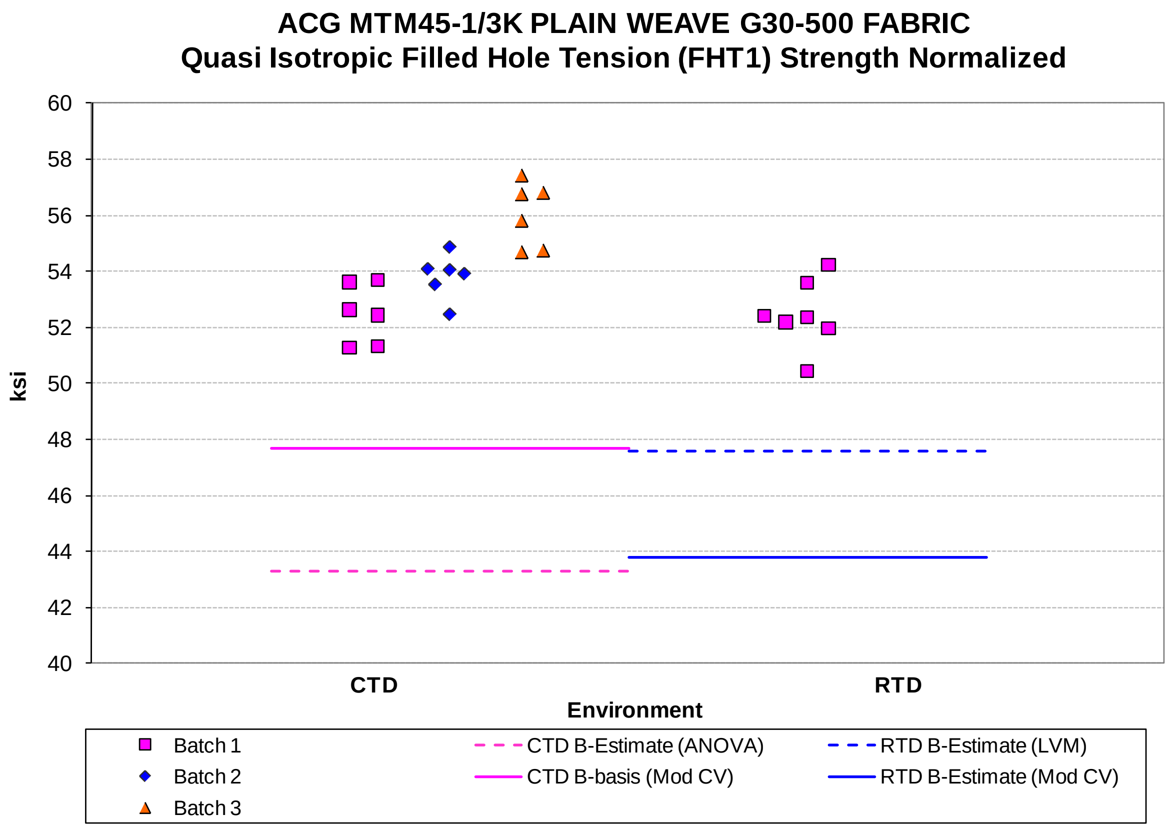

Figure 21: Batch plot for FHT1 Strength normalized

Filled Hole Tension Properties (FHT1) Strength (ksi) Statistics				
	Normalized		As Measured	
Env	CTD	RTD	CTD	RTD
Mean	54.124	52.466	53.092	51.660
Stdev	1.781	1.211	1.478	1.272
CV	3.291	2.309	2.784	2.463
Modified CV	6.000	8.000	6.000	8.000
Min	51.265	50.454	50.880	49.597
Max	57.420	54.245	55.658	53.588
No. Batches	3	1	3	1
No. Spec.	18	7	18	7
Basis values and/or estimates				
B-estimate	43.261	47.576	45.694	46.556
A-estimate	35.509	NA	40.419	NA
Method	ANOVA	LVM	ANOVA	LVM
Modified CV basis values and/or estimates				
B-basis Value	47.713		46.803	
B-estimate		43.844		43.171
A-estimate	43.178	NA	42.354	NA
Method	Normal	LVM	Normal	LVM

Table 4-32: Statistics and Basis Values for FHT1 Strength data

5.6.2 "Soft" Filled Hole Tension (FHT2)

There was data from only one batch available, so there was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G. There were no outliers or test failures. Statistics and B-estimates are given for the FHT2 strength data in Table 4-33. The normalized data and the B-estimates are shown graphically in Figure 22.

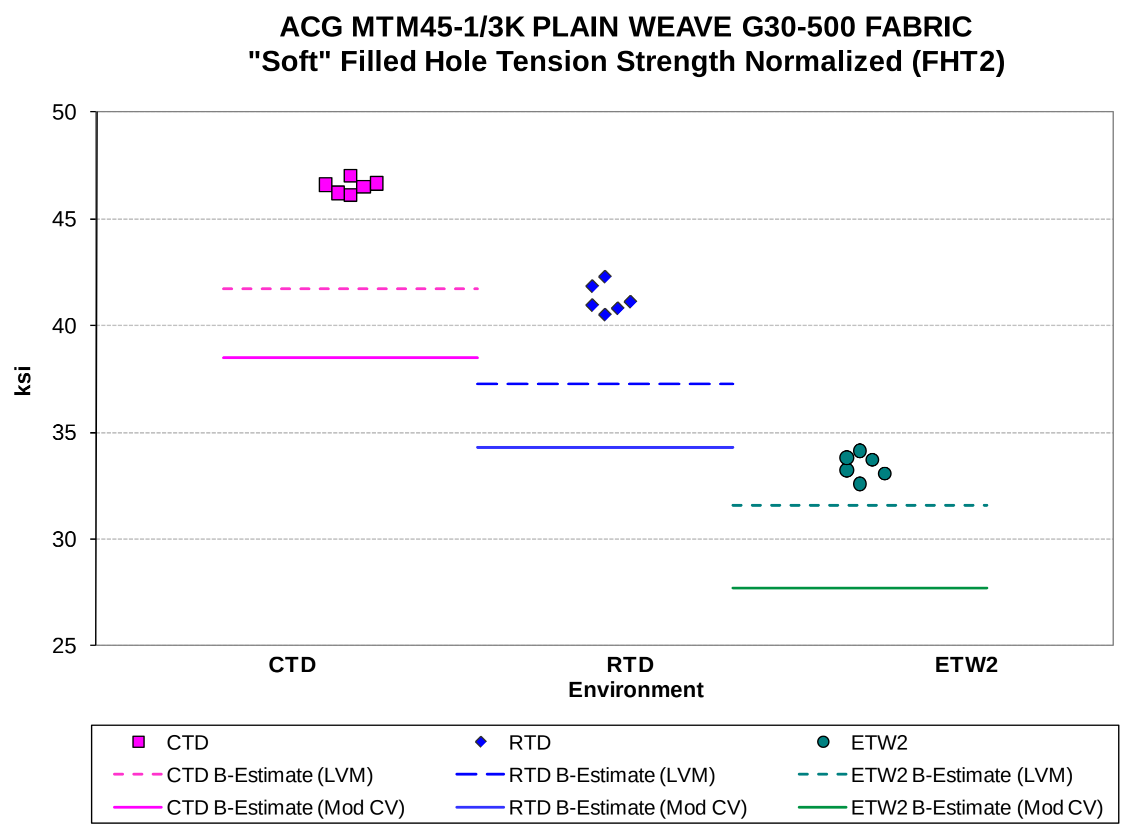

Figure 22: Batch plot for FHT2 Strength normalized

Filled Hole Tension (FHT2) Strength (ksi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	46.523	41.251	33.428	46.112	40.645	32.606
Stdev	0.325	0.667	0.566	0.585	0.705	0.638
CV	0.698	1.616	1.693	1.268	1.734	1.956
Modified CV	8.000	8.000	8.000	8.000	8.000	8.000
Min	46.124	40.518	32.588	45.264	39.717	31.946
Max	47.013	42.273	34.138	47.044	41.391	33.697
No. Batches	1	1	1	1	1	1
No. Spec.	6	6	6	6	6	6
LVM B-estimates						
B-estimate	41.696	37.318	31.629	40.719	36.538	30.720
Modified CV LVM B-estimates						
B-estimate	38.529	34.318	27.727	38.188	33.813	27.045

Table 4-33: Statistics and Basis Values for FHT2 Strength data

5.6.3 "Hard" Filled Hole Tension (FHT3)

There was data from only one batch available, so there was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G. There were no outliers or test failures. Statistics and B-estimates are given for the FHT3 strength data in Table 4-34. The normalized data and B-estimates are shown graphically in Figure 23.

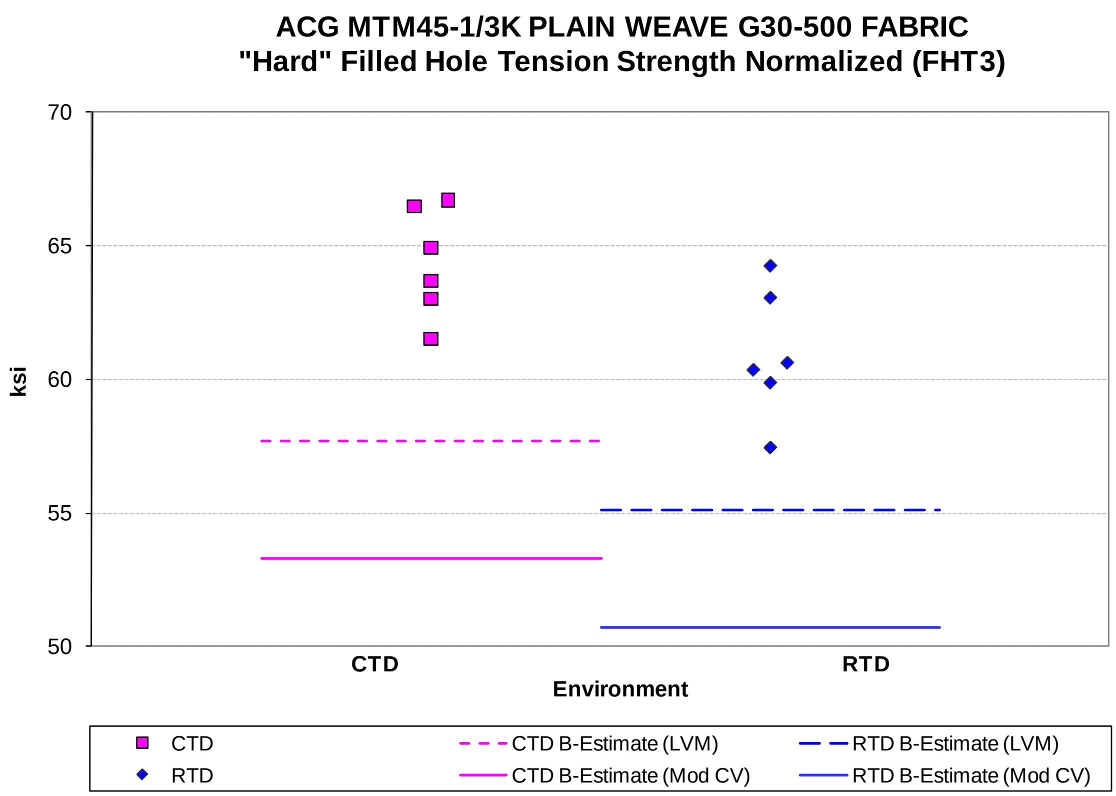

Figure 23: Batch plot for FHT3 Strength normalized

Filled Hole Tension Properties (FHT3) Strength (ksi) Statistics				
	Normalized		As Measured	
Env	CTD	RTD	CTD	RTD
Mean	64.398	60.951	62.823	59.428
Stdev	2.036	2.410	2.158	2.120
CV	3.161	3.954	3.436	3.568
Modified CV	8.000	8.000	8.000	8.000
Min	61.522	57.474	59.823	56.248
Max	66.714	64.258	65.447	61.865
No. Batches	1	1	1	1
No. Spec.	6	6	6	6
LVM B-estimates				
B-estimate	57.716	55.140	55.475	53.422
Modified CV LVM B-estimates				
B-estimate	53.332	50.706	52.027	49.439

Table 4-34: Statistics and Basis Values for FHT3 Strength data

5.7 Filled Hole Compression (FHC1, FHC2, FHC3) Properties

5.7.1 Quasi Isotropic Filled Hole Compression (FHC1)

There was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G. There were no outliers or test failures. Statistics and B-estimates are given for the FHC1 strength data in Table 4-35. The normalized data and B-estimates are shown graphically in Figure 24.

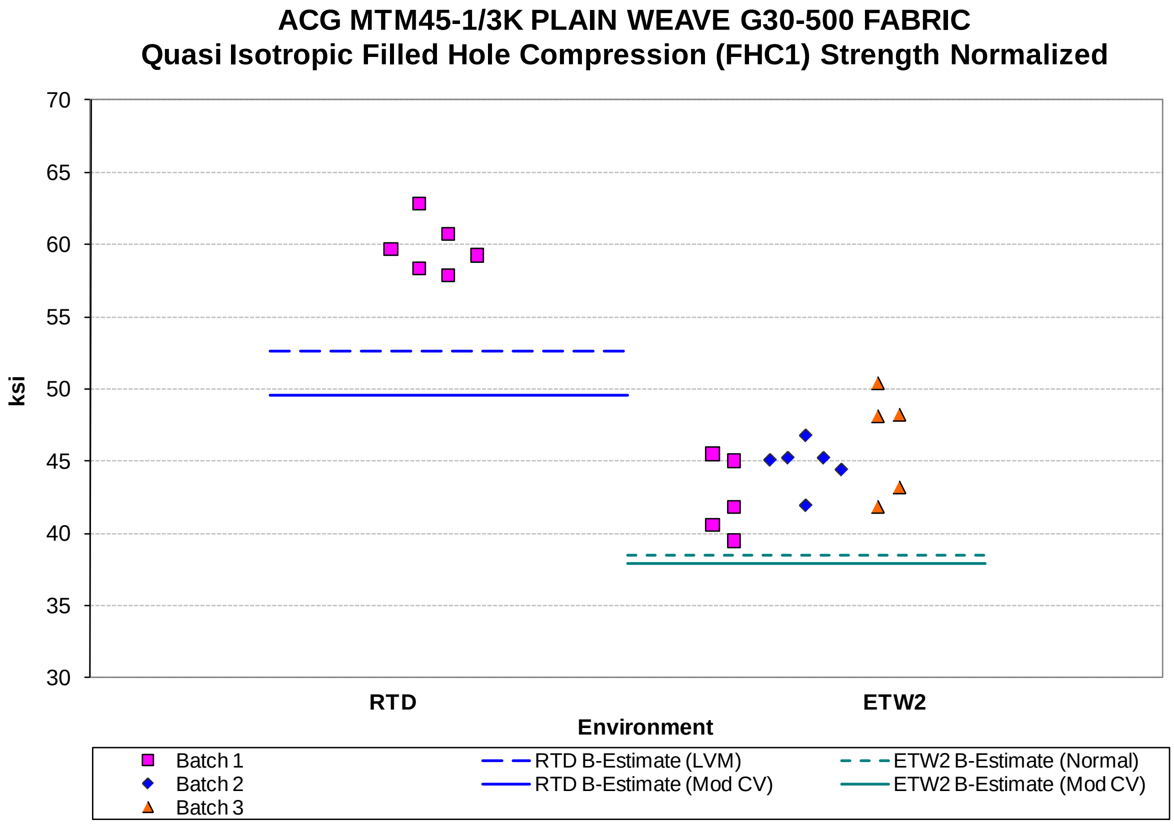

Figure 24: Batch plot for FHC1 Strength normalized

Filled Hole Compression Properties (FHC1) Strength (ksi) Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	59.800	44.299	59.039	43.377
Stdev	1.785	3.064	2.085	3.137
CV	2.986	6.916	3.532	7.233
Modified CV	8.000	7.458	8.000	7.616
Min	57.903	39.502	56.400	37.998
Max	62.810	50.401	62.106	49.366
No. Batches	1	3	1	3
No. Spec.	6	17	6	17
Basis values and/or estimates				
B-estimate	52.608	38.163	51.823	37.094
A-estimate	NA	33.825	NA	32.651
Method	LVM	Normal	LVM	Normal
Modified CV basis values and/or estimates				
B-estimate	49.600	37.684	48.969	36.762
A-estimate	NA	33.017	NA	32.095
Method	LVM	Normal	LVM	Normal

Table 4-35: Statistics and Basis Values for FHC1 Strength data

5.7.2 "Soft" Filled Hole Compression (FHC2)

The ETW2 data meets the requirements of CMH-17 Rev G. There was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G for the RTD environment, so only estimates are provided. The normalized ETW2 data failed the Anderson Darling k-sample test for batch to batch variation. However, that data does pass the normality test, and passes the ADK test under the modified CV transformation, so the modified CV values are provided for that dataset. There were no outliers.

Statistics, estimates and basis values are given for the FHC2 strength data in Table 4-36. The normalized data, B-estimates and B-basis values are shown graphically in Figure 25.

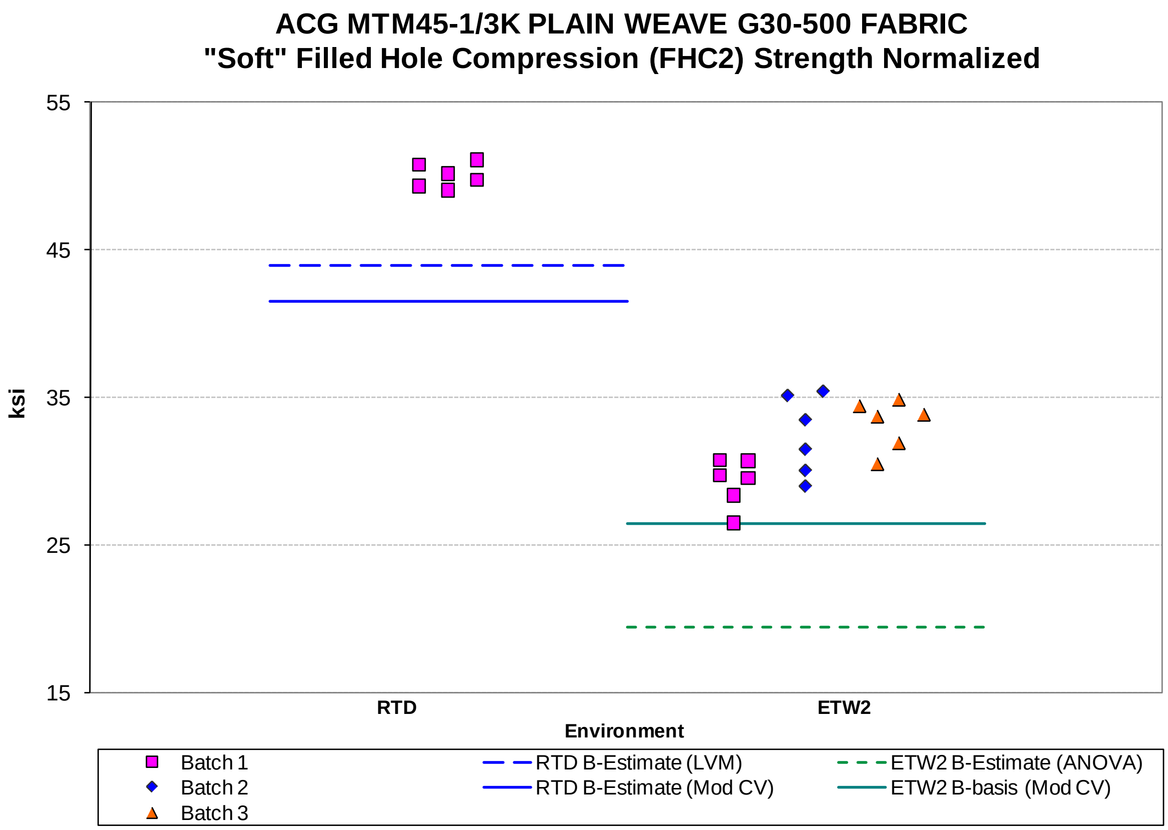

Figure 25: Batch plot for FHC2 Strength normalized

Filled Hole Compression Properties (FHC2) Strength (ksi) Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	50.047	31.647	49.462	30.977
Stdev	0.811	2.600	0.802	2.364
CV	1.621	8.215	1.622	7.633
Modified CV	8.000	8.215	8.000	7.817
Min	49.072	26.524	48.631	26.546
Max	51.131	35.433	50.489	34.262
No. Batches	1	3	1	3
No. Spec.	6	18	6	18
Basis values and/or estimates				
B-basis Value				26.309
B-estimate	44.028	19.500	43.417	
A-estimate	NA	10.840	NA	23.001
Method	LVM	ANOVA	LVM	Normal
Modified CV basis values and/or estimates				
B-basis Value		26.514		26.197
B-estimate	41.511		41.025	
A-estimate	NA	22.883	NA	22.815
Method	LVM	Normal	LVM	Normal

Table 4-36: Statistics and Basis Values for FHC2 Strength data

5.7.3 "Hard" Filled Hole Compression (FHC3)

The ETW2 data meets the requirements of CMH-17 Rev G. There was insufficient data to produce basis values that meet the requirements of CMH-17 Rev G for the RTD environment, so only estimates are provided. The ETW2 data failed the Anderson Darling test for normality; the Weibull distribution provided the best fit to the data. There were no outliers.

Statistics, estimates and basis values are given for the FHC3 strength data in Table 4-37. The normalized data, B-estimates and B-basis values are shown graphically in Figure 26.

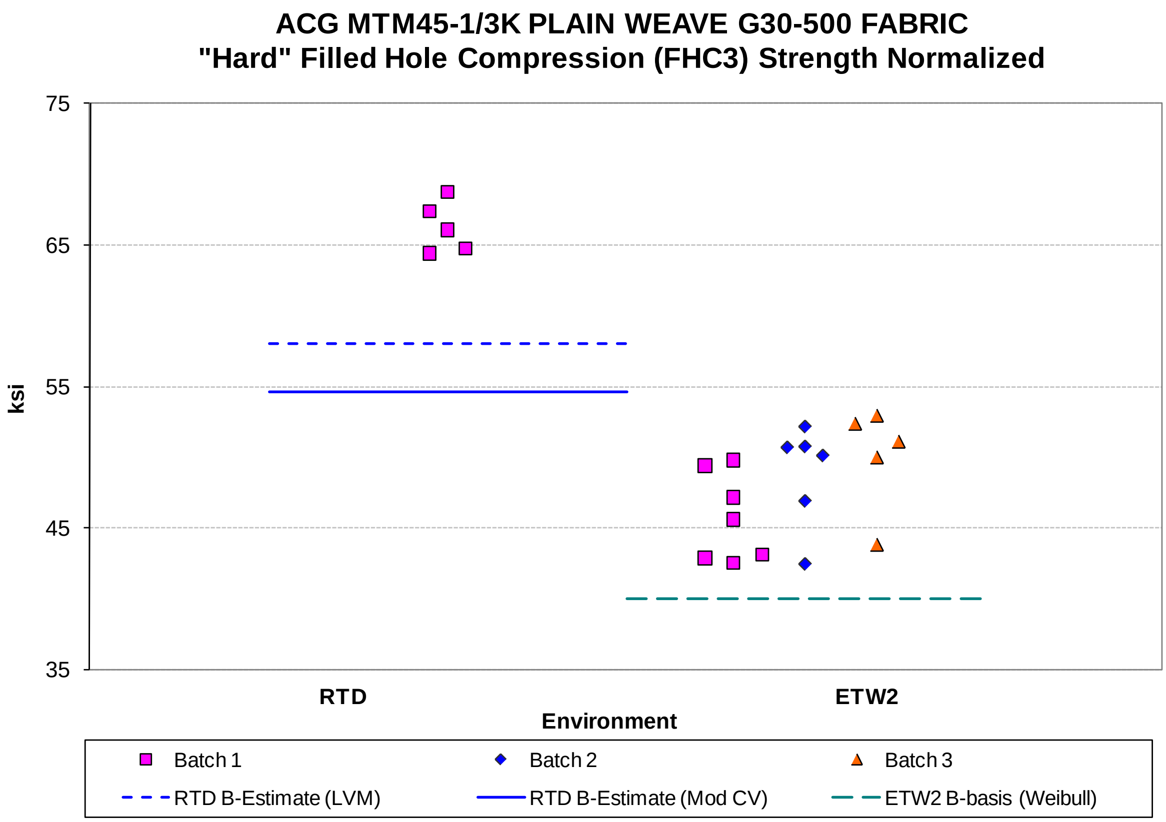

Figure 26: Batch plot for FHC3 Strength normalized

Filled Hole Compression Properties (FHC3) Strength (ksi) Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	66.297	48.011	65.315	47.274
Stdev	1.812	3.705	1.981	3.448
CV	2.733	7.717	3.034	7.293
Modified CV	8.000	7.858	8.000	7.646
Min	64.443	42.491	63.462	41.961
Max	68.785	52.928	67.982	51.551
No. Batches	1	3	1	3
No. Spec.	5	18	5	18
Basis values and/or estimates				
B-basis Value		40.026		39.871
B-estimate	58.065		57.074	
A-estimate	NA	32.519	NA	32.814
Method	LVM	Weibull	LVM	Weibull
Modified CV basis value estimates				
B-estimate	54.623	NA	53.814	NA
A-estimate	NA	NA	NA	NA
Method	LVM	NA	LVM	NA

Table 4-37: Statistics and Basis Values for FHC3 Strength data

5.8 Pin Bearing (PB1, PB2, PB3) Properties

5.8.1 Quasi Isotropic Pin Bearing (PB1)

This data could be pooled across the two available environments for both as measured and normalized values. There were no outliers, but three specimens were removed from the RTD data due to fixture hole deformation. The values for those specimens are shown in Figure 27.

Statistics, estimates and basis values are given for PB1 2% offset strength in Table 4-38. The normalized data and the B-basis values are shown graphically in Figure 27.

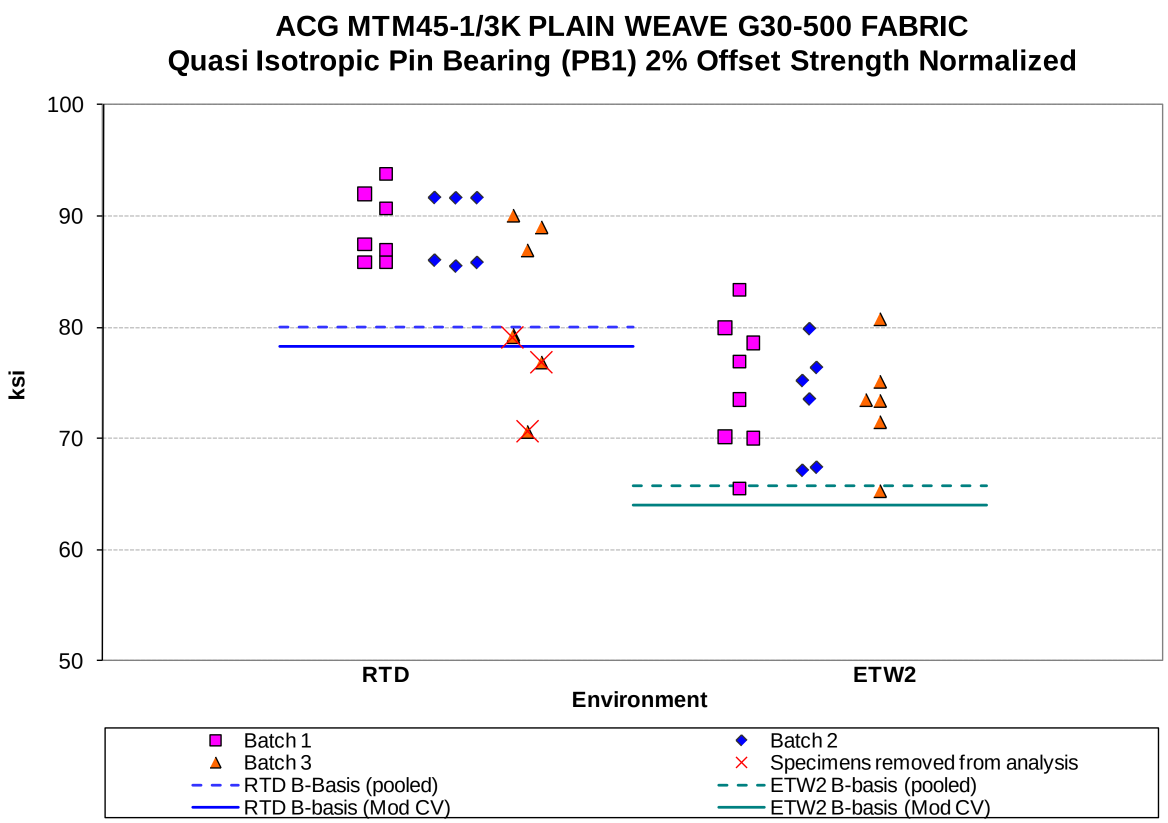

Figure 27: Batch plot for PB1 2% Offset Strength normalized

Pin Bearing (PB1) Strength (ksi) Statistics				
	Normalized		As measured	
Env	RTD	ETW2	RTD	ETW2
Mean	88.263	73.856	87.981	73.948
Stdev	3.556	5.224	3.989	5.317
CV	4.029	7.073	4.534	7.191
Modified CV	6.015	7.536	6.267	7.595
Min	79.343	65.288	78.659	64.912
Max	93.758	83.396	93.720	82.731
No. Batches	3	3	3	3
No. Spec.	17	20	17	20
Basis values and/or estimates				
B-basis Value	79.975	65.689	79.294	65.388
A-estimate	74.381	60.068	73.431	59.496
Method	pooled	pooled	pooled	pooled
Modified CV Basis values and/or estimates				
B-basis Value	78.309	64.048	77.808	63.924
A-estimate	71.592	57.297	70.943	57.025
Method	pooled	pooled	pooled	pooled

Table 4-38: Statistics and Basis Values for PB1 2% Offset Strength data

5.8.2 "Soft" Pin Bearing (PB2)

The ETW2 and the pooled data failed the Anderson Darling test for normality for 2% offset strength; the Weibull distribution provided the best fit to the ETW2 data. The RTD environment had insufficient data for publication in the handbook, so only estimates are provided. There was one outlier in the normalized data. The outlier was in batch one on the high side for the ETW2 2% normalized strength data. It was an outlier before, but not after, pooling batches together. It was retained for this analysis.

Statistics, estimates and basis values are given in Table 4-39. The normalized data, B-estimates and B-basis values are shown graphically in Figure 28.

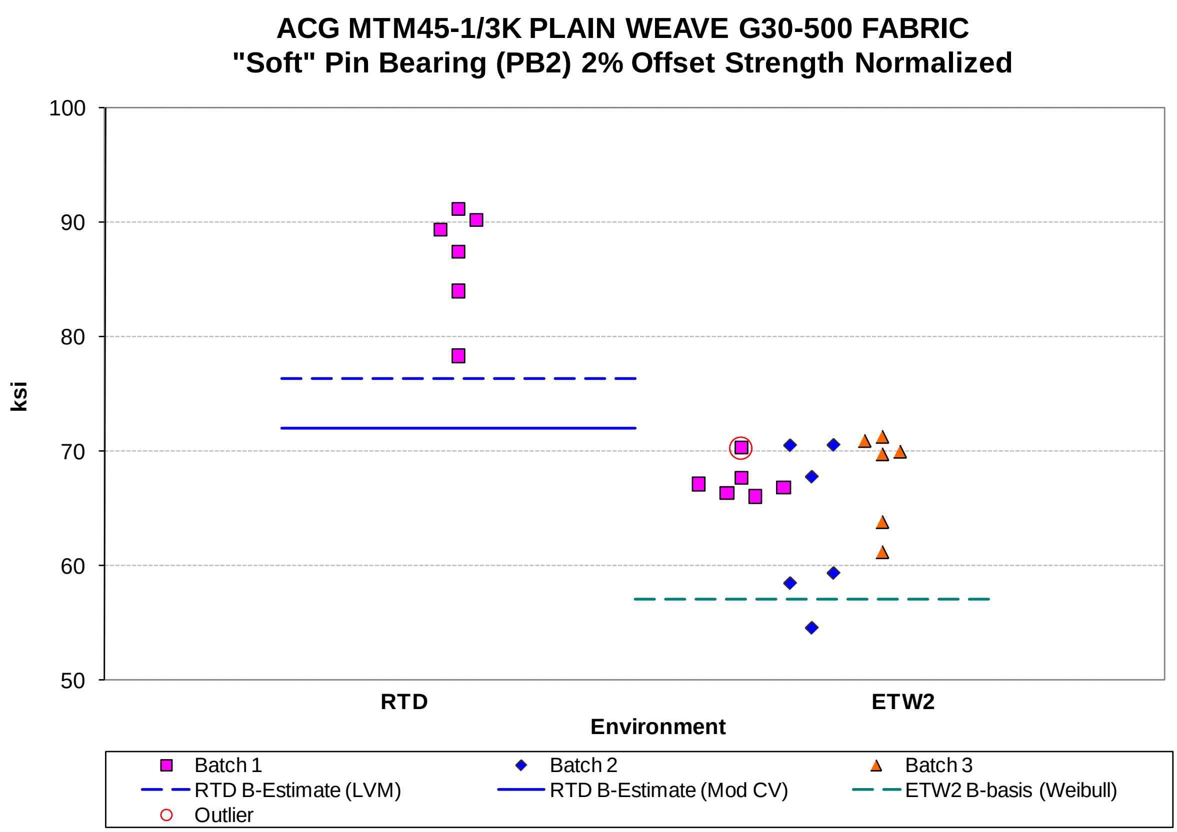

Figure 28: Batch plot for PB2 2% Offset Strength normalized

Pin Bearing (PB2) Strength (ksi) Statistics				
	Normalized		As measured	
Env	RTD	ETW2	RTD	ETW2
Mean	86.800	66.362	86.379	66.112
Stdev	4.846	4.968	5.002	4.506
CV	5.583	7.486	5.791	6.815
Modified CV	8.000	7.743	8.000	7.408
Min	78.378	54.603	78.263	55.292
Max	91.218	71.562	90.497	71.187
No. Batches	1	3	1	3
No. Spec.	6	18	6	18
Basis values and/or estimates				
B-basis Value		56.897		57.353
B-estimate	76.360		75.714	
A-estimate	NA	47.626	NA	48.669
Method	LVM	Weibull	LVM	Weibull
Modified CV Basis values and/or estimates				
B-estimate	71.995	NA	71.646	NA
A-estimate	NA	NA	NA	NA
Method	LVM	NA	LVM	NA

Table 4-39: Statistics and Basis Values for PB2 2% Offset Strength data

5.8.3 "Hard" Pin Bearing (PB3)

The normalized 2% offset ETW2 data failed the Anderson Darling test for normality. There was no distribution found to adequately fit the dataset, so the non parametric method was used to compute basis values. Modified CV values could not be computed due to the non normality. The RTD environment had insufficient data for publication in the handbook, so only estimates are provided. There was one outlier in the normalized data. It was in batch three on the low side for the ETW2 normalized strength data. It was an outlier before, but not after, pooling batches together. It was retained for this analysis.

Statistics, estimates and basis values are given in Table 4-40. The normalized data, B-estimates and B-basis values are shown graphically in Figure 29.

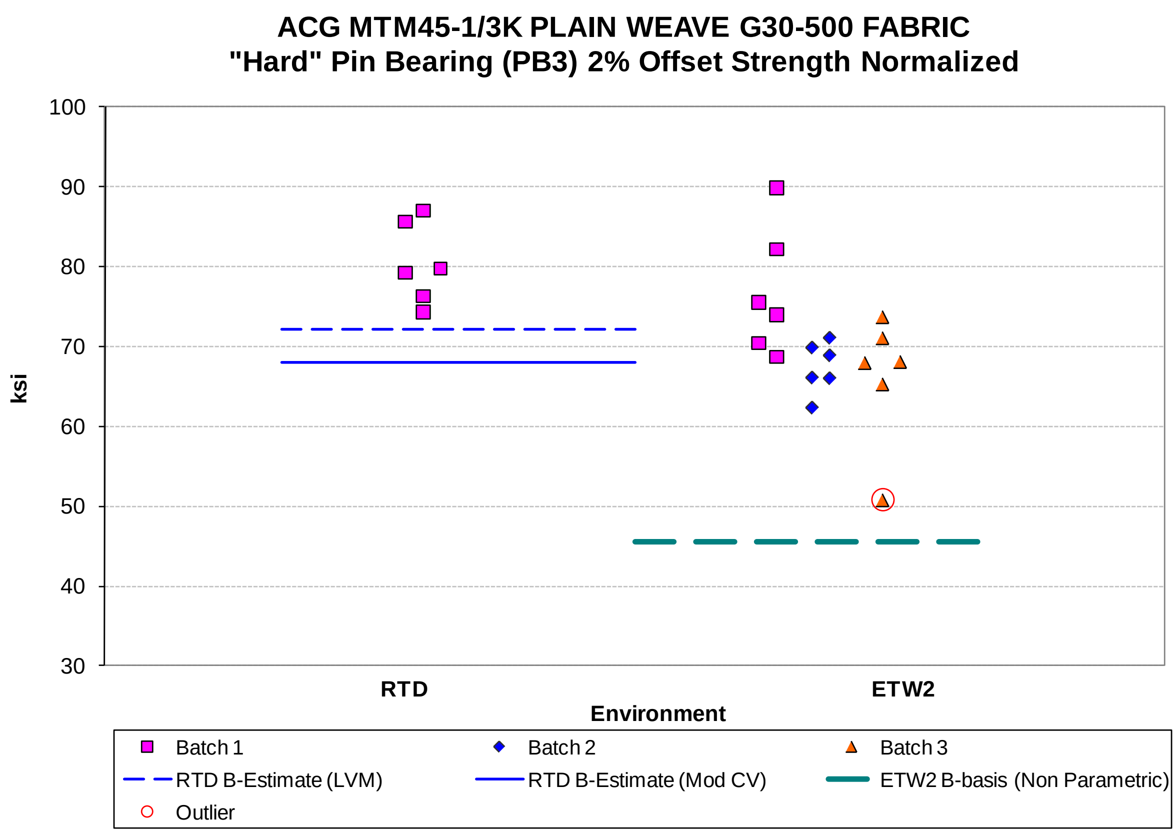

Figure 29: Batch plot for PB3 2% Offset Strength normalized

Pin Bearing (PB3) Strength (ksi) Statistics				
	Normalized		As measured	
Env	RTD	ETW2	RTD	ETW2
Mean	82.130	70.181	80.385	70.566
Stdev	5.240	8.043	5.014	8.127
CV	6.381	11.460	6.237	11.516
Modified CV	8.000	11.460	8.000	11.516
Min	74.987	50.754	74.307	53.469
Max	88.888	89.872	86.991	89.120
No. Batches	1	3	1	3
No. Spec.	6	18	6	18
Basis values and/or estimates				
B-basis Value		45.561		
B-estimate	70.957		69.695	34.386
A-estimate	NA	21.582	NA	8.597
Method	LVM	Non-Parametric	LVM	ANOVA
Modified CV Basis values and/or estimates				
B-estimate	68.122	NA	66.674	NA
A-estimate	NA	NA	NA	NA
Method	LVM	NA	LVM	NA

Table 4-40: Statistics and Basis Values for PB3 2% Offset Strength data

5.9 Compression After Impact Data

Basis values are not computed for the compression after impact data. Test results only are presented here. Statistics are given for CAI strength data in Table 4-41 and the data are displayed graphically in Figure 30. It was tested at only one environmental condition (RTD).

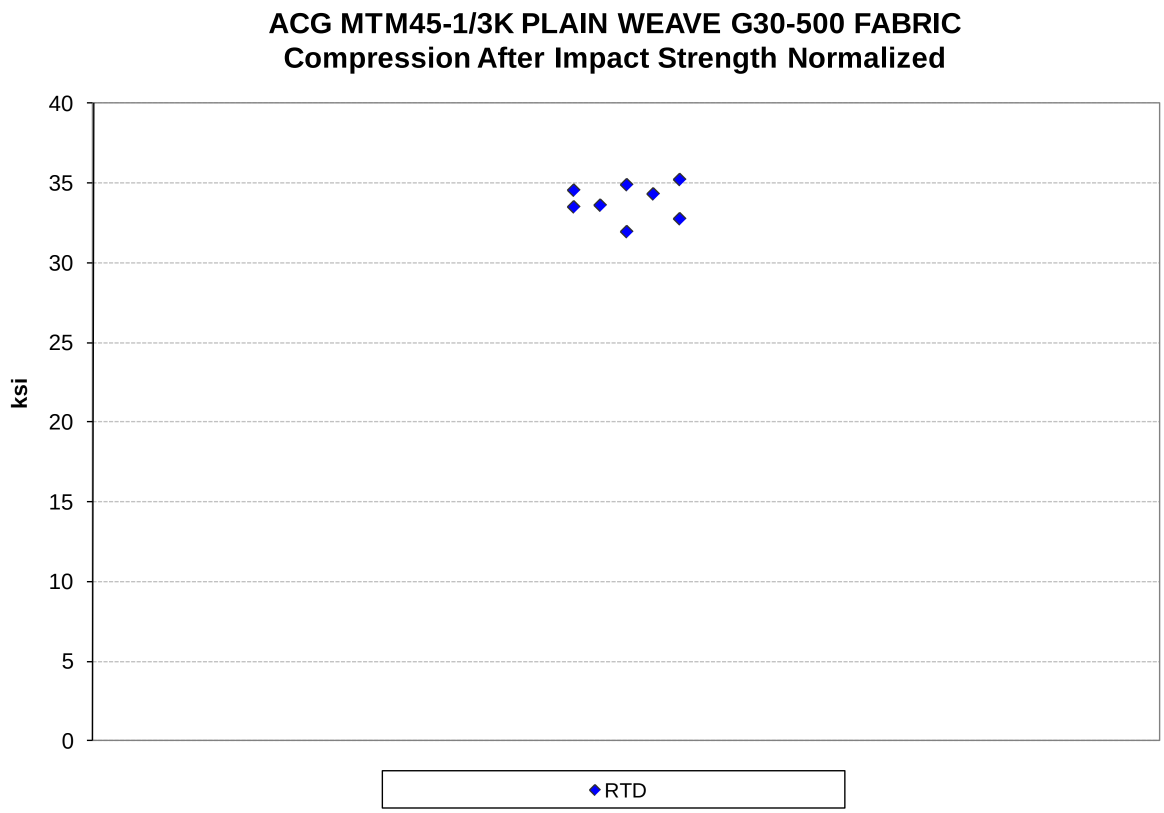

Figure 30: Plot for Compression After Impact normalized Strength Data

Compression After Impact Strength (ksi) Statistics		
RTD Environment	Normalized	As Measured
Mean	33.844	33.691
Stdev	1.126	1.120
CV	3.326	3.325
Modified CV	8.000	8.000
Min	31.920	31.779
Max	35.229	34.847
No. Batches	1	1
No. Spec.	8	8

Table 4-41: Statistics for CAI Strength data normalized

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

The Interlaminar Tension and Curved Beam Strength data is not normalized. Basis values are not computed for the ILT and CBS data. Test results only are presented here. Statistics are given for the Interlaminar Tension (ILT) and Curved Beam strength (CBS) data in Table 4-42 and the data are displayed graphically in Figure 31. ILT tests were performed at both RTD and ETW2 environmental conditions.

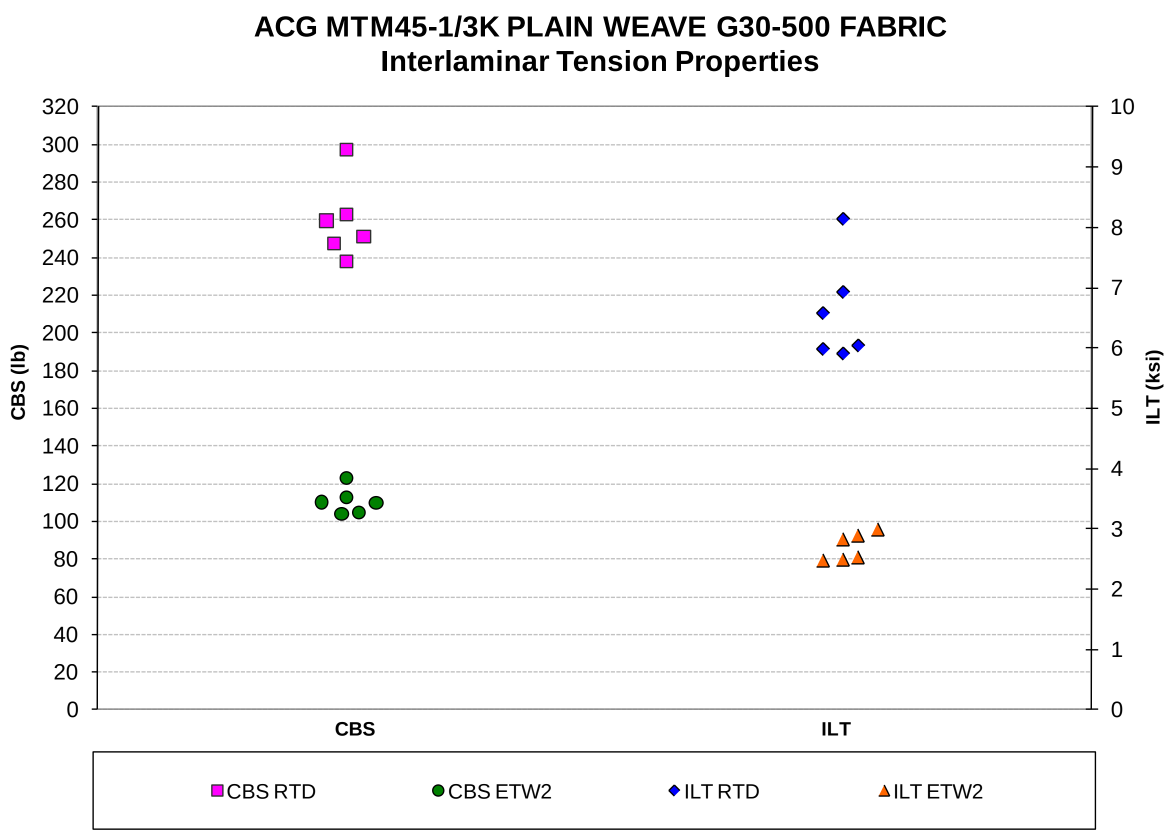

Figure 31: Plot for ILT and CBS Data as measured

Interlaminate Strength (ksi) and Curved Beam Strength (lb) Statistics				
Property	**ILT (ksi)**		**CBS (lb)**	
Env	RTD	ETW2	RTD	ETW2
Mean	6.596	2.699	259.361	110.697
Stdev	0.850	0.224	20.507	6.960
CV	12.885	8.289	7.907	6.287
Mod CV	12.885	8.289	8.000	8.000
Min	5.911	2.479	238.105	103.744
Max	8.131	2.984	297.144	122.994
No. Batches	1	1	1	1
No. Spec.	6	6	6	6

Table 4-42: Statistics for ILT and CBS data as measured

6. 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, NCP-RP-2008-003 Rev D.

Outliers for which no causes could be identified are listed in Table 6-1. 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
WT	CTD	2	A0NJB216B	137.102	Not an outlier	High	Yes	No
FC	ETW2	1	A0NZA21HD	Not an outlier	44.260	Low	Yes	No
IPS - 0.2% Offset	RTD	1	A0NNA2R3A	NA	6.626	High	Yes	No
IPS - 5% Strain				NA	11.301			
IPS - 0.2% Offset	ETW2	1	A0NNA11GD	NA	3.467	High	Yes	No
SBS	CTD	2	A0NQB1U5B	NA	10.727	Low	Yes	Yes
UNT1	RTD	1	A0NAA116A	90.195	89.289	Low	Yes	No
UNT1	RTD	3	A0NAC212A	102.414	Not an outlier	High	Yes	No
UNC1	RTD	3	A0NWC212A	66.078	66.587	Low	Yes	No
UNC1	ETW	1	A0NWA214N	56.871	56.692	High	Yes	NA
UNC1	ETW2	1	A0NWA219D	Not an outlier	45.488	Low	Yes	No
UNC2	RTD	1	A0NXA211A	45.089	46.220	Low	Yes	No
UNC3	ETW2	1	A0NYA118D	45.367	45.738	Low	Yes	No
OHT1	CTD	2	A0NDB211B	54.291	Not an outlier	High	Yes	No
OHT1	ETW2	2	A0NDB21BD	53.846	Not an outlier	Low	Yes	No
OHC1	RTD	3	A0NGC212A	45.064	Not an outlier	High	Yes	Yes
PB2	ETW2	1	A0N2A215D	71.562	Not an outlier	High	Yes	No
PB3	ETW2	3	A0N3C111D	50.754	Not an outlier	Low	Yes	No

Table 6-1: List of outliers

7. References

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