SOLVAY
(Formerly known as Advanced Composites Group)
MTM45-1/IM7-145gsm-32%RW
Qualification Statistical Analysis Report

FAA Special Project Number: SP3505WI-Q

NCAMP Report Number: NCP-RP-2008-006 Rev A

Report Date: March 28, 2018

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REVISIONS:

Rev	**By**	**Date**	**Rev App By**	**Pages Revised or Added**
N/C	Elizabeth Clarkson	06/07/2011	Yeow Ng	Document Initial Release
A	Elizabeth Clarkson	3/28/2018	Royal Lovingfoss	Correction to TT data and analysis. Correction to TC modulus data. Correction to LC Strength data computed using the UNC0 back-out factor Correction to IPS CTD 5% strain data and RTD and ETW 0.2% offset data. Correction to FHC3 normalized strength data Correction to UNT1 ETW2 data and analysis Correction to UNT3 ETW2 modulus data Updated Lamina & Laminate Summary Tables

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1. Introduction

This report contains statistical analysis of ACG MTM45-1/IM7-145gsm-32%RW material property data published in NCAMP Test Report CAM-RP-2008-007 Rev B. 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, A-estimates and B-estimates were calculated using a variety of techniques that are detailed in section two. Qualification material was procured in accordance with ACG material specification ACGM 1001-06 or NCAMP Material Specification NMS 451/6. The qualification test panels were fabricated per ACGP 1001-02 Revision E or an equivalent NCAMP Process Specification NPS 81451 using "MH" cure cycle. The panels were fabricated at Advanced Composites Group, 5350 S 129th E. Ave, Tulsa, OK 74134. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas. The ACG Test Plan AI/TR/1392 Revision E was used for this qualification program.

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

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

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

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

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

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

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 451/6. NMS 451/6 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 451/6. NMS 451/6* is a free, publicly available, non-proprietary aerospace industry material specification.

1.1 Symbols and Abbreviations

Test Property	Abbreviation
Longitudinal Compression	LC
Longitudinal Tension	LT
Transverse Compression	TC
Transverse Tension	TT
In Plane Shear	IPS
Unnotched Tension	UNT
Unnotched Compression	UNC
Short Beam Shear	SBS
Open Hole Tension	OHT
Open Hole Compression	OHC
Filled Hole Tension	FHT
Filled Hole Compression	FHC
Pin Bearing Strength	PB
Laminate Short Beam Shear	SBS1
Compression After Impact	CAI

Table 1-1: Test Property Abbreviations

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

Table 1-2: Test Property Symbols

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

Table 1-3: Environmental Conditions Abbreviations

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

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

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

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2008-007 Rev B.

1.2 Pooling Across Environments

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

When pooling across environments was not 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 Stat17 version 5.

1.3 Basis Value Computational Process

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

1.4 Modified Coefficient of Variation (CV) Method

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

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

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

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

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

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

2. Background

Statistical computations are performed with AGATE Statistical Analysis Program (ASAP) when pooling across environments is permissible according to CMH-17 guidelines. If pooling is not permissible, a single point analysis using STAT17 is performed for each environmental condition with sufficient test results. If the data does not meet the CMH-17 requirements for a single point analysis, estimates are created by a variety of methods depending on which is most appropriate for the dataset available. Specific procedures used are presented in the individual sections where the data is presented.

2.1 ASAP Statistical Formulas and Computations

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

2.1.1 Basic Descriptive Statistics

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

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

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

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

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

2.1.2 Statistics for Pooled Data

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

2.1.2.1 Pooled Standard Deviation

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

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

Where k refers to the number of batches and n_i refers to the number of specimens in the i^{th} sample.

2.1.2.2 Pooled Coefficient of Variation

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

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

2.1.3 Basis Value Computations

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

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

2.1.3.1 K-factor computations

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

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

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

Where

r = the number of environments being pooled together

n_j= number of data values for environment j

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

$$f = N - r$$

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

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

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

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

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

2.1.4 Modified Coefficient of Variation

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

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

This is converted to percent by multiplying by 100%.

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

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

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

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

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

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

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 $z_{(1)}, z_{(2)}, \ldots z_{(L)}$, where L will be less than n if there are tied observations. These rankings are used to compute the test statistic.

The k-sample Anderson-Darling test statistic is:

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

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.

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

With

$$a = (4g-6)(k-1) + (10-6g)S$$
$$b = (2g-4)k^2 + 8Tk + (2g-14T-4)S - 8T + 4g - 6$$
$$c = (6T+2g-2)k^2 + (4T-4g+6)k + (2T-6)S + 4T$$
$$d = (2T+6)k^2 - 4Tk$$
$$S = \sum_{i=1}^{k} \frac{1}{n_i}$$
$$T = \sum_{i=1}^{n-1} \frac{1}{i}$$
$$g = \sum_{i=1}^{n-2} \sum_{j=i+1}^{n-1} \frac{1}{(n-i)j}$$

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

2.1.7 The Anderson Darling Test for Normality

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

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

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

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

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

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

The Anderson Darling test statistic (AD) is:

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

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

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

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

2.1.8 Levene's Test for Equality of Coefficient of Variation

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

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

If this computed F statistic is less than the critical value for the F-distribution having k-1 numerator and n-k denominator degrees of freedom at the 1-α level of confidence, then the data is not rejected as being too different in terms of the co-efficient of variation. This test is used to check whether different environmental conditions should be pooled. For more information on this procedure see reference 4.

2.2 STAT17

This section contains the details of the specific formulas STAT17 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-17-1G. Levene's test is used to check the assumption of equal variances when using an ANOVA analysis.

2.2.1 Distribution Tests

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

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

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

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

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

2.2.2 Computing Normal Distribution Basis Values

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

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

Table 2-1: K factors for normal distribution

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

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

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

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

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

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

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

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

2.2.2.3 Two-parameter Weibull Distribution

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

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

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

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

2.2.2.3.1 Estimating Weibull Parameters

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

$$\hat{\alpha}\hat{\beta}n - \frac{\hat{\beta}}{\hat{\alpha}^{\hat{\beta}-1}}\sum_{i=1}^{n} x_i^{\hat{\beta}} = 0$$ **Equation 36**

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

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

2.2.2.3.2 Goodness-of-fit test for the Weibull distribution

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

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

The Anderson-Darling test statistic is

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

and the observed significance level is

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

where

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

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

2.2.2.3.3 Basis value calculations for the Weibull distribution

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

$$B = \hat{q} \cdot \exp\left\{\frac{-V}{\hat{\beta}\sqrt{n}}\right\} \qquad \textbf{Equation 42}$$

where

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

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

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

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

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

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

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

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

Table 2-2: Weibull Distribution Basis Value Factors

2.2.2.4 Lognormal Distribution

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

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

2.2.2.4.1 Goodness-of-fit test for the Lognormal distribution

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

$$z_{(i)} = \frac{\ln(\overline{x}_{(i)}) - \overline{x}_L}{s_L}, \quad \text{for } i = 1,\ldots,n$$ **Equation 47**

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

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

2.2.2.4.2 Basis value calculations for the Lognormal distribution

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

2.2.3 Non-parametric Basis Values

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

2.2.3.1 Non-parametric Basis Values for large samples

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

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

For B-basis values:

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

For A-Basis values:

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

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

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

2.2.3.2 Non-parametric Basis Values for small samples

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

The Hanson-Koopmans B-basis value is:

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

The A-basis value is:

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

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

The Hanson-Koopmans method can be used to calculate A-basis values for n less than 299. Find the value k_A corresponding to the sample size n in Table 2-4. For an A-basis value publishable according to the standards of CMH-17-1G, there must be at least five batches represented in the data and at least 55 data points. For a B-basis value, there must be at least three batches represented in the data and at least 18 data points.

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

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

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

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

2.2.4 Analysis of Variance (ANOVA) Basis Values

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

2.2.4.1 Calculation of basis values using ANOVA

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

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

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

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

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

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

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

Next, the mean sums of squares are computed:

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

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

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

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

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

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

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

Denote the ratio of mean squares by

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

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

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

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

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

2.3 Single Batch and Two Batch Estimates using Modified CV

This method has not been approved for use by the CMH-17 organization. Values computed in this manner are estimates only. It is used only when fewer than three batchs 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 = $\bar{X} - k_b S_{adj} = \bar{X} - k_b \cdot Max(8\%, CV) \cdot \bar{X}$ **Equation 61**

2.4 Lamina Variability Method (LVM)

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

To compute the estimate, the coefficients of variation (CVs) of laminate data are paired with lamina CV's for the same loading condition and environmental condition. For example, the 0º compression lamina CV CTD condition is used with open hole compression CTD condition.

Bearing and in-plane shear laminate CV's are paired with 0º compression lamina CV's. However, if the laminate CV is larger than the corresponding lamina CV, the larger laminate CV value is used.

The LVM B-basis value is then computed as:

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

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

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

With:

$\bar{X}_1$ the mean of the laminate (small dataset)

N_1 the sample size of the laminate (small dataset)

N_2 the sample size of the lamina (large dataset)

CV_1 is the coefficient of variation of the laminate (small dataset)

CV_2 is the coefficient of variation of the lamina (large dataset)

$K_{(N_1,N_2)}$ is given in Table 2-5

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

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

2.5 0° Lamina Strength Derivation

Lamina strength values in the 0º direction were not obtained directly for any conditions during compression tests. They are derived from the cross-ply lamina test results using a back out formula. Unless stated otherwise, the 0° lamina strength values were derived using the following formula:

$F^u_{0^\circ} = F^u_{0^\circ/90^\circ} \cdot BF$ where BF is the **B**ackout **F**actor.

$F^u_{0^\circ/90^\circ}$ =UNC0 or UNT0 strength values

$$BF = \frac{E_1\left[V_0E_2 + \left(1-V_0\right)E_1\right] - \left(\nu_{12}E_2\right)^2}{\left[V_0E_1 + \left(1-V_0\right)E_2\right]\left[V_0E_2 + \left(1-V_0\right)E_1\right] - \left(\nu_{12}E_2\right)^2} \qquad \textbf{Equation 64}$$

V_0=fraction of 0º plies in the cross-ply laminate (½ for UNT0 and 1/3 for UNC0)
E_1 = Average across of batches of modulus for LC and LT as appropriate
E_2 = Average across of batches of modulus for TC and TT as appropriate
ν_{12} = major Poisson's ratio of 0º plies from an average of all batches

This formula can also be found in the Composite Materials Handbook (CMH17 Rev G) in section 2.4.2, equation 2.4.2.1(b).

In computing these strength values, the values for each environment are computed separately. The compression values are computed using only compression data, the tension values are computed using only tension data. Both normalized and as measured computations are done using the as measured and normalized strength values from the UNC0 and UNT0 strength values.

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

3.1 NCAMP Recommended B-basis Values

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

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

NCAMP Recommended B-basis Values for
ACG - MTM45-1/IM7-145 gsm Unidirectional Tape

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	LT from UNT0**	LC from UNC0**	TT	TC	SBS*	IPS* 0.2% Offset	IPS* 5% Strain	UNT0	UNC0
CTD (-65°F)	B-basis	327.72	NA: I	NA:A	35.24	NA: I	NA: I	NA: I	162.11	NA: I
	Mean	370.50	204.89	8.34	38.26	20.85	7.74	13.00	184.31	116.81
	CV	6.91	8.84	16.97	7.10	4.64	7.99	9.05	6.91	8.84
RTD (75°F)	B-basis	315.11	NA: I	NA:A	24.92	NA: I	NA: I	NA: I	159.47	NA: I
	Mean	357.65	181.54	7.59	27.96	14.47	5.90	9.63	181.55	99.65
	CV	6.47	9.69	16.97	6.00	3.75	8.77	8.71	6.47	9.69
ETD (200°F)	B-basis					NA: I				NA: I
	Mean					11.15				90.17
	CV					2.77				6.76
ETW (200°F)	B-basis	327.05	NA: I	2.13	12.67	8.28***	NA: I	NA: I	168.85	NA: I
	Mean	368.98	154.23	4.30	15.71	8.54	3.53	5.48	190.61	83.27
	CV	6.69	6.62	23.44	6.71	2.24	7.56	7.46	6.69	6.62
ETW (250°F)	B-basis	300.25	NA: I	NA:A	9.89	5.98	NA: I	NA: I	166.25	NA: I
	Mean	342.57	138.09	3.49	12.91	6.92	3.00	4.58	188.22	76.56
	CV	7.30	9.90	21.10	6.52	4.10	6.88	6.56	7.30	9.90

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
** Derived from cross-ply using back-out factor
*** indicates the Stat17 B-basis value is greater than 90% of the mean value.

Table 3-1: NCAMP recommended B-basis values for lamina data

NCAMP Recommended B-basis Values for ACG - MTM45-1/IM7-145 gsm Unidirectional Tape

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	59.00		61.89		112.92			
		Mean	66.59		69.79		130.69			
		CV	6.00		6.00		6.89			
	RTD (75°F)	B-basis	60.46	37.79	NA: I	NA: I	115.85	NA: I	83.73	NA: I
		Mean	68.01	42.87	70.35	66.57	132.81	80.93	94.24	10.22
		CV	6.00	6.00	2.51	2.64	6.47	3.57	6.00	8.59
	ETW (200°F)	B-basis	NA: I	NA: I				NA: I		NA: I
		Mean	73.24	34.76				70.42		7.12
		CV	3.36	1.29				2.16		7.38
	ETW2 (250°F)	B-basis	65.44	28.13		38.92	NA: I	NA: I	71.49	NA: I
		Mean	72.99	31.91		44.43	124.13	70.42	82.04	5.80
		CV	6.57	6.00		6.28	4.37	2.16	7.28	13.48
10/80/10	CTD (-65°F)	B-basis	42.99		NA: I		NA: I			
		Mean	48.77		52.73		78.43			
		CV	6.00		1.87		4.06			
	RTD (75°F)	B-basis	NA: I	NA: I	NA: I	NA: I	NA: I	NA: I	NA: I	
		Mean	46.98	38.05	48.76	53.80	75.11	58.08	101.38	
		CV	3.50	3.26	2.44	2.75	1.95	5.63	3.73	
	ETW2 (250°F)	B-basis	NA: I	22.66	NA: I	30.72	NA: I	NA: I	64.00	
		Mean	42.72	25.71	43.80	35.67	58.64	42.47	78.84	
		CV	3.44	6.00	3.16	7.03	3.23	3.14	9.02	
50/40/10	CTD (-65°F)	B-basis	93.09		NA: I		NA: I			
		Mean	108.07		105.08		207.55			
		CV	7.02		6.77		5.37			
	RTD (75°F)	B-basis	NA: I	NA: I	NA: I	NA: I	NA: I	NA: I	NA: I	
		Mean	115.39	49.93	106.60	77.85	206.81	93.43	99.93	
		CV	3.80	7.64	2.84	3.60	5.08	4.63	6.04	
	ETW2 (250°F)	B-basis	NA: I	34.00		NA: I	NA: I	NA: I	66.77	
		Mean	134.75	39.70		51.87	205.72	71.40	77.41	
		CV	9.80	7.27		9.18	3.91	5.28	6.96	

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

Table 3-2: NCAMP recommended B-basis values for laminate data

3.2 Lamina and Laminate Summary Tables

Prepreg Material:	Advanced Composites Group - MTM45-1/IM7-145 gsm Unidirectional Tape		**ACG - MTM45-1/IM7-145 gsm Unidirectional Tape Lamina Properties Summary**
Material Specification:	ACGM 1001-06 or NMS 451/6		
Process Specification:	ACGP 1001-02 or NPS 81451 "MH" Cure Cycle		
Fiber:	Hexcel Corp., IM7-GP fiber, 12K tow (HS-CP-5000/IM7specification)	**Resin:** MTM45-1	
	Tg(dry): 349.06°F **Tg(wet):** 317.11°F	**Tg METHOD:** DMA (SRM 18-94)	

	Lot 1	Lot 2	Lot 3		
Date of fiber manufacture:	12/12/06	01/20/05	08/31/06	**Date of testing:**	March 2007 - February 2008
Date of resin manufacture:	01/17/07	08/25/06	12/06/06	**Date of data submittal:**	June-08
Date of prepreg manufacture:	01/17/07	08/25/06	12/06/06	**Date of analysis:**	June 2008 - December 2009, May 2012
Date of composite manufacture:	01/18/07	09/25/06	12/06/07		

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY
Data reported: As measured followed by normalized values in parentheses, normalizing tply: 0.0055 in
Values shown in shaded boxes do not meet CMH17 Rev G requirements and are estimates only
These values may not be used for certification unless specifically allowed by the certifying agency

	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^{tu} (ksi)	323.13	314.54	354.11	312.80	304.26	343.61				325.36	316.94	355.73	303.29	294.79	333.93
from UNT0*	(334.89)	(327.72)	(370.50)	(322.24)	(315.11)	(357.65)				(334.07)	327.05	(368.98)	(307.34)	(300.25)	(342.57)
E_1^t			22.34			22.00						21.37			23.24
(Msi)			(23.36)			(22.90)						(22.12)			(23.82)
F_2^{tu} (ksi)	0.23	NA	8.34	1.53	NA	7.59				2.13	NA	4.30	0.00	NA	3.49
E_2^t (Msi)			1.24			1.11						0.95			0.82
F_1^{cu} (ksi)	171.65	171.40	200.54	148.08	147.82	177.80				123.13	122.87	154.11	107.10	106.85	136.37
from UNC0*	(174.08)	(173.83)	(204.89)	(149.84)	(149.59)	(181.54)				(121.19)	(120.93)	(154.23)	(106.88)	(106.63)	(138.09)
E_1^c			19.96			19.84						20.13			20.21
(Msi)			(20.41)			(20.24)						(20.25)			(20.42)
ν_{12}^c			0.346			0.361						0.373			0.389
F_2^{cu} (ksi)	35.85	35.24	38.26	25.53	24.92	27.96				13.28	12.67	15.71	10.50	9.89	12.91
E_2^c (Msi)			1.30			1.22						1.09			1.01
ν_{21}^c			0.027			0.026						0.021			0.022
$F_{12}^{s5\%}$ (ksi)	10.69	NA	13.00	7.80	NA	9.63				4.73	4.67	5.48	4.12	3.99	4.58
$F_{12}^{s0.2\%}$ (ksi)	6.68	6.68	7.74	4.50	NA	5.90				3.00	NA	3.53	2.66	2.59	3.00
G_{12}^s (Msi)			0.632			0.525						0.358			0.325
SBS (ksi)	18.81	18.07	20.85	12.83	11.85	14.47	10.49	9.71	11.15	8.28	NA	8.54	5.98	NA	6.92
UNT0 Strength	161.50	157.07	177.76	158.54	154.13	174.71				170.57	166.22	186.51	167.71	163.33	183.80
(ksi)	(165.77)	(162.11)	(184.31)	(163.11)	(159.47)	(181.55)				(172.43)	(168.85)	(190.61)	(169.87)	(166.25)	(188.22)
UNT0 Modulus			11.21			11.19						11.20			12.79
(Msi)			(11.62)			(11.62)						(11.43)			(13.09)
UNC0 Strength	98.47	98.23	113.57	81.25	81.00	96.80	72.24	72.00	87.80	66.02	65.77	82.24	60.02	59.78	75.32
(ksi)	(100.76)	(100.49)	(116.81)	(83.12)	(82.85)	(99.65)	(73.65)	(73.37)	(90.17)	(66.03)	(65.75)	(83.27)	(60.30)	(60.03)	(76.56)
UNC0 Modulus			11.30			10.80			10.98			10.74			11.16
(Msi)			(11.64)			(11.11)			(11.24)			(10.93)			(11.32)
ν of UNC0			0.047			0.040			0.039			0.039			0.036

** Derived from cross-ply using back-out factor*

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

ACG - MTM45-1/IM7-145 gsm Unidirectional Tape Laminate Properties Summary

Prepreg Material: Advanced Composites Group - MTM45-1/IM7-145 gsm Unidirectional Tape
Material Specification: ACGM 1001-06 or NMS 451/6
Process Specification: ACGP 1001-02 or NPS 81451 "MH" Cure Cycle

Fiber: Hexcel Corp., IM7-GP fiber, 12K tow (HS-CP-5000/IM7specification) **Resin:** MTM45-1

Tg(dry): 349.06°F **Tg(wet):** 317.11°F **Tg METHOD:** DMA (SRM 18-94)

	Lot 1	Lot 2	Lot 3
Date of fiber manufacture:	12/12/06	01/20/05	08/31/06
Date of resin manufacture:	01/17/07	08/25/06	12/06/06
Date of prepreg manufacture:	01/17/07	08/25/06	12/06/06
Date of composite manufacture:	01/18/07	09/25/06	12/06/07

Date of testing: March 2007 - February 2008
Date of data submittal: June-08
Date of analysis: June 2008 - December 2009, May 2012

LAMINATE MECHANICAL PROPERTY B-BASIS SUMMARY
Data reported as normalized used a normalizing t_{ply} of 0.0055 in
Values shown in shaded boxes do not meet CMH17 Rev G requirements and are estimates only
These values may not be used for certification unless specifically allowed by the certifying agency

Test	Property	Layup:		Quasi Isotropic 25/50/25			"Soft" 10/80/10			"Hard" 40/20/40		
		Test Condition	Unit	B-value	Modified CV B-value	Mean	B-value	Modified CV B-value	Mean	B-value	Modified CV B-value	Mean
OHT (normalized)	Strength	CTD	ksi	61.47	59.00	66.59	47.18	42.99	48.77	95.18	93.09	108.07
		RTD	ksi	62.92	60.46	68.01	42.00	38.91	46.98	103.73	96.49	115.39
		ETW	ksi	67.33	64.48	73.24						
		ETW2	ksi	67.90	65.44	72.99	36.69	35.41	42.72	107.21	NA	134.75
OHC (normalized)	Strength	RTD	ksi	36.58	37.79	42.87	29.42	NA	38.05	38.98	NA	49.93
		ETW	ksi	29.18	28.02	34.76						
		ETW2	ksi	29.75	28.13	31.91	23.77	22.66	25.71	34.57	34.00	39.70
UNT (normalized)	Strength	CTD	ksi	115.79	112.92	130.69	68.59	64.90	78.43	181.52	171.73	207.55
	Modulus		Msi	---	---	8.27	---	---	5.07	---	---	12.96
	Strength	RTD	ksi	101.08	115.85	132.81	67.15	62.21	75.11	184.24	171.27	206.81
	Modulus		Msi	---	---	8.13	---	---	4.91	---	---	12.68
	Strength	ETW2	ksi	106.61	102.89	124.13	50.37	48.61	58.64	176.68	170.52	205.72
	Modulus		Msi	---	---	8.31	---	---	4.73	---	---	12.78
UNC (normalized)	Strength	RTD	ksi	74.55	70.20	80.93	45.34	NA	58.08	72.24	NA	93.43
	Modulus		Msi	---	---	7.59	---	---	4.81	---	---	12.25
	Poisson's Ratio			---	---	0.292	---	---	0.574	---	---	0.447
	Strength	ETW	ksi	56.81	53.98	70.42	---	---	---	---	---	---
	Modulus		Msi	---	---	7.67	---	---	---	---	---	---
	Poisson's Ratio			---	---	0.319	---	---	---	---	---	---
	Strength	ETW2	ksi	50.09	49.77	59.76	32.77	NA	42.47	55.09	NA	71.40
	Modulus		Msi	---	---	7.52	---	---	4.45	---	---	11.53
	Poisson's Ratio			---	---	0.292	---	---	0.584	---	---	0.440
FHT (normalized)	Strength	CTD	ksi	66.55	61.89	69.79	46.29	43.86	52.73	88.56	85.56	105.08
		RTD	ksi	63.24	58.83	70.35	43.72	40.60	48.76	94.43	86.89	106.60
		ETW2	ksi	---	---	---	37.62	36.31	43.80	---	---	---
FHC (normalized)	Strength	RTD	ksi	51.47	NA	66.57	42.00	NA	53.80	57.13	NA	77.85
		ETW2	ksi	40.43	38.92	44.43	25.55	30.72	35.67	42.01	42.01	51.87
Pin Bearing (normalized)	2% Offset Strength	RTD	ksi	86.02	83.73	94.24	78.39	NA	101.38	77.27	NA	99.93
		ETW2	ksi	73.79	71.49	82.04	64.00	NA	78.84	68.35	66.77	77.41
SBS1 (as measured)	Strength	RTD	ksi	4.93	8.28	10.22	---	---	---	---	---	---
		ETW	ksi	5.59	5.46	7.12						
		ETW2	ksi	2.06	4.11	5.80	---	---	---	---	---	---
CAI (Normalized)	Strength	RTD	ksi	---	---	36.83	---	---	---	---	---	---

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 horizontal axis values will vary depending on the data and how much overlapping of there was of the data within and between batches. When there was little variation, the batches were graphed from left to right and the environmental conditions were identified by the shape and color of the symbol used to plot the data. Otherwise, the environmental conditions were graphed from left to right and the batches were identified by the shape and color of the symbol.

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

4.1 Longitudinal (0º) Tension Properties (LT)

The longitudinal tension strengths are computed indirectly from UNT0 specimens via equation 64 specified in section 2.5. There were no outliers or test failures. Basis values were computed by pooling across environments. Statistics and basis values are given for strength data in Table 4-1 and for the modulus data in Table 4-2. The data and the B-basis values are shown graphically in Figure 4-1.

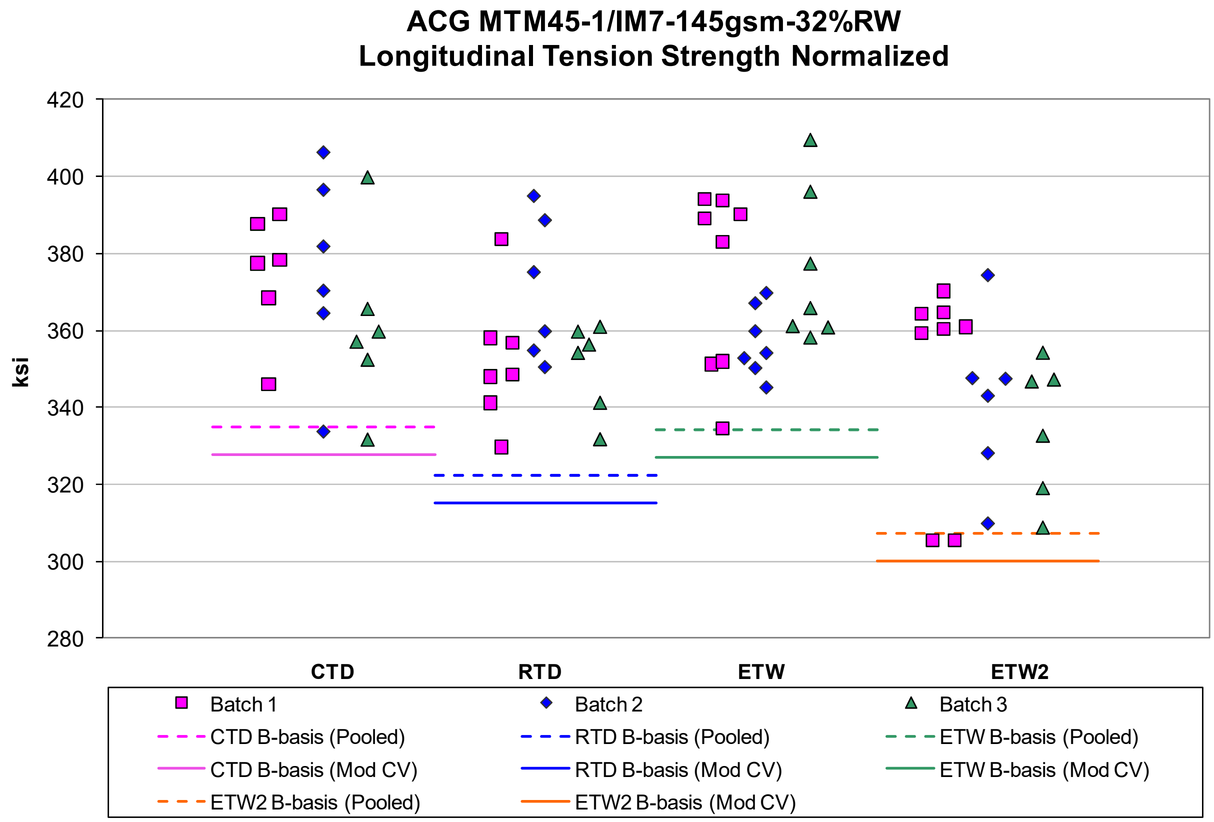

Figure 4-1: Batch plot for LT normalized strength derived from UNT0 specimens

Longitudinal Tension (LT) Strength (ksi) derived from UNT0 specimens Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	370.50	357.65	368.98	342.57	354.11	343.61	355.73	333.93
Stdev	21.54	17.66	19.86	22.61	17.51	16.34	17.14	20.05
CV	5.81	4.94	5.38	6.60	4.95	4.76	4.82	6.00
Mod CV	6.91	6.47	6.69	7.30	6.47	6.38	6.41	7.00
Min	331.71	329.70	334.46	305.47	315.11	315.87	315.04	293.05
Max	406.38	395.06	409.63	374.50	377.01	377.81	388.80	362.37
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	19	22	20	18	19	22	20
Basis Values and/or Estimates								
B-basis Value	334.89	322.24	334.07	307.34	323.13	312.80	325.36	303.29
A-Estimate	311.49	298.81	310.57	283.89	302.78	292.42	304.91	282.88
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-basis Value	327.72	315.11	327.05	300.25	314.54	304.26	316.94	294.79
A-Estimate	299.61	286.97	298.81	272.07	288.54	278.23	290.82	268.72
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-1: Statistics and Basis Values for LT strength from UNT0 data

Longitudinal Tension (LT) Modulus (Msi) Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	23.36	22.90	22.12	23.82	22.34	22.00	21.37	23.24
Stdev	1.12	1.21	0.81	0.76	0.49	0.49	0.62	1.05
CV	4.81	5.28	3.64	3.19	2.21	2.23	2.90	4.52
Mod CV	6.41	6.64	6.00	6.00	6.00	6.00	6.00	6.26
Min	21.96	21.46	20.73	22.68	21.22	21.10	20.36	21.56
Max	25.11	25.47	23.74	25.23	22.99	22.75	22.34	25.07
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	17	16	16	15	17	16	16	15

Table 4-2: Statistics from LT modulus

4.2 Longitudinal (0º) Compression Properties (LC)

The longitudinal compression strengths are computed indirectly from UNC0 specimens via equation 64 specified in section 2.5. There were no test failures, so basis values were computed by pooling across environments. However, there were insufficient specimens to meet the requirements of CMH-17-1G, so only estimates of basis values are provided.

There was one outlier. It was in the ETW2 condition, on the low side of batch 2. It was an outlier only for the normalized data, not for the as measured data. It was an outlier only for the condition, not for the batch, although with only three specimens available from that batch, it is not surprising that it was not identified as an outlier at the batch level. Statistics and basis values are given for strength data in Table 4-3 and for the normalized modulus data in Table 4-4. The normalized data and the B-basis values are shown graphically in Figure 4-2.

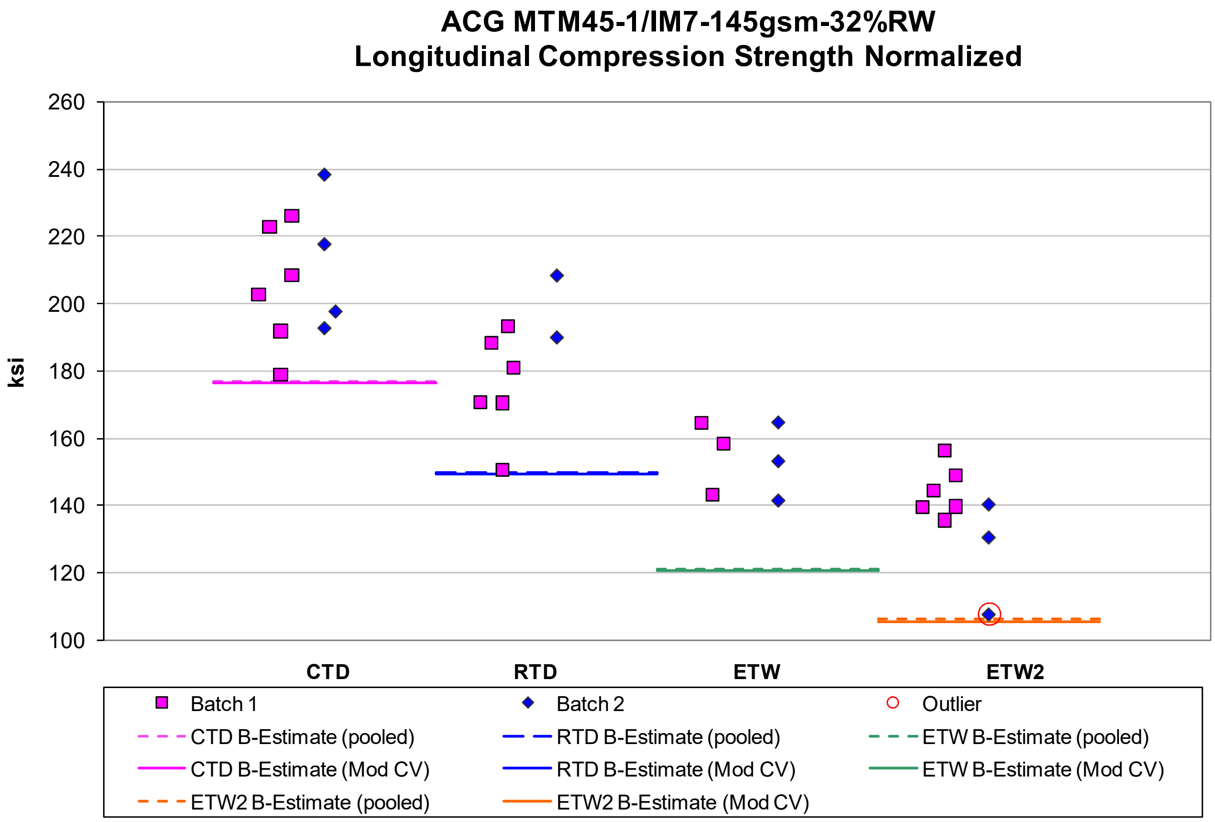

Figure 4-2: Batch plot for LC normalized strength derived from UNC0 specimens

Longitudinal Compression (LC) Strength (ksi) derived from UNC0 specimens Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	204.89	181.54	154.23	138.09	200.54	177.80	154.11	136.37
Stdev	18.11	17.60	10.21	13.67	18.02	15.14	10.34	12.31
CV	8.84	9.69	6.62	9.90	8.99	8.52	6.71	9.03
Mod CV	8.84	9.69	7.31	9.90	8.99	8.52	7.35	9.03
Min	176.54	150.52	141.45	107.57	173.01	150.91	139.18	109.76
Max	235.05	208.31	164.67	156.29	232.27	199.16	167.45	153.20
No. Batches	2	2	2	2	2	2	2	2
No. Spec.	10	8	6	9	10	8	6	9
Basis Values and/or Estimates								
B-Estimate	174.08	149.84	121.19	106.88	171.65	148.08	123.13	107.10
A-Estimate	154.57	130.49	102.03	87.44	153.36	129.93	105.16	88.88
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-Estimate	173.83	149.59	120.93	106.63	171.40	147.82	122.87	106.85
A-Estimate	154.17	130.08	101.61	87.04	152.96	129.52	104.75	88.47
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-3: Statistics and Basis values for LC strength normalized from UNC0

Longitudinal Compression (LC) Modulus (Msi) Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	20.41	20.24	20.25	20.42	19.96	19.84	20.13	20.21
Stdev	1.41	0.98	1.03	0.90	1.03	0.75	0.75	0.64
CV	6.89	4.86	5.06	4.43	5.17	3.78	3.73	3.17
Mod CV	7.44	6.43	6.53	6.21	6.59	6.00	6.00	6.00
Min	17.71	18.01	18.54	18.91	18.36	18.25	18.61	18.82
Max	22.49	21.75	22.22	21.75	21.60	21.03	21.34	21.45
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	20	23	18	20	20	23	18	20

Table 4-4: Statistics from LC modulus

4.3 Transverse (90°) Tension Properties (TT)

The Transverse Tension data is not normalized for unidirectional material. CTD, RTD and ETW2 environments failed the Anderson-Darling k-sample test for batch to batch variability. This means the ANOVA method was required to compute basis values which may result in overly conservative basis values. All three environments also failed the ADK test under the modified CV transformation. The ETW data passes the ADK test, but failed the normality test, so no modified CV values are provided. There were no outliers. Statistics and basis values are given for strength data as measured in Table 4-5 and for the modulus data as measured in Table 4-6. The data, B-estimates, and B-basis values are shown graphically in Figure 4-3.

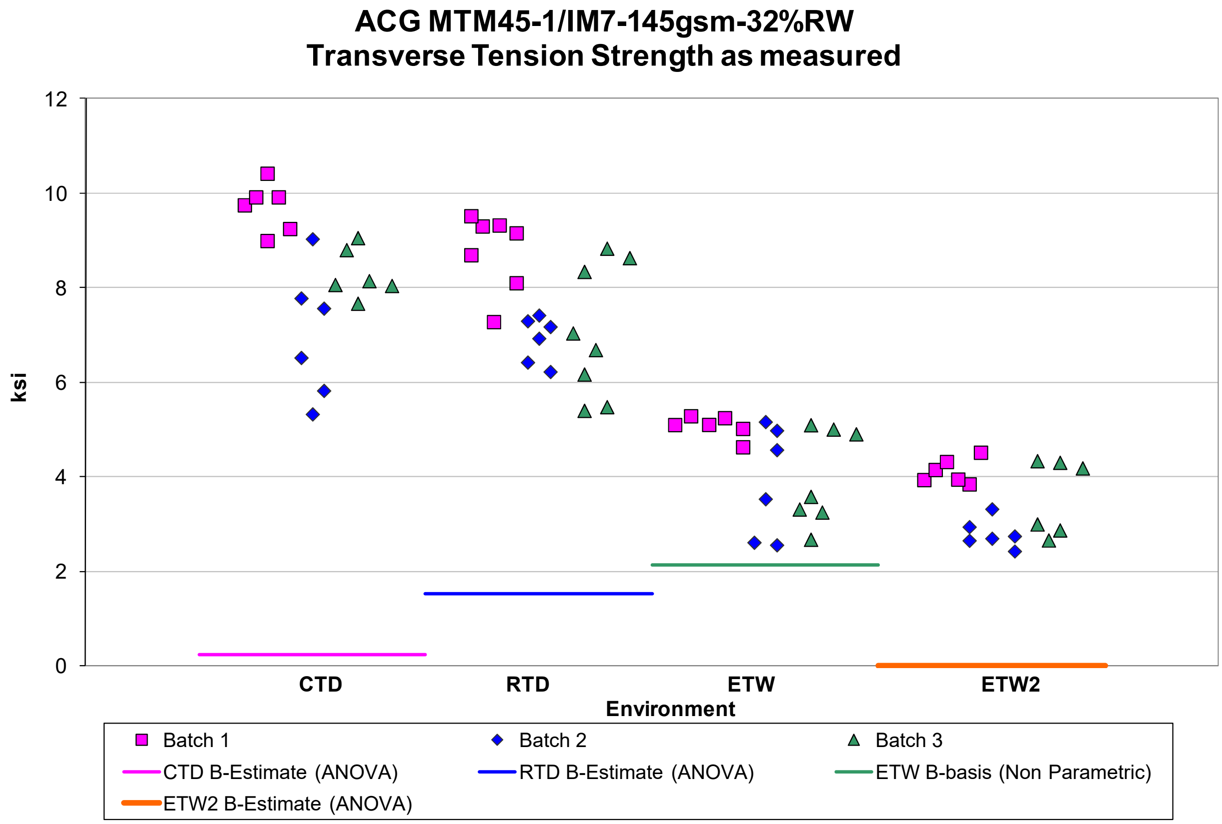

Figure 4-3: Batch Plot for TT strength as measured

Transverse Tension (TT) Strength (ksi) Basis Values and Statistics As Measured				
Env	CTD	RTD	ETW	ETW2
Mean	8.34	7.59	4.30	3.49
Stdev	1.42	1.29	1.01	0.74
CV	16.97	16.97	23.44	21.10
Mod CV	16.97	16.97	23.44	21.10
Min	5.33	5.41	2.56	2.43
Max	10.42	9.52	5.29	4.52
No. Batches	3	3	3	3
No. Spec.	18	21	19	18
Basis Values and/or Estimates				
B-basis Value			2.13	
B-Estimate	0.23	1.53		0.00
A-Estimate	0.00	0.00	0.91	0.00
Method	ANOVA	ANOVA	Non-Parametric	ANOVA

Table 4-5: Statistics and Basis Values for TT Strength data

Transverse Tension (TT) Modulus (Msi) Statistics As Measured				
Env	CTD	RTD	ETW	ETW2
Mean	1.24	1.11	0.95	0.82
Stdev	0.08	0.06	0.05	0.06
CV	6.07	5.08	5.12	7.55
Mod CV	7.04	6.54	6.56	7.78
Min	1.14	1.01	0.87	0.70
Max	1.45	1.24	1.03	0.97
No. Batches	3	3	3	3
No. Spec.	22	23	19	18

Table 4-6: Statistics from TT Modulus data

4.4 Transverse (90º) Compression Properties (TC)

The Transverse Compression data is not normalized for unidirectional material. The Transverse Compression data could be pooled across all environments. There was one outlier in the ETW2 data, batch 3, on the high side. It was an outlier before, but not after, pooling batches together. It was retained for this analysis. Statistics and basis values are given for strength data as measured in Table 4-7 and for the modulus data as measured in Table 4-8. The data and the B-basis values are shown graphically in Figure 4-4.

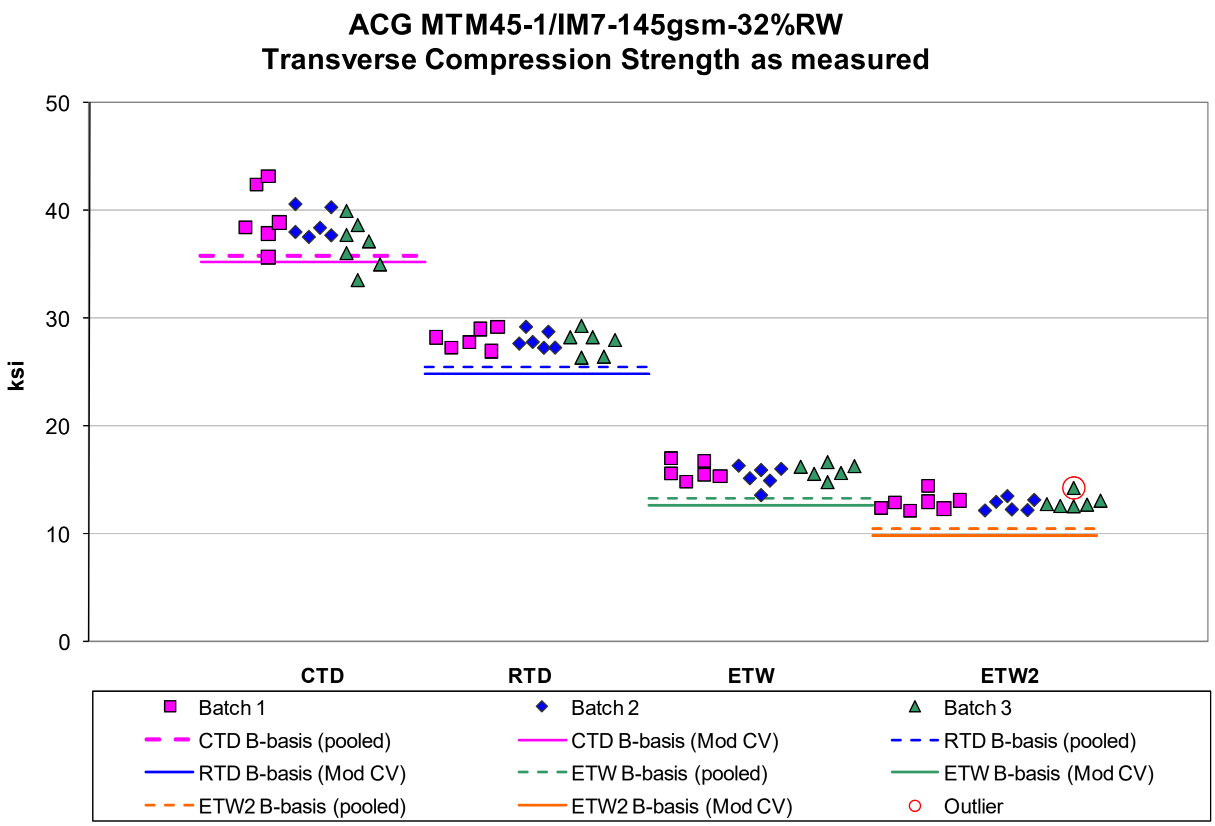

Figure 4-4: Batch Plot for TC strength as measured

Transverse Compression (TC) Strength (ksi) Basis Values and Statistics As Measured				
Env	CTD	RTD	ETW	ETW2
Mean	38.26	27.96	15.71	12.91
Stdev	2.37	0.92	0.85	0.65
CV	6.20	3.29	5.41	5.03
Mod CV	7.10	6.00	6.71	6.52
Min	33.54	26.37	13.58	12.16
Max	43.16	29.30	17.06	14.50
No. Batches	3	3	3	3
No. Spec.	19	18	18	19
Basis Values and/or Estimates				
B-basis value	35.85	25.53	13.28	10.50
A-Estimate	34.25	23.93	11.68	8.90
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates				
B-basis Value	35.24	24.92	12.67	9.89
A-Estimate	33.24	22.92	10.67	7.89
Method	pooled	pooled	pooled	pooled

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

Transverse Compression (TC) Modulus (Msi) Statistics As Measured				
Env	CTD	RTD	ETW	ETW2
Mean	1.30	1.22	1.09	1.01
Stdev	0.08	0.04	0.05	0.07
CV	6.16	3.07	4.70	6.69
Mod CV	7.08	6.00	6.35	7.35
Min	1.18	1.16	0.96	0.93
Max	1.48	1.30	1.15	1.15
No. Batches	3	3	3	3
No. Spec.	18	18	18	19

Table 4-8: Statistics from TC Modulus data

4.5 0°/90° Unnotched Tension Properties (UNT0)

There were no outliers or test failures. Basis values were computed by pooling across environments. Statistics and basis values are given for strength data in Table 4-9 and for the modulus data in Table 4-10. The normalized data and the B-basis values are shown graphically in Figure 4-5.

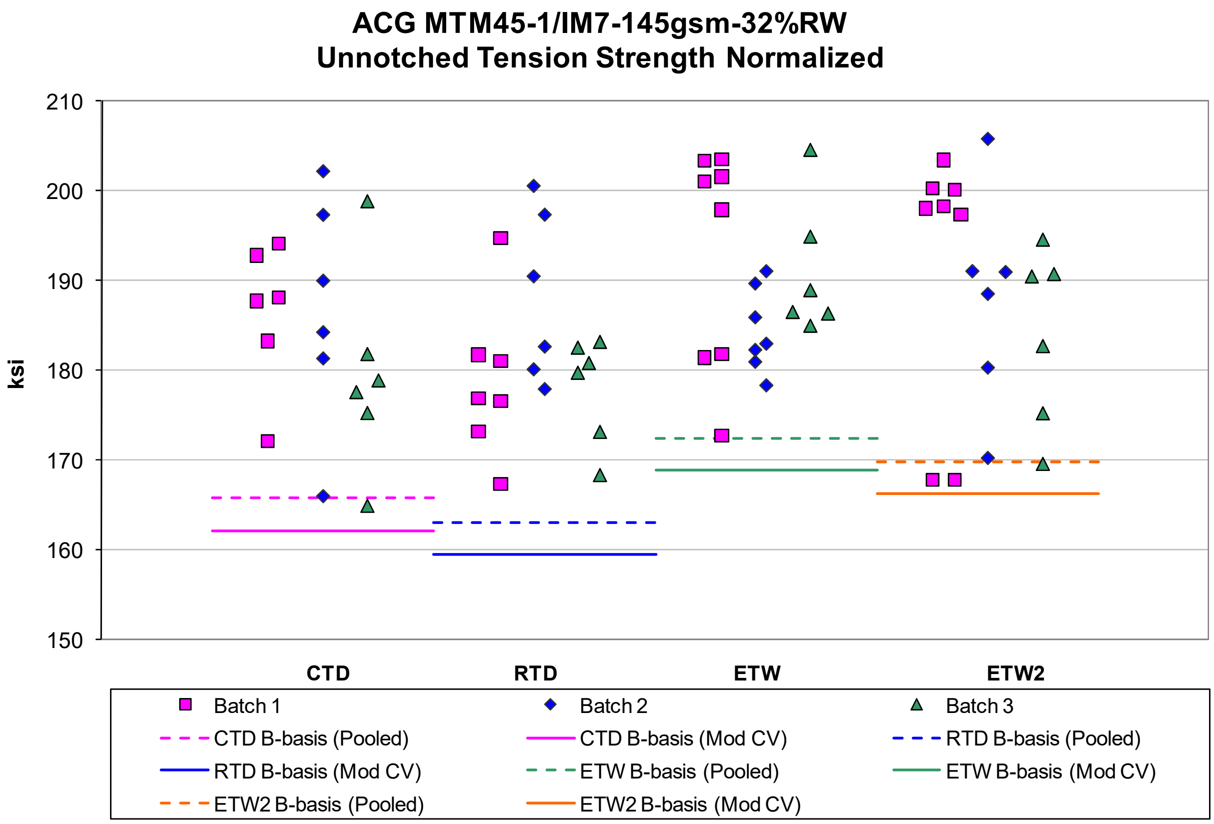

Figure 4-5: Batch Plot for UNT0 strength normalized

Unnotched Tension (UNT0) Strength (ksi) Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	184.31	181.55	190.61	188.22	177.76	174.71	186.51	183.80
Stdev	10.72	8.96	10.26	12.42	8.79	8.31	8.99	11.04
CV	5.81	4.94	5.38	6.60	4.95	4.76	4.82	6.00
Modified CV	6.91	6.47	6.69	7.30	6.47	6.38	6.41	7.00
Min	165.01	167.36	172.78	167.83	158.18	160.60	165.17	161.29
Max	202.16	200.54	211.61	205.76	189.25	192.10	203.85	199.45
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	19	22	20	18	19	22	20
Basis Values and/or Estimates								
B-basis Value	165.77	163.11	172.43	169.87	161.50	158.54	170.57	167.71
A-Estimate	153.58	150.91	160.19	157.66	150.81	147.84	159.83	157.00
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-basis Value	162.11	159.47	168.85	166.25	157.07	154.13	166.22	163.33
A-Estimate	147.52	144.86	154.19	151.63	143.47	140.52	152.56	149.69
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-9: Statistics and Basis Values for UNT0 Strength data

Unnotched Tension (UNT0) Modulus (Msi) Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	11.62	11.62	11.43	13.09	11.21	11.19	11.20	12.79
Stdev	0.60	0.52	0.46	0.91	0.53	0.44	0.38	0.95
CV	5.20	4.48	3.99	6.92	4.70	3.91	3.39	7.41
Mod CV	6.60	6.24	6.00	7.46	6.35	6.00	6.00	7.70
Min	9.92	10.69	10.74	11.04	9.51	10.29	10.34	10.51
Max	12.53	12.33	12.15	14.90	11.91	11.77	11.91	14.44
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	20	22	20	18	20	22	20

Table 4-10: Statistics from UNT0 Modulus data

4.6 0°/90º Unnotched Compression Properties (UNC0)

Only two batches of material and only eight to ten specimens were available for this analysis. This is insufficient to meet the requirements of CMH-17-1G which requires three independent batches and a minimum of 15 specimens for each condition when pooling is used. Both A-Estimates and B-Estimates based on this data are provided. There were no test failures, so pooling was acceptable for both normalized and as measured data. There was one outlier. It was in the ETW2 normalized data after pooling batches within that environment. Statistics and basis values are given for strength data in Table 4-11 and for the modulus data in Table 4-12. The normalized data and the B-estimates are shown graphically in Figure 4-6.

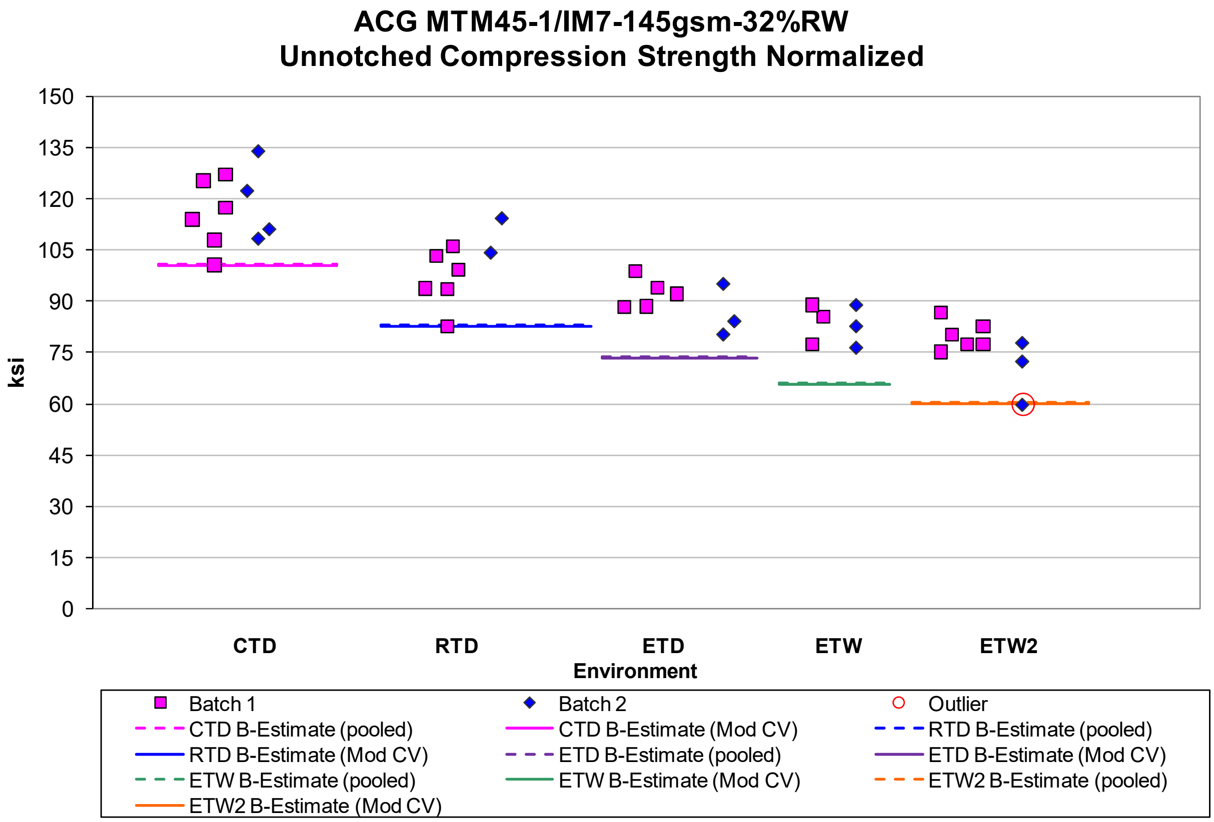

Figure 4-6: Batch Plot for UNC0 strength normalized

Unnotched Compression (UNC0) Strength (ksi) Basis Values and Statistics										
	Normalized					As Measured				
Env	CTD	RTD	ETD	ETW	ETW2	CTD	RTD	ETD	ETW	ETW2
Mean	116.81	99.65	90.17	83.27	76.56	113.57	96.80	87.80	82.24	75.32
Stdev	10.33	9.66	6.10	5.51	7.58	10.21	8.24	6.14	5.52	6.80
CV	8.84	9.69	6.76	6.62	9.90	8.99	8.52	7.00	6.71	9.03
Modified CV	8.84	9.69	7.38	7.31	9.90	8.99	8.52	7.50	7.35	9.03
Min	100.64	82.62	80.27	76.37	59.64	97.97	82.16	77.88	74.28	60.63
Max	134.00	114.34	98.91	88.91	86.65	131.53	108.43	95.86	89.36	84.62
No. Batches	2	2	2	2	2	2	2	2	2	2
No. Spec.	10	8	8	6	9	10	8	8	6	9
Basis Values and/or Estimates										
B-Estimate	100.76	83.12	73.65	66.03	60.30	98.47	81.25	72.24	66.02	60.02
A-Estimate	90.73	73.16	63.69	56.16	50.30	89.03	71.87	62.87	56.73	50.61
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates										
B-Estimate	100.49	82.85	73.37	65.75	60.03	98.23	81.00	72.00	65.77	59.78
A-Estimate	90.29	72.72	63.25	55.71	49.86	88.64	71.48	62.48	56.33	50.22
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-11: Statistics and Basis Values for UNC0 Strength data

Unnotched Compression (UNC0) Modulus (Msi) Statistics										
	Normalized					As Measured				
Env	CTD	RTD	ETD	ETW	ETW2	CTD	RTD	ETD	ETW	ETW2
Mean	11.64	11.11	11.24	10.93	11.32	11.30	10.80	10.98	10.74	11.16
Stdev	1.21	0.73	0.73	0.86	0.78	1.05	0.72	0.70	0.82	0.78
CV	10.38	6.54	6.46	7.90	6.89	9.30	6.64	6.40	7.62	6.95
Mod CV	10.38	7.27	7.23	7.95	7.44	9.30	7.32	7.20	7.81	7.47
Min	9.88	10.16	9.78	9.23	10.31	9.71	9.76	9.59	9.05	10.07
Max	13.25	12.24	12.05	12.42	12.83	12.70	11.86	11.72	12.10	12.69
No. Batches	2	2	2	2	2	2	2	2	2	2
No. Spec.	10	8	11	12	11	10	8	11	12	11

Table 4-12: Statistics from UNC0 Modulus data

4.7 In-Plane Shear Properties (IPS)

Only two batches of material were available for this analysis. This is insufficient to meet the requirements of CMH-17-1G which requires three independent batches. However, both A-Estimates and B-Estimates based on this data are provided.

For the 0.2% offset strength data, the RTD and ETW environments failed the normality test as did the combined data, which meant that pooling was not appropriate. There were two outliers before pooling batches only, in the ETW2 environment, batch one, on the low side. These outliers were retained for this analysis.

The strength at 5% strain data could not be pooled across environments due to the non-normality of the pooled dataset. Modified CV values could not be provided for CTD and RTD data due to non-normality. There were no outliers.

Statistics and basis values are given for strength data as measured in Table 4-13 and the modulus data as measured in Table 4-14. The data and the B-basis values are shown graphically in Figure 4-7 for 0.2% offset strength and in Figure 4-8 for 5% strain strength.

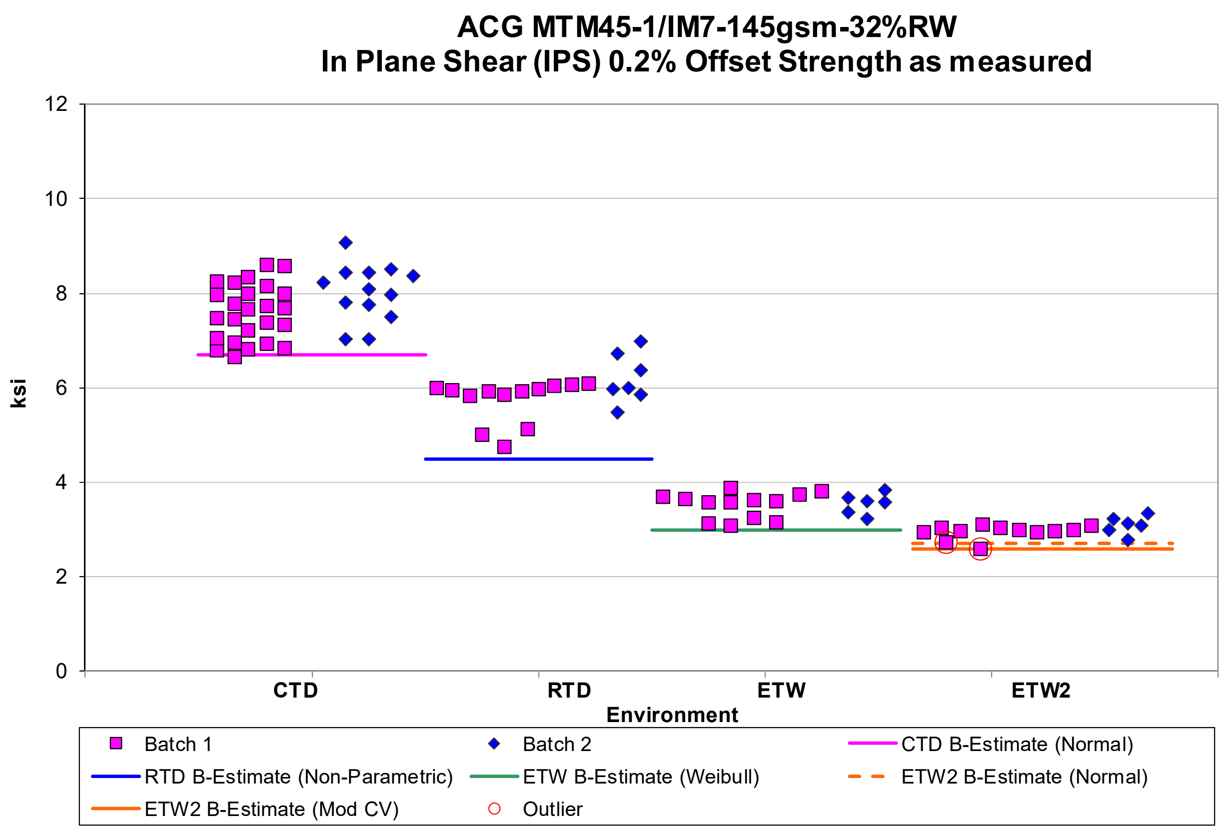

Figure 4-7: Batch plot for IPS 0.2% offset strength as measured

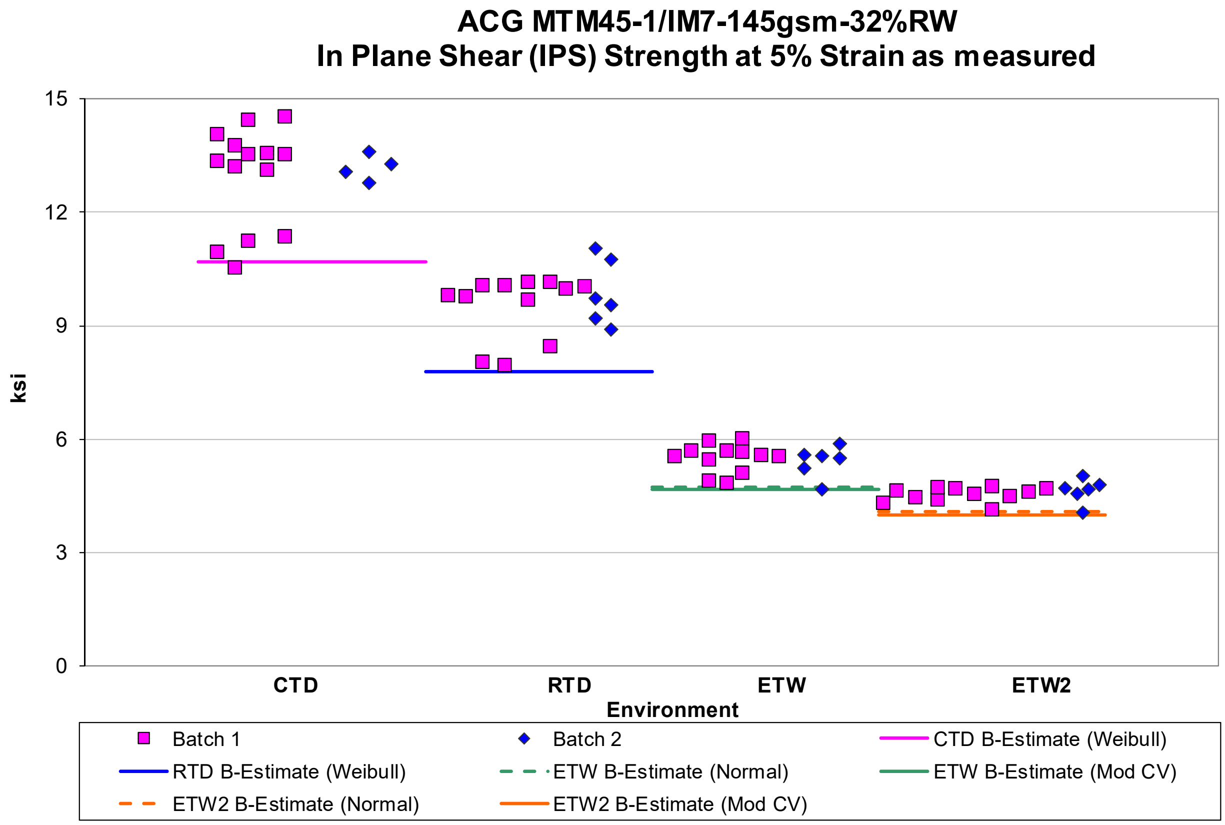

Figure 4-8: Batch plot for IPS strength at 5% strain as measured

In-Plane Shear (IPS) Properties Basis Values and Statistics As Measured								
	0.2% Offset Strength (ksi)				Strength at 5% Strain (ksi)			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	7.74	5.90	3.53	3.00	13.00	9.63	5.48	4.58
Stdev	0.62	0.52	0.25	0.17	1.18	0.84	0.38	0.23
CV	7.98	8.77	7.12	5.75	9.05	8.71	6.93	5.12
Mod CV	7.99	8.77	7.56	6.88	9.05	8.71	7.46	6.56
Min	6.66	4.76	3.08	2.60	10.56	7.96	4.68	4.07
Max	9.08	6.99	3.89	3.35	14.53	11.03	6.02	5.03
No. Batches	2	2	2	2	2	2	2	2
No. Spec.	38	20	19	18	18	18	18	18
Basis Values and/or Estimates								
B-Estimate	6.68	4.50	3.00	2.66	10.69	7.80	4.73	4.12
A-Estimate	5.91	2.82	2.48	2.42	8.55	6.14	4.20	3.79
Method	Normal	Non-Parametric	Weibull	Normal	Weibull	Weibull	Normal	Normal
Modified CV Basis Values and/or Estimates								
B-Estimate	NA	NA	NA	2.59	NA	NA	4.67	3.99
A-Estimate	NA	NA	NA	2.30	NA	NA	4.10	3.57
Method	NA	NA	NA	Normal	NA	NA	Normal	Normal

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

In-Plane Shear (IPS) Modulus (Msi) Statistics				
Env	CTD	RTD	ETW	ETW2
Mean	0.63	0.52	0.36	0.32
Stdev	0.05	0.05	0.03	0.02
CV	8.44	9.14	7.11	7.52
Mod CV	8.44	9.14	7.55	7.76
Min	0.54	0.42	0.32	0.27
Max	0.75	0.62	0.40	0.36
No. Batches	2	2	2	2
No. Spec.	38	20	19	18

Table 4-14: Statistics for IPS modulus

4.8 Short Beam Strength (SBS)

Only the ETW and ETW2 environments have sufficient data to meet the requirements of CMH-17-1G. However, both the ETW and ETW2 data fail the normality test, so pooling cannot be done and the modified CV method cannot be used with those environments. In addition, the RTD environment lacks sufficient data for pooling across environments. There were two outliers, one in batch two after pooling the batches in ETW and one in batch one of the ETW2 data before pooling batches. Both outliers were on the high side and both were retained for this analysis. Statistics and basis values are given for SBS data as measured in Table 4-15. The data, B-estimates and B-basis values are shown graphically in Figure 4-9.

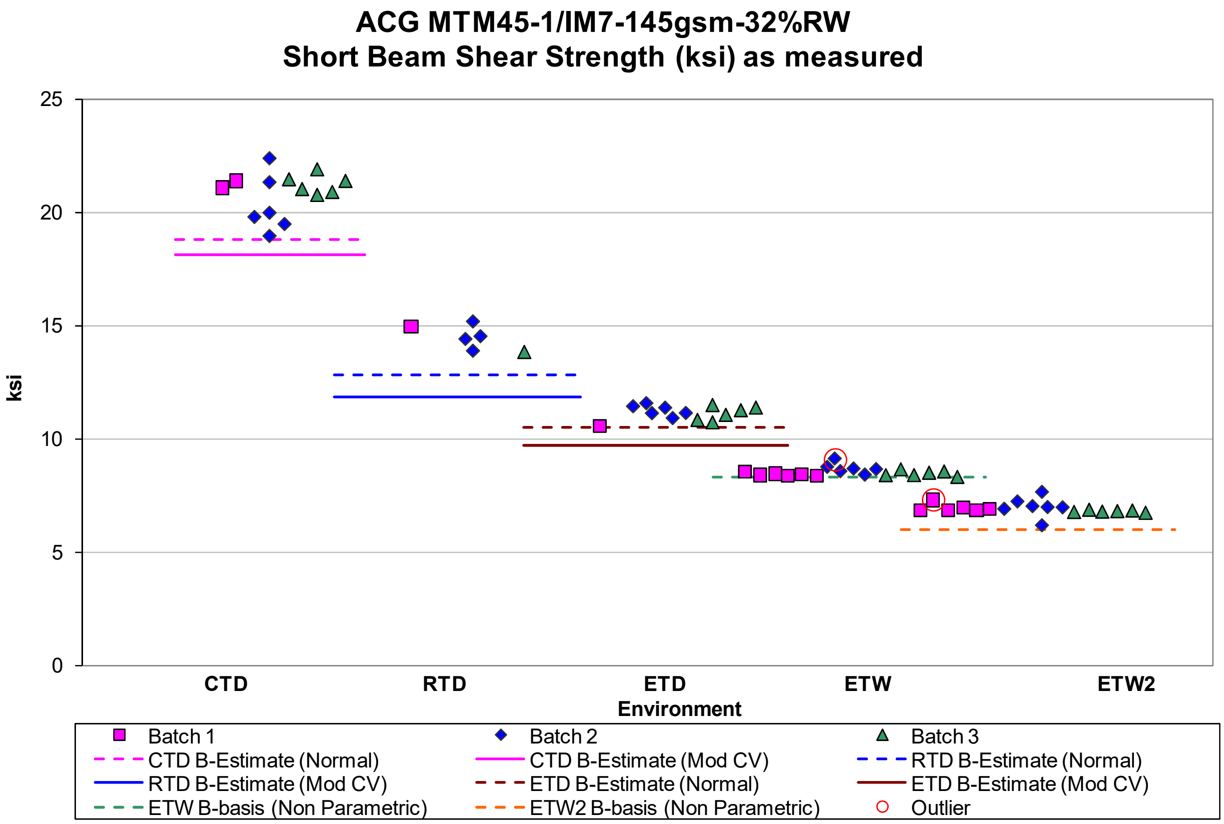

Figure 4-9: Batch plot for SBS Strength as measured

Short Beam Strength (SBS) Basis Values and Statistics As Measured					
Env	CTD	RTD	ETD	ETW	ETW2
Mean	20.85	14.47	11.15	8.54	6.92
Stdev	0.97	0.54	0.31	0.19	0.28
CV	4.64	3.75	2.77	2.24	4.10
Mod CV	6.32	6.00	6.00	6.00	6.05
Min	18.95	13.85	10.59	8.33	6.18
Max	22.39	15.18	11.57	9.12	7.65
No. Batches	3	3	3	3	3
No. Spec.	14	6	13	18	19
Basis Values and/or Estimates					
B-basis Value				8.28	5.98
B-Estimate	18.81	12.83	10.49		
A-Estimate	17.39	11.72	10.02	7.27	4.55
Method	Normal	Normal	Normal	Non-Parametric	Non-Parametric
Modified CV Basis Values and/or Estimates					
B-Estimate	18.07	11.85	9.71	NA	NA
A-Estimate	16.13	10.06	8.70	NA	NA
Method	Normal	Normal	Normal	NA	NA

Table 4-15: Statistics and Basis Values for SBS data

5. Laminate Test Results, Statistics, Basis Values and Graph

Many of the laminate tests were performed with one batch only. In those cases, there was insufficient data to produce basis values meeting the requirements of CMH-17-1G, so only estimates are provided. When possible, estimates were prepared in the following ways and multiple estimates are provided.

1. Using the ASAP program to pool across the available environments. The modified CV values from this program are provided.
2. The Lamina Variability method detailed in section 2.4. For properties that use the CV of the LC datasets, modified CV values are not available for the CTD, RTD and ETW2 conditions due to the large CV (over 8%) of those datasets.

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

5.1.1 Quasi Isotropic Open Hole Tension (OHT1)

The only test failure is for the normalized ETW2 data which fails the normality test. However, the normality of the pooled dataset is acceptable, so all environments can be pooled. There are no outliers. The ETW environment, with only six specimens from a single batch, has insufficient data to produce a publishable B-basis value, but it was included in the pooled data analysis and estimates are provided. Statistics and basis values are given for OHT1 strength data in Table 5-1. The normalized data, B-estimates, and B-basis values are shown graphically in Figure 5-1.

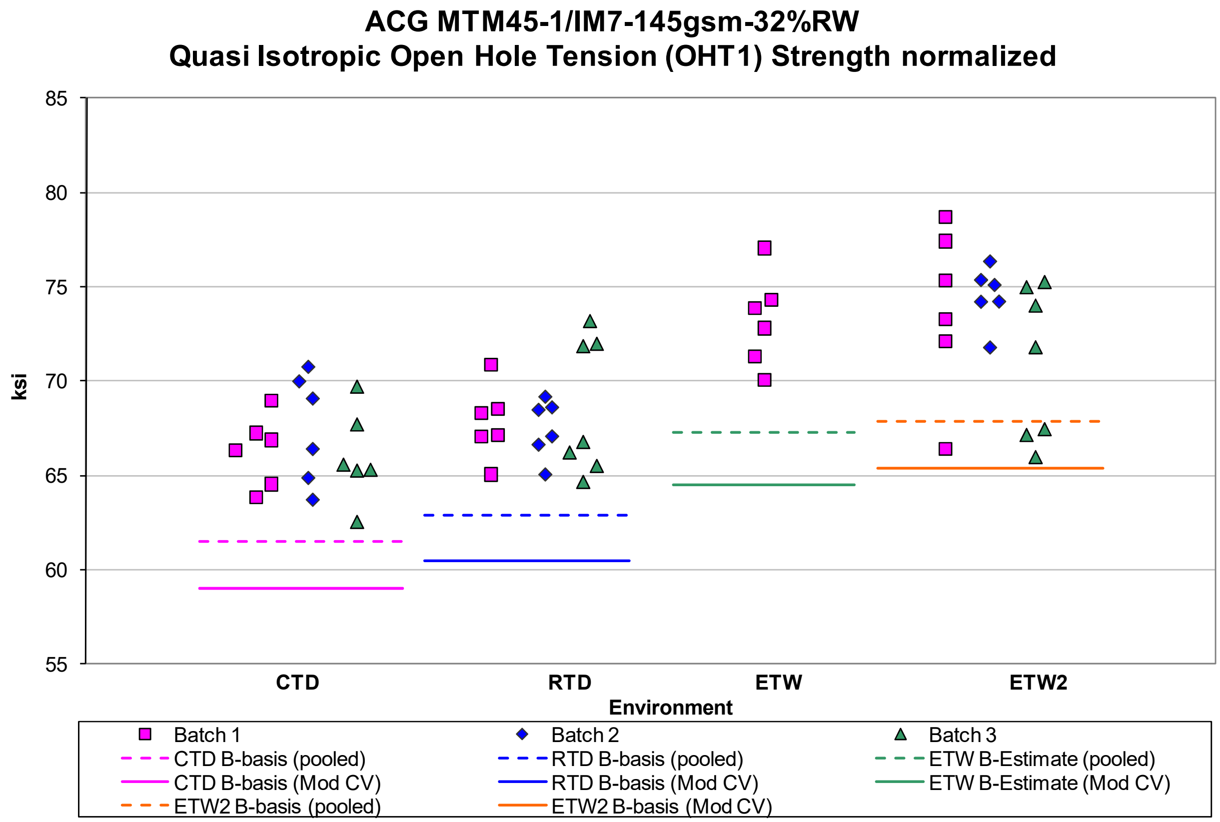

Figure 5-1: Batch plot for OHT1 strength normalized

Laminate Open Hole Tension (OHT1) Strength (ksi) Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	66.59	68.01	73.24	72.99	65.42	66.79	71.45	71.68
Stdev	2.38	2.49	2.46	3.75	2.43	2.12	2.70	3.26
CV	3.57	3.67	3.36	5.14	3.72	3.17	3.78	4.54
Modified CV	6.00	6.00	6.00	6.57	6.00	6.00	6.00	6.27
Min	62.52	64.64	70.05	65.96	60.59	63.40	67.65	65.38
Max	70.75	73.19	77.07	78.69	69.38	71.30	75.73	75.95
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	19	6	19	18	19	6	19
Basis Values and/or Estimates								
B-basis Value	61.47	62.92		67.90	60.76	62.15		67.04
B-Estimate			67.33				66.07	
A-Estimate	58.08	59.52	64.03	64.49	57.66	59.05	63.05	63.94
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-basis Value	59.00	60.46		65.44	58.10	59.50		64.39
B-Estimate			64.48				63.00	
A-Estimate	53.96	55.42	59.58	60.39	53.24	54.64	58.27	59.53
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 5-1: Statistics and Basis Values for OHT1 Strength data

5.1.2 "Soft" Open Hole Tension (OHT2)

Only the CTD environment has sufficient data B-basis values to meet the standards of CMH-17-1G. The RTD and ETW2 datasets each have only six specimens from a single batch. Estimates were prepared for those environments using the lamina variability method (LVM).

There were two outliers in the CTD data. One outlier was on the high side of batch two. It was an outlier in both the normalized and as measured data and both before and after pooling the three batches. The second outlier was on the high side of batch one. It was an outlier only in the as measured data and only after pooling the three batches. Both outliers were retained for this analysis.

The CTD did not pass the normality test. This was due to the single outlier in batch two. An override of the normality test result is recommended and modified CV basis values are provided assuming a normal distribution.

Statistics and basis values are given for OHT2 strength data in Table 5-2. The normalized data, B-estimates, and B-basis values are shown graphically in Figure 5-2.

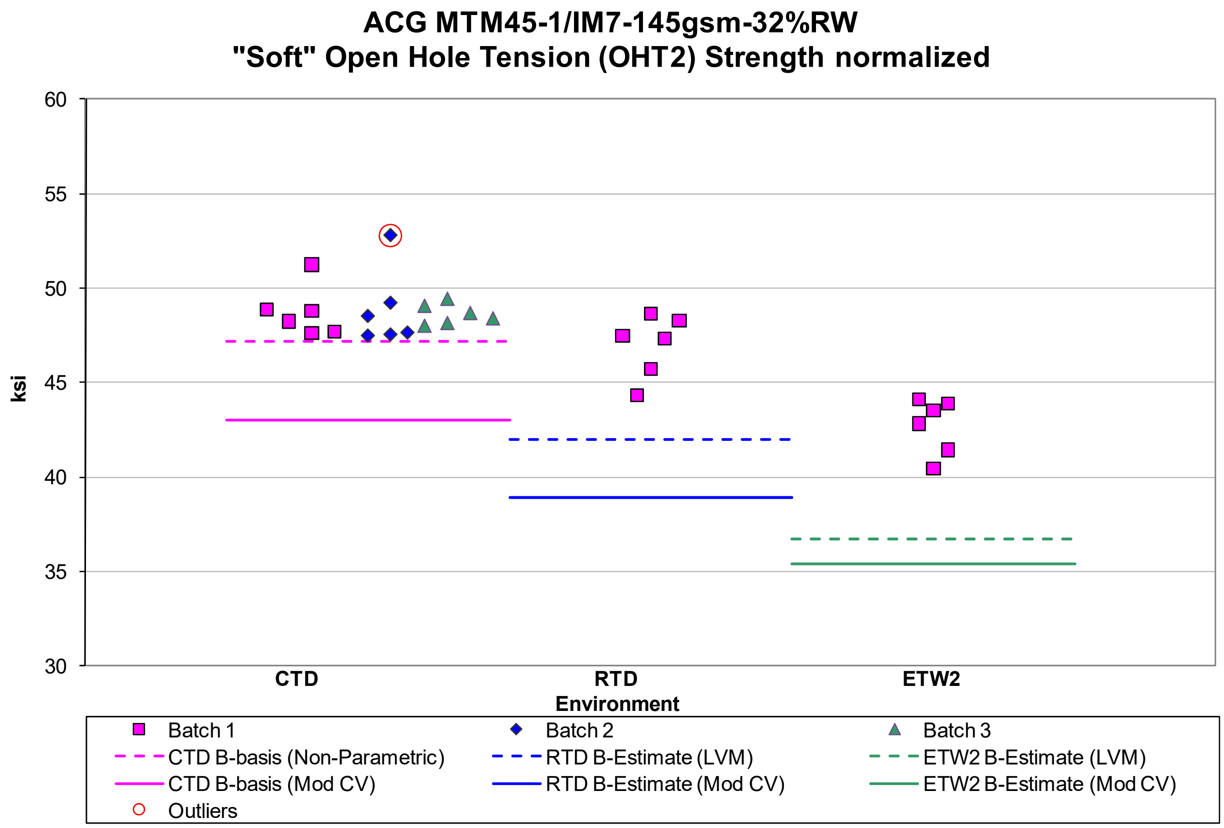

Figure 5-2: Batch plot for OHT2 strength normalized

Laminate Open Hole Tension (OHT2) Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	48.77	46.98	42.72	48.06	46.41	42.04
Stdev	1.36	1.65	1.47	1.35	1.64	1.16
CV	2.79	3.50	3.44	2.81	3.54	2.75
Modified CV	6.00	8.00	8.00	6.00	8.00	8.00
Min	47.50	44.34	40.44	46.12	44.46	40.34
Max	52.81	48.68	44.11	52.19	48.90	43.79
No. Batches	3	1	1	3	1	1
No. Spec.	18	6	6	18	6	6
Basis Values and/or Estimates						
B-basis Value	47.18			45.53		
B-Estimate		42.00	36.69		41.67	36.64
A-Estimate	40.53	NA	NA	38.32	NA	NA
Method	on-Parametr	LVM	LVM	on-Parametr	LVM	LVM
Modified CV Basis Values and/or Estimates with recommended override						
B-basis Value	42.99			42.37		
B-Estimate		38.91	35.41		38.43	34.85
A-Estimate	38.90	NA	NA	38.34	NA	NA
Method	Normal	LVM	LVM	Normal	LVM	LVM

Table 5-2: Statistics and Basis Values for OHT2 Strength data

5.1.3 "Hard" Open Hole Tension (OHT3)

Only the CTD environment has sufficient data to produce B-basis values that meet the standards of CMH-17-1G. The RTD environment has eight specimens from a single batch. The ETW2 datasets has seven specimens from a single batch. Estimates were prepared for those environments using the lamina variability method (LVM). There were no outliers. Statistics and basis values are given for OHT3 strength data in Table 5-3. The normalized data and the B-basis values and estimates are shown graphically in Figure 5-3.

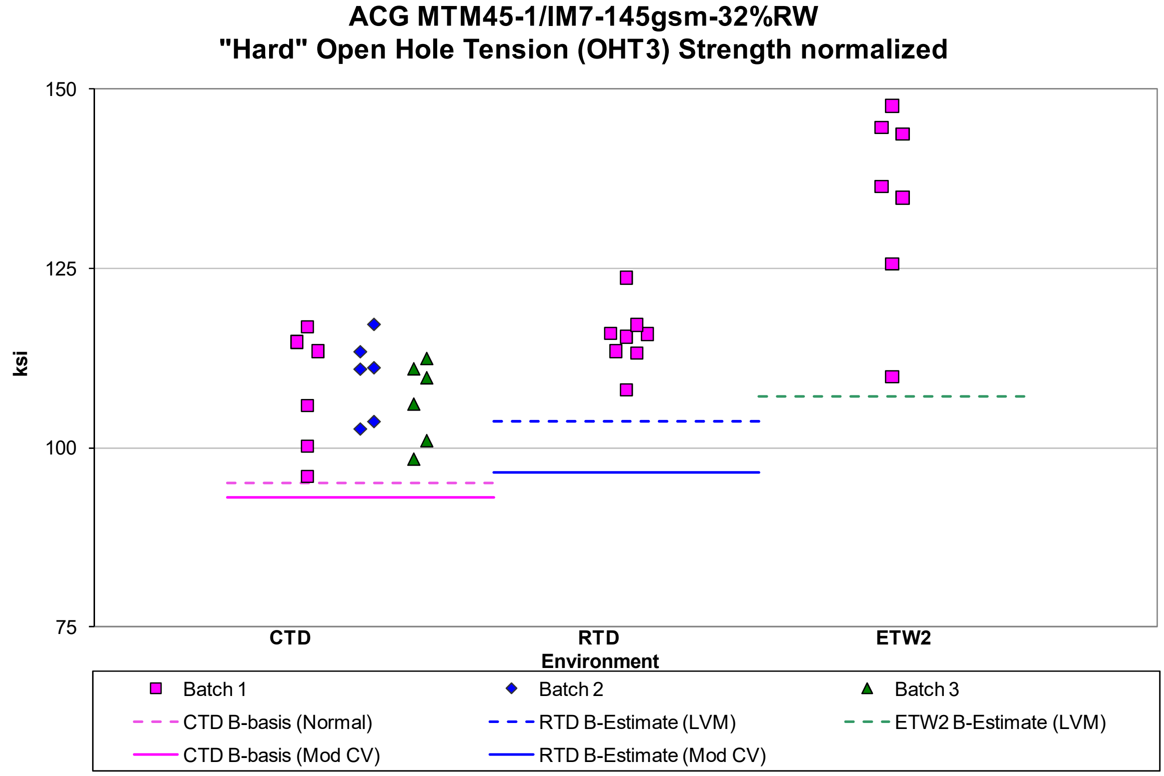

Figure 5-3: Batch plot for OHT3 strength normalized

Laminate Open Hole Tension (OHT3) Strength(ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	108.07	115.39	134.75	106.97	113.42	133.60
Stdev	6.53	4.39	13.21	6.59	6.25	10.88
CV	6.04	3.80	9.80	6.16	5.51	8.14
Modified CV	7.02	8.00	9.80	7.08	8.00	8.14
Min	95.97	108.07	109.98	94.08	103.46	112.02
Max	117.28	123.73	147.71	118.68	124.07	143.92
No. Batches	3	1	1	3	1	1
No. Spec.	18	8	7	18	8	7
Basis Values and/or Estimates						
B-basis Value	95.18			93.96		
B-Estimate		103.73	107.21		100.63	110.92
A-Estimate	86.05	NA	NA	84.74	NA	NA
Method	Normal	LVM	LVM	Normal	LVM	LVM
Modified CV Basis Values and/or Estimates						
B-basis Value	93.09			92.02		
B-Estimate		96.49	NA		94.85	NA
A-Estimate	82.50	NA	NA	81.44	NA	NA
Method	Normal	LVM	NA	Normal	LVM	NA

Table 5-3: Statistics and Basis Values for OHT3 strength data

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

5.2.1 Quasi Isotropic Open Hole Compression (OHC1)

There is insufficient data to produce B-basis values that meet the standards of CMH-17-1G for the ETW environment, so only estimates are provided for that environment. B-estimates were prepared using the lamina variability method (LVM). The RTD data did not pass the Anderson-Darling k-sample test for batch to batch variability. This means the ANOVA method was required to compute basis values which may result in overly conservative basis values. However, the RTD data did pass the ADK test after the transformation for the modified CV method, so modified CV values are provided.

There were two outliers in the OHC1 data with both being on the high side of the as measured data only. One outlier was in the ETW condition which had only one batch of material available, so it was an outlier for the batch only. The second outlier was in the ETW2 condition. It was an outlier only for the batch and not for the condition. Statistics and basis values are given for OHC1 strength data in Table 5-4. The normalized data, B-estimates, and B-basis values are shown graphically in Figure 5-4.

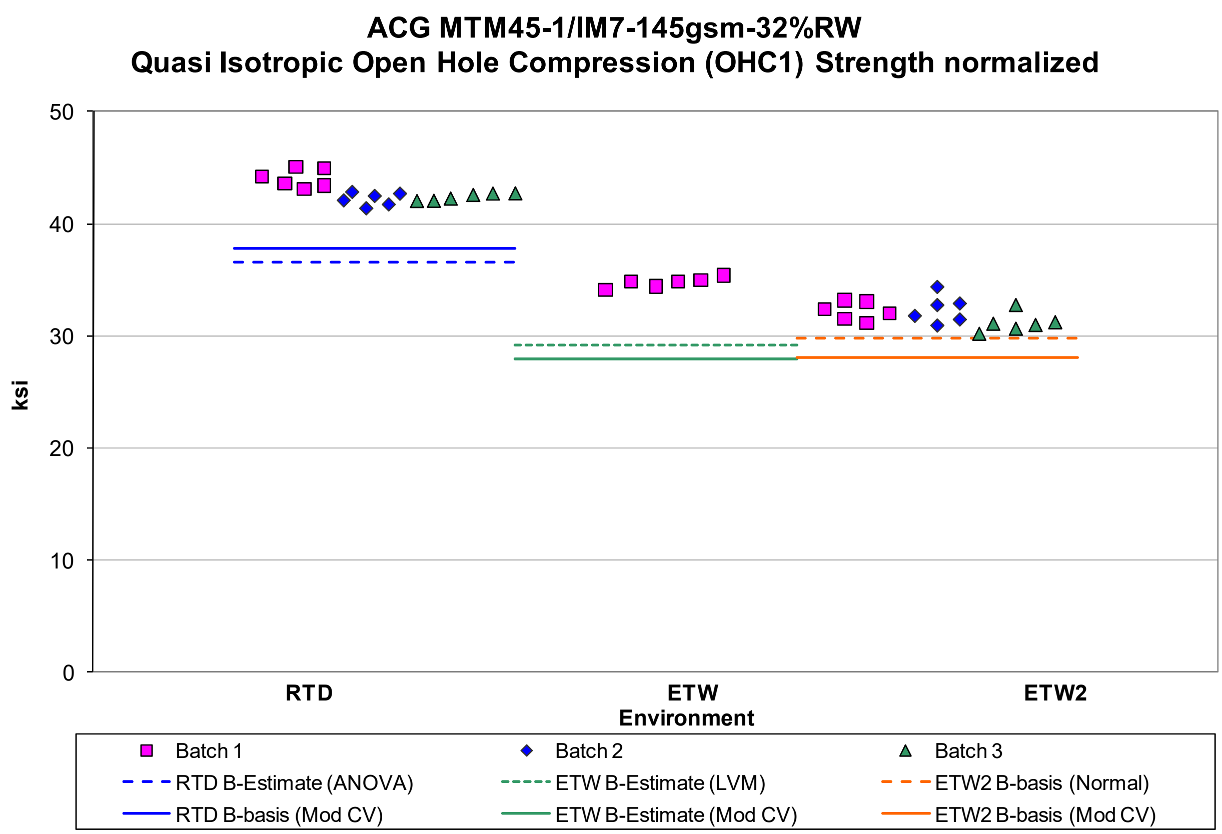

Figure 5-4: Batch plot for OHC1 strength normalized

Laminate Open Hole Compression (OHC1) Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	RTD	ETW	ETW2	RTD	ETW	ETW2
Mean	42.87	34.76	31.91	42.32	33.97	31.61
Stdev	1.05	0.45	1.09	0.75	0.47	0.84
CV	2.44	1.29	3.42	1.77	1.39	2.65
Modified CV	6.00	8.00	6.00	6.00	8.00	6.00
Min	41.35	34.12	30.18	40.80	33.57	30.44
Max	45.10	35.40	34.36	43.43	34.89	33.46
No. Batches	3	1	3	3	1	3
No. Spec.	18	6	18	18	6	18
Basis Values and/or Estimates						
B-basis Value			29.75			29.96
B-Estimate	36.58	29.18		38.37	28.44	
A-Estimate	32.09	NA	28.23	35.56	NA	28.79
Method	ANOVA	LVM	Normal	ANOVA	LVM	Normal
Modified CV Basis Values and/or Estimates						
B-basis Value	37.79		28.13	37.31		27.86
B-Estimate		28.02			27.38	
A-Estimate	34.20	NA	25.46	33.76	NA	25.22
Method	Normal	LVM	Normal	Normal	LVM	Normal

Table 5-4: Statistics and Basis Values for OHC1 Strength data

5.2.2 “Soft” Open Hole Compression (OHC2)

There is insufficient data to produce B-basis values that meet the standards of CMH-17-1G for the RTD environment, so only estimates are provided for that environment. B-estimates were prepared using the lamina variability method (LVM). There were no outliers. Statistics and basis values are given for OHC2 strength data in Table 5-5. The normalized data and the B-basis values and estimates are shown graphically in Figure 5-5.

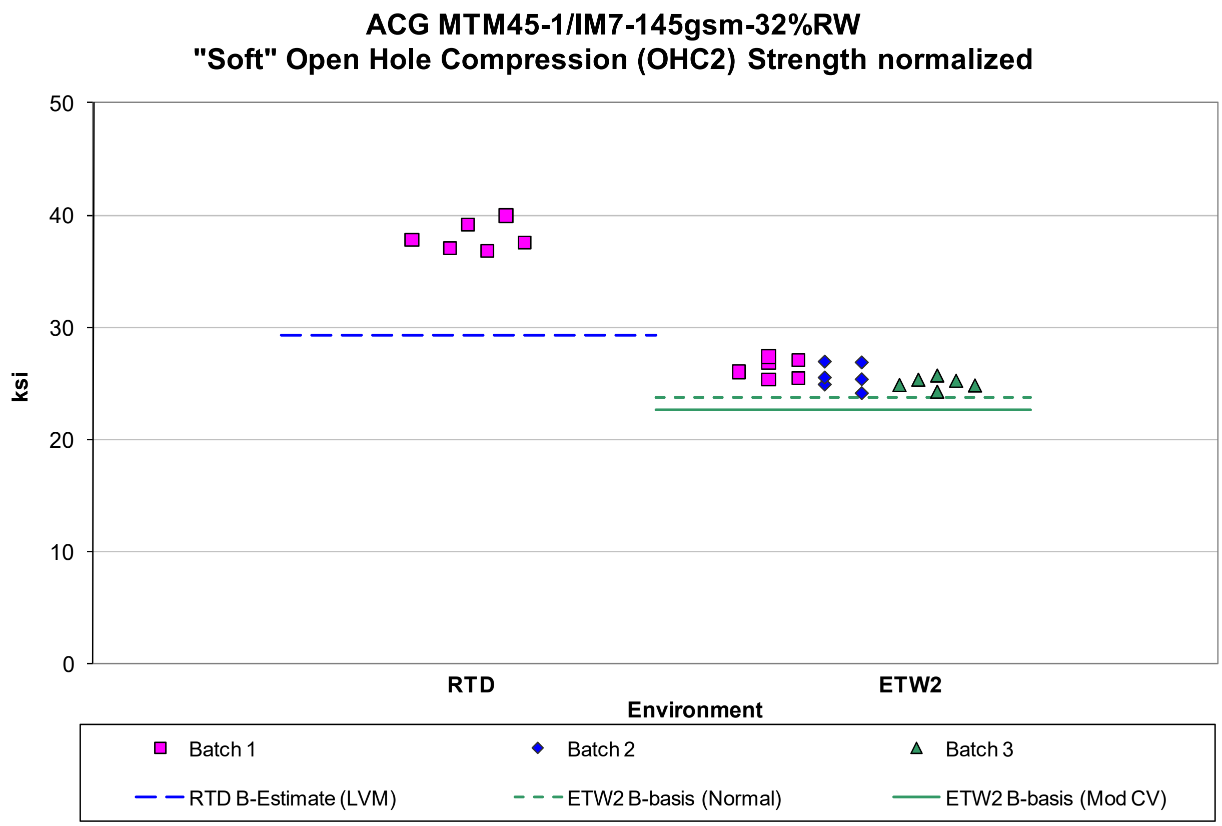

Figure 5-5: Batch plot for OHC2 strength normalized

Laminate Open Hole Compression (OHC2) Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	38.05	25.71	36.76	25.20
Stdev	1.24	0.98	0.56	0.78
CV	3.26	3.82	1.53	3.08
Modified CV	8.00	6.00	8.00	6.00
Min	36.84	24.11	35.90	23.88
Max	39.94	27.39	37.53	26.78
No. Batches	1	3	1	3
No. Spec.	6	18	6	18
Basis Values and/or Estimates				
B-basis Value		23.77		23.67
B-Estimate	29.42		29.43	
A-Estimate	NA	22.40	NA	22.59
Method	LVM	Normal	LVM	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value		22.66		22.22
B-Estimate	NA		NA	
A-Estimate	NA	20.51	NA	20.10
Method	NA	Normal	NA	Normal

Table 5-5: Statistics and Basis Values for OHC2 Strength data

5.2.3 "Hard" Open Hole Compression (OHC3)

There is insufficient data to produce B-basis values that meet the standards of CMH-17-1G for the RTD environment, so only estimates are provided for that condition. B-estimates were prepared using the lamina variability method (LVM). There were no outliers. Statistics and basis values are given for OHC3 strength data in Table 5-6. The normalized data and the B-basis values are shown graphically in Figure 5-6.

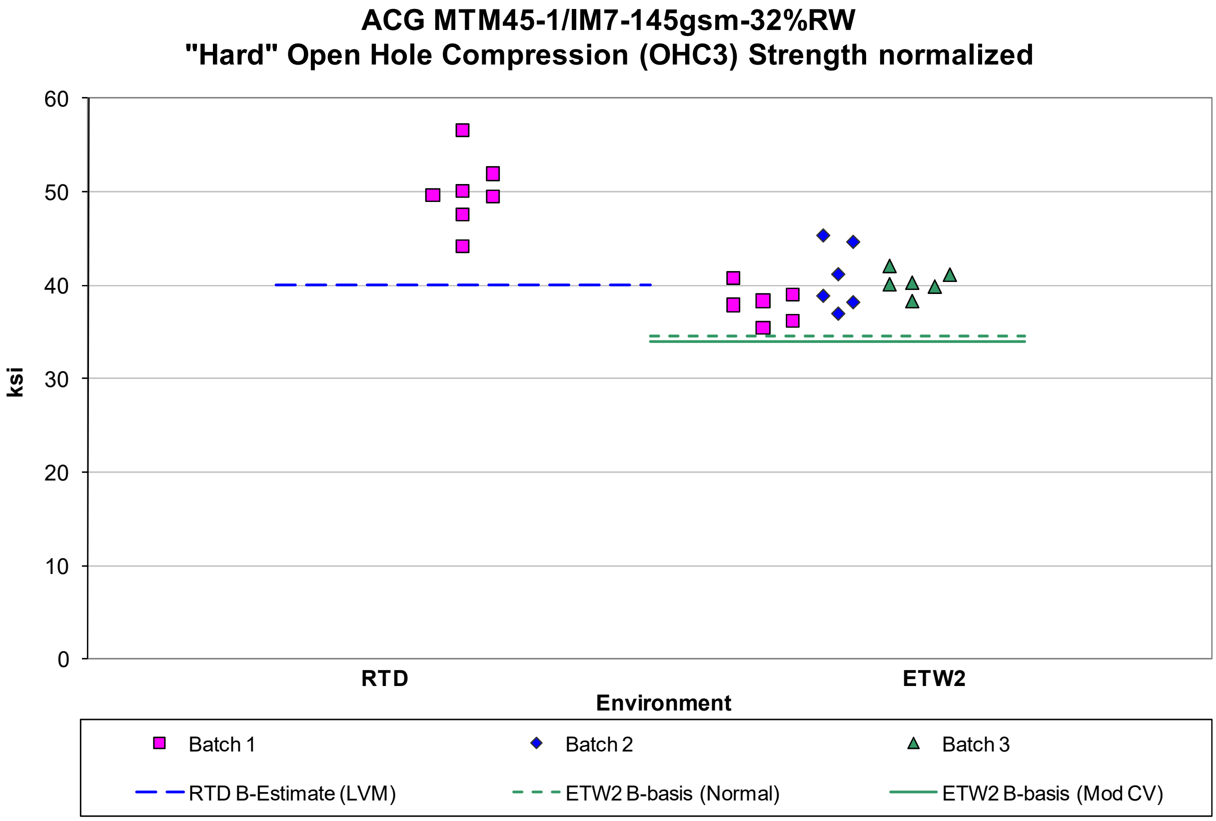

Figure 5-6: Batch plot for OHC3 strength normalized

Laminate Open Hole Compression (OHC3) Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	49.93	39.70	49.12	39.41
Stdev	3.82	2.60	4.86	2.95
CV	7.64	6.55	9.90	7.49
Modified CV	8.00	7.27	9.90	7.75
Min	44.21	35.42	41.99	34.13
Max	56.62	45.27	56.77	45.34
No. Batches	1	3	1	3
No. Spec.	7	18	7	18
Basis Values and/or Estimates				
B-basis Value		34.57		33.58
B-Estimate	38.98		38.12	
A-Estimate	NA	30.94	NA	29.45
Method	LVM	Normal	LVM	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value		34.00		33.38
B-Estimate	NA		NA	
A-Estimate	NA	29.97	NA	29.12
Method	NA	Normal	NA	Normal

Table 5-6: Statistics and Basis Values for OHC3 Strength data

5.3 Unnotched Tension (UNT1, UNT2, UNT3) Properties

5.3.1 Quasi Isotropic Unnotched Tension (UNT1)

The normalized RTD 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. The RTD data does pass the normality test, and passes the ADK test under the Modified CV transformation, so the modified CV values are provided. However, pooling is not acceptable for the modified CV method because the pooled transformed data does not pass the normality test. The as measured data passed all tests for pooling, so pooled basis values are provided.

There was insufficient data to produce B-basis values that meet the standards of CMH-17-1G for the ETW2 environment, so only estimates are provided for that condition. B-estimates were prepared using the lamina variability method for the normalized data.

There is one outlier on the low side of batch 1 of the CTD data. It is an outlier before, but not after, pooling the CTD batches. It is an outlier in both the normalized and the as measured data. It was retained for this analysis. Statistics and basis values are given for the UNT1 strength data in Table 5-7. Modulus statistics are given in Table 5-8. The normalized data, B-estimates, and B-basis values are shown graphically in Figure 5-7.

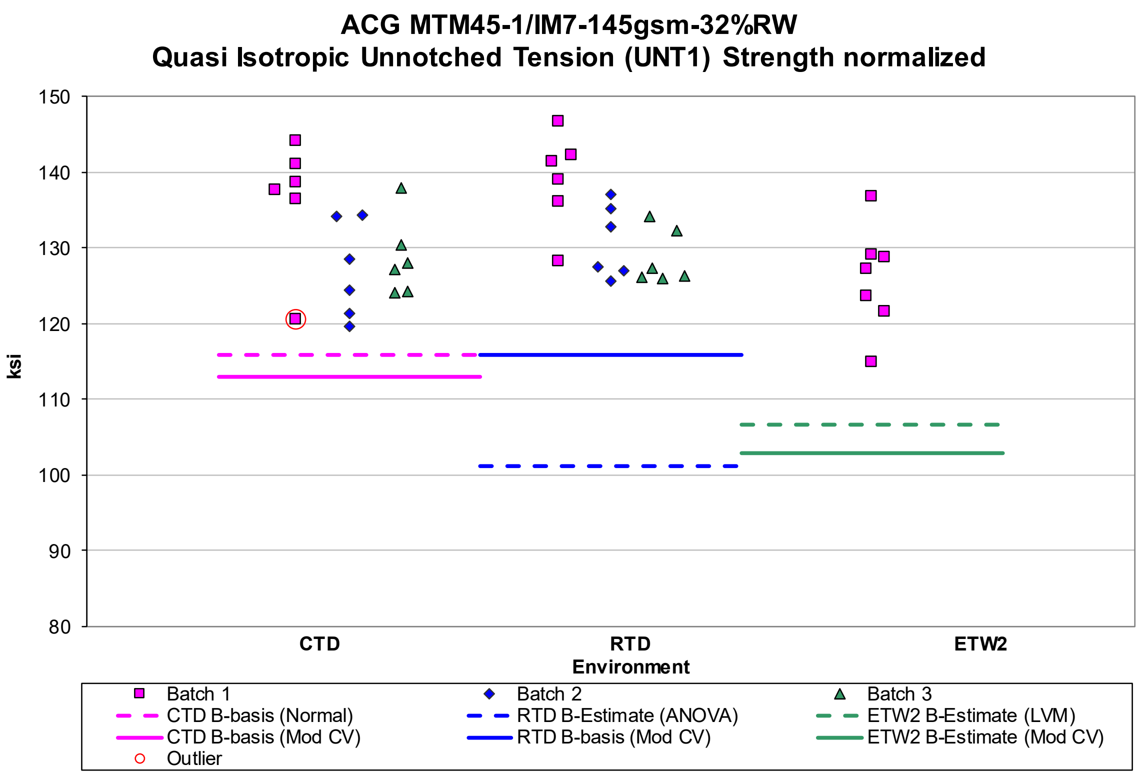

Figure 5-7: Batch plot for UNT1 strength normalized

Laminate Unnotched Tension (UNT1) Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	130.69	132.81	124.13	128.55	130.80	120.97
Stdev	7.55	6.56	5.43	6.76	5.53	5.58
CV	5.78	4.94	4.37	5.26	4.23	4.62
Modified CV	6.89	6.47	8.00	6.63	6.11	6.31
Min	119.58	125.59	114.85	117.88	123.17	111.02
Max	144.13	146.63	129.07	140.31	142.85	126.33
No. Batches	3	3	1	3	3	1
No. Spec.	18	18	6	18	18	6
Basis Values and/or Estimates						
B-basis Value	115.79			117.55	119.80	
B-Estimate		101.08	106.61			108.35
A-Estimate	105.23	78.45	NA	110.11	112.37	101.16
Method	Normal	ANOVA	LVM	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	112.92	115.85		113.80	116.05	
B-Estimate			102.89			104.06
A-Estimate	100.35	103.85	NA	103.83	106.08	94.41
Method	Normal	Normal	LVM	pooled	pooled	pooled

Table 5-7: Statistics and Basis Values for UNT1 Strength data

Laminate Unnotched Tension (UNT1) Modulus (Msi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	8.27	8.13	8.31	8.14	8.01	8.10
Stdev	0.30	0.19	0.45	0.32	0.21	0.45
CV	3.58	2.33	5.38	3.91	2.59	5.50
Mod CV	6.00	6.00	6.69	6.00	6.00	6.75
Min	7.71	7.65	7.89	7.59	7.50	7.63
Max	8.83	8.41	9.00	8.83	8.32	8.75
No. Batches	3	3	1	3	3	1
No. Spec.	18	18	6	18	18	6

Table 5-8: Statistics from UNT1 Modulus Data

5.3.2 "Soft" Unnotched Tension (UNT2)

This property had data from only one batch available, so there was insufficient data to produce B-basis values that meet the standards of CMH-17-1G. B-estimates were prepared using the lamina variability method. There were no outliers. Statistics and estimated basis values are given for UNT2 strength data in Table 5-9. Modulus statistics are given in Table 5-10. The normalized data, B-estimates, and B-basis values are shown graphically in Figure 5-8.

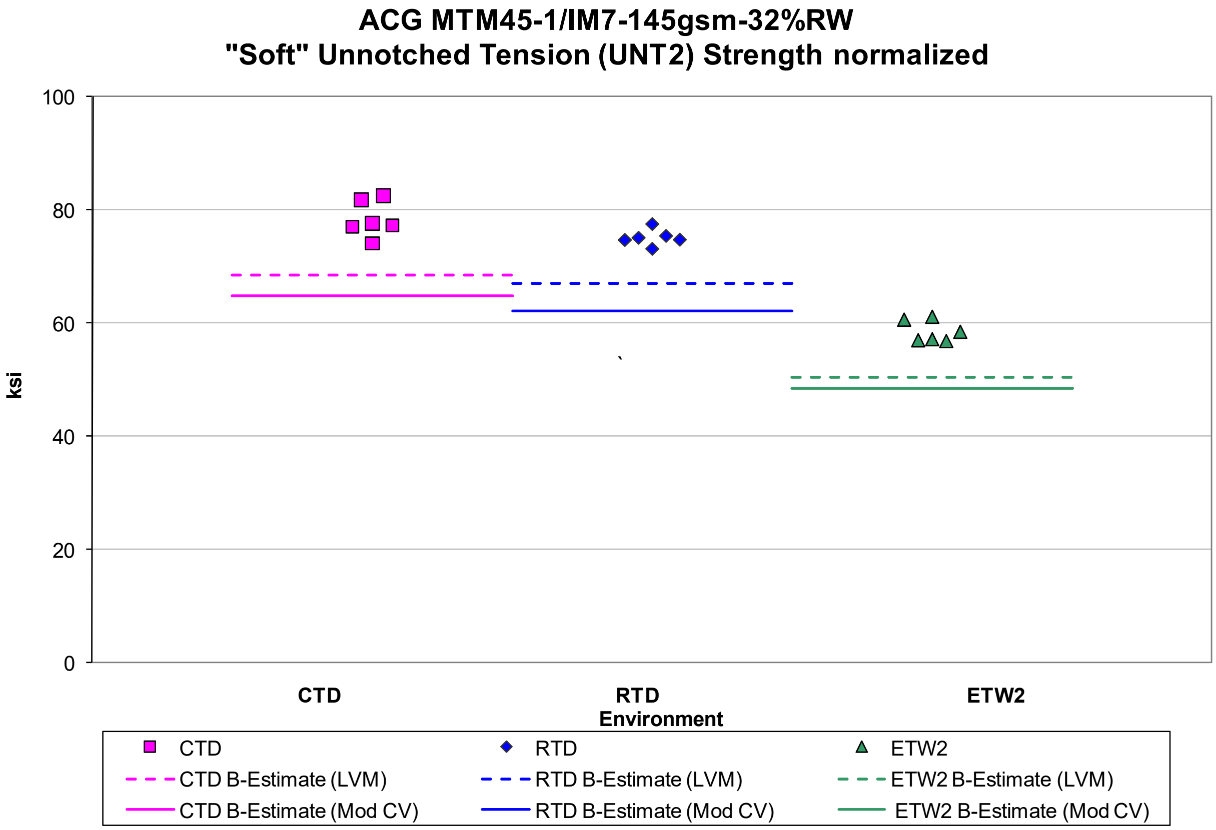

Figure 5-8: Batch plot for UNT2 strength normalized

Laminate Unnotched Tension (UNT2) Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	78.43	75.11	58.64	75.90	73.05	57.41
Stdev	3.18	1.46	1.89	3.02	1.24	2.07
CV	4.06	1.95	3.23	3.98	1.69	3.61
Modified CV	8.00	8.00	8.00	8.00	8.00	8.00
Min	74.13	73.09	56.96	71.98	71.66	55.29
Max	82.57	77.60	61.22	79.74	75.28	60.14
No. Batches	1	1	1	1	1	1
No. Spec.	6	6	6	6	6	6
Basis Values and/or Estimates						
B-Estimate	68.59	67.15	50.37	67.80	65.59	50.03
Method	LVM	LVM	LVM	LVM	LVM	LVM
Modified CV Basis Values and/or Estimates						
B-Estimate	64.90	62.21	48.61	62.80	60.50	47.58
Method	LVM	LVM	LVM	LVM	LVM	LVM

Table 5-9: Statistics and Basis Values for UNT2 Strength data

Unnotched Tension Properties (UNT2) Modulus (Msi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	5.07	4.91	4.73	4.90	4.78	4.63
Stdev	0.15	0.12	0.16	0.15	0.12	0.17
CV	3.01	2.35	3.37	3.14	2.45	3.75
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	4.82	4.80	4.58	4.66	4.67	4.45
Max	5.30	5.12	4.98	5.13	5.00	4.89
No. Batches	1	1	1	1	1	1
No. Spec.	6	6	6	6	6	6

Table 5-10: Statistics from UNT2 Modulus Data

5.3.3 "Hard" Unnotched Tension (UNT3)

This property had data from only one batch available, so there was insufficient data to produce B-basis values that meet the standards of CMH-17-1G. B-estimates were prepared using the lamina variability method. There was one outlier on the low side of the normalized CTD data. It was retained for this analysis. Statistics and basis values are given for UNT3 strength data in Table 5-11. Modulus statistics are given in Table 5-12. The normalized data, B-estimates, and B-basis values are shown graphically in Figure 5-9.

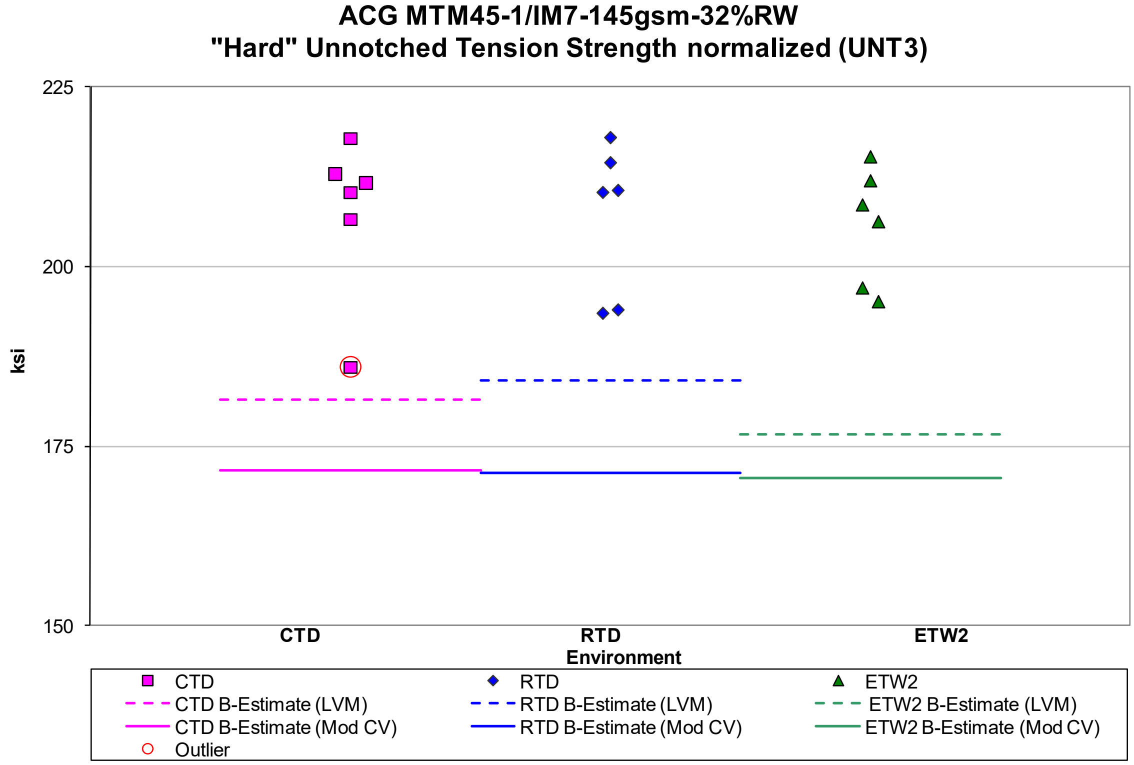

Figure 5-9: Batch plot for UNT3 strength normalized

Laminate Unnotched Tension (UNT3) Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	207.55	206.81	205.72	200.97	199.82	198.73
Stdev	11.15	10.51	8.05	9.94	9.98	7.52
CV	5.37	5.08	3.91	4.95	4.99	3.78
Modified CV	8.00	8.00	8.00	8.00	8.00	8.00
Min	186.03	193.50	195.18	182.87	185.90	188.08
Max	217.78	217.97	215.26	211.81	213.13	205.64
No. Batches	1	1	1	1	1	1
No. Spec.	6	6	6	6	6	6
Basis Values and/or Estimates						
B-Estimate	181.52	184.24	176.68	179.53	178.40	173.20
Method	LVM	LVM	LVM	LVM	LVM	LVM
Modified CV Basis Values and/or Estimates						
B-Estimate	171.73	171.27	170.52	166.29	165.49	164.72
Method	LVM	LVM	LVM	LVM	LVM	LVM

Table 5-11: Statistics and Basis Values for UNT3 Strength data

Laminate Unnotched Tension (UNT3) Modulus (Msi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	12.96	12.68	12.78	12.55	12.25	12.35
Stdev	0.71	0.55	0.79	0.63	0.54	0.79
CV	5.51	4.30	6.16	5.03	4.42	6.36
Mod CV	6.76	6.15	7.08	6.51	6.21	7.18
Min	11.70	11.70	11.78	11.50	11.24	11.35
Max	13.78	13.16	13.70	13.40	12.81	13.23
No. Batches	1	1	1	1	1	1
No. Spec.	6	6	4	6	6	4

Table 5-12: Statistics for UNT3 Modulus data

5.4 Unnotched Compression (UNC1, UNC2, UNC3) Properties

5.4.1 Quasi Isotropic Unnotched Compression (UNC1)

There is insufficient data to produce B-basis values that meet the standards of CMH-17-1G for UNC1, so only estimates are provided. B-estimates were prepared using different methods for the different environments, as appropriate for the data available. The methods used and results obtained are noted in Table 5-13.

The as measured RTD 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. The RTD data does pass the normality test, and passes the ADK test under the Modified CV transformation, so the modified CV values are provided.

There were no outliers. Statistics and basis values are given for UNC1 strength data in Table 5-13. Modulus statistics are given in Table 5-14. The normalized data and B-estimates are shown graphically in Figure 5-10.

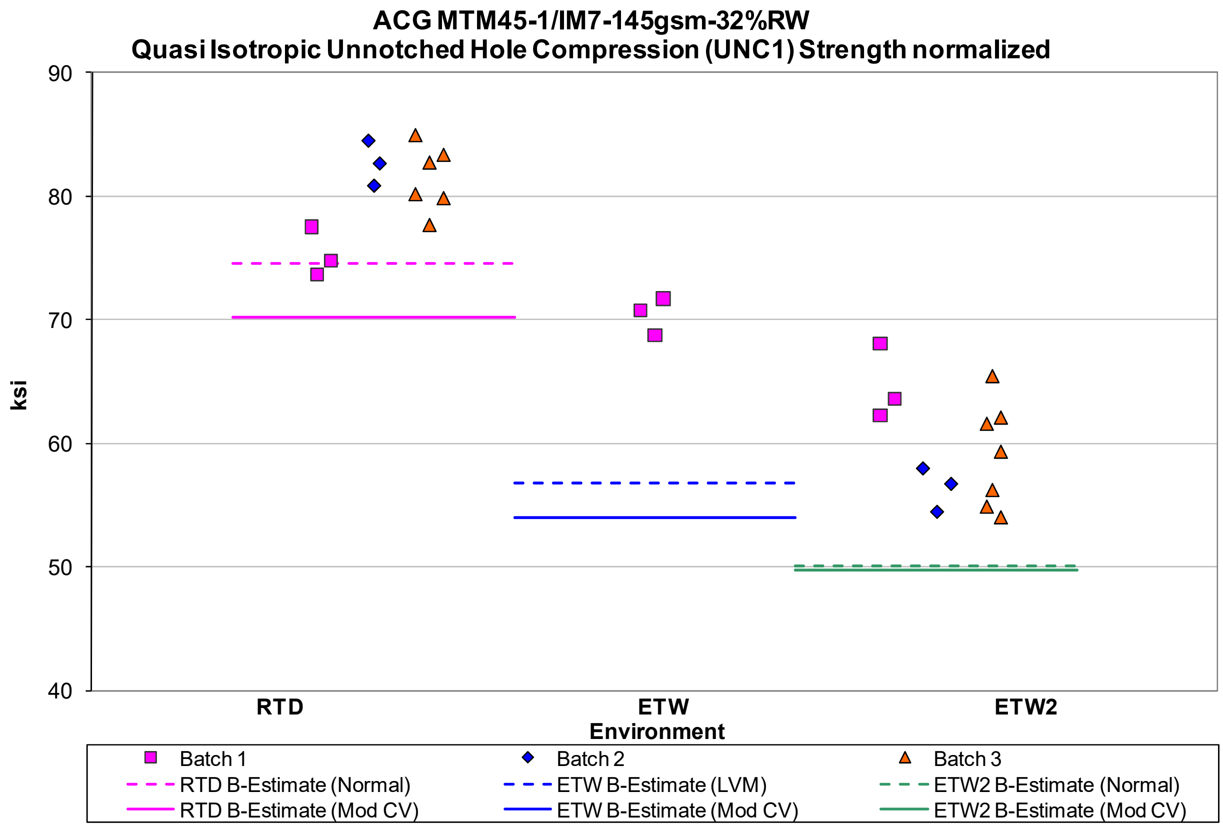

Figure 5-10: Batch plot for UNC1 strength normalized

Laminate Unnotched Compression (UNC1) Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	RTD	ETW	ETW2	RTD	ETW	ETW2
Mean	80.93	70.42	59.76	80.24	67.84	59.32
Stdev	2.89	1.52	4.49	3.70	1.51	3.73
CV	3.57	2.16	7.51	4.61	2.23	6.29
Modified CV	6.00	8.00	7.75	6.30	8.00	7.15
Min	76.38	68.74	54.04	73.65	66.22	53.78
Max	84.90	71.71	68.08	84.97	69.21	65.41
No. Batches	3	1	3	3	1	3
No. Spec.	12	3	13	12	3	13
Basis Values and/or Estimates						
B-Estimate	74.55	56.81	50.09	58.84	54.56	51.27
A-Estimate	70.11	NA	43.34	43.60	NA	45.66
Method	Normal	LVM	Normal	ANOVA	LVM	Normal
Modified CV Basis Values and/or Estimates						
B-Estimate	70.20	53.98	49.77	69.06	52.00	50.18
A-Estimate	62.73	NA	42.80	61.28	NA	43.80
Method	Normal	LVM	Normal	Normal	LVM	Normal

Table 5-13: Statistics and Basis Values for UNC1 Strength data

Laminate Unnotched Compression (UNC1) Modulus (Msi) Statistics						
	Normalized			As Measured		
Env	RTD	ETW	ETW2	RTD	ETW	ETW2
Mean	7.59	7.67	7.52	7.52	7.39	7.46
Stdev	0.23	0.06	0.25	0.19	0.04	0.30
CV	3.05	0.74	3.36	2.52	0.61	4.00
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	7.23	7.64	7.09	7.22	7.36	6.96
Max	8.01	7.74	8.07	7.90	7.44	8.10
No. Batches	3	1	3	3	1	3
No. Spec.	13	3	15	13	3	15

Table 5-14: Statistics from UNC1 Modulus data

5.4.2 "Soft" Unnotched Compression (UNC2)

This property had data from only one batch available, so there was insufficient data to produce B-basis values that meet the standards of CMH-17-1G. B-estimates were prepared using the lamina variability method. There were no outliers. Statistics and basis values are given for UNC2 strength data in Table 5-15. Modulus statistics are given in Table 5-16. The normalized data and B-estimates are shown graphically in Figure 5-11.

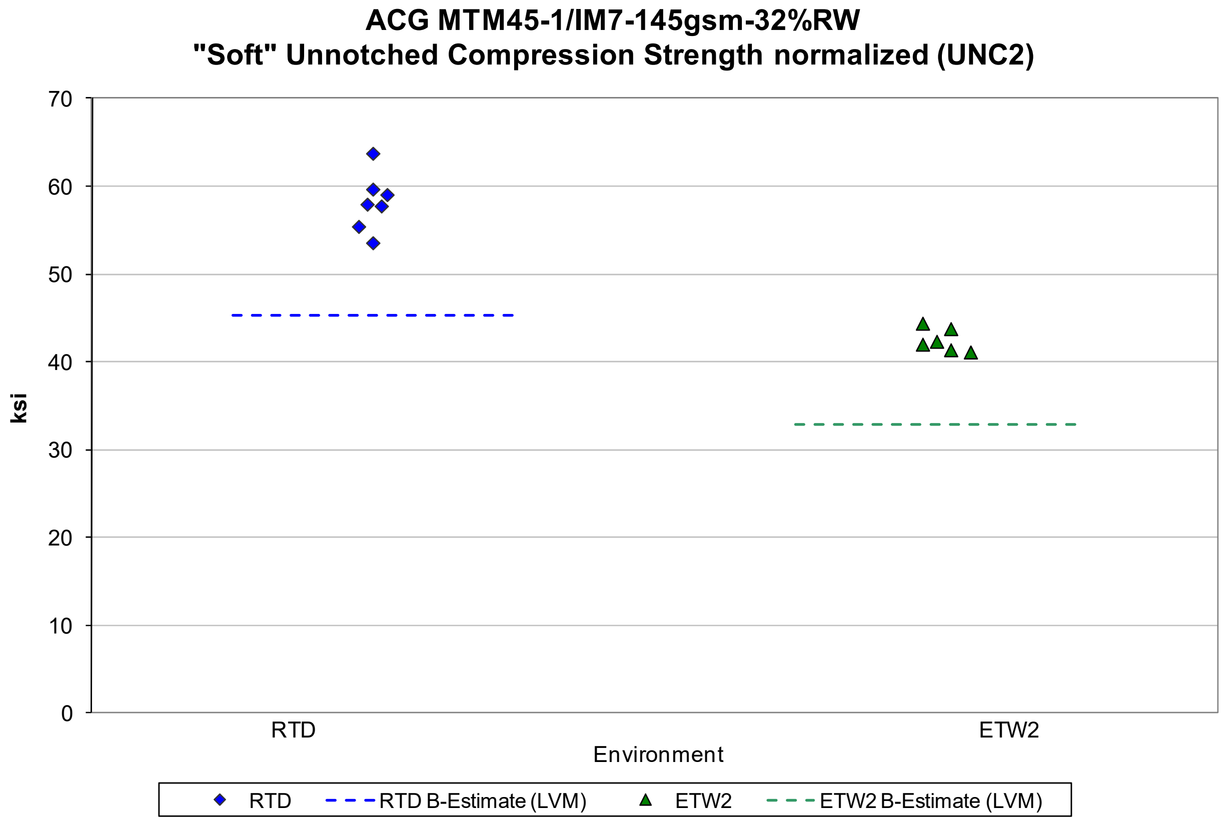

Figure 5-11: Batch plot for UNC2 strength normalized

Laminate Unnotched Compression (UNC2) Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	58.08	42.47	57.14	41.77
Stdev	3.27	1.34	3.13	1.30
CV	5.63	3.14	5.48	3.11
Modified CV	8.00	8.00	8.00	8.00
Min	53.44	41.07	52.91	40.49
Max	63.71	44.39	62.96	43.57
No. Batches	1	1	1	1
No. Spec.	7	6	7	6
Basis Values and/or Estimates				
B-Estimate	45.34	32.77	46.13	33.06
Method	LVM	LVM	LVM	LVM

Table 5-15: Statistics and Basis Values for UNC2 Strength data

Laminate Unnotched Compression (UNC2) Modulus (Msi) Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	4.81	4.45	4.73	4.37
Stdev	0.13	0.05	0.12	0.06
CV	2.71	1.22	2.49	1.30
Mod CV	8.00	8.00	8.00	8.00
Min	4.57	4.38	4.52	4.31
Max	4.93	4.52	4.88	4.46
No. Batches	1	1	1	1
No. Spec.	6	7	6	7

Table 5-16: Statistics from UNC2 Modulus data

5.4.3 "Hard" Unnotched Compression (UNC3)

This property had data from only one batch available, so there was insufficient data to produce B-basis values that meet the standards of CMH-17-1G. B-estimates were prepared using the lamina variability method. There were no outliers. Statistics and basis values are given for UNC3 strength data in Table 5-17. Modulus statistics are given in Table 5-18. The normalized data and B-estimates are shown graphically in Figure 5-12.

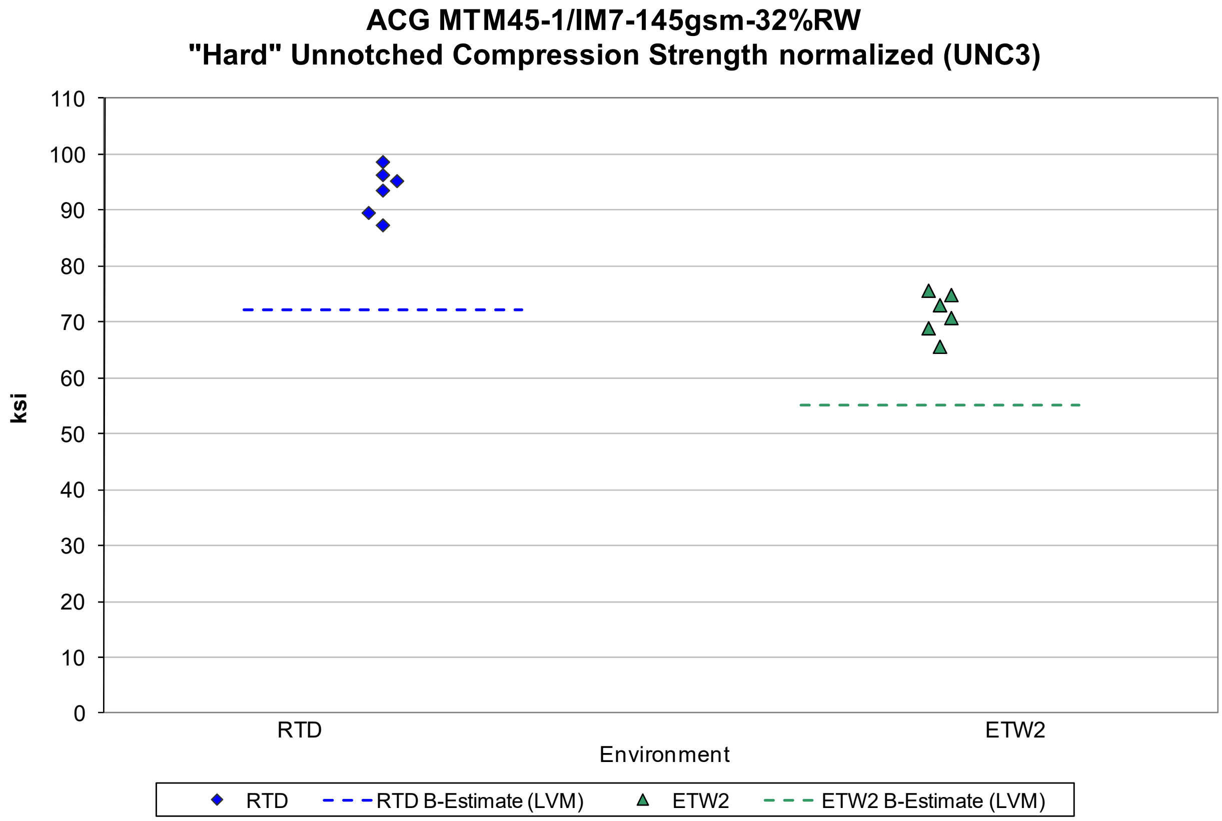

Figure 5-12: Batch plot for UNC3 strength normalized

Laminate Unnotched Compression (UNC3) Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	93.43	71.40	91.70	70.08
Stdev	4.32	3.77	4.04	3.16
CV	4.63	5.28	4.40	4.50
Modified CV	8.00	8.00	8.00	8.00
Min	87.24	65.61	84.40	66.02
Max	98.71	75.52	95.83	73.84
No. Batches	1	1	1	1
No. Spec.	6	6	6	6
Basis Values and/or Estimates				
B-Estimate	72.24	55.09	73.42	55.47
Method	LVM	LVM	LVM	LVM

Table 5-17: Statistics and Basis Values for UNC3 Strength data

Laminate Unnotched Compression (UNC3) Modulus (Msi) Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	12.25	11.53	12.00	11.30
Stdev	0.38	0.45	0.29	0.37
CV	3.14	3.92	2.42	3.24
Mod CV	8.00	8.00	8.00	8.00
Min	11.60	10.73	11.57	10.75
Max	12.70	11.91	12.29	11.63
No. Batches	1	1	1	1
No. Spec.	7	7	7	7

Table 5-18: Statistics from UNC3 Modulus Data

5.5 Laminate Short Beam Shear Strength (SBS1)

There is insufficient data to produce B-basis values that meet the standards of CMH-17-1G for SBS1, so only estimates are provided. B-estimates were prepared using different methods for the different environments, as appropriate for the data available. The RTD data did not pass the Anderson-Darling k-sample test for batch-to-batch variation even after the modified CV transform, so that dataset required the ANOVA method to compute basis values which may result in overly conservative basis values. The ETW2 data did not fit a tested distribution so the non-parametric method was used. For the modified CV estimates, overrides of the ADK test for the RTD environment and the normality test for the ETW2 environment were necessary to compute the modified CV basis values.

There were two outliers, both on the low side. One outlier was in the RTD condition. It was an outlier only for batch two, not for the RTD condition. The second outlier was in the ETW2 condition. It was an outlier both for batch three and for the ETW2 condition.

Statistics and basis value estimates are given for SBS1 strength data as measured in Table 5-19. The data and B-estimates are shown graphically in Figure 5-13.

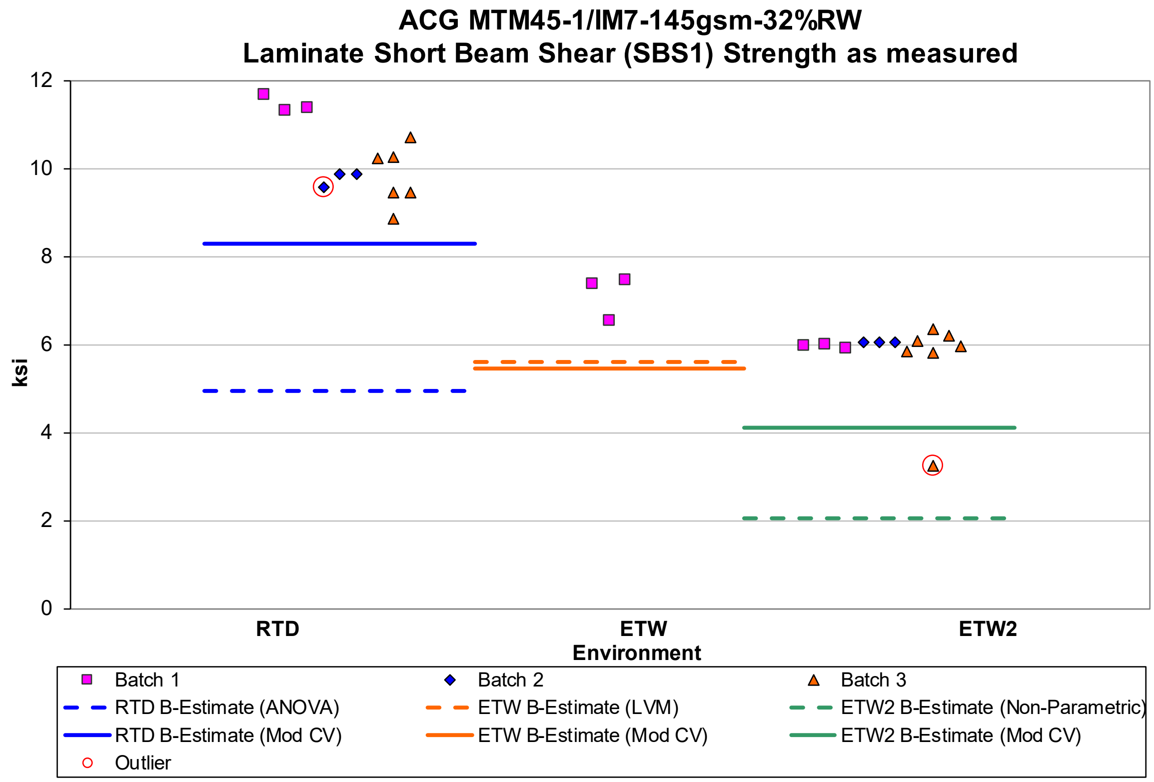

Figure 5-13: Batch plot for SBS1 strength as measured

Laminate Short Beam Shear (SBS1) Strength (ksi) Basis Values and Statistics As Measured			
Env	RTD	ETW	ETW2
Mean	10.22	7.12	5.80
Stdev	0.88	0.53	0.78
CV	8.59	7.38	13.48
Mod CV	8.59	8.00	13.48
Min	8.85	6.51	3.24
Max	11.65	7.46	6.34
No. Batches	3	1	3
No. Spec.	12	3	13
Basis Values and/or Estimates			
B-Estimate	4.93	5.59	2.06
A-Estimate	1.16	NA	0.85
Method	ANOVA	LVM	Non-Parametric
Modified CV Basis Values and/or Estimates with Overrides			
B-Estimate	8.28	5.46	4.11
A-Estimate	6.93	NA	2.94
Method	Normal	LVM	Normal

Table 5-19: Statistics and Basis Values for SBS1 Strength

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

5.6.1 Quasi Isotropic Filled Hole Tension (FHT1)

There is insufficient data to produce B-basis values that meet the standards of CMH-17-1G for this data. The RTD environment has insufficient specimens while the CTD environment has data from only two batches. Estimates were prepared using different methods for the different environments, as appropriate for the data available.

There was one outlier in the as measured CTD dataset. It was on the low side of batch two and was an outlier only for batch 2 and not for the CTD condition. It was retained for this analysis. Statistics and basis values are given for FHT1 strength data in Table 5-20. The data and the B-estimates are shown graphically in Figure 5-14.

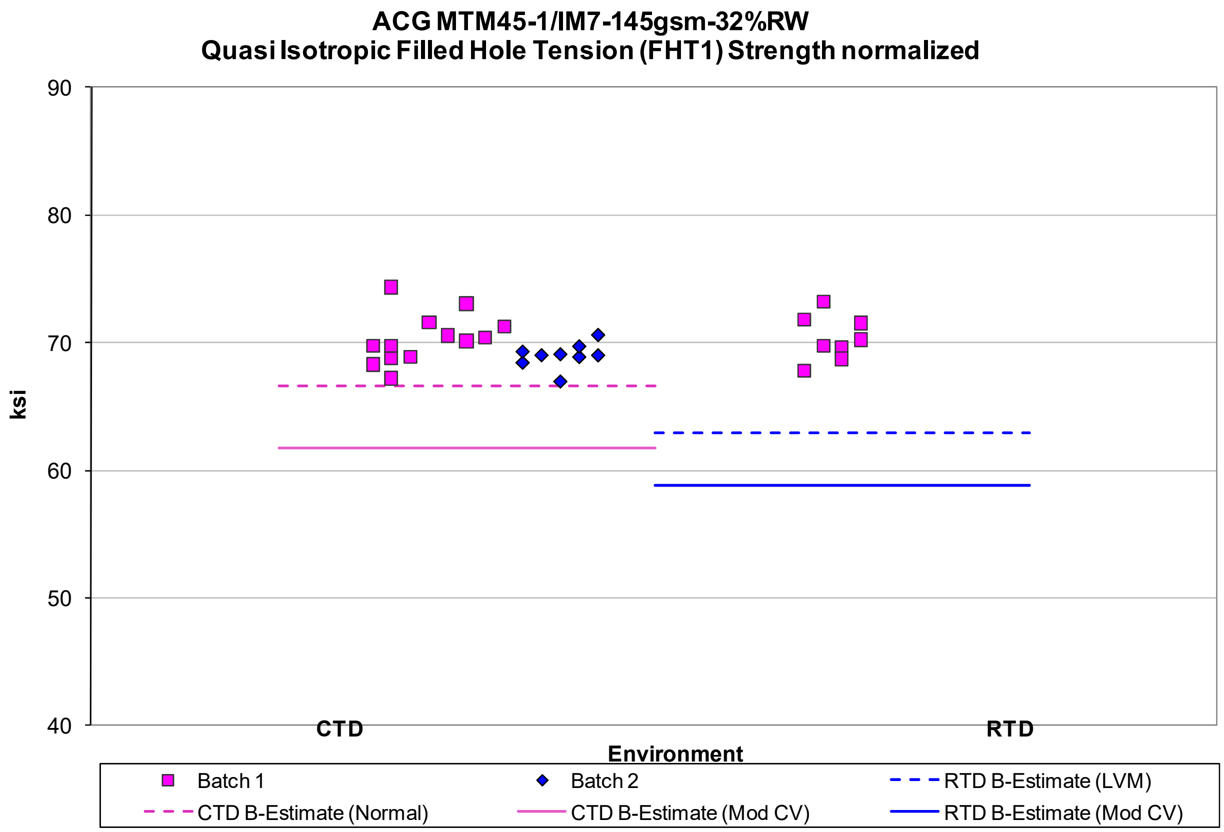

Figure 5-14: Batch plot for FHT1 strength normalized

Laminate Filled Hole Tension (FHT1) Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	CTD	RTD	CTD	RTD
Mean	69.79	70.35	68.61	69.65
Stdev	1.72	1.76	1.94	1.97
CV	2.46	2.51	2.83	2.82
Modified CV	6.00	8.00	6.00	8.00
Min	66.98	67.78	65.54	66.18
Max	74.36	73.19	73.75	72.10
No. Batches	2	1	2	1
No. Spec.	22	8	22	8
Basis Values and/or Estimates				
B-Estimate	66.55	63.24	64.95	62.87
A-Estimate	64.24	NA	62.33	NA
Method	Normal	LVM	Normal	LVM
Modified CV Basis Values and/or Estimates				
B-Estimate	61.89	58.83	60.84	58.24
A-Estimate	56.25	NA	55.30	NA
Method	Normal	LVM	Normal	LVM

Table 5-20: Statistics and Basis Values for FHT1 Strength data

5.6.2 "Soft" Filled Hole Tension (FHT2)

This property had data from only one batch available, so there was insufficient data to produce B-basis values that meet the standards of CMH-17-1G. B-estimates were prepared using the lamina variability method. There was one outlier in the as measured CTD dataset. It was on the low side and was retained for this analysis. Statistics and basis values are given for FHT2 strength data in Table 5-21. The normalized data and the B-estimates are shown graphically in Figure 5-15.

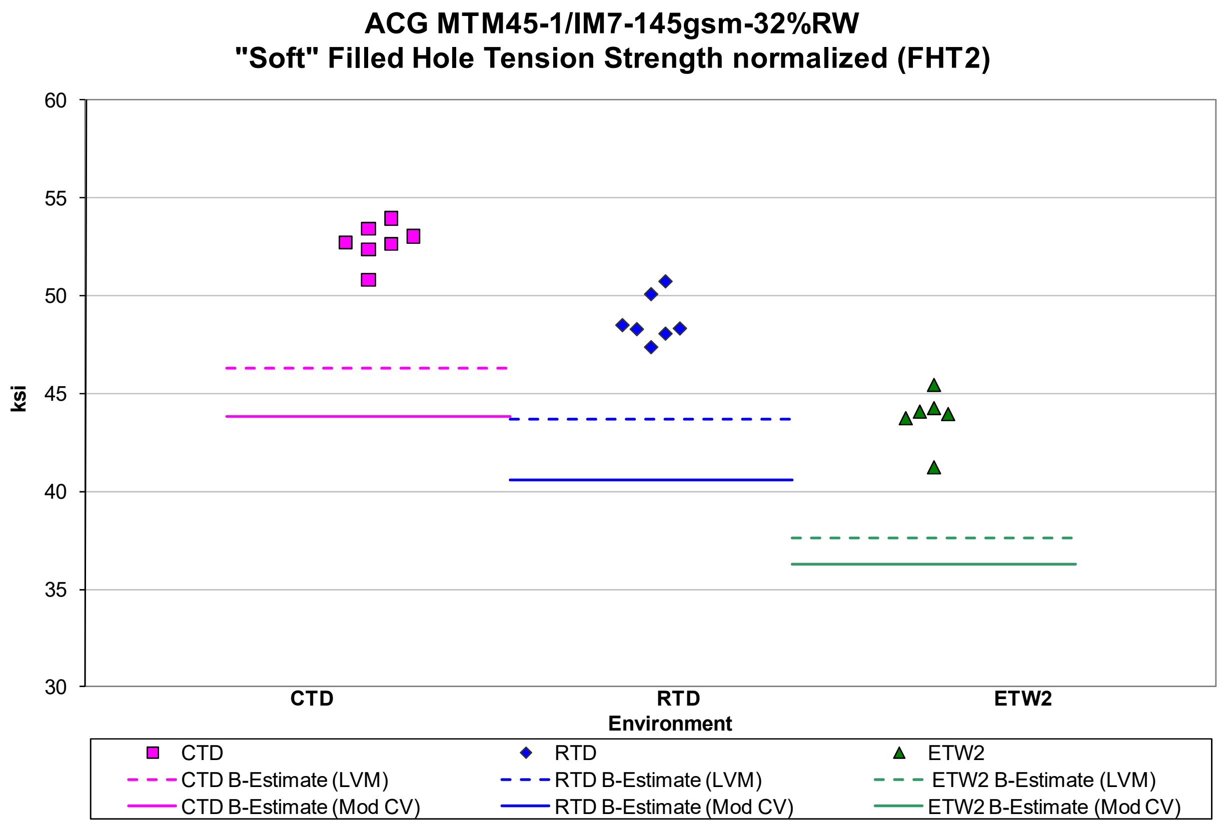

Figure 5-15: Batch plot for FHT2 strength normalized

Laminate Filled Hole Tension (FHT2) Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	52.73	48.76	43.80	50.82	47.21	42.04
Stdev	0.99	1.19	1.38	1.13	1.12	1.16
CV	1.87	2.44	3.16	2.21	2.38	2.75
Modified CV	8.00	8.00	8.00	8.00	8.00	8.00
Min	50.84	47.37	41.25	48.50	45.46	40.00
Max	53.96	50.72	45.46	52.13	48.90	43.36
No. Batches	1	1	1	1	1	1
No. Spec.	7	7	6	7	7	6
Basis Values and/or Estimates						
B-Estimate	46.29	43.72	37.62	45.54	42.51	36.64
Method	LVM	LVM	LVM	LVM	LVM	LVM
Modified CV Basis Values and/or Estimates						
B-Estimate	43.86	40.60	36.31	42.28	39.31	34.84
Method	LVM	LVM	LVM	LVM	LVM	LVM

Table 5-21: Statistics and Basis Values for FHT2 Strength data

5.6.3 "Hard" Filled Hole Tension (FHT3)

This property had data from only one batch available and only four specimens from that batch for each environment, so there was insufficient data to produce B-basis values that meet the standards of CMH-17-1G. B-estimates were prepared using the lamina variability method. There was one outlier. The lowest value in the CTD data was an outlier for both the normalized and the as measured data. It was retained for this analysis. Statistics and B-estimates are given for FHT3 strength data in Table 5-22. The normalized data and the B-basis values are shown graphically in Figure 5-16.

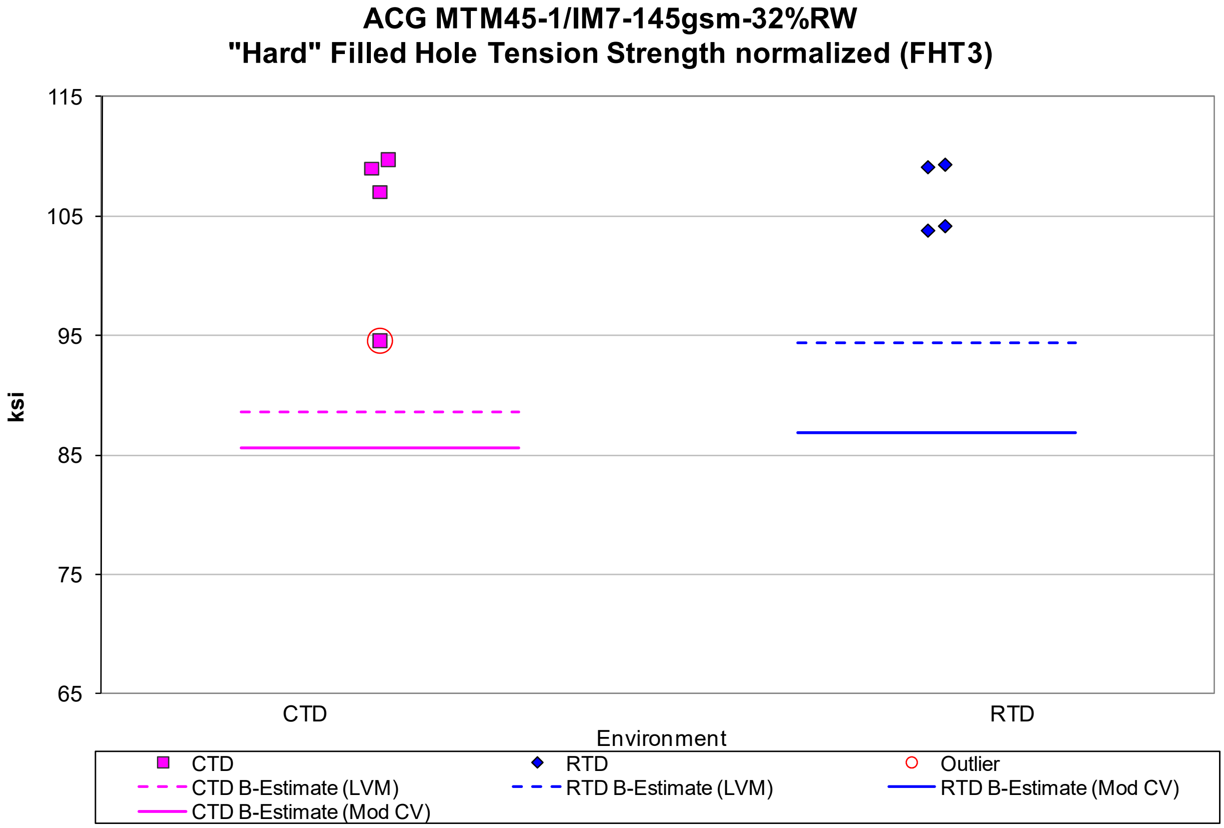

Figure 5-16: Batch plot for FHT3 strength normalized

Laminate Filled Hole Tension (FHT3) Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	CTD	RTD	CTD	RTD
Mean	105.08	106.60	100.27	101.87
Stdev	7.11	3.03	6.62	2.46
CV	6.77	2.84	6.60	2.42
Modified CV	8.00	8.00	8.00	8.00
Min	94.56	103.80	90.44	99.11
Max	109.74	109.33	104.73	104.30
No. Batches	1	1	1	1
No. Spec.	4	4	4	4
Basis Values and/or Estimates				
B-Estimate	88.56	94.43	84.89	90.67
Method	LVM	LVM	LVM	LVM
Modified CV Basis Values and/or Estimates				
B-Estimate	85.56	86.89	81.63	83.03
Method	LVM	LVM	LVM	LVM

Table 5-22: 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)

The RTD environment had data from only one batch available and only six specimens from that batch, so there was insufficient data to produce B-basis values that meet the standards of CMH-17-1G. Estimates were prepared using the lamina variability method. There were no outliers. The as measured ETW2 data did not pass the normality test. It required the non-parametric method, so no modified CV values are given. Statistics and basis values are given for FHC1 strength data in Table 5-23. The normalized data and the B-estimates are shown graphically in Figure 5-17.

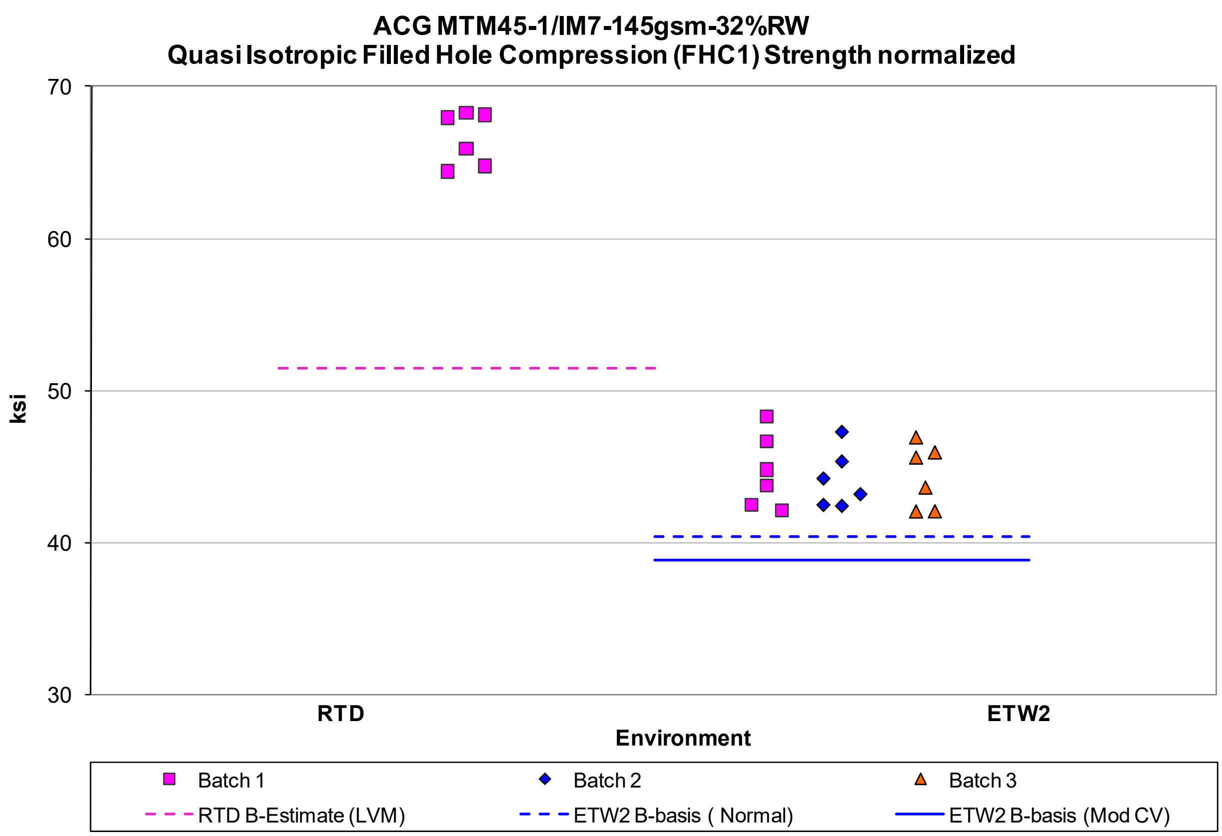

Figure 5-17: Batch plot for FHC1 strength normalized

Laminate Filled Hole Compression (FHC1) Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	66.57	44.43	65.58	43.92
Stdev	1.76	2.02	1.84	2.11
CV	2.64	4.56	2.80	4.81
Modified CV	8.00	6.28	8.00	6.41
Min	64.41	42.09	63.22	41.35
Max	68.25	48.33	67.38	47.89
No. Batches	1	3	1	3
No. Spec.	6	18	6	18
Basis Values and/or Estimates				
B-basis Value		40.43		40.82
B-Estimate	51.47		52.51	
A-Estimate	NA	37.60	NA	33.19
Method	LVM	Normal	LVM	Non-Parametric
Modified CV Basis Values and/or Estimates				
B-basis Value	NA	38.92	NA	NA
A-Estimate	NA	35.03	NA	NA
Method	NA	Normal	NA	NA

Table 5-23: Statistics and Basis Values for FHC1 Strength data

5.7.2 "Soft" Filled Hole Compression (FHC2)

There is insufficient data to produce B-basis values that meet the standards of CMH-17-1G for the RTD environment, so only estimates are provided for that condition. They were prepared using the lamina variability method. There was one outlier on the low side of the as measured RTD data. It was retained for this analysis.

The normalized and as measured ETW2 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. The normalized ETW2 data does pass the normality test, and passes the ADK test under the modified CV transformation, so the Modified CV values are provided. However, the as measured ETW2 data did not pass the ADK test after the modified CV transformation, so modified CV basis values are not provided for this data.

Statistics and B-estimates are given for FHC2 strength data in Table 5-24. The normalized data and the B-basis values are shown graphically in Figure 5-18.

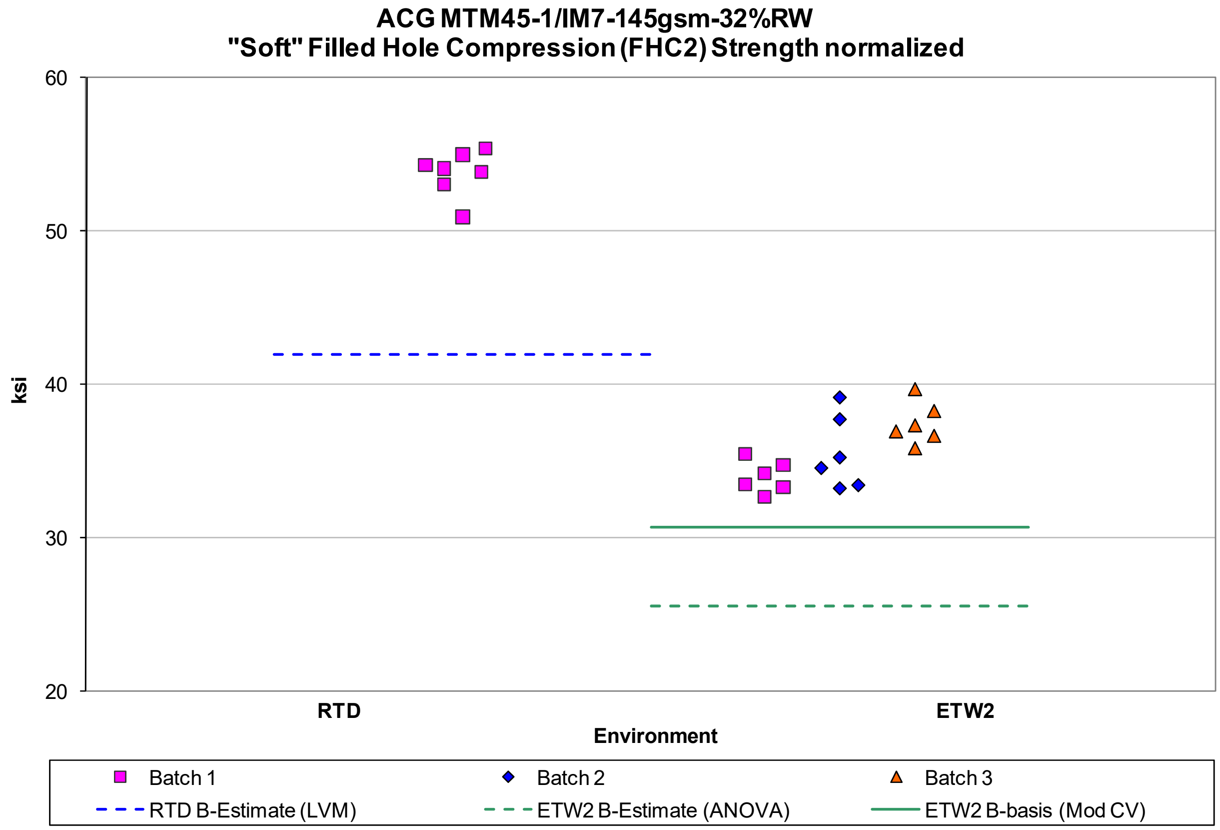

Figure 5-18: Batch plot for FHC2 strength normalized

Laminate Filled Hole Compression (FHC2) Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	53.80	35.67	52.58	35.34
Stdev	1.48	2.16	1.13	2.44
CV	2.75	6.07	2.15	6.92
Modified CV	8.00	7.03	8.00	7.46
Min	50.93	32.68	50.29	32.17
Max	55.39	39.72	53.45	40.30
No. Batches	1	3	1	3
No. Spec.	7	18	7	18
Basis Values and/or Estimates				
B-Estimate	42.00	25.55	42.45	21.68
A-Estimate	NA	18.34	NA	11.93
Method	LVM	ANOVA	LVM	ANOVA
Modified CV Basis Values and/or Estimates				
B-basis Value	NA	30.72	NA	NA
A-Estimate	NA	27.22	NA	NA
Method	NA	Normal	NA	NA

Table 5-24: Statistics and Basis Values for FHC2 Strength data

5.7.3 "Hard" Filled Hole Compression (FHC3)

There is insufficient data to produce B-basis values that meet the standards of CMH-17-1G for either the RTD or the ETW2 environments. For the RTD environment, only three specimens were available. A B-estimate was prepared using the lamina variability method (LVM). For the ETW2 environment, there were only 15 specimens available, so the LVM approach could be used, but the normal method could also be used. However, the CV was so large that the modified CV method would not alter the result, so modified CV values are not given. There were no outliers. Statistics and basis values are given for FHC3 strength data in Table 5-25. The normalized data and the B-basis values are shown graphically in Figure 5-19.

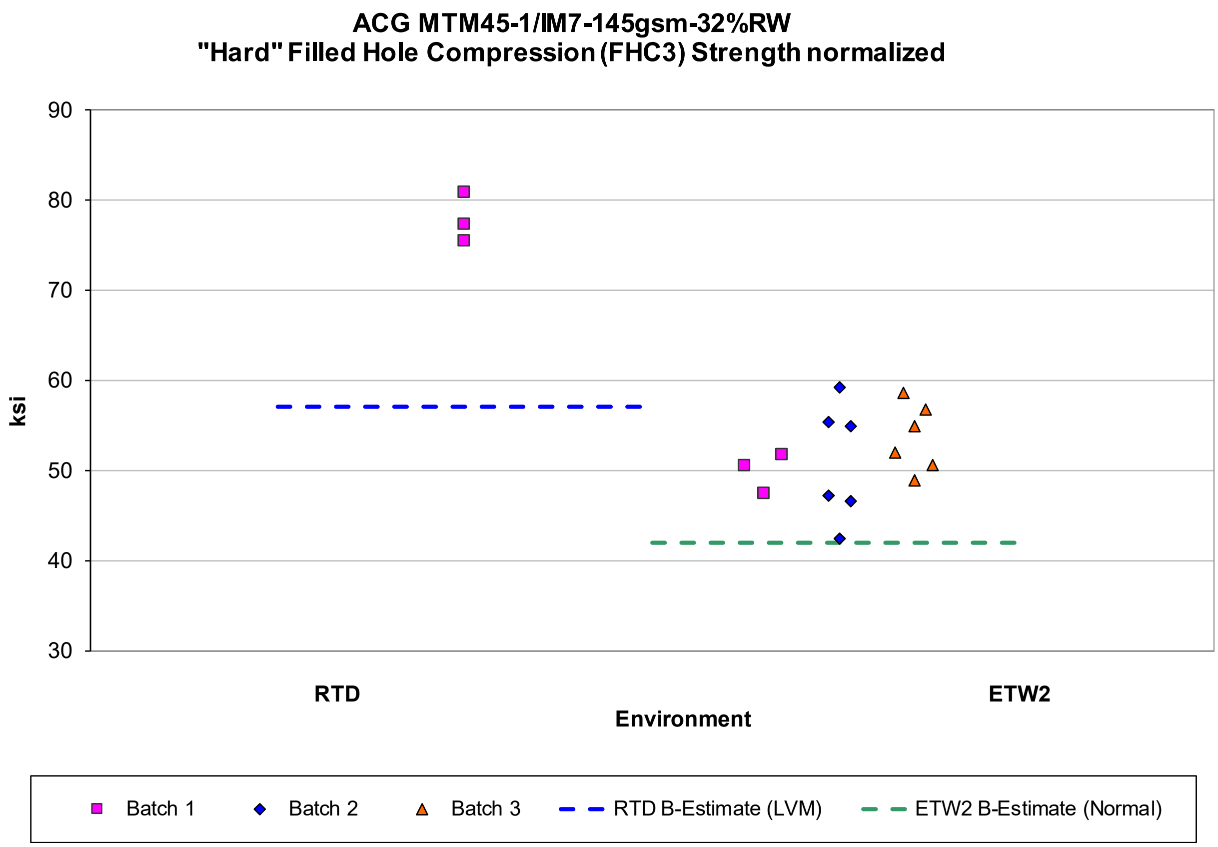

Figure 5-19: Batch plot for FHC3 strength normalized

Laminate Filled Hole Compression (FHC3) Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	77.85	51.87	77.20	51.44
Stdev	2.80	4.76	3.06	4.65
CV	3.60	9.18	3.96	9.03
Modified CV	8.00	9.18	8.00	9.03
Min	75.38	42.47	74.50	42.73
Max	80.89	59.21	80.52	58.51
No. Batches	1	3	1	3
No. Spec.	3	15	3	15
Basis Values and/or Estimates				
B-Estimate	57.13	41.94	59.15	42.45
Method	LVM	LVM	LVM	LVM
Estimates using Normal Distribution				
B-Estimate	NA	42.01	NA	41.83
A-Estimate	NA	35.10	NA	35.09
Method	NA	Normal	NA	Normal

Table 5-25: Statistics and Basis Values for FHC3 Strength data

5.8 Pin Bearing Properties

5.8.1 Pin Bearing 1 (PB1)

The laminate bearing properties (PB1) data was poolable across environments, so the ASAP program was used to compute basis values and modified CV basis values. There were no outliers. Statistics and basis values are given for the 2% offset strength data in Table 5-26. The normalized data and the B-basis values are shown graphically in Figure 5-20.

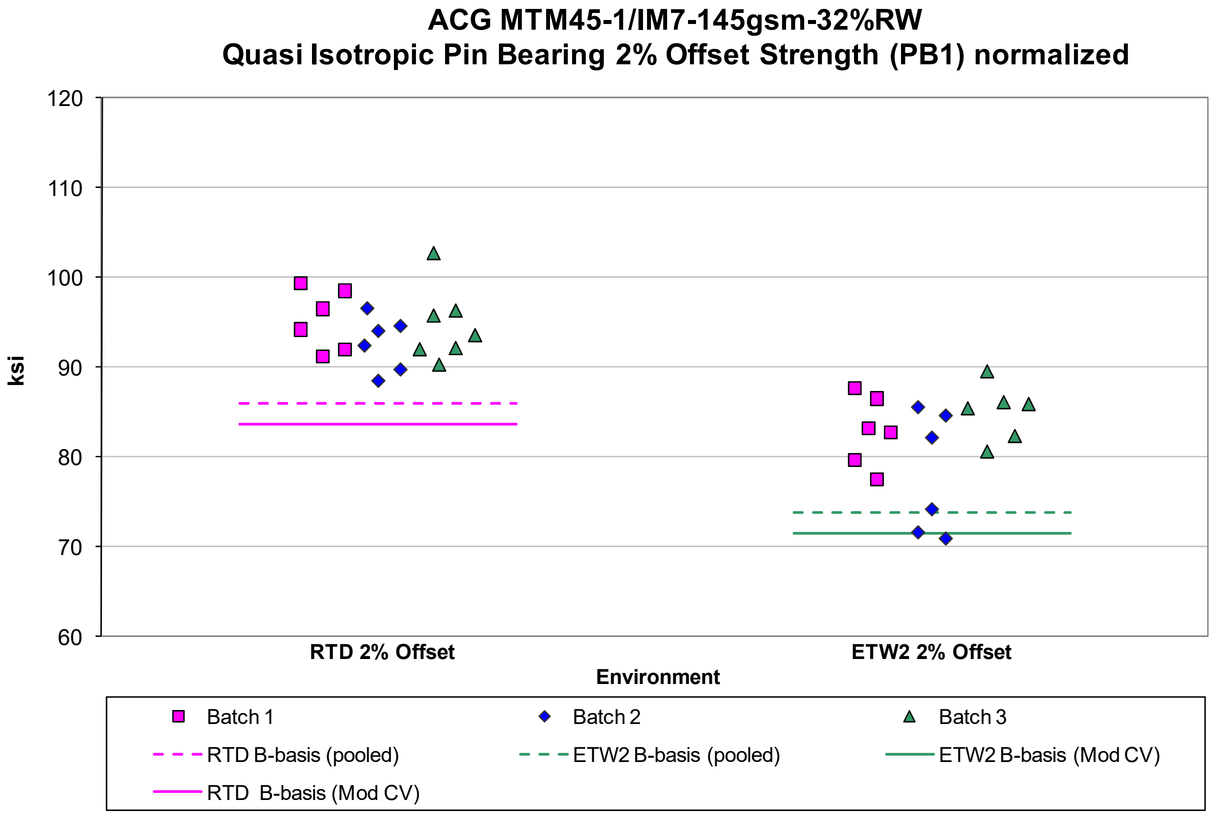

Figure 5-20: Batch plot for PB1 2% Offset strength normalized

Laminate Pin Bearing (PB1) 2% Offset Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	94.24	82.04	93.92	82.33
Stdev	3.58	5.38	3.54	5.18
CV	3.80	6.56	3.77	6.29
Modified CV	6.00	7.28	6.00	7.15
Min	88.49	70.97	89.00	72.86
Max	102.71	89.58	102.33	90.73
No. Batches	3	3	3	3
No. Spec.	19	18	19	18
Basis Values and/or Estimates				
B-basis Value	86.02	73.79	85.94	74.31
A-Estimate	80.40	68.18	80.48	68.87
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates				
B-basis Value	83.73	71.49	83.51	71.87
A-Estimate	76.55	64.31	76.39	64.77
Method	pooled	pooled	pooled	pooled

Table 5-26: Statistics and Basis Values for PB1 2% Offset Strength data

5.8.2 Pin Bearing 2 (PB2)

The ETW2 data meets all requirements of CMH-17-1G. For the RTD environment, specimens from only one batch were available. B-estimates were prepared using the lamina variability method.

The ETW2 environment fails the normality test and has CV greater than 8%, so no modified CV values are provided. There was one outlier on the high side of batch one of the ETW2 data. It is an outlier in both the normalized and as measured data for batch one, but not for the ETW2 condition. It was retained for this analysis.

Statistics and basis values are given for the 2% offset strength data in Table 5-27. The normalized data, B-estimates, and B-basis values are shown graphically in Figure 5-21.

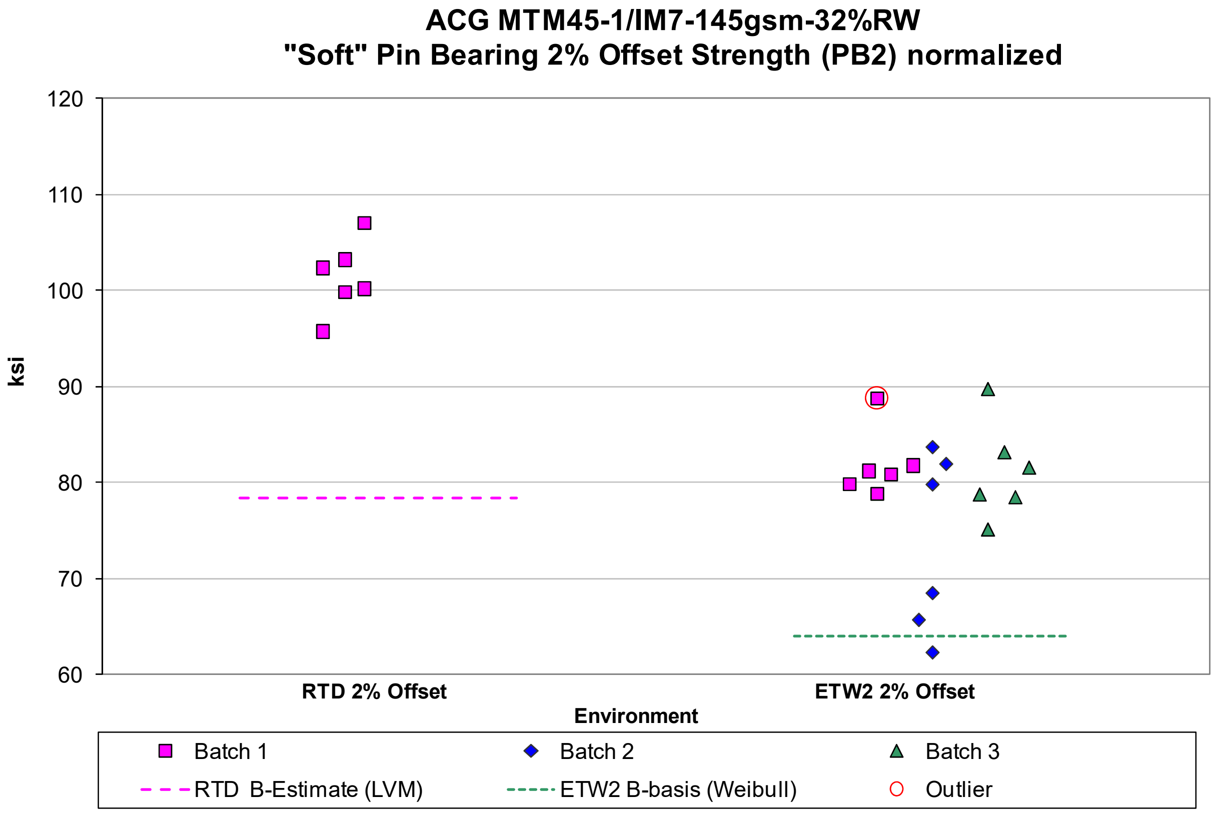

Figure 5-21: Batch plot for PB2 2% Offset strength normalized

Laminate Pin Bearing (PB2) 2% Offset Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	101.38	78.84	99.58	76.16
Stdev	3.78	7.12	4.24	8.28
CV	3.73	9.02	4.26	10.87
Modified CV	8.00	9.02	8.00	10.87
Min	95.73	62.31	94.19	59.91
Max	106.99	89.66	106.41	89.83
No. Batches	1	3	1	3
No. Spec.	6	18	6	18
Basis Values and/or Estimates				
B-basis Value		64.00		54.27
B-Estimate	78.39		79.73	
A-Estimate	NA	50.52	NA	32.67
Method	LVM	Weibull	LVM	Non-Parametric

Table 5-27: Statistics and Basis Values for PB2 2% Offset Strength data

5.8.3 Pin Bearing 3 (PB3)

The ETW2 data meets all requirements of CMH-17-1G. For the RTD environment, specimens from only one batch were available. B-estimates were prepared using the lamina variability method. There were no outliers. Statistics and basis values are given for the 2% offset strength data in Table 5-28. The normalized data, B-estimates and B-basis values for the strength data are shown graphically in Figure 5-22.

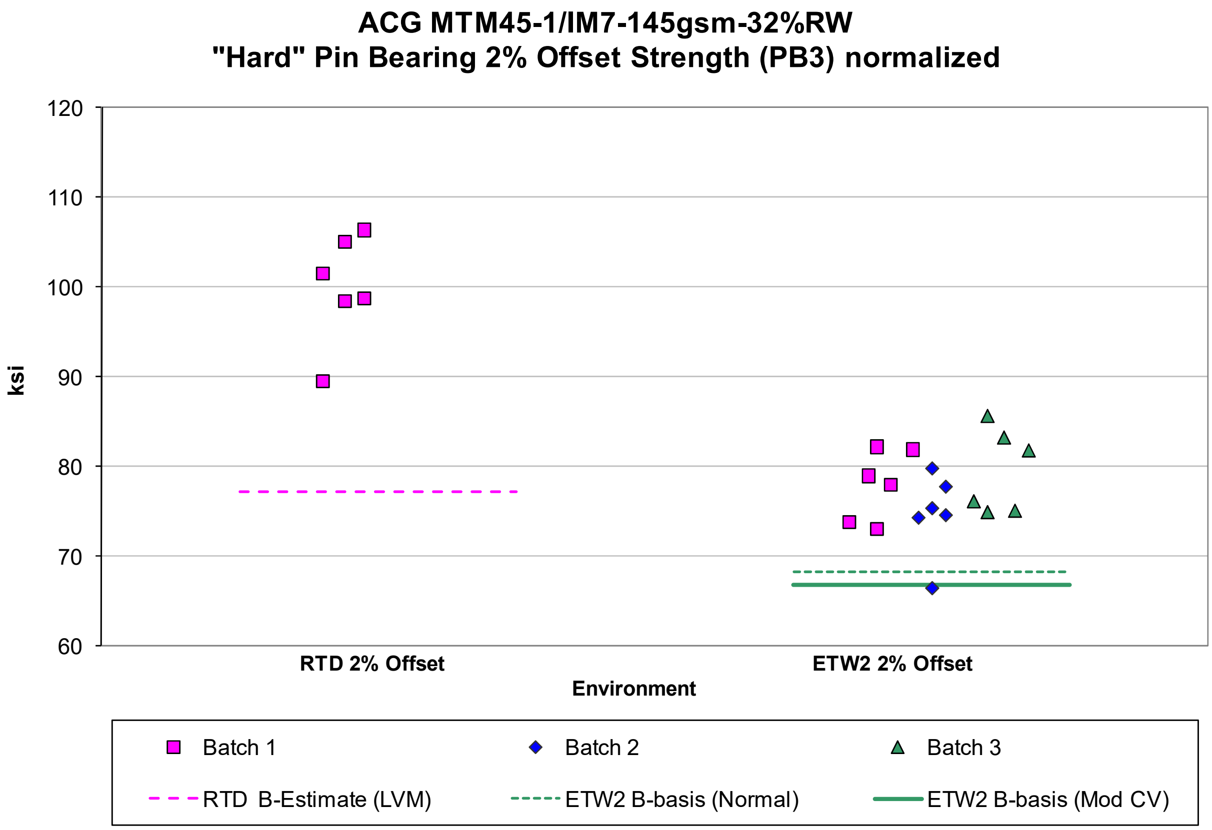

Figure 5-22: Batch plot for PB3 2% Offset strength normalized

Laminate Pin Bearing (PB3) 2% Offset Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	99.93	77.41	98.65	77.50
Stdev	6.04	4.59	5.90	4.80
CV	6.04	5.93	5.98	6.19
Modified CV	8.00	6.96	8.00	7.10
Min	89.50	66.50	87.90	66.27
Max	106.37	85.63	103.82	86.84
No. Batches	1	3	1	3
No. Spec.	6	18	6	18
Basis Values and/or Estimates				
B-basis Value		68.35		68.02
B-Estimate	77.27		78.99	
A-Estimate	NA	61.93	NA	61.31
Method	LVM	Normal	LVM	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value	NA	66.77	NA	66.64
A-Estimate	NA	59.24	NA	58.96
Method	NA	Normal	NA	Normal

Table 5-28: Statistics and Basis Values for PB3 2% Offset Strength data

5.9 Compression After Impact Data

Basis values are not computed for the CAI data. However, statistics are given for both normalized and as measured CAI strength data in Table 5-29. The normalized data are shown graphically in Figure 5-23.

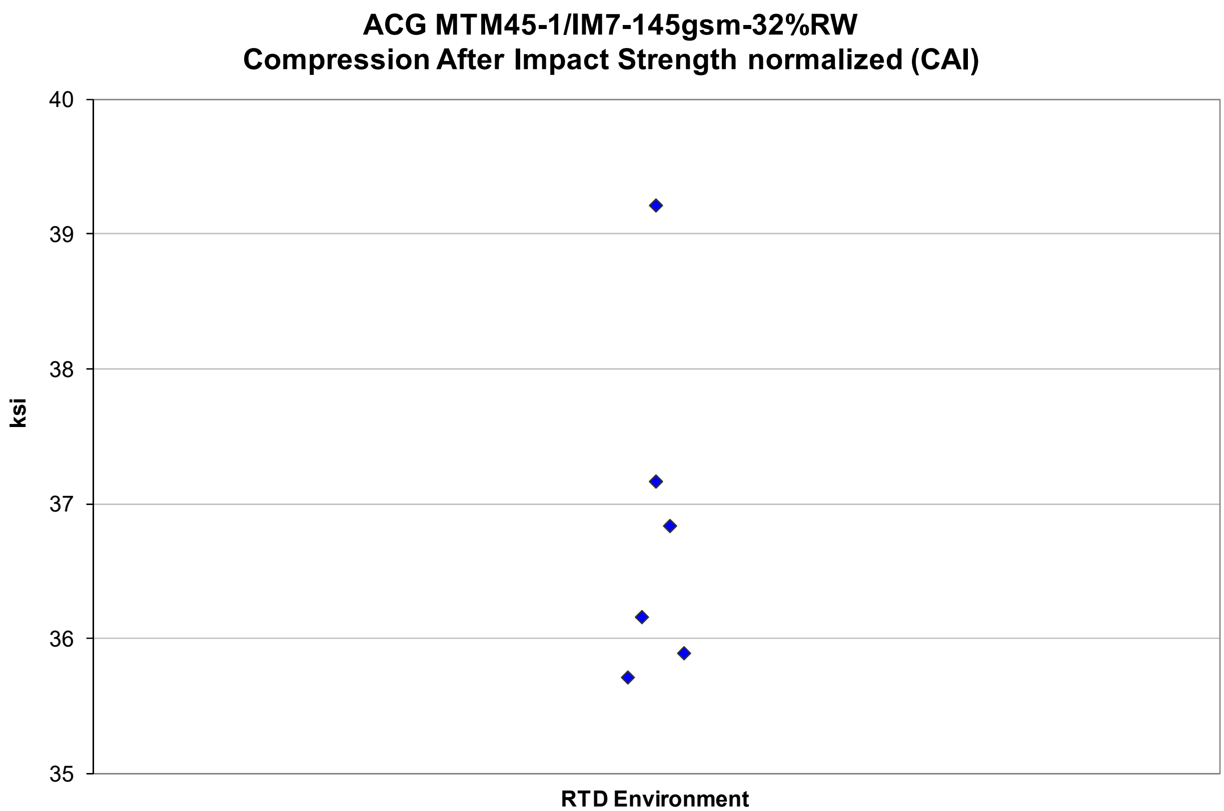

Figure 5-23: Batch plot for CAI strength normalized

Compression After Impact (CAI) Strength (ksi) Statistics		
RTD Env	Normalized	As Measured
Mean	36.83	36.47
Stdev	1.30	1.40
CV	3.52	3.85
Modified CV	8.00	8.00
Min	35.71	35.05
Max	39.22	38.84
No. Batches	1	1
No. Spec.	6	6

Table 5-29: Statistics from CAI strength data

6. Outliers

Outliers were identified according to the standards documented in section 2.1.4, which are in accordance with the guidelines developed in CMH-17-1G Chapter 8. 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.

Outliers with an identified cause were removed from the dataset and the remaining specimens were analyzed for this report. Information about specimens that were removed from the dataset along with the cause for removal is documented in the material property data report, NCAMP Test Report CAM-RP-2008-007 Rev B.

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
LSBS	ETW2	3	IMU-SBS1-C-MH2-ETW2-2	NA	3.24	Low	Yes	Yes
LC	ETW2	2	IMU-UNC0-B-MH1-ETW2-1	107.57	Not an Outlier	Low	No	Yes
UNC0				59.64	Not an Outlier	Low	No	Yes
TC	ETW2	3	IMU-TC-C-MH1-ETW2-2	NA	14.29	High	Yes	No
IPS 0.2% Offset	ETW2	3	IMU-IPS-A-MH4-ETW2-4	NA	2.60	Low	Yes	No
IPS 0.2% Offset	ETW2	3	IMU-IPS-A-MH4-ETW2-3	NA	2.74	Low	Yes	No
SBS	ETW	2	IMU-SBS-B-MH1-ETW-2	NA	9.12	High	No	Yes
SBS	ETW2	1	IMU-SBS-A-MH1-ETW2-1	NA	7.31	High	Yes	No
OHT2	CTD	1	IMU-OHT2-A-MH2-CTD-3	51.27	Not an Outlier	High	No	Yes
OHT2	CTD	2	IMU-OHT2-B-MH2-CTD-2	52.81	52.19	High	Yes	Yes
OHC1	ETW	1	IMU-OHC1-A-MH2-ETW-1	Not an Outlier	34.89	High	Yes	NA
OHC1	ETW2	3	IMU-OHC1-C-MH1-ETW2-2	Not an Outlier	32.72	High	Yes	No
UNT1	CTD	1	IMU-UNT1-A-MH1-CTD-3	120.49	118.51	Low	Yes	No
UNT3	CTD	1	IMU-UNT3-A-MH2-CTD-3	186.03	Not an Outlier	Low	Yes	NA
LSBS	RTD	2	IMU-SBS1-B-MH1-RTD-3	NA	9.59	Low	Yes	No
LSBS	ETW2	3	IMU-SBS1-C-MH2-ETW2-2	NA	3.24	Low	Yes	Yes
FHT1	CTD	2	IMU-FHT1-B-MH1-CTD-3	Not an Outlier	65.54	Low	Yes	No
FHT2	CTD	1	IMU-FHT2-A-MH2-CTD-2	Not an Outlier	48.50	Low	Yes	NA
FHT3	CTD	1	IMU-FHT3-A-MH1-CTD-3	94.56	90.44	Low	Yes	NA
FHC2	RTD	1	IMU-FHC2-A-MH2-RTD-3	Not an Outlier	50.29	Low	Yes	NA
PB2 - 2% Offset	ETW2	1	IMU-PB2-A-MH2-ETW2-3	88.74	89.83	High	Yes	No

Table 6-1: List of outliers

7. References

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