NATIONAL CENTER for ADVANCED MATERIALS PERFORMANCE

Hexcel 8552 IM7 Unidirectional Prepreg 190 gsm & 35%RC Qualification Statistical Analysis Report

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1 Introduction

This report contains statistical analysis of Hexcel IM7 Unidirectional Prepreg 190 gsm 35% RC data. Material property data is published in NCAMP Test Report CAM-RP-2009-015 Rev A. The lamina and laminate material property data have been generated with FAA oversight through FAA Special Project Number SP4652WI-Q and also meet the requirements outlined in NCAMP Standard Operating Procedure NSP 100. The test panels, test specimens, and test setups have been conformed by the FAA and the testing has been witnessed by the FAA.

B-Basis values, A-estimates, and B-estimates were calculated using a variety of techniques that are detailed in section two. The qualification material was procured to NCAMP Material Specification NMS 128/2 Rev - Initial Release dated February 6, 2007. The qualification material was procured to NCAMP Material Specification NMS 128/2 Rev - Initial Release dated February 6, 2007. The qualification test panels were cured in accordance with Baseline Cure Cycle (M) of NCAMP Process Specification NPS 81228 Rev A Initial Release June 7, 2007. The NCAMP Test Plan NTP 1828Q1 Rev B was used for this qualification program.

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

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

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

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

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

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

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 128/2. NMS 128/2 has additional requirements that are listed in its prepreg process control document (PCD), fiber specification, fiber PCD, and other raw material specifications and PCDs which impose essential quality controls on the raw materials and raw material manufacturing equipment and processes. *Aircraft companies and certifying agencies should assume that the material property data published in this report is not applicable when the material is not procured to NCAMP Material Specification NMS 128/2.* NMS 128/2 is a free, publicly available, non-proprietary aerospace industry material specification.

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

1.1 Symbols and Abbreviations

Test Property	Abbreviation
Longitudinal Compression	LC
Longitudinal Tension	LT
Transverse Compression	TC
Transverse Tension	TT
In Plane Shear	IPS
Short Beam Shear	SBS
Laminate Short Beam Shear	LSBS
Unnotched Tension	UNT
Unnotched Compression	UNC
Filled Hole Tension	FHT
Filled Hole Compression	FHC
Open Hole Tension	OHT
Open Hole Compression	OHC
Single Shear Bearing Strength	SSB
Interlaminar Tension Strength	ILT
Curved Beam Strength	CBS
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
Longitudinal Tension Poisson's Ratio	ν_{12}^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 (250°)	ETD
Elevated Temperature Wet (250°)	ETW

Table 1-3: Environmental Conditions Abbreviations

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

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

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

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2009-015 Rev A.

1.2 Pooling Across Environments

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

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

1.3 Basis Value Computational Process

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

1.4 Modified Coefficient of Variation (CV) Method

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

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

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

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

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

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

2 Background

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

2.1 ASAP Statistical Formulas and Computations

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

2.1.1 Basic Descriptive Statistics

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

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

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

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

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

2.1.2 Statistics for Pooled Data

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

2.1.2.1 Pooled Standard Deviation

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

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

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.

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

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 Rev G. The approximation formulas are given below:

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

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

Where

r = the number of environments being pooled together

n_j= number of data values for environment j

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

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

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

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

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

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

2.1.4 Modified Coefficient of Variation

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

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

This is converted to percent by multiplying by 100%.

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

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

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

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

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

2.1.4.1 Transformation of data based on Modified CV

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

To accomplish this requires a transformation in two steps:

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

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

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

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

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

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

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

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

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

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

2.1.5 Determination of Outliers

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

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

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

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

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

2.1.6 The k-Sample Anderson Darling Test for batch equivalency

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

The k-sample Anderson-Darling test statistic is:

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

Where

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

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

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

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

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

With

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

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

2.1.7 The Anderson Darling Test for Normality

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

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

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

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

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

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:

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

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

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

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

2.1.8 Levene's test for Equality of Coefficient of Variation

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

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

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

2.2 STAT-17

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

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

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

2.2.1 Distribution tests

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

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

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

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

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

2.2.2 Computing Normal Distribution Basis values

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

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

Table 2-1: K factors for normal distribution

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

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

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

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:

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

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

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

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

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

2.2.2.3.1 Estimating Weibull Parameters

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

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

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

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

2.2.2.3.2 Goodness-of-fit test for the Weibull distribution

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

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

The Anderson-Darling test statistic is

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

and the observed significance level is

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

where

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

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

2.2.2.3.3 Basis value calculations for the Weibull distribution

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

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

where

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

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

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

V is the value in Table 2-2. 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 $\left(0 < a < b < \infty\right)$ is given by the area under the normal distribution between ln(a) and ln(b).

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

2.2.2.4.1 Goodness-of-fit test for the Lognormal distribution

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

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

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

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

2.2.2.4.2 Basis value calculations for the Lognormal distribution

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

2.2.3 Non-parametric Basis Values

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

2.2.3.1 Non-parametric Basis Values for large samples

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

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

For B-basis values:

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

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.

2.2.4 Non-parametric Basis Values for small samples

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

The Hanson-Koopmans B-basis value is:

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

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

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

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

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

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

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

2.2.5 Analysis of Variance (ANOVA) Basis Values

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

2.2.5.1 Calculation of basis values using ANOVA

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

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

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

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

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

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 = $\overline{X} - k_b S_{adj} = \overline{X} - k_b \cdot 0.08 \cdot \overline{X}$ **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													
N1+N2-2	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4.508	0	0	0	0	0	0	0	0	0	0	0	0	0
4	3.827	3.607	0	0	0	0	0	0	0	0	0	0	0	0
5	3.481	3.263	3.141	0	0	0	0	0	0	0	0	0	0	0
6	3.273	3.056	2.934	2.854	0	0	0	0	0	0	0	0	0	0
7	3.134	2.918	2.796	2.715	2.658	0	0	0	0	0	0	0	0	0
8	3.035	2.820	2.697	2.616	2.558	2.515	0	0	0	0	0	0	0	0
9	2.960	2.746	2.623	2.541	2.483	2.440	2.405	0	0	0	0	0	0	0
10	2.903	2.688	2.565	2.484	2.425	2.381	2.346	2.318	0	0	0	0	0	0
11	2.856	2.643	2.519	2.437	2.378	2.334	2.299	2.270	2.247	0	0	0	0	0
12	2.819	2.605	2.481	2.399	2.340	2.295	2.260	2.231	2.207	2.187	0	0	0	0
13	2.787	2.574	2.450	2.367	2.308	2.263	2.227	2.198	2.174	2.154	2.137	0	0	0
14	2.761	2.547	2.423	2.341	2.281	2.236	2.200	2.171	2.147	2.126	2.109	2.093	0	0
15	2.738	2.525	2.401	2.318	2.258	2.212	2.176	2.147	2.123	2.102	2.084	2.069	2.056	0
16	2.719	2.505	2.381	2.298	2.238	2.192	2.156	2.126	2.102	2.081	2.063	2.048	2.034	2.022
17	2.701	2.488	2.364	2.280	2.220	2.174	2.138	2.108	2.083	2.062	2.045	2.029	2.015	2.003
18	2.686	2.473	2.348	2.265	2.204	2.158	2.122	2.092	2.067	2.046	2.028	2.012	1.999	1.986
19	2.673	2.459	2.335	2.251	2.191	2.144	2.108	2.078	2.053	2.032	2.013	1.998	1.984	1.971
20	2.661	2.447	2.323	2.239	2.178	2.132	2.095	2.065	2.040	2.019	2.000	1.984	1.970	1.958
21	2.650	2.437	2.312	2.228	2.167	2.121	2.084	2.053	2.028	2.007	1.988	1.972	1.958	1.946
22	2.640	2.427	2.302	2.218	2.157	2.110	2.073	2.043	2.018	1.996	1.978	1.962	1.947	1.935
23	2.631	2.418	2.293	2.209	2.148	2.101	2.064	2.033	2.008	1.987	1.968	1.952	1.938	1.925
24	2.623	2.410	2.285	2.201	2.139	2.092	2.055	2.025	1.999	1.978	1.959	1.943	1.928	1.916
25	2.616	2.402	2.277	2.193	2.132	2.085	2.047	2.017	1.991	1.969	1.951	1.934	1.920	1.907
26	2.609	2.396	2.270	2.186	2.125	2.078	2.040	2.009	1.984	1.962	1.943	1.927	1.912	1.900
27	2.602	2.389	2.264	2.180	2.118	2.071	2.033	2.003	1.977	1.955	1.936	1.920	1.905	1.892
28	2.597	2.383	2.258	2.174	2.112	2.065	2.027	1.996	1.971	1.949	1.930	1.913	1.899	1.886
29	2.591	2.378	2.252	2.168	2.106	2.059	2.021	1.990	1.965	1.943	1.924	1.907	1.893	1.880
30	2.586	2.373	2.247	2.163	2.101	2.054	2.016	1.985	1.959	1.937	1.918	1.901	1.887	1.874
40	2.550	2.337	2.211	2.126	2.063	2.015	1.977	1.946	1.919	1.897	1.877	1.860	1.845	1.832
50	2.528	2.315	2.189	2.104	2.041	1.993	1.954	1.922	1.896	1.873	1.853	1.836	1.820	1.807
60	2.514	2.301	2.175	2.089	2.026	1.978	1.939	1.907	1.880	1.857	1.837	1.819	1.804	1.790
70	2.504	2.291	2.164	2.079	2.016	1.967	1.928	1.896	1.869	1.846	1.825	1.808	1.792	1.778
80	2.496	2.283	2.157	2.071	2.008	1.959	1.920	1.887	1.860	1.837	1.817	1.799	1.783	1.769
90	2.491	2.277	2.151	2.065	2.002	1.953	1.913	1.881	1.854	1.830	1.810	1.792	1.776	1.762
100	2.486	2.273	2.146	2.060	1.997	1.948	1.908	1.876	1.849	1.825	1.805	1.787	1.771	1.757
125	2.478	2.264	2.138	2.051	1.988	1.939	1.899	1.867	1.839	1.816	1.795	1.777	1.761	1.747
150	2.472	2.259	2.132	2.046	1.982	1.933	1.893	1.861	1.833	1.809	1.789	1.770	1.754	1.740
175	2.468	2.255	2.128	2.042	1.978	1.929	1.889	1.856	1.828	1.805	1.784	1.766	1.750	1.735
200	2.465	2.252	2.125	2.039	1.975	1.925	1.886	1.853	1.825	1.801	1.781	1.762	1.746	1.732

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

2.5 0º 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 backout factor.

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

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

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 section 2.4.2 of the CMH-17 Rev G, 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.

2.5.1 0º Lamina Strength Derivation (Alternate Formula)

In some cases, the previous formula cannot be used. For example, there were no ETD tests run for transverse tension and compression, so the value for E_2 was not available. In that case, an alternative formula is used to compute the strength values for longitudinal tension and compression. It is similar to, but not quite the same as the formula detailed above. It requires the UNC0 and UNT0 strength and modulus data in addition to the LC and LT modulus data.

The 0° lamina strength values for the LC ETD condition were derived using the formula:

$$F^{cu}_{0^\circ} = F^{cu}_{0^\circ/90^\circ}\frac{E^c_1}{E^c_{0^\circ/90^\circ}}, \quad F^{tu}_{0^\circ} = F^{tu}_{0^\circ/90^\circ}\frac{E^t_1}{E^t_{0^\circ/90^\circ}} \quad \textbf{Equation 65}$$

with $F^{cu}_{0^\circ}, F^{tu}_{0^\circ}$ the derived mean lamina strength value for compression and tension respectively

$F^{cu}_{0^\circ/90^\circ}, \quad F^{tu}_{0^\circ/90^\circ}$ are the mean strength values for UNC0 and UNT0 respectively

$E^c_1, \quad E^t_1$ are the modulus values for LC and LT respectively

$E^c_{0^\circ/90^\circ}, \quad E^t_{0^\circ/90^\circ}$ are the modulus values for UNC0 and UNT0 respectively

This formula can also be found in section 2.4.2 of the CMH-17 Rev G, equation 2.4.2.1(d).

3 Summary of Results

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

3.1 NCAMP Recommended B-basis Values

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

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

NCAMP Recommended B-basis Values for
Hexcel Corporation - Hexcel 8552 IM7 Unidirectional

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	LT from LT	LC from UNC0	TT*	TC*	SBS*	IPS* 0.2% Offset	IPS* 5% Strain
CTD (-65º F)	B-basis	251.63	318.49	NA: I	NA: A	48.28	19.30**	10.43	
	Mean	286.78	357.39	296.49	9.60	55.31	21.04	11.29	
	CV	6.00	6.00	6.10	8.30	6.60	3.05	6.00	
RTD (70º F)	B-basis	289.28	323.09	NA: I	7.59	36.45	15.10	6.87	NA: I
	Mean	324.62	362.69	248.94	9.29	41.44	17.13	7.76	13.22
	CV	6.71	6.21	6.96	9.47	6.25	6.00	6.00	1.60
ETD (250º F)	B-basis			NA: I			9.92		
	Mean			201.93			11.23		
	CV			7.30			6.00		
ETW (250º F)	B-basis	311.51	263.95	NA: I	3.00	16.66	7.78**	2.44	4.89
	Mean	346.85	333.50	173.00	3.49	19.02	8.25	3.31	5.54
	CV	6.00	11.64	8.23	7.14	6.74	2.93	6.32	6.00

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 CMH17-G requirements.
"NA: A" indicates ANOVA with 3 batches, "NA: I" indicates insufficient data,
Shaded empty boxes indicate that no test data is available for that property and condition.
* Data is as measured rather than normalized
** indicates the Stat17 B-basis value is greater than 90% of the mean value.

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

NCAMP Recommended B-basis Values for
Hexcel Corporation - Hexcel 8552 IM7 Unidirectional

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

Laminate Strength Tests

Lay-up	ENV	Statistic	OHT	OHC	FHT	FHC	UNT	UNC	SSB 2% Offset	LSBS*
25/50/25	CTD (-65º F)	B-basis	51.20		56.75		86.58			
		Mean	57.75		64.02		99.35			
		CV	6.11		6.19		6.00			
	RTD (70º F)	B-basis	52.44	44.44	58.60	62.04	91.92	NA: I	95.42	9.03
		Mean	59.00	49.08	65.87	69.19	104.69	87.05	109.89	12.13
		CV	6.00	6.00	6.47	6.67	7.48	9.32	6.76	6.85
	ETW (250º F)	B-basis	60.44	30.87	63.11	44.49	99.70	NA: A	65.05	6.17
		Mean	66.97	35.52	70.29	51.68	112.46	57.68	88.14	6.99
		CV	6.13	6.03	6.00	6.21	6.49	11.02	10.10	6.00
10/80/10	CTD (-65º F)	B-basis	40.58		46.14		63.00			
		Mean	45.95		52.25		70.22			
		CV	6.00		6.00		6.00			
	RTD (70º F)	B-basis	39.19	35.15	42.51	49.24	59.82	58.02	101.71	
		Mean	43.65	38.80	48.15	54.57	67.01	66.44	114.02	
		CV	6.00	6.00	6.02	6.06	6.85	7.68	6.44	
	ETW (250º F)	B-basis	33.90	22.15	37.65	35.84	46.98	32.66	73.91	
		Mean	38.39	25.76	42.63	41.17	54.17	40.61	86.22	
		CV	6.00	6.51	6.00	6.20	6.00	10.91	7.26	
50/40/10	CTD (-65º F)	B-basis	NA:A		69.94		153.71			
		Mean	78.75		80.70		174.18			
		CV	5.03		6.85		6.24			
	RTD (70º F)	B-basis	73.93	57.00	NA:A	88.86	155.44	105.84	100.94	
		Mean	86.59	63.24	91.95	98.57	175.63	120.84	113.90	
		CV	6.73	6.27	7.20	6.30	6.39	6.93	6.51	
	ETW (250º F)	B-basis	102.26	40.21	89.42	63.13	166.96	65.09	78.72	
		Mean	114.86	46.42	101.26	72.79	187.43	79.42	91.67	
		CV	6.97	6.27	6.00	6.00	6.92	10.31	7.58	

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

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

3.2 Lamina and Laminate Summary Tables

Material:	Hexcel Corporation - Hexcel 8552 IM7 Unidirectional NMS 128/2 Material Specification			**Hexcel 8552 IM7 Unidirectional Tape Lamina Properties Summary**
Fiber:	IM7 unidirectional	**Resin:**	Hexcel 8552	
	Tg(dry): 406.43 ° F	**Tg(wet):** 321.41 ° F	**Tg METHOD:** DMA (SRM 18-94)	
PROCESSING:	NPS 81228 "M" Cure Cycle			

	Lot 1	Lot 2	Lot 3		
Date of fiber manufacture	1/26/07	12/25/06	2/5/07	**Date of testing**	01/22/08 to 03/04/10
Date of resin manufacture	2/28/07	1/24/07	3/1/07	**Date of data submittal**	4/5/2010
Date of prepreg manufacture	2/28/07	1/24/07	3/1/07	**Date of analysis**	12/21/09 to 4/30/10
Date of composite manufacture	9/2007 to 10/2007				

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported: As measured followed by normalized values in parentheses, normalizing tply: 0.0072 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		
	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)	260.34	248.19	281.57	299.45	287.23	320.79				319.12	306.91	340.46
from UNT0*	(262.57)	(251.63)	(286.78)	(300.28)	289.28	(324.62)				(322.51)	(311.51)	(346.85)
F_1^{tu} (ksi)	328.73	315.07	353.70	345.66	331.76	371.08				265.58	NA	327.96
from LT	(332.10)	(318.49)	(357.39)	(336.95)	(323.09)	(362.69)				(263.95)	NA	(333.50)
E_1^t			22.33			23.51						23.77
(Msi)			(22.57)			(22.99)						(24.00)
ν_{12}^t			0.270			0.316						0.393
F_2^{tu} (ksi)	5.69	8.08	9.60	7.59	NA	9.29				3.06	3.00	3.49
E_2^t (Msi)			1.46			1.30						0.81
F_1^{cu} (ksi)	265.22	260.48	291.99	224.35	219.61	251.13	172.73	167.98	199.50	147.69	143.28	172.58
from UNC0*	(269.62)	(265.75)	(296.49)	(222.07)	(218.20)	(248.94)	(175.06)	(171.19)	(201.93)	(148.02)	(144.42)	(173.00)
E_1^c			20.53			20.44			20.00			20.65
(Msi)			(20.68)			(20.04)			(20.25)			(20.37)
ν_{12}^c			0.362			0.356			0.374			0.383
F_2^{cu} (ksi)	49.78	48.28	55.31	34.07	36.45	41.44				17.11	16.66	19.02
E_2^c (Msi)			1.53			1.41						1.18
ν_{21}^c			0.028			0.024						0.018
$F_{12}^{s5\%}$ (ksi)	NA	NA	NA	12.76	11.47	13.22				4.49	4.89	5.54
$F_{12}^{s0.2\%}$ (ksi)	10.25	10.43	11.29	7.38	6.87	7.76				2.61	2.44	3.31
G_{12}^s (Msi)			0.86			0.68						0.31
SBS (ksi)	19.30	NA	21.04	16.28	15.10	17.13	10.81	9.92	11.23	7.78	NA	8.25
UNT0	138.75	132.38	149.90	157.96	151.55	169.16				164.78	158.37	175.98
(ksi)	(139.85)	(134.12)	(152.58)	(158.59)	152.83	(171.38)				(166.44)	(160.68)	(179.23)
			11.71			11.85						11.74
(Msi)			(11.92)			(11.99)						(11.94)
UNC0	101.62	99.79	111.64	85.09	83.26	95.11	65.11	63.28	75.13	54.71	53.02	64.03
(ksi)	(103.17)	(101.68)	(113.26)	(84.42)	(82.93)	(94.51)	(65.44)	(63.95)	(75.53)	(54.90)	(53.51)	(64.28)
			7.64			7.52			7.53			7.82
(Msi)			(7.75)			(7.47)			(7.57)			(7.74)
ν of UNC0			0.041			0.035			0.030			0.017

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

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

Material:	Hexcel Corporation - Hexcel 8552 IM7 Unidirectional NMS 128/2 Material Specification			**Hexcel 8552 IM7 Unidirectional Tape Laminate Properties Summary**
Fiber:	IM7 unidirectional	**Resin:**	Hexcel 8552	
Tg(dry): 406.43 ° F	**Tg(wet):** 321.41 ° F	**Tg METHOD :** DMA (SRM 18-94)		
PROCESSING:	NPS 81228 "M" Cure Cycle			

	Lot 1	Lot 2	Lot 3		
Date of fiber manufacture	01/26/07	12/25/06	02/05/07	**Date of testing**	01/22/08 to 03/04/10
Date of resin manufacture	02/28/07	01/24/07	03/01/07	**Date of data submittal**	4/5/2010
Date of prepreg manufacture	02/28/07	01/24/07	03/01/07	**Date of analysis**	12/21/09 to 4/30/10
Date of composite manufacture	9/2007 to 10/2007				

LAMINATE MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported as normalized used a normalizing t_{ply} of 0.0072 in

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

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

Test	Property	Test Condition	Unit	Quasi Isotropic 25/50/25 B-value	Quasi Isotropic 25/50/25 Mod. CV B-value	Quasi Isotropic 25/50/25 Mean	"Soft" 10/80/10 B-value	"Soft" 10/80/10 Mod. CV B-value	"Soft" 10/80/10 Mean	"Hard" 50/40/10 B-value	"Hard" 50/40/10 Mod. CV B-value	"Hard" 50/40/10 Mean
OHT (normalized)	Strength	CTD	ksi	44.35	51.20	57.75	42.97	40.58	45.95	54.89	68.75	78.75
		RTD	ksi	54.29	52.44	59.00	41.27	39.19	43.65	75.97	73.93	86.59
		ETW	ksi	62.28	60.44	66.97	35.99	33.90	38.39	104.29	102.26	114.86
OHC (normalized)	Strength	RTD	ksi	46.15	44.44	49.08	36.47	35.15	38.80	58.72	57.00	63.24
		ETW	ksi	32.58	30.87	35.52	23.46	22.15	25.76	41.92	40.21	46.42
UNT (normalized)	Strength	CTD	ksi	85.41	84.23	97.24	65.21	63.00	70.22	158.24	153.71	174.18
	Modulus		msi	---	---	8.06	---	---	5.52	---	---	13.11
	Strength	RTD	ksi	89.21	90.42	103.43	59.48	59.82	67.01	159.91	155.44	175.63
	Modulus		msi	---	---	8.19	---	---	5.22	---	---	13.15
	Strength	ETW	ksi	81.82	97.64	110.53	51.50	46.98	54.17	171.50	166.96	187.43
	Modulus		msi	---	---	7.66	---	---	4.47	---	---	13.14
UNC (normalized)	Strength	RTD	ksi	70.54	74.39	87.05	58.16	58.02	66.44	106.66	105.84	120.84
	Modulus		msi	---	---	7.86	---	---	4.90	---	---	11.90
	Poisson's Ratio			---	---	0.334	---	---	0.587	---	---	0.423
	Strength	ETW	ksi	31.92	45.69	57.68	32.79	32.66	40.61	65.88	65.09	79.42
	Modulus		msi	---	---	7.13	---	---	4.10	---	---	11.77
	Poisson's Ratio			---	---	0.356	---	---	0.665	---	---	0.416
FHT (normalized)	Strength	CTD	ksi	47.28	56.75	64.02	49.20	46.14	52.25	60.44	69.94	80.70
		RTD	ksi	59.52	58.60	65.87	44.37	42.51	48.15	58.26	78.33	91.95
		ETW	ksi	60.13	63.11	70.29	41.20	37.65	42.63	93.56	89.42	101.26
FHC (normalized)	Strength	RTD	ksi	53.43	62.04	69.19	50.18	49.24	54.57	92.14	88.86	98.57
		ETW	ksi	47.24	44.49	51.68	30.49	35.84	41.17	66.39	63.13	72.79
Single Shear Bearing (normalized)	2% Offset Strength	RTD	ksi	98.08	95.42	109.89	103.93	101.71	114.02	102.81	100.94	113.90
		ETW	ksi	65.05	NA	88.14	76.13	73.91	86.22	80.58	78.72	91.67
LSBS (as measured)	Strength	RTD	ksi	9.03	NA	12.13	---	---	---	---	---	---
		ETW	ksi	6.49	6.17	6.99	---	---	---	---	---	---
ILT (as measured)	Strength	CTD	ksi	---	---	11.96	---	---	---	---	---	---
		RTD	ksi	---	---	11.04	---	---	---	---	---	---
		ETW	ksi	---	---	6.46	---	---	---	---	---	---
CBS (as measured)	Strength	CTD	lbs	---	---	380.63	---	---	---	---	---	---
		RTD	lbs	---	---	356.85	---	---	---	---	---	---
		ETW	lbs	---	---	208.68	---	---	---	---	---	---
CAI (Normalized)	Strength	RTD	ksi	---	---	31.45	---	---	---	---	---	---

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 of section 8.3.10 of CMH-17 Rev G.

4.1 Longitudinal (0°) Tension Properties (LT)

The longitudinal tension strengths are computed two different ways; directly from LT specimens and indirectly (derived) from UNT0 specimens via equation 64 specified in section 2.5. The results of both are presented here.

For the LT strength values derived from the UNT0 specimens pooling across environments was acceptable. There was one outlier on the low side of batch three of the RTD data. It was an outlier only after pooling the three RTD batches for the as measured data, but it was an outlier both before and after pooling the three RTD batches for the normalized data. It was retained for this analysis.

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.

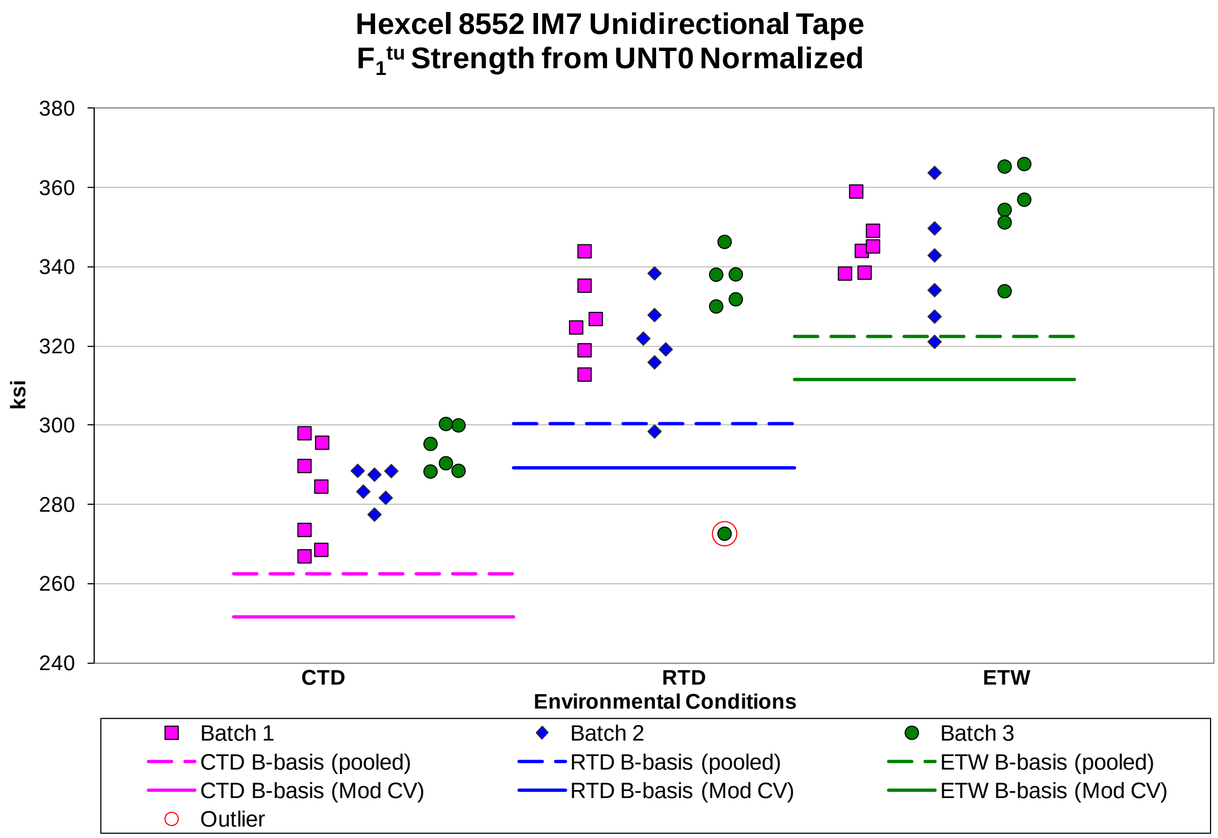

Figure 4-1 Batch plot for F_1^{tu} strength from UNT0 normalized

Longitudinal Tension Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	286.78	324.62	346.85	281.57	320.79	340.46
Stdev	9.72	17.62	13.00	10.18	13.42	12.48
CV	3.39	5.43	3.75	3.61	4.18	3.67
Mod CV	6.00	6.71	6.00	6.00	6.09	6.00
Min	267.02	272.74	321.20	259.93	285.19	318.34
Max	300.46	346.44	366.11	294.31	345.25	366.30
No. Batches	3	3	3	3	3	3
No. Spec.	19	18	18	19	18	18
Basis Values and/or Estimates						
B-basis Value	262.57	300.28	322.51	260.34	299.45	319.12
A-estimate	246.31	284.05	306.27	246.09	285.21	304.89
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	251.63	289.28	311.51	248.19	287.23	306.91
A-estimate	228.02	265.71	287.94	225.78	264.85	284.53
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-1: Statistics and Basis values for F_1^{tu} strength from UNT0

Longitudinal Tension Modulus Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	22.57	22.99	24.00	22.33	23.51	23.77
Stdev	0.39	0.81	0.56	0.37	0.53	0.69
CV	1.72	3.53	2.32	1.65	2.27	2.92
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	21.85	20.71	23.22	21.74	22.78	22.69
Max	23.22	23.94	25.58	22.97	24.38	26.17
No. Batches	3	3	3	3	3	3
No. Spec.	22	18	29	22	18	29

Table 4-2: Statistics from E_1^t modulus

The statistics and basis values for strength computed from the LT specimens are provided in Table 4-3. The data and the B-basis values are shown graphically in Figure 4-2. The ETW data did not fit a normal distribution, nor did the pooled dataset with the ETW data included. However, the CTD and RTD data could be pooled. There were no outliers.

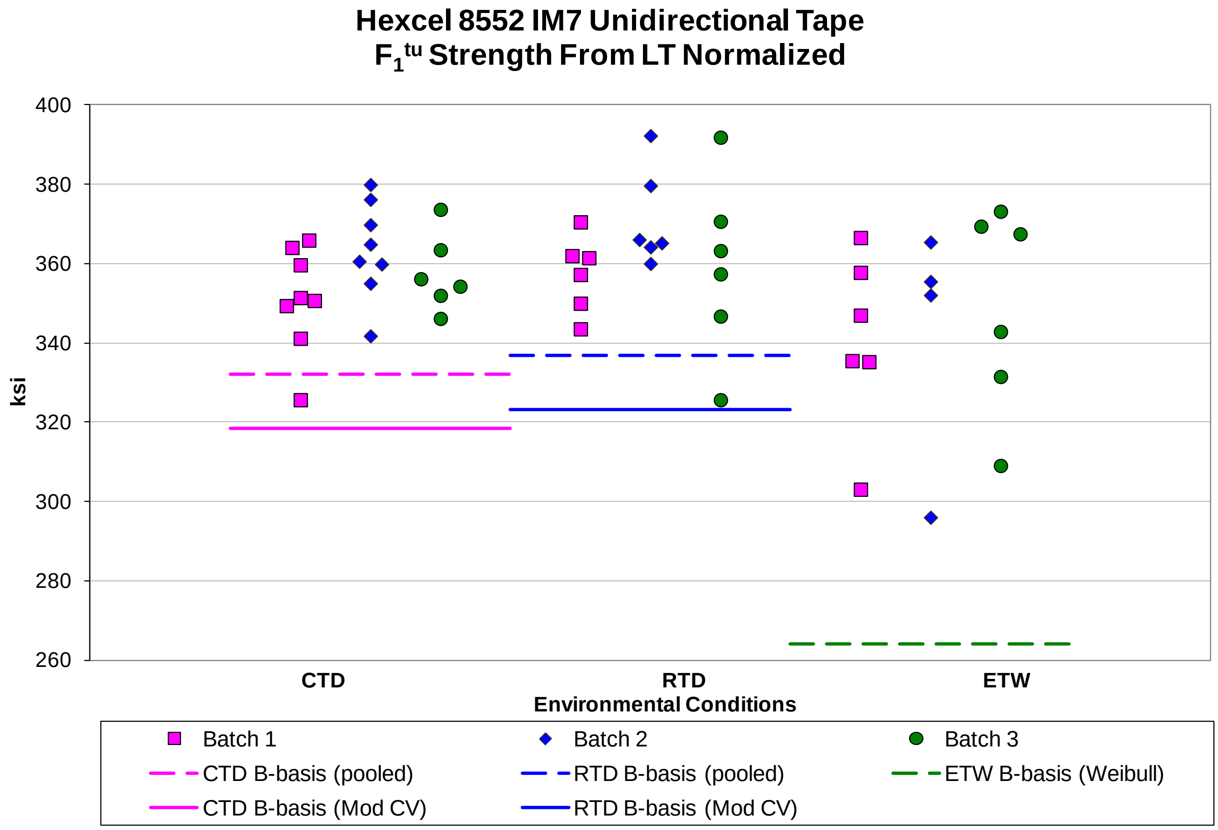

Figure 4-2 Batch plot for F_1^{tu} from LT strength normalized

Longitudinal Tension Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	357.39	362.69	333.50	353.70	371.08	327.96
Stdev	12.62	16.06	38.82	13.09	15.23	35.18
CV	3.53	4.43	11.64	3.70	4.10	10.73
Mod CV	6.00	6.21	11.64	6.00	6.05	10.73
Min	325.69	325.68	244.53	322.58	340.31	241.83
Max	379.97	392.32	373.23	378.95	401.22	366.86
No. Batches	3	3	3	3	3	3
No. Spec.	22	18	18	22	18	18
Basis Values and/or Estimates						
B-basis Value	332.102	336.953	263.95	328.725	345.661	265.58
A-estimate	314.576	319.530	201.738	311.416	328.453	208.248
Method	pooled	pooled	Weibull	pooled	pooled	Weibull
Modified CV Basis Values and/or Estimates						
B-basis Value	318.487	323.093	NA	315.074	331.764	NA
A-estimate	291.524	296.289	NA	288.303	305.151	NA
Method	pooled	pooled	NA	pooled	pooled	NA

Table 4-3: Statistics and Basis values for F_1^{tu} from LT strength

4.2 Transverse (90º) Tension Properties (TT)

Transverse Tension data is not normalized because it is not a fiber dominated property for unidirectional tape. The CTD data fails the Anderson-Darling K-sample test (ADK test), even with modified CV transformation, so the ANOVA analysis method was required for the CTD environment, which means that with data from less than five batches available it is an estimate only. Pooling across environments was not appropriate due to failure of Levene's test. The CV in the RTD environment was too large for the modified CV method to have any effect, so modified CV basis values were not included.

Estimates were computed using the modified CV method for the CTD environment. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method. Since the CV is greater than 8%, these estimates are identical to the basis values computed using the normal distribution.

There were no outliers. Statistics, basis values and estimates are given for strength data as measured in Table 4-4 and for the modulus data as measured in Table 4-5. The data, B-basis values and B-estimates are shown graphically in Figure 4-3.

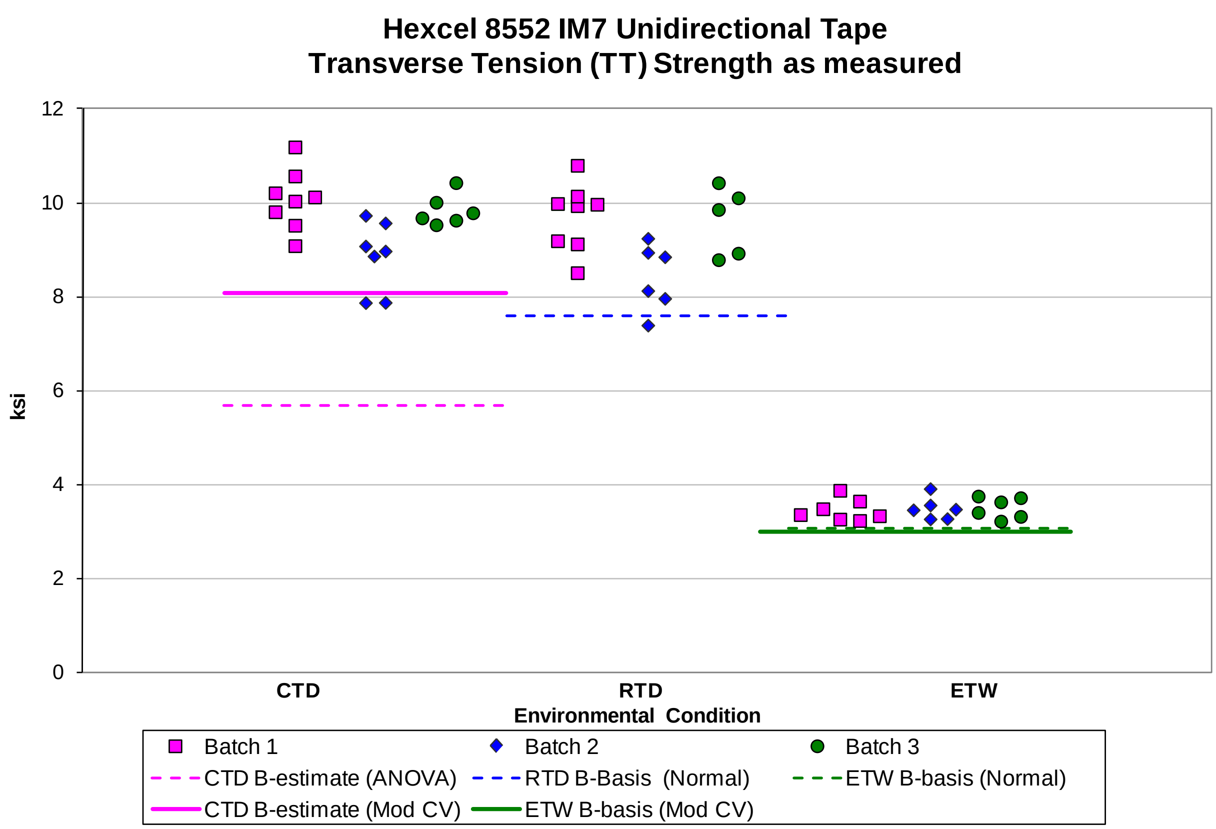

Figure 4-3: Batch Plot for TT strength as measured

Transverse Tension Strength Basis Values and Statistics			
As Measured			
Env	CTD	RTD	ETW
Mean	9.60	9.29	3.49
Stdev	0.80	0.88	0.22
CV	8.30	9.47	6.28
Mod CV	8.30	9.47	7.14
Min	7.88	7.40	3.22
Max	11.19	10.80	3.91
No. Batches	3	3	3
No. Spec.	21	20	19
Basis Values and/or Estimates			
B-basis Value		7.59	3.06
B-estimate	5.69		
A-estimate	2.91	6.39	2.76
Method	ANOVA	Normal	Normal
Mod CV Basis Values and/or Estimates			
B-basis Value		NA	3.00
B-estimate	8.08		
A-estimate	7.00	NA	2.66
Method	normal	NA	normal

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

Transverse Tension Modulus Statistics			
	As Measured		
Env	CTD	RTD	ETW
Mean	1.46	1.30	0.81
Stdev	0.03	0.04	0.04
CV	2.04	3.37	5.15
Mod CV	6.00	6.00	6.57
Min	1.42	1.21	0.76
Max	1.53	1.40	0.89
No. Batches	3	3	3
No. Spec.	21	20	19

Table 4-5: Statistics from TT Modulus data as measured

4.3 Longitudinal (0º) Compression Properties (LC)

The strength values for 0º properties are computed via the formulas specified in section 2.5. For the CTD, RTD and ETW condition, equation 64 was used. For the ETD values, a different formula was required because there were no specimens tested in that condition for the transverse compression and the modulus value of TC is needed to use the same formula as was used for the CTD, RTD and ETW conditions. Therefore, the ETD strength values were computed using equation 65.

There were no outliers or test failures, but due to problems with lay-up, there was insufficient data for the basis values to meet CMH-17 Rev G standards. Therefore only estimates are provided. Statistics and B-estimates are given for strength data in Table 4-6 and for the modulus data in Table 4-7. The data and the B-estimates are shown graphically in Figure 4-4.

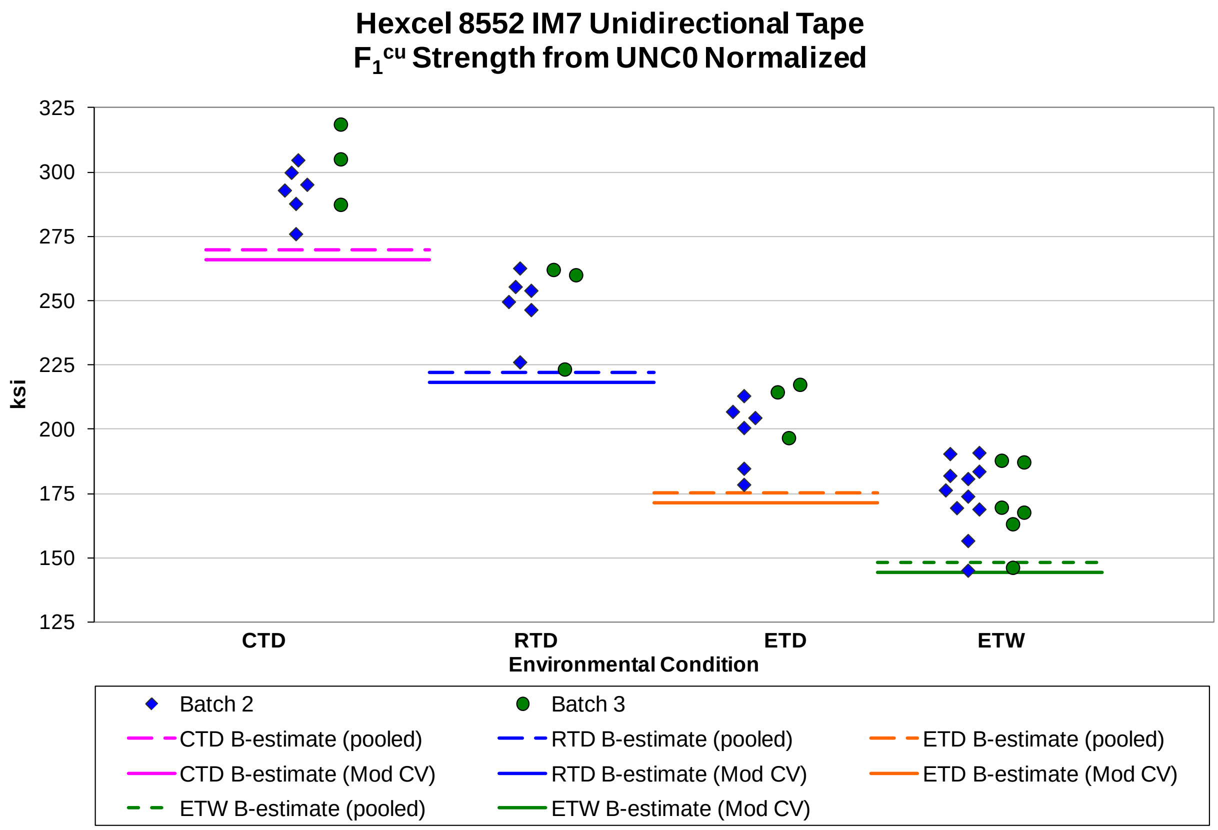

Figure 4-4 Batch plot for F_1^{cu} strength from UNC0 normalized

Longitudinal Compression Strength Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	296.49	248.94	201.93	173.00	291.99	251.13	199.50	172.58
Stdev	12.43	14.72	13.35	14.23	11.73	8.08	13.59	16.73
CV	4.19	5.91	6.61	8.23	4.02	3.22	6.81	9.70
Mod CV	6.10	6.96	7.30	8.23	6.01	6.00	7.41	9.70
Min	276.09	223.44	178.55	145.17	273.52	237.07	176.76	140.31
Max	318.72	262.73	217.48	190.96	310.99	260.19	216.77	202.05
No. Batches	2	2	2	2	2	2	2	2
No. Spec.	9	9	9	17	9	9	9	17
Basis Values and/or Estimates								
B-Estimate	269.62	222.07	175.06	148.02	265.22	224.35	172.73	147.69
A-Estimate	253.20	205.65	158.64	131.27	248.85	207.99	156.36	131.00
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-Estimate	265.75	218.20	171.19	144.42	260.48	219.61	167.98	143.28
A-Estimate	246.96	199.41	152.40	125.26	241.21	200.34	148.72	123.64
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-6: Statistics and Basis Values for F_1^{cu} strength from UNC0 normalized

Longitudinal Compression Modulus Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	20.68	20.04	20.25	20.37	20.53	20.44	20.00	20.65
Stdev	1.32	1.36	1.17	1.83	0.60	0.32	0.46	1.75
CV	6.40	6.81	5.76	9.00	2.94	1.55	2.31	8.49
Mod CV	7.20	7.41	6.88	9.00	6.00	6.00	6.00	8.49
Min	17.80	18.19	18.37	15.61	19.05	19.80	19.37	17.67
Max	22.39	22.43	22.12	24.76	21.29	20.89	20.92	26.64
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	20	15	17	35	20	15	17	35

Table 4-7: Statistics from E_1^c modulus

4.4 Transverse (90º) Compression Properties (TC)

Transverse Compression data is not normalized because it is not a fiber dominated property for unidirectional tape. The RTD data fails the Anderson-Darling K-sample test, but passes with the modified CV transform, so modified CV basis values are provided. However, the pooled dataset does not pass Levene's test for equality of variance, so pooling across environments was not acceptable.

There was one outlier. It was on the high side of batch three in the RTD environment. It was an outlier before, but not after, pooling the three RTD batches together. It was retained for this analysis.

Statistics, basis values and estimates are given for strength data in Table 4-8 and for the modulus data in Table 4-9. The data, B-estimates, and B-basis values are shown graphically in Figure 4-5.

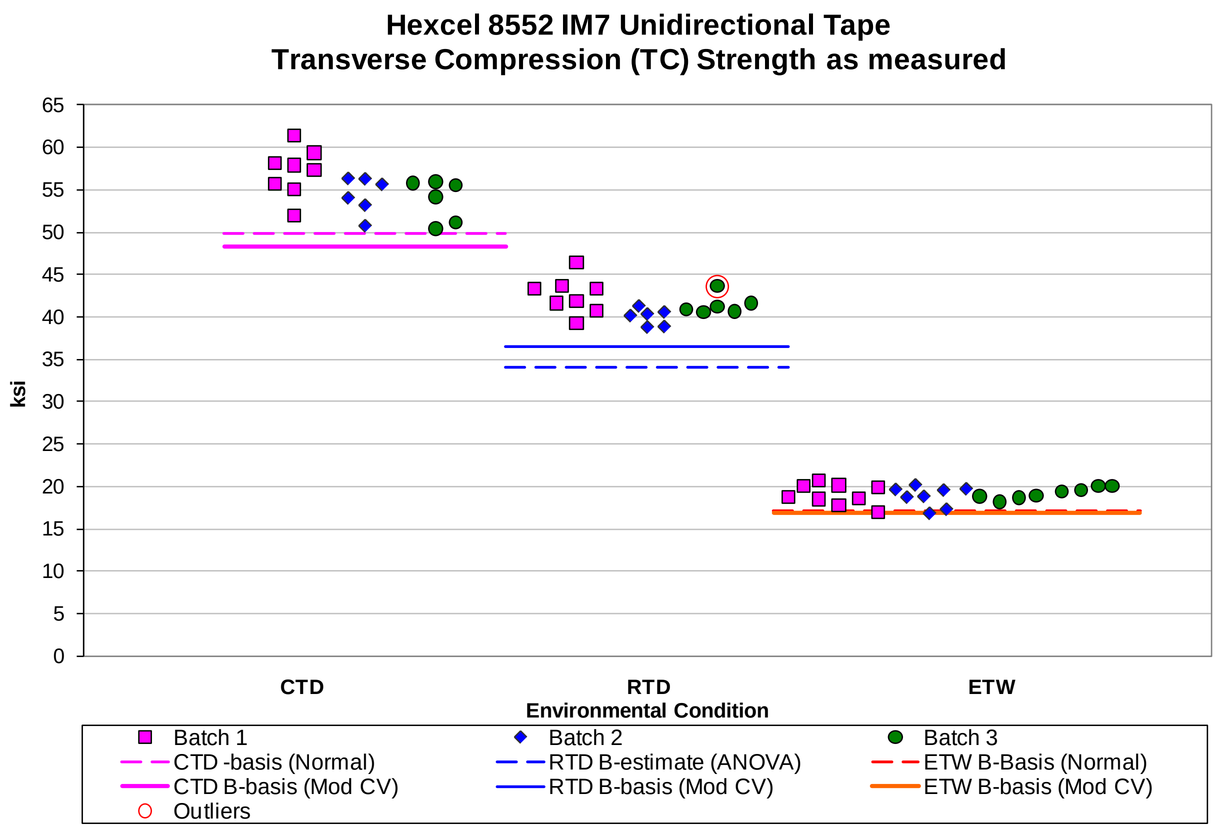

Figure 4-5: Batch Plot for TC strength as measured

Transverse Compression Strength Basis Values and Statistics			
As Measured			
Env	CTD	RTD	ETW
Mean	55.31	41.44	19.02
Stdev	2.87	1.86	1.04
CV	5.19	4.50	5.47
Mod CV	6.60	6.25	6.74
Min	50.41	38.79	16.78
Max	61.39	46.40	20.70
No. Batches	3	3	3
No. Spec.	20	20	25
Basis Values and/or Estimates			
B-basis Value	49.78		17.11
B-estimate		34.07	
A-estimate	45.84	28.81	15.73
Method	Normal	ANOVA	Normal
Mod CV Basis Values and/or Estimates			
B-basis Value	48.28	36.45	16.66
A-estimate	43.29	32.90	14.97
Method	normal	normal	normal

Table 4-8: Statistics and Basis Values for TC Strength data

Transverse Compression Modulus Statistics			
	As Measured		
Env	CTD	RTD	ETW
Mean	1.53	1.41	1.18
Stdev	0.12	0.09	0.09
CV	7.64	6.63	7.99
Mod CV	7.82	7.32	8.00
Min	1.26	1.25	1.03
Max	1.70	1.66	1.35
No. Batches	3	3	3
No. Spec.	20	20	9

Table 4-9: Statistics from TC Modulus data

4.5 In-Plane Shear Properties (IPS)

In-plane shear data is not normalized because in-plane shear is not a fiber dominated property. For the 5% strain strength data, there was no data available for the CTD environment and insufficient data (12 specimens) available for the RTD environment. The original data from the ETW environment did not pass the Anderson-Darling K-sample test, but did pass after the modified CV transformation of the data, so modified CV basis values are provided.

For the 0.2% offset strength data, the CTD and ETW environments initially failed the ADK test, but passed it after the modified CV transformation of the data so modified CV basis values are provided for those environments. Pooling was acceptable for the modified CV basis values. Levene's test indicated failure for the transformed data, but when the modified CV transformed data is normalized as described in section 5.3.1.3 of DOT/FAA/AR-03/19 it passes Levene's test. This procedure normalizes the data from each environment to have a mean of 1.0, and then compares their respective variances. This is a different normalization procedure than the normalization to the average cured ply thickness which is done for all fiber-dominated properties.

There were no outliers. Statistics, estimates and basis values are given for the strength data in Table 4-10 and modulus data in Table 4-11. The data, B-estimates and B-basis values are shown graphically in Figure 4-6.

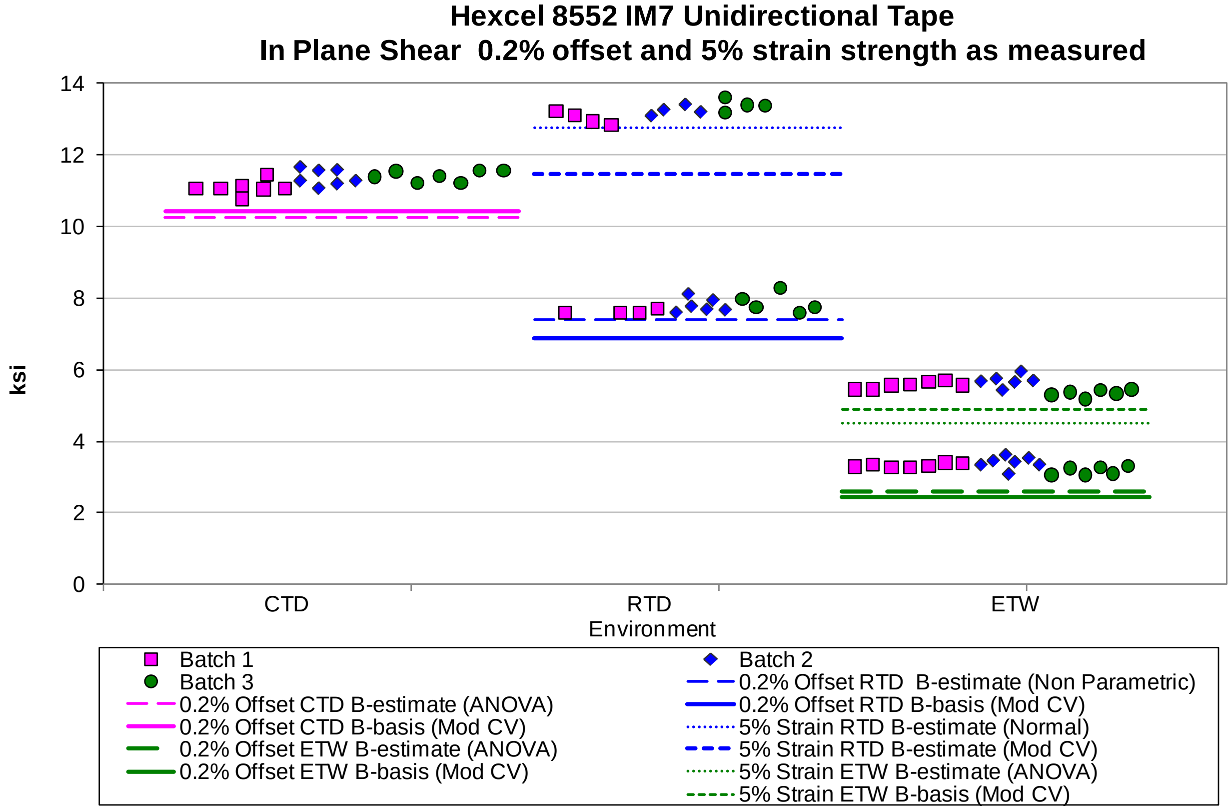

Figure 4-6: Batch plot for IPS for 0.2% offset strength and strength at 5% strain as measured

In Plane Shear Strength Basis Values and Statistics					
	Strength at 5% Strain		0.2% Offset Strength		
Env	RTD	ETW	CTD	RTD	ETW
Mean	13.22	5.54	11.29	7.76	3.31
Stdev	0.21	0.19	0.24	0.22	0.15
CV	1.60	3.38	2.10	2.81	4.63
Mod CV	6.00	6.00	6.00	6.00	6.32
Min	12.85	5.18	10.78	7.48	3.05
Max	13.61	5.95	11.66	8.28	3.63
No. Batches	3	3	3	3	3
No. Spec.	12	19	21	16	20
Basis Values and/or Estimates					
B-estimate	12.76	4.49	10.25	7.38	2.61
A-estimate	12.43	3.75	9.50	6.32	2.12
Method	Normal	ANOVA	ANOVA	Non-parametric	ANOVA
Mod CV Basis Values and/or Estimates					
B-basis Value		4.89	10.43	6.87	2.44
B-estimate	11.47				
A-estimate	10.25	4.43	9.85	6.29	1.86
Method	normal	normal	pooled	pooled	pooled

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

In Plane Shear Modulus Statistics			
	As Measured		
Env	CTD	RTD	ETW
Mean	0.86	0.68	0.31
Stdev	0.02	0.02	0.01
CV	2.90	3.27	4.51
Mod CV	6.00	6.00	6.26
Min	0.81	0.65	0.28
Max	0.89	0.73	0.34
No. Batches	3	3	3
No. Spec.	21	16	20

Table 4-11: Statistics from IPS Modulus data

4.6 Short Beam Strength (SBS) Data

The Short Beam Strength data is not normalized because it is not a fiber dominated property. The pooled dataset fail the normality test. The pooled data also fails Levene's test. For these reasons, pooling across environments is not acceptable. The CTD and ETW environments do not have an adequate fit with the normal, Weibull or lognormal distributions, so the non-parametric method was used to compute the basis values. There were two outliers. One in the CTD environment on the low side of batch one. The other was in the ETW environment on the high side of batch one. Both were outliers before, but not after pooling the three batches. These outliers were retained for this analysis.

Statistics and basis values are given for SBS data in Table 4-12. The data and the B-basis values are shown graphically in Figure 4-7.

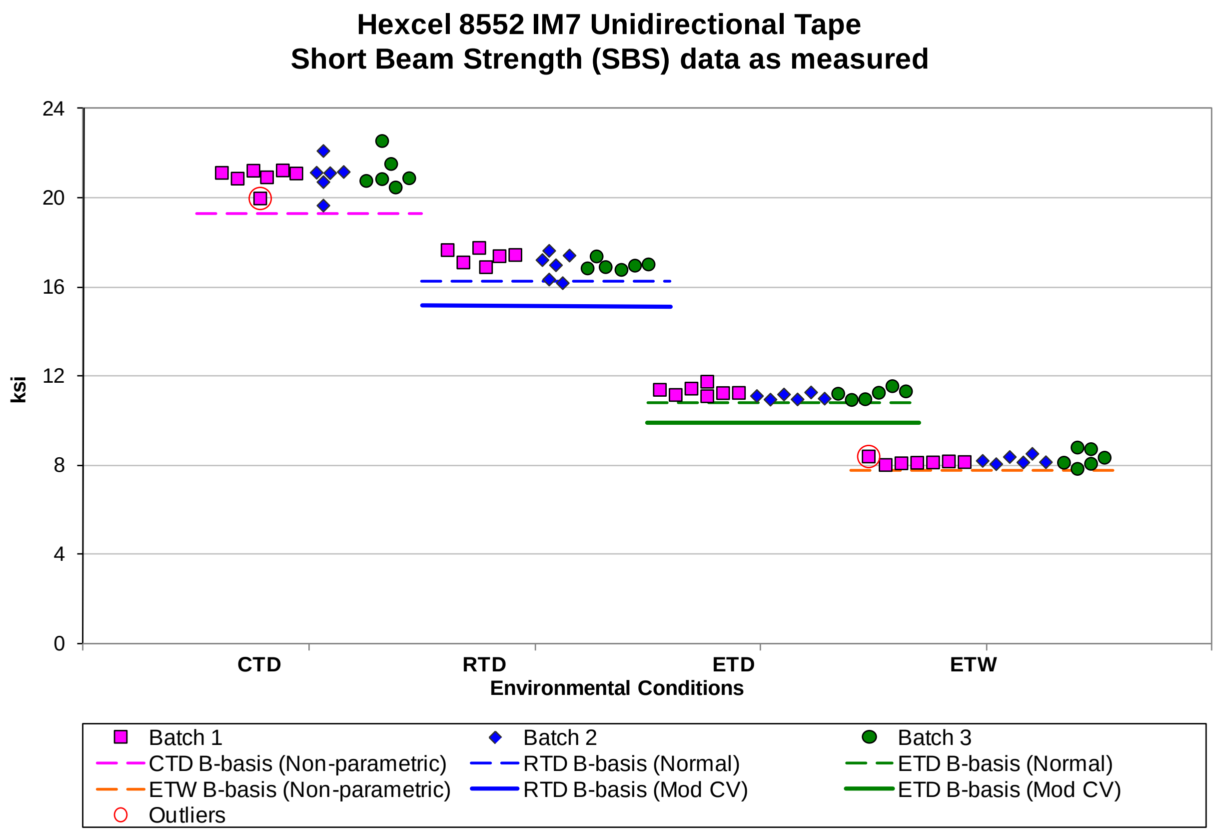

Figure 4-7: Batch plot for SBS as measured

Short Beam Strength (SBS) as measured				
Env	CTD	RTD	ETD	ETW
Mean	21.04	17.13	11.23	8.25
Stdev	0.64	0.43	0.22	0.24
CV	3.05	2.51	1.94	2.93
Mod CV	6.00	6.00	6.00	6.00
Min	19.68	16.20	10.96	7.86
Max	22.58	17.78	11.77	8.82
No. Batches	3	3	3	3
No. Spec.	19	18	19	19
Basis Values and/or Estimates				
B-basis Value	19.30	16.28	10.81	7.78
A-estimate	16.17	15.67	10.51	6.67
Method	Non-parametric	Normal	Normal	Non-parametric
Mod CV Basis Values and/or Estimates				
B-basis Value	NA	15.10	9.92	NA
A-estimate	NA	13.66	8.99	NA
Method	NA	normal	normal	NA

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

4.7 Unnotched Tension Properties (UNT0)

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

Statistics and basis values are given for strength data in Table 4-13 and for the modulus data in Table 4-14. The normalized data and the B-basis values are shown graphically in Figure 4-8.

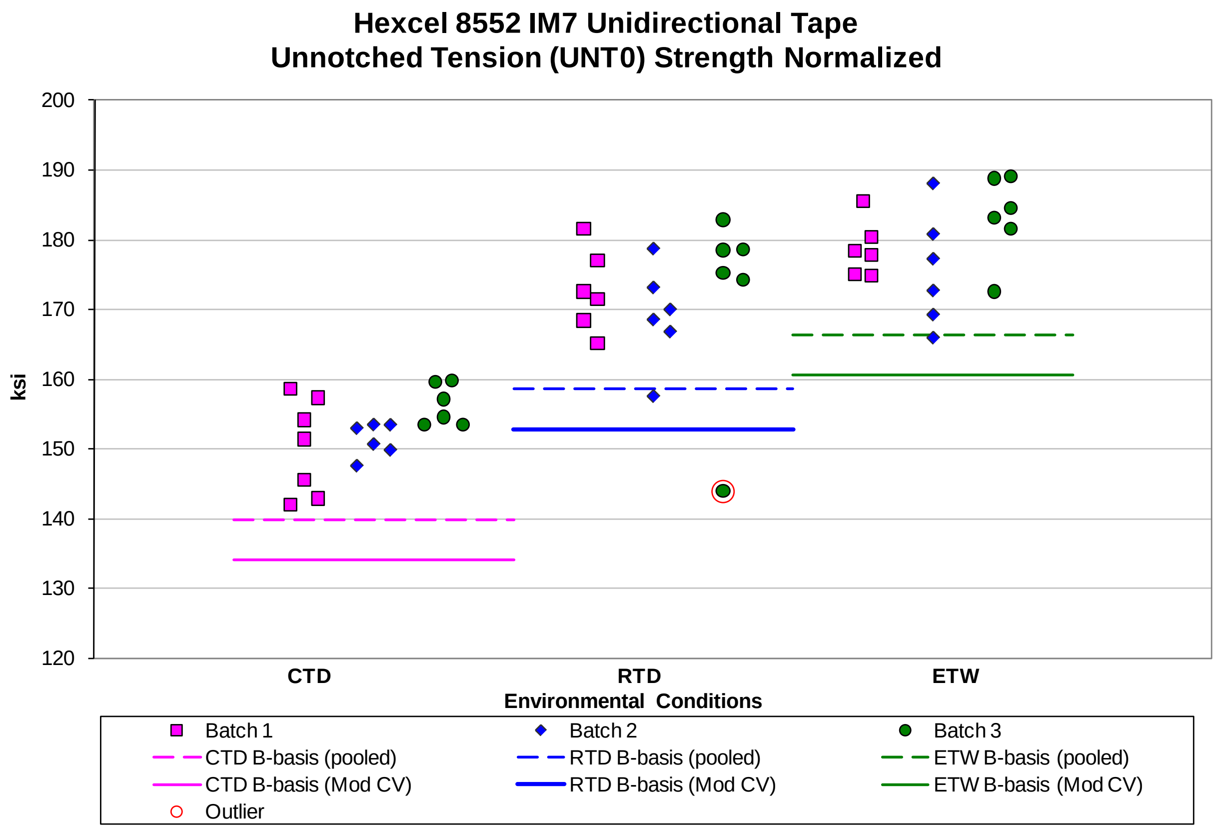

Figure 4-8: Batch Plot for UNT0 strength normalized

Unnotched Tension (UNT0) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	152.58	171.38	179.23	149.90	169.16	175.98
Stdev	5.17	9.30	6.72	5.42	7.08	6.45
CV	3.39	5.43	3.75	3.61	4.18	3.67
Mod CV	6.00	6.71	6.00	6.00	6.09	6.00
Min	142.06	143.99	165.98	138.38	150.39	164.55
Max	159.85	182.90	189.18	156.68	182.06	189.34
No. Batches	3	3	3	3	3	3
No. Spec.	19	18	18	19	18	18
Basis Values and/or Estimates						
B-basis Value	139.85	158.59	166.44	138.75	157.96	164.78
A-estimate	131.31	150.06	157.91	131.27	150.48	157.31
Method	pooled	pooled	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates						
B-basis Value	134.12	152.83	160.68	132.38	151.55	158.37
A-estimate	121.73	140.45	148.30	120.62	139.80	146.63
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-13: Statistics and Basis Values for UNT0 Strength data

Unnotched Tension (UNT0) Modulus Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	11.92	11.99	11.94	11.71	11.85	11.74
Stdev	0.15	0.21	0.21	0.19	0.30	0.25
CV	1.24	1.76	1.76	1.61	2.50	2.09
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	11.55	11.50	11.60	11.25	11.33	11.29
Max	12.15	12.34	12.35	11.91	12.46	12.26
No. Batches	3	3	3	3	3	3
No. Spec.	19	18	19	19	18	19

Table 4-14: Statistics from UNT0 Modulus data

4.8 Unnotched Compression Properties (UNC0)

There were no outliers or test failures, but due to problems with lay-up, there was insufficient data for the basis values to meet CMH-17 Rev G standards. Therefore only estimates are provided. Statistics and estimates of basis values are given for strength data in Table 4-15 and for the modulus data in Table 4-16. The normalized data and the B-estimates are shown graphically in Figure 4-9.

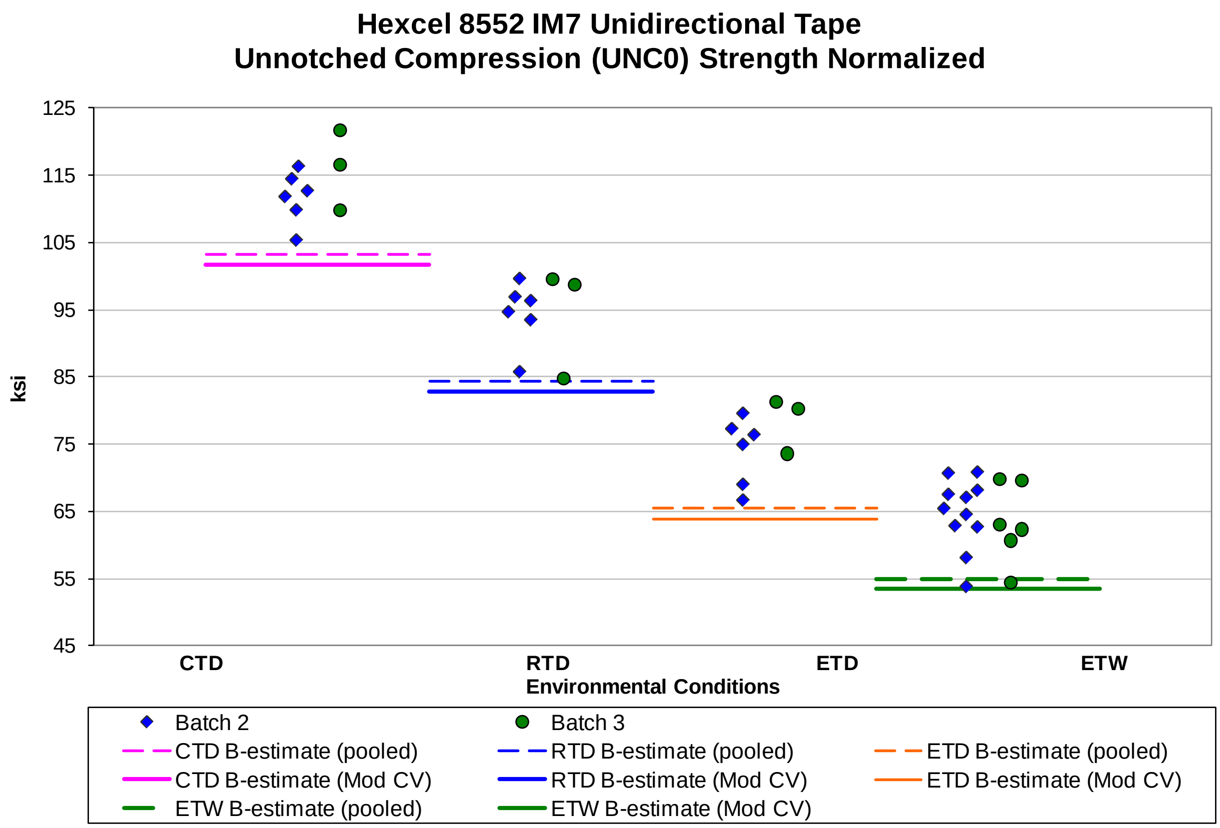

Figure 4-9: Batch Plot for UNC0 strength normalized

Unnotched Compression (UNC0) Strength Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	113.26	94.51	75.53	64.28	111.64	95.11	75.13	64.03
Stdev	4.75	5.59	4.99	5.29	4.48	3.06	5.12	6.21
CV	4.19	5.91	6.61	8.23	4.02	3.22	6.81	9.70
Mod CV	6.10	6.96	7.30	8.23	6.01	6.00	7.41	9.70
Min	105.46	84.82	66.78	53.94	104.58	89.79	66.57	52.06
Max	121.75	99.74	81.34	70.95	118.90	98.54	81.64	74.96
No. Batches	2	2	2	2	2	2	2	2
No. Spec.	9	9	9	17	9	9	9	17
Basis Values and/or Estimates								
B-estimate	103.17	84.42	65.44	54.90	101.62	85.09	65.11	54.71
A-estimate	97.00	78.25	59.27	48.61	95.49	78.96	58.98	48.47
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates								
B-estimate	101.68	82.93	63.95	53.51	99.79	83.26	63.28	53.02
A-estimate	94.60	75.85	56.87	46.30	92.55	76.02	56.04	45.63
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-15: Statistics and Basis Values for UNC0 Strength data

Unnotched Compression (UNC0) Modulus Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	7.75	7.47	7.57	7.74	7.64	7.52	7.53	7.82
Stdev	0.24	0.20	0.26	0.24	0.18	0.12	0.24	0.30
CV	3.08	2.62	3.41	3.04	2.36	1.53	3.12	3.88
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Min	7.47	7.04	7.11	7.41	7.43	7.32	7.11	7.30
Max	8.03	7.60	7.88	8.12	7.85	7.73	7.84	8.22
No. Batches	2	2	2	2	2	2	2	2
No. Spec.	9	9	9	8	9	9	9	8

Table 4-16: Statistics from UNC0 Modulus data

Note: The specification limit for this property as given in NMS 128/2 Rev A is that the average of 5 specimens must be greater than or equal to 85 ksi. The specification as computed per DOT/FAA/AR-03/19 with alpha = 1% is 87 ksi. If these B-estimates are converted into B-basis values, the spec limit will also need to be revised.

5 Laminate Test Results, Statistics, Basis Values and Graph

5.1 Unnotched Tension Properties

5.1.1 Quasi Isotropic Unnotched Tension Properties (UNT1)

The UNT1 ETW data, both normalized and as measured, fails the ADK test, but passes with the modified CV transform, so modified CV basis values are provided. Since there were only three batches available, the ANOVA values provided are estimates only. For the as measured data, the CTD and RTD environments could be pooled, but the normalized CTD and RTD failed the normality test when pooled together, so single point analysis was required for the normalized data. Since these conditions have fewer than 18 specimens available, the single point analysis results are considered estimates.

The as measured data passed the normality and Levene's test for equality of variance when the modified CV transformation is applied to all three environments, so modified CV basis values were computed by pooling the three environments. After the modified CV transformation was applied to all three environments, the normalized data passed Levene's test but failed the Anderson-Darling test for normality. The pooled dataset had an observed significance level (OSL) of 0.0228 while the specified requirement is for an OSL of 0.05 or higher. An override of this test result is recommended based on section 8.3.10.3 of CMH-17 Rev G.

There was one outlier. It was in the RTD environment, on the low side of batch three. It was an outlier only for the normalized data and only before pooling the three batches.

Statistics, basis values and estimates are given for UNT1 strength data in Table 5-1and for the modulus data in Table 5-2. The normalized data, B-estimates and B-basis values are shown graphically in Figure 5-1.

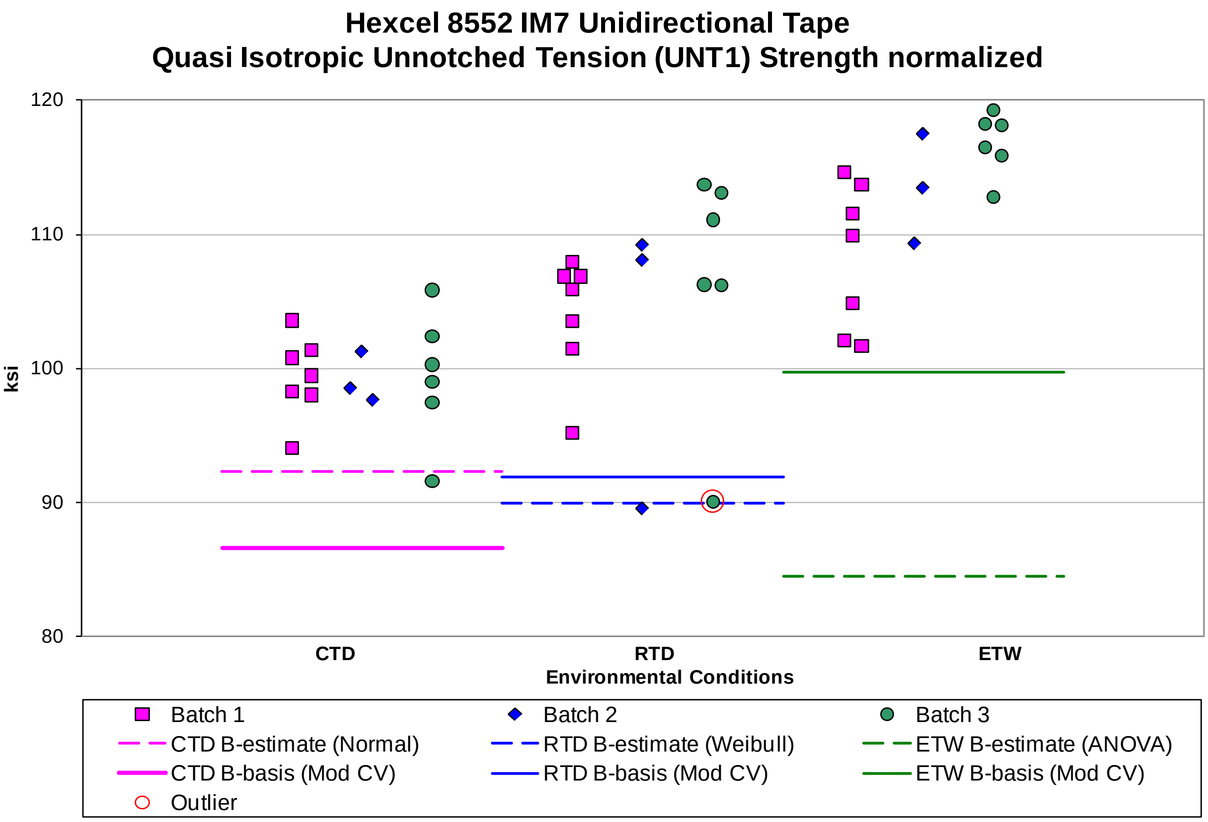

Figure 5-1: Batch Plot for UNT1 strength normalized

Unnotched Tension (UNT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	99.35	104.69	112.46	98.79	104.01	111.50
Stdev	3.44	7.28	5.61	2.75	4.05	3.90
CV	3.46	6.95	4.99	2.78	3.90	3.50
Mod CV	6.00	7.48	6.49	6.00	6.00	6.00
Min	91.60	89.56	101.64	93.70	96.38	104.09
Max	105.84	113.71	119.29	104.20	111.12	119.12
No. Batches	3	3	3	3	3	3
No. Spec.	16	16	16	16	16	16
Basis Values and/or Estimates						
B-basis Value				92.34	97.56	
B-estimate	92.35	89.96	84.54			92.13
A-estimate	87.41	75.69	64.65	87.99	93.21	78.33
Method	Normal	Weibull	ANOVA	pooled	pooled	ANOVA
Mod CV Basis Values with Recommended Override of Normality Test						
B-basis Value	86.58	91.92	99.70	87.43	92.65	100.14
A-estimate	78.14	83.48	91.25	79.92	85.14	92.63
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 5-1: Statistics and Basis Values for UNT1 Strength data

Unnotched Tension (UNT1) Modulus Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	8.35	8.39	7.99	8.30	8.34	7.92
Stdev	0.31	0.48	0.41	0.14	0.22	0.31
CV	3.70	5.73	5.16	1.74	2.68	3.86
Mod CV	6.00	6.86	6.58	6.00	6.00	6.00
Min	7.29	7.28	7.07	7.91	7.90	7.15
Max	8.75	8.98	8.51	8.52	8.69	8.29
No. Batches	3	3	3	3	3	3
No. Spec.	16	16	17	16	16	17

Table 5-2: Statistics from UNT1 Modulus data

5.1.2 "Soft" Unnotched Tension Properties (UNT2)

For the UNT2 data, the CTD condition failed the normality test for the normalized data but not the as measured data. The pooled dataset for the as measured data was sufficiently close to normal for pooling across environments to be acceptable. For the normalized data, this was not the case. Pooling was not acceptable due to the non-normality of the normalized pooled dataset. After applying the modified CV transform, the pooled data was sufficiently close to normal for modified CV basis values to be computed by pooling the data from the three environmental conditions.

The CTD dataset had insufficient specimens to meet CMH-17 Rev G guidelines for single-point computations (18 specimens), so that value is an estimate. When pooling across environments, only 15 specimens are required and the CTD dataset had sufficient specimens to meet that requirement.

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

Statistics, basis values and estimates are given for UNT2 strength data in Table 5-3 and for the modulus data in Table 5-4. The normalized data, B-estimates and B-basis values are shown graphically in Figure 5-2.

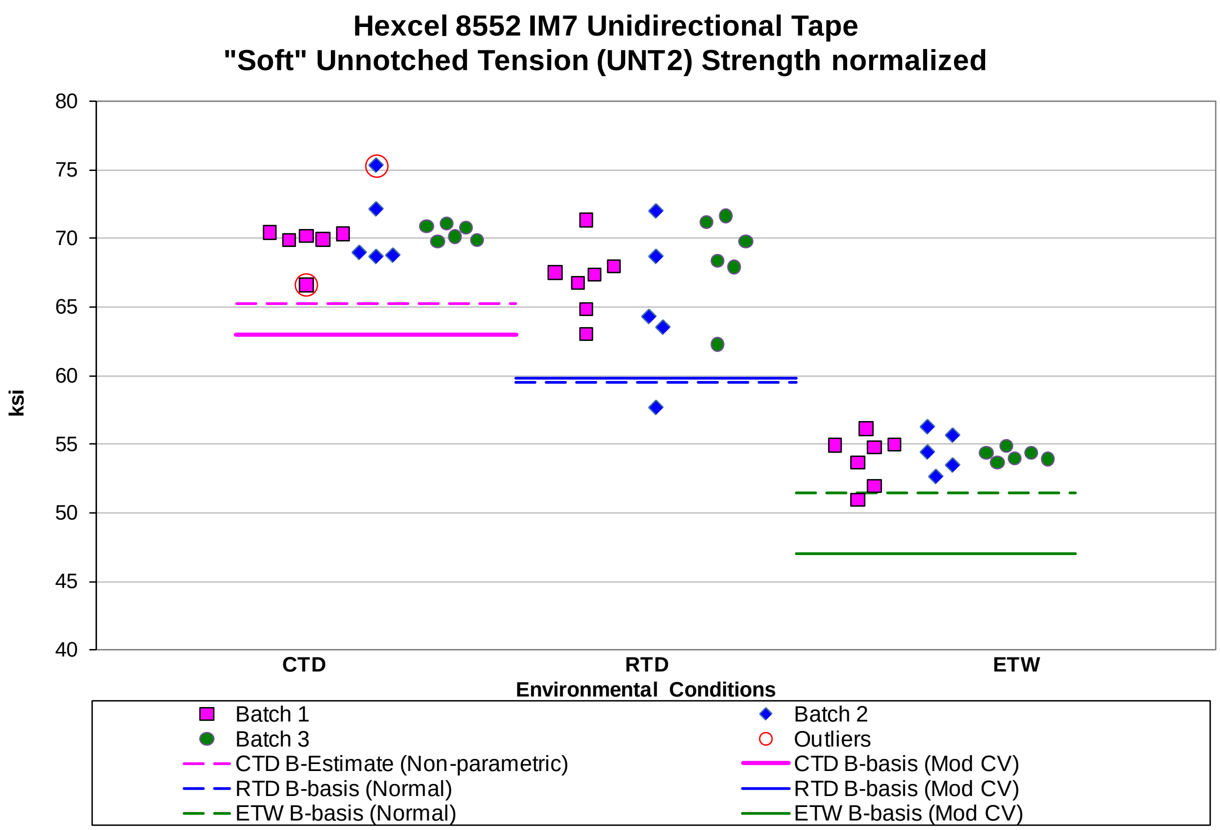

Figure 5-2: Batch Plot for UNT2 strength normalized

Unnotched Tension (UNT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	70.22	67.01	54.17	68.97	67.08	53.44
Stdev	1.78	3.81	1.35	1.61	2.12	1.55
CV	2.54	5.69	2.49	2.33	3.17	2.90
Mod CV	6.00	6.85	6.00	6.00	6.00	6.00
Min	66.60	57.64	50.96	65.98	62.42	50.23
Max	75.29	71.95	56.23	72.93	69.98	56.42
No. Batches	3	3	3	3	3	3
No. Spec.	17	18	18	17	18	18
Basis Values and/or Estimates						
B-basis Value		59.48	51.50	65.80	63.92	50.28
B-estimate	65.21					
A-estimate	54.92	54.14	49.61	63.69	61.81	48.17
Method	Non-parametric	Normal	Normal	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates						
B-basis Value	63.00	59.82	46.98	62.19	60.33	46.70
A-estimate	58.20	55.03	42.19	57.69	55.83	42.19
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 5-3: Statistics and Basis Values for UNT2 Strength data

Unnotched Tension (UNT2) Modulus Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	5.52	5.22	4.47	5.42	5.23	4.41
Stdev	0.11	0.28	0.10	0.12	0.17	0.09
CV	2.03	5.27	2.13	2.26	3.31	1.93
Mod CV	6.00	6.64	6.00	6.00	6.00	6.00
Min	5.31	4.70	4.33	5.14	4.95	4.28
Max	5.77	5.72	4.65	5.62	5.54	4.51
No. Batches	3	3	3	3	3	3
No. Spec.	17	18	18	17	18	18

Table 5-4: Statistics from UNT2 Modulus data

5.1.3 "Hard" Unnotched Tension Properties (UNT3)

Both the as measured and normalized UNT3 data could be pooled across environments. There was one outlier. It was in both the normalized and the as measured data. It was in the CTD environment, on the low side of batch two. It was an outlier only before pooling the three batches.

Statistics and basis values are given for UNT3 strength data in Table 5-5 and for the modulus data in Table 5-6. The normalized data and the B-basis values are shown graphically in Figure 5-3.

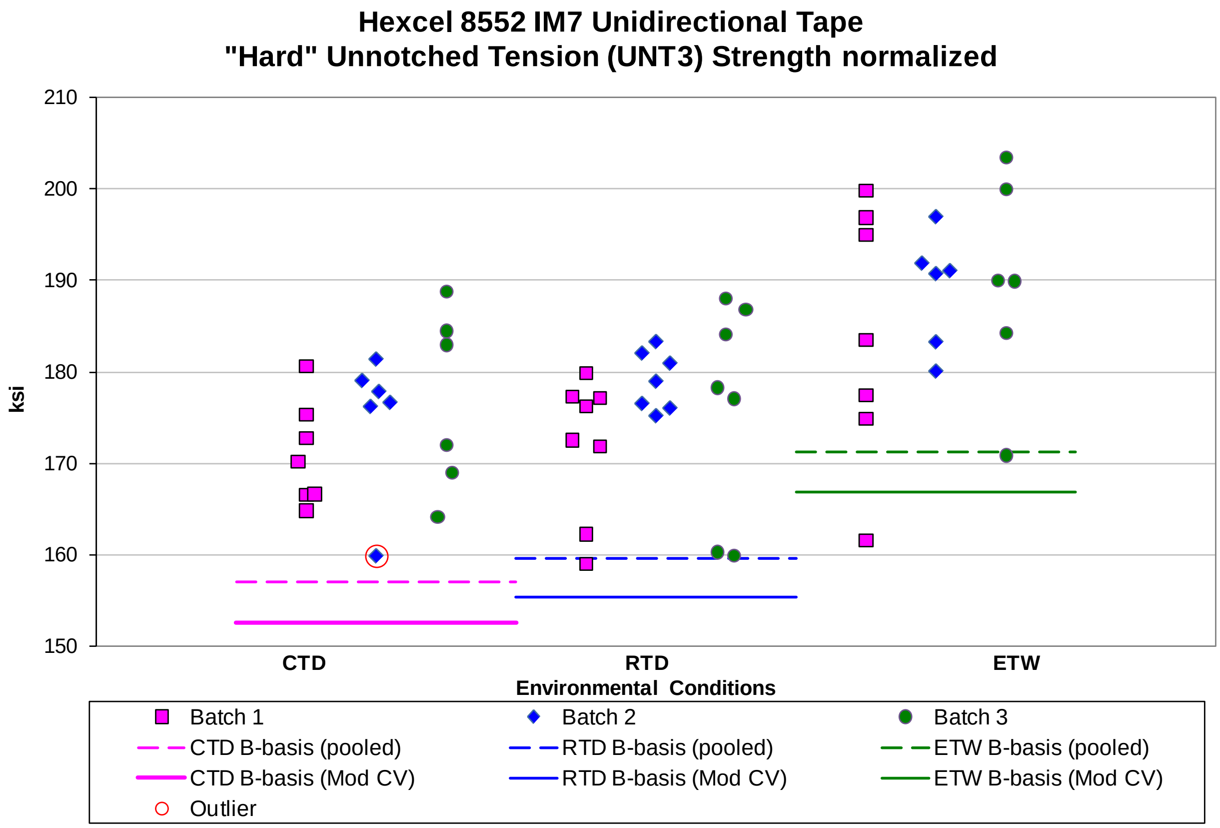

Figure 5-3: Batch Plot for UNT3 strength normalized

Unnotched Tension (UNT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	174.18	175.63	187.43	173.12	176.22	187.30
Stdev	7.79	8.39	10.94	8.21	7.42	8.10
CV	4.47	4.78	5.84	4.74	4.21	4.33
Mod CV	6.24	6.39	6.92	6.37	6.11	6.16
Min	159.91	159.04	161.56	160.82	158.49	172.30
Max	188.80	188.00	203.39	187.85	190.86	199.33
No. Batches	3	3	3	3	3	3
No. Spec.	19	22	19	19	22	19
Basis Values and/or Estimates						
B-basis Value	158.24	159.91	171.50	159.30	162.60	173.48
A-estimate	147.59	149.21	160.84	150.06	153.32	164.24
Method	pooled	pooled	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates						
B-basis Value	153.71	155.44	166.96	153.69	157.07	167.88
A-estimate	140.02	141.70	153.28	140.70	144.03	154.89
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

Unnotched Tension (UNT3) Modulus Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	13.11	13.15	13.14	13.02	13.20	13.15
Stdev	0.26	0.79	0.61	0.28	0.74	0.35
CV	1.98	6.04	4.65	2.17	5.63	2.68
Mod CV	6.00	7.02	6.33	6.00	6.81	6.00
Min	12.57	11.50	11.69	12.36	11.40	12.48
Max	13.60	15.13	14.41	13.41	14.84	13.90
No. Batches	3	3	3	3	3	3
No. Spec.	19	22	22	19	22	22

Table 5-6: Statistics from UNT3 Modulus data

5.2 Unnotched Compression

5.2.1 Quasi Isotropic Unnotched Compression (UNC1)

The UNC1 data for the ETW condition (both normalized and as measured) did not pass the ADK test, not even after the modified CV transformation of the data. This means that pooling with the RTD data was not appropriate nor could modified CV basis values be provided. Since there were only three batches available, the ANOVA values provided are estimates only. The normalized RTD data has a large CV, so modified CV basis values are not provided for that condition either. The RTD dataset had insufficient specimens to meet CMH-17 Rev G guidelines, so the values provided are estimates only.

Since the ANOVA result is overly conservative, pooled basis values are provided based on an override of the ADK test result. These values are considered estimates.

There was one outlier. It was on the low side of batch one of the normalized RTD data. It was an outlier before, but not after pooling the three batches. It was retained for this analysis.

Statistics, basis values and estimates are given for UNC1 strength data in Table 5-7 and for the modulus data in Table 5-8. The normalized data and B-estimates are shown graphically in Figure 5-4.

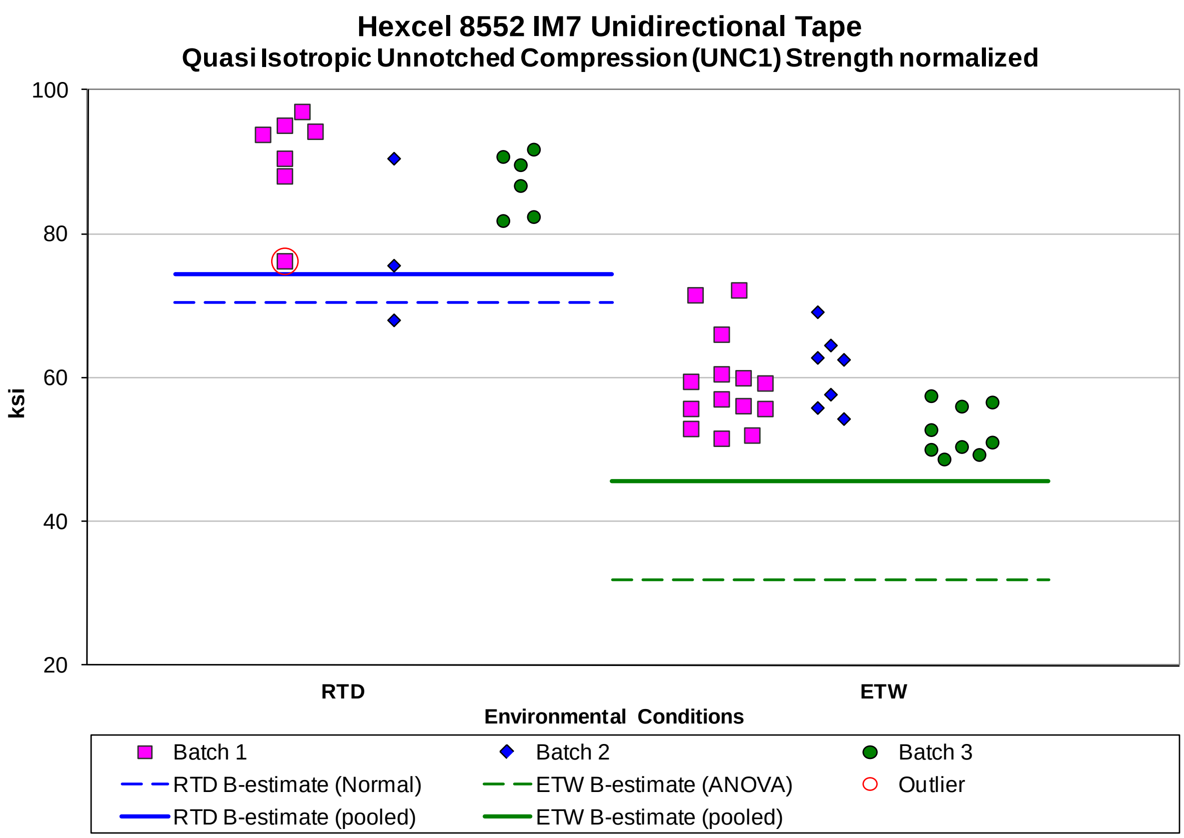

Figure 5-4: Batch plot for UNC1 strength normalized

Unnotched Compression (UNC1) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	87.05	57.68	86.95	57.09
Stdev	8.11	6.36	6.53	6.21
CV	9.32	11.02	7.51	10.87
Mod CV	9.32	11.02	7.75	10.87
Min	68.07	48.72	73.46	48.54
Max	97.04	72.23	96.78	70.98
No. Batches	3	3	3	3
No. Spec.	16	30	16	30
Basis Values and/or Estimates				
B-estimate	70.54	31.92	73.67	31.35
A-estimate	58.90	13.46	64.30	12.91
Method	Normal	ANOVA	Normal	ANOVA
Basis Values and/or Estimates with override of ADK test				
B-estimate	74.39	45.69	75.53	46.27
A-estimate	66.01	37.16	67.97	38.58
Method	pooled	pooled	pooled	pooled

Table 5-7: Statistics and Basis Values for UNC1 Strength data

Unnotched Compression (UNC1) Modulus Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	7.86	7.13	7.86	7.06
Stdev	0.37	0.13	0.38	0.16
CV	4.75	1.80	4.86	2.28
Mod CV	6.37	6.00	6.43	6.00
Min	6.89	6.85	7.20	6.79
Max	8.41	7.34	8.61	7.38
No. Batches	3	3	3	3
No. Spec.	16	16	16	16

Table 5-8: Statistics from UNC1 Modulus data

5.2.2 "Soft" Unnotched Compression (UNC2)

There were no outliers and pooling the two environments together was acceptable. Statistics and basis values are given for UNC2 strength data in Table 5-9 and for the modulus data in Table 5-10. The normalized data and the B-basis values are shown graphically in Figure 5-5.

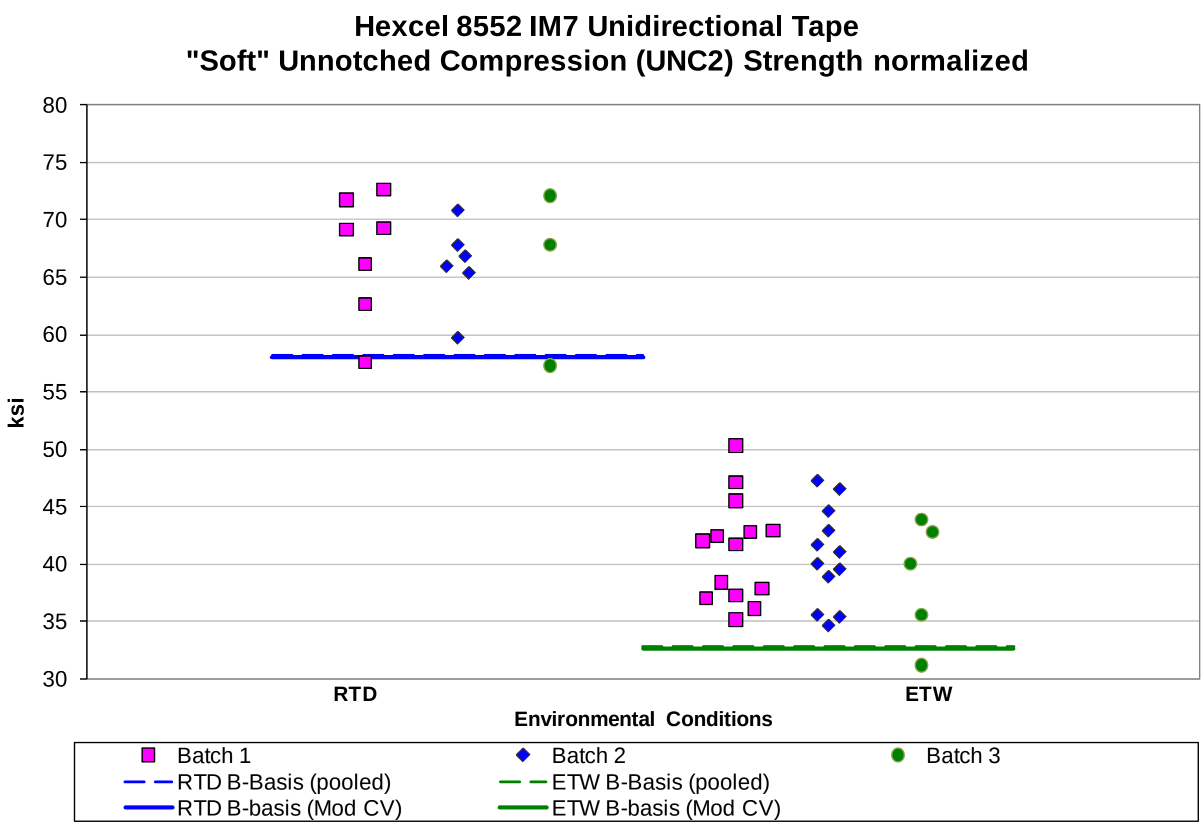

Figure 5-5: Batch plot for UNC2 strength normalized

Unnotched Compression (UNC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	66.44	40.61	67.49	40.43
Stdev	4.89	4.43	3.73	4.33
CV	7.36	10.91	5.53	10.71
Mod CV	7.68	10.91	6.77	10.71
Min	57.29	31.19	60.87	31.31
Max	72.61	50.34	73.01	49.44
No. Batches	3	3	3	3
No. Spec.	16	31	16	31
Basis Values and/or Estimates				
B-basis Value	58.16	32.79	60.01	33.37
A-estimate	52.68	27.21	55.07	28.34
Method	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	58.02	32.66	59.53	32.91
A-estimate	52.45	26.99	54.26	27.55
Method	pooled	pooled	pooled	pooled

Table 5-9: Statistics and Basis Values for UNC2 Strength data

Unnotched Compression (UNC2) Modulus Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	4.90	4.10	4.98	4.06
Stdev	0.30	0.09	0.24	0.11
CV	6.10	2.21	4.84	2.72
Mod CV	7.05	6.00	6.42	6.00
Min	4.35	3.96	4.58	3.85
Max	5.35	4.25	5.33	4.18
No. Batches	3	3	3	3
No. Spec.	16	16	16	16

Table 5-10: Statistics from UNC2 Modulus data

5.2.3 "Hard" Unnotched Compression (UNC3)

For the UNC3 data there were no outliers or test failures. Data could be pooled across the two environments. Statistics, basis values and estimates are given for UNC3 strength data in Table 5-11 and for the modulus data in Table 5-12. The normalized data and the B-basis values are shown graphically in Figure 5-6.

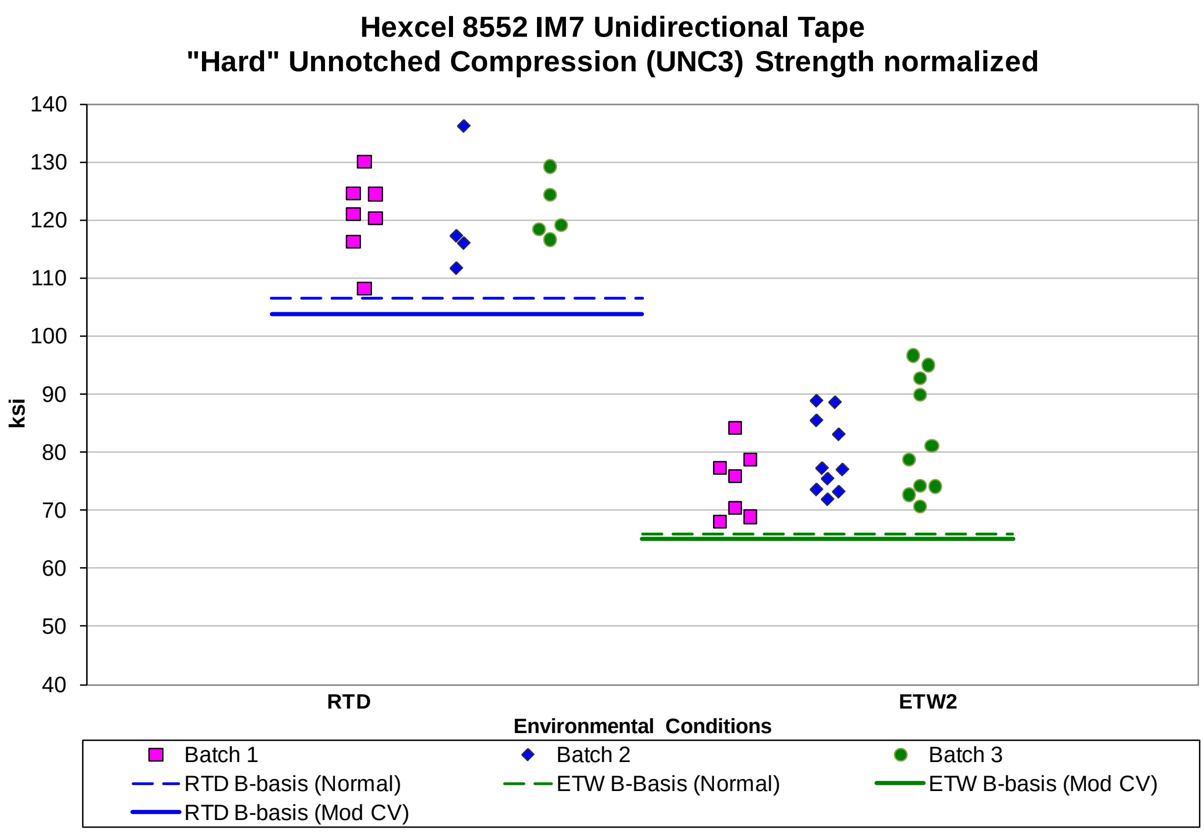

Figure 5-6: Batch plot for UNC3 strength normalized

Unnotched Compression (UNC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	120.84	79.42	121.06	78.79
Stdev	7.08	8.19	6.70	7.87
CV	5.86	10.31	5.53	9.99
Mod CV	6.93	10.31	6.77	9.99
Min	108.20	68.05	111.74	67.56
Max	136.09	96.63	137.70	94.50
No. Batches	3	3	3	3
No. Spec.	16	27	16	27
Basis Values and/or Estimates				
B-basis Value	106.66	65.88	107.51	65.85
A-estimate	97.25	56.33	98.51	56.71
Method	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	105.84	65.09	106.55	64.94
A-estimate	95.87	54.98	96.91	55.15
Method	pooled	pooled	pooled	pooled

Table 5-11: Statistics and Basis Values for UNC3 Strength data

Unnotched Compression (UNC3) Modulus Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	11.90	11.77	11.93	11.66
Stdev	0.52	0.28	0.40	0.24
CV	4.35	2.35	3.38	2.09
Mod CV	6.18	6.00	6.00	6.00
Min	10.32	11.24	11.20	11.22
Max	12.58	12.22	12.74	11.96
No. Batches	3	3	3	3
No. Spec.	17	15	17	15

Table 5-12: Statistics from UNC3 Modulus data

5.3 Open Hole Tension Properties

5.3.1 Quasi Isotropic Open Hole Tension Properties (OHT1)

The data for the CTD condition (both normalized and as measured) and the RTD condition (as measured only) fail the ADK test but pass with the modified CV transformation. Since there are only three batches available, this means that the basis values computed using ANOVA method (which must be used when the data does not pass the ADK test) will be estimates only. However, modified CV basis values can be computed. The RTD and ETW normalized data can be pooled and all three environments can be pooled for the modified CV basis value computations. There were no outliers.

Statistics, basis values and estimates are given for OHT1 strength data in Table 5-13. The normalized data, B-basis values and B-estimates are shown graphically in Figure 5-7.

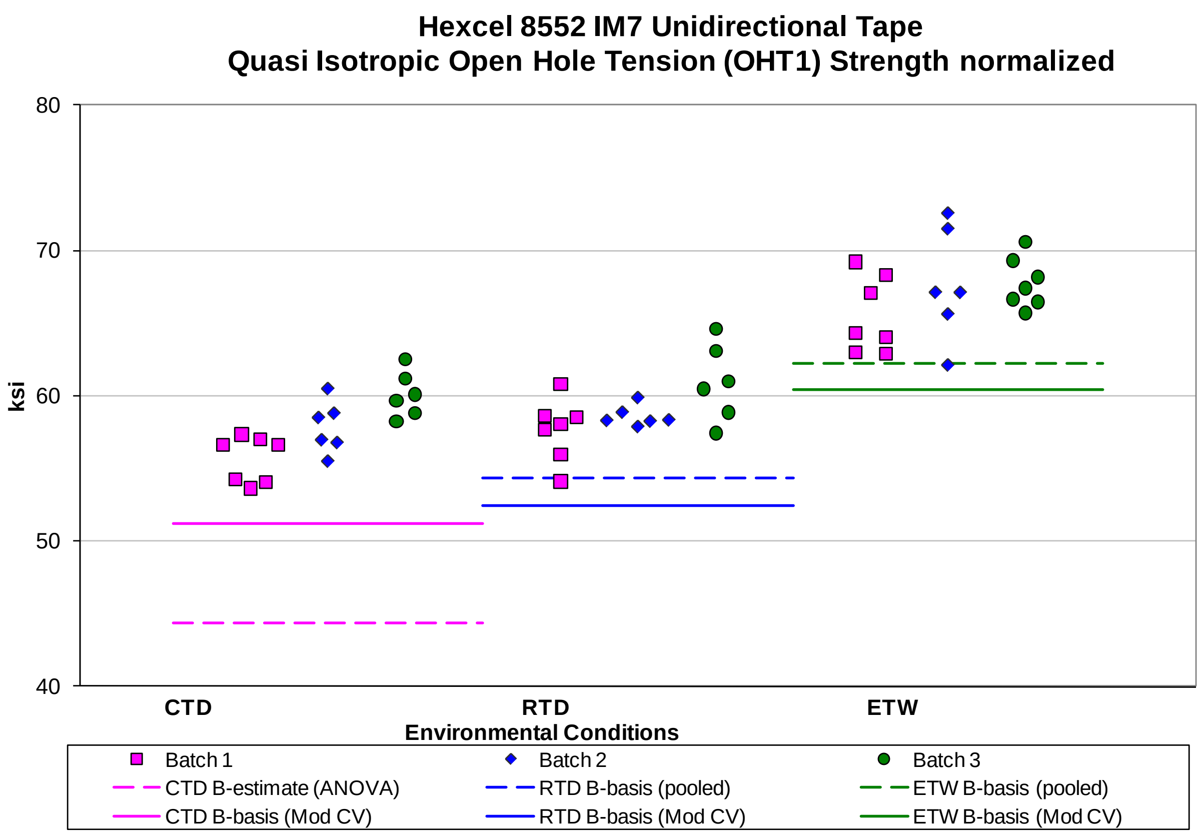

Figure 5-7: Batch Plot for OHT1 strength normalized

Open Hole Tension (OHT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	57.75	59.00	66.97	57.28	58.70	66.48
Stdev	2.43	2.35	2.85	2.26	2.39	2.85
CV	4.21	3.98	4.26	3.95	4.07	4.29
Mod CV	6.11	6.00	6.13	6.00	6.04	6.15
Min	53.64	54.12	62.15	53.27	53.32	62.21
Max	62.52	64.61	72.59	61.67	64.44	73.23
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	20	19	19	20
Basis Values and/or Estimates						
B-basis Value		54.29	62.28			60.98
B-estimate	44.35			44.41	47.06	
A-estimate	34.78	51.08	59.06	35.24	38.76	57.07
Method	ANOVA	pooled	pooled	ANOVA	ANOVA	Normal
Mod CV Basis Values and/or Estimates						
B-basis Value	51.20	52.44	60.44	50.78	52.20	60.01
A-estimate	46.80	48.05	56.04	46.42	47.84	55.65
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 5-13: Statistics and Basis Values for OHT1 Strength data

5.3.2 "Soft" Open Hole Tension Properties (OHT2)

The data for the CTD condition (both normalized and as measured) and the ETW condition (as measured only) fail the ADK test but pass with the modified CV transformation. Since there are only three batches available, this means that the basis values computed using ANOVA method (which must be used when the data does not pass the ADK test) will be estimates only. However, modified CV basis values can be computed.

The RTD and ETW normalized data can be pooled, but the CTD data cannot be included due to the failure of Levene's test when it is included. The as measured data cannot be pooled due to the failure of Levene's test.

There were two outliers. They were both in the normalized data only and both were on the low side. One outlier was in batch one in the RTD condition. The other outlier was in batch 3 of the CTD condition. Both were outliers before, but not after, pooling the three batches together. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for OHT2 strength data in Table 5-14. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 5-8.

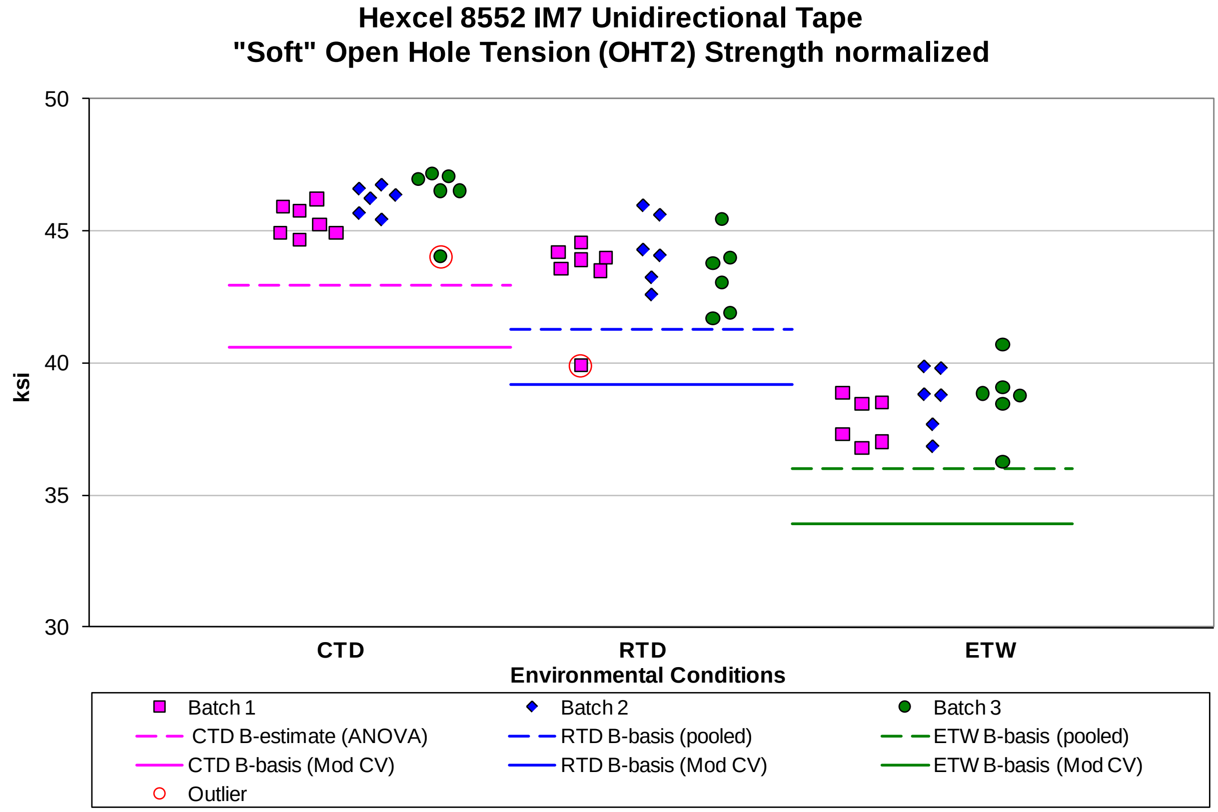

Figure 5-8: Batch Plot for OHT2 strength normalized

Open Hole Tension (OHT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	45.95	43.65	38.39	45.63	43.65	38.34
Stdev	0.88	1.43	1.19	0.99	1.21	1.19
CV	1.92	3.28	3.10	2.16	2.77	3.11
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	44.04	39.91	36.27	43.88	41.05	36.18
Max	47.20	45.96	40.71	47.02	45.86	40.04
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	18	19	19	18
Basis Values and/or Estimates						
B-basis Value		41.27	35.99		41.29	
B-estimate	42.97			39.87		33.07
A-estimate	40.84	39.63	34.36	35.76	39.62	29.32
Method	ANOVA	pooled	pooled	ANOVA	Normal	ANOVA
Mod CV Basis Values and/or Estimates						
B-basis Value	40.58	39.19	33.90	40.29	39.18	33.85
A-estimate	36.77	36.13	30.85	36.51	36.13	30.80
Method	normal	pooled	pooled	normal	pooled	pooled

Table 5-14: Statistics and Basis Values for OHT2 Strength data

5.3.3 "Hard" Open Hole Tension Properties (OHT3)

The RTD and ETW normalized data can be pooled. The data for the CTD condition (both normalized and as measured) and for the RTD and ETW conditions (as measured only) fail the ADK test, which means that the ANOVA analysis method is required. Only the as measured ETW condition data passes the ADK test with the modified CV transformation, so modified CV basis values are provided for that dataset.

Estimates computed using the modified CV method are provided for the data from the CTD condition (both normalized and as measured) and for the as measured data from the RTD condition. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method.

There were no outliers. Statistics, basis values and estimates are given for OHT3 strength data in Table 5-15. The normalized data, B-estimates and B-basis values are shown graphically in Figure 5-9.

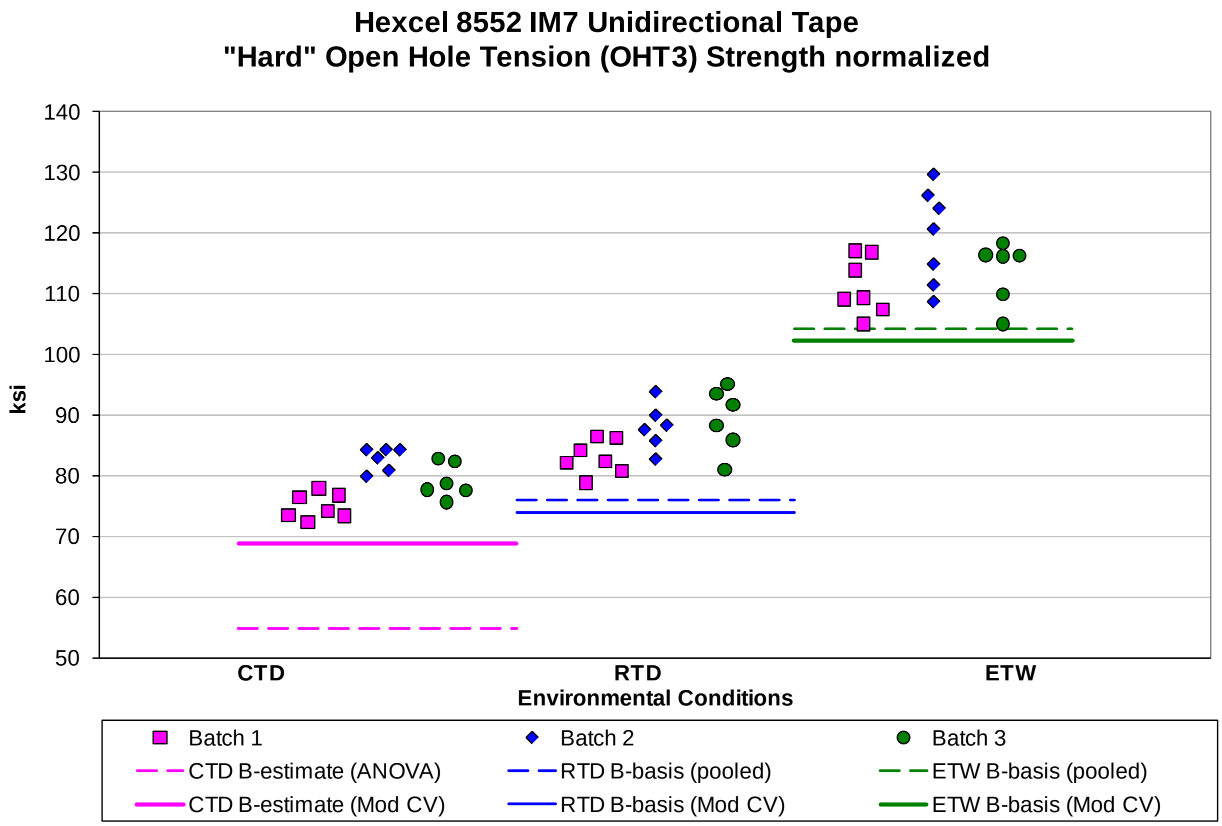

Figure 5-9: Batch Plot for OHT3 strength normalized

Open Hole Tension (OHT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	78.75	86.59	114.86	77.97	86.63	113.87
Stdev	3.96	4.72	6.83	4.68	4.96	7.25
CV	5.03	5.46	5.95	6.01	5.72	6.37
Mod CV	6.52	6.73	6.97	7.00	6.86	7.18
Min	72.41	78.90	105.04	70.75	79.07	102.24
Max	84.29	95.17	129.75	84.38	94.49	128.78
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	20	19	19	20
Basis Values and/or Estimates						
B-basis Value		75.97	104.29			
B-estimate	54.89			47.70	57.48	82.20
A-estimate	37.87	68.73	97.03	26.09	36.68	59.61
Method	ANOVA	pooled	pooled	ANOVA	ANOVA	ANOVA
Mod CV Basis Values and/or Estimates						
B-basis Value		73.93	102.26			98.11
B-estimate	68.75			67.32	75.04	
A-estimate	61.66	65.30	93.61	59.78	66.83	86.91
Method	normal	pooled	pooled	normal	normal	normal

Table 5-15: Statistics and Basis Values for OHT3 Strength data

5.4 Filled Hole Tension

5.4.1 Quasi Isotropic Filled Hole Tension (FHT1)

The normalized data for the CTD and ETW conditions fail the ADK test but pass with the modified CV transformation. Since there are only three batches available, this means that the basis values computed using ANOVA method (which must be used when the data does not pass the ADK test) will be estimates only. However, modified CV basis values can be computed and the normalized data for all three environments can be pooled for the modified CV computations.

The as measured data failed the ADK test for all three conditions. The RTD and ETW data pass the ADK test with the modified CV transformation but the CTD data does not. The RTD and ETW data can be pooled to compute the modified CV basis values, but no modified CV basis values can be provided for the as measured CTD data.

There was one outlier. It was on the high side of batch two of the normalized RTD data. It was an outlier only within batch two, not after pooling the three batches together. It was retained for this analysis.

Statistics, estimates and basis values are given for FHT1 strength data in Table 5-16. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 5-10 .

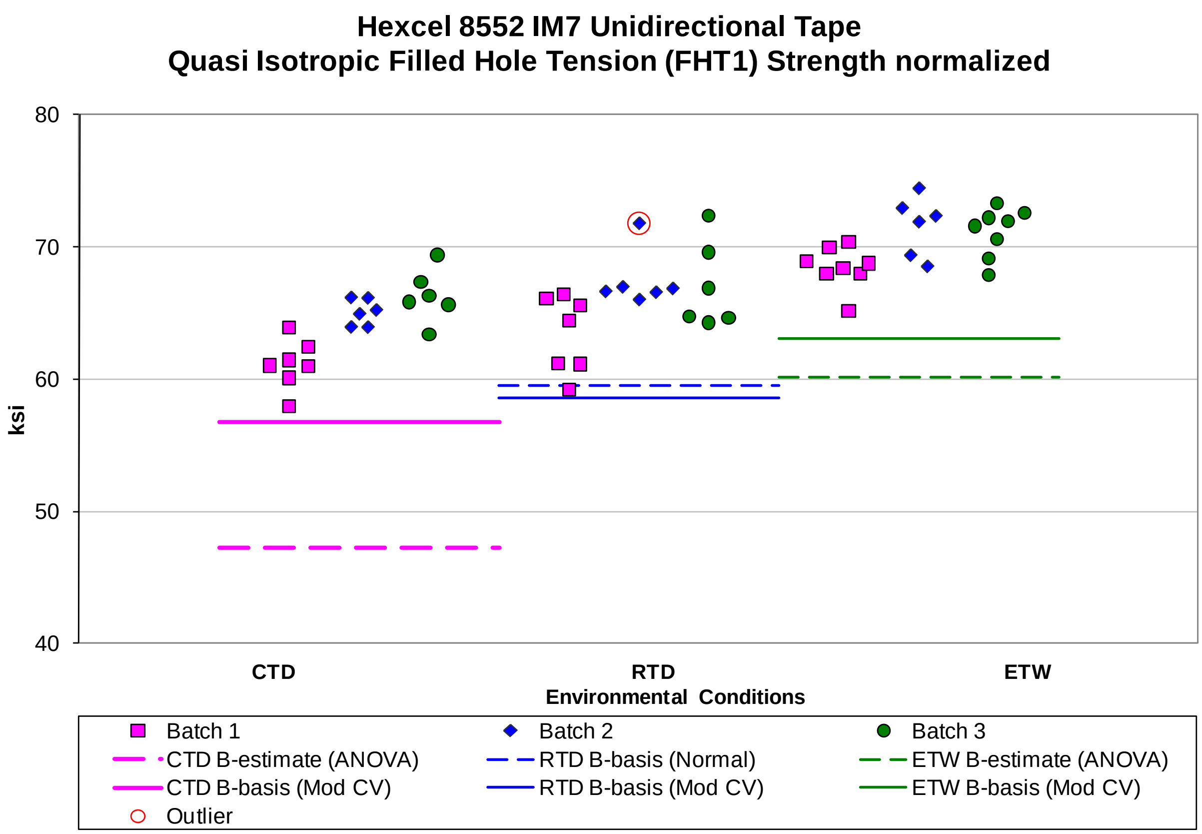

Figure 5-10: Batch plot for FHT1 strength normalized

Filled-Hole Tension (FHT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	64.02	65.87	70.29	63.52	65.95	69.52
Stdev	2.81	3.26	2.28	3.08	3.57	2.71
CV	4.39	4.95	3.24	4.86	5.41	3.90
Mod CV	6.19	6.47	6.00	6.43	6.71	6.00
Min	58.00	59.20	65.17	57.30	59.60	64.29
Max	69.40	72.34	74.40	68.01	72.19	74.58
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	22	19	19	22
Basis Values and/or Estimates						
B-basis Value		59.52				
B-estimate	47.28		60.13	43.77	46.71	57.05
A-estimate	35.33	55.01	52.87	29.68	32.97	48.15
Method	ANOVA	Normal	ANOVA	ANOVA	ANOVA	ANOVA
Mod CV Basis Values and/or Estimates						
B-basis Value	56.75	58.60	63.11	NA	58.26	61.93
A-estimate	51.89	53.73	58.23	NA	53.03	56.67
Method	pooled	pooled	pooled	NA	pooled	pooled

Table 5-16: Statistics and Basis Values for FHT1 Strength data

5.4.2 “Soft”Filled Hole Tension (FHT2)

The pooled data, both normalized and as measured, fails Levene’s test, so pooling is not appropriate. There was one outlier. It was on the low side of batch three in the ETW environment. It was an outlier for both the normalized and as measured data. It was an outlier before, but not after, pooling the three batches together. It was retained for this analysis.

Statistics and basis values are given for FHT2 strength data in Table 5-17. The normalized data and the B-basis values are shown graphically in Figure 5-11.

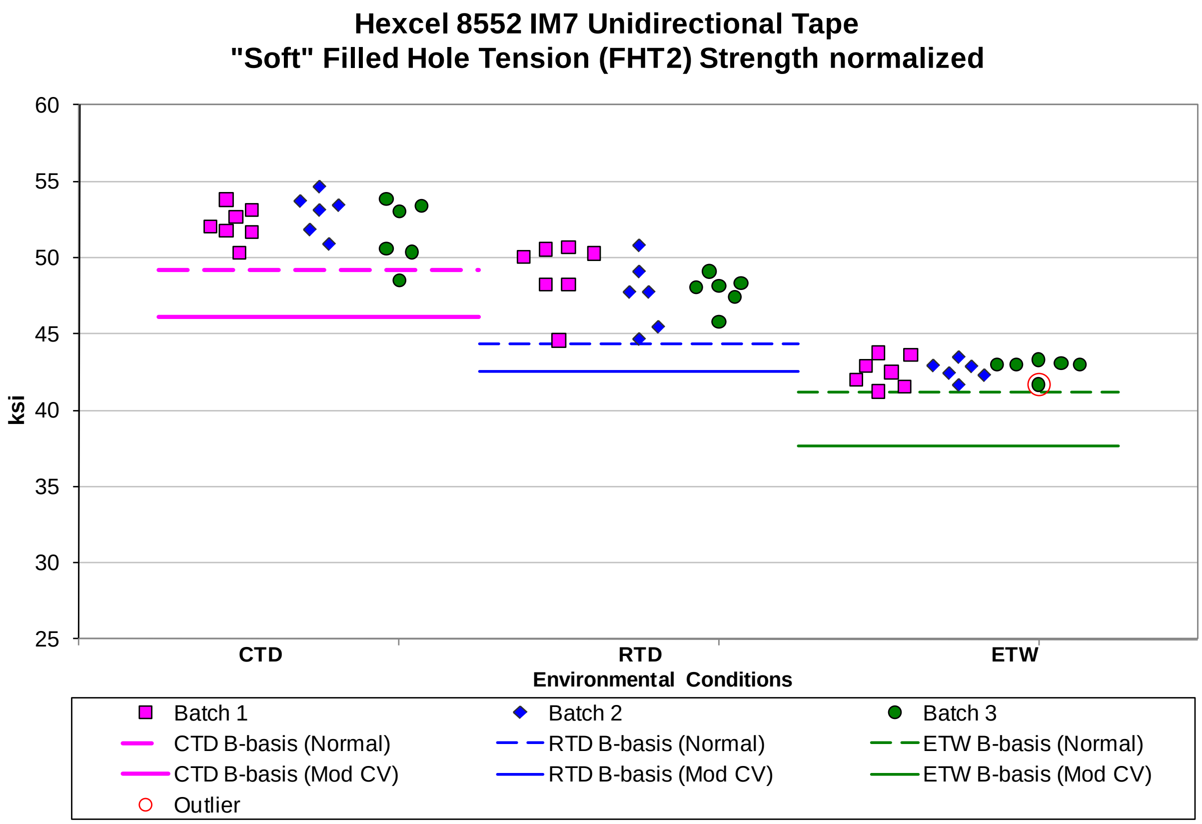

Figure 5-11: Batch plot for FHT2 strength normalized

Filled-Hole Tension (FHT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	52.25	48.15	42.63	52.05	48.08	42.30
Stdev	1.57	1.94	0.74	1.32	1.60	0.83
CV	3.00	4.03	1.73	2.53	3.34	1.97
Mod CV	6.00	6.02	6.00	6.00	6.00	6.00
Min	48.54	44.59	41.22	50.23	44.67	40.75
Max	54.64	50.79	43.75	54.73	50.24	43.54
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	19	19	19	19
Basis Values and/or Estimates						
B-basis Value	49.20	44.37	41.20	49.48	44.95	40.68
A-estimate	47.03	41.68	40.17	47.66	42.73	39.53
Method	Normal	Normal	Normal	Normal	Normal	Normal
Mod CV Basis Values and/or Estimates						
B-basis Value	46.14	42.51	37.65	45.96	42.46	37.35
A-estimate	41.81	38.50	34.11	41.64	38.47	33.85
Method	normal	normal	normal	normal	normal	normal

Table 5-17: Statistics and Basis Values for FHT2 Strength data

5.4.3 "Hard" Filled Hole Tension (FHT3)

Both the normalized and the as measured data from the CTD and RTD conditions fail the ADK test which means that the ANOVA analysis method is required. Since there are only three batches available, this means that the basis values computed using ANOVA method (which must be used when the data does not pass the ADK test) will be estimates only. Only the normalized CTD data passed the ADK test with the modified CV transformation. The as measured CTD data, the as measured RTD data, and the normalized RTD data did not pass the ADK test. Pooling across environments is not acceptable since the RTD data could not be included.

Estimates computed using the modified CV method are provided for the as measured data from the CTD condition and for both normalized and as measured data from the RTD condition. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method.

There was one outlier. It was on the low side of batch two of the normalized CTD data. It was an outlier only within batch two, not after pooling the three batches together. It was retained for this analysis.

Statistics, estimates and basis values are given for FHT3 strength data in Table 5-18. The normalized data, B-estimates and B-basis values are shown graphically in Figure 5-12.

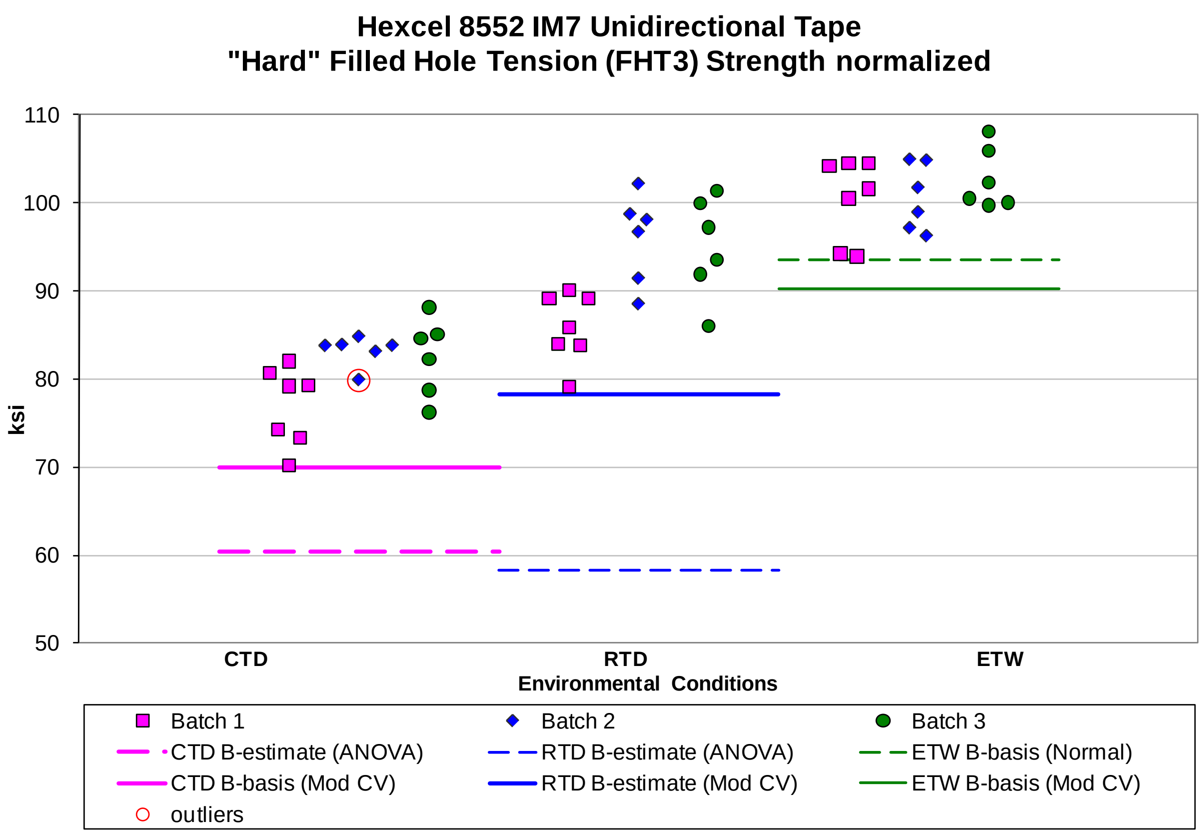

Figure 5-12: Batch plot for FHT3 strength normalized

Filled-Hole Tension (FHT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	80.70	91.95	101.26	80.53	91.93	100.77
Stdev	4.59	6.62	3.95	4.94	7.27	3.85
CV	5.69	7.20	3.90	6.13	7.91	3.82
Mod CV	6.85	7.60	6.00	7.06	7.95	6.00
Min	70.25	79.15	93.92	71.22	77.08	92.01
Max	88.15	102.16	108.11	88.23	102.61	107.29
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	19	19	19	19
Basis Values and/or Estimates						
B-basis Value			93.56			93.26
B-estimate	60.44	58.26		52.84	50.82	
A-estimate	45.99	34.23	88.09	33.07	21.49	87.93
Method	ANOVA	ANOVA	Normal	ANOVA	ANOVA	Normal
Mod CV Basis Values and/or Estimates						
B-basis Value	69.94		89.42			88.98
B-estimate		78.33		69.44	77.68	
A-estimate	62.30	68.67	81.02	61.58	67.58	80.63
Method	normal	normal	normal	normal	normal	normal

Table 5-18: Statistics and Basis Values for FHT3 Strength data

5.5 Open Hole Compression

5.5.1 Quasi Isotropic Open Hole Compression 1 (OHC1)

The normalized RTD condition data failed the normality test, but the pooled data set did not, so pooling was acceptable for both the normalized and as measured data. There were two outliers. Both outliers were in the RTD normalized data only. One outlier was on the low side of batch one; it was an outlier before, but not after, pooling the three batches. The other outlier was on the low side of batch three; it was an outlier both before and after pooling the three batches. Both outliers were retained for this analysis.

Statistics, estimates and basis values are given for OHC1 strength data in Table 5-19. The normalized data and the B-basis values are shown graphically in Figure 5-13.

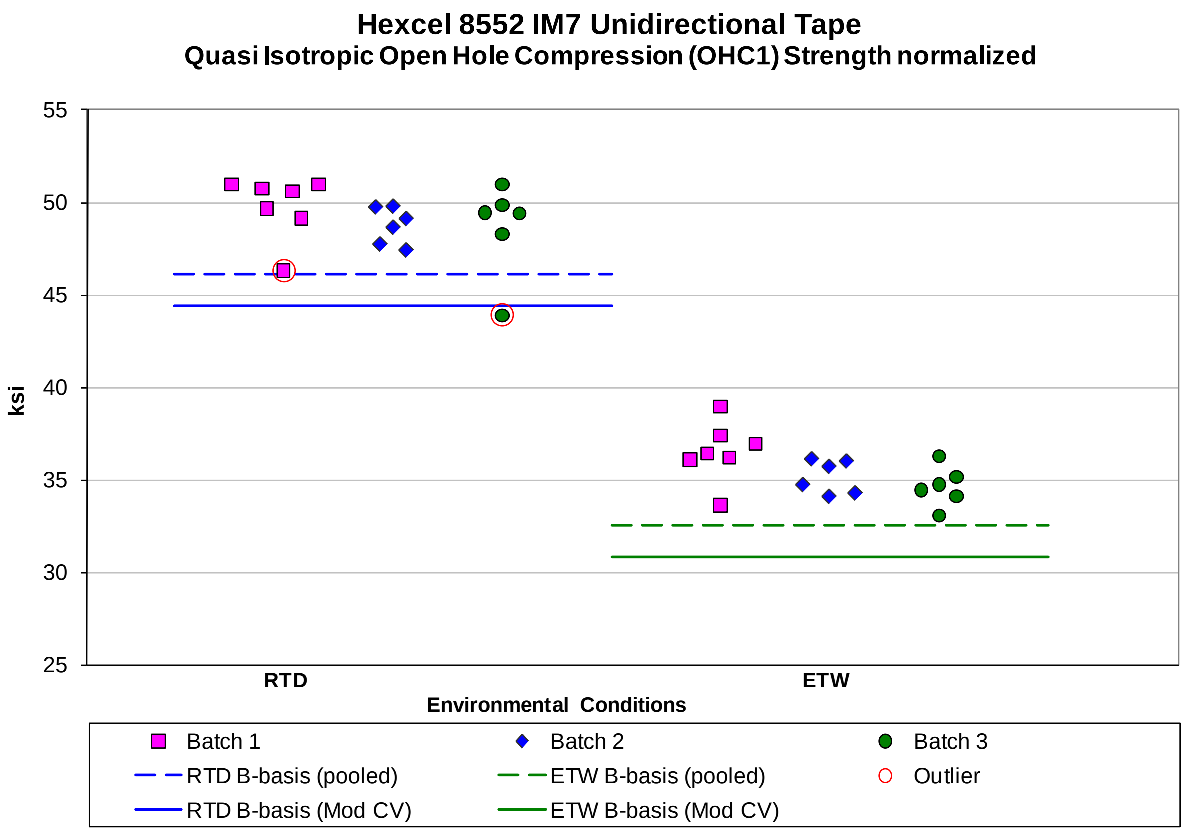

Figure 5-13: Batch plot for OHC1 strength normalized

Open Hole Compression (OHC1) Strength Basis Values and				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	49.08	35.52	48.89	35.29
Stdev	1.79	1.45	1.45	1.15
CV	3.65	4.07	2.96	3.25
Mod CV	6.00	6.03	6.00	6.00
Min	43.91	33.08	45.15	33.59
Max	50.99	38.96	51.28	37.50
No. Batches	3	3	3	3
No. Spec.	19	19	19	19
Basis Values and/or Estimates				
B-basis Value	46.15	32.58	46.54	32.93
A-estimate	44.14	30.57	44.93	31.32
Method	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	44.44	30.87	44.28	30.67
A-estimate	41.26	27.70	41.13	27.52
Method	pooled	pooled	pooled	pooled

Table 5-19: Statistics and Basis Values for OHC1 Strength data

5.5.2 "Soft" Open Hole Compression (OHC2)

There were no diagnostic test failures. Both the as measured and normalized data could be pooled across the two environments. There was one outlier. It was on the low side of batch three in the ETW environment. It was an outlier both before and after pooling the three batches in the as measured dataset, but only before pooling the three batches in the normalized dataset.

Statistics, estimates and basis values are given for OHC2 strength data in Table 5-20. The normalized data and the B-basis values are shown graphically in Figure 5-14.

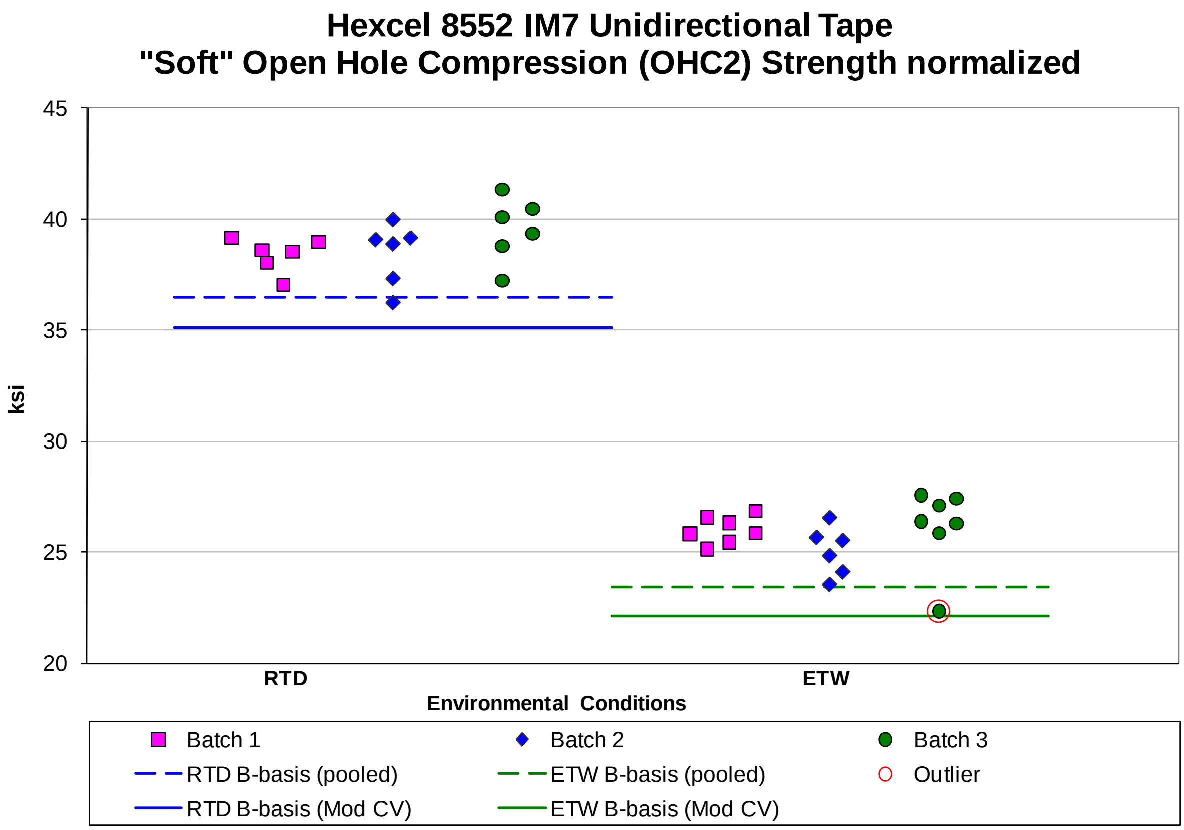

Figure 5-14: Batch plot for OHC2 strength normalized

Open-Hole Compression (OHC2) Strength Basis Values and				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	38.80	25.76	38.40	25.57
Stdev	1.28	1.29	1.31	1.12
CV	3.29	5.02	3.41	4.40
Mod CV	6.00	6.51	6.00	6.20
Min	36.25	22.36	35.93	22.24
Max	41.33	27.57	40.85	27.56
No. Batches	3	3	3	3
No. Spec.	18	20	18	20
Basis Values and/or Estimates				
B-basis Value	36.47	23.46	36.20	23.39
A-estimate	34.89	21.87	34.70	21.88
Method	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	35.15	22.15	34.85	22.05
A-estimate	32.68	19.67	32.45	19.64
Method	pooled	pooled	pooled	pooled

Table 5-20: Statistics and Basis Values for OHC2 Strength data

5.5.3 "Hard" Open Hole Compression (OHC3)

There were no diagnostic test failures. Both the as measured and normalized data could be pooled across the two environments. There was one outlier. It was on the high side of batch two in the normalized RTD data. It was an outlier before, but not after, pooling the three batches. It was retained for this analysis.

Statistics, estimates and basis values are given for OHC3 strength data in Table 5-21. The normalized data and the B-basis values are shown graphically in Figure 5-15.

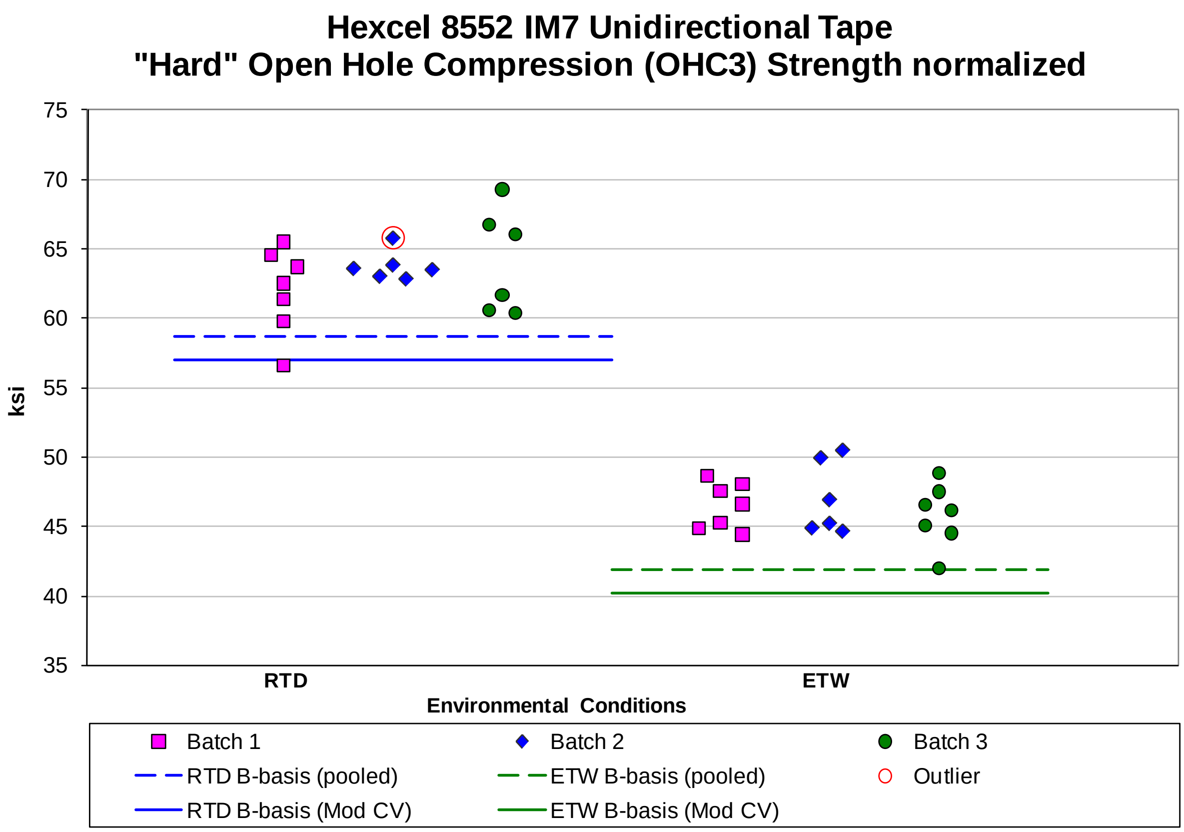

Figure 5-15: Batch plot for OHC3 strength normalized

Open-Hole Compression (OHC3) Strength Basis Values				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	63.24	46.42	63.36	46.22
Stdev	2.87	2.11	2.71	2.20
CV	4.54	4.55	4.28	4.76
Mod CV	6.27	6.27	6.14	6.38
Min	56.63	42.01	59.06	42.66
Max	69.28	50.50	69.24	51.35
No. Batches	3	3	3	3
No. Spec.	19	20	19	20
Basis Values and/or Estimates				
B-basis Value	58.72	41.92	58.93	41.80
A-estimate	55.64	38.83	55.90	38.77
Method	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	57.00	40.21	57.17	40.05
A-estimate	52.75	35.95	52.95	35.82
Method	pooled	pooled	pooled	pooled

Table 5-21: Statistics and Basis Values for OHC3 Strength data

5.6 Filled Hole Compression

5.6.1 Quasi Isotropic Filled Hole Compression (FHC1)

Both the normalized and the as measured data from the RTD condition fails the ADK test. Since there are only three batches available, this means that the basis values computed using ANOVA method (which must be used when the data does not pass the ADK test) will be estimates only. The normalized RTD data pass the ADK test with the modified CV transformation, so modified CV basis values are provided for that dataset. However, the as measured data did not pass the ADK test with the modified CV transform, so modified CV basis values are not provided for the as measured data. Pooling the normalized data across environments was acceptable.

There was one outlier. It was on the high side of batch three of the normalized RTD data. It was an outlier only within batch three, not after pooling the three batches together. It was retained for this analysis.

Statistics, estimates and basis values are given for FHC1 strength data in Table 5-22. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 5-16.

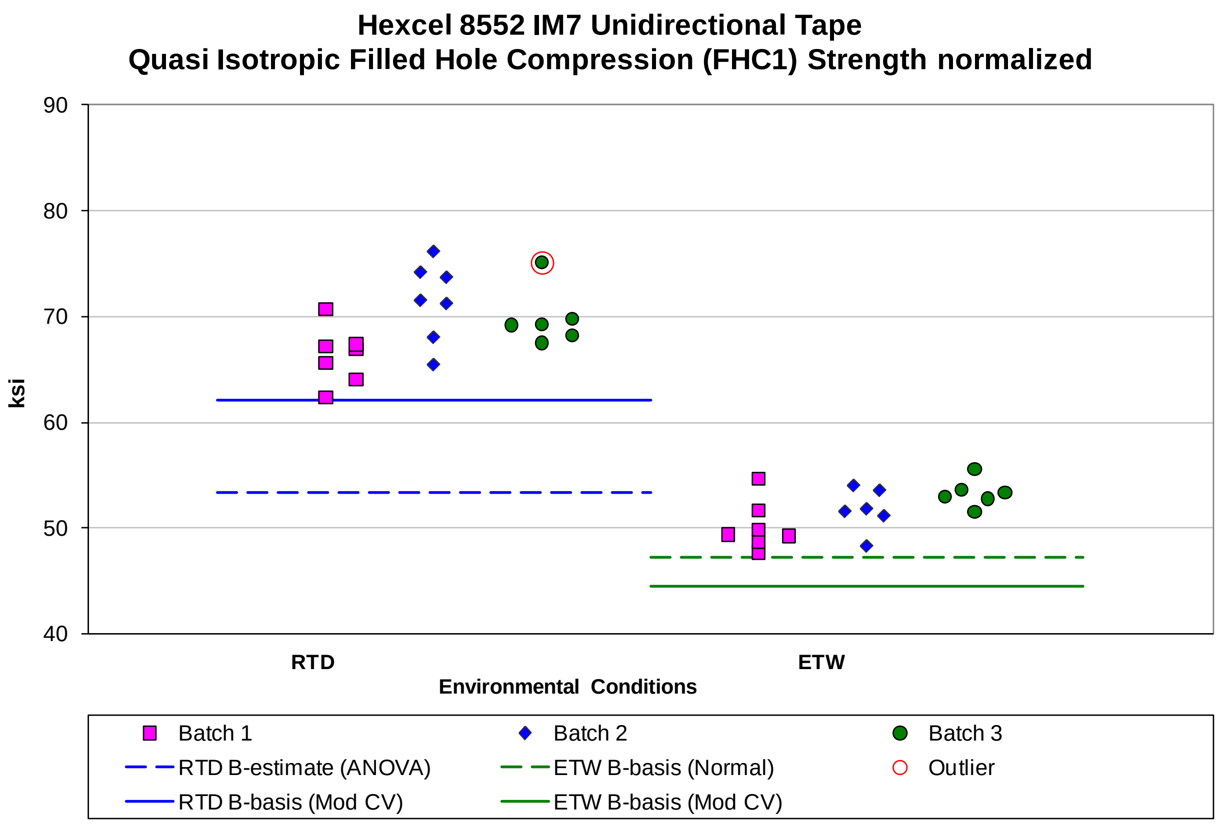

Figure 5-16: Batch plot for FHC1 strength normalized

Filled-Hole Compression (FHC1) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	69.19	51.68	69.30	51.61
Stdev	3.69	2.28	3.85	1.99
CV	5.34	4.41	5.56	3.85
Mod CV	6.67	6.21	6.78	6.00
Min	62.34	47.70	62.44	47.93
Max	76.17	55.60	76.20	54.57
No. Batches	3	3	3	3
No. Spec.	20	19	20	19
Basis Values and/or Estimates				
B-basis Value		47.24		
B-estimate	53.43		48.57	41.22
A-estimate	42.19	44.08	33.77	33.81
Method	ANOVA	Normal	ANOVA	ANOVA
Mod CV Basis Values and/or Estimates				
B-basis Value	62.04	44.49	NA	45.58
A-estimate	57.13	39.59	NA	41.30
Method	pooled	pooled	NA	normal

Table 5-22: Statistics and Basis Values for FHC1 Strength data

5.6.2 "Soft" Filled Hole Compression (FHC2)

Both the normalized and the as measured data from the ETW condition failed the ADK test. Since there are only three batches available, this means that the basis values computed using ANOVA method (which must be used when the data does not pass the ADK test) will be estimates only. Both the normalized and the as measured ETW data pass the ADK test with the modified CV transformation, so modified CV basis values are provided. There were no outliers.

Statistics, estimates and basis values are given for FHC2 strength data in Table 5-23. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 5-17.

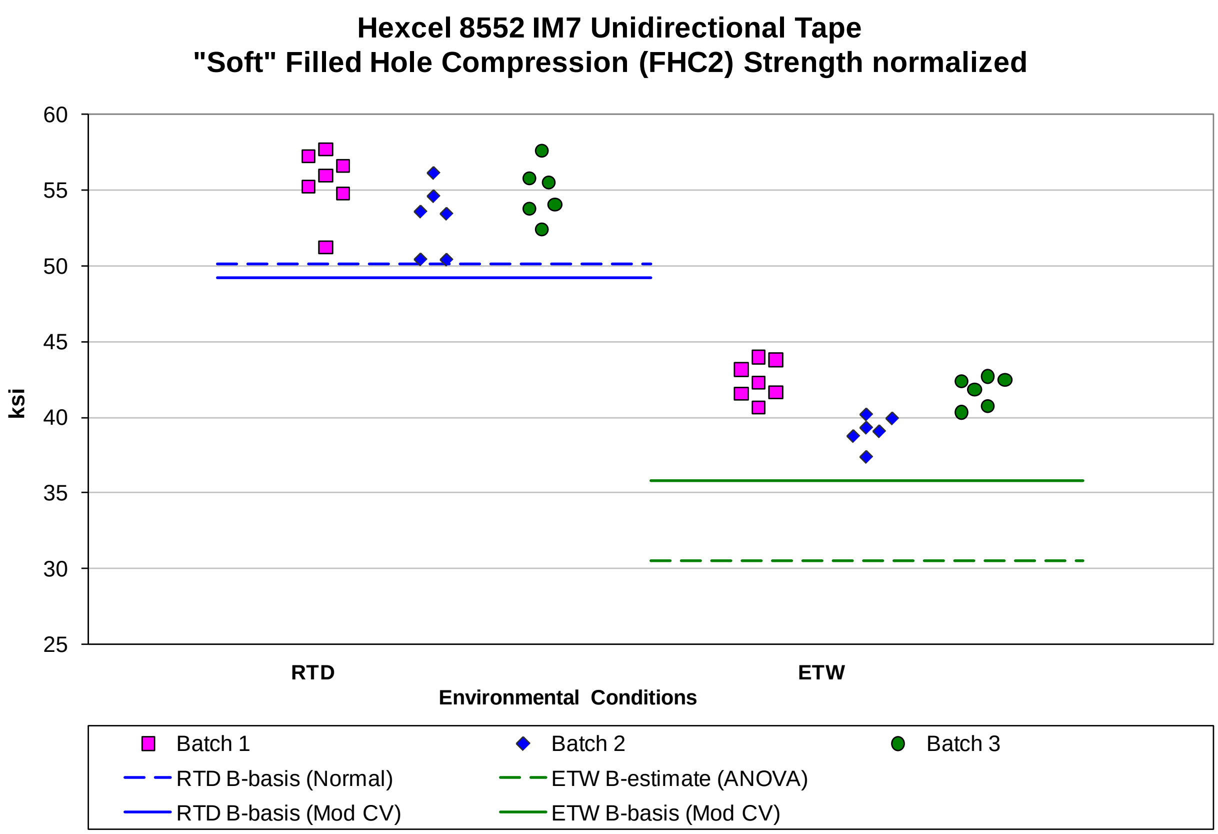

Figure 5-17: Batch plot for FHC2 strength normalized

Filled-Hole Compression (FHC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	54.57	41.17	54.25	40.86
Stdev	2.25	1.81	1.72	1.50
CV	4.13	4.39	3.17	3.66
Mod CV	6.06	6.20	6.00	6.00
Min	50.41	37.36	50.57	37.86
Max	57.71	43.99	57.54	43.20
No. Batches	3	3	3	3
No. Spec.	19	19	19	19
Basis Values and/or Estimates				
B-basis Value	50.18		50.90	
B-estimate		30.49		32.22
A-estimate	47.06	22.86	48.53	26.05
Method	Normal	ANOVA	Normal	ANOVA
Mod CV Basis Values and/or Estimates				
B-basis Value	49.24	35.84	49.05	35.66
A-estimate	45.60	32.20	45.50	32.11
Method	pooled	pooled	pooled	pooled

Table 5-23: Statistics and Basis Values for FHC2 Strength data

5.6.3 "Hard" Filled Hole Compression (FHC3)

The FHC3 data had no diagnostic test failures. Pooling the RTD and ETW data was acceptable for both the as measured and the normalized data. There was one outlier. In was on the low side of batch two in the RTD environment. It was an outlier before, but not after, pooling the three batches together. It was retained for this analysis.

Statistics, estimates and basis values are given for FHC3 strength data in Table 5-24. The normalized data and the B-basis values are shown graphically in Figure 5-18.

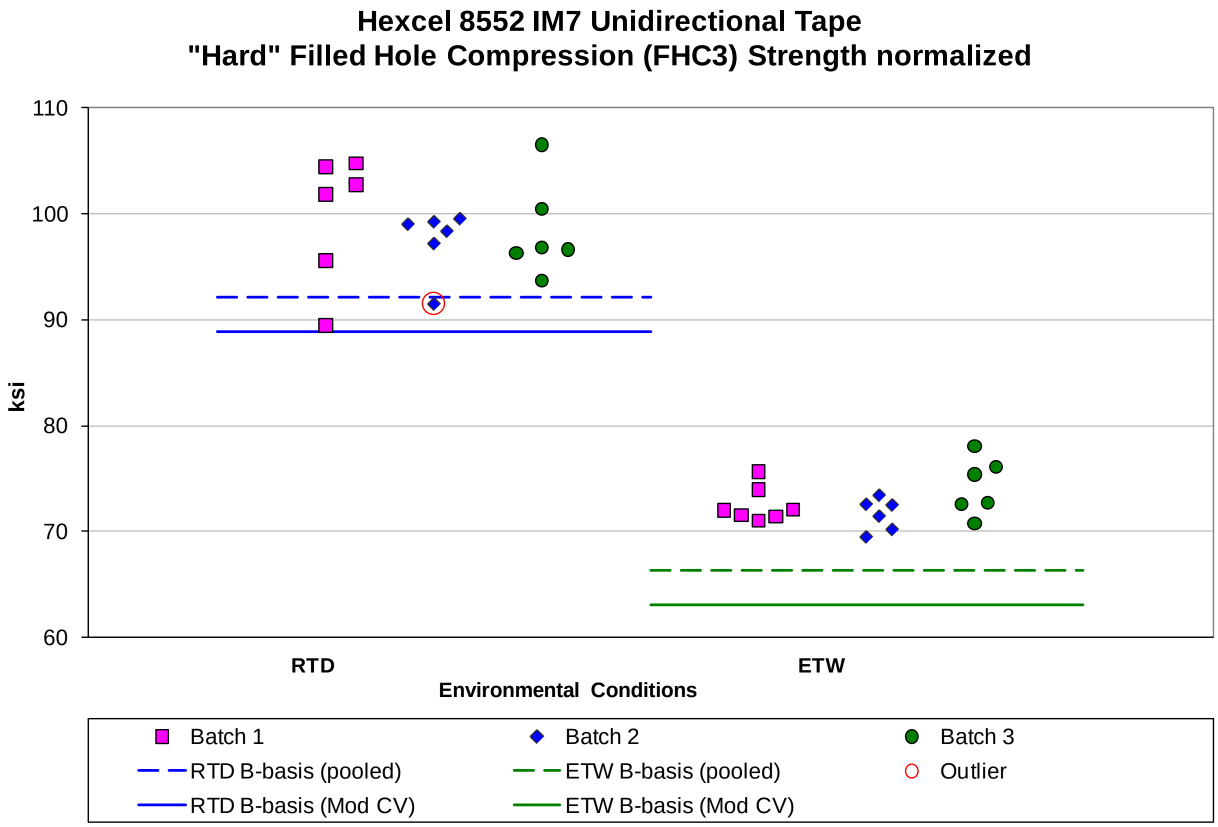

Figure 5-18: Batch plot for FHC3 strength normalized

Filled-Hole Compression (FHC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	98.57	72.79	98.16	72.20
Stdev	4.54	2.21	4.18	2.26
CV	4.61	3.03	4.25	3.14
Mod CV	6.30	6.00	6.13	6.00
Min	89.45	69.47	87.81	68.99
Max	106.54	78.09	104.25	77.22
No. Batches	3	3	3	3
No. Spec.	18	19	18	19
Basis Values and/or Estimates				
B-basis Value	92.14	66.39	92.10	66.17
A-estimate	87.77	62.01	87.99	62.05
Method	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	88.86	63.13	88.68	62.76
A-estimate	82.26	56.52	82.24	56.31
Method	pooled	pooled	pooled	pooled

Table 5-24: Statistics and Basis Values for FHC3 Strength data

5.7 Laminate Short Beam Strength (LSBS) Data

The Laminate Short Beam Strength data is not normalized because it is not a fiber dominated property. The data from the RTD condition did not pass the normality test, nor did it fit the lognormal or Weibull distributions, so the non-parametric method was the best choice. This means that modified CV basis values cannot be provided for this condition. Pooling the RTD and ETW data was not appropriate due to non-normality of the pooled dataset.

There were three outliers. One outlier was in the ETW condition. It was on the high side of batch 1. It was an outlier only after pooling the three batches together. There were two outliers in the RTD condition. One was on the low side of batch two; it was an outlier before, but not after, pooling the three batches. The other outlier in the RTD condition was on the low side of batch three. It was an outlier both before and after pooling the data from the three batches together. All three outliers were retained for this analysis.

Statistics, estimates and basis values are given for LSBS data in Table 5-25. The data and the B-basis values are shown graphically in Figure 5-19.

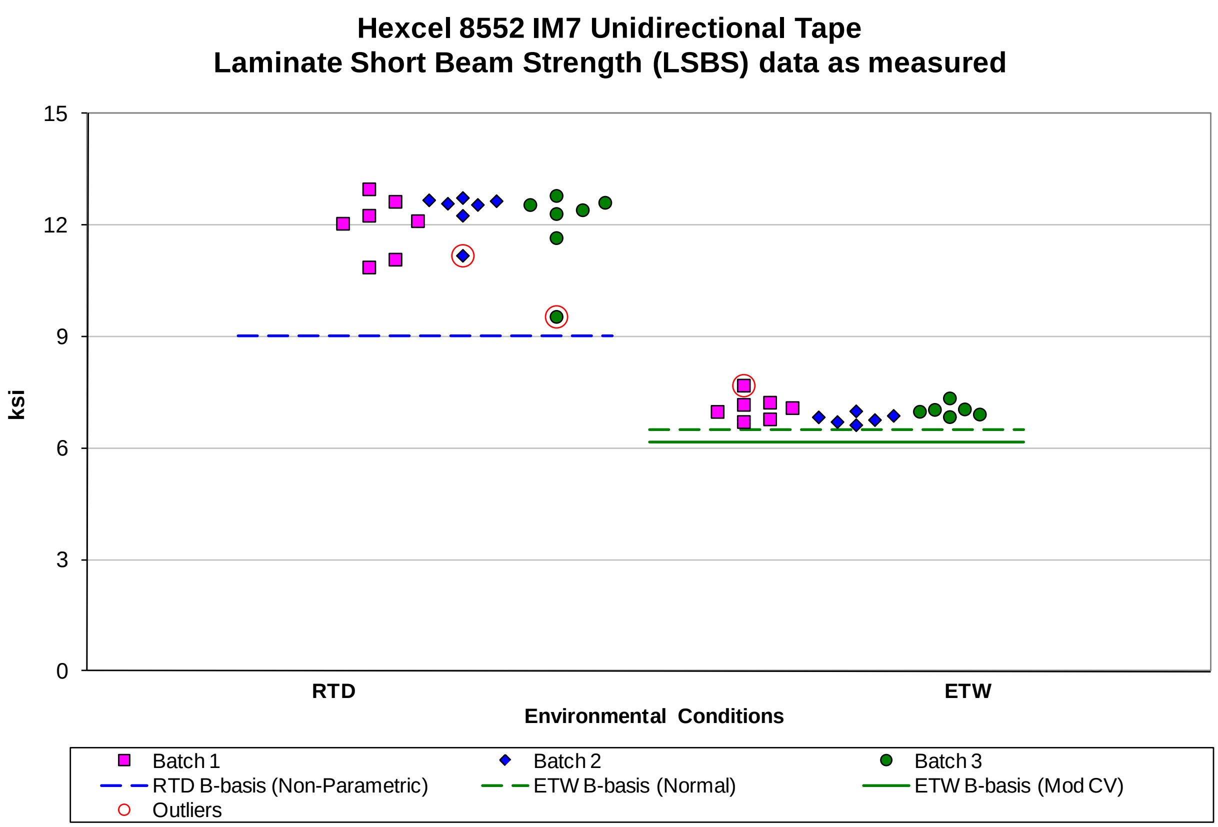

Figure 5-19: Batch plot for LSBS as measured

Laminate Short Beam Strength Properties (LSBS) Basis Values and Statistics		
	As measured	
Env	RTD	ETW
Mean	12.13	6.99
Stdev	0.83	0.25
CV	6.85	3.65
Mod CV	7.43	6.00
Min	9.55	6.63
Max	12.98	7.70
No. Batches	3	3
No. Spec.	21	19
Basis Values and/or Estimates		
B-basis Value	9.03	6.49
A-estimate	6.38	6.14
Method	Non-parametric	Normal
Mod CV Basis Values and Estimates		
B-basis Value	NA	6.17
A-estimate	NA	5.59
Method	NA	normal

Table 5-25: Statistics and Basis Values for LSBS data

5.8 Single Shear Bearing

5.8.1 Quasi Isotropic Single Shear Bearing (SSB1)

The as measured data from the RTD condition failed the ADK test. Since there are only three batches available, this means that the basis values computed using ANOVA method (which must be used when the data does not pass the ADK test) will be estimates only. However, the as measured RTD data did pass the ADK test with the modified CV transformation, so modified CV basis values are provided. The data from the ETW condition (both normalized and as measured) did not pass the normality test, nor did it fit the lognormal or Weibull distributions, so the non-parametric method was the best choice. This means that modified CV basis values cannot be provided for this condition. Pooling the RTD and ETW data was not appropriate due to non-normality of the pooled dataset. There were no outliers.

Statistics, estimates 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.

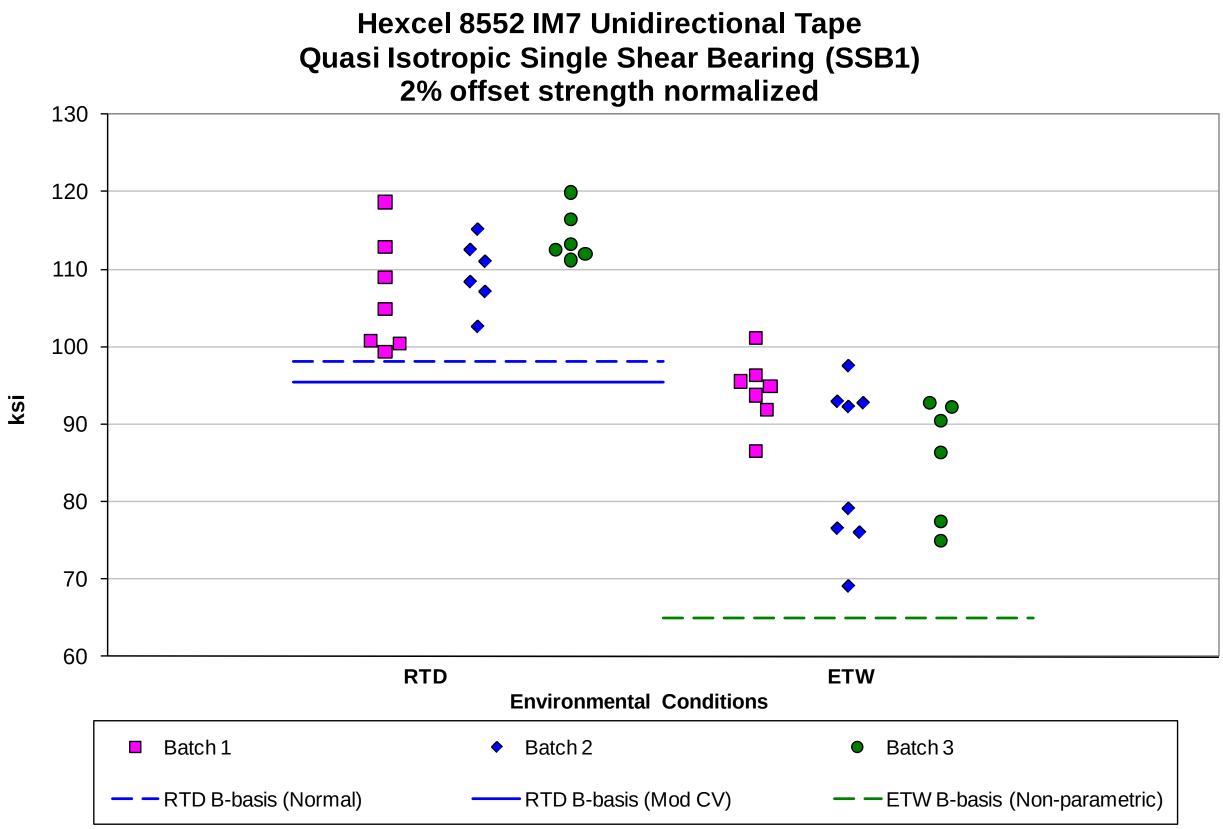

Figure 5-20: Batch plot for SSB1 strength normalized

Single Shear Bearing (SSB1) Strength Basis Values and Statistics				
2% Offset Strength	Normalized		As measured	
Env	RTD	ETW	RTD	ETW
Mean	109.89	88.14	112.98	89.88
Stdev	6.06	8.90	4.02	8.53
CV	5.51	10.10	3.56	9.49
Mod CV	6.76	10.10	6.00	9.49
Min	99.31	69.19	106.30	68.62
Max	119.86	101.13	118.98	99.81
No. Batches	3	3	3	3
No. Spec.	19	21	19	21
Basis Values and/or Estimates				
B-basis Value	98.08	65.05		64.23
B-estimate			94.81	
A-estimate	89.70	42.07	81.84	41.98
Method	Normal	Non-parametric	ANOVA	Non-parametric
Mod CV Basis Values and/or Estimates				
B-basis Value	95.42	NA	99.77	NA
A-estimate	85.16	NA	90.40	NA
Method	normal	NA	normal	NA

Table 5-26: Statistics and Basis Values for SSB1 2% Offset Strength data

5.8.2 "Soft" Single Shear Bearing (SSB2)

There were no diagnostic test failures. Both the as measured and normalized data could be pooled across the two environments. There were no outliers. Statistics, estimates and basis values are given for the 2% offset strength data in Table 5-27. The normalized data and the B-basis values are shown graphically in Figure 5-21.

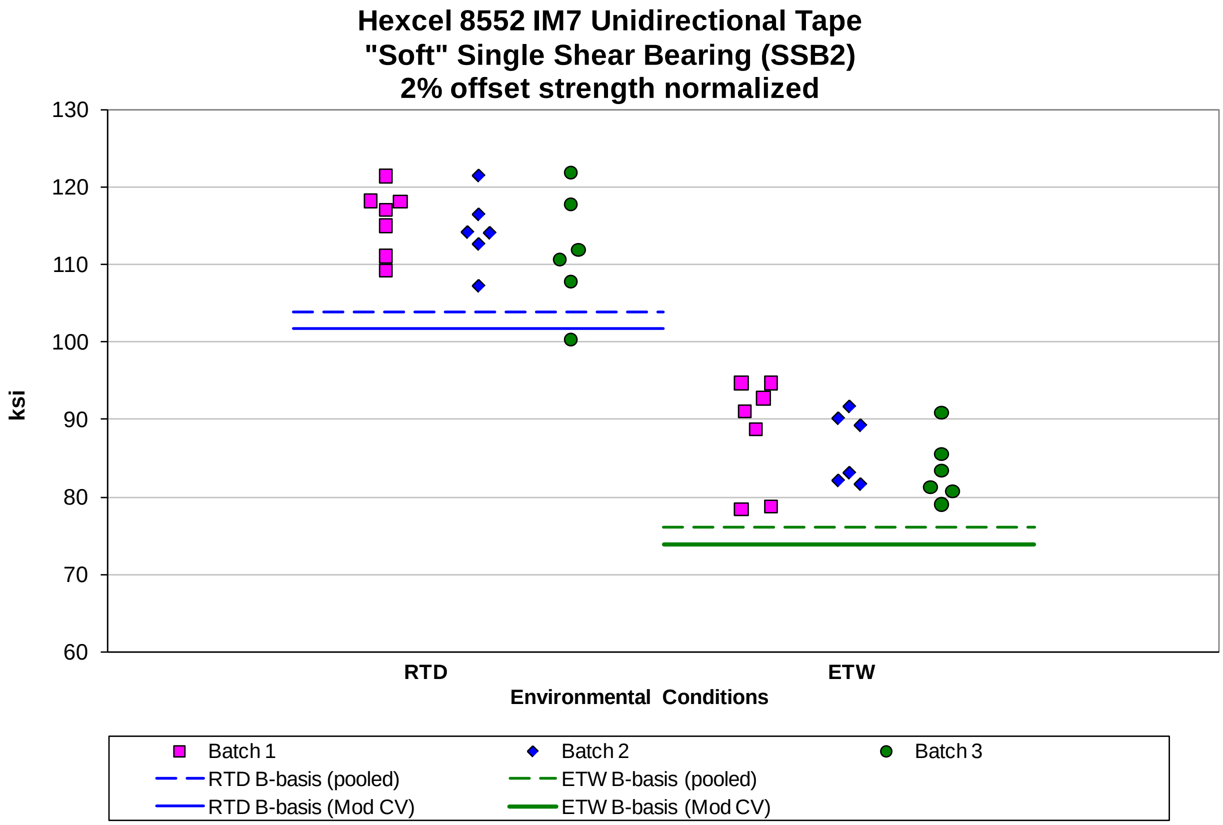

Figure 5-21: Batch plot for SSB2 strength normalized

Single Shear Bearing (SSB2) Strength Basis Values and Statistics				
2% Offset Strength	Normalized		As measured	
Env	RTD	ETW	RTD	ETW
Mean	114.02	86.22	114.20	86.87
Stdev	5.57	5.62	4.41	5.39
CV	4.88	6.52	3.86	6.21
Mod CV	6.44	7.26	6.00	7.10
Min	100.30	78.40	104.42	77.48
Max	121.80	94.73	122.56	97.23
No. Batches	3	3	3	3
No. Spec.	19	19	19	19
Basis Values and/or Estimates				
B-basis Value	103.93	76.13	105.31	77.99
A-estimate	97.04	69.24	99.24	71.92
Method	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	101.71	73.91	102.44	75.11
A-estimate	93.30	65.51	94.40	67.08
Method	pooled	pooled	pooled	pooled

Table 5-27: Statistics and Basis Values for SSB2 2% Offset Strength data

5.8.3 “Hard” Single Shear Bearing (SSB3)

There were no diagnostic test failures. Both the as measured and normalized data could be pooled across the two environments. There was one outlier. It was on the low side of batch three in the RTD condition. It was an outlier in both the normalized and the as measured data. It was an outlier before, but not after, pooling the three batches. It was retained for this analysis.

Statistics, estimates and basis values are given for the 2% offset strength data in Table 5-28. The normalized data and the B-basis values are shown graphically in Figure 5-22.

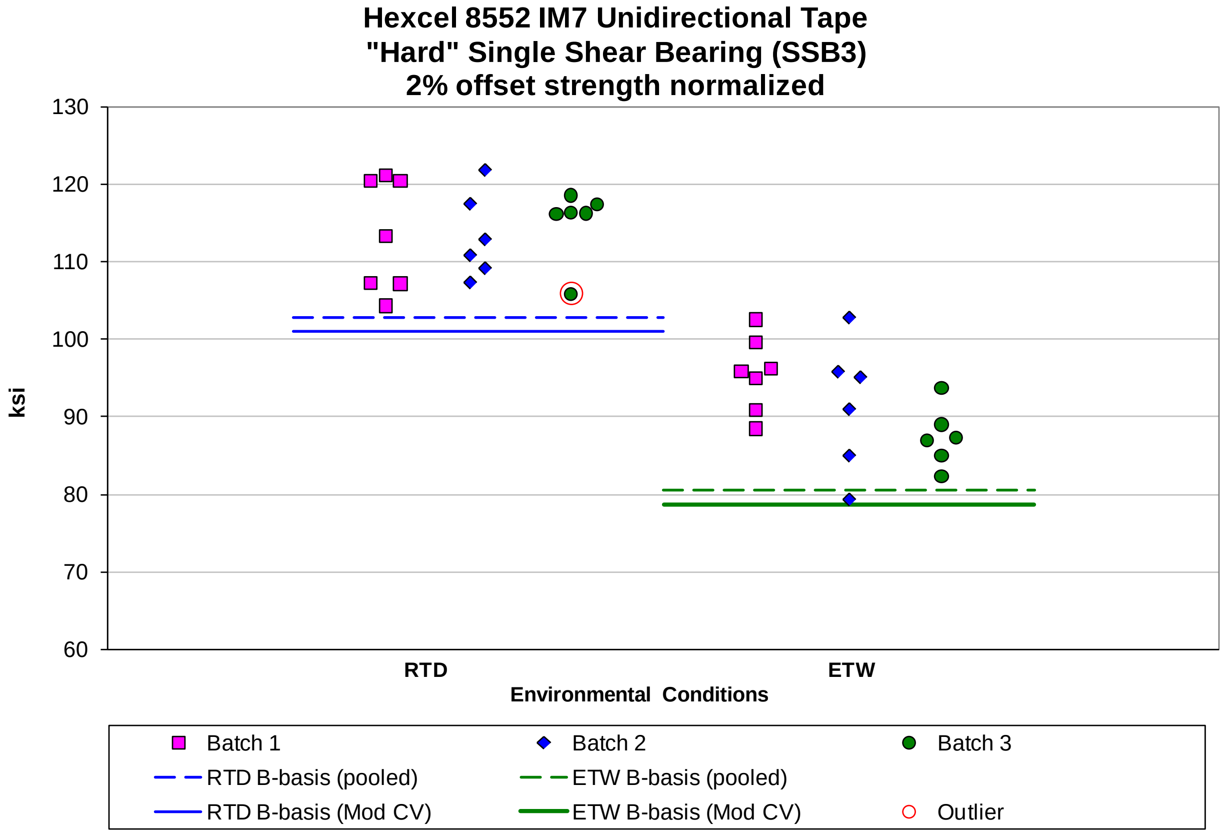

Figure 5-22: Batch plot for SSB3 strength normalized

Single Shear Bearing (SSB3) Strength Basis Values and Statistics				
2% Offset Strength	Normalized		As measured	
Env	RTD	ETW	RTD	ETW
Mean	113.90	91.67	113.93	91.80
Stdev	5.71	6.56	4.32	6.27
CV	5.01	7.15	3.79	6.83
Mod CV	6.51	7.58	6.00	7.42
Min	104.32	79.33	104.57	81.00
Max	121.80	102.78	122.04	101.30
No. Batches	3	3	3	3
No. Spec.	19	19	19	19
Basis Values and/or Estimates				
B-basis Value	102.81	80.58	104.22	82.09
A-estimate	95.23	73.01	97.58	75.45
Method	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	100.94	78.72	101.62	79.49
A-estimate	92.09	69.87	93.22	71.09
Method	pooled	pooled	pooled	pooled

Table 5-28: Statistics and Basis Values for SSB3 2% Offset Strength data

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

The ILT and CBS data is not normalized. Basis values are not computed for these properties. However the summary statistics are presented in Table 5-29 and the data are displayed graphically in Figure 5-23.

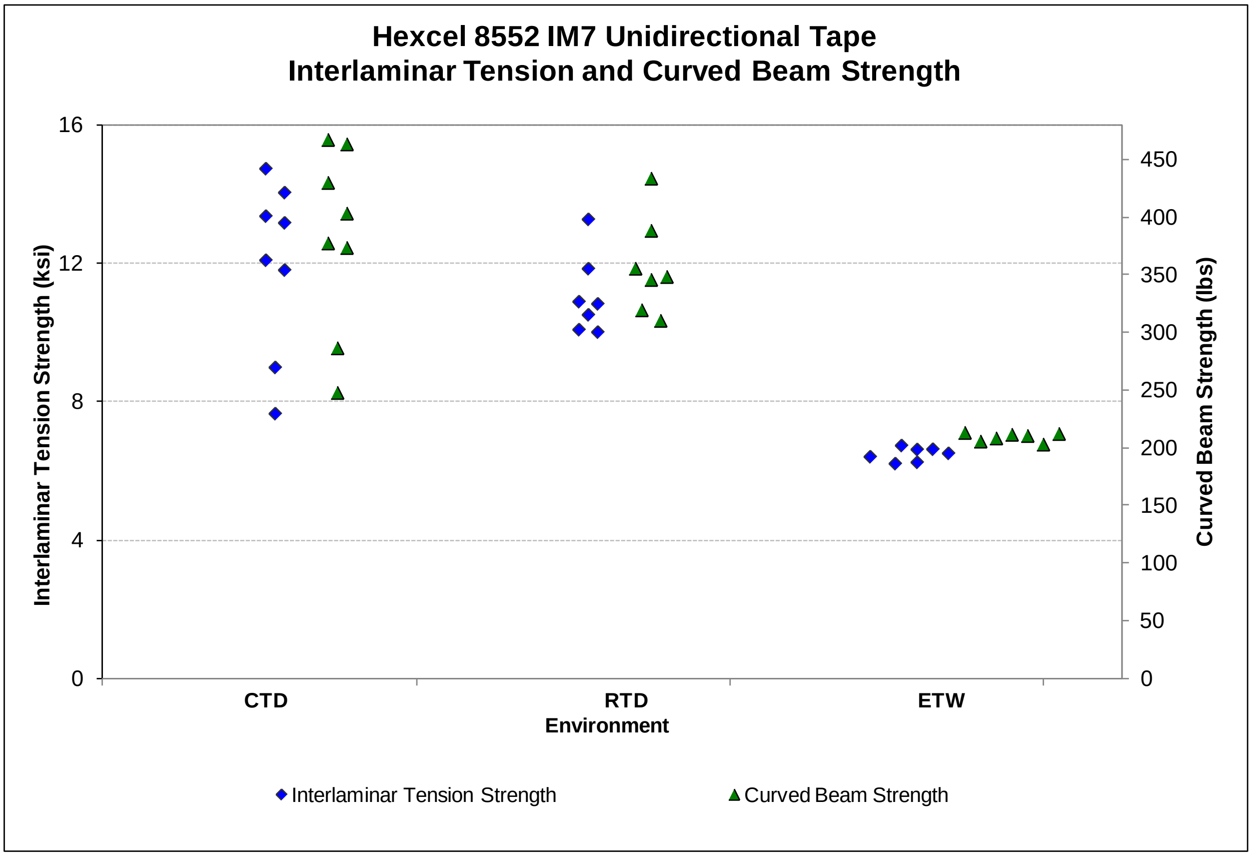

Figure 5-23: Plot for ILT and CBS Strength data as measured

Property	Interlaminar Strength (ksi)			Curved Beam Strength (lbs)		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	11.96	11.04	6.46	380.63	356.85	208.68
Stdev	2.47	1.15	0.20	79.14	42.12	3.73
CV	20.68	10.41	3.08	20.79	11.80	1.79
Min	7.64	9.99	6.19	247.30	309.81	202.50
Max	14.71	13.25	6.71	466.69	433.11	212.63
No. Batches	1	1	1	1	1	1
No. Spec.	8	7	7	8	7	7

Table 5-29: Statistics for ILT and CBS Strength data

5.10 Compression After Impact (CAI)

Basis values are not computed for these properties. However the summary statistics are presented in Table 5-30 and the data are displayed graphically in Figure 5-24.

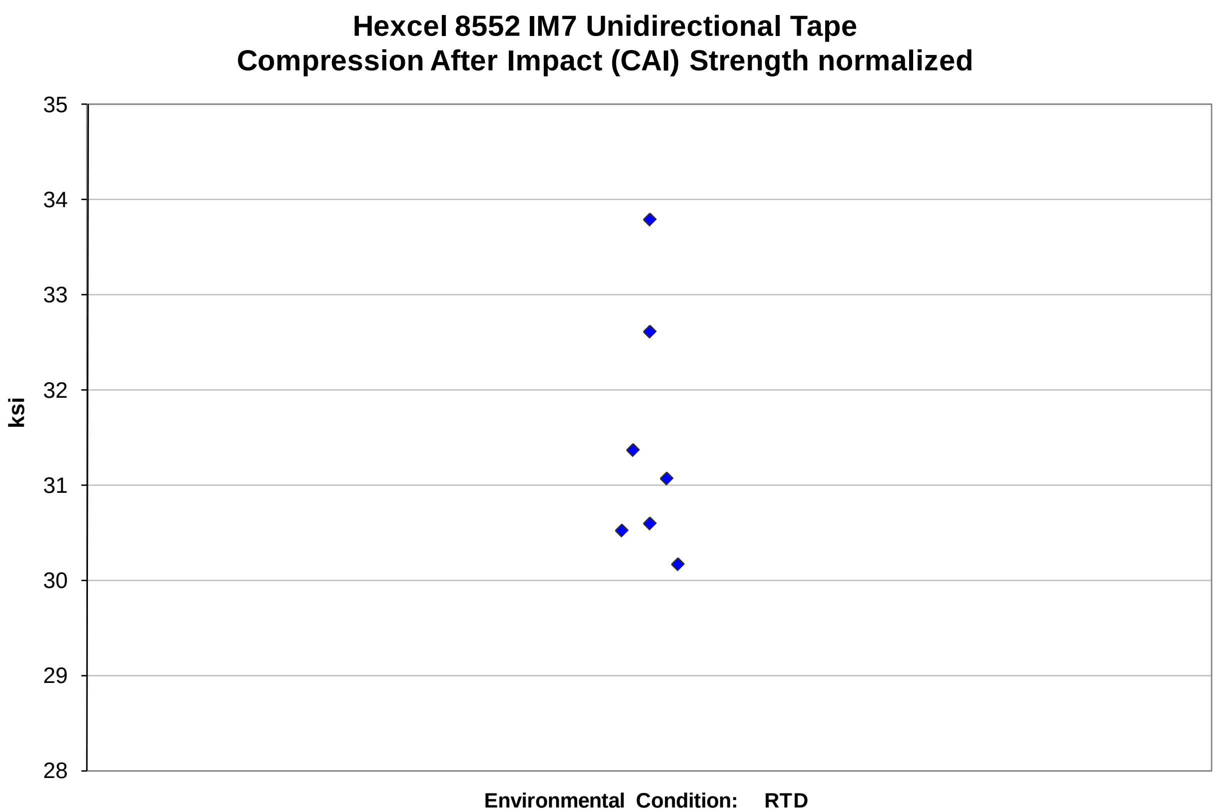

Figure 5-24: Plot for Compression After Impact strength normalized

Compression After Impact Strength (ksi)		
	Normalized	As Measured
Env	RTD	RTD
Mean	31.45	30.96
Stdev	1.31	1.44
CV	4.16	4.65
Mod CV	6.08	6.32
Min	30.17	29.53
Max	33.80	33.43
No. Batches	1	1
No. Spec.	7	7

Table 5-30: Statistics for Compression After Impact Strength data

6 Outliers

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

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

All outliers identified were investigated to determine if a cause could be found. Outliers with causes were removed from the dataset and the remaining specimens were analyzed for this report. For example, specimen HFIGCZ11A in batch three of the original OHC1 RTD dataset was found to have a severe taper on both ends. It was removed from the dataset and is no longer included in the statistical analysis of that property. 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-2009-015 Rev A.

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
TC	RTD	3	HFIZC214A	NA	43.63	High	Yes	No
IPS 0.2% Offset	RTD	1	HFINA115A	NA	7.05	Low	Yes	No
SBS	CTD	1	HFIQA11CB	NA	20.00	Low	Yes	No
SBS	ETW	1	HFIQA21DD	NA	8.42	High	Yes	No
UNT1	RTD	3	HFIAC211A	90.08	Not Outlier	Low	Yes	No
UNT3	CTD	2	HFICB216B	159.91	160.82	Low	Yes	No
OHT2	CTD	3	HFIEC115B	44.04	Not Outlier	Low	Yes	No
OHT2	RTD	1	HFIEA211A	39.91	Not Outlier	Low	Yes	No
FHT1	RTD	2	HFI4B214A	71.76	Not Outlier	High	Yes	No
FHT2	ETW	3	HFI5C11CD	41.68	41.45	Low	Yes	No
FHT3	CTD	2	HFI6B217B	79.90	Not Outlier	Low	Yes	No
OHC1	RTD	1	HFIGA211A	46.32	Not Outlier	Low	Yes	No
OHC1	RTD	3	HFIGC211A	43.91	Not Outlier	Low	Yes	**Yes**
OHC3	RTD	2	HFIIB111A	65.80	Not Outlier	High	Yes	No
FHC1	RTD	3	HFI7C213A	75.10	Not Outlier	High	Yes	No
FHC3	RTD	2	HFI9B111A	91.49	Not Outlier	Low	Yes	No
LSBS	RTD	2	HFIqB173A	NA	11.19	Low	Yes	No
LSBS	RTD	3	HFIqC272A	NA	9.55	Low	Yes	**Yes**
LSBS	ETW	1	HFIqA27X6D	NA	7.70	High	No	**Yes**
SSB3	RTD	3	HFI3C212A	105.84	104.57	Low	Yes	No

Table 6-1: List of outliers

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