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Hexcel 8552 AS4 Unidirectional Prepreg Qualification Statistical Analysis Report

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1. Introduction

This report contains statistical analysis of Hexcel 8552 AS4 Unidirectional prepreg at 190 gsm & 35% RC qualification data. Material property data is published in NCAMP Test Report CAM-RP-2010-002. The lamina and laminate material property data have been generated with FAA oversight through FAA Special Project Number SP4614WI-Q and also meet the requirements outlined in NCAMP Standard Operating Procedure NSP 100. The test panels, test specimens, and test setups have been conformed by the FAA and the testing has been witnessed by the FAA.

B-Basis values, A-estimates, and B-estimates were calculated using a variety of techniques that are detailed in section two. The qualification material was procured to NCAMP Material Specification NMS 128/1 Rev – Initial Release dated February 6, 2007. The qualification test panels were cured in accordance with NCAMP Process Specification 81228 Cure "M," June 7, 2007. The panels were fabricated by Cessna Aircraft Company, 5800 E. Pawnee, Wichita, KS 67218. The NCAMP Test Plan NTP 1628Q1 Rev. B was used for this qualification program. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas.

The panels were fabricated by Cessna Aircraft Company, 5800 E Pawnee, Wichita, KS 67218 and cured in accordance with Baseline Cure Cycle (M) of NCAMP Process Specification NPS 81228 Rev A. The NCAMP Test Plan NTP 1128Q1 was used for this qualification program. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas.

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

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

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

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

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

Part fabricators that wish to utilize the material property data, allowables, and specifications may be able to do so by demonstrating the capability to reproduce the original material properties; a process known as equivalency. More information about this equivalency process including the test statistics and its limitations can be found in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of working draft 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 working draft 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 128/1. NMS 128/1 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 128/1*. NMS 128/1 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 (70°)	RTD
Elevated Temperature Dry (250°)	ETD
Elevated Temperature Wet (250°)	ETW

Table 1-3: Environmental Conditions Abbreviations

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

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

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

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2010-002.

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 working draft CMH-17 Revision 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 working draft 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 working draft 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:

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

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

2.1.2.2 Pooled Coefficient of Variation

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

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

2.1.3 Basis Value Computations

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

Basis Values:

$$A-basis = \bar{X} - K_a S$$
$$B-basis = \bar{X} - K_b S$$

Equation 6

2.1.3.1 K-factor computations

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

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

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

Where

r = the number of environments being pooled together
n_j= number of data values for environment j

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

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

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

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

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

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

2.1.4 Modified Coefficient of Variation

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

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

This is converted to percent by multiplying by 100%.

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

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

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

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

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

2.1.4.1 Transformation of data based on Modified CV

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

To accomplish this requires a transformation in two steps:

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

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

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

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

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

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

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

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

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

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

2.1.5 Determination of Outliers

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 working draft CMH-17 Rev G.

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

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

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

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

2.1.6 The k-Sample Anderson Darling Test for batch equivalency

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

The k-sample Anderson-Darling test statistic is:

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

Where

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

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

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

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

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

With

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

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

2.1.7 The Anderson Darling Test for Normality

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

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

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

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

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

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

The Anderson Darling test statistic (AD) is:

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

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

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

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

2.1.8 Levene's test for Equality of Coefficient of Variation

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

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

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

2.2 STAT-17

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

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

Outliers must be dispositioned before checking any other test results. The results of the Anderson Darling k-Sample (ADK) Test for batch equivalency must be checked. If the data passes the ADK test, then the appropriate distribution is determined. If it does not pass the ADK test, then the ANOVA procedure is the only approach remaining that will result in basis values that meet the requirements of working draft 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 $x_1, \ldots, x_n$, and the sample observations ordered from least to greatest by $x_{(1)}, \ldots, x_{(n)}$.

2.2.2 Computing Normal Distribution Basis values

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

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

Table 2-1: K factors for normal distribution

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

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

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

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

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

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

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

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

2.2.2.3 Two-parameter Weibull Distribution

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

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

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

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

2.2.2.3.1 Estimating Weibull Parameters

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

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

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

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

2.2.2.3.2 Goodness-of-fit test for the Weibull distribution

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

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

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 $(0 < a < b < \infty)$ is given by the area under the normal distribution between ln(a) and ln(b).

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

2.2.2.4.1 Goodness-of-fit test for the Lognormal distribution

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

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

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 working draft CMH-17 Rev G, there must be at least five batches represented in the data and at least 55 data points. For a B-basis value, there must be at least three batches represented in the data and at least 18 data points.

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

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

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

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

2.2.5 Analysis of Variance (ANOVA) Basis Values

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

2.2.5.1 Calculation of basis values using ANOVA

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

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

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

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

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

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

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

Next, the mean sums of squares are computed:

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

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

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

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

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

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

Two k-factors are computed using the methodology of section 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

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

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

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

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

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

2.3 Single Batch and Two Batch estimates using modified CV

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

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

2.4 Lamina Variability Method (LVM)

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

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

The LVM B-basis value is then computed as:

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

With:

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

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

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

2.5 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

$$BF = \frac{E_1\left[V_0E_2 + (1-V_0)E_1\right] - (\nu_1\ E_{22})^2}{\left[V_0E_1 + (1-V_0)E_2\right]\left[V_0E_2 + (1-V_0)E_1\right] - (\nu_1\ E_{22})^2} \qquad \textbf{Equation 64}$$

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

This formula can also be found in the Composite Materials Handbook (working draft CMH-17 Rev G) in section 2.4.2, equation 2.4.2.1(b).

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

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:

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

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

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

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

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

This formula can also be found in the Composite Materials Handbook (working draft CMH-17 Rev G) in section 2.4.2, 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 of working draft CMH-17 Rev G. However, not all test data meets those requirements. The summary tables provide a complete listing of all computed basis values and estimates of basis values. Data that does not meet the requirements of working draft 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 of working draft CMH-17 Rev G are recommended.
2. Modified CV basis values are preferred. Recommended values will be the modified CV basis value when available. The CV provided with the recommended basis value will be the one used in the computation of the basis value.
3. Only normalized basis values are given for properties that are normalized.
4. ANOVA B-basis values are not recommended since only three batches of material are available and working draft 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 8552 AS4 Unidirectional Prepreg at 190 gsm & 35% RC

All B-basis values in this table meet the standards for publication in CMH-17G Handbook

Values are for normalized data unless otherwise noted

Lamina Strength Tests

Environment	Statistic	LT from UNT0	LT from LT	LC from UNC0	TT*	TC*	SBS*	IPS* 0.2% Offset	IPS* 5% Strain
CTD (-65° F)	B-basis	209.13	260.55	223.63	NA: I	44.42	19.30	9.89	
	Mean	236.95	295.06	247.73	9.73	51.49	20.87	10.73	
	CV	6.00	6.00	7.00	8.39	7.13	6.00	6.00	
RTD (70° F)	B-basis	243.64	NA: A	179.31	NA: I	34.31	15.03	7.17	NA: I
	Mean	271.47	289.47	202.70	9.27	38.85	16.63	8.00	13.28
	CV	6.07	8.76	6.28	9.47	6.00	6.00	6.00	2.74
ETD (250° F)	B-basis			194.84			9.35		
	Mean			218.47			10.95		
	CV			6.00			6.00		
ETW (250° F)	B-basis	251.48	NA: A	126.94	3.01	17.03	6.65	2.52	NA: A
	Mean	279.17	244.68	150.22	3.49	19.71	8.25	3.36	5.51
	CV	6.00	10.36	7.69	7.06	6.97	6.00	6.25	6.48

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

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

NCAMP Recommended B-basis Values for
Hexcel 8552 AS4 Unidirectional Prepreg at 190 gsm & 35% RC

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

Laminate Strength Tests

Lay-up	ENV	Statistic	OHT	OHC	FHT	FHC	UNT	UNC	SSB 2% Offset Strength	SSB Ultimate Strength	LSBS*
25/50/25	CTD (-65º F)	B-basis	40.01		45.50		74.36				
		Mean	45.05		51.52		84.21				
		CV	6.00		6.00		6.00				
	RTD (75º F)	B-basis	42.56	42.92	47.11	68.83	77.46	NA: A	89.18	121.22	10.35
		Mean	47.63	47.28	53.35	76.02	88.61	81.32	103.24	135.55	11.94
		CV	6.00	6.00	6.00	6.02	6.45	7.22	7.67	6.47	6.84
	ETW (250º F)	B-basis	46.68	28.77	48.68	47.68	84.18	NA: A	83.58	91.85	6.01
		Mean	51.68	33.09	55.13	54.87	95.18	62.93	97.58	106.12	6.81
		CV	6.00	6.00	6.00	6.00	6.00	7.95	7.90	6.70	6.00
10/80/10	CTD (-65º F)	B-basis	36.17		41.43		60.29				
		Mean	40.06		45.86		66.61				
		CV	6.00		6.00		6.00				
	RTD (75º F)	B-basis	35.26	35.42	39.63	52.17	57.30	56.28	84.95	124.71	
		Mean	39.17	40.63	44.08	57.65	63.62	62.42	97.45	137.87	
		CV	6.00	6.59	6.00	6.00	6.00	6.08	6.58	6.00	
	ETW (250º F)	B-basis	28.24	23.16	31.53	33.28	41.85	39.54	NA: A	93.67	
		Mean	32.08	26.41	35.93	38.79	48.17	45.60	83.27	106.52	
		CV	6.00	6.32	6.00	6.64	6.00	6.73	10.43	6.23	
50/40/10	CTD (-65º F)	B-basis	55.03		58.28		134.01				
		Mean	62.56		65.96		149.38				
		CV	6.00		6.02		6.00				
	RTD (75º F)	B-basis	61.02	56.38	66.33	89.60	137.68	118.13	92.59	119.48	
		Mean	68.55	62.78	74.02	100.15	152.32	131.05	104.96	133.34	
		CV	6.25	6.00	6.00	6.31	6.00	6.00	6.00	6.62	
	ETW (250º F)	B-basis	71.64	41.96	70.61	64.37	129.07	75.20	NA: A	92.60	
		Mean	79.07	48.36	78.30	74.96	144.59	88.01	85.93	106.28	
		CV	6.00	6.85	6.00	7.19	6.00	7.43	7.89	6.26	

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

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

3.2 Lamina and Laminate Summary Tables

Material:	Hexcel Corporation - Hexcel 8552 AS4 Unidirectional Prepreg at 190 gsm and 35% RC NMS 128/1 Material Specification		**Hexcel 8552 AS4 Unidirectional Prepreg at 190 gsm & 35% RC Lamina Properties Summary**
Fiber:	AS4 Unidirectional	**Resin:**	Hexcel 8552
	Tg(dry): 400.27° F	**Tg(wet):** 321.04 ° F	**Tg METHOD:** DMA (SRM 18-94)
PROCESSING:	NPS 81228 Cure Cycle "M"		

	Lot 1	Lot 2	Lot 3		
Date of fiber manufacture	1/4/07	12/17/06	1/21/07	**Date of testing**	2/11/2009 to 4/6/2010
Date of resin manufacture	2/26/07	1/25/07	2/21/07	**Date of data submittal**	4/8/2010
Date of prepreg manufacture	2/26/07	1/25/07	2/21/07	**Date of analysis**	05/06/2007 to 08/02/2010
Date of composite manufacture	12/1/2007 to 2/1/2007				

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported: As measured followed by normalized values in parentheses, normalizing tply: 0.0074 in

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

	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)	221.79	211.35	240.12	261.29	250.84	279.61				266.62	256.22	284.85
from UNT0	(220.78)	(209.13)	(236.95)	(255.29)	(243.64)	(271.47)				(263.07)	(251.48)	(279.17)
F_1^{tu} (ksi)	276.82	264.87	299.95	175.86	253.67	299.22				121.35	NA	247.84
from LT	(272.74)	(260.55)	(295.06)	(182.22)	NA	(289.47)				(129.69)	NA	(244.68)
E_1^t			18.48			19.09						19.00
(Msi)			(18.17)			(18.46)						(18.76)
ν_{12}^t			0.275			0.302						0.366
F_2^{tu} (ksi)	8.12	NA	9.73	7.51	NA	9.27				3.07	3.01	3.49
E_2^t (Msi)			1.50			1.34						0.81
F_1^{cu} (ksi)	230.46	226.53	252.51	193.89	190.08	215.29	199.00	195.15	220.63	137.48	133.69	158.78
from UNC0	(228.28)	(223.63)	(247.73)	(183.83)	(179.31)	(202.70)	(199.40)	(194.84)	(218.47)	(131.44)	(126.94)	(150.22)
E_1^c			15.57			16.76			16.70			17.00
(Msi)			(15.43)			(16.17)			(16.53)			(16.66)
ν_{12}^c			0.335			0.335			0.348			0.386
F_2^{cu} (ksi)	45.29	44.42	51.49	34.07	34.31	38.85				17.43	17.03	19.71
E_2^c (Msi)			1.56			1.43						1.14
ν_{21}^c			0.033			0.029						0.023
$F_{12}^{s5\%}$ (ksi)	NA	NA	NA	11.11	11.66	13.28				3.06	4.73	5.51
$F_{12}^{s0.2\%}$ (ksi)	8.40	9.89	10.73	6.69	7.17	8.00				2.55	2.52	3.36
G_{12}^s (Msi)			0.81			0.70						0.34
SBS (ksi)	19.78	19.30	20.87	16.09	15.03	16.63	9.92	9.35	10.95	6.70	6.65	8.25
UNT0	119.96	114.42	129.69	139.75	134.21	149.48				138.74	133.22	148.42
(ksi)	(119.52)	(113.35)	(128.14)	(136.83)	130.65	(145.45)				(136.96)	(130.82)	(145.54)
			9.82			10.04						10.00
(Msi)			(9.70)			(9.77)						(9.81)
UNC0	92.24	90.72	100.79	75.56	74.08	83.85	75.31	73.81	83.69	51.70	50.22	59.95
(ksi)	(91.46)	(89.66)	(99.02)	(72.02)	(70.28)	(79.36)	(74.72)	(72.96)	(82.13)	(49.56)	(47.82)	(56.86)
			6.36			6.50			6.33			6.12
(Msi)			(6.26)			(6.16)			(6.21)			(5.96)
ν of UNC0			0.041			0.037			0.033			0.027

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

Material:	Hexcel Corporation - Hexcel 8552 AS4 Unidirectional Prepreg at 190 gsm & 35% RC NMS 128/1 Material Specification			**Hexcel 8552 AS4 Unidirectional Prepreg at 190 gsm & 35% RCLaminate Properties Summary**
Fiber:	AS4 Unidirectional	**Resin:**	Hexcel 8552	
Tg(dry): 400.27° F	**Tg(wet):** 321.04 ° F	**Tg METHOD :** DMA (SRM 18-94)		
PROCESSING:	NPS 81228 Cure Cycle "M"			

	Lot 1	Lot 2	Lot 3		
Date of fiber manufacture	1/4/07	12/17/06	1/21/07	**Date of testing**	2/11/2009 to 4/6/2010
Date of resin manufacture	2/26/07	1/25/07	2/21/07	**Date of data submittal**	4/8/2010
Date of prepreg manufacture	2/26/07	1/25/07	2/21/07	**Date of analysis**	05/06/2007 to 08/02/2010
Date of composite manufacture	12/1/2007 to 2/1/2007				

LAMINATE MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported as normalized used a normalizing t_{ply} of 0.0074 in

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

Test	Property	Test Condition	Layup: Unit	Quasi Isotropic 25/50/25 B-value	Quasi Isotropic 25/50/25 Mod. CV B-value	Quasi Isotropic 25/50/25 Mean	"Soft" 10/80/10 B-value	"Soft" 10/80/10 Mod. CV B-value	"Soft" 10/80/10 Mean	"Hard" 50/40/10 B-value	"Hard" 50/40/10 Mod. CV B-value	"Hard" 50/40/10 Mean
OHT (normalized)	**Strength**	CTD	ksi	42.55	40.01	45.05	38.77	36.17	40.06	57.81	55.03	62.56
		RTD	ksi	45.11	42.56	47.63	37.88	35.26	39.17	63.80	61.02	68.55
		ETW	ksi	49.20	46.68	51.68	30.81	28.24	32.08	74.39	71.64	79.07
OHC (normalized)	**Strength**	RTD	ksi	45.90	42.92	47.28	36.54	35.42	40.63	58.22	56.38	62.78
		ETW	ksi	31.73	28.77	33.09	24.02	23.16	26.41	32.77	41.96	48.36
UNT (normalized)	Strength	CTD	ksi	80.53	74.36	84.21	59.58	60.29	66.61	141.39	134.01	149.38
	Modulus		msi	---	---	7.03	---	---	4.72	---	---	10.53
	Strength	RTD	ksi	80.13	77.46	88.61	61.20	57.30	63.62	141.23	137.68	152.32
	Modulus		msi	---	---	6.96	---	---	4.53	---	---	10.55
	Strength	ETW	ksi	79.56	84.18	95.18	41.18	41.85	48.17	135.33	129.07	144.59
	Modulus		msi	---	---	6.61	---	---	3.76	---	---	10.41
UNC (normalized)	Strength	RTD	ksi	56.66	NA	81.32	57.87	56.28	62.42	121.08	118.13	131.05
	Modulus		msi	---	---	6.43	---	---	4.30	---	---	9.63
	Poisson's Ratio			---	---	0.300	---	---	0.526	---	---	0.430
	Strength	ETW	ksi	40.65	NA	62.93	41.11	39.54	45.60	78.12	75.20	88.01
	Modulus		msi	---	---	6.30	---	---	3.84	---	---	9.59
	Poisson's Ratio			---	---	0.334	---	---	0.581	---	---	0.415
FHT (normalized)	**Strength**	CTD	ksi	42.64	45.50	51.52	44.36	41.43	45.86	54.60	58.28	65.96
		RTD	ksi	50.14	47.11	53.35	42.58	39.63	44.08	68.28	66.33	74.02
		ETW	ksi	47.99	48.68	55.13	34.44	31.53	35.93	75.07	70.61	78.30
FHC (normalized)	**Strength**	RTD	ksi	71.27	68.83	76.02	54.19	52.17	57.65	91.72	89.60	100.15
		ETW	ksi	50.11	47.68	54.87	35.31	33.28	38.79	66.50	64.37	74.96
Single Shear Bearing (normalized)	**2% Offset Strength**	RTD	ksi	89.56	89.18	103.24	87.64	84.95	97.45	92.59	NA	104.96
		ETW	ksi	83.97	83.58	97.58	41.66	67.30	83.27	54.74	73.05	85.93
LSBS (as measured)	**Strength**	RTD	ksi	8.98	10.35	11.94	---	---	---	---	---	---
		ETW	ksi	5.78	6.01	6.81	---	---	---	---	---	---
ILT (as measured)	**Strength**	CTD	ksi	---	---	8.42	---	---	---	---	---	---
		RTD	ksi	---	---	7.90	---	---	---	---	---	---
		ETW	ksi	---	---	4.25	---	---	---	---	---	---
CBS (as measured)	**Strength**	CTD	lbs	---	---	294.17	---	---	---	---	---	---
		RTD	lbs	---	---	272.67	---	---	---	---	---	---
		ETW	lbs	---	---	148.95	---	---	---	---	---	---
CAI (Normalized)	**Strength**	RTD	ksi	---	---	25.57	---	---	---	---	---	---

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 conser vative. The ADK test is performed again after a transformation of the data according to the assumptions of the modified CV method (see section 2.1.4 for details). If the dataset still passes the ADK test at this point, modified CV basis values are provided. If the dataset does not pass the ADK test after the transformation, estimates may be computed using the modified CV method per the guidelines of working draft CMH-17 Rev G section 8.3.10.

4.1 Longitudinal (0º) Tension Properties (LT)

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

For the LT strength values derived from the UNT0 specimens there were no outliers or test failures, so pooling across environments is permissible. Statistics, estimates and basis values are given for strength data in Table 4-1 and for the modulus data in Table 4-2. The data and the B-basis values are shown graphically in Figure 4-1.

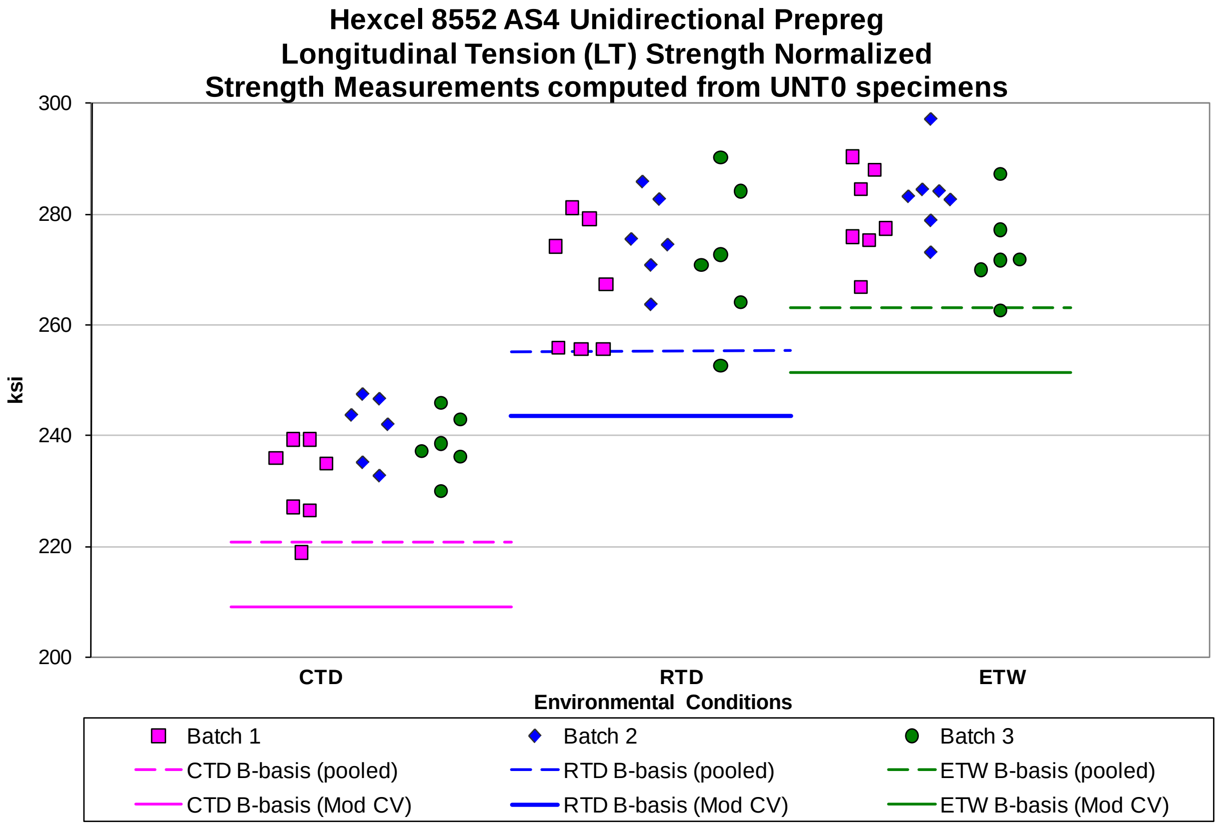

Figure 4-1 Batch plot for LT normalized strength (from UNT0 specimens)

Longitudinal Tension Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	236.95	271.47	279.17	240.12	279.61	284.85
Stdev	7.52	11.21	8.58	7.87	12.64	10.29
CV	3.18	4.13	3.07	3.28	4.52	3.61
Mod CV	6.00	6.07	6.00	6.00	6.26	6.00
Min	218.94	252.71	262.58	222.91	255.04	263.16
Max	247.64	290.25	297.21	254.09	306.97	305.09
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	20	19	19	20
Basis Values and/or Estimates						
B-basis Value	220.78	255.29	263.07	221.79	261.29	266.62
A-estimate	209.94	244.46	252.22	209.52	249.02	254.33
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	209.13	243.64	251.48	211.35	250.84	256.22
A-estimate	190.49	225.00	232.81	192.08	231.57	236.93
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-1: Statistics and Basis values for LT strength computed from UNT0 specimens

Longitudinal Tension Modulus Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	18.17	18.46	18.76	18.48	19.09	19.00
Stdev	0.16	0.61	0.19	0.21	0.59	0.23
CV	0.91	3.28	1.03	1.16	3.07	1.20
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	17.94	16.29	18.34	18.18	18.29	18.60
Max	18.60	19.15	19.09	18.89	20.69	19.36
No. Batches	3	3	3	3	3	3
No. Spec.	19	21	24	19	21	24

Table 4-2: Statistics from LT modulus

The statistics and basis values for strength computed from the LT specimens are provided in Table 4-3. Pooling across environments was not acceptable because the RTD and ETW datasets did not pass the ADK test. ANOVA was the only appropriate method that could be used with those datasets and because there were only three batches, those values are considered to be estimates only. Estimates computed using the modified CV method are provided for the RTD environment but not the ETW environment due to the non-normality of the data from the ETW environment. Pooling across the environments was not acceptable due to the non-normality as well. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method.

There was one outlier, the lowest value in batch 2 of the RTD data. It was retained for this analysis. The data, B-estimates and B-basis values are shown graphically in Figure 4-2.

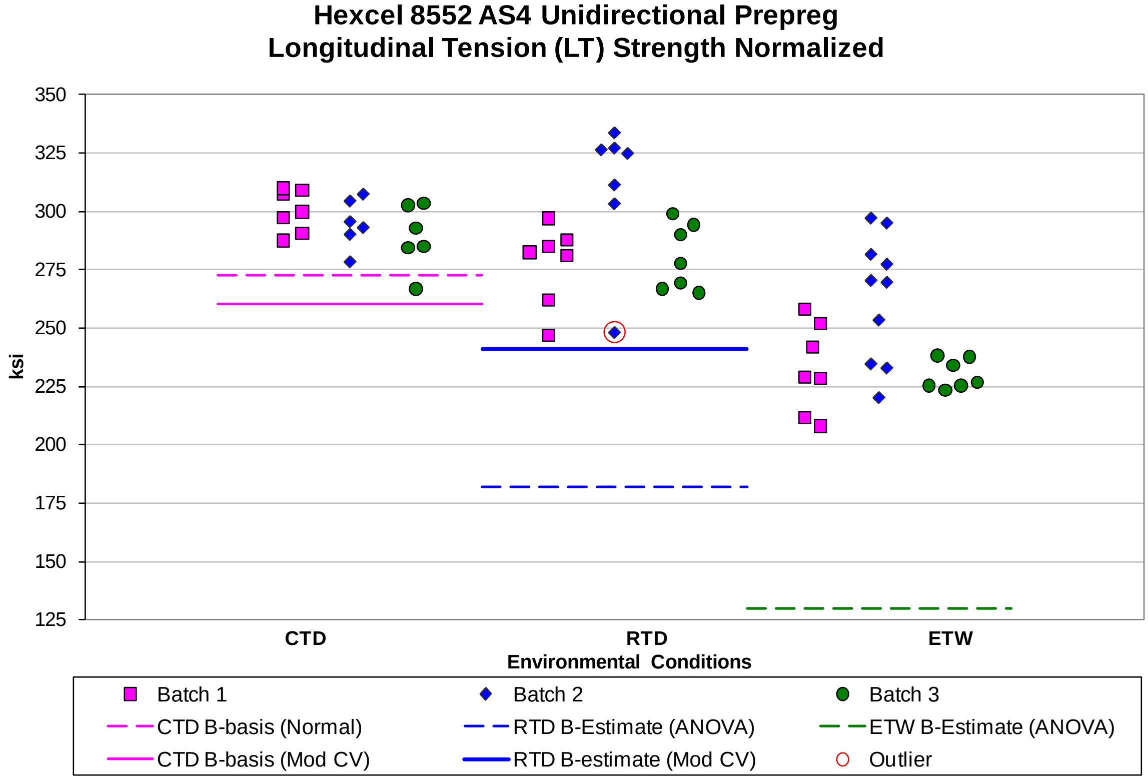

Figure 4-2 Batch plot for LT normalized strength from LT specimens

Longitudinal Tension Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	295.06	289.47	244.68	299.95	299.22	247.84
Stdev	11.45	25.37	25.36	11.87	23.87	26.40
CV	3.88	8.76	10.36	3.96	7.98	10.65
Mod CV	6.00	8.76	10.36	6.00	7.99	10.65
Min	266.88	246.92	207.98	270.95	264.86	207.75
Max	309.94	333.58	297.09	315.50	350.00	296.87
No. Batches	3	3	3	3	3	3
No. Spec.	19	21	24	19	21	24
Basis Values and/or Estimates						
B-basis Value	272.74			276.82		
B-estimate		182.22	129.69		175.86	121.35
A-estimate	256.89	105.67	47.52	260.39	87.80	30.97
Method	Normal	ANOVA	ANOVA	Normal	ANOVA	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	260.55		NA	264.87		NA
B-estimate		241.13			253.67	
A-estimate	236.09	206.70	NA	240.00	221.23	NA
Method	normal	normal	NA	normal	normal	NA

Table 4-3: Statistics and Basis values for LT strength from LT specimens

4.2 Transverse (º) Tension Properties (TT)

Transverse Tension data is not normalized for unidirectional tape. The pooled dataset failed Levene's test for equality of variance, so pooling across environments was not acceptable. CTD and RTD environments have data from only two batches because specimens from the third batch were removed due to deep scratches on those specimens. This means that only estimates are provided for the CTD and RTD environments. Due to the large CV of the CTD and RTD environments, modified CV basis values are not available. There were no outliers.

Statistics, estimates and basis values 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-estimates and the B-basis values are shown graphically in Figure 4-3.

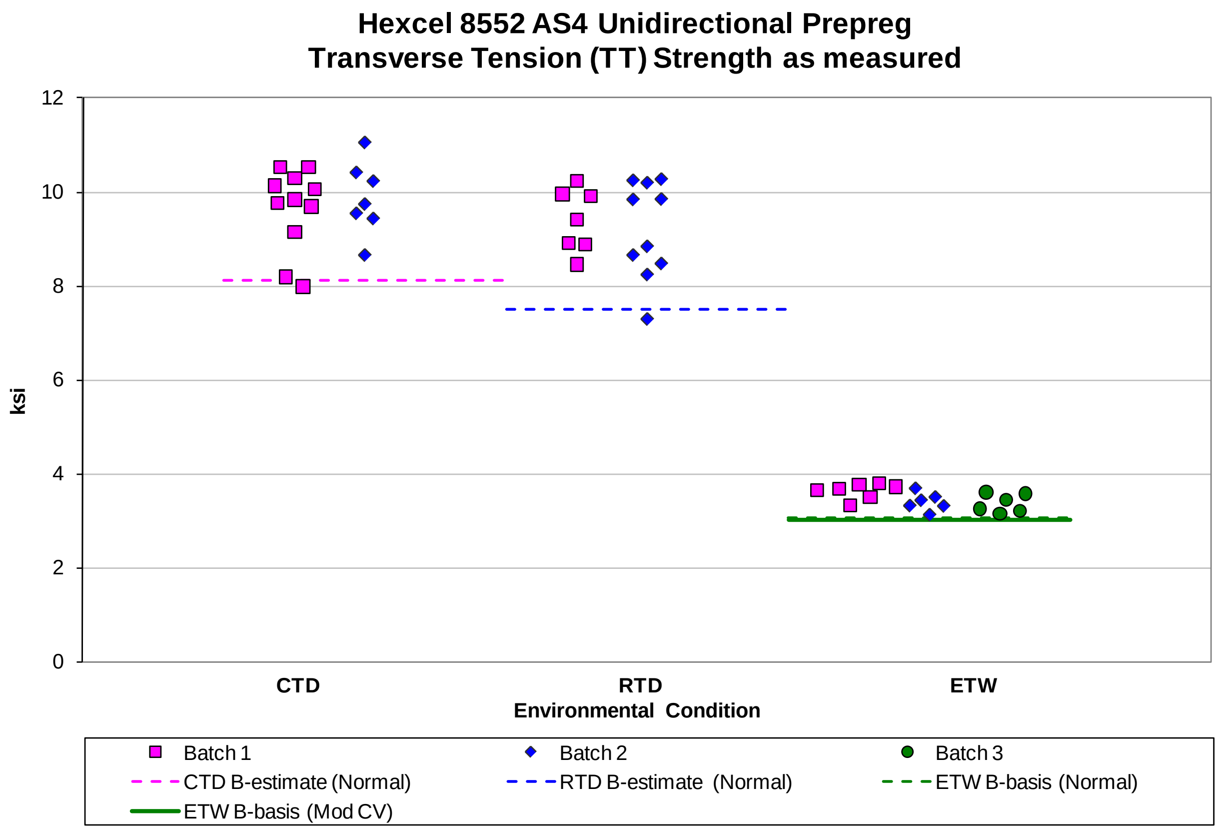

Figure 4-3: Batch Plot for TT strength as measured

Transverse Tension Strength Basis Values and Statistics			
As Measured			
Env	CTD	RTD	ETW
Mean	9.73	9.27	3.49
Stdev	0.82	0.88	0.21
CV	8.39	9.47	6.11
Mod CV	8.39	9.47	7.06
Min	7.99	7.29	3.14
Max	11.04	10.26	3.80
No. Batches	2	2	3
No. Spec.	18	17	19
Basis Values and/or Estimates			
B-basis Value			3.07
B-estimate	8.12	7.51	
A-estimate	6.98	6.27	2.78
Method	Normal	Normal	Normal
Modified CV Basis Values and/or Estimates			
B-basis Value	NA	NA	3.01
A-estimate	NA	NA	2.67
Method	NA	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	1.50	1.34	0.81
Stdev	0.08	0.03	0.06
CV	5.38	2.56	7.39
Mod CV	6.69	6.00	7.69
Min	1.37	1.29	0.67
Max	1.63	1.39	0.97
No. Batches	2	2	3
No. Spec.	18	17	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 test failures and no outliers. Statistics, basis values and estimates are given for strength data in Table 4-6 and for the modulus data in Table 4-7. The data and the B-basis values are shown graphically in Figure 4-4.

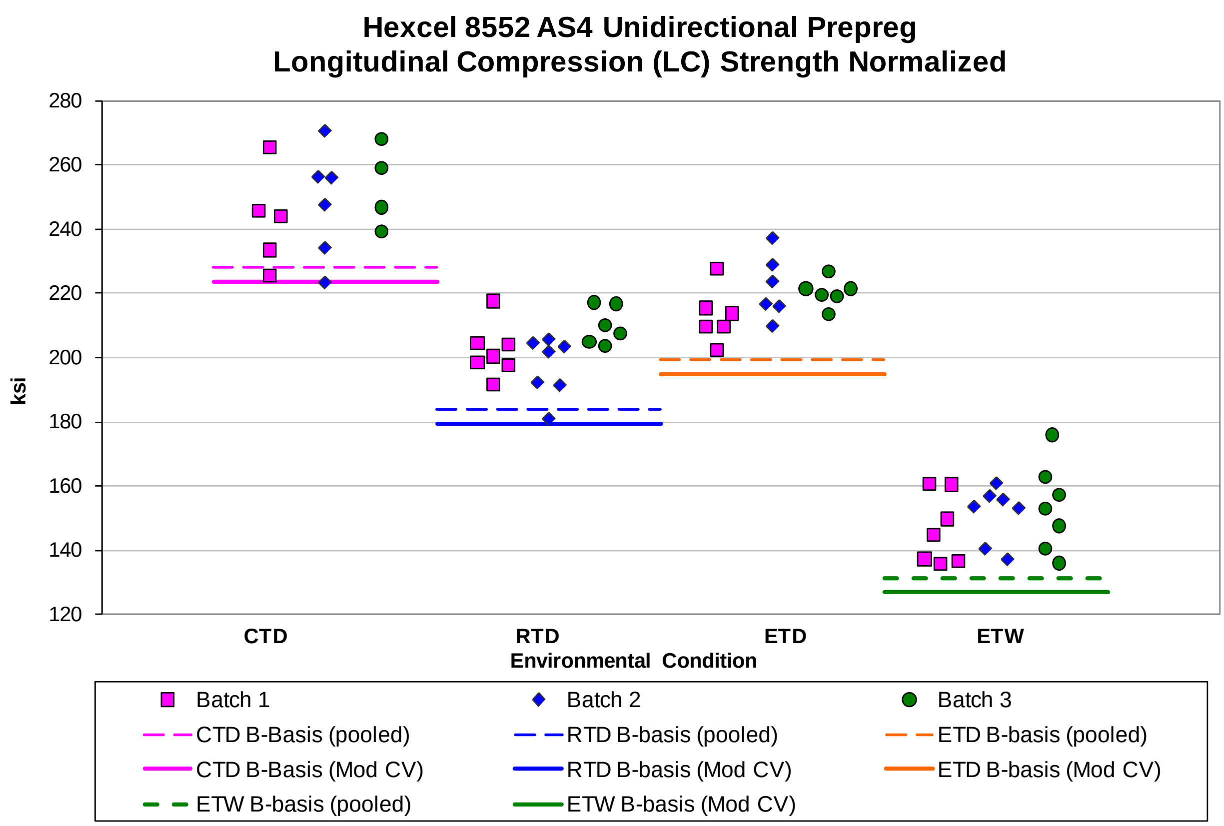

Figure 4-4 Batch plot for LC normalized strength data (from UNC0 specimens)

Longitudinal Compression Strength Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	247.73	202.70	218.47	150.22	252.51	215.29	220.63	158.78
Stdev	14.84	9.26	8.45	11.09	15.38	11.93	8.57	13.26
CV	5.99	4.57	3.87	7.38	6.09	5.54	3.89	8.35
Mod CV	7.00	6.28	6.00	7.69	7.05	6.77	6.00	8.35
Min	223.33	180.82	202.38	135.75	229.71	195.02	204.26	138.68
Max	270.64	217.67	237.20	175.96	280.80	242.42	238.24	181.42
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	15	20	18	21	15	20	18	21
Basis Value Estimates								
B-basis Value	228.28	183.83	199.40	131.44	230.46	193.89	199.00	137.48
A-Estimate	215.77	171.23	186.83	118.82	216.27	179.61	184.75	123.18
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Value Estimates								
B-basis Value	223.63	179.31	194.84	126.94	226.53	190.08	195.15	133.69
A-Estimate	208.12	163.70	179.26	111.31	209.82	173.25	178.36	116.84
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-6: Statistics and Basis Values for LC strength computed from UNC0 specimens

Longitudinal Compression Modulus Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	15.43	16.17	16.53	16.66	15.57	16.76	16.70	17.00
Stdev	1.44	0.81	0.20	0.58	1.37	0.42	0.19	0.27
CV	9.33	5.03	1.24	3.47	8.79	2.52	1.16	1.58
Mod CV	9.33	6.52	6.00	6.00	8.79	6.00	6.00	6.00
Min	12.44	14.32	16.30	14.84	12.75	15.29	16.43	16.22
Max	18.24	17.26	17.08	17.27	18.22	17.26	17.19	17.42
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	20	19	19	21	20	19	19	21

Table 4-7: Statistics from LC modulus

4.4 Transverse (90º) Compression Properties (TC)

Transverse Compression data is not normalized for unidirectional tape. The pooled data fails Levene's test for equality of variance, so the data cannot be pooled across environments. The data for the RTD environment failed the ADK test, so only the ANOVA method could be used to compute basis values. Since there are only three batches available, this means that basis values computing using the ANOVA method are estimates only. However, the RTD data passed the ADK test after applying the modified CV transformation so modified CV basis values are provided for that environment. There were no outliers.

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 the B-basis values are shown graphically in Figure 4-5.

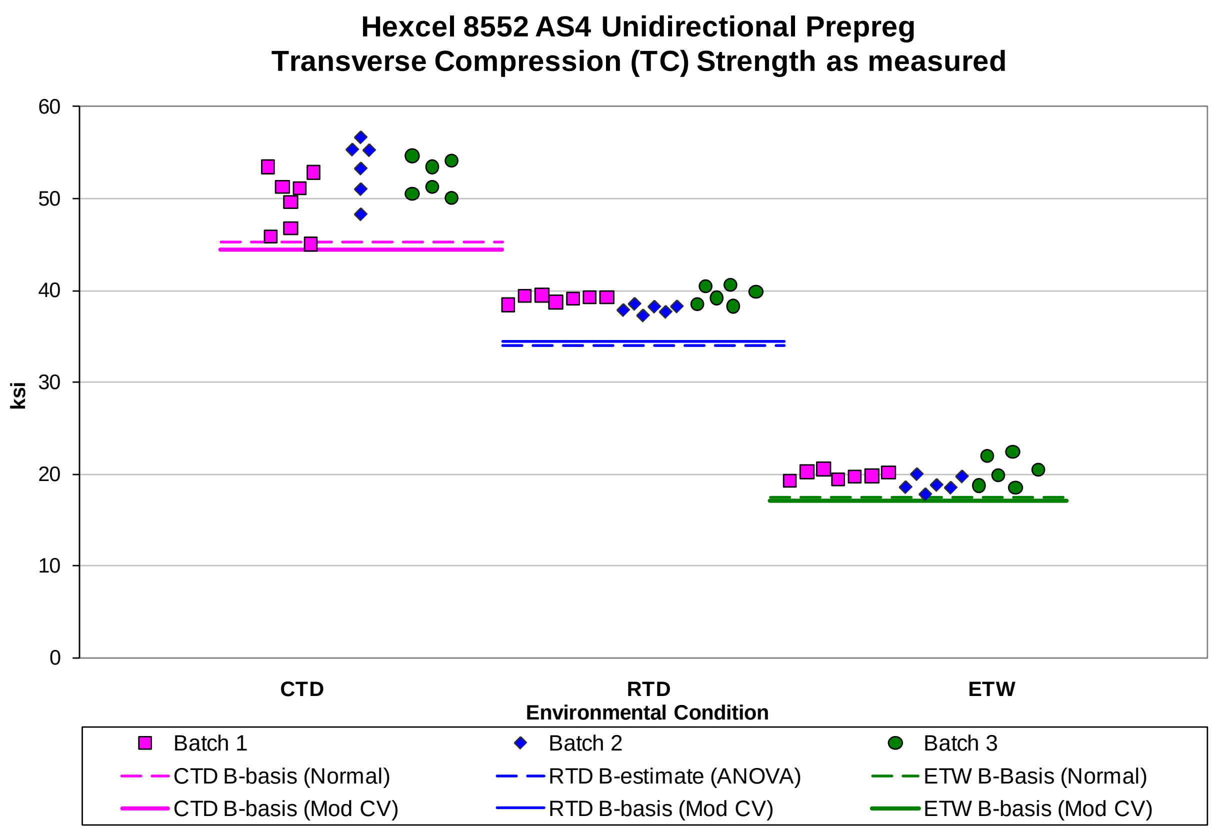

Figure 4-5: Batch Plot for TC strength as measured

Transverse Compression Strength Basis Values and Statistics			
As Measured			
Env	CTD	RTD	ETW
Mean	51.49	38.85	19.71
Stdev	3.22	0.91	1.17
CV	6.25	2.35	5.94
Mod CV	7.13	6.00	6.97
Min	45.06	37.22	17.77
Max	56.60	40.64	22.42
No. Batches	3	3	3
No. Spec.	20	19	19
Basis Values and/or Estimates			
B-basis Value	45.29		17.43
B-estimate		34.07	
A-estimate	40.88	30.65	15.81
Method	Normal	ANOVA	Normal
Modified CV Basis Values and/or Estimates			
B-basis Value	44.42	34.31	17.03
A-estimate	39.40	31.09	15.13
Method	normal	normal	normal

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

Transverse Compression Modulus Statistics			
	As Measured		
Env	CTD	RTD	ETW
Mean	1.56	1.43	1.14
Stdev	0.06	0.04	0.08
CV	3.55	2.94	6.59
Mod CV	6.00	6.00	7.30
Min	1.46	1.37	1.04
Max	1.65	1.50	1.31
No. Batches	3	3	3
No. Spec.	20	19	19

Table 4-9: Statistics from TC Modulus data as measured

4.5 In-Plane Shear Properties (IPS)

In Plane Shear data is not normalized. The 0.2% strength data failed the ADK test for all three environments tested, so only the ANOVA method could be used to compute basis values. Since there are only three batches available, this means that basis values computing using the ANOVA method are estimates only. The data for each of the three environments tested passed the ADK test with the modified CV transform, so modified CV basis values are provided. The data could be pooled across environments for computing the modified CV basis values. There was no problem with the normality of the pooled dataset. Levene's test showed a problem, but the dataset passed that test after the both the transformation for pooling and the transformation for modified CV.

For the 5% strain strength data, there was no data available for the CTD environment. The remaining two environments, RTD and ETW, both fail the ADK test, although the RTD environment data passes the ADK test after the modified CV transform, so modified CV basis values are provided for the RTD environment.

There were two outliers in this dataset. Both were in the RTD environment and both were outliers before, but not after, pooling the three batches for that environment. One outlier was on the low side of batch 1, the other was on the low side of batch 3.

Statistics, basis values and estimates 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 for the 0.2% offset strength in Figure 4-6 and the strength at 5% strain in Figure 4-7.

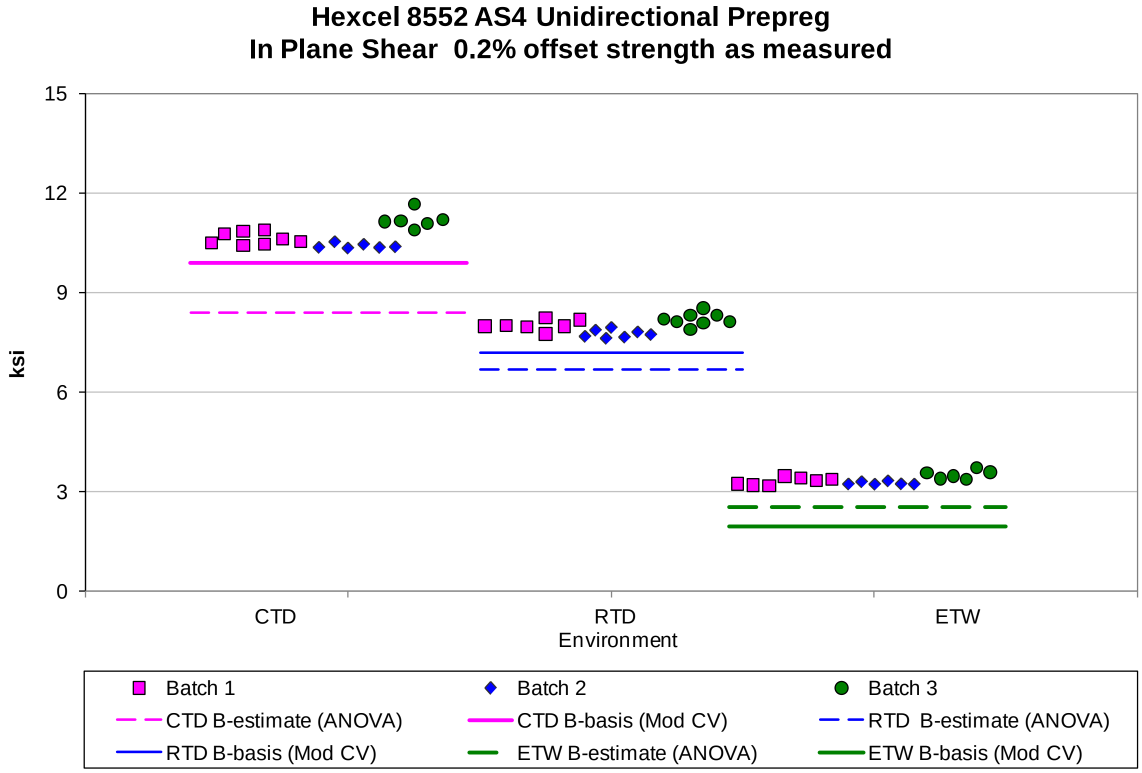

Figure 4-6: Batch plot for IPS for 0.2% offset strength as measured

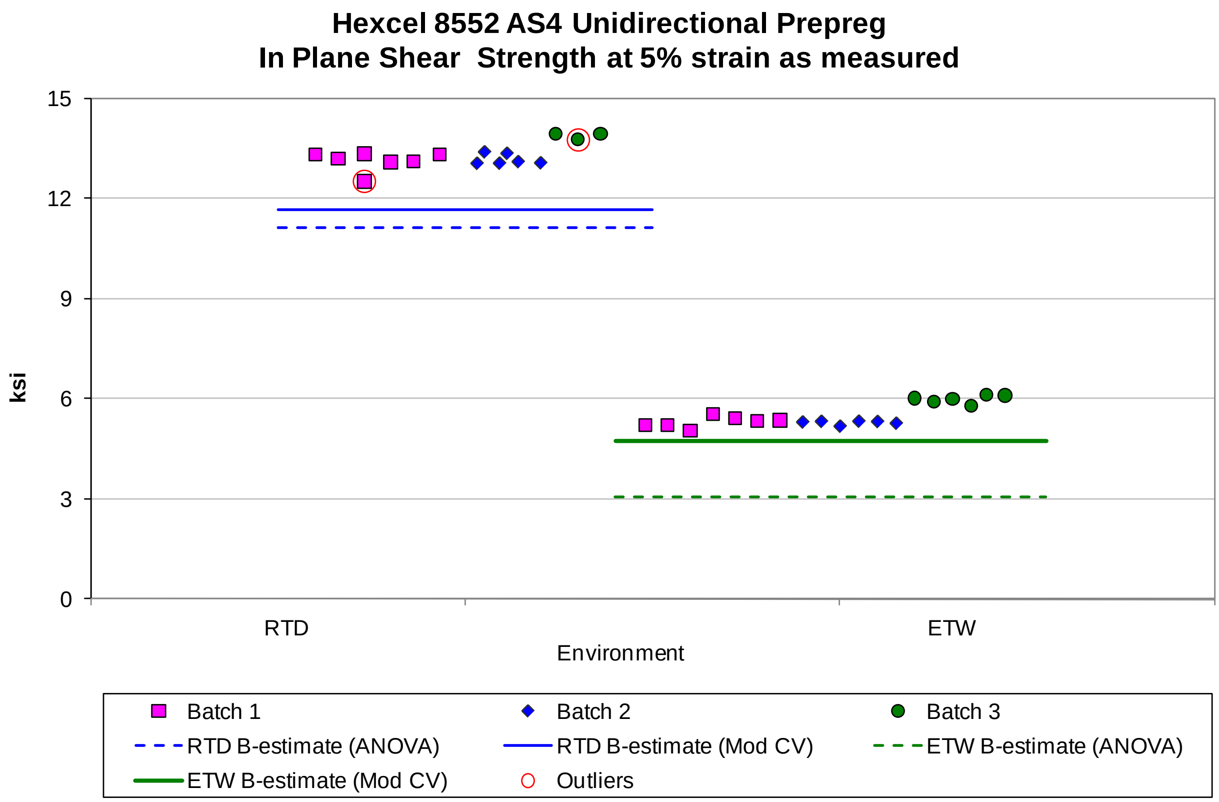

Figure 4-7: Batch plot for IPS for strength at 5% strain as measured

In Plane Shear Strength Basis Values and Statistics					
Strength at 5% Strain			0.2% Offset Strength		
Env	RTD	ETW	CTD	RTD	ETW
Mean	13.28	5.51	10.73	8.00	3.36
Stdev	0.36	0.36	0.37	0.24	0.15
CV	2.74	6.48	3.43	2.98	4.49
Mod CV	6.00	7.24	6.00	6.00	6.25
Min	12.51	5.04	10.35	7.63	3.19
Max	13.95	6.13	11.68	8.53	3.73
No. Batches	3	3	3	3	3
No. Spec.	16	19	20	22	19
Basis Values and/or Estimates					
B-estimate	11.11	3.06	8.40	6.69	2.55
A-estimate	9.56	1.31	6.73	5.75	1.98
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
ModifiedBasis Values and/or Estimates					
B-basis Value			9.89	7.17	2.52
B-estimate	11.66	4.73			
A-estimate	10.52	4.18	9.33	6.60	1.95
Method	normal	normal	pooled	pooled	pooled

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

In Plane Shear Modulus Statistics		
As measured		
CTD	RTD	ETW
0.81	0.70	0.34
0.02	0.02	0.02
2.37	3.41	5.03
6.00	6.00	6.51
0.79	0.66	0.32
0.85	0.75	0.39
3	3	3
20	22	19

Table 4-11: Statistics from IPS Modulus data as measured

4.6 Short Beam Strength (SBS) Data

The Short Beam Shear data is not normalized. The ETD and ETW environment data failed the ADK test, so only the ANOVA method could be used to compute basis values. Since there are only three batches available, this means that basis values computing using the ANOVA method are estimates only. The data for both environments passed the ADK test with the modified CV transform, so modified CV basis values are provided. The modified CV basis values could be computed by pooling across the environments. There was no problem with the normality of the pooled dataset. Levene's test showed a problem, but the dataset passed that test after the both the transformation for pooling and the transformation for modified CV.

There was one outlier. It was in the CTD environment on the low side of batch two. It was an outlier only for batch two, not after pooling the three batches together. Statistics, basis values and estimates are given for SBS strength data in Table 4-12. The data, B-estimates and B-basis values are shown graphically in Figure 4-8.

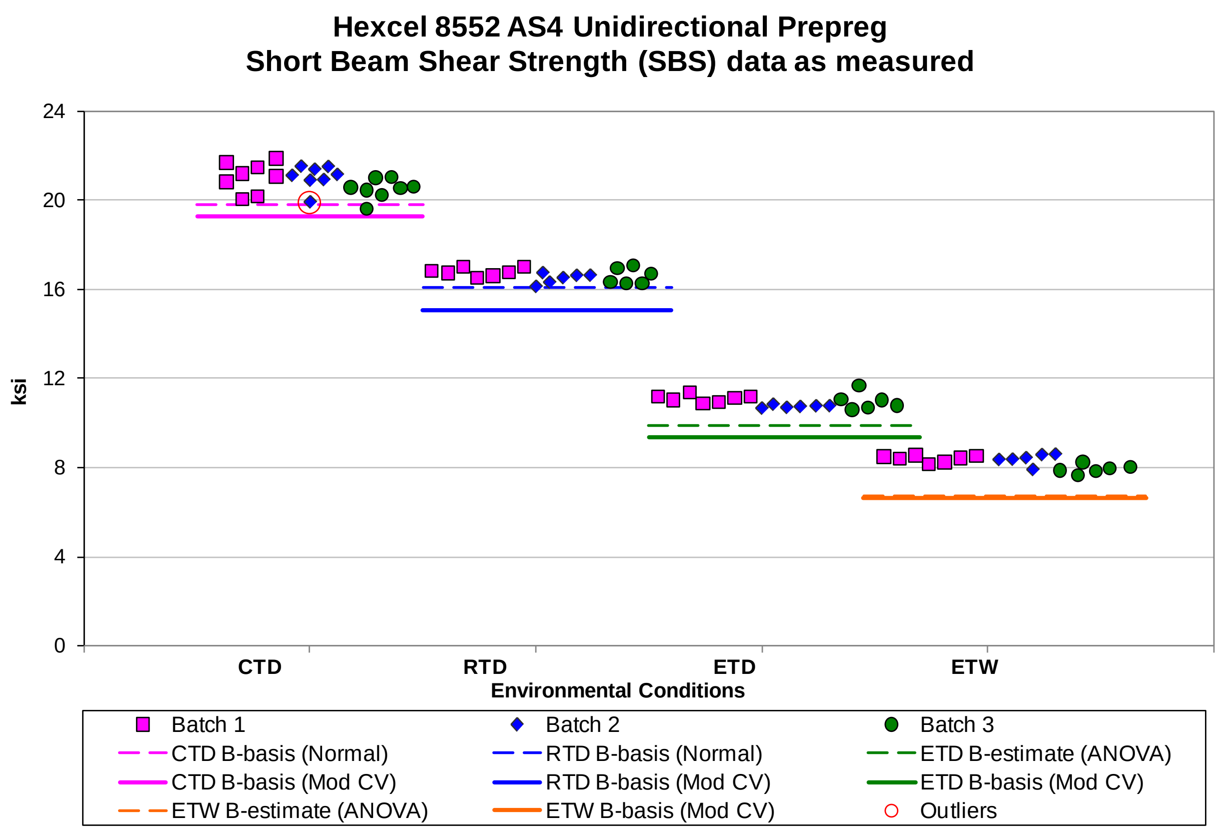

Figure 4-8: Batch plot for SBS as measured

Short Beam Shear (SBS) Strength (ksi) Basis Values and Statistics				
As Measured				
Env	CTD	RTD	ETD	ETW
Mean	20.87	16.63	10.95	8.25
Stdev	0.59	0.28	0.27	0.29
CV	2.82	1.68	2.50	3.52
Mod CV	6.00	6.00	6.00	6.00
Min	19.61	16.12	10.60	7.65
Max	21.87	17.06	11.68	8.60
No. Batches	3	3	3	3
No. Spec.	24	19	19	19
Basis Values and/or Estimates				
B-basis Value	19.78	16.09		
B-estimate			9.92	6.70
A-estimate	19.00	15.70	9.19	5.59
Method	Normal	Normal	ANOVA	ANOVA
Modified CV Basis Values and/or Estimates				
B-basis Value	19.30	15.03	9.35	6.65
A-estimate	18.24	13.98	8.29	5.59
Method	pooled	pooled	pooled	pooled

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

4.7 Unnotched Tension Properties (UNT0)

There were no outliers or test failures. Pooling across environments was permissible. Statistics, basis values and estimates 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 4-9.

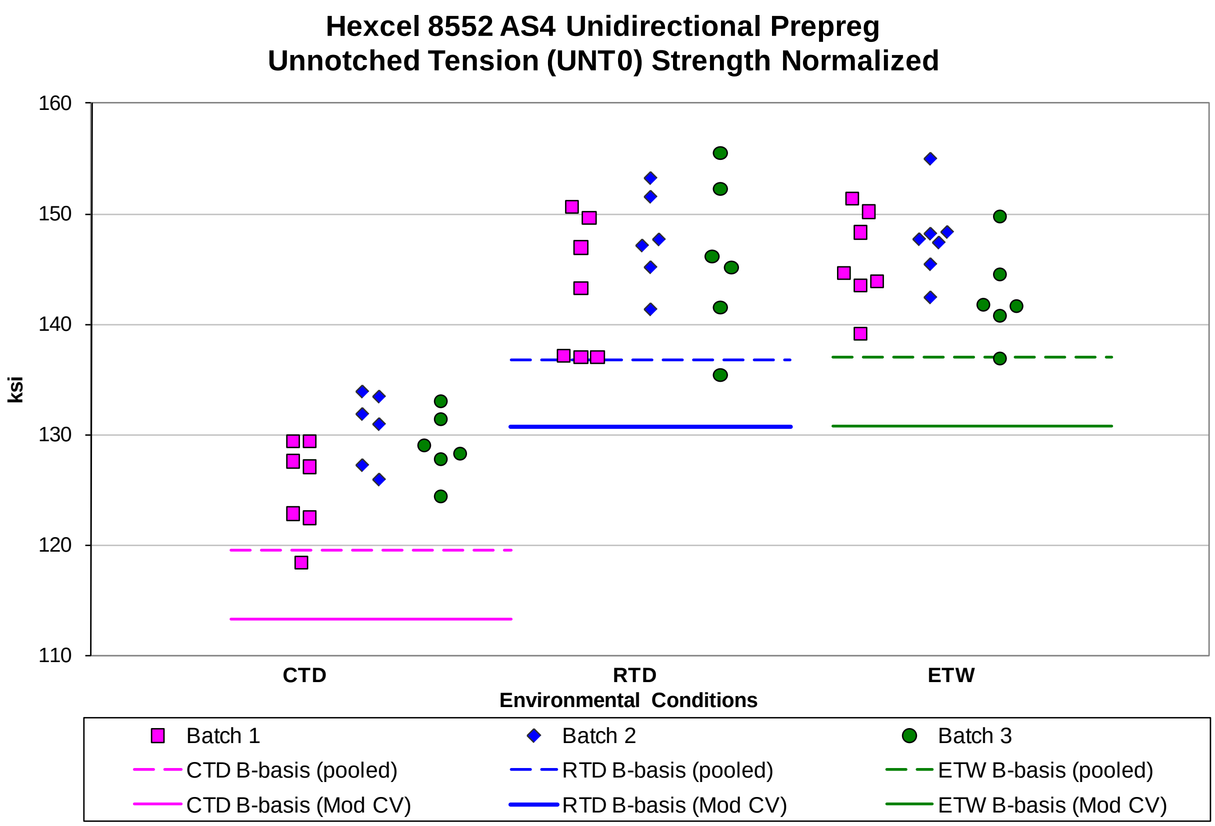

Figure 4-9: Batch Plot for UNT0 normalized strength

Unnotched Tension (UNT0) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	128.14	145.45	145.54	129.69	149.48	148.42
Stdev	4.07	6.01	4.47	4.25	6.76	5.36
CV	3.18	4.13	3.07	3.28	4.52	3.61
Modified CV	6.00	6.07	6.00	6.00	6.26	6.00
Min	118.40	135.40	136.89	120.40	136.34	137.12
Max	133.92	155.51	154.94	137.24	164.11	158.97
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	20	19	19	20
Basis Values and/or Estimates						
B-basis Value	119.52	136.83	136.96	119.96	139.75	138.74
A-estimate	113.75	131.06	131.18	113.44	133.23	132.21
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	113.35	130.65	130.82	114.42	134.21	133.22
A-estimate	103.44	120.75	120.89	104.19	123.97	122.98
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	9.70	9.77	9.81	9.82	10.04	10.00
Stdev	0.15	0.25	0.18	0.16	0.40	0.18
CV	1.53	2.58	1.88	1.62	3.96	1.80
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	9.48	9.38	9.47	9.54	9.59	9.63
Max	10.08	10.33	10.18	10.25	11.29	10.35
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	20	19	19	20

Table 4-14: Statistics from UNT0 Modulus data

4.8 Unnotched Compression Properties (UNC0)

There were no test failures or outliers. Statistics, basis values and estimates are given for strength data in Table 4-15 and for the modulus data in Table 4-16. The normalized data and the B-basis values are shown graphically in Figure 4-10.

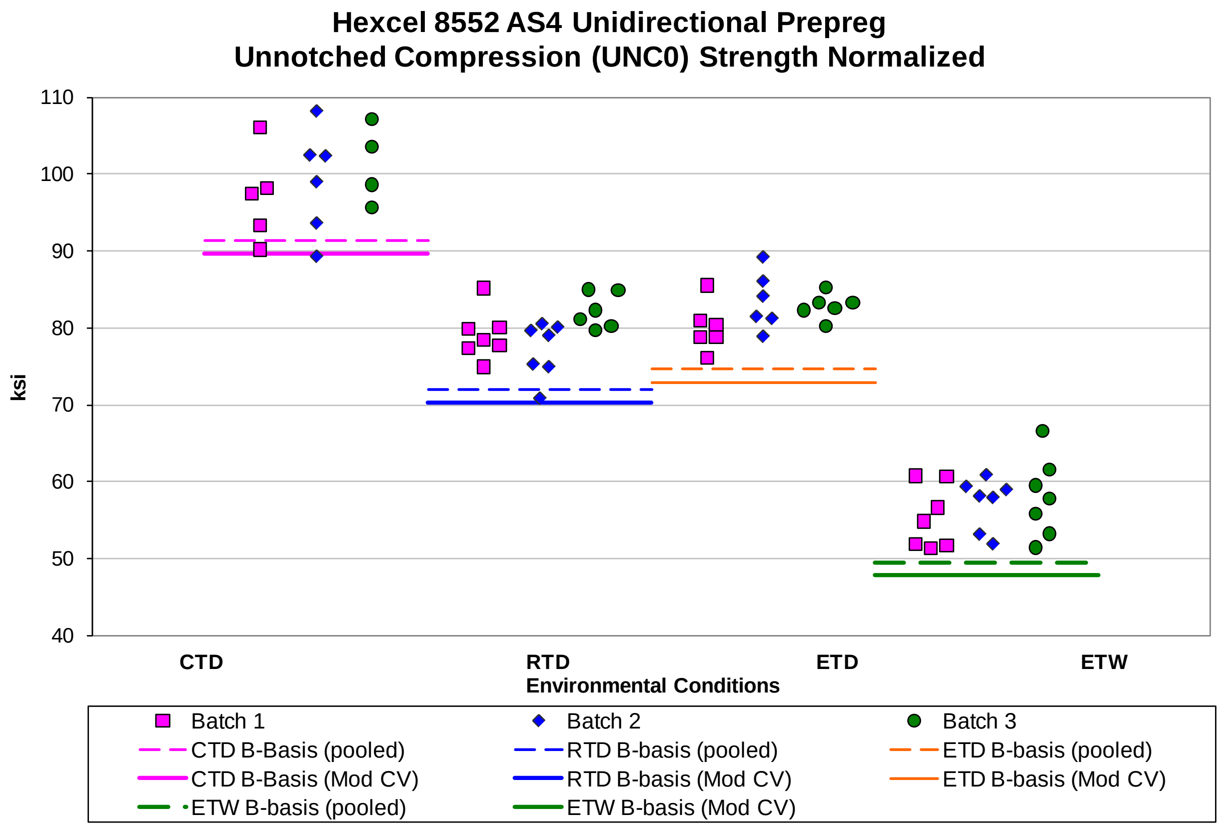

Figure 4-10: Batch Plot for UNC0 normalized strength

Unnotched Compression (UNC0) Strength Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	99.02	79.36	82.13	56.86	100.79	83.85	83.69	59.95
Stdev	5.93	3.63	3.18	4.20	6.14	4.65	3.25	5.00
CV	5.99	4.57	3.87	7.38	6.09	5.54	3.89	8.35
Modified CV	7.00	6.28	6.00	7.69	7.05	6.77	6.00	8.35
Min	89.26	70.79	76.08	51.38	91.69	75.96	77.48	52.36
Max	108.17	85.22	89.17	66.60	112.08	94.42	90.37	68.50
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	15	20	18	21	15	20	18	21
Basis Values and/or Estimates								
B-basis Value	91.46	72.02	74.72	49.56	92.24	75.56	75.31	51.70
A-estimate	86.60	67.13	69.84	44.66	86.74	70.02	69.79	46.15
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-basis Value	89.66	70.28	72.96	47.82	90.72	74.08	73.81	50.22
A-estimate	83.65	64.22	66.92	41.76	84.24	67.56	67.31	43.69
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	6.26	6.16	6.21	5.96	6.36	6.50	6.33	6.12
Stdev	0.20	0.25	0.16	0.39	0.22	0.22	0.18	0.40
CV	3.18	4.02	2.59	6.57	3.46	3.45	2.77	6.54
Mod CV	6.00	6.01	6.00	7.29	6.00	6.00	6.00	7.27
Min	5.73	5.56	5.83	5.12	5.83	6.06	5.89	5.22
Max	6.52	6.50	6.47	6.43	6.73	6.93	6.57	6.91
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	20	19	19	19	20	19	19

Table 4-16: Statistics from UNC0 Modulus data

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

5.1 Quasi Isotropic Unnotched Tension Properties (UNT1)

The data from the ETW environment failed the ADK test, so only the ANOVA method could be used to compute basis values. Since there are only three batches available, this means that basis values computing using the ANOVA method are estimates only. However, the ETW data passed the ADK test with the modified CV transform, so modified CV basis values are provided. The pooled data failed Levene's test, so pooling across environments was not appropriate.

There were three outliers altogether, two in the as measured data and the third outlier in the normalized data. In the as measured data, one outlier was on the low side of batch 3 in the CTD environment and the other outlier was on the low side of batch 2 in the ETW environment. The outlier in the normalized data was on the high side of batch 2 in the CTD environment. All three were outliers before, but not after, pooling the three batches for their respective environments. All three outliers were retained for this analysis.

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

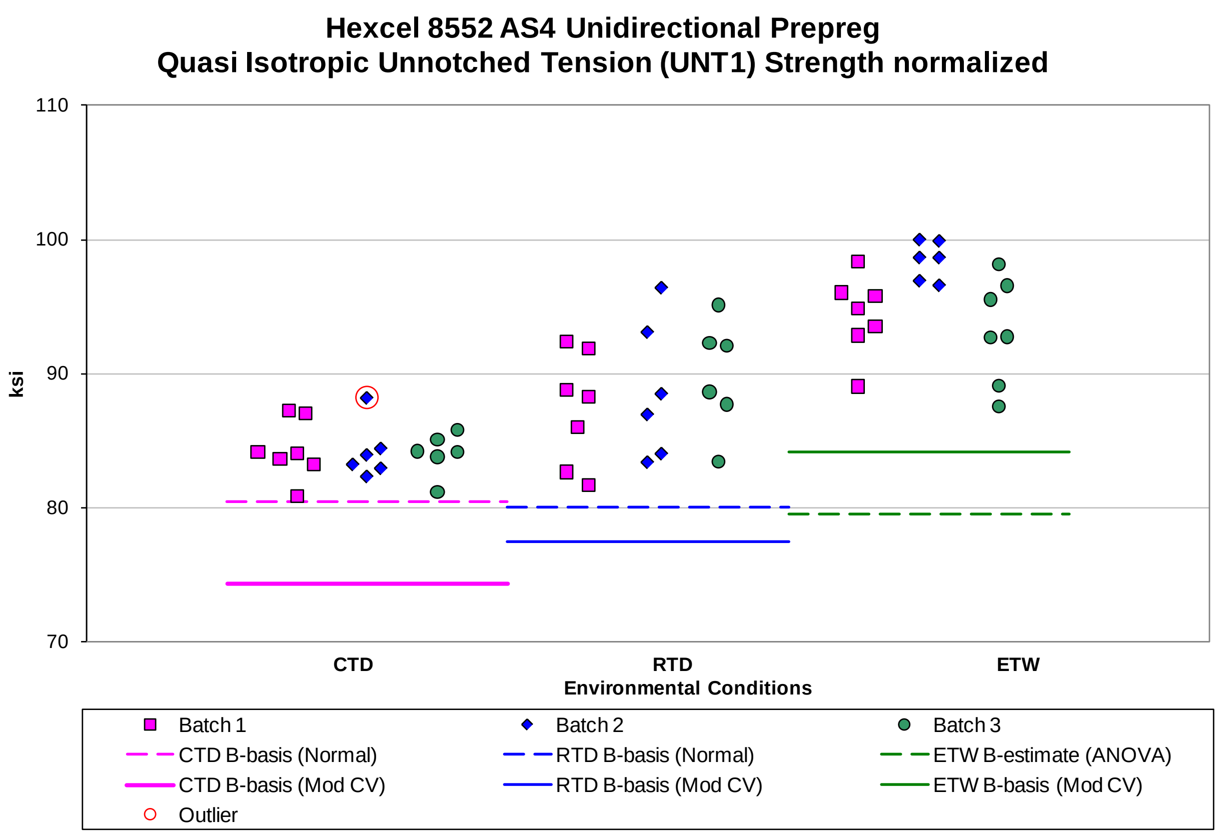

Figure 5-1: Batch Plot for UNT1 normalized strength

Unnotched Tension (UNT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	84.21	88.61	95.18	85.14	90.09	95.91
Stdev	1.89	4.35	3.62	1.98	3.76	3.64
CV	2.24	4.91	3.80	2.33	4.17	3.80
Modified CV	6.00	6.45	6.00	6.00	6.09	6.00
Min	80.88	81.73	87.53	81.70	83.50	88.21
Max	88.20	96.39	99.96	89.81	96.03	100.76
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	20	19	19	20
Basis Values and/or Estimates						
B-basis Value	80.53	80.13		81.28	82.77	
B-estimate			79.56			79.67
A-estimate	77.91	74.12	68.42	78.53	77.56	68.09
Method	Normal	Normal	ANOVA	Normal	Normal	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	74.36	77.46	84.18	75.18	79.41	84.82
A-estimate	67.38	69.56	76.36	68.12	71.83	76.94
Method	normal	normal	normal	normal	normal	normal

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	7.03	6.96	6.61	7.11	7.08	6.66
Stdev	0.14	0.12	0.19	0.15	0.18	0.17
CV	2.02	1.76	2.80	2.16	2.56	2.53
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	6.82	6.69	6.30	6.91	6.85	6.35
Max	7.34	7.16	7.01	7.43	7.53	6.99
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	20	19	19	20

Table 5-2: Statistics from UNT1 Modulus data

5.2 "Soft" Unnotched Tension Properties (UNT2)

The data from the ETW environment failed the ADK test, so only the ANOVA method could be used to compute basis values. Since there are only three batches available, this means that basis values computing using the ANOVA method are estimates only. However, the ETW data passed the ADK test with the modified CV transform, so modified CV basis values are provided. The normalized data could be pooled across the three environments to compute the modified CV basis values.

There were two outliers. One outlier was in the CTD environment, on the low side of batch three. It was an outlier both before and after pooling the three batches of CTD data. It was an outlier in both the as measured and the normalized data. The second outlier was an outlier for the as measured data only. It was on the low side of batch one in the ETW environment. It was an outlier only after pooling the three batches of ETW data.

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.

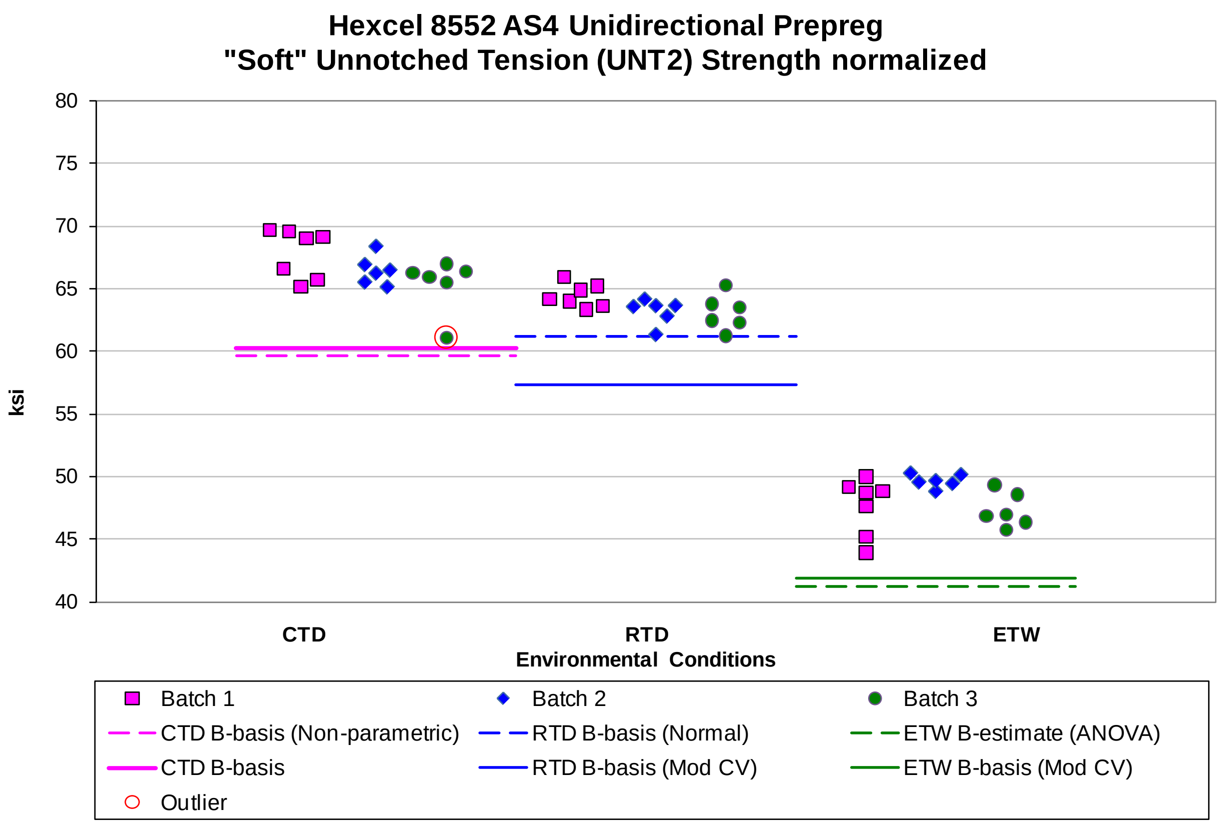

Figure 5-2: Batch Plot for UNT2 normalized strength

Unnotched Tension (UNT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	66.61	63.62	48.17	67.21	64.14	48.37
Stdev	2.00	1.24	1.82	1.71	1.01	1.92
CV	3.00	1.95	3.79	2.54	1.57	3.96
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	61.11	61.25	43.93	62.36	62.78	43.13
Max	69.66	65.91	50.26	69.84	66.24	50.51
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	19	19	19	19
Basis Values and/or Estimates						
B-basis Value	59.58	61.20		63.88	62.17	
B-estimate			41.18			40.23
A-estimate	50.68	59.49	36.20	61.51	60.77	34.42
Method	Non-parametric	Normal	ANOVA	Normal	Normal	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	60.29	57.30	41.85	59.35	56.64	42.72
A-estimate	56.06	53.07	37.61	53.78	51.32	38.71
Method	pooled	pooled	pooled	normal	normal	normal

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	4.72	4.53	3.76	4.76	4.57	3.77
Stdev	0.09	0.10	0.12	0.09	0.09	0.12
CV	1.93	2.10	3.15	1.98	1.99	3.10
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	4.59	4.32	3.47	4.58	4.43	3.45
Max	4.86	4.69	3.90	4.93	4.72	3.92
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	19	19	19	19

Table 5-4: Statistics from UNT2 Modulus data

5.3 "Hard" Unnotched Tension Properties (UNT3)

The data from normalized pooled dataset failed the normality test, which means that pooling across environments is not appropriate. However, the normalized data could be pooled for the modified CV basis values and the as measured data could be pooled across the three environments.

There were three outliers, one in the normalized data and two in the as measured data. The outlier in the normalized dataset was on the high side of batch three in the ETW environment. It was an outlier only before pooling the data from the three batches for the ETW environment. In the as measured data, one outlier was on the high side of batch three in the CTD environment, the other was on the low side of batch two in the RTD environment. Both were outliers only after pooling the data from the three batches.

Statistics, basis values and estimates 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.

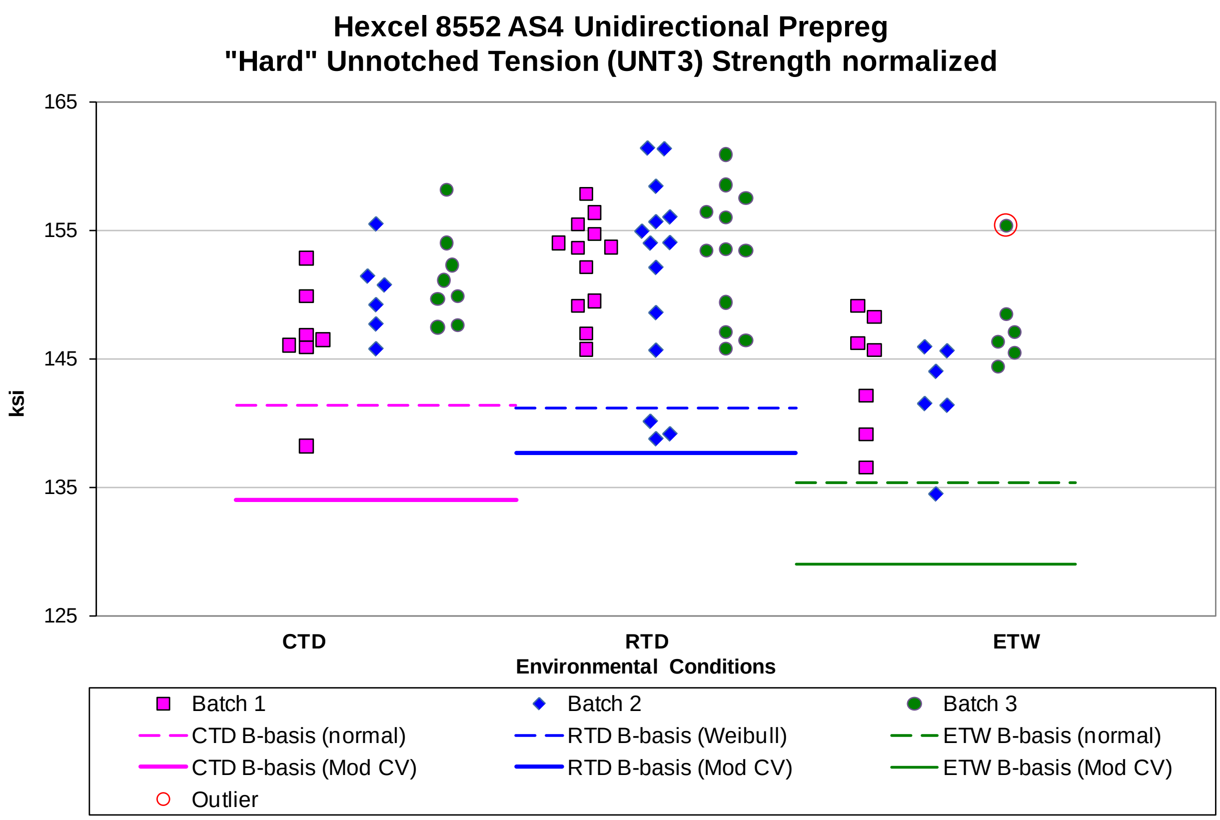

Figure 5-3: Batch Plot for UNT3 normalized strength

Unnotched Tension (UNT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	149.38	152.32	144.59	151.36	154.86	145.49
Stdev	4.19	5.82	4.75	4.14	4.82	4.79
CV	2.81	3.82	3.29	2.73	3.11	3.29
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	138.21	138.75	134.44	144.34	140.06	134.96
Max	158.16	161.42	155.38	162.75	163.00	155.70
No. Batches	3	3	3	3	3	3
No. Spec.	21	38	19	21	38	19
Basis Values and/or Estimates						
B-basis Value	141.39	141.23	135.33	143.42	147.30	137.47
A-estimate	135.70	128.95	128.75	138.10	141.91	132.16
Method	Normal	Weibull	Normal	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	134.01	137.68	129.07	135.78	140.03	129.76
A-estimate	123.71	127.25	118.80	125.35	129.45	119.35
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	10.53	10.55	10.41	10.67	10.73	10.48
Stdev	0.19	0.28	0.18	0.21	0.35	0.16
CV	1.82	2.66	1.72	1.99	3.27	1.54
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	10.26	9.92	10.17	10.36	10.44	10.27
Max	11.08	11.62	10.78	11.29	12.60	10.82
No. Batches	3	3	3	3	3	3
No. Spec.	21	39	20	21	39	20

Table 5-6: Statistics from UNT3 Modulus data

5.4 Quasi Isotropic Unnotched Compression 1 (UNC1)

The normalized RTD data and the ETW data (both normalized and as measured) fail the ADK test, so only the ANOVA method could be used to compute basis values. Since there are only three batches available, this means that basis values computing using the ANOVA method are estimates only. Estimates computed using the modified CV method are provided for the normalized RTD data and the ETW data, both normalized and as measured. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method. The normalized RTD and ETW data could be pooled to compute these modified CV basis value estimates.

There were two outliers, both in the RTD condition. One outlier was on the high side of batch one (it was an outlier in both the normalized and as measured datasets), the other was on the high side of the normalized data for batch three. Both were outliers only within that batch, not after pooling the three batches of RTD data together. Both outliers were 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 the B-estimates are shown graphically in Figure 5-4.

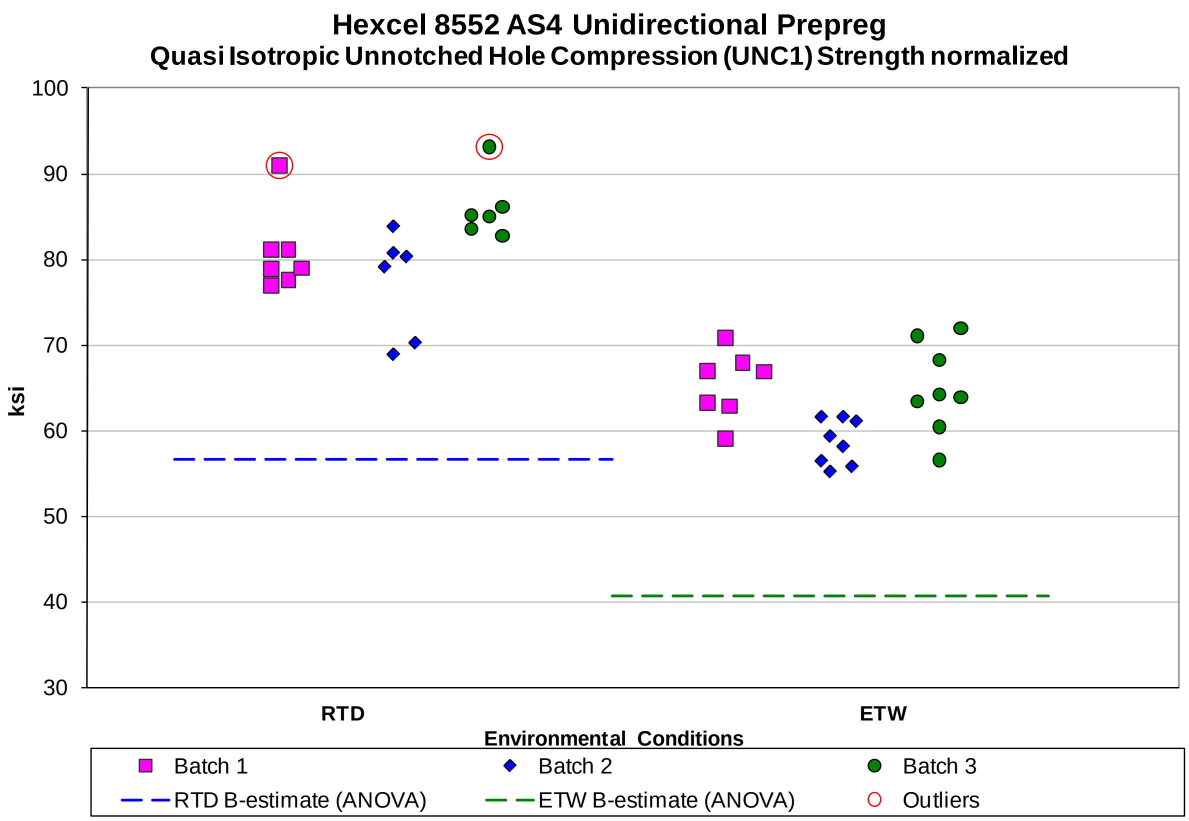

Figure 5-4: Batch plot for UNC1 normalized strength

Unnotched Compression (UNC1) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	81.32	62.93	84.27	64.34
Stdev	5.88	5.00	4.96	4.82
CV	7.22	7.95	5.89	7.50
Modified CV	7.61	7.97	6.94	7.75
Min	68.96	55.29	75.75	56.80
Max	93.16	71.96	96.41	74.12
No. Batches	3	3	3	3
No. Spec.	19	23	19	23
Basis Values and/or Estimates				
B-basis Value			74.60	
B-estimate	56.66	40.65		41.43
A-estimate	39.08	24.74	67.73	25.07
Method	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates				
B-basis Value			72.86	
B-estimate	71.34	53.12		55.02
A-estimate	64.56	46.30	64.78	48.36
Method	pooled	pooled	normal	normal

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

Unnotched Compression (UNC1) Modulus				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	6.43	6.30	6.66	6.40
Stdev	0.28	0.18	0.24	0.17
CV	4.32	2.93	3.57	2.68
Modified CV	6.16	6.00	6.00	6.00
Min	5.85	5.98	6.20	6.14
Max	6.97	6.69	7.33	6.72
No. Batches	3	3	3	3
No. Spec.	19	19	19	19

Table 5-8: Statistics from UNC1 Modulus data

5.5 "Soft" Unnotched Compression (UNC2)

The normalized RTD data did not pass the test for normality, but the pooled dataset did, so pooling the two environments is acceptable. There was one outlier, it was in the normalized RTD environment. It was on the low side of batch three. It was an outlier only for batch three, not for the three RTD batches pooled together. It was retained for this analysis.

Statistics, basis values and estimates 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.

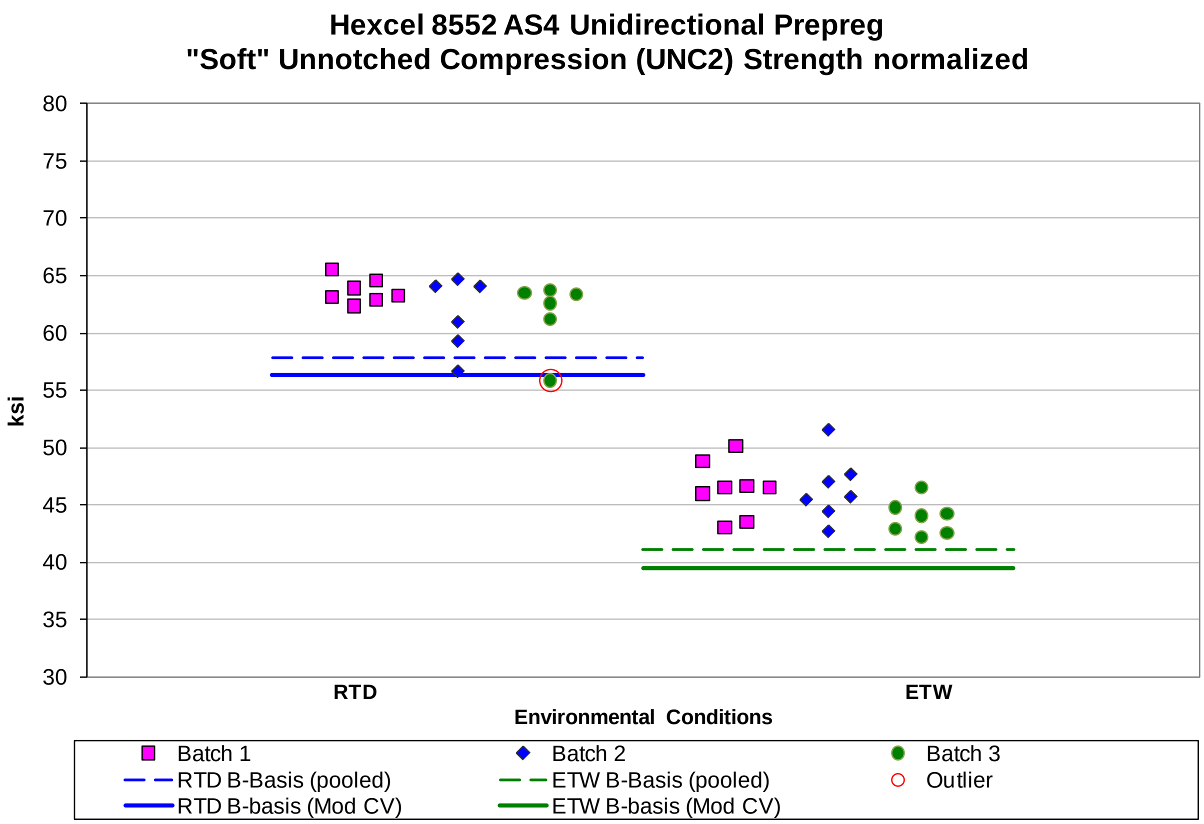

Figure 5-5: Batch plot for UNC2 normalized strength

Unnotched Compression (UNC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	62.42	45.60	65.39	46.55
Stdev	2.60	2.49	3.00	2.78
CV	4.17	5.46	4.58	5.97
Modified CV	6.08	6.73	6.29	6.99
Min	55.87	42.20	59.18	42.76
Max	65.53	51.58	69.42	53.58
No. Batches	3	3	3	3
No. Spec.	19	22	19	22
Basis Values and/or Estimates				
B-basis Value	57.87	41.11	60.22	41.45
A-estimate	54.77	37.99	56.71	37.92
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates				
B-basis Value	56.28	39.54	58.80	40.05
A-estimate	52.11	35.35	54.32	35.55
Method	pooled	pooled	pooled	pooled

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

Unnotched Compression (UNC2) Modulus				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	4.30	3.84	4.51	3.93
Stdev	0.13	0.10	0.14	0.11
CV	3.08	2.69	3.05	2.69
Modified CV	6.00	6.00	6.00	6.00
Min	4.03	3.67	4.14	3.71
Max	4.49	4.01	4.72	4.11
No. Batches	3	3	3	3
No. Spec.	19	19	19	19

Table 5-10: Statistics from UNC2 Modulus data

5.6 "Hard" Unnotched Compression (UNC3)

There were no outliers or test failures. 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.

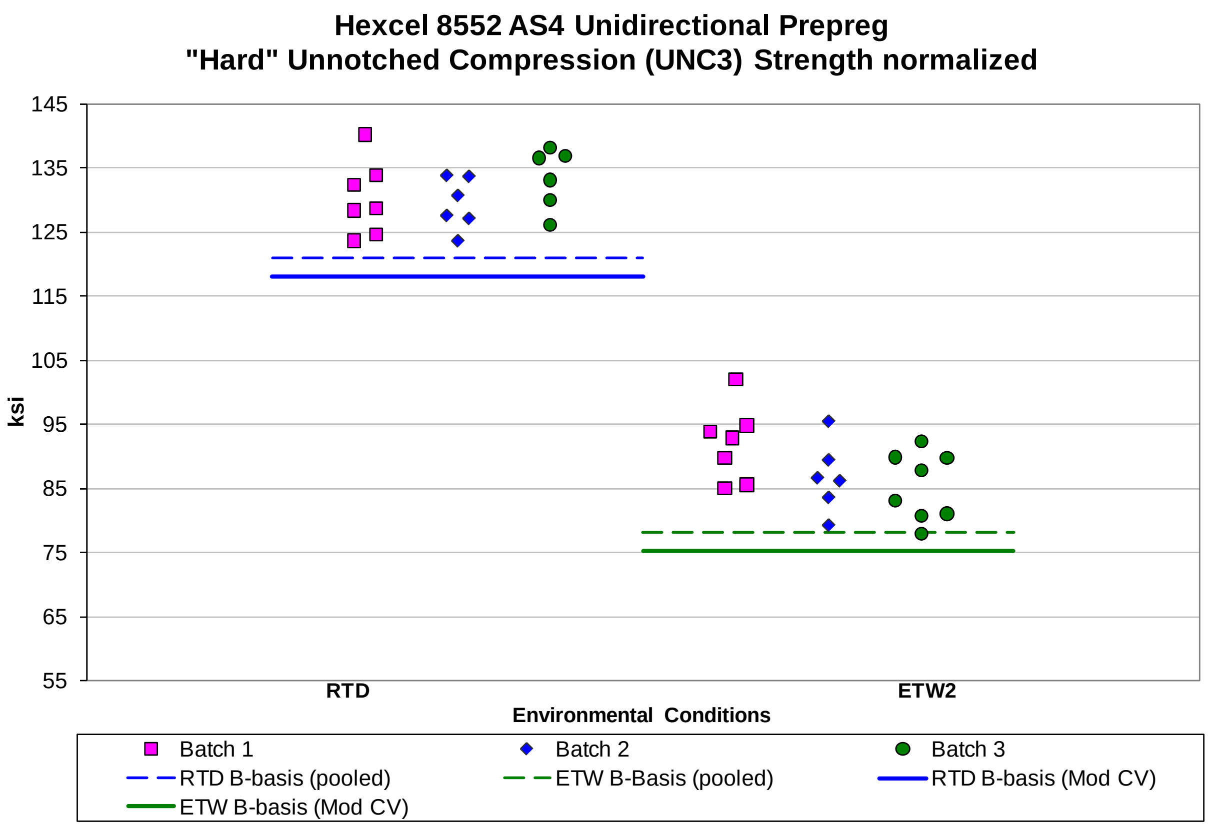

Figure 5-6: Batch plot for UNC3 normalized strength

Unnotched Compression (UNC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	131.05	88.01	134.64	89.16
Stdev	4.96	6.04	6.11	5.76
CV	3.79	6.86	4.54	6.46
Modified CV	6.00	7.43	6.27	7.23
Min	123.68	78.03	124.11	78.81
Max	140.28	102.09	146.13	101.71
No. Batches	3	3	3	3
No. Spec.	19	21	19	21
Basis Values and/or Estimates				
B-basis Value	121.08	78.12	123.99	78.61
A-estimate	114.28	71.31	116.74	71.33
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates				
B-basis Value	118.13	75.20	121.24	75.88
A-estimate	109.32	66.37	112.12	66.73
Method	pooled	pooled	pooled	pooled

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

Unnotched Compression (UNC3) Modulus				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	9.63	9.59	9.89	9.69
Stdev	0.26	0.19	0.23	0.18
CV	2.71	1.98	2.32	1.86
Modified CV	6.00	6.00	6.00	6.00
Min	9.04	9.14	9.60	9.31
Max	9.98	10.02	10.52	10.03
No. Batches	3	3	3	3
No. Spec.	19	19	19	19

Table 5-12: Statistics from UNC3 Modulus data

5.7 Quasi Isotropic Open Hole Tension Properties (OHT1)

The data from the ETW environment both normalized and as measured, did not pass the test for normality. However, the pooled dataset did pass the normality test, so pooling the three environments is acceptable.

There were three outliers altogether. One outlier in the RTD condition for the as measured data only. This was an outlier before, but not after, pooling the three batches of RTD data together.

There were two outliers in the ETW condition. One outlier was on the high side of batch one. This was an outlier both before and after pooling the three batches of normalized ETW data, but it was only an outlier after pooling the three batches of as measured data. The second outlier in the ETW data was on the high side of batch two. This was an outlier both before and after pooling the three batches of normalized ETW data, but it was only an outlier before pooling the three batches of as measured data.

All outliers were retained for this analysis. Statistics, basis values and estimates are given for OHT1 strength data in Table 5-13. The normalized data and the B-basis values are shown graphically in Figure 5-7.

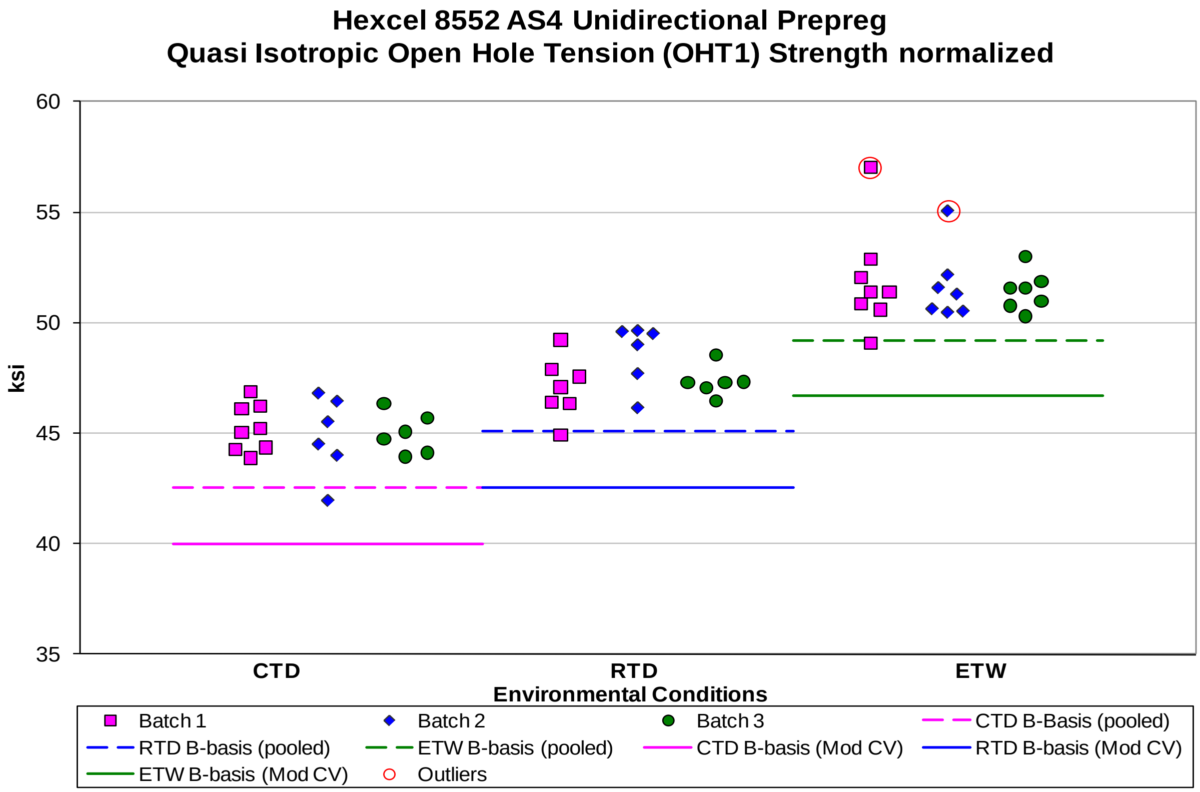

Figure 5-7: Batch Plot for OHT1 normalized strength

Open Hole Tension (OHT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	45.05	47.63	51.68	45.27	47.84	51.79
Stdev	1.23	1.33	1.68	1.25	1.45	1.80
CV	2.74	2.79	3.26	2.76	3.04	3.48
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	41.95	44.91	49.09	43.34	44.86	48.62
Max	46.87	49.64	57.02	47.29	49.85	56.81
No. Batches	3	3	3	3	3	3
No. Spec.	20	19	22	20	19	22
Basis Values and/or Estimates						
B-basis Value	42.55	45.11	49.20	42.60	45.16	49.14
A-estimate	40.86	43.43	47.51	40.81	43.37	47.35
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	40.01	42.56	46.68	40.20	42.75	46.77
A-estimate	36.61	39.17	43.28	36.80	39.35	43.35
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

5.8 "Soft" Open Hole Tension Properties (OHT2)

The as measured data for the CTD environment did not pass the normality test. However, the pooled dataset did pass the normality test, so pooling across the environments is acceptable. There were no test failures for the normalized data and pooling across the environments was acceptable. There was one outlier. It was in the as measured data only. The lowest value in batch two of the as measured RTD data was an outlier before, but not after, pooling the three batches of RTD data.

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

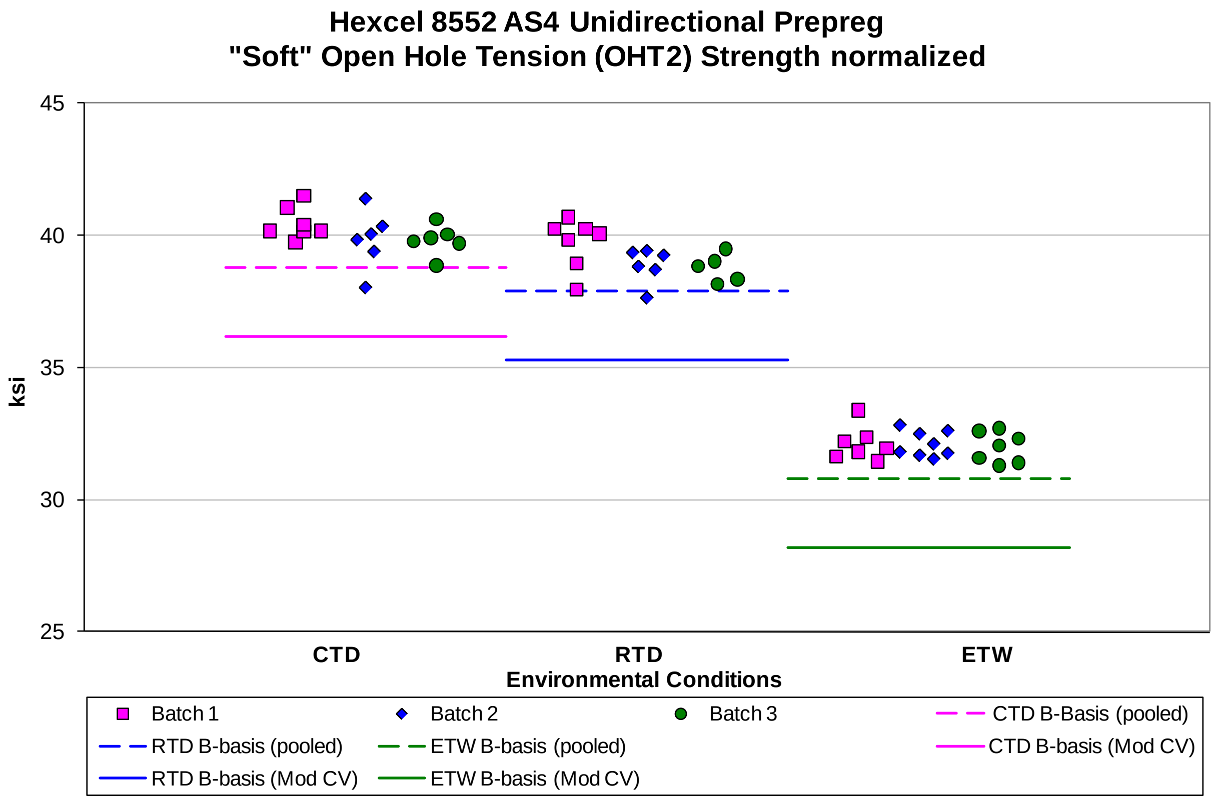

Figure 5-8: Batch Plot for OHT2 normalized strength

Open Hole Tension (OHT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	40.06	39.17	32.08	41.21	40.13	32.55
Stdev	0.81	0.84	0.54	0.69	0.59	0.59
CV	2.02	2.16	1.69	1.67	1.48	1.81
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	38.03	37.64	31.30	40.30	38.57	31.55
Max	41.51	40.69	33.38	42.45	41.00	33.61
No. Batches	3	3	3	3	3	3
No. Spec.	19	18	22	19	18	22
Basis Values and/or Estimates						
B-basis Value	38.77	37.88	30.81	40.11	39.03	31.47
A-estimate	37.91	37.02	29.95	39.38	38.30	30.73
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	36.17	35.26	28.24	37.23	36.13	28.62
A-estimate	33.57	32.66	25.63	34.57	33.47	25.95
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

5.9 "Hard" Open Hole Tension Properties (OHT3)

There were no test failures, so pooling across environments was acceptable. There were no outliers. Statistics, basis values and estimates are given for OHT3 strength data in Table 5-15. The normalized data and the B-basis values are shown graphically in Figure 5-9.

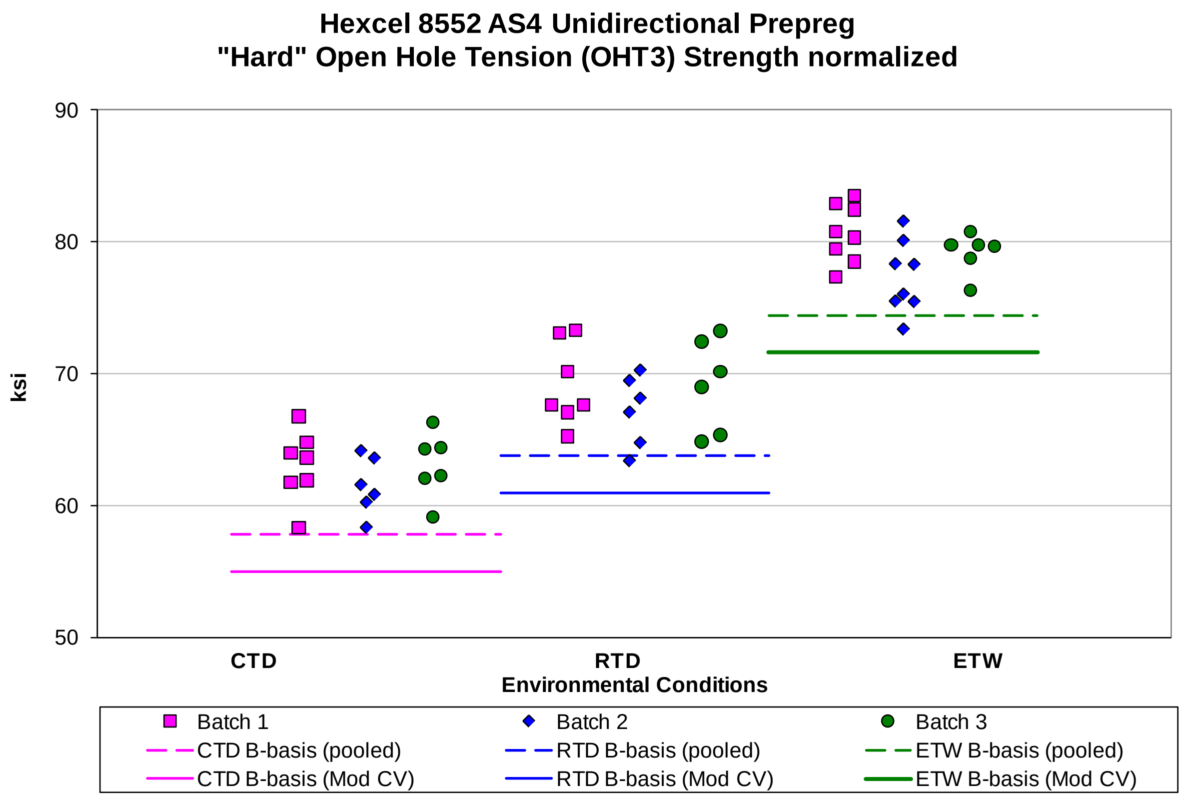

Figure 5-9: Batch Plot for OHT3 normalized strength

Open Hole Tension (OHT3) Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	62.56	68.55	79.07	63.95	70.28	80.38
Stdev	2.45	3.08	2.59	2.47	2.87	2.46
CV	3.92	4.50	3.27	3.87	4.09	3.06
Modified CV	6.00	6.25	6.00	6.00	6.05	6.00
Min	58.33	63.42	73.42	59.60	66.04	75.00
Max	66.78	73.31	83.51	67.21	76.53	84.43
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	22	19	19	22
Basis Value Estimates						
B-basis Value	57.81	63.80	74.39	59.40	65.72	75.89
A-estimate	54.64	60.63	71.20	56.36	62.68	72.84
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	55.03	61.02	71.64	56.34	62.66	72.87
A-estimate	49.99	55.98	66.58	51.25	57.57	67.76
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

5.10 Quasi Isotropic Filled Hole Tension (FHT1)

Only the normalized RTD data passes the ADK test for batch-to-batch variation, so only the ANOVA method could be used to compute basis values for all other datasets. Since there are only three batches available, this means that basis values computing using the ANOVA method are estimates only. However, all the datasets passed the ADK test with the modified CV transform, so modified CV basis values are provided, but pooling across environments was not appropriate for the normalized data due to a normality test failure of the transformed data.

There was one outlier. In was on the high side of batch two in the as measured ETW dataset. It was not an outlier in the normalized ETW dataset. It was an outlier only after pooling the three batches of ETW data. It was retained for this analysis.

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

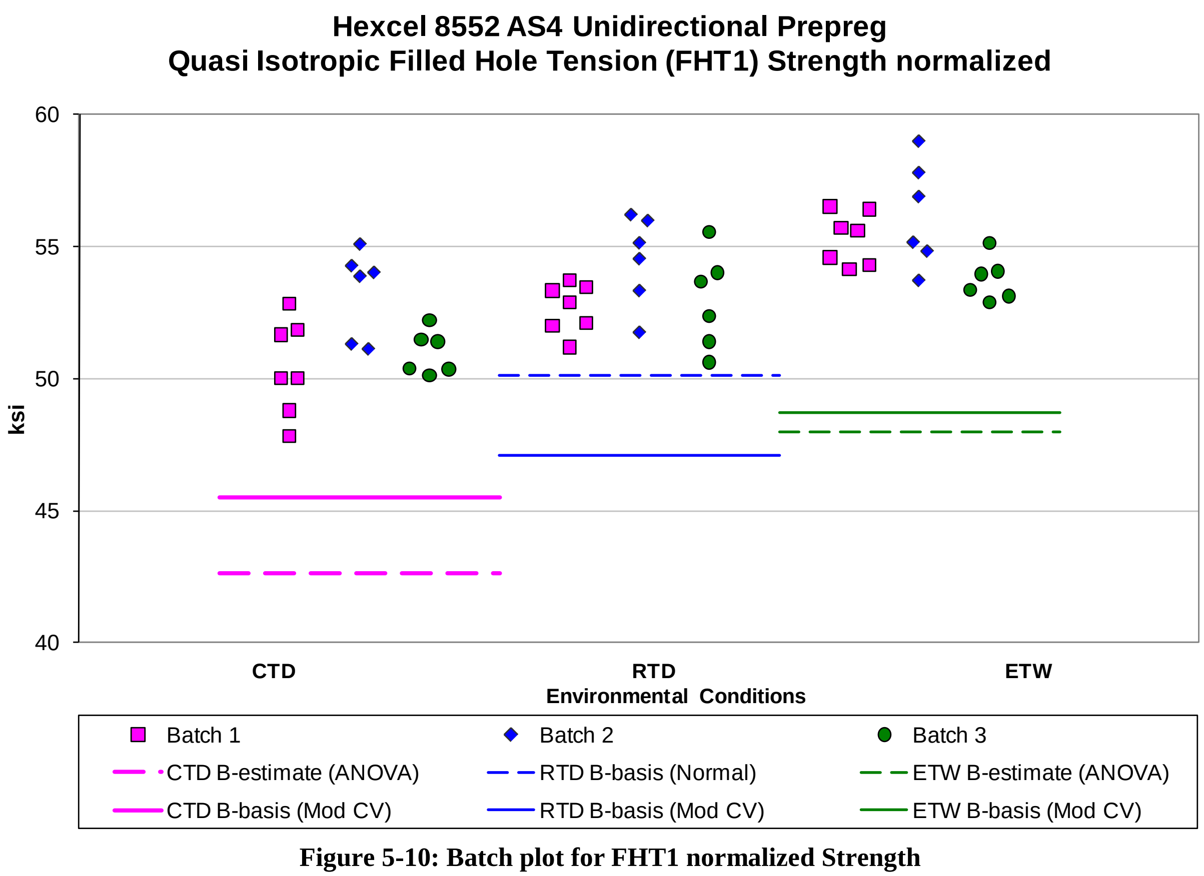

Figure 5-10: Batch plot for FHT1 normalized Strength

Filled-Hole Tension (FHT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	51.52	53.35	55.13	52.75	54.62	55.73
Stdev	1.91	1.64	1.63	2.09	1.65	1.73
CV	3.70	3.08	2.97	3.96	3.02	3.11
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	47.83	50.62	52.91	49.50	51.22	53.83
Max	55.12	56.23	59.02	56.62	57.50	60.38
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	19	19	19	19
Basis Values and/or Estimates						
B-basis Value		50.14				
B-estimate	42.64		47.99	39.59	47.35	48.09
A-estimate	36.30	47.87	42.90	30.20	42.16	42.65
Method	ANOVA	Normal	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	45.50	47.11	48.68	47.02	48.89	50.00
A-estimate	41.22	42.68	44.11	43.18	45.05	46.16
Method	normal	normal	normal	pooled	pooled	pooled

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

5.11 "Soft" Filled Hole Tension (FHT2)

The FHT2 data had no test failures or outliers. Pooling across environments was acceptable. Statistics, basis values and estimates 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.

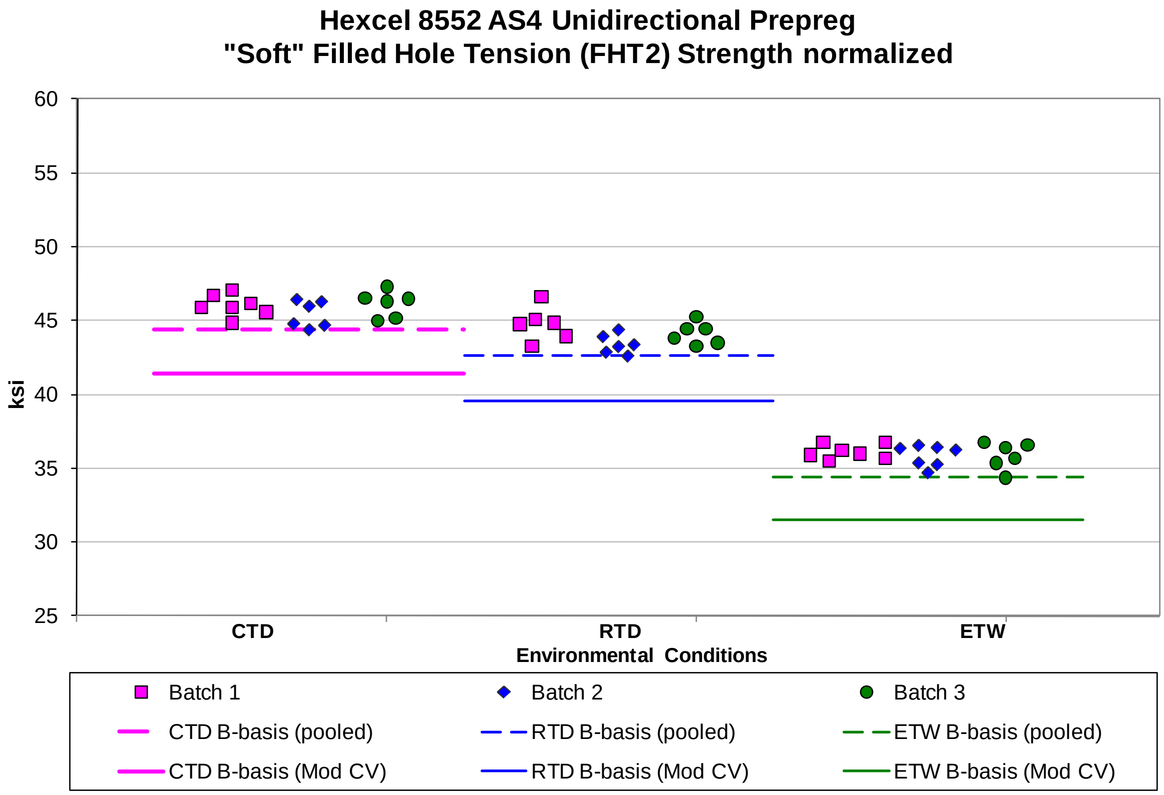

Figure 5-11: Batch plot for FHT2 normalized Strength

Filled-Hole Tension (FHT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	45.86	44.08	35.93	46.72	44.65	36.46
Stdev	0.85	1.01	0.69	0.66	0.86	0.69
CV	1.86	2.29	1.92	1.41	1.91	1.89
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	44.35	42.57	34.36	45.44	43.41	34.98
Max	47.28	46.62	36.77	47.96	46.70	37.43
No. Batches	3	3	3	3	3	3
No. Spec.	19	18	20	19	18	20
Basis Values and/or Estimates						
B-basis Value	44.36	42.58	34.44	45.43	43.36	35.17
A-estimate	43.35	41.57	33.44	44.56	42.49	34.30
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	41.43	39.63	31.53	42.22	40.13	31.98
A-estimate	38.46	36.67	28.56	39.21	37.12	28.96
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

5.12 "Hard" Filled Hole Tension (FHT3)

The normalized CTD data failed the ADK test, so only the ANOVA method could be used to compute basis values. Since there are only three batches available, this means that basis values computing using the ANOVA method are estimates only. However, the normalized CTD dataset passed the ADK test with the modified CV transform, so modified CV basis values are provided. Pooling was acceptable for the modified CV transformed data.

There were three outliers, two in the as measured data and one in the normalized data. In the as measured data, one outlier was on the low side of batch three in the CTD data. The second outlier in the as measured data was on the high side of batch one in the ETW data. The normalized data had one outlier on the low side of batch two in the CTD environment. Each of these outliers were outliers only before the three batches were pooled for their respective environments. All of these outliers were retained for this analysis.

Statistics, basis values and estimates 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.

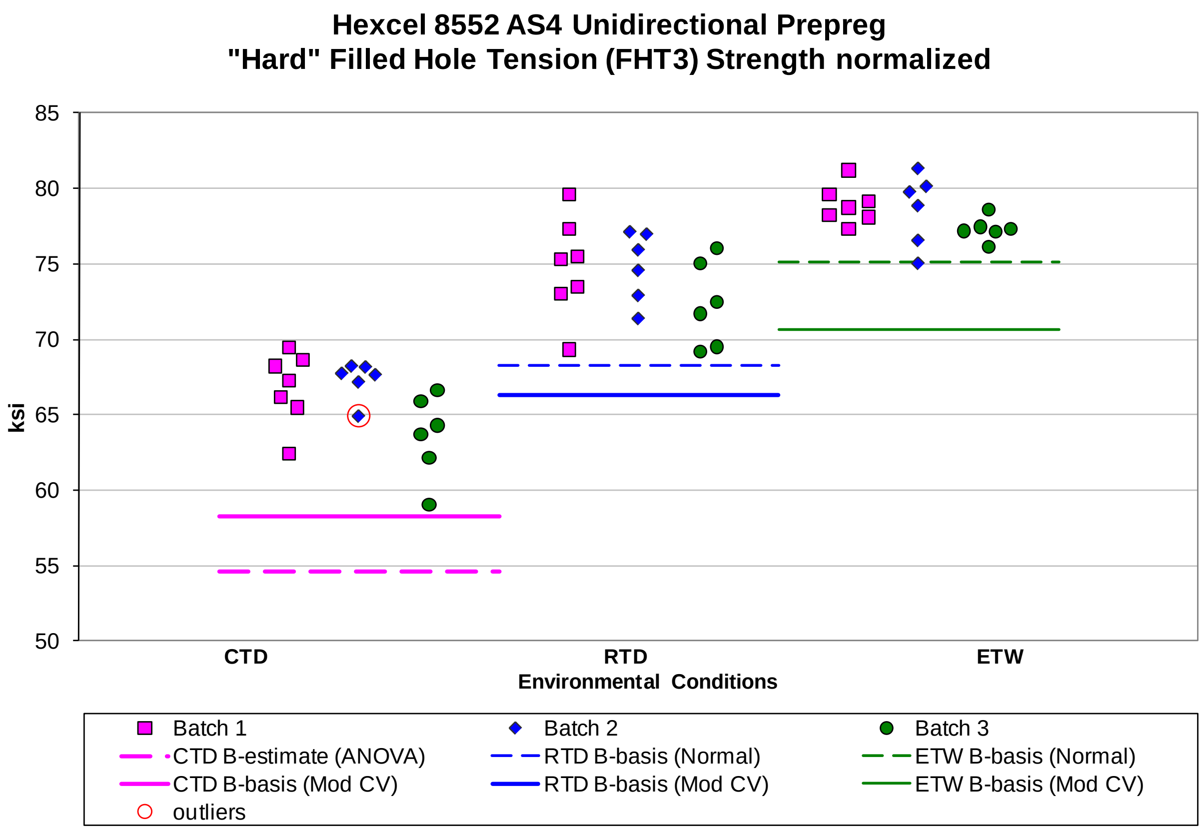

Figure 5-12: Batch plot for FHT3 normalized Strength

Filled-Hole Tension (FHT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	65.96	74.02	78.30	67.78	75.29	79.37
Stdev	2.66	2.94	1.66	2.50	2.69	1.73
CV	4.04	3.98	2.12	3.68	3.58	2.19
Modified CV	6.02	6.00	6.00	6.00	6.00	6.00
Min	59.07	69.21	75.02	62.20	69.81	75.93
Max	69.46	79.63	81.30	72.05	79.83	82.71
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	19	19	19	19
Basis Values and/or Estimates						
B-basis Value		68.28	75.07	63.66	71.18	75.25
B-estimate	54.60					
A-estimate	46.49	64.21	72.77	60.90	68.42	72.49
Method	ANOVA	Normal	Normal	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	58.28	66.33	70.61	59.95	67.47	71.54
A-estimate	53.12	61.18	65.46	54.71	62.22	66.30
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

5.13 Quasi Isotropic Open Hole Compression 1 (OHC1)

There were no test failures or outliers in the normalized data. The as measured RTD environment and pooled dataset failed the normality test so pooling was unacceptable for the as measured data. There was one outlier in the as measured data. It was on the high side of batch three in the RTD environment. It was an outlier only within batch 3, not after pooling the three batches of RTD data together.

Statistics, B-basis values and A-estimates 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.

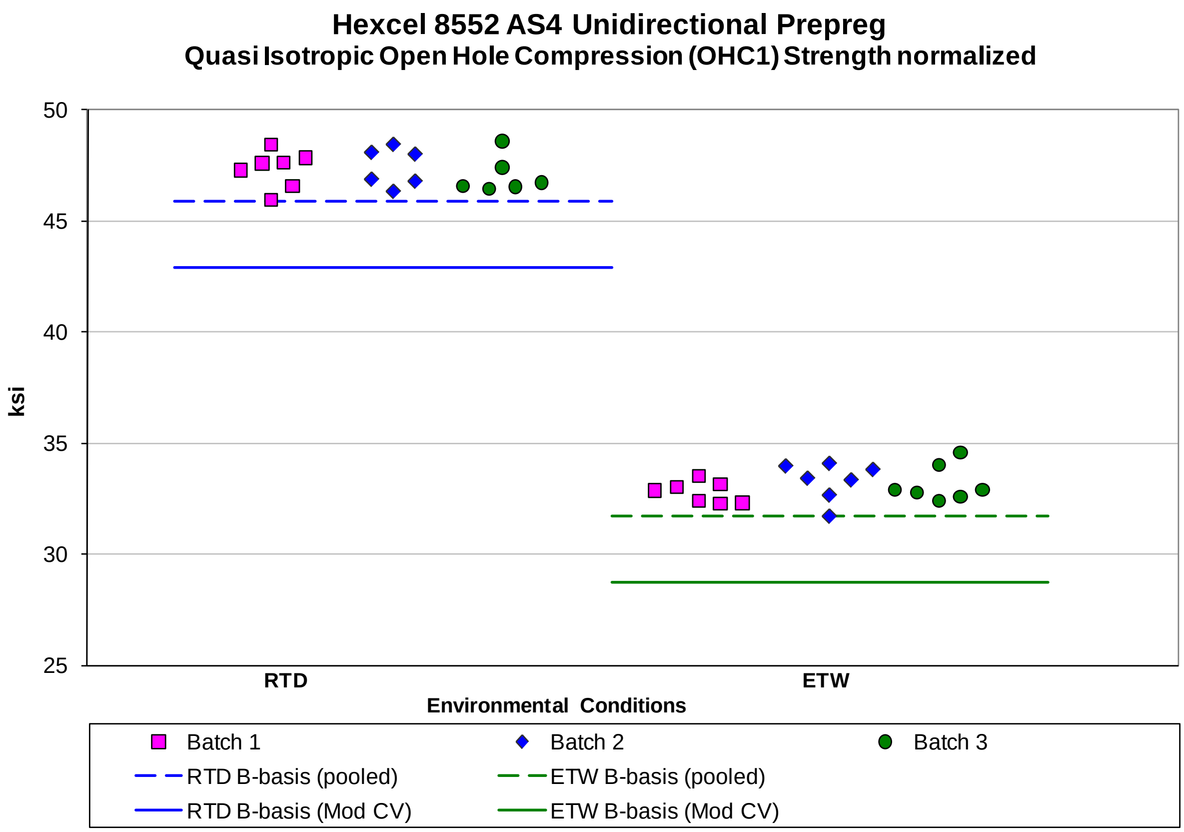

Figure 5-13: Batch plot for OHC1 normalized strength

Open Hole Compression (OHC1) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	47.28	33.09	47.82	33.46
Stdev	0.81	0.73	0.96	0.97
CV	1.72	2.19	2.00	2.91
Modified CV	6.00	6.00	6.00	6.00
Min	45.95	31.72	46.63	32.05
Max	48.61	34.61	49.72	35.52
No. Batches	3	3	3	3
No. Spec.	19	21	19	21
Basis Values and/or Estimates				
B-basis Value	45.90	31.73	46.38	31.60
A-estimate	44.96	30.78	42.54	30.28
Method	pooled	pooled	Non-parametric	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value	42.92	28.77	42.23	29.63
A-estimate	39.95	25.79	38.26	26.91
Method	pooled	pooled	normal	normal

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

5.14 "Soft" Open Hole Compression (OHC2)

The as measured data from the RTD environment failed the normality test, but the as measured pooled data was acceptably normal, so pooling was appropriate for the as measured dataset. Despite the data from both environments passing the normality test individually, the normalized pooled dataset did not, so pooling was not appropriate for the normalized dataset. There were no outliers.

Statistics, basis values and estimates 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.

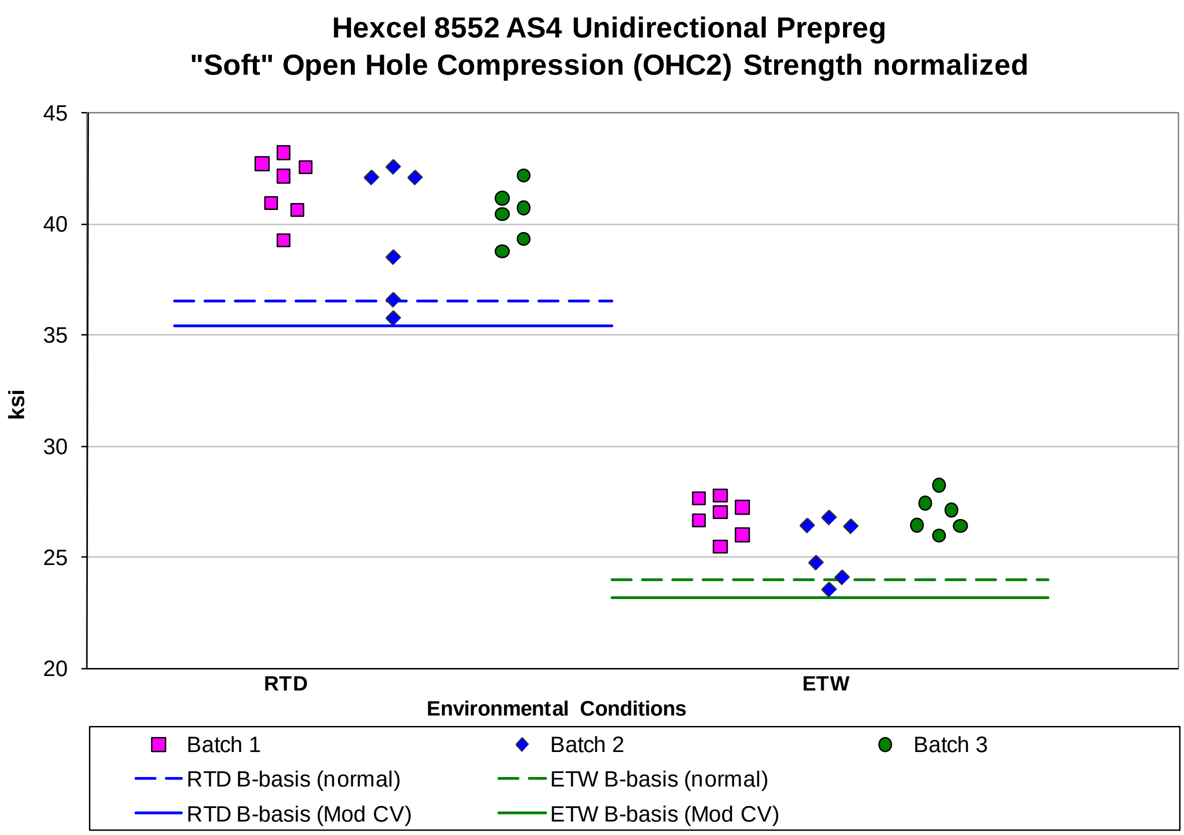

Figure 5-14: Batch plot for OHC2 normalized strength

Open-Hole Compression (OHC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	40.63	26.41	41.78	27.02
Stdev	2.10	1.22	1.55	0.93
CV	5.17	4.63	3.70	3.43
Modified CV	6.59	6.32	6.00	6.00
Min	35.78	23.56	39.03	25.11
Max	43.23	28.26	43.67	28.67
No. Batches	3	3	3	3
No. Spec.	19	19	19	19
Basis Values and/or Estimates				
B-basis Value	36.54	24.02	39.48	24.72
A-estimate	33.63	22.33	37.91	23.15
Method	Normal	Normal	pooled	pooled
Modified CV Basis Values and/or Estimates				
B-basis Value	35.42	23.16	37.97	23.22
A-estimate	31.72	20.85	35.37	20.61
Method	normal	normal	pooled	pooled

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

5.15 "Hard" Open Hole Compression (OHC3)

The data from the ETW condition (normalized and as measured) failed ADK test for batch-to-batch variation, so only the ANOVA method could be used to compute basis values. Since there are only three batches available, this means that basis values computing using the ANOVA method are estimates only. However, the ETW data passed the ADK test with the modified CV transform, so modified CV basis values are provided.

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

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

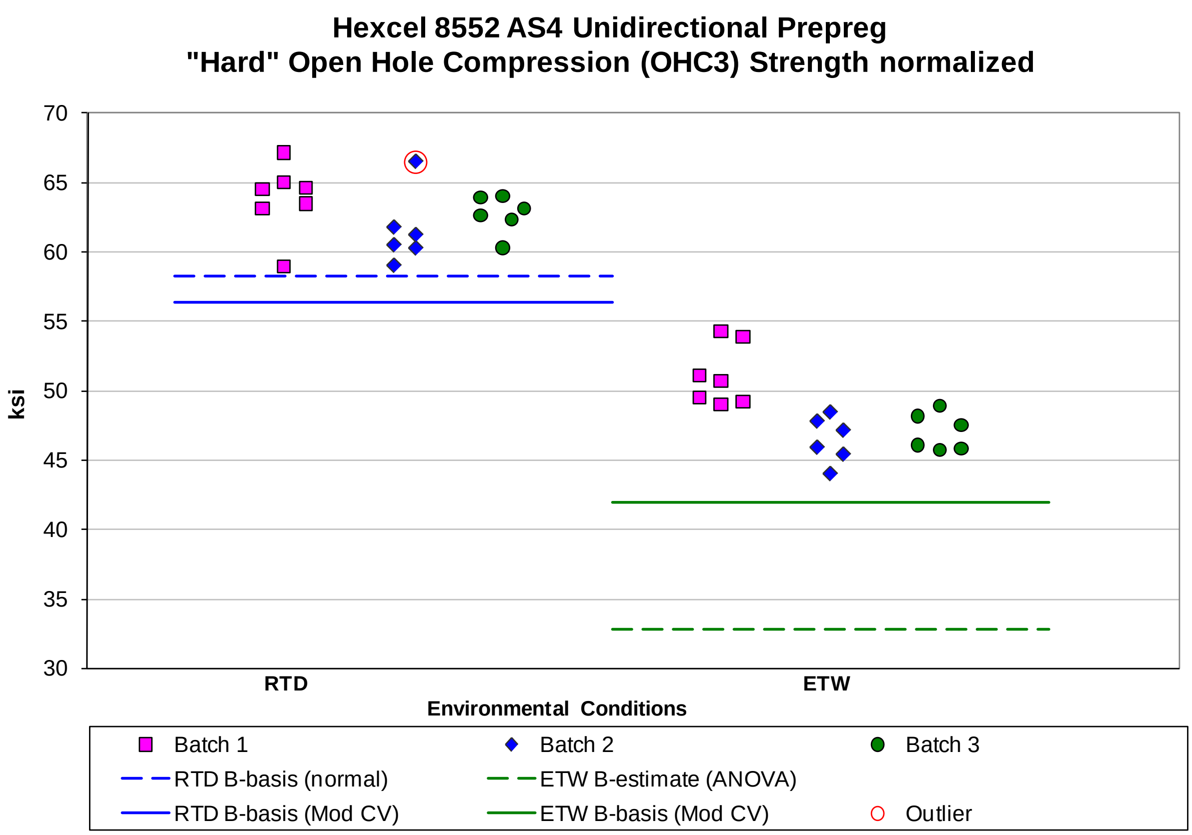

Figure 5-15: Batch plot for OHC3 normalized strength

Open-Hole Compression (OHC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	62.78	48.36	64.09	49.32
Stdev	2.34	2.76	2.25	2.45
CV	3.73	5.70	3.51	4.97
Modified CV	6.00	6.85	6.00	6.48
Min	58.95	44.01	60.88	45.74
Max	67.17	54.31	67.57	54.11
No. Batches	3	3	3	3
No. Spec.	19	19	19	19
Basis Values and/or Estimates				
B-basis Value	58.22		59.71	
B-estimate		32.77		34.84
A-estimate	54.98	21.64	56.60	24.50
Method	Normal	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates				
B-basis Value	56.38	41.96	57.71	42.94
A-estimate	52.01	37.59	53.36	38.58
Method	pooled	pooled	pooled	pooled

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

5.16 Quasi Isotropic Filled Hole Compression (FHC1)

The FHC1 data had no test failures or outliers. Pooling across environments was acceptable. Statistics, basis values and estimates are given for FHC1 strength data in Table 5-22. The normalized data and the B-basis values are shown graphically in Figure 5-16.

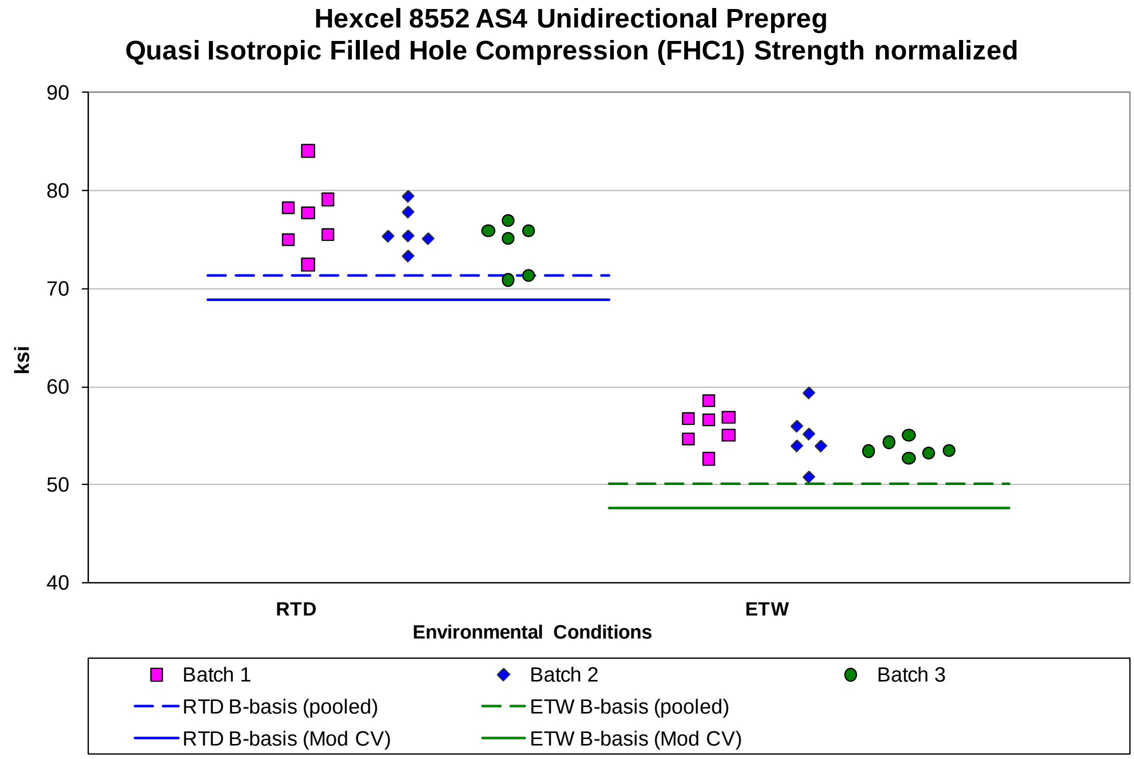

Figure 5-16: Batch plot for FHC1 normalized Strength

Filled-Hole Compression (FHC1) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	76.02	54.87	78.08	56.04
Stdev	3.08	2.11	3.06	1.80
CV	4.05	3.85	3.92	3.21
Modified CV	6.02	6.00	6.00	6.00
Min	70.91	50.76	72.19	53.81
Max	84.08	59.33	84.80	60.79
No. Batches	3	3	3	3
No. Spec.	19	19	19	19
Basis Values and/or Estimates				
B-basis Value	71.27	50.11	73.56	51.51
A-estimate	68.02	46.86	70.46	48.42
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates				
B-basis Value	68.83	47.68	70.73	48.69
A-estimate	63.92	42.76	65.70	43.66
Method	pooled	pooled	pooled	pooled

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

5.17 "Soft" Filled Hole Compression (FHC2)

The FHC2 data had no test failures or outliers. Pooling across environments was acceptable. Statistics, basis values and estimates are given for FHC2 strength data in Table 5-23. The normalized data and the B-basis values are shown graphically in Figure 5-17.

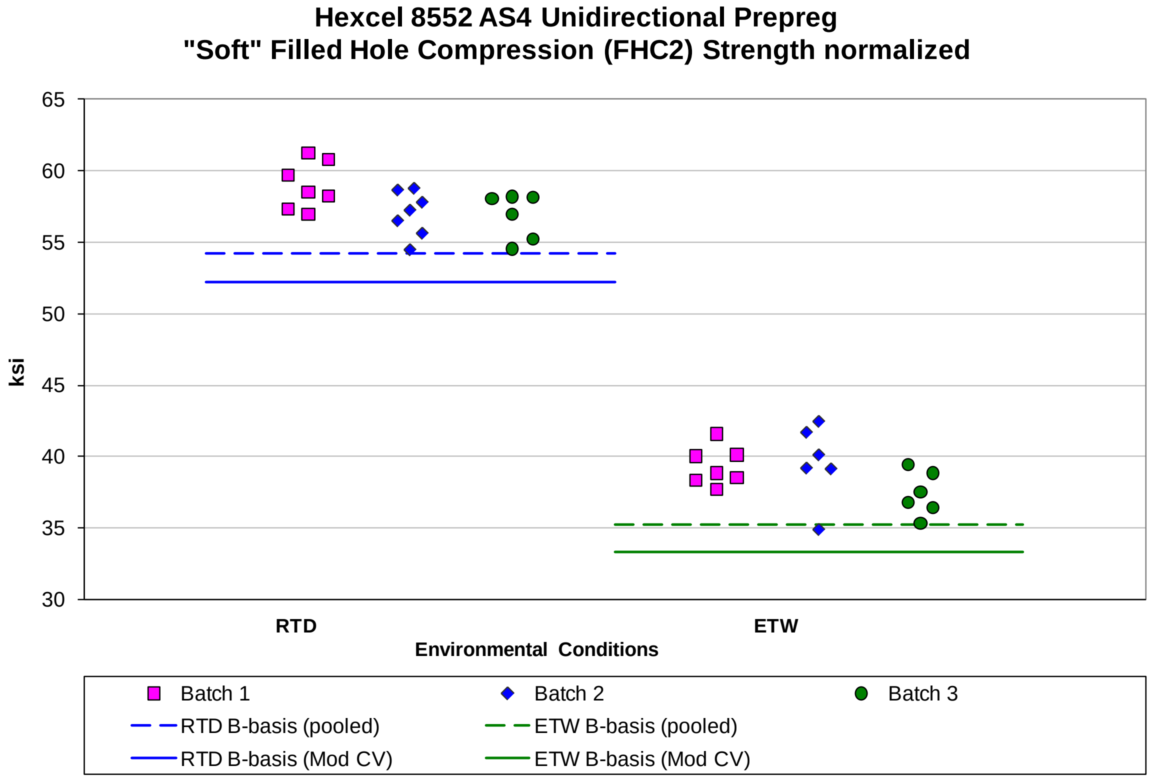

Figure 5-17: Batch plot for FHC2 normalized Strength

Filled-Hole Compression (FHC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	57.65	38.79	59.17	39.94
Stdev	1.83	2.05	1.99	2.23
CV	3.17	5.27	3.37	5.58
Modified CV	6.00	6.64	6.00	6.79
Min	54.48	34.86	55.59	35.94
Max	61.24	42.45	64.33	44.19
No. Batches	3	3	3	3
No. Spec.	20	19	20	19
Basis Values and/or Estimates				
B-basis Value	54.19	35.31	55.38	36.14
A-estimate	51.81	32.93	52.79	33.55
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates				
B-basis Value	52.17	33.28	53.49	34.23
A-estimate	48.41	29.52	49.59	30.34
Method	pooled	pooled	pooled	pooled

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

5.18 "Hard" Filled Hole Compression (FHC3)

The as measured data from the RTD environment and the as measured pooled dataset failed the normality test, so pooling was not appropriate for the as measured dataset. The normalized data had no test failures, so pooling was appropriate.

There was one outlier. It was on the low side of batch two of the RTD data. It was an outlier only after pooling the three batches of RTD data. It was an outlier in both the normalized and as measured datasets.

Statistics, basis values and estimates 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.

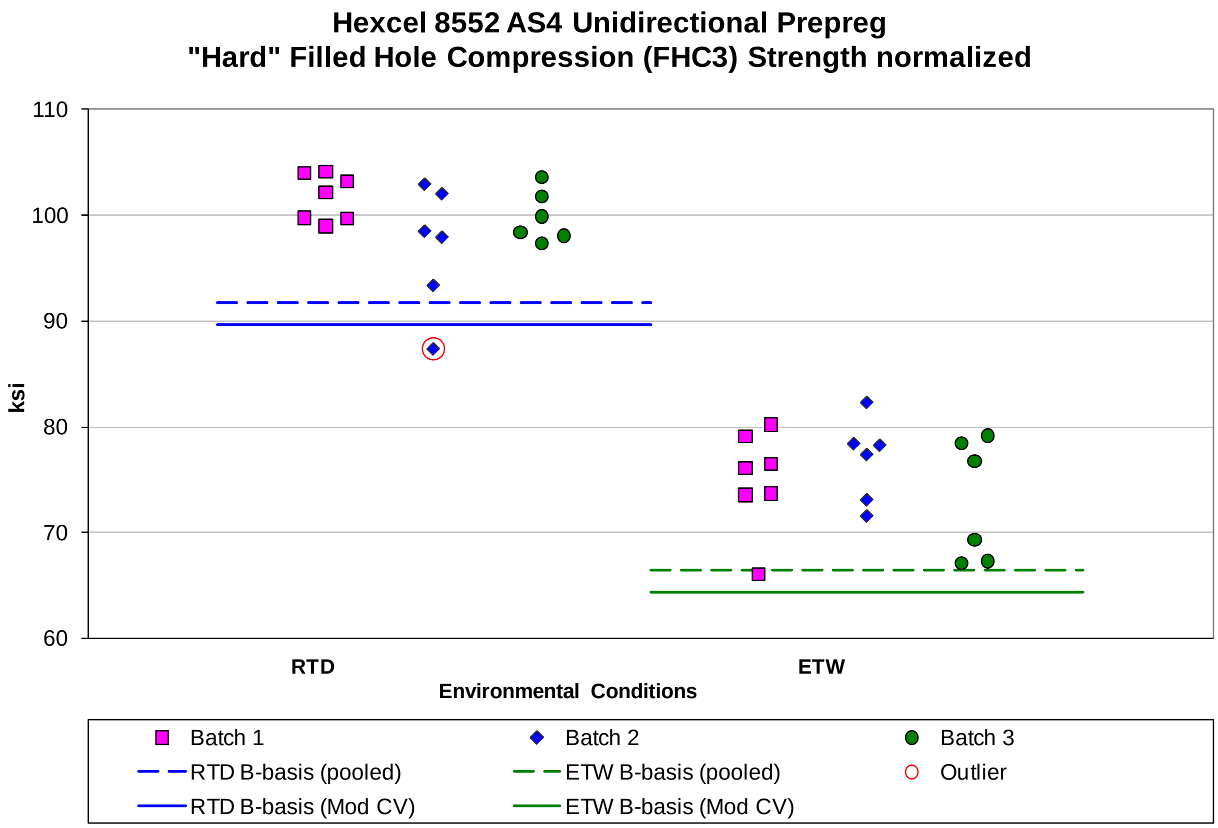

Figure 5-18: Batch plot for FHC3 normalized Strength

Filled-Hole Compression (FHC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	100.15	74.96	102.10	76.13
Stdev	4.62	4.79	4.62	4.69
CV	4.61	6.39	4.53	6.16
Modified CV	6.31	7.19	6.26	7.08
Min	87.32	66.06	88.21	67.10
Max	110.13	82.26	111.66	83.52
No. Batches	3	3	3	3
No. Spec.	20	19	20	19
Basis Values and/or Estimates				
B-basis Value	91.72	66.50	90.87	66.99
A-estimate	85.94	60.72	79.66	60.50
Method	pooled	pooled	Weibull	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value	89.60	64.37	89.78	65.62
A-estimate	82.37	57.14	81.02	58.17
Method	pooled	pooled	normal	normal

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

5.19 Laminate Short Beam Shear Strength (LSBS) Data

The Laminate Short Beam Shear data is not normalized. The data from the RTD and ETW conditions failed ADK test for batch-to-batch variation, so only the ANOVA method could be used to compute basis values. Since there are only three batches available, this means that basis values computing using the ANOVA method are estimates only. However, both the RTD and ETW data passed the ADK test with the modified CV transform, so modified CV basis values are provided.

Pooling was not acceptable due to large differences in standard deviations and CV between the RTD and ETW datasets. There was one outlier. It was on the low side of batch one in the ETW data. It was an outlier only before pooling the three batches of ETW data together.

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

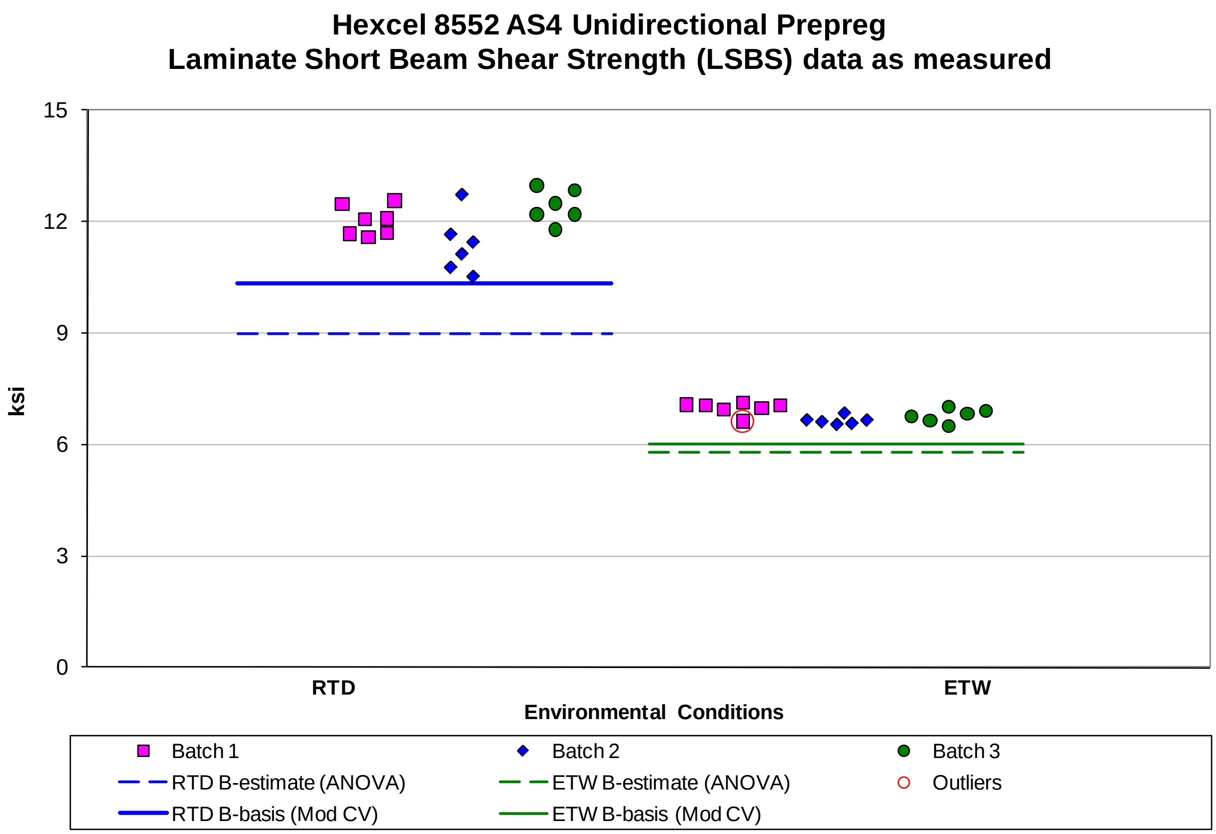

Figure 5-19: Batch plot for LSBS data as measured

Laminate Short Beam Shear (LSBS) Strength Basis Values and Statistics		
	As measured	
Env	RTD	ETW
Mean	11.94	6.81
Stdev	0.68	0.21
CV	5.69	3.06
Modified CV	6.84	6.00
Min	10.52	6.49
Max	12.97	7.13
No. Batches	3	3
No. Spec.	19	19
Basis Values and/or Estimates		
B-estimate	8.98	5.78
A-estimate	6.86	5.05
Method	ANOVA	ANOVA
Modified CV Basis Values and/or Estimates		
B-basis Value	10.35	6.01
A-estimate	9.22	5.45
Method	normal	normal

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

5.20 Quasi Isotropic Single Shear Bearing (SSB1)

The as measured 2% offset strength data from the RTD environment and the as measured pooled dataset failed the normality test, so pooling was not appropriate. However, after applying the modified CV transform to the RTD dataset, normality was acceptable and pooling was appropriate for the modified CV basis values. The normalized 2% offset strength data and the ultimate strength data, both normalized and as measured, had no test failures, so pooling was appropriate.

There were four outliers. Three of the outliers were in the as measured 2% offset strength data. They were not outliers in the normalized 2% offset strength data. One outlier was on the high side of batch two in the RTD environment. When this outlier was excluded, the next highest value in batch two then became an outlier. Both of these outliers were outliers for the RTD condition, but not for batch two.

There were two outliers in batch three of the ETW data. One outlier was on the low side of batch three in the as measured (but not normalized) 2% offset strength data. Another outlier was on the low side of batch three in the as measured (but not normalized) ultimate strength data. These were two separate outliers, not the same specimen. In both case, they were outliers for batch three only, not for the ETW condition. All four outliers were retained for this analysis.

Statistics, basis values and estimates are given for the strength data in Table 5-26. The normalized data and the B-basis values are shown graphically in Figure 5-20.

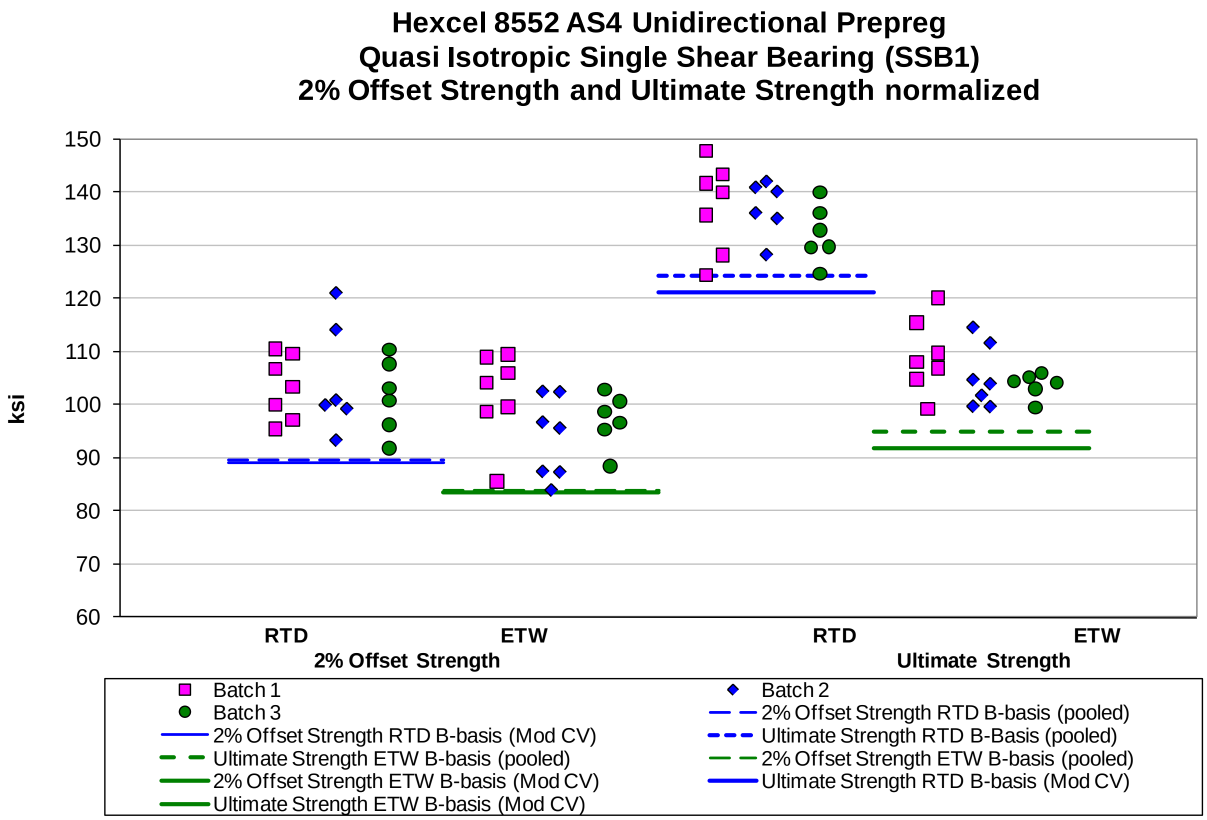

Figure 5-20: Batch plot for SSB1 normalized Strength Data

Quasi Isotropic Single Shear Bearing (SSB1) Strength Basis Values and Statistics								
	Normalized				As measured			
	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	103.24	97.58	135.55	106.12	107.49	102.97	141.16	111.96
Stdev	7.58	7.62	6.70	5.72	6.82	8.32	5.54	5.89
CV	7.34	7.80	4.95	5.39	6.34	8.08	3.92	5.26
Modified CV	7.67	7.90	6.47	6.70	7.17	8.08	6.00	6.63
Min	91.82	84.04	124.34	99.20	96.98	89.12	131.45	101.48
Max	121.01	109.47	147.83	120.12	126.85	123.46	148.76	123.77
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	20	19	20	19	20	19	20
Basis Values and/or Estimates								
B-basis Value	89.56	83.97	124.35	94.98	94.49	86.96	130.86	101.71
A-estimate	80.23	74.62	116.72	87.33	66.09	75.56	123.83	94.67
Method	pooled	pooled	pooled	pooled	Non-parametric	Normal	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-basis Value	89.18	83.58	121.22	91.85	93.04	88.59	126.86	97.72
A-estimate	79.58	73.97	111.44	82.06	83.19	78.73	117.09	87.94
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

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

5.21 "Soft" Single Shear Bearing 2 (SSB2)

The SSB2 ETW data for 2% offset strength and ultimate strength, both normalized and as measured, failed the ADK test, which means the ANOVA method was required to compute basis values. Since there are only three batches available, the basis values computed using the ANOVA method are estimates only. The ultimate strength ETW data (both normalized and as measured) passed the ADK test after the modified CV transform was applied but the 2% offset strength data (both normalized and as measured) did not. Modified CV basis values are provided for normalized ultimate strength ETW dataset. Estimates computed using the modified CV method are provided for the 2% offset strength ETW datasets. There were no outliers.

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

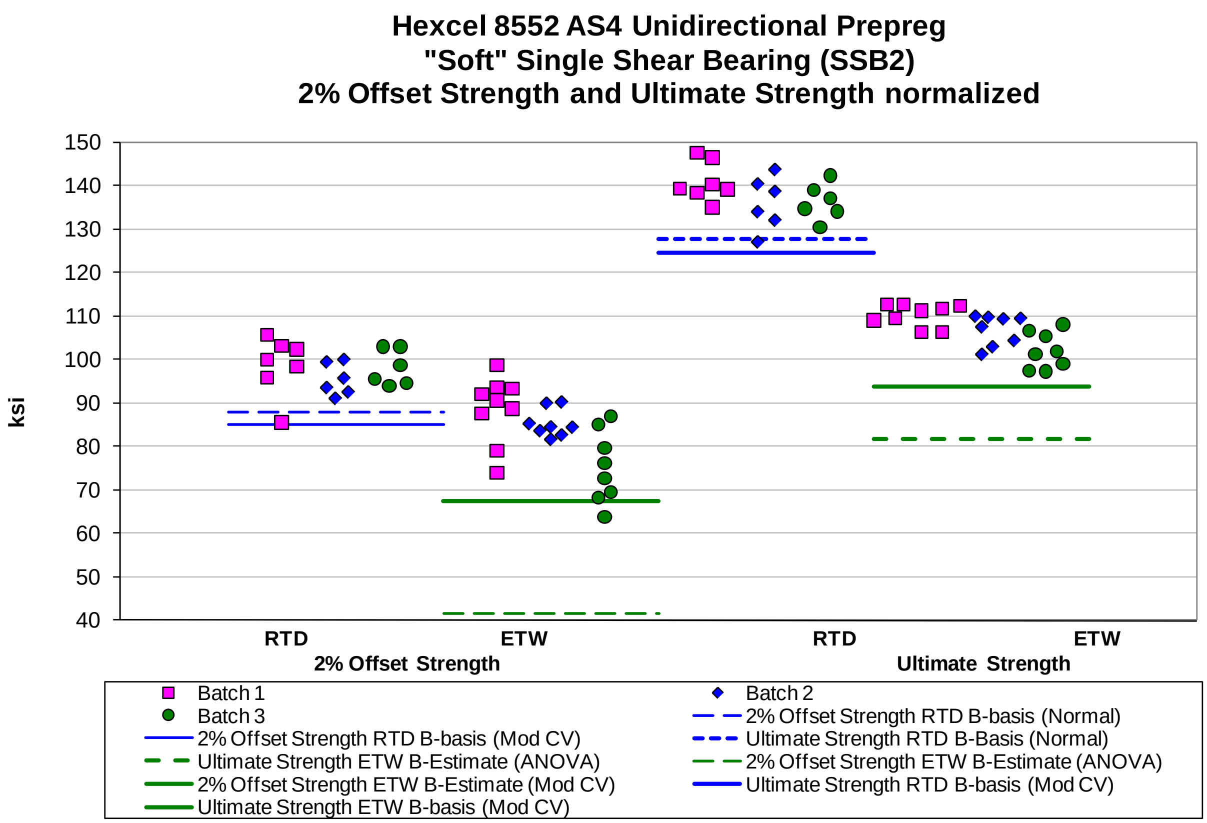

Figure 5-21: Batch plot for SSB2 normalized Strength Data

"Soft" Single Shear Bearing (SSB2) Strength Basis Values and Statistics								
	Normalized				As measured			
	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	97.45	83.27	137.87	106.52	102.23	87.07	144.68	111.46
Stdev	5.03	8.69	5.25	4.74	4.42	8.60	5.41	5.22
CV	5.17	10.43	3.81	4.45	4.32	9.88	3.74	4.68
Modified CV	6.58	10.43	6.00	6.23	6.16	9.88	6.00	6.34
Min	85.54	63.81	127.02	97.27	93.76	68.50	130.19	102.64
Max	105.66	98.60	147.58	112.76	108.20	103.45	153.64	122.50
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	25	19	25	19	25	19	25
Basis Values and/or Estimates								
B-basis Value	87.64		127.64		93.62		134.13	
B-estimate		41.66		81.78		45.22		89.42
A-estimate	80.68	11.93	120.37	64.09	87.50	15.32	126.64	73.67
Method	Normal	ANOVA	Normal	ANOVA	Normal	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates								
B-basis Value	84.95		124.71	93.67	89.96		130.78	97.87
B-estimate		67.30				71.25		
A-estimate	76.08	55.83	115.79	84.68	81.25	59.90	121.35	88.37
Method	normal	normal	pooled	pooled	normal	normal	pooled	pooled

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

5.22 "Hard" Single Shear Bearing 3 (SSB3)

The pooled dataset for 2% offset strength failed the normality test for both the normalized and as measured datasets, so pooling was not appropriate. However, the as measured 2% pooled dataset passed the normality test after the Mod CV transformation, so pooling was appropriate for the modified CV basis values.

For the normalized RTD 2% offset strength data, the Weibull distribution proved to have the best fit for that data. Modified CV basis values are not available for the normalized RTD 2% offset data due to the non-normality. Pooling the RTD and ETW environments was acceptable for the ultimate strength datasets, both normalized and as measured.

The normalized 2% offset strength ETW data failed both the normality test and the ADK test. The failure of the ADK test means the ANOVA method was required to compute basis values. Since there are only three batches available, the basis values computed using the ANOVA method are estimates only. After applying the modified CV transform to this dataset, it passed the normality test but still failed the ADK test. Estimates computed using the modified CV method are provided for the ETW environment. These are termed estimates due to the dataset failing the ADK test after the transformation for the modified CV method.

There were a total of five outliers in the SSB3 data, two in the 2% offset strength data and three in the ultimate strength data. All five outliers were retained for this analysis.

In the 2% offset strength data, one outlier was on the low side of batch two in the normalized RTD data. It was an outlier for batch two only, not for the RTD condition. The second outlier in the 2% offset strength data was on the low side of batch three in the ETW data. It was an outlier in both the as measured and the normalized datasets. It was an outlier only after pooling the three batches of ETW data.

There were three outliers in the ultimate strength data, two in the RTD condition and one in the ETW condition. In the RTD ultimate strength data, one on the low side of batch one and the other on the low side of batch three. In the as measured data, both of these outliers were only outliers for their respective batches but not for the RTD condition. In the normalized data, both of these were outliers both for their respective batches and for the RTD condition. In the ETW ultimate strength data, the highest value in batch two was an outlier only for batch two and only for the normalized data.

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

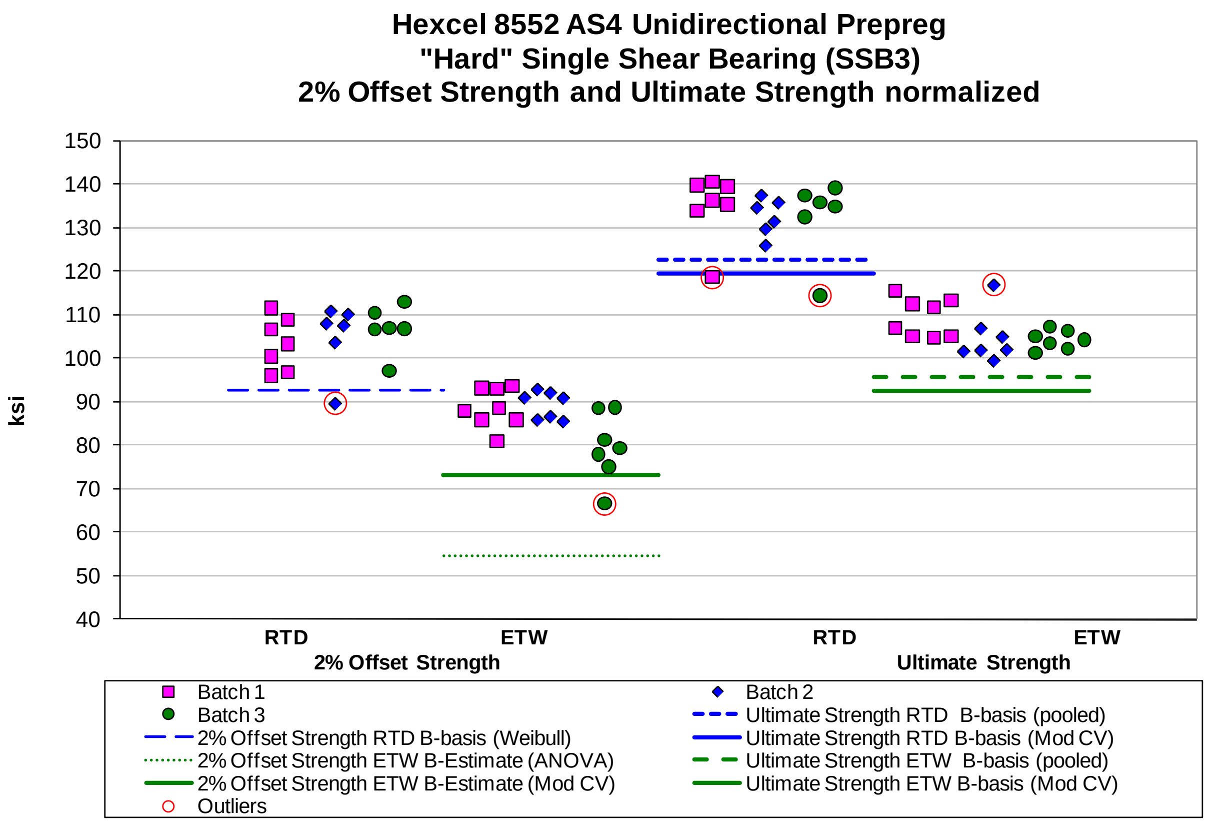

Figure 5-22: Batch plot for SSB3 normalized Strength Data

"Hard" Single Shear Bearing (SSB3) Strength Basis Values and Statistics								
	Normalized				As measured			
	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	104.96	85.93	133.34	106.28	108.18	87.01	137.45	107.63
Stdev	6.30	6.78	6.98	4.81	6.69	6.77	7.95	4.91
CV	6.00	7.89	5.23	4.53	6.19	7.78	5.78	4.56
Modified CV	7.00	7.94	6.62	6.26	7.09	7.89	6.89	6.28
Min	89.52	66.59	114.38	99.42	91.34	67.20	117.48	99.81
Max	113.05	93.59	140.51	116.83	117.56	95.99	146.84	118.00
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	22	19	22	19	22	19	22
Basis Values and/or Estimates								
B-basis Value	92.59		122.75	95.82	95.13	74.24	125.82	96.15
B-estimate		54.74						
A-estimate	80.07	32.47	115.54	88.58	85.87	65.11	117.90	88.20
Method	Weibull	ANOVA	pooled	pooled	Normal	Normal	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-basis Value			119.48	92.60	95.18	74.18	122.88	93.26
B-estimate	NA	73.05						
A-estimate	NA	63.86	110.05	83.13	86.33	65.30	112.98	83.31
Method	NA	normal	pooled	pooled	pooled	pooled	pooled	pooled

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

5.23 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.

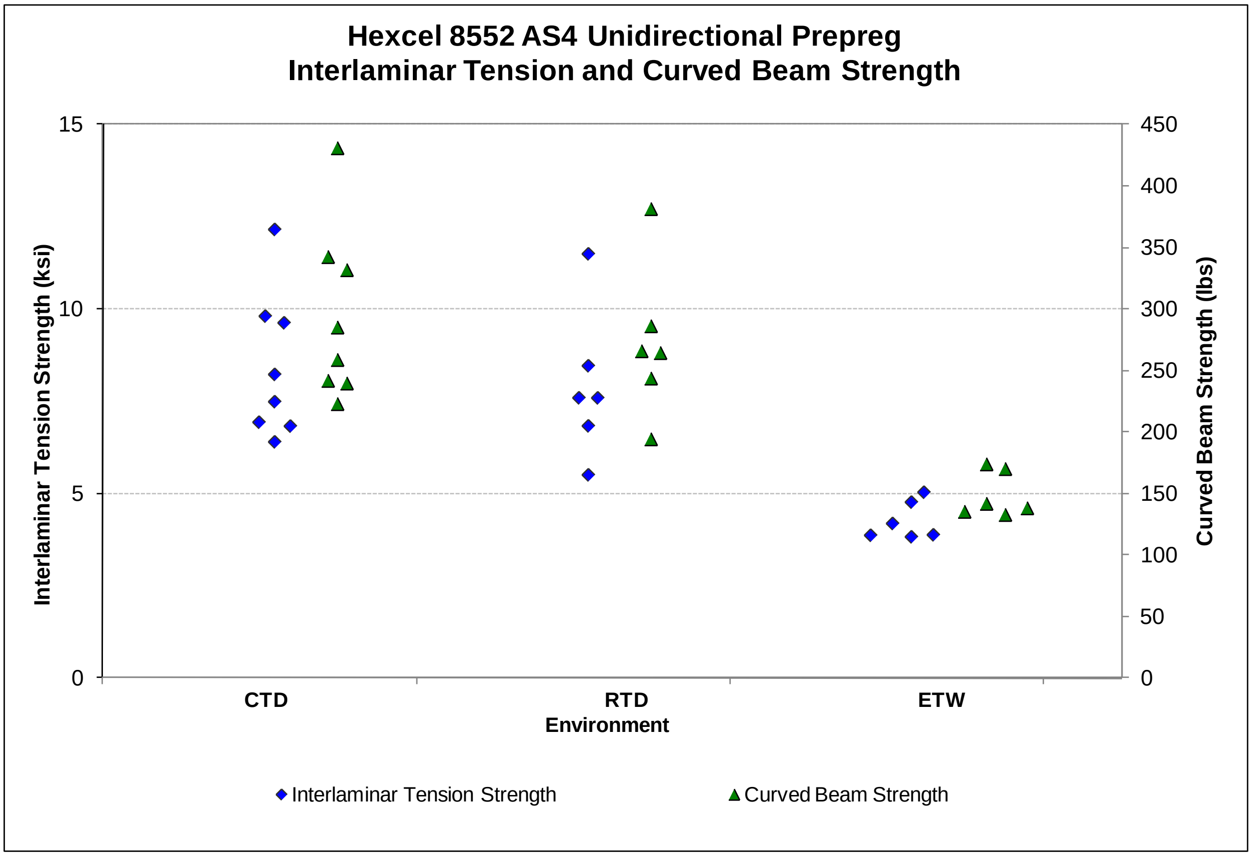

Figure 5-23: Plot for ILT and CBS as measured data

Property	Interlaminar Tension Strength (ksi)			Curved Beam Strength (lbs)		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	8.42	7.90	4.25	294.17	272.67	148.95
Stdev	1.96	2.01	0.52	70.15	61.72	18.31
CV	23.35	25.49	12.21	23.85	22.63	12.29
Min	6.38	5.49	3.81	223.03	194.44	133.07
Max	12.13	11.47	5.02	430.66	381.27	174.12
No. Batches	1	1	1	1	1	1
No. Spec.	8	6	6	8	6	6

Table 5-29: Statistics for ILT and CBS as measured data

5.24 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.

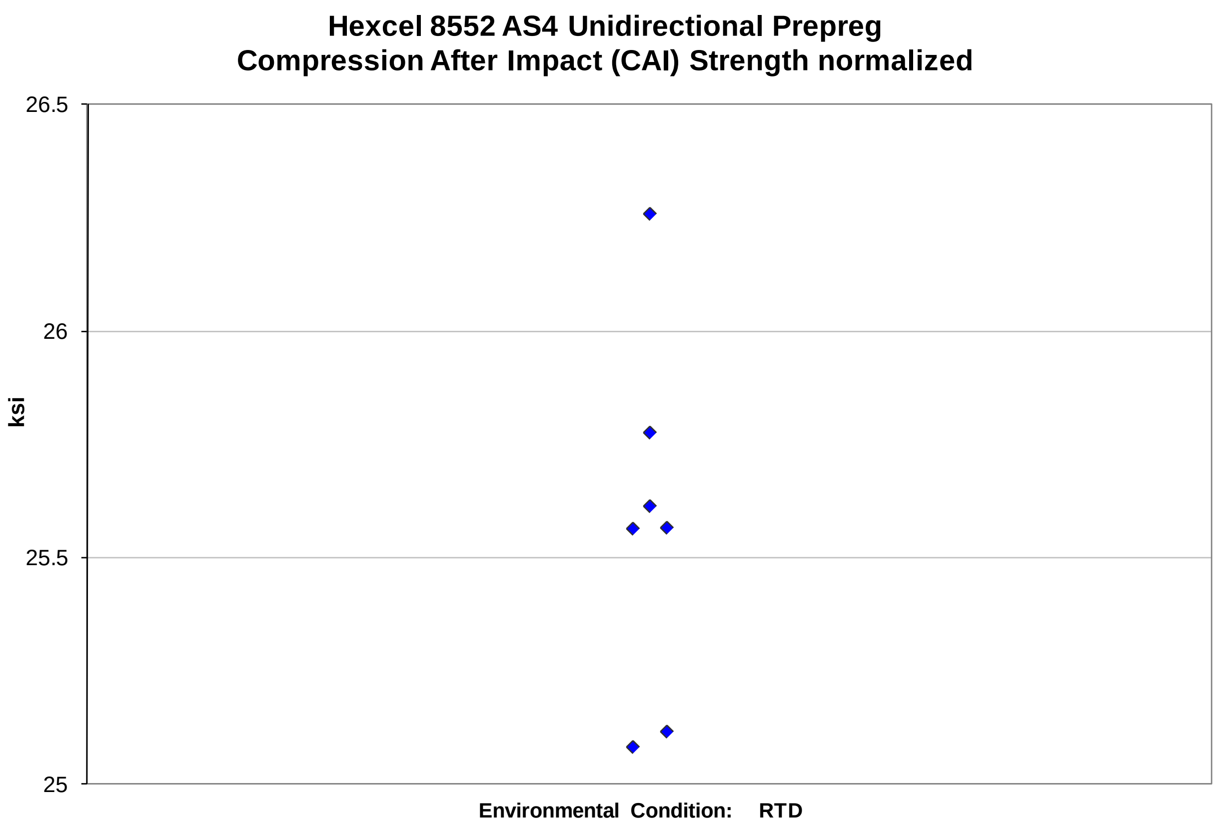

Figure 5-24: Plot for Compression After Impact normalized Strength Data

Compression After Impact Strength (ksi)		
	Normalized	As Measured
Env	RTD	RTD
Mean	25.57	25.56
Stdev	0.40	0.52
CV	1.57	2.05
Modified CV	6.00	6.00
Min	25.08	24.83
Max	26.26	26.39
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 working draft CMH-17 Rev G section 8.3.3. An outlier may be an outlier in the normalized data, the as measured data, or both. A specimen may be an outlier for the batch only (before pooling the three batches within a condition together) or for the condition (after pooling the three batches within a condition together) or both.

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

All outliers identified were investigated to determine if a cause could be found. Outliers with causes were removed from the dataset and the remaining specimens were analyzed for this report. Information about specimens that were removed from the dataset along with the cause for removal is documented in the material property data report, NCAMP Test Report CAM-RP-2010-002.

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
FHC3	RTD	2	HFU9B215A	87.32	88.21	Low	No	Yes
FHT3	CTD	2	HFU6B116B	64.90	Not an outlier	Low	Yes	No
FHT3	CTD	3	HFU6C118B	Not an outlier	62.20	Low	Yes	No
FHT3	ETW	1	HFU6A11BD	Not an outlier	82.71	High	Yes	No
IPS - 5% Strain	RTD	1	HFUNA211A	NA	12.51	Low	Yes	No
IPS - 5% Strain	RTD	3	HFUNC117A	NA	13.76	Low	Yes	No
LSBS	ETW	1	HFUqA279D	NA	6.63	Low	Yes	No
LT	RTD	2	HFUJB211A	248.11	Not an outlier	Low	Yes	No
OHC3	RTD	2	HFUIB213A	66.52	Not an outlier	High	Yes	No
OHT1	**ETW**	**1**	**HFUDA21CD**	**57.02**	**56.81**	**High**	**Yes**	**Yes**
OHT1	**ETW**	**2**	**HFUDB21AD**	**55.06**	**55.14**	**High**	**Yes**	**Yes**
OHT1	RTD	2	HFUDB113A	Not an outlier	44.86	Low	Yes	No
OHT2	RTD	2	HFUEB112A	Not an outlier	39.20	Low	Yes	No
SBS	CTD	2	HFUQB119B	NA	19.91	Low	Yes	No
SSB1 - 2% Offset Strength	ETW	3	HFU1C216D	Not an outlier	92.66	Low	Yes	No
SSB1 - 2% Offset Strength	RTD	2	HFU1B112A	Not an outlier	126.85	High	No	Yes
SSB1 - 2% Offset Strength	RTD	2	HFU1B113A	Not an outlier	121.13	High	No	Yes
SSB1 - Ultimate Strength	ETW	3	HFU1C118D	Not an outlier	108.02	Low	Yes	No
SSB3 - 2% Offset Strength	RTD	2	HFU3B113A	89.52	Not an outlier	Low	Yes	No
SSB3 - 2% Offset Strength	ETW	3	HFU3C217D	66.59	67.20	Low	No	Yes
SSB3 - Ultimate Strength	**RTD**	**1**	**HFU3A213A**	**118.64**	**119.98**	**Low**	**Yes**	**Yes - norm** **No - as meas**
SSB3 - Ultimate Strength	**RTD**	**3**	**HFU3C112A**	**114.38**	**117.48**	**Low**	**Yes**	**Yes - norm** **No - as meas**
SSB3 - Ultimate Strength	ETW	2	HFU3B219D	116.83	Not an outlier	High	Yes	No
UNC1	RTD	1	HFUWA211A	90.94	96.41	High	Yes	No
UNC1	RTD	3	HFUWC113A	93.16	Not an outlier	High	Yes	No
UNC2	RTD	3	HFUXC111A	55.87	Not an outlier	Low	Yes	No
UNT1	CTD	2	HFUAB216B	88.20	Not an outlier	High	Yes	No
UNT1	CTD	3	HFUAC217B	Not an outlier	81.70	Low	Yes	No
UNT1	ETW	2	HFUAB11BD	Not an outlier	96.18	Low	Yes	No
UNT2	**CTD**	**3**	**HFUBC217B**	**61.11**	**62.36**	**Low**	**Yes**	**Yes**
UNT2	ETW	1	HFUBA21BD	Not an outlier	43.13	Low	No	Yes
UNT3	CTD	3	HFUCC219B	Not an outlier	162.75	High	No	Yes
UNT3	ETW	3	HFUCC11BD	155.38	Not an outlier	High	Yes	No

Table 6-1: List of outliers

7. References

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