Newport NCT4708 MR60H 300gsm 38%RC Unidirectional Material Allowables Statistical Analysis Report

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1. Introduction

This report contains statistical analysis of the Newport NCT4708 MR60H 300gsm 38%RC Unidirectional Prepreg. Qualification material property data is published in NCAMP Test Report CAM-RP-2010-041 N/C. The lamina and laminate material property data have been generated with NCAMP oversight in accordance with NCAMP Standard Operating Procedure NSP 100.

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 4708/1 Rev Initial Release dated January 15, 2009. The qualification test panels were cured in accordance with NCAMP NPS 4708 Process Specification Initial Release. The panels were fabricated at NIAR Composites Lab at WSU, 1845 N. Fairmount, Wichita, KS 67260-0093. The NCAMP Test Plan NTP 4708Q1 Rev B was used for this qualification program.

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

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

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

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

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

Part fabricators that wish to utilize the material property data, allowables, and specifications may be able to do so by demonstrating the capability to reproduce the original material properties; a process known as equivalency. More information about this equivalency process including the test statistics and its limitations can be found in Section 6 of DOT/FAA/AR-03/19 and Section

8.4.1 of 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 4708/1. NMS 4708/1 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 4708/1. NMS* 4708/1 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 Strength	SBS
Laminate Short Beam Strength	SBS1
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	SSB
Compression After Impact	CAI
Interlaminar Tension Strength	ILT
Curved Beam Strength	CBS

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	Temperature	Abbreviation
Cold Temperature Dry	−65°F	CTD
Room Temperature Dry	70°F	RTD
Elevated Temperature Dry	180°F	ETD
Elevated Temperature Wet	180°F	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-2010-041 N/C.

1.2 Pooling Across Environments

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

When pooling across environments was not advisable because the data was not eligible for pooling and engineering judgment indicated there was no justification for overriding the result, then B-Basis values were computed for each environmental condition separately using Stat-17 version 5.

1.3 Basis Value Computational Process

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

1.4 Modified Coefficient of Variation (CV) Method

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

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

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

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

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

2. Background

Statistical computations are performed with AGATE Statistical Analysis Program (ASAP) when pooling across environments is permissible according to 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 "Approximation for Allowable k-factors" by Fritz Scholz[1]. 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**

[1] Scholz, Fritz, "Approximation for Allowable k-factors," Boeing Computer Services, The Boeing Company, Seattle, WA.

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

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

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

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

2.2 STAT-17

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

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

Outliers must be dispositioned before checking any other test results. The results of the Anderson Darling k-Sample (ADK) Test for batch equivalency must be checked. If the data passes the ADK test, then the appropriate distribution is determined. If it does not pass the ADK test, then the ANOVA procedure is the only approach remaining that will result in basis values that meet the requirements of 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); Stat-17 also tests to see if the Weibull or Lognormal distribution is a good fit for the data.

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

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

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

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

2.2.2 Computing Normal Distribution Basis values

Stat-17 uses a table of values for the k-factors (shown in Table 2-1) 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:

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

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

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

2.2.2.3.2 Goodness-of-fit test for the Weibull distribution

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

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

The Anderson-Darling test statistic is

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

and the observed significance level is

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

where

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

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

2.2.2.3.3 Basis value calculations for the Weibull distribution

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

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

where

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

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

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

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

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

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

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

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

Table 2-2: Weibull Distribution Basis Value Factors

2.2.2.4 Lognormal Distribution

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

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

2.2.2.4.1 Goodness-of-fit test for the Lognormal distribution

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

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

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

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

2.2.2.4.2 Basis value calculations for the Lognormal distribution

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

2.2.3 Non-parametric Basis Values

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

2.2.3.1 Non-parametric Basis Values for large samples

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

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

For B-basis values:

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

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

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

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

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

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

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

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

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

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 = $\bar{X}_1 - K_{(N_1,N_2)} \cdot \bar{X}_1 \cdot \max(CV_1, CV_2)$ **Equation 62**

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

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

With:

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

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

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

2.5 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

$$BF = \frac{E_1\left[V_0E_2 + \left(1-V_0\right)E_1\right] - \left(\nu_{12}E_2\right)^2}{\left[V_0E_1 + \left(1-V_0\right)E_2\right]\left[V_0E_2 + \left(1-V_0\right)E_1\right] - \left(\nu_{12}E_2\right)^2}$$ **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 CMH17 Rev G) in section 2.4.2, equation 2.4.2.1(b).

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

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:

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

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

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

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

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

This formula can also be found in 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 for publication in 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 for publication in the CMH-17 handbook are shown in shaded boxes and labeled as estimates. Basis values computed with the modified coefficient of variation (CV) are presented whenever possible. Basis values and estimates computed without that modification are presented for all tests.

3.1 NCAMP Recommended B-basis Values

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

1. Recommended values are NEVER estimates. Only B-basis values that meet all requirements for publication in CHM-17 are recommended.
2. Modified CV basis values are preferred. Recommended values will be the modified CV basis value when available. The CV provided with the recommended basis value will be the one used in the computation of the basis value.
3. Only normalized basis values are given for properties that are normalized.
4. ANOVA B-basis values are not recommended since only three batches of material are available and 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 STAT-17 when the B-basis value is 90% or more of the average value. Basis values of 90% or more of the mean value imply that the CV is unusually low and may not be conservative. Such values will be indicated.
6. If the data appear questionable (e.g. when the CTD-RTD-ETW trend of the basis values are not consistent with the CTD-RTD-ETW trend of the average values), then the B-basis values will not be recommended.

NCAMP Recommended B-basis Values for Newport NCT4708 MR60H 300gsm 38% RC Unitape

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

Values are for normalized data unless otherwise noted

Lamina Strength Tests

Environment	Statistic	LT from UNT0	LT from LT	LC from UNC0	TT*	TC*	SBS*	IPS* 0.2% Offset	IPS* 5% Strain
CTD (-65º F)	B-basis	291.27	301.64	189.63	4.71	28.49	11.65	6.96	8.11
	Mean	330.01	346.72	217.93	5.57	31.94	12.65	7.89	8.88
	CV	6.00	7.34	7.98	7.80	6.91	6.00	6.00	6.00
RTD (70º F)	B-basis	319.59	320.99	164.98	4.90	20.53	9.17	5.38	7.04
	Mean	358.82	366.07	192.93	5.75	23.98	10.18	6.10	7.80
	CV	7.16	6.89	10.79	8.74	6.35	6.00	6.00	6.00
ETD (180º F)	B-basis	325.17	332.58	147.94			7.41	3.88	6.21
	Mean	363.91	377.92	175.74			8.42	4.39	6.96
	CV	6.00	7.07	7.64			6.00	6.00	6.00
ETW (180º F)	B-basis	321.37	329.39	106.98	2.41	NA: A	5.14	2.92	3.98
	Mean	359.71	374.47	135.28	2.85	13.66	6.14	3.31	4.74
	CV	6.00	6.92	7.31	8.03	7.55	6.00	6.00	6.00

Notes: The modified CV B-basis value is recommended when available.

The CV provided corresponds with the B-basis value given.

NA implies that tests were run but data did not meet 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
Newport NCT4708 MR60H 300gsm 38% RC Unitape

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 Str.	SSB Ult. Str.	SBS1*
25/50/25	CTD (-65º F)	B-basis	57.84		56.94		81.07				
		Mean	66.11		64.74		92.62				
		CV	7.60		6.00		6.69				
	RTD (70º F)	B-basis	60.88	34.18	60.71	46.47	97.05	58.80	83.64	96.00	5.85
		Mean	69.15	38.09	68.52	52.14	108.60	69.42	93.66	106.51	6.53
		CV	6.39	6.00	7.07	6.67	6.29	7.85	6.28	6.00	6.13
	ETW (180º F)	B-basis	66.52	25.60	66.27	31.90	97.28	34.79	59.09	73.20	4.59
		Mean	74.83	29.47	74.08	37.52	108.83	40.73	69.05	83.65	5.28
		CV	6.22	7.03	6.00	7.41	6.00	7.48	7.28	6.00	6.56
9/73/18	CTD (-65º F)	B-basis	33.95		34.96		44.73				
		Mean	38.20		38.91		50.32				
		CV	6.00		6.00		6.00				
	RTD (70º F)	B-basis	34.12	26.31	33.88	NA:A	45.82	41.33	89.22	105.88	
		Mean	38.35	29.00	37.82	41.24	51.47	46.38	99.64	117.29	
		CV	6.93	6.00	6.00	6.30	6.00	6.88	6.82	6.00	
	ETW (180º F)	B-basis	31.74	17.09	30.69	23.85	NA:I	27.30	62.98	78.31	
		Mean	35.97	19.78	34.63	27.49	46.61	32.31	73.41	89.72	
		CV	6.07	6.00	6.00	6.71	7.34	6.97	6.00	6.00	
55/36/9	CTD (-65º F)	B-basis	111.06		100.74		176.25				
		Mean	127.15		114.18		199.95				
		CV	6.75		6.22		6.86				
	RTD (70º F)	B-basis	124.07	49.96	104.63	72.29	185.29	83.22	84.45	104.34	
		Mean	140.07	56.23	118.21	80.14	208.99	92.11	94.33	115.39	
		CV	7.03	7.08	7.03	6.00	6.00	6.00	6.80	6.00	
	ETW (180º F)	B-basis	127.72	36.79	112.02	47.68	145.19	60.48	60.37	73.41	
		Mean	143.63	43.06	125.46	55.53	169.03	69.16	70.25	84.45	
		CV	6.00	6.52	6.00	6.74	8.20	6.46	6.00	6.00	

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

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

3.2 Lamina and Laminate Summary Tables

Material:	Newport NCT4708 MR60H 300gsm 38% RC Unitape		**Newport NCT4708 MR60H 300 gsm 38% RC Unitape Lamina Properties Summary**
Material Specification:	NMS 4708/1		
Fiber:	MR60H	**Resin:**	NB 4708
Tg(dry): 297.97˚F	**Tg(wet):** 215.81˚F	**Tg METHOD:**	DMA (SRM 18R-94)
Process Specification:	NPS 4708		

Date of fiber manufacture	April 2008 - June 2008	**Date of testing**	12/2009 - 9/2010
Date of resin manufacture	September 16, 2008 to October 1, 2008	**Date of data submittal**	1/2010 - 9/2010
Date of prepreg manufacture	September 18, 2008 to October 2, 2008	**Date of analysis**	Oct-10
Date of composite manufacture	July 27, 2009 to November 5, 2009		

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported: As measured followed by normalized values in parentheses, normalizing tply: 0.0126 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)	306.05	293.68	332.37	249.08	317.34	356.51	341.80	327.41	366.09	332.94	319.42	357.70
from UNT0	(305.78)	(291.27)	(330.01)	(233.43)	(319.59)	(358.82)	(336.22)	(325.17)	(363.91)	(337.02)	(321.37)	(359.71)
F_1^{tu} (ksi)	243.07	293.56	349.14	237.82	NA	366.03	232.99	NA	380.90	250.67	NA	378.83
from LT	(301.00)	(301.64)	(346.72)	(273.69)	(320.99)	(366.07)	(260.24)	(332.58)	(377.92)	(267.69)	(329.39)	(374.47)
E_1^t			20.56			20.63			21.16			21.10
(Msi)			(20.44)			(20.63)			(21.01)			(20.85)
ν_{12}^t			0.316			0.337			0.345			0.325
F_2^{tu} (ksi)	4.72	4.71	5.57	4.91	4.90	5.75				2.41	NA	2.85
E_2^t (Msi)			1.28			1.12						0.82
F_1^{cu} (ksi)	183.05	(190.49)	218.90	157.86	(165.26)	193.32	119.86	154.13	182.03	95.51	106.60	135.01
from UNC0	(182.25)	(189.63)	(217.93)	(157.65)	(164.98)	(192.93)	(125.76)	(147.94)	(175.74)	(86.28)	(106.98)	(135.28)
E_1^c			18.67			18.80			18.45			18.57
(Msi)			(18.07)			(18.45)			(17.72)			(18.30)
ν_{12}^c			0.359			0.355			0.371			0.367
F_2^{cu} (ksi)	27.05	28.49	31.94	18.20	20.53	23.98				7.46	11.57	13.66
E_2^c (Msi)			1.39			1.23						1.01
ν_{21}^c			0.029			0.025						0.020
$F_{12}^{s5\%}$ (ksi)	8.55	8.11	8.88	7.47	7.04	7.80	6.63	6.21	6.96	4.41	3.98	4.74
$F_{12}^{s0.2\%}$ (ksi)	7.48	6.96	7.89	5.50	5.38	6.10	4.23	3.88	4.39	2.89	2.92	3.31
G_{12}^s (Msi)			0.64			0.55			0.44			0.36
SBS (ksi)	11.76	11.65	12.65	9.38	9.17	10.18	8.02	7.41	8.42	4.87	5.14	6.14
UNT0	162.48	156.23	176.45	131.21	167.32	187.80	175.94	168.22	188.44	172.92	165.76	185.78
(ksi)	(162.40)	(154.92)	(175.27)	(122.96)	(168.41)	(189.01)	(176.39)	(170.57)	(190.92)	(175.11)	(166.76)	(186.90)
			10.84			10.76			10.89			10.90
(Msi)			(10.77)			(10.84)			(11.02)			(10.96)
UNC0	70.08	70.08	83.66	59.36	59.36	72.79	44.53	57.60	67.64	35.27	42.93	49.86
(ksi)	(70.09)	(71.74)	(83.64)	(59.40)	(61.04)	(72.80)	(48.56)	(56.16)	(67.86)	(31.91)	(42.59)	(50.03)
			7.06			6.98			6.85			7.03
(Msi)			(7.04)			(7.00)			(6.84)			(7.05)
ν of UNC0			0.033			0.032			0.029			0.018

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

Material:	Newport NCT4708 MR60H 300gsm 38% RC Unitape		**Newport NCT4708 MR60H 300 gsm 38% RC Unitape Laminate Properties Summary**
Material Specification:	NMS 4708/1		
Fiber:	MR60H	**Resin:** NB 4708	
Tg(dry): 297.97˚F	**Tg(wet):** 215.81˚F	**Tg METHOD :** DMA (SRM 18R-94)	
Process Specification:	NPS 4708		

Date of fiber manufacture	April 2008 - June 2008	**Date of testing**	12/2009 - 9/2010
Date of resin manufacture	Sep. 16, 2008 to Oct. 1, 2008	**Date of data submittal**	1/2010 - 9/2010
Date of prepreg manufacture	Sep. 18, 2008 to Oct. 2, 2008	**Date of analysis**	Oct-10
Date of composite manufacture	July 27, 2009 to November 5, 2009		

LAMINATE MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported as normalized used a normalizing t_{ply} of 0.0126 in

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

Test	Property		Layup:	Quasi Isotropic 25/50/25			"Soft" 9/73/18			"Hard" 55/36/9		
		Test Condition	Unit	B-basis	Mod. CV B-basis	Mean	B-basis	Mod. CV B-basis	Mean	B-basis	Mod. CV B-basis	Mean
OHT (normalized)	Strength	CTD	ksi	59.32	57.84	66.11	35.03	33.95	38.20	113.13	111.06	127.15
		RTD	ksi	62.36	60.88	69.15	35.19	34.12	38.35	112.07	124.07	140.07
		ETW	ksi	68.01	66.52	74.83	32.81	31.74	35.97	136.00	127.72	143.63
OHC (normalized)	Strength	RTD	ksi	35.46	34.18	38.09	26.96	26.31	29.00	50.97	49.96	56.23
		ETW	ksi	26.86	25.60	29.47	18.25	17.09	19.78	37.80	36.79	43.06
UNT (normalized)	Strength	CTD	ksi	66.81	81.07	92.62	47.19	44.73	50.32	180.36	176.25	199.95
	Modulus		Msi	---	---	7.20	---	---	4.76	---	---	12.48
	Strength	RTD	ksi	100.42	97.05	108.60	48.31	45.82	51.47	189.40	185.29	208.99
	Modulus		Msi	---	---	7.44	---	---	4.53	---	---	12.55
	Strength	ETW	ksi	100.66	97.28	108.83	40.28	39.65	46.61	149.32	145.19	169.03
	Modulus		Msi	---	---	7.30	---	---	4.13	---	---	12.70
UNC (normalized)	Strength	RTD	ksi	59.01	58.80	69.42	42.13	41.33	46.38	86.44	83.22	92.11
	Modulus		Msi	---	---	6.65	---	---	4.17	---	---	11.31
	Poisson's Ratio			---	---	0.348	---	---	0.540	---	---	0.473
	Strength	ETW	ksi	35.21	34.79	40.73	28.09	27.30	32.31	54.53	60.48	69.16
	Modulus		Msi	---	---	6.35	---	---	3.78	---	---	10.88
	Poisson's Ratio			---	---	0.376	---	---	0.630	---	---	0.514
FHT (normalized)	Strength	CTD	ksi	59.06	56.94	64.74	36.13	34.96	38.91	103.04	100.74	114.18
		RTD	ksi	62.83	60.71	68.52	33.92	33.88	37.82	106.96	104.63	118.21
		ETW	ksi	68.39	66.27	74.08	32.92	30.69	34.63	118.03	112.02	125.46
FHC (normalized)	Strength	RTD	ksi	46.65	46.47	52.14	26.07	35.49	41.24	74.61	72.29	80.14
		ETW	ksi	32.60	31.90	37.52	24.55	23.85	27.49	50.00	47.68	55.53
Single Shear Bearing (normalized)	2% Offset Strength	RTD	ksi	85.57	83.64	93.66	88.57	89.22	99.64	83.91	84.45	94.33
		ETW	ksi	61.00	59.09	69.05	68.58	62.98	73.41	66.63	60.37	70.25
	Ultimate Strength	RTD	ksi	101.64	96.00	106.51	111.43	105.88	117.29	108.37	104.34	115.39
		ETW	ksi	78.81	73.20	83.65	83.86	78.31	89.72	80.60	73.41	84.45
LSBS (as measured)	Strength	RTD	ksi	5.98	5.85	6.53	---	---	---	---	---	---
		ETW	ksi	4.42	4.59	5.28	---	---	---	---	---	---
CAI (Normalized)	Strength	RTD	ksi	---	---	28.66	---	---	---	---	---	---
ILT (as measured)	Strength	CTD	ksi	---	---	7.86	---	---	---	---	---	---
		RTD	ksi	---	---	5.11	---	---	---	---	---	---
		ETW	ksi	---	---	4.36	---	---	---	---	---	---
CBS (as measured)	Strength	CTD	lb	---	---	323.66	---	---	---	---	---	---
		RTD	lb	---	---	211.56	---	---	---	---	---	---
		ETW	lb	---	---	179.79	---	---	---	---	---	---

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.

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 formulas specified in section 2.5. The derived values for the CTD, RTD and ETW conditions were computed using equation 64 in that section. The derived values for the ETD condition were computed using the alternate formula (equation 65) in section 2.5.1. The results of both the values measured directly from the LT specimens and the values computed from the UNT0 specimens are presented here.

The as measured and the normalized data from the RTD environmental condition fails the ADK test, so pooling is not appropriate and the ANOVA method must be used with the data from the RTD environment. Pooling was appropriate for the modified CV basis values, both normalized and as measured. While ASAP shows a failure of Levene's test for this data, when the data from all of the environments is transformed (ASAP only transforms those that fail the ADK test) to fit the assumptions of the modified CV method, the data passes Levene's test and can be pooled.

One outlier was identified. The highest value in the batch two of the normalized CTD condition was an outlier only before pooling the data from the three batches together. It was an outlier in the normalized data but not the as measured data. This outlier was retained for this analysis.

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.

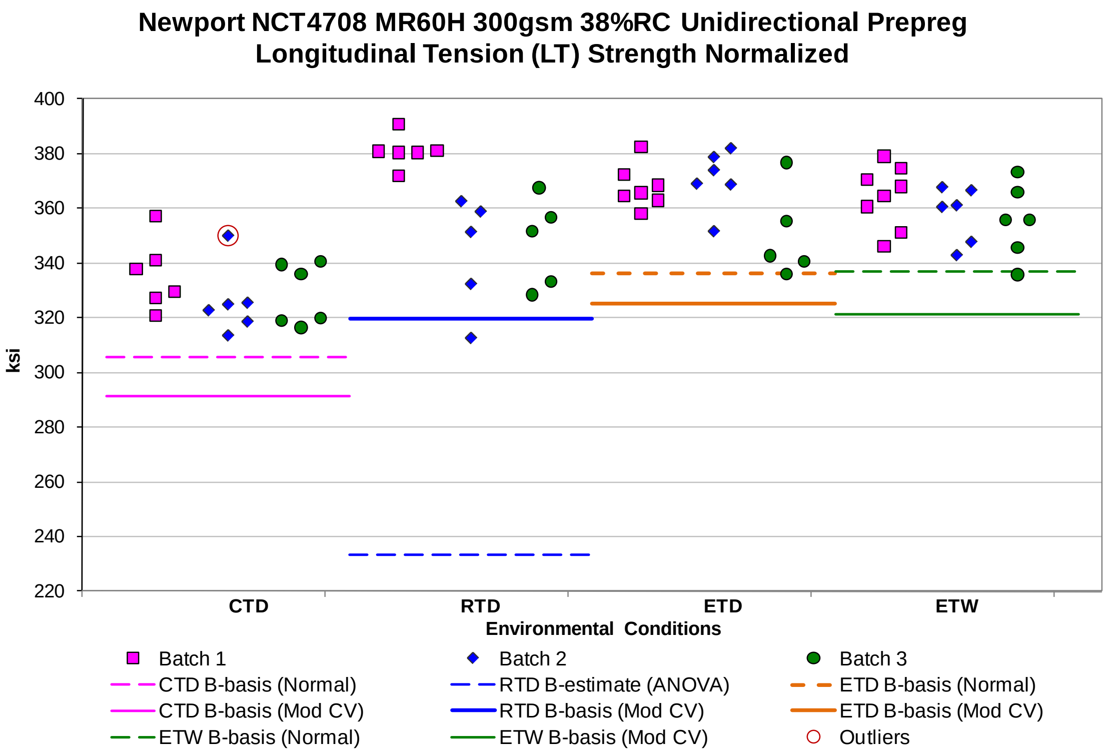

Figure 4-1 Batch plot for LT normalized strength (from UNT0 specimens)

Longitudinal Tension Strength Basis Values and Statistics from UNT0 Specimens and Back out formula								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	330.01	358.82	363.91	359.71	332.37	356.51	366.09	357.70
Stdev	12.27	22.69	14.02	11.78	13.33	22.34	12.30	12.86
CV	3.72	6.32	3.85	3.28	4.01	6.27	3.36	3.59
Mod CV	6.00	7.16	6.00	6.00	6.01	7.13	6.00	6.00
Min	313.51	312.58	336.00	335.73	311.72	307.44	347.10	336.48
Max	357.12	390.88	382.64	379.09	350.55	389.59	390.33	383.75
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	16	18	20	18	16	18	20
Basis Values and/or Estimates								
B-basis Value	305.78		336.22	337.02	306.05		341.80	332.94
B-estimate		233.43				249.08		
A-estimate	288.61	144.02	316.61	320.87	287.39	172.54	324.60	315.33
Method	Normal	ANOVA	Normal	Normal	Normal	ANOVA	Normal	Normal
Mod CV Basis Values and/or Estimates								
B-basis Value	291.27	319.59	325.17	321.37	293.68	317.34	327.41	319.42
A-estimate	265.72	294.11	299.61	295.75	268.16	291.90	301.89	293.84
Method	pooled	pooled	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	ETD	ETW	CTD	RTD	ETD	ETW
Mean	20.44	20.63	21.01	20.85	20.56	20.63	21.16	21.10
Stdev	0.57	0.39	0.42	0.45	0.80	0.60	0.61	0.51
CV	2.80	1.91	1.98	2.14	3.88	2.92	2.88	2.43
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Min	19.01	19.99	20.14	19.79	18.53	19.54	20.10	20.06
Max	21.56	21.45	21.87	21.39	21.58	21.74	22.15	22.21
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18	18	18

Table 4-2: Statistics from LT modulus

For completeness and for comparison purposes, the statistics and basis values for strength computed from the LT specimens are provided in Table 4-3 with the data and the B-basis values shown graphically in Figure 4-2.

The normalized data from the RTD, ETD and ETW environments did not pass the ADK test, so pooling was not appropriate. This means that those environments required the ANOVA method to compute the basis values. Since data was available from only three batches, these values are considered estimates only and may be overly conservative. However, the normalized data from those environments passed the ADK test after applying the transform for the modified CV method, so pooling was used for computation of the modified CV basis values.

The as measured data from each of the four environments tested did not pass the ADK test. Only the data from the CTD condition passed the ADK test with the transform for the modified CV method, so modified CV basis values are provided for the as measured data only for the CTD environmental condition.

There was one outlier. The lowest value in batch three of the as measured CTD condition data was an outlier for that batch only.

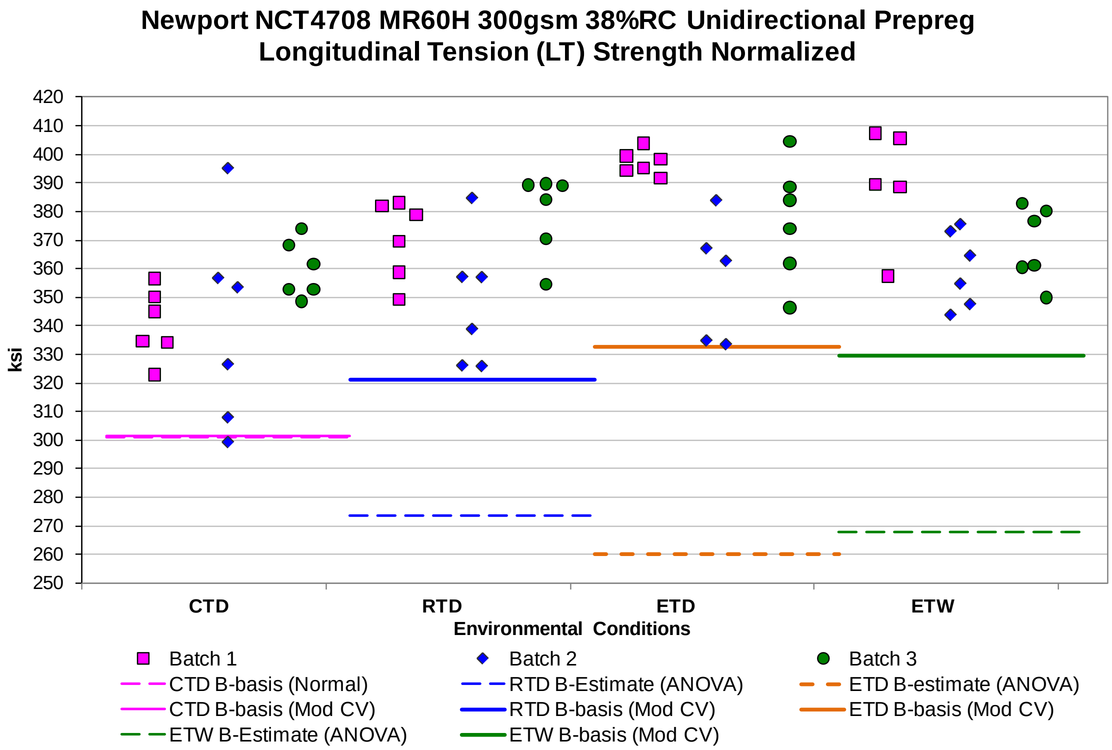

Figure 4-2 Batch plot for LT normalized strength from LT specimens

Longitudinal Tension Strength Basis Values and Statistics from LT specimens								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	346.72	366.07	377.92	374.47	349.14	366.03	380.90	378.83
Stdev	23.16	21.14	23.22	21.86	28.15	23.02	26.16	22.98
CV	6.68	5.77	6.14	5.84	8.06	6.29	6.87	6.07
Mod CV	7.34	6.89	7.07	6.92	8.06	7.14	7.43	7.03
Min	299.47	326.04	333.68	343.96	295.56	326.90	333.44	350.80
Max	395.25	389.75	404.53	420.84	389.20	397.10	413.30	423.77
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	17	18	18	18	17	18
Basis Values and/or Estimates								
B-basis Value	301.00							
B-estimate		273.69	260.24	267.69	243.07	237.82	232.99	250.67
A-estimate	268.61	207.85	176.34	191.54	167.52	146.35	127.48	159.24
Method	Normal	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Mod CV Basis Values and/or Estimates								
B-basis Value	301.64	320.99	332.58	329.39	293.56	NA	NA	NA
A-estimate	271.90	291.25	302.87	299.65	254.24	NA	NA	NA
Method	pooled	pooled	pooled	pooled	Normal	NA	NA	NA

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

4.2 Transverse (90º) Tension Properties (TT)

Transverse Tension data is not normalized for unidirectional tape. Pooling all three environmental conditions together was not appropriate due to a failure of Levene's test which indicated that the environments did not all have equal variance. However, the CTD and RTD environments could be pooled together. There were no outliers.

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

Newport NCT4708 MR60H 300gsm 38%RC Unidirectional Prepreg
Transverse Tension (TT) Strength as measured

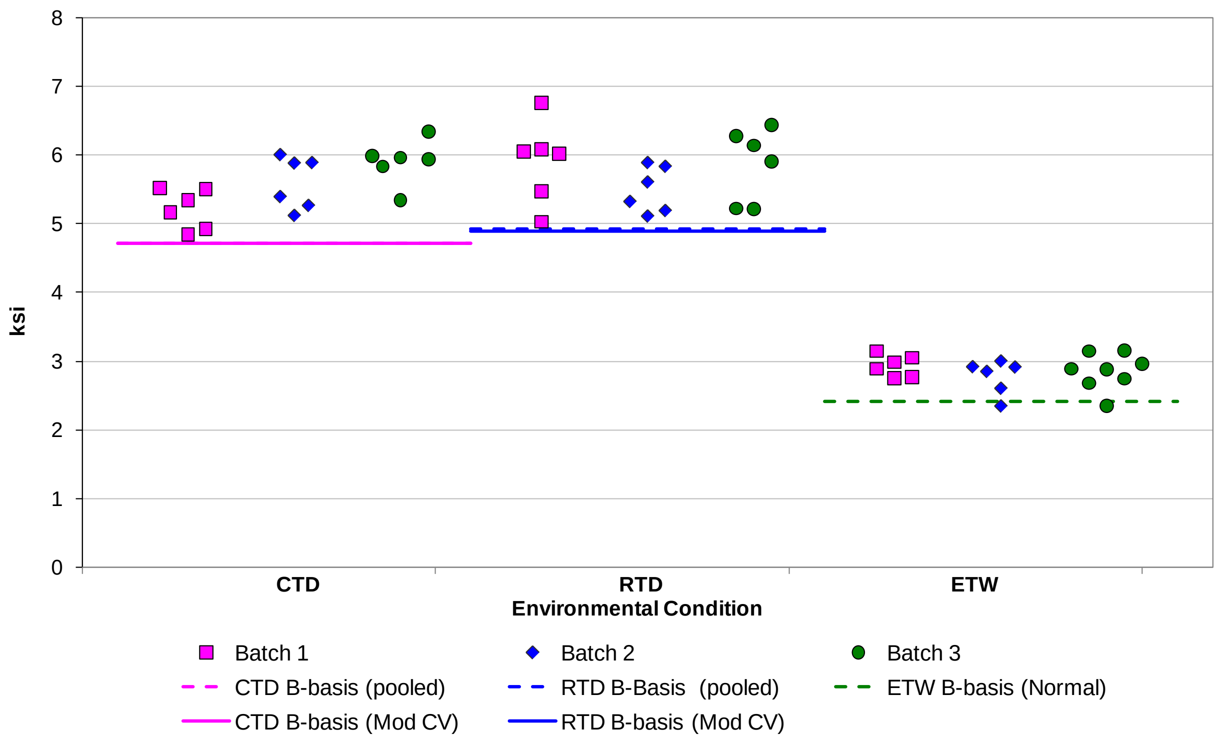

Figure 4-3: Batch Plot for TT strength as measured

Transverse Tension Strength Basis Values and Statistics for Strength and Modulus						
	Strength			Modulus		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	5.57	5.75	2.85	1.28	1.12	0.82
Stdev	0.42	0.50	0.23	0.03	0.02	0.03
CV	7.59	8.74	8.03	2.15	2.07	3.85
Mod CV	7.80	8.74	8.03	6.00	6.00	6.00
Min	4.84	5.03	2.35	1.25	1.07	0.78
Max	6.33	6.76	3.16	1.34	1.15	0.88
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	20	18	20	18
Basis Values and/or Estimates						
B-basis Value	4.72	4.91	2.41			
A-estimate	4.15	4.33	2.10			
Method	pooled	pooled	Normal			
Mod CV Basis Values and/or Estimates						
B-basis Value	4.71	4.90	NA			
A-estimate	4.13	4.32	NA			
Method	pooled	pooled	NA			

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

4.3 Longitudinal (0º) Compression Properties (LC)

The strength values for 0º properties are not measured directly from the LC specimens, but computed via the formulas specified in section 2.5. The derived values for the CTD, RTD and ETW conditions were computed using equation 64 in that section. The derived values for the ETD condition were computed using the alternate formula (equation 65) in section 2.5.1. The results of both the values measured directly from the LT specimens and the values computed from the UNT0 specimens are presented here.

The CTD and ETW environments have data from only 16 specimens available. While 16 specimens is adequate for the pooled methodology, it is not for the single point method so values from those environments using the single point method are considered estimates.

The data from the ETD and ETW conditions (both normalized and as measured) fail the ADK test, which means that working draft CMH-17 Rev G requires the ANOVA method to be used to compute basis values for those environments. However, the data from the normalized ETD condition and the as measured ETW condition pass the ADK test with the transform for the modified CV method, so a modified CV basis values can be provided for those datasets.

The CTD and RTD data could be pooled together. For the normalized data, the ETD data could be included in the pooled dataset for computing the modified CV basis values. The ETW datasets and the as measured ETD dataset are considered estimates only.

An override of the ADK test result is recommended for the normalized ETW and the as measured ETD datasets for the modified CV basis values only. This override is permissible according to section 8.3.10.1 of CMH17 Rev G and allows pooling across all the environments. A transformation of the data in each environment to have a mean of 1.0 was made and then the pooled data was checked for batch to batch variability differences using both the ADK test and Levene’s test. There were no significant differences between batches after this transformation. However, the as measured data did not pass Levene’s test for equality of variance between environments at the 0.05 level. It did pass at the 0.025 level and an override of this test result to allow pooling is also recommended.

There was one outlier. The outlier was the highest value in batch three of the as measured RTD dataset. It was an outlier only before pooling the data from all three batches together.

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

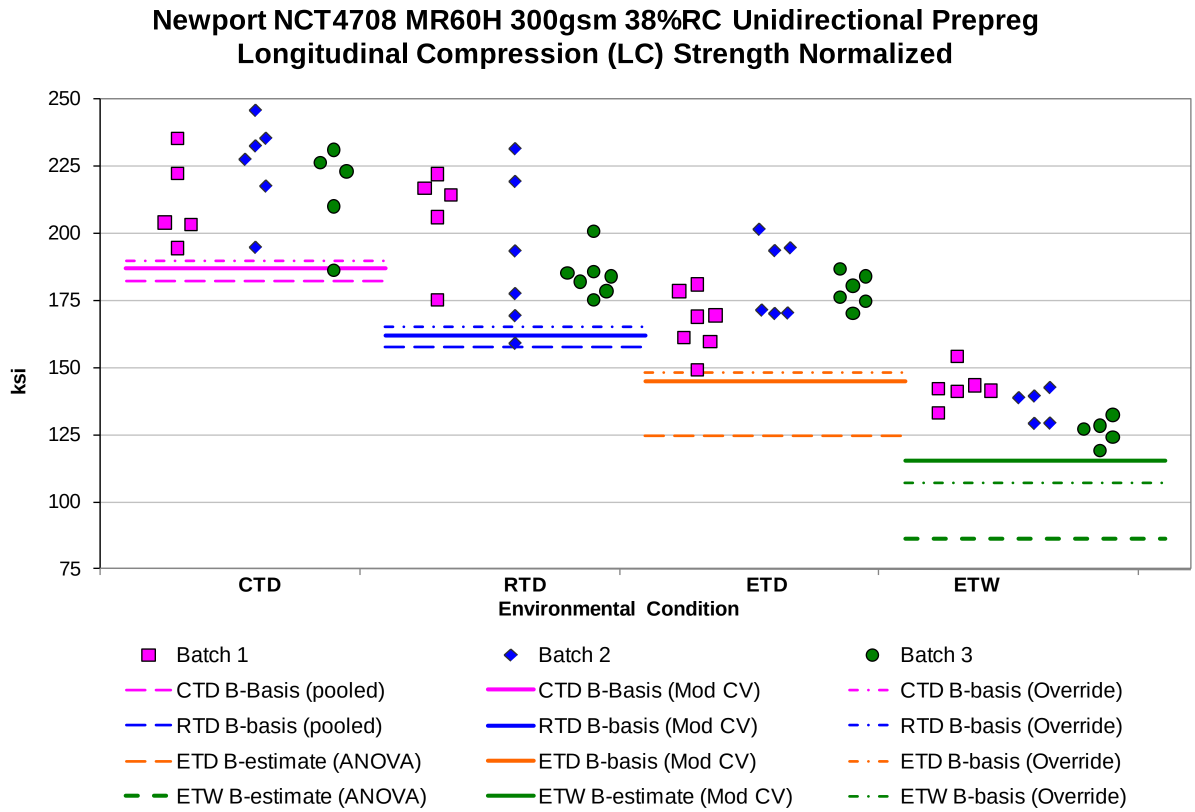

Figure 4-4 Batch plot for LC normalized strength (from UNC0 specimens)

Longitudinal Compression Strength Basis Values and Statistics from UNC0 Specimens and back out formula								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	217.93	192.93	175.74	135.28	218.90	193.32	182.03	135.01
Stdev	17.37	20.82	12.79	8.95	18.10	20.43	13.16	7.64
CV	7.97	10.79	7.28	6.62	8.27	10.57	7.23	5.66
Mod CV	7.98	10.79	7.64	7.31	8.27	10.57	7.62	6.83
Min	186.06	158.83	149.06	119.17	191.52	155.65	155.71	121.12
Max	245.56	231.28	201.28	154.19	247.90	231.71	206.39	150.58
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	16	18	19	16	16	18	19	16
Basis Values and/or Estimates								
B-basis Value	182.25	157.65			183.05	157.86		
B-Estimate			125.76	86.28			119.86	95.51
A-Estimate	158.24	133.55	90.13	51.34	158.92	133.64	75.52	67.36
Method	pooled	pooled	ANOVA	ANOVA	pooled	pooled	ANOVA	ANOVA
Mod CV Basis Values and/or Estimates								
B-basis Value	186.71	162.08	145.05		NA	NA		
B-Estimate				115.17			155.01	116.26
A-Estimate	166.16	141.47	124.41	101.02	NA	NA	135.85	103.07
Method	pooled	pooled	pooled	Normal	NA	NA	Normal	Normal
Mod CV Basis Values with Recommended Overrides								
B-basis Value	189.63	164.98	147.94	106.98	190.49	165.26	154.13	106.60
A-Estimate	171.21	146.51	129.44	88.56	172.00	146.72	135.56	88.11
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-5: 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	18.07	18.45	17.72	18.30	18.67	18.80	18.45	18.57
Stdev	0.69	0.42	0.63	0.54	0.74	0.43	0.74	0.56
CV	3.81	2.26	3.56	2.97	3.94	2.27	4.02	3.01
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00	6.01	6.00
Min	16.91	17.69	16.33	17.05	17.21	18.13	17.05	17.28
Max	19.21	19.05	18.49	19.10	20.06	19.67	20.02	19.47
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	19	18	18	18	19

Table 4-6: Statistics from LC modulus data

4.4 Transverse (90º) Compression Properties (TC)

Transverse Compression data is not normalized for unidirectional tape.

The data from the RTD and ETW conditions fail the ADK test, which means that only the ANOVA method can be used to compute basis values for those environments. However, the data from the RTD condition did pass the ADK test with the transform for the modified CV method, so modified CV basis values are provided. The CTD and RTD data could be pooled together for computing the modified CV basis values. The data from batch one for the ETW data had significantly more variability than the data from either batch two or batch three, requiring the ANOVA method of analysis. It could not be pooled with the CTD and RTD data. A- and B-estimates are provided using the modified CV method for the ETW condition.

There was one outlier. It was the lowest value in batch two of the CTD condition. It was an outlier only before pooling the data from the three batches together.

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

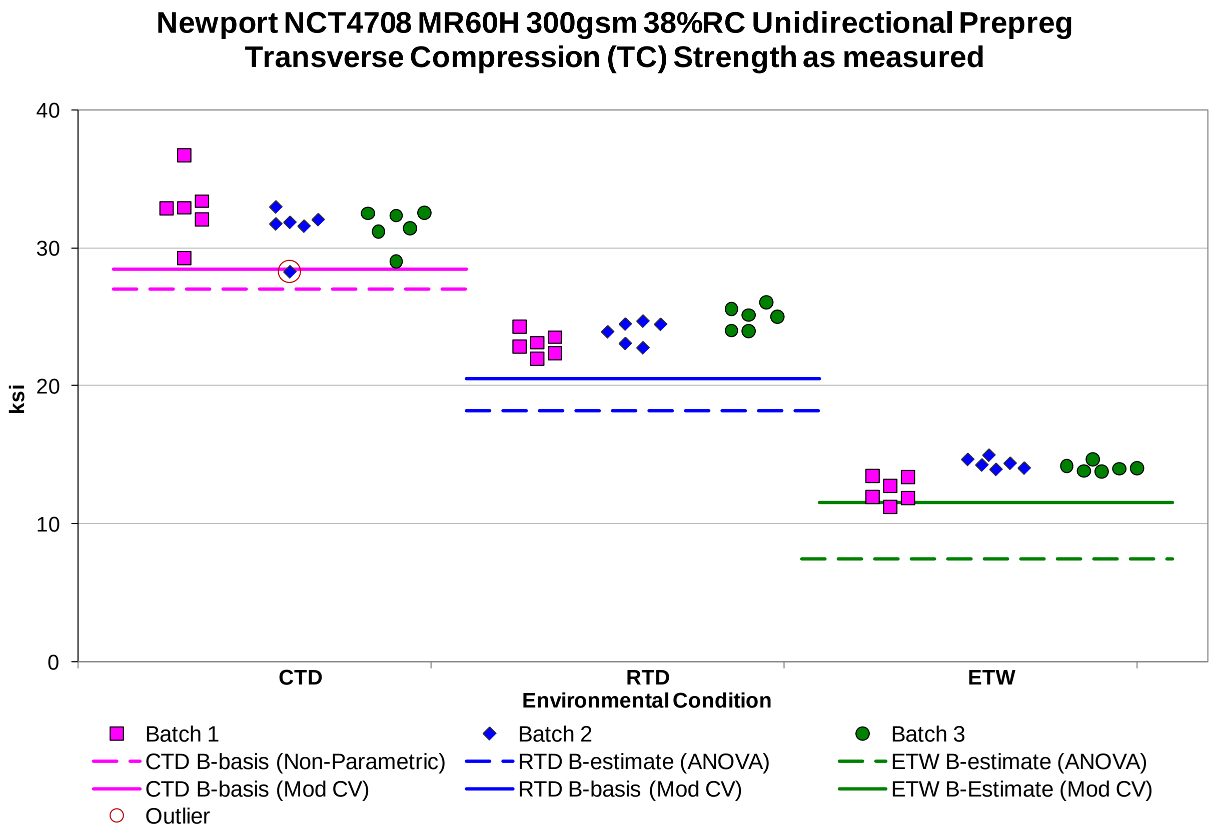

Figure 4-5: Batch Plot for TC strength as measured

Transverse Compression Strength Basis Values and Statistics for Strength and Modulus						
	Strength			Modulus		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	31.94	23.98	13.66	1.39	1.23	1.01
Stdev	1.86	1.13	1.03	0.07	0.03	0.04
CV	5.82	4.70	7.55	4.78	2.82	3.65
Mod CV	6.91	6.35	7.78	6.39	6.00	6.00
Min	28.28	22.02	11.27	1.24	1.18	0.94
Max	36.73	26.09	14.96	1.50	1.32	1.07
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and/or Estimates						
B-basis Value	27.05					
B-estimate		18.20	7.46			
A-estimate	19.13	14.08	3.04			
Method	Non-Parametric	ANOVA	ANOVA			
Mod CV Basis Values and/or Estimates						
B-basis Value	28.49	20.53				
B-estimate			11.57			
A-estimate	26.14	18.18	10.08			
Method	pooled	pooled	Normal			

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

4.5 In-Plane Shear Properties (IPS)

In-Plane Shear data is not normalized. Measurements are taken on each specimen, when possible, for 0.2% offset strength, strength at 5% strain, and modulus.

For the 0.2% offset strength, the data from conditions RTD and ETW fail the ADK test, which means the ANOVA method must be used to estimate basis values. However, when the transform for the modified CV method is used, the data from both those conditions pass the ADK test so modified CV basis values can be computed. However, the data cannot be pooled across the environments due to failing Levene's test with indicates that the different conditions have different variances. There were no test failures in the data for strength at 5% strain, so the data could be pooled across the environments for that property.

There were a total of six outliers, two in the 0.2% offset data and four in the strength at 5% strain data. In the 0.2% offset data, the highest value in batch one of data from the ETD condition was an outlier only before pooling the data from the three batches together and the highest value in batch two of the CTD data was an outlier only after pooling the data from the three batches together. In the strength at 5% strain data, there were three outliers in the CTD condition and one in the ETW condition. The two highest values in the CTD condition data were found to be outliers only after pooling the data from the three batches together. The lowest value in batch three for the CTD condition was an outlier only before pooling the three batches together. The lowest value in batch one of the ETW condition data was an outlier both before and after pooling the data from the three batches together.

Statistics, basis values and estimates are given for the strength data in Table 4-8 and modulus data in Table 4-9. 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.

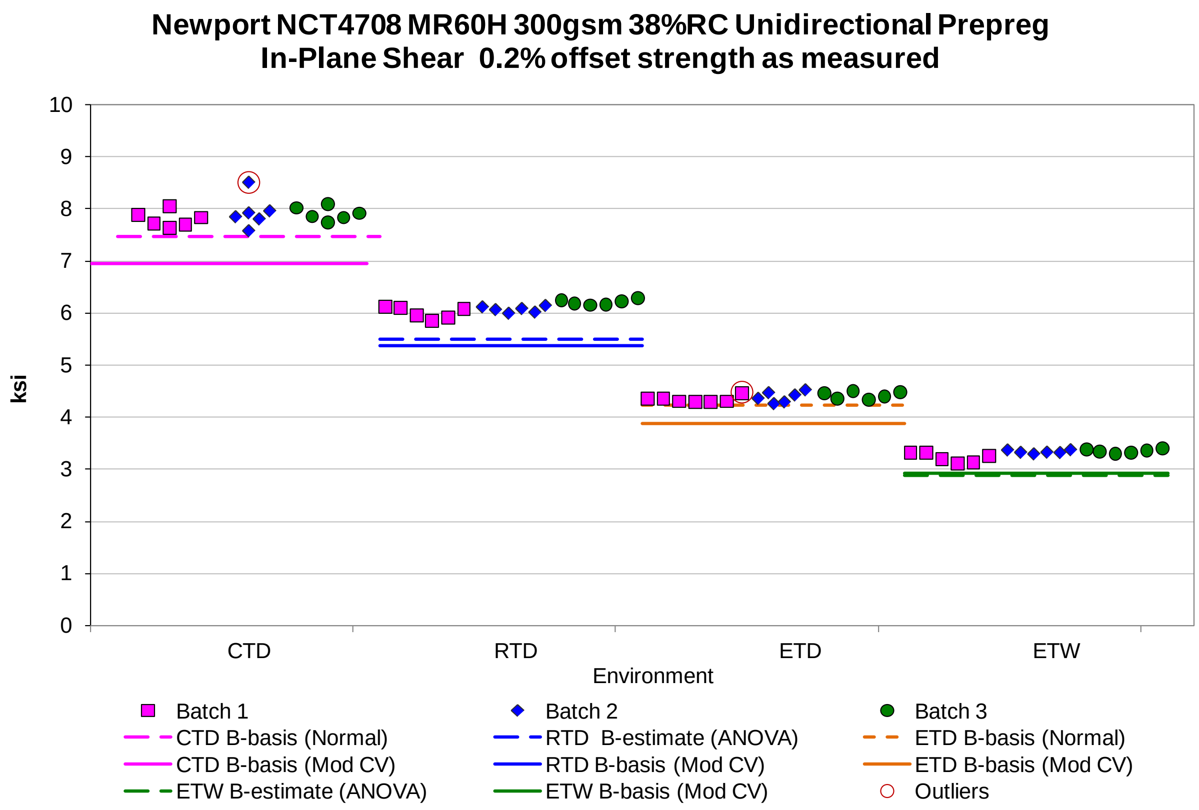

Figure 4-6: Batch plot for IPS for 0.2% offset strength as measured

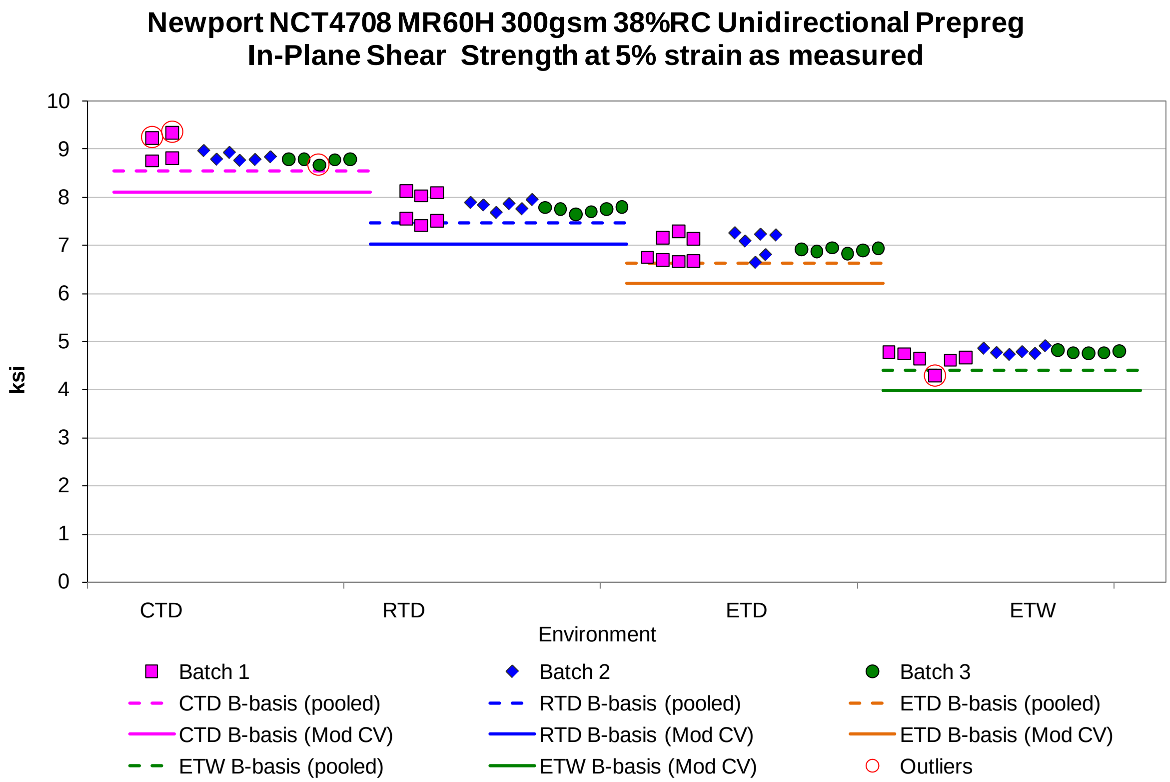

Figure 4-7: Batch plot for IPS for strength at 5% strain as measured

In-Plane Shear Strength Basis Values and Statistics								
	Strength at 5% Strain				0.2% Offset Strength			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	8.88	7.80	6.96	4.74	7.89	6.10	4.39	3.31
Stdev	0.19	0.19	0.22	0.13	0.21	0.11	0.08	0.08
CV	2.10	2.45	3.11	2.83	2.64	1.84	1.89	2.48
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Min	8.69	7.42	6.64	4.30	7.58	5.87	4.27	3.12
Max	9.36	8.14	7.30	4.91	8.51	6.29	4.53	3.41
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	15	18	19	17	18	18	19	18
Basis Values and/or Estimates								
B-basis Value	8.55	7.47	6.63	4.41	7.48		4.23	
B-estimate						5.50		2.89
A-estimate	8.33	7.26	6.42	4.20	7.19	5.07	4.11	2.59
Method	pooled	pooled	pooled	pooled	Normal	ANOVA	Normal	ANOVA
Modified CV Basis Values and/or Estimates								
B-basis Value	8.11	7.04	6.21	3.98	6.96	5.38	3.88	2.92
A-estimate	7.61	6.54	5.71	3.48	6.30	4.87	3.51	2.64
Method	pooled	pooled	pooled	pooled	Normal	Normal	Normal	Normal

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

In-Plane Shear Modulus Statistics				
Env	CTD	RTD	ETD	ETW
Mean	0.64	0.55	0.44	0.36
Stdev	0.01	0.01	0.01	0.01
CV	2.24	2.72	2.32	2.82
Mod CV	6.00	6.00	6.00	6.00
Min	0.61	0.52	0.43	0.33
Max	0.66	0.58	0.47	0.37
No. Batches	3	3	3	3
No. Spec.	18	18	19	18

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

4.6 Short Beam Strength (SBS) Data

The Short Beam Strength data is not normalized. The data from the ETW condition fails the ADK test, so the ANOVA method must be used to compute estimates of basis values for that condition. However, when the transform for the modified CV method is used, the data from the ETW condition passes the ADK test so modified CV basis values can be computed. All four environments can be pooled together to compute the modified CV basis values. There were no outliers.

Statistics, basis values and estimates are given for SBS data in Table 4-10. The data, B-estimates and B-basis values are shown graphically in Figure 4-8.

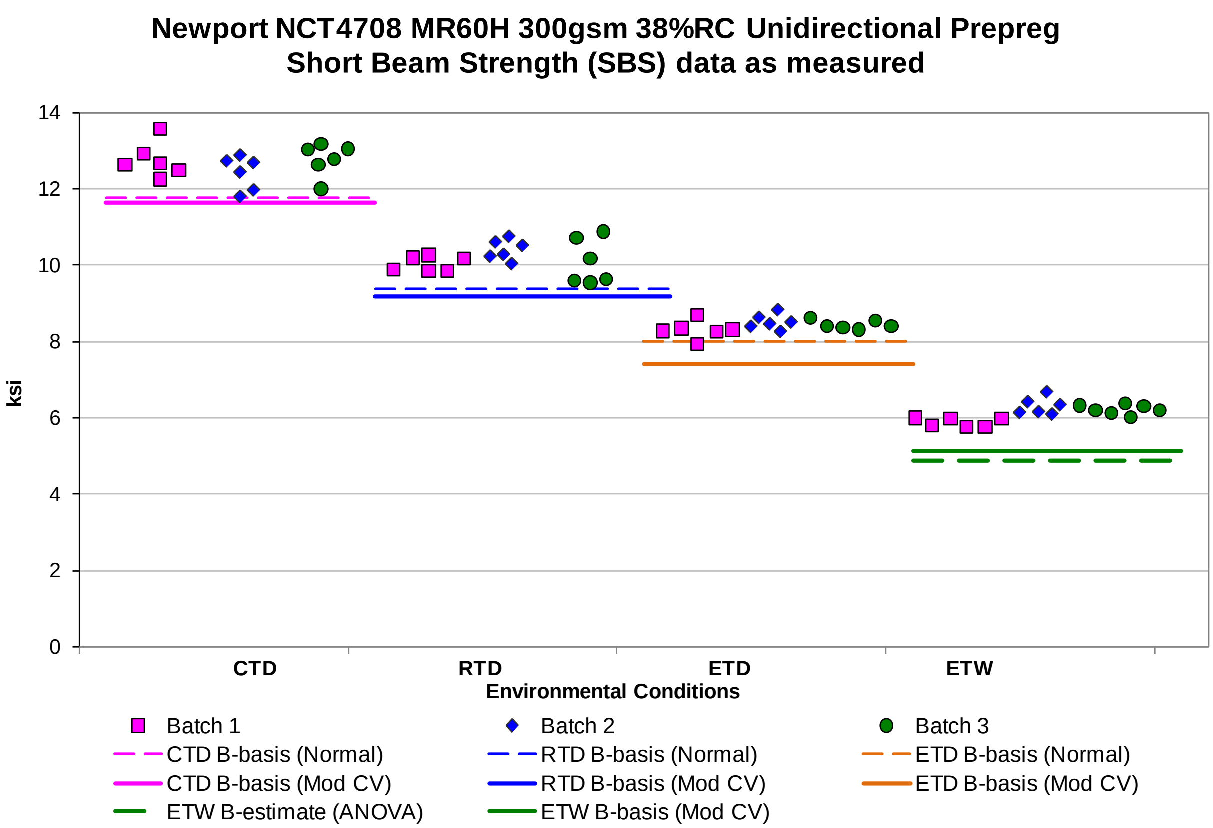

Figure 4-8: Batch plot for SBS as measured

Short Beam Strength (SBS) as measured				
Env	CTD	RTD	ETD	ETW
Mean	12.65	10.18	8.42	6.14
Stdev	0.45	0.40	0.20	0.23
CV	3.57	3.98	2.38	3.80
Mod CV	6.00	6.00	6.00	6.00
Min	11.79	9.54	7.94	5.77
Max	13.57	10.88	8.82	6.67
No. Batches	3	3	3	3
No. Spec.	18	18	18	19
Basis Values and/or Estimates				
B-basis Value	11.76	9.38	8.02	
B-estimate				4.87
A-estimate	11.13	8.81	7.74	3.96
Method	Normal	Normal	Normal	ANOVA
Mod CV Basis Values and/or Estimates				
B-basis Value	11.65	9.17	7.41	5.14
A-estimate	10.98	8.51	6.75	4.48
Method	pooled	pooled	pooled	pooled

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

4.7 Unnotched Tension Properties (UNT0)

The normalized data from the RTD environmental condition fails the ADK test, so pooling is not appropriate and the ANOVA method must be used for the data from the RTD environment. The as measured data from the RTD conditions fails the ADK test, so pooling is not appropriate for the as measured data either.

The data from the RTD condition, both as measured and normalized, did pass the ADK test with the transform for the modified CV method, so modified CV basis values are provided for the RTD condition. Pooling was appropriate for the modified CV basis values. While ASAP shows a failure of Levene's test for this data, when the data from all of the environments is transformed (ASAP only transforms those that fail the ADK test) to fit the assumptions of the modified CV method, the data passes Levene's test and can be pooled to compute the modified CV basis values.

The UNT0 data had one outlier. It was an outlier in the normalized data but not the as measured data. The highest value in the batch two of the normalized CTD condition was an outlier only before pooling the data from the three batches together. This outlier was retained for this analysis.

Statistics, basis values and estimates are given for strength data in Table 4-11 and for the modulus data in Table 4-12. The normalized data, B-estimates, and the B-basis values are shown graphically in Figure 4-9.

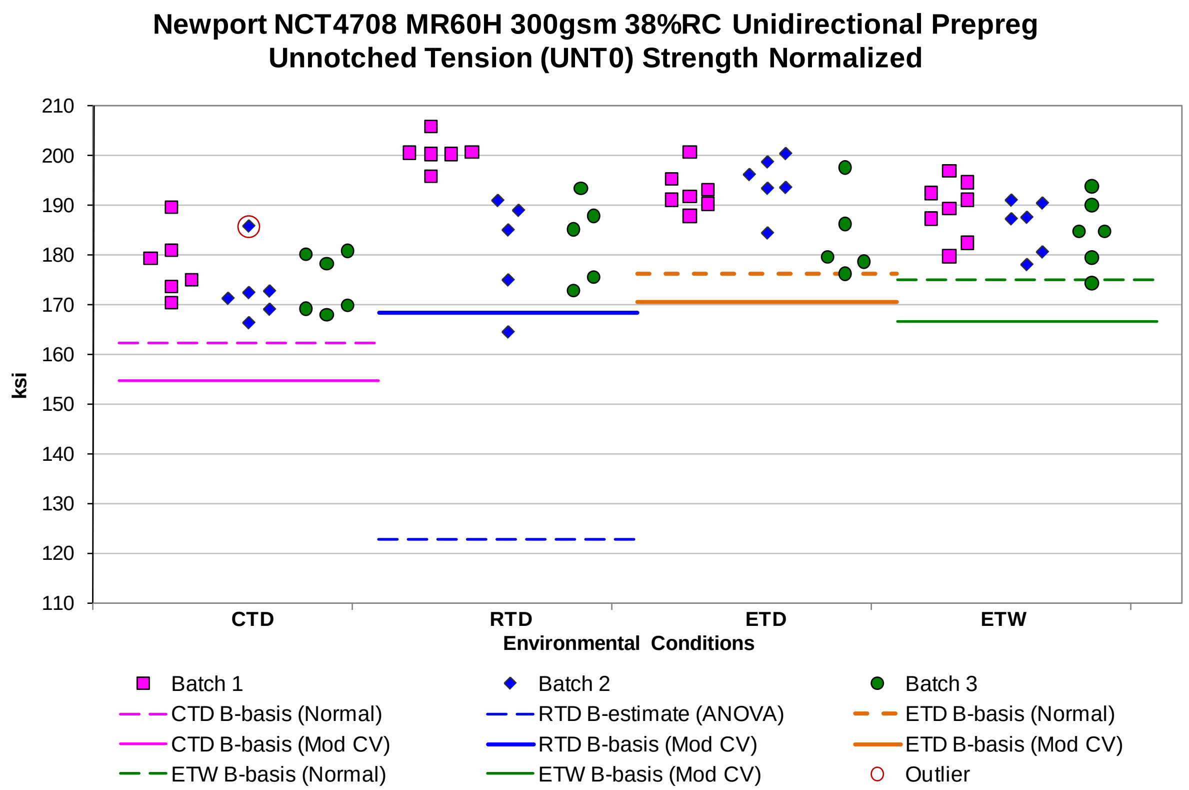

Figure 4-9: Batch Plot for UNT0 normalized strength

Unnotched Tension (UNT0) Strength Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	175.27	189.01	190.92	186.90	176.45	187.80	188.44	185.78
Stdev	6.52	11.95	7.36	6.12	7.08	11.77	6.33	6.68
CV	3.72	6.32	3.85	3.28	4.01	6.27	3.36	3.59
Mod CV	6.00	7.16	6.00	6.00	6.01	7.13	6.00	6.00
Min	166.50	164.66	176.28	174.44	165.49	161.95	178.67	174.75
Max	189.66	205.90	200.75	196.97	186.10	205.22	200.92	199.30
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	16	18	20	18	16	18	20
Basis Values and/or Estimates								
B-basis Value	162.40		176.39	175.11	162.48		175.94	172.92
B-estimate		122.96				131.21		
A-estimate	153.28	75.86	166.10	166.72	152.58	90.89	167.08	163.77
Method	Normal	ANOVA	Normal	Normal	Normal	ANOVA	Normal	Normal
Modified CV Basis Values and/or Estimates								
B-basis Value	154.92	168.41	170.57	166.76	156.23	167.32	168.22	165.76
A-estimate	141.50	155.02	157.15	153.31	142.89	154.02	154.88	152.39
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-11: Statistics and Basis Values for UNT0 Strength data

Unnotched Tension (UNT0) Modulus Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	10.77	10.84	11.02	10.96	10.84	10.76	10.89	10.90
Stdev	0.21	0.30	0.26	0.20	0.28	0.39	0.24	0.20
CV	1.98	2.74	2.40	1.81	2.63	3.62	2.19	1.79
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Min	10.16	10.06	10.48	10.64	9.97	9.90	10.56	10.45
Max	11.08	11.24	11.41	11.44	11.19	11.23	11.36	11.23
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	19	20	18	18	19	20

Table 4-12: Statistics from UNT0 Modulus data

4.8 Unnotched Compression Properties (UNC0)

The data from the ETD and ETW conditions fail the ADK test, which means that only the ANOVA method can be used to compute basis values for those environments. However, the data from the normalized ETD condition and the as measured ETW condition pass the ADK test with the transform for the modified CV method, so modified CV basis values are provided for those datasets. Estimates computing using the modified CV method are provided for the as measured ETD condition and the normalized ETW condition.

The CTD and RTD data could be pooled together, and the normalized ETD data could be included in the pooled dataset for computing the modified CV basis values. Since the as measured data from the ETW condition did pass the ADK test with the transform for the modified CV method, modified CV estimates of basis values are provided. It could not be included in the pooled dataset due to the ETD data failing the ADK test. Since data from only sixteen specimens is available in the ETW condition, only estimates could be computed using the single point method.

There was one outlier. The outlier was the highest value in batch three of the as measured RTD dataset. It was an outlier only before pooling the data from all three batches together.

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 4-10.

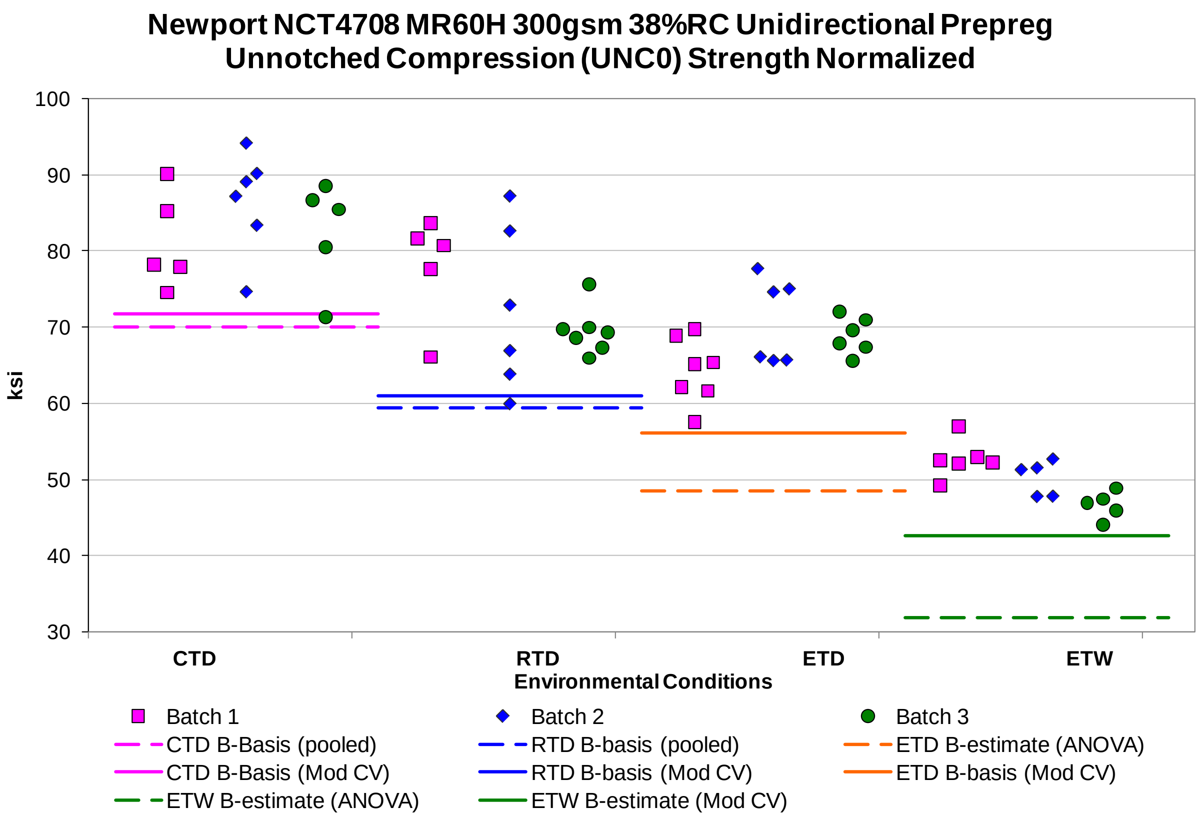

Figure 4-10: Batch Plot for UNC0 normalized strength

Unnotched Compression (UNC0) Strength Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	83.64	72.80	67.86	50.03	83.66	72.79	67.64	49.86
Stdev	6.67	7.86	4.94	3.31	6.92	7.69	4.89	2.82
CV	7.97	10.79	7.28	6.62	8.27	10.57	7.23	5.66
Mod CV	7.98	10.79	7.64	7.31	8.27	10.57	7.62	6.83
Min	71.41	59.93	57.56	44.07	73.20	58.61	57.86	44.73
Max	94.24	87.27	77.72	57.02	94.74	87.25	76.69	55.61
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	16	18	19	16	16	18	19	16
Basis Values and/or Estimates								
B-basis Value	70.09	59.40			70.08	59.36		
B-estimate			48.56	31.91			44.53	35.27
A-estimate	60.97	50.25	34.80	18.98	60.94	50.18	28.06	24.87
Method	pooled	pooled	ANOVA	ANOVA	pooled	pooled	ANOVA	ANOVA
Modified CV Basis Values and/or Estimates								
B-basis Value	71.74	61.04	56.16		70.08	59.36		
B-estimate				42.59			57.60	42.93
A-estimate	63.91	53.18	48.29	37.36	60.94	50.18	50.48	38.06
Method	pooled	pooled	pooled	Normal	pooled	pooled	Normal	Normal

Table 4-13: Statistics and Basis Values for UNC0 Strength data

Unnotched Compression (UNC0) Modulus Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	7.04	7.00	6.84	7.05	7.06	6.98	6.85	7.03
Stdev	0.31	0.26	0.30	0.31	0.38	0.28	0.30	0.28
CV	4.36	3.69	4.32	4.41	5.37	3.98	4.33	3.93
Mod CV	6.18	6.00	6.16	6.21	6.69	6.00	6.17	6.00
Min	6.63	6.44	6.37	6.55	6.62	6.29	6.41	6.55
Max	7.79	7.65	7.48	7.63	8.04	7.65	7.45	7.51
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	17	18	18	18	17	18	18	18

Table 4-14: Statistics from UNC0 Modulus data

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

5.1 Quasi Isotropic Unnotched Tension Properties (UNT1)

The data from the CTD condition, both as measured and normalized, fail the ADK test, which means that only the ANOVA method can be used to compute basis values for that environment. The RTD and ETW data can be pooled together. The normalized (but not the as measured) CTD data pass the ADK test with the transform for the modified CV method and could be pooled with the RTD and ETW data, so modified CV basis values were computed for the normalized data by pooling all three environments together. There were no outliers.

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.

Newport NCT4708 MR60H 300gsm 38%RC Unidirectional Prepreg
Quasi Isotropic Unnotched Tension (UNT1) Strength Normalized

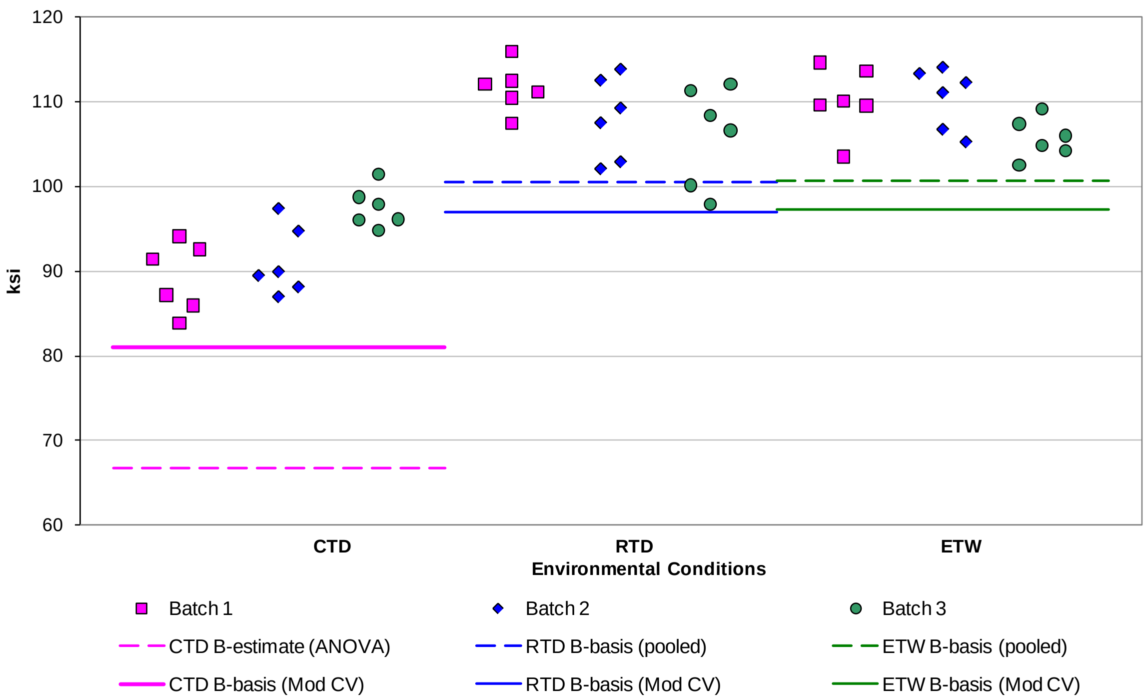

Figure 5-1: Batch Plot for UNT1 normalized strength

Unnotched Tension (UNT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	92.62	108.60	108.83	93.01	108.81	109.14
Stdev	4.98	4.98	3.95	6.45	4.48	3.54
CV	5.38	4.58	3.63	6.93	4.12	3.25
Mod CV	6.69	6.29	6.00	7.47	6.06	6.00
Min	83.88	97.95	102.93	83.16	101.01	102.34
Max	101.45	115.96	114.71	105.99	114.43	115.06
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and/or Estimates						
B-basis Value		100.42	100.66		101.45	101.78
B-estimate	66.81			54.72		
A-estimate	48.40	94.85	95.09	27.39	96.44	96.77
Method	ANOVA	pooled	pooled	ANOVA	pooled	pooled
Mod CV Basis Values and/or Estimates						
B-basis Value	81.07	97.05	97.28	NA	96.84	97.17
A-estimate	73.36	89.34	89.57	NA	88.70	89.02
Method	pooled	pooled	pooled	NA	pooled	pooled

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

Unnotched Tension (UNT1) Modulus Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	7.20	7.44	7.30	7.23	7.45	7.32
Stdev	0.15	0.15	0.10	0.21	0.20	0.10
CV	2.14	2.02	1.42	2.94	2.65	1.37
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	6.92	6.96	7.12	6.82	6.92	7.12
Max	7.48	7.65	7.46	7.62	7.77	7.52
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18

Table 5-2: Statistics from UNT1 Modulus data

5.2 "Soft" Unnotched Tension Properties (UNT2)

The as measured data had no test failures or outliers, so pooling across environments was acceptable. The normalized data failed Levene's test for equality of variance. The normalized data from the ETW environment had significantly larger variance than the CTD and RTD environments, so only the CTD and RTD environments could be pooled together.

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 and B-basis values are shown graphically in Figure 5-2.

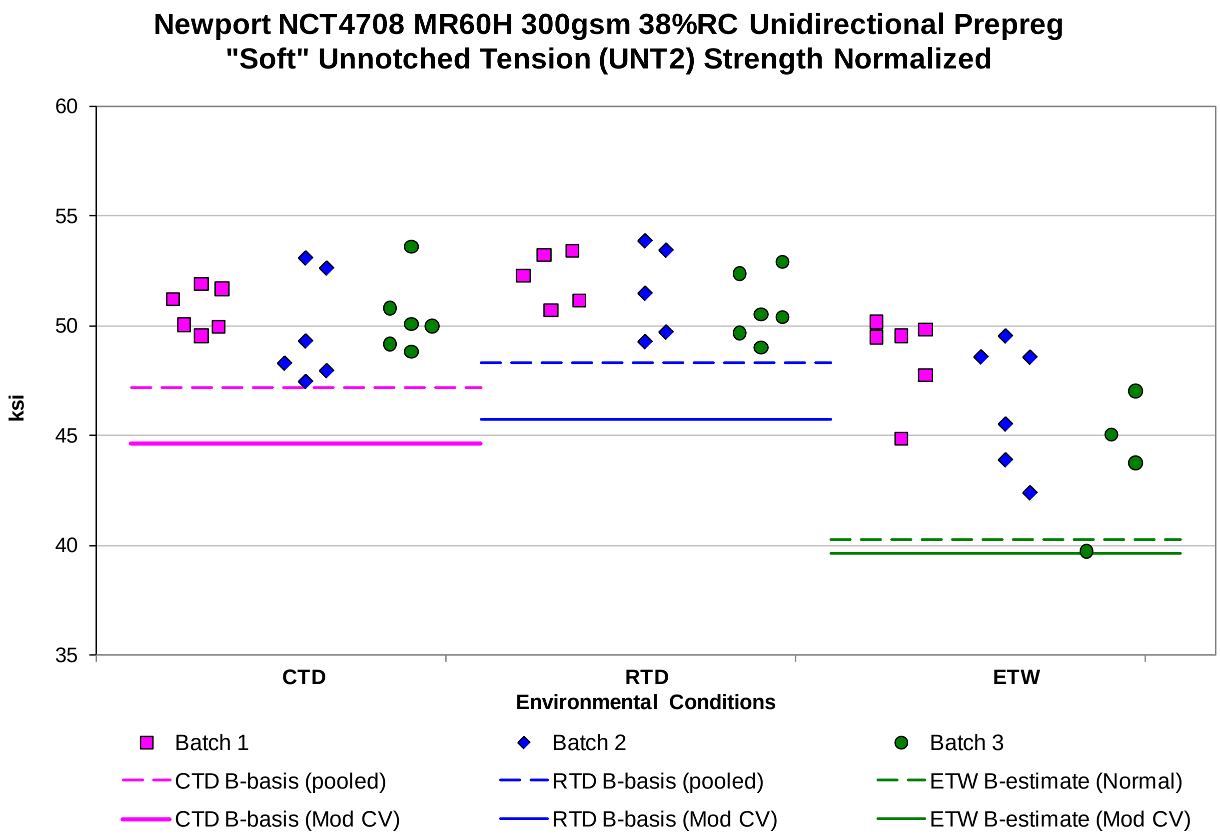

Figure 5-2: Batch Plot for UNT2 normalized strength

Unnotched Tension (UNT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	50.32	51.47	46.61	50.38	51.47	46.40
Stdev	1.76	1.64	3.11	2.04	1.50	2.68
CV	3.51	3.18	6.67	4.05	2.91	5.77
Mod CV	6.00	6.00	7.34	6.02	6.00	6.88
Min	47.45	49.01	39.74	47.56	48.95	40.84
Max	53.63	53.88	50.18	55.26	53.93	49.18
No. Batches	3	3	3	3	3	3
No. Spec.	18	16	16	18	16	16
Basis Values and/or Estimates						
B-basis Value	47.19	48.31		46.61	47.65	42.58
B-estimate			40.28			
A-estimate	45.06	46.19	35.81	44.07	45.13	40.06
Method	pooled	pooled	Normal	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates						
B-basis Value	44.73	45.82		44.86	45.88	40.82
B-estimate			39.65			
A-estimate	40.92	42.02	34.76	41.16	42.20	37.13
Method	pooled	pooled	Normal	pooled	pooled	pooled

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

Unnotched Tension (UNT2) Modulus Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	4.76	4.53	4.13	4.77	4.52	4.12
Stdev	0.10	0.12	0.07	0.13	0.15	0.08
CV	2.08	2.73	1.69	2.83	3.33	1.94
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	4.53	4.25	4.03	4.41	4.27	3.98
Max	4.97	4.71	4.29	4.95	4.82	4.27
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	17	18	18	17

Table 5-4: Statistics from UNT2 Modulus data

5.3 "Hard" Unnotched Tension Properties (UNT3)

There were no test failures so pooling across all three environmental conditions was acceptable. There were no outliers.

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.

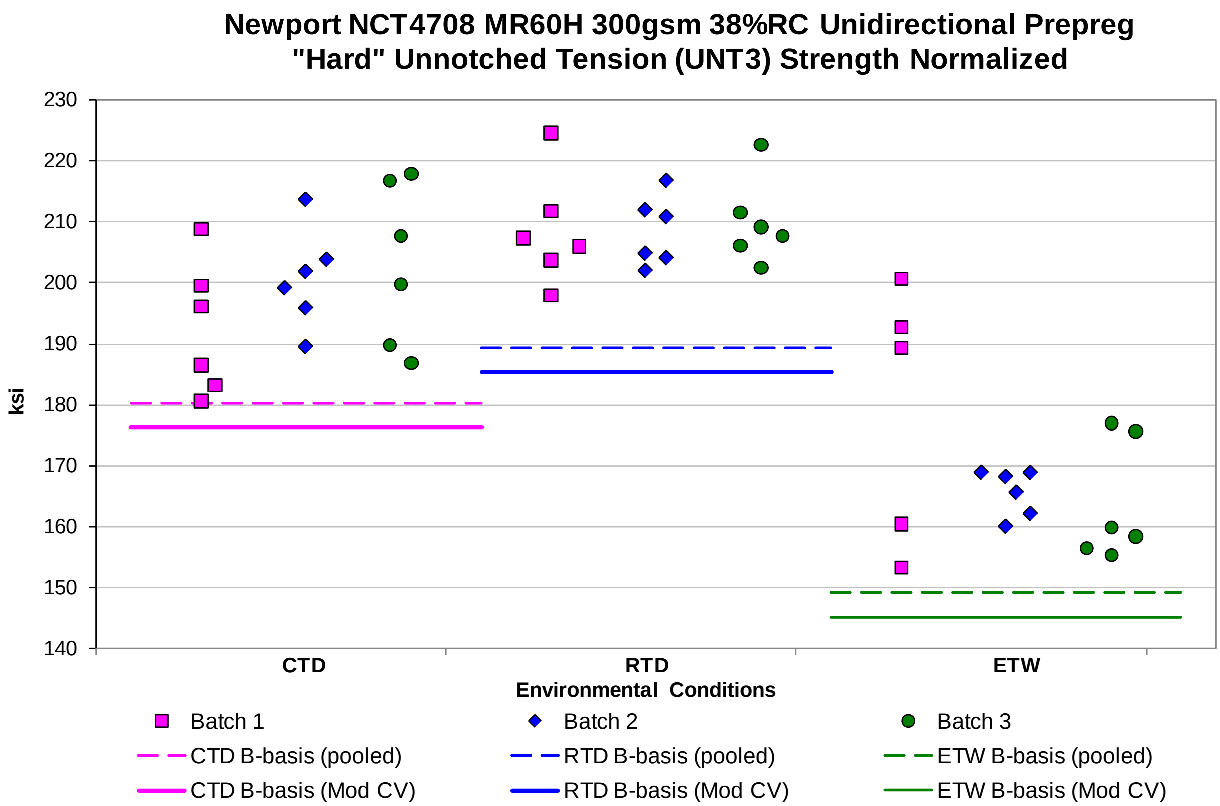

Figure 5-3: Batch Plot for UNT3 normalized strength

Unnotched Tension (UNT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	199.95	208.99	169.03	200.71	209.41	169.01
Stdev	11.43	6.92	13.86	12.96	7.80	13.43
CV	5.71	3.31	8.20	6.46	3.72	7.94
Mod CV	6.86	6.00	8.20	7.23	6.00	7.97
Min	180.64	197.95	153.30	175.70	196.58	149.72
Max	217.88	224.52	200.60	221.99	227.30	198.29
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	17	18	18	17
Basis Values and/or Estimates						
B-basis Value	180.36	189.40	149.32	180.08	188.78	148.27
A-estimate	167.27	176.31	136.26	166.30	175.00	134.51
Method	pooled	pooled	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates						
B-basis Value	176.25	185.29	145.19	176.71	185.41	144.88
A-estimate	160.41	169.45	129.38	160.68	169.38	128.87
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	12.48	12.55	12.70	12.52	12.57	12.69
Stdev	0.33	0.16	0.23	0.40	0.19	0.26
CV	2.65	1.24	1.84	3.23	1.52	2.06
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	11.89	12.27	12.25	11.57	12.21	12.22
Max	12.98	12.82	13.11	13.06	12.83	13.07
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	21	18	18	21

Table 5-6: Statistics from UNT3 Modulus data

5.4 Quasi Isotropic Unnotched Compression (UNC1)

The UNC1 data could not be pooled across the two environments. The as measured data from the ETW failed the ADK test even with the modified CV transform. This means the ANOVA analysis is required for that dataset and also that modified CV basis values cannot be provided. The normalized data failed Levene's test for equality of variance, so the two environments could not be pooled for the normalized data.

There was one outlier. It was the highest value in batch one of the ETW data. It was an outlier in both the as measured and the normalized data, but it was an outlier only before pooling the three batches together. The outlier was retained for this analysis.

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

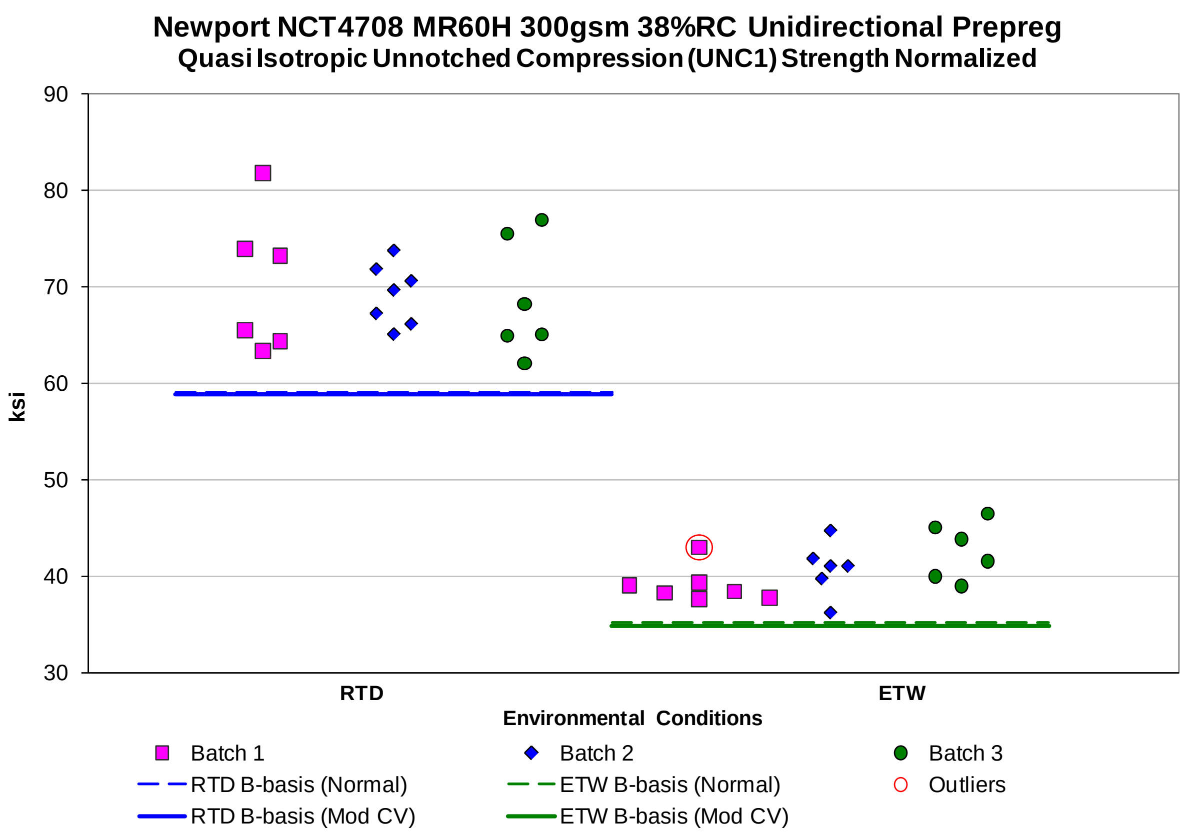

Figure 5-4: Batch plot for UNC1 normalized strength

Unnotched Compression (UNC1) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	69.42	40.73	70.12	41.63
Stdev	5.34	2.83	5.75	3.34
CV	7.70	6.96	8.21	8.03
Mod CV	7.85	7.48	8.21	8.03
Min	62.06	36.21	62.17	37.21
Max	81.76	46.48	82.12	48.76
No. Batches	3	3	3	3
No. Spec.	19	19	19	19
Basis Values and/or Estimates				
B-basis Value	59.01	35.21	58.90	
B-estimate				25.41
A-estimate	51.61	31.28	50.94	13.84
Method	Normal	Normal	Normal	ANOVA
Mod CV Basis Values and/or Estimates				
B-basis Value	58.80	34.79	NA	NA
A-estimate	51.27	30.58	NA	NA
Method	Normal	Normal	NA	NA

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

Unnotched Compression (UNC1) Modulus Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	6.65	6.35	6.76	6.48
Stdev	0.37	0.26	0.38	0.30
CV	5.60	4.10	5.66	4.71
Mod CV	6.80	6.05	6.83	6.35
Min	6.12	5.90	6.17	5.98
Max	7.44	6.77	7.47	7.10
No. Batches	3	3	3	3
No. Spec.	18	19	18	19

Table 5-8: Statistics from UNC1 Modulus data

5.5 "Soft" Unnotched Compression (UNC2)

There were no test failures and the UNC2 data from the RTD and ETW environments could be pooled together. There was one outlier. It was the lowest value in batch two of the ETW data. It was an outlier in both the as measured and the normalized data, but it was an outlier only before pooling the three batches together. The outlier 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, B-estimates and B-basis values are shown graphically in Figure 5-5.

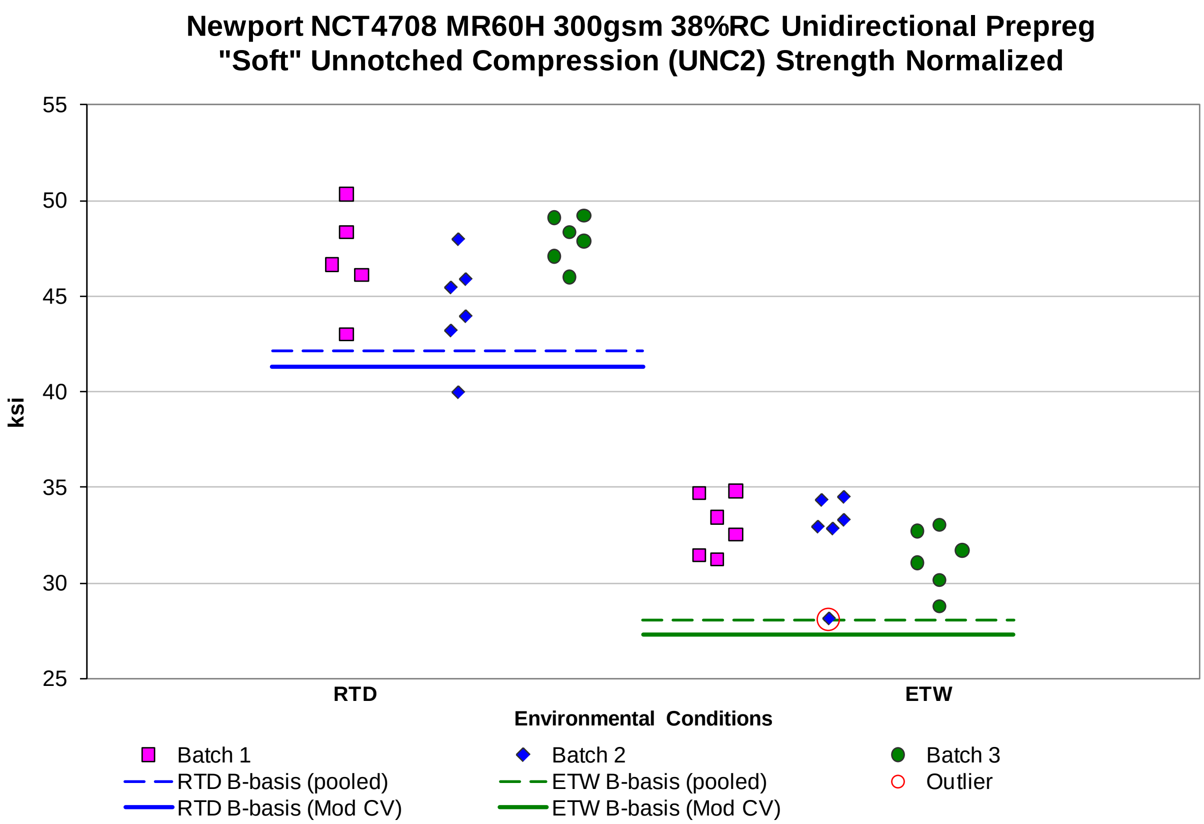

Figure 5-5: Batch plot for UNC2 normalized strength

Unnotched Compression (UNC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	46.38	32.31	46.97	32.85
Stdev	2.67	1.92	2.96	1.93
CV	5.76	5.94	6.30	5.87
Mod CV	6.88	6.97	7.15	6.93
Min	39.96	28.12	40.86	28.68
Max	50.34	34.81	51.10	35.17
No. Batches	3	3	3	3
No. Spec.	17	18	17	18
Basis Values and/or Estimates				
B-basis Value	42.13	28.09	42.41	28.31
A-estimate	39.25	25.21	39.33	25.22
Method	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	41.33	27.30	41.73	27.64
A-estimate	37.92	23.88	38.19	24.08
Method	pooled	pooled	pooled	pooled

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

Unnotched Compression (UNC2) Modulus Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	4.17	3.78	4.21	3.84
Stdev	0.18	0.12	0.19	0.16
CV	4.43	3.17	4.49	4.16
Mod CV	6.22	6.00	6.24	6.08
Min	3.77	3.56	3.85	3.52
Max	4.41	3.97	4.59	4.15
No. Batches	3	3	3	3
No. Spec.	18	21	18	21

Table 5-10: Statistics from UNC2 Modulus data

5.6 "Hard" Unnotched Compression (UNC3)

Both the as measured and the normalized data from the ETW condition fail the ADK test, which means that only the ANOVA method can be used to compute basis values for those environments. However, the ETW data does pass the ADK test with the transform for the modified CV method, so modified CV basis values are provided for those datasets. Pooling the RTD and ETW environments was acceptable to compute the modified CV basis values. There were no outliers.

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.

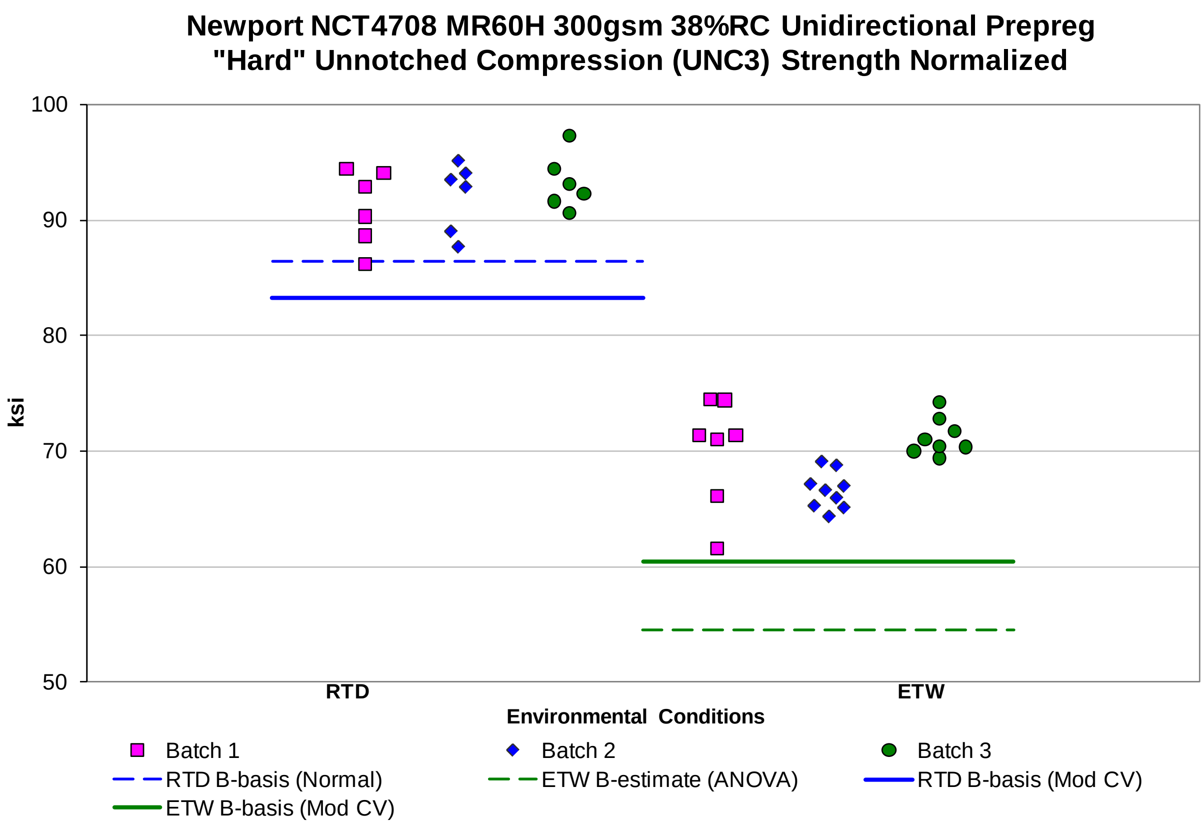

Figure 5-6: Batch plot for UNC3 normalized strength

Unnotched Compression (UNC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	92.11	69.16	93.21	70.16
Stdev	2.87	3.41	3.10	3.54
CV	3.12	4.93	3.33	5.05
Mod CV	6.00	6.46	6.00	6.52
Min	86.17	61.54	87.52	62.39
Max	97.28	74.50	98.42	75.62
No. Batches	3	3	3	3
No. Spec.	18	24	18	24
Basis Values and/or Estimates				
B-basis Value	86.44		87.09	
B-estimate		54.53		52.74
A-estimate	82.42	44.08	82.75	40.29
Method	Normal	ANOVA	Normal	ANOVA
Mod CV Basis Values and/or Estimates				
B-basis Value	83.22	60.48	84.16	61.34
A-estimate	77.21	54.43	78.05	55.17
Method	pooled	pooled	pooled	pooled

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

Unnotched Compression (UNC3) Modulus Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	11.31	10.88	11.48	11.03
Stdev	0.27	0.24	0.27	0.32
CV	2.42	2.19	2.36	2.95
Mod CV	6.00	6.00	6.00	6.00
Min	10.70	10.37	11.08	10.45
Max	11.75	11.43	12.06	11.85
No. Batches	3	3	3	3
No. Spec.	18	26	18	26

Table 5-12: Statistics from UNC3 Modulus data

5.7 Quasi Isotropic Open Hole Tension Properties (OHT1)

There were no diagnostic test failures in the OHT1 data, so the data could be pooled across the three environments. There were no outliers.

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.

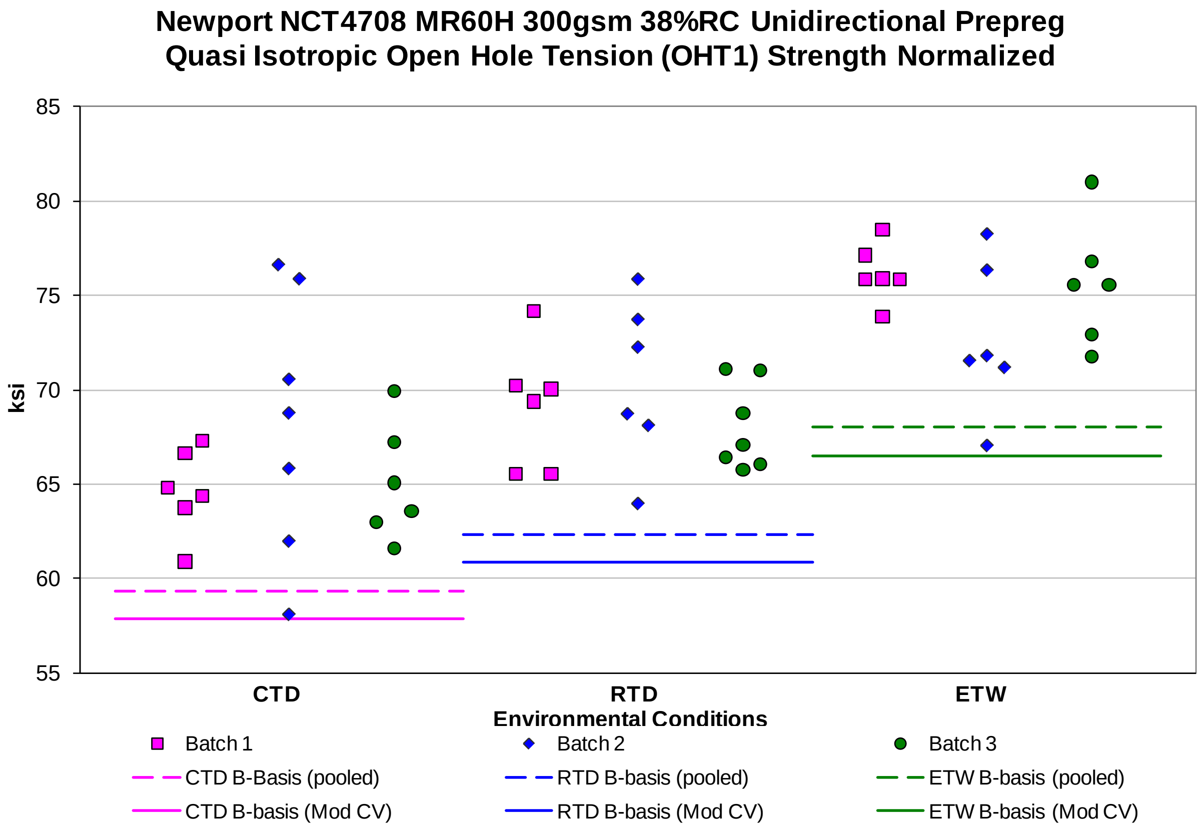

Figure 5-7: Batch Plot for OHT1 normalized strength

Open Hole Tension (OHT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	66.11	69.15	74.83	66.21	69.03	74.73
Stdev	4.76	3.31	3.32	5.07	3.36	3.39
CV	7.19	4.79	4.43	7.66	4.87	4.54
Mod CV	7.60	6.39	6.22	7.83	6.44	6.27
Min	58.09	63.97	67.05	57.84	63.29	67.80
Max	76.64	75.88	81.02	76.45	75.48	81.97
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	18	19	19	18
Basis Values and/or Estimates						
B-basis Value	59.32	62.36	68.01	59.12	61.94	67.61
A-estimate	54.76	57.81	63.46	54.36	57.19	62.86
Method	pooled	pooled	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates						
B-basis Value	57.84	60.88	66.52	57.80	60.63	66.28
A-estimate	52.29	55.33	60.98	52.16	54.99	60.65
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)

There were no diagnostic test failures in the OHT2 data, so the data could be pooled across the three environments. There were no outliers.

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.

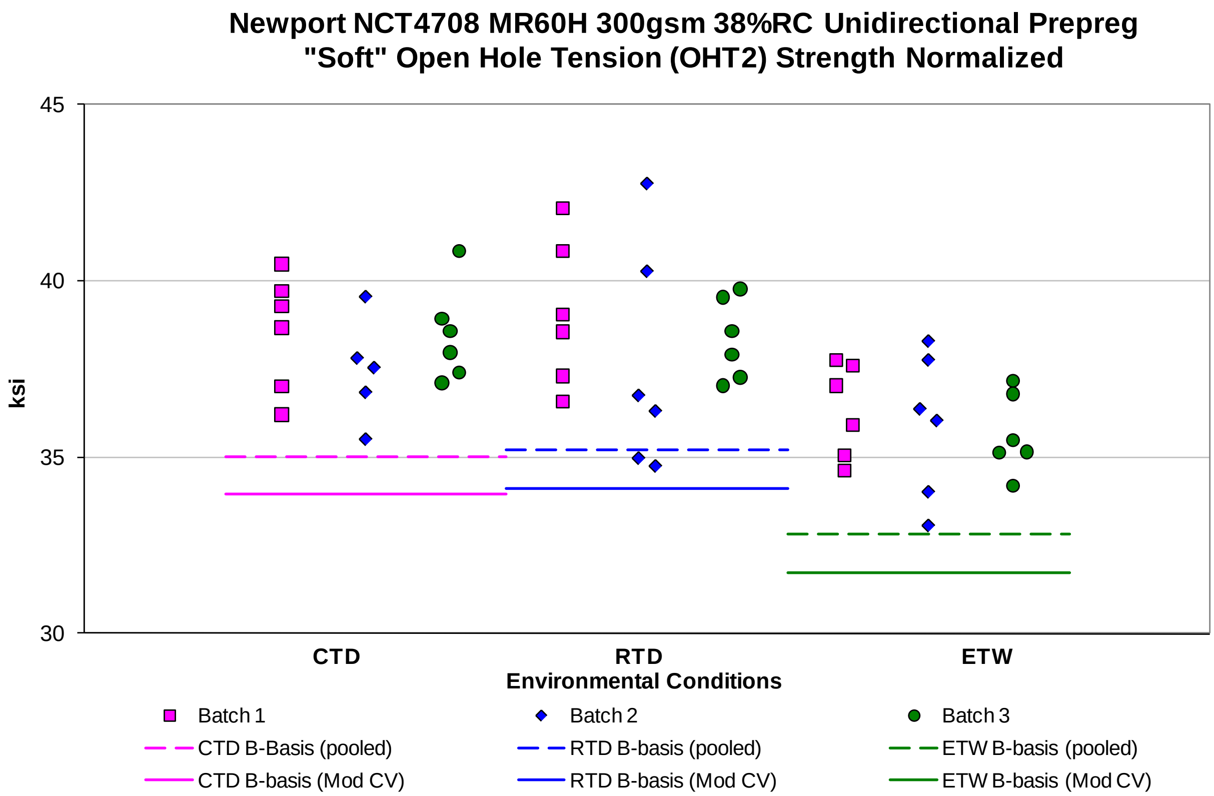

Figure 5-8: Batch Plot for OHT2 normalized strength

Open Hole Tension (OHT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	38.20	38.35	35.97	37.99	38.13	35.86
Stdev	1.49	2.25	1.49	1.66	2.29	1.52
CV	3.89	5.86	4.13	4.36	6.00	4.24
Mod CV	6.00	6.93	6.07	6.18	7.00	6.12
Min	35.51	34.75	33.06	34.79	35.04	33.36
Max	40.86	42.77	38.29	41.74	43.23	38.55
No. Batches	3	3	3	3	3	3
No. Spec.	17	18	18	17	18	18
Basis Values and/or Estimates						
B-basis Value	35.03	35.19	32.81	34.68	34.84	32.58
A-estimate	32.92	33.08	30.70	32.48	32.64	30.38
Method	pooled	pooled	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates						
B-basis Value	33.95	34.12	31.74	33.69	33.85	31.59
A-estimate	31.12	31.29	28.91	30.83	30.99	28.73
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)

The normalized data from the RTD condition and the as measured data from the ETW condition fail the ADK test, which means that only the ANOVA method can be used to compute basis values for those environments. However, the data from both conditions pass the ADK test with the transform for the modified CV method, so modified CV basis values are provided for those datasets.

For the as measured data, the CTD and RTD conditions could not be pooled due to non-normality of the pooled dataset. However, all three environments could be pooled for the computation of the modified CV basis values. For the normalized data, ASAP shows a failure of Levene's test for this data. However, when the data from all of the environments is transformed (ASAP only transforms those that fail the ADK test) to fit the assumptions of the modified CV method, the data passes Levene's test and can be pooled to compute the modified CV basis values.

There were three separate outliers in the OHT3 data, one in the as measured data and two in the normalized data. The highest value in batch three of the RTD condition as measured data was an outlier only before pooling the three batches together. The highest value in batch one of the CTD condition normalized data was an outlier only before pooling the three batches together. The lowest value in batch two of the ETW data was an outlier only after pooling the three batches together.

Statistics, basis values and estimates are given for OHT3 strength data in Table 5-15. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 5-9.

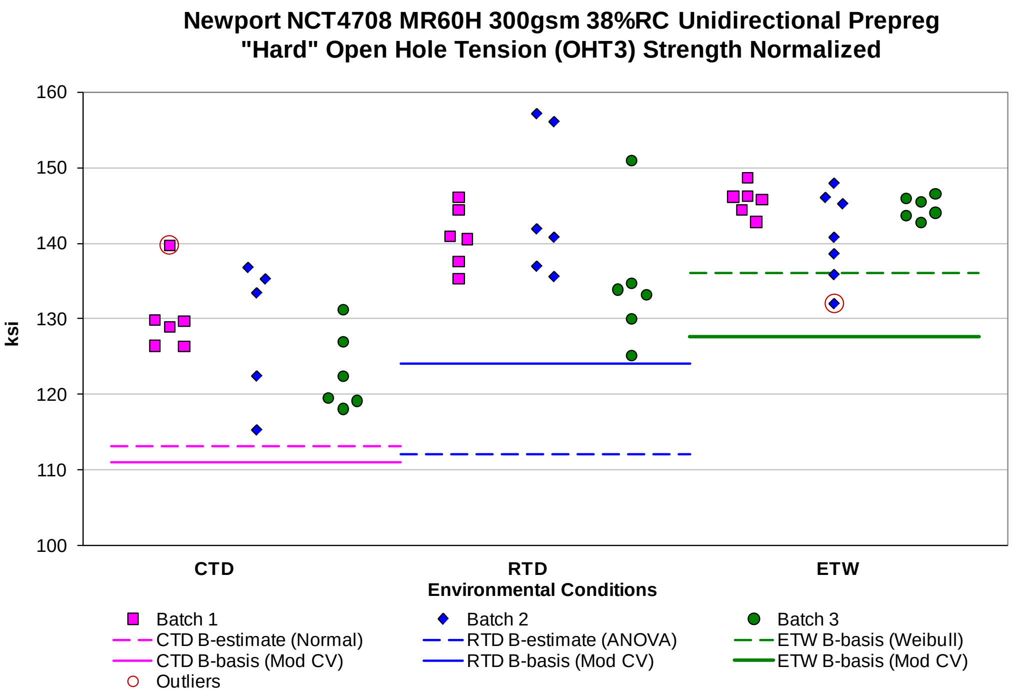

Figure 5-9: Batch Plot for OHT3 normalized strength

Open Hole Tension (OHT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	127.15	140.07	143.63	128.25	140.08	143.33
Stdev	7.00	8.49	4.22	6.45	9.36	4.78
CV	5.50	6.06	2.93	5.03	6.68	3.33
Mod CV	6.75	7.03	6.00	6.51	7.34	6.00
Min	115.24	125.16	131.99	117.10	129.55	132.82
Max	139.75	157.17	148.69	141.06	161.35	150.34
No. Batches	3	3	3	3	3	3
No. Spec.	17	18	19	17	18	19
Basis Values and/or Estimates						
B-basis Value			136.00		126.86	
B-estimate	113.13	112.07		115.33		121.30
A-estimate	103.22	92.14	127.55	106.20	93.28	105.59
Method	Normal	ANOVA	Weibull	Normal	Non-Parametric	ANOVA
Mod CV Basis Values and/or Estimates						
B-basis Value	111.06	124.07	127.72	112.00	123.93	127.26
A-estimate	100.40	113.40	117.02	101.24	113.15	116.46
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)

The only diagnostic test failure was Levene's test for the normalized pooled dataset. Levene's test result indicated that the assumption of equal variances would be rejected at the 95% confidence level but not at the 96% confidence level. An override of this test result is recommended and the data was pooled across the three environments. There was one outlier, the lowest value in batch two of the ETW condition data. It was an outlier in both the as measured and the normalized data. It was an outlier only before pooling the data from the three batches together.

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

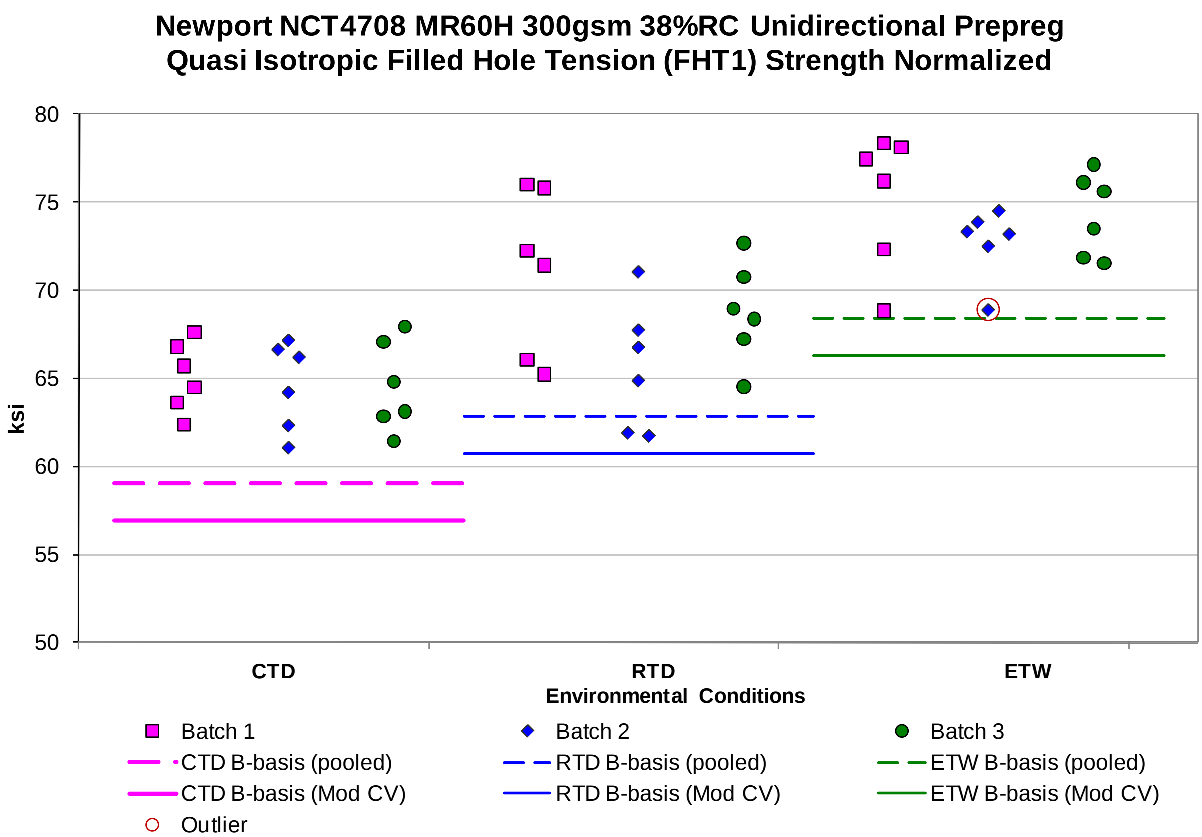

Figure 5-10: Batch plot for FHT1 normalized strength

Filled Hole Tension (FHT1) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	64.74	68.52	74.08	64.82	68.59	74.24
Stdev	2.23	4.21	2.86	2.47	4.22	2.98
CV	3.45	6.15	3.87	3.81	6.15	4.01
Mod CV	6.00	7.07	6.00	6.00	7.07	6.00
Min	61.06	61.73	68.85	60.71	61.89	67.84
Max	67.93	76.01	78.33	69.20	74.58	78.51
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and/or Estimates with override of Levene's Test						
B-basis Value	59.06	62.83	68.39	58.97	62.75	68.40
A-estimate	55.26	59.04	64.60	55.07	58.84	64.49
Method	pooled	pooled	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates						
B-basis Value	56.94	60.71	66.27	57.00	60.77	66.42
A-estimate	51.73	55.50	61.06	51.78	55.55	61.20
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

5.11 "Soft" Filled Hole Tension (FHT2)

The normalized data from the RTD condition and the as measured data from the ETW condition fail the ADK test, which means that only the ANOVA method can be used to compute basis values for those environments. However, the data from both conditions pass the ADK test with the transform for the modified CV method, so modified CV basis values are provided for those datasets.

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

The FHT2 data has only one outlier. It was an outlier for the as measured data but not the normalized data. The highest value in batch two of the as measured ETW data was an outlier only before pooling the data from the three batches together. This outlier was retained for this analysis. Statistics, basis values and estimates are given for FHT2 strength data in Table 5-17. The normalized data, B-estimates, and B-basis values are shown graphically in Figure 5-11.

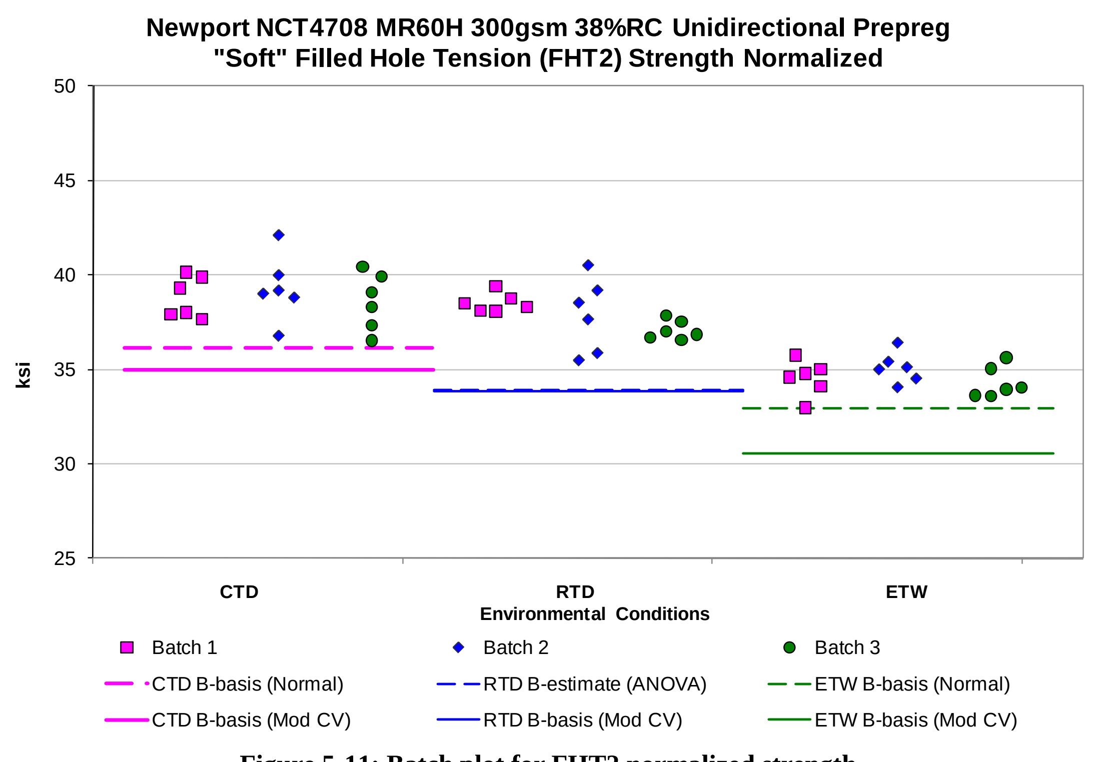

Figure 5-11: Batch plot for FHT2 normalized strength

Filled Hole Tension (FHT2) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	38.91	37.82	34.63	38.84	37.75	34.67
Stdev	1.41	1.28	0.87	1.33	1.04	1.18
CV	3.62	3.38	2.51	3.42	2.76	3.39
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	36.54	35.46	32.98	36.75	35.75	31.93
Max	42.09	40.49	36.39	41.61	40.11	36.94
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Values and/or Estimates						
B-basis Value	36.13		32.92	36.67	35.57	
B-estimate		33.92				28.83
A-estimate	34.15	31.14	31.70	35.19	34.10	24.66
Method	Normal	ANOVA	Normal	pooled	pooled	ANOVA
Mod CV Basis Values and/or Estimates						
B-basis Value	34.96	33.88	30.69	34.90	33.80	30.73
A-estimate	32.33	31.24	28.05	32.26	31.17	28.10
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 as measured data from the ETW condition fails the ADK test, which means that only the ANOVA method can be used to compute basis values for that environment. However, the data pass the ADK test with the transform for the modified CV method, so modified CV basis values are provided for that dataset.

For the as measured data, the CTD and RTD conditions could be pooled and all three environments could be pooled for the computation of the modified CV basis values. For the normalized data, ASAP shows a failure of Levene's test for this data. However, when the data from all of the environments is transformed (ASAP only transforms those that fail the ADK test) to fit the assumptions of the modified CV method, the data passes Levene's test and can be pooled to compute the modified CV basis values. There were no outliers.

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

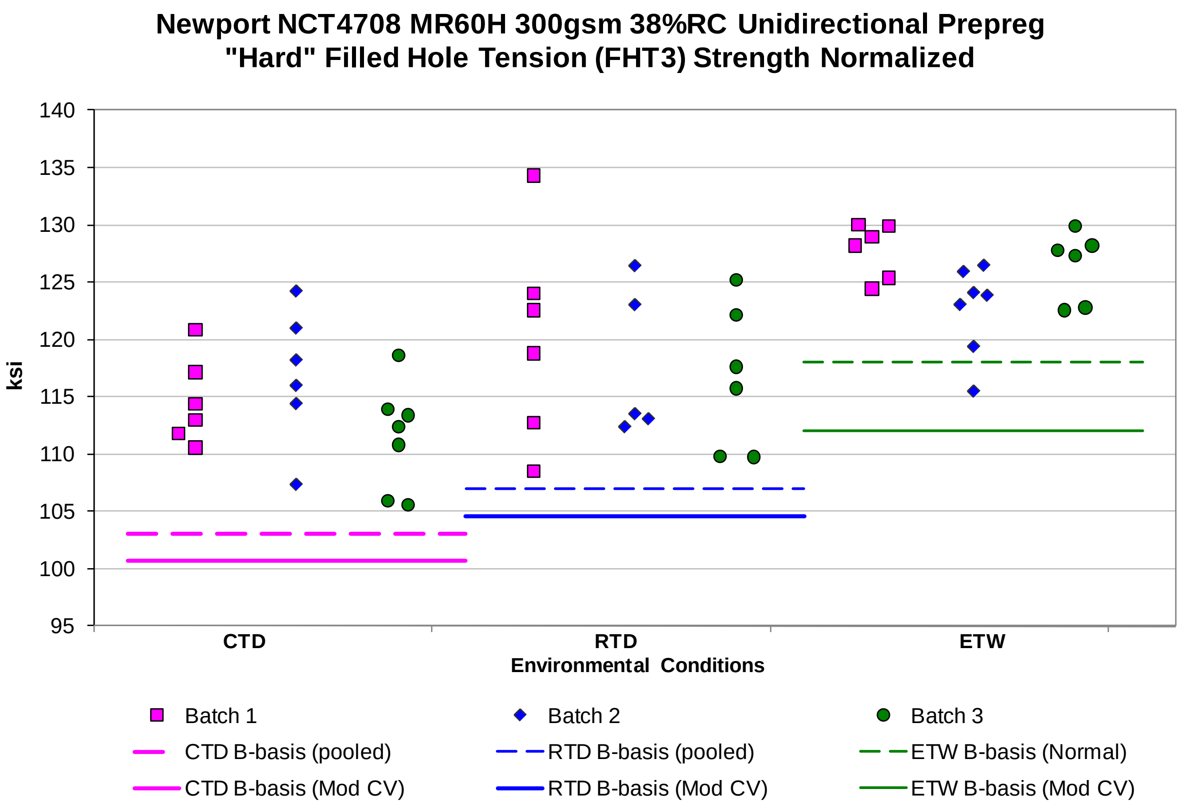

Figure 5-12: Batch plot for FHT3 normalized strength

Filled Hole Tension (FHT3) Strength Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	114.18	118.21	125.46	114.36	117.59	124.59
Stdev	5.07	7.17	3.81	4.87	7.07	4.11
CV	4.44	6.06	3.04	4.26	6.01	3.30
Mod CV	6.22	7.03	6.00	6.13	7.01	6.00
Min	105.59	108.54	115.47	107.41	105.61	116.02
Max	124.22	134.30	130.04	125.95	130.41	131.58
No. Batches	3	3	3	3	3	3
No. Spec.	19	17	19	19	17	19
Basis Values and/or Estimates						
B-basis Value	103.04	106.96	118.03	103.48	106.59	
B-estimate						104.38
A-estimate	95.40	99.35	112.75	96.02	99.16	89.96
Method	pooled	pooled	Normal	pooled	pooled	ANOVA
Mod CV Basis Values and/or Estimates						
B-basis Value	100.74	104.63	112.02	101.06	104.14	111.28
A-estimate	91.72	95.64	103.00	92.12	95.23	102.34
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 (OHC1)

There were no diagnostic test failures in the OHC1 data, so the data could be pooled across the two environments. There was one outlier, in the normalized data only. The highest value in batch one of the ETW condition data was an outlier. It was an outlier only after pooling the data from the three batches together. The outlier was retained for this analysis.

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.

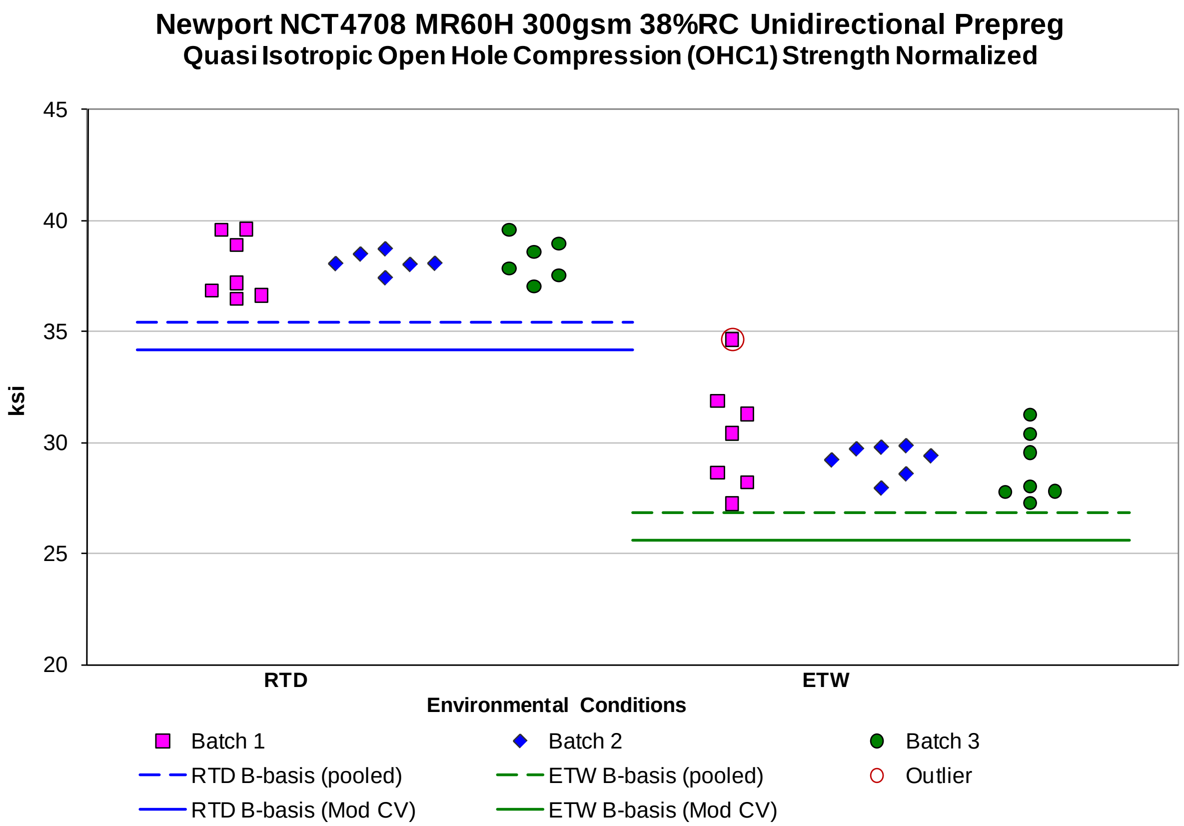

Figure 5-13: Batch plot for OHC1 normalized strength

Open Hole Compression (OHC1) Strength Basis Values and				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	38.09	29.47	38.15	29.42
Stdev	1.00	1.79	1.14	1.63
CV	2.62	6.07	3.00	5.55
Mod CV	6.00	7.03	6.00	6.77
Min	36.49	27.25	35.59	26.69
Max	39.62	34.65	40.30	33.51
No. Batches	3	3	3	3
No. Spec.	19	21	19	21
Basis Values and/or Estimates				
B-basis Value	35.46	26.86	35.59	26.89
A-estimate	33.66	25.06	33.85	25.14
Method	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	34.18	25.60	34.31	25.62
A-estimate	31.52	22.93	31.69	22.99
Method	pooled	pooled	pooled	pooled

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

5.14 “Soft” Open Hole Compression (OHC2)

Although both the RTD and ETW environments passed the normality test individually, the pooled normalized data did not. However, after applying the modified CV transformation, the normalized pooled dataset did pass normality and modified CV basis values were computed by pooling the two environments. There were no other diagnostic test failures in the OHC2 data. The as measured data could be pooled across the two environments. 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.

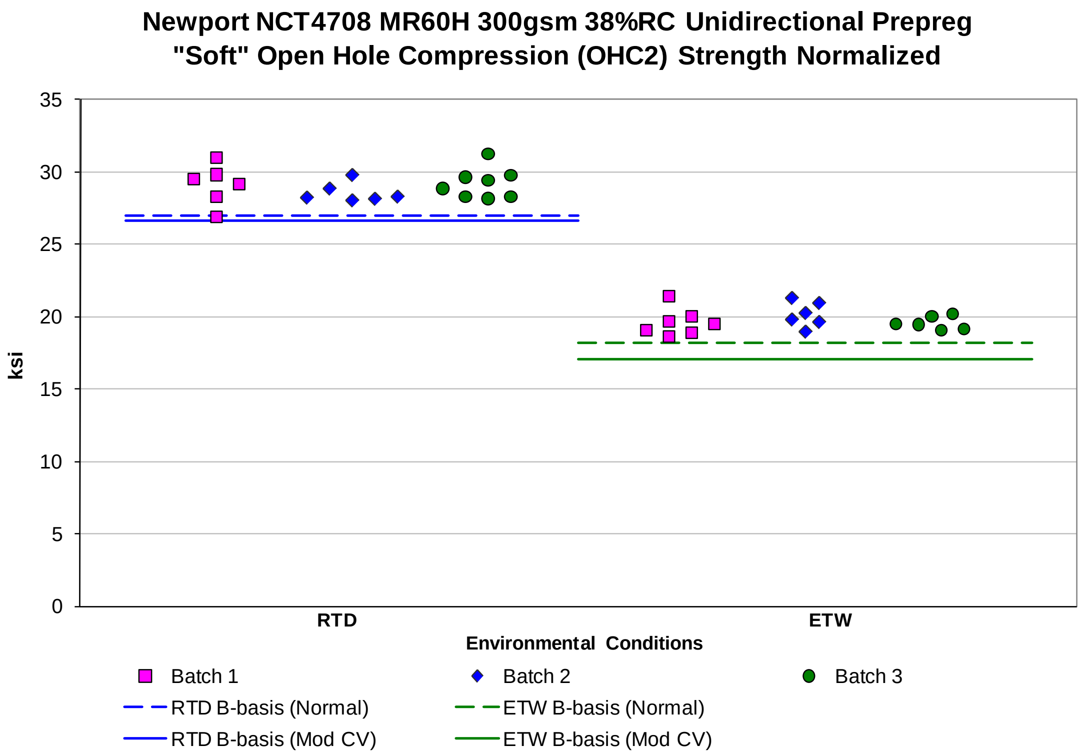

Figure 5-14: Batch plot for OHC2 normalized strength

Open Hole Compression (OHC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	29.00	19.78	29.24	19.82
Stdev	1.06	0.79	1.14	0.82
CV	3.64	3.98	3.89	4.14
Mod CV	6.00	6.00	6.00	6.07
Min	26.93	18.64	27.19	18.09
Max	31.27	21.41	31.98	21.29
No. Batches	3	3	3	3
No. Spec.	20	19	20	19
Basis Values and/or Estimates				
B-basis Value	26.96	18.25	27.46	18.03
A-estimate	25.52	17.16	26.23	16.80
Method	Normal	Normal	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	26.31	17.09	26.53	17.10
A-estimate	24.47	15.25	24.67	15.24
Method	pooled	pooled	pooled	pooled

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

5.15 "Hard" Open Hole Compression (OHC3)

There were no diagnostic test failures in the OHC3 data, so the data could be pooled across the two environments. There was one outlier, in the as measured data only. The highest value in batch three of the RTD condition data was an outlier. It was an outlier only before pooling the data from the three batches together. The outlier was retained for this analysis.

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

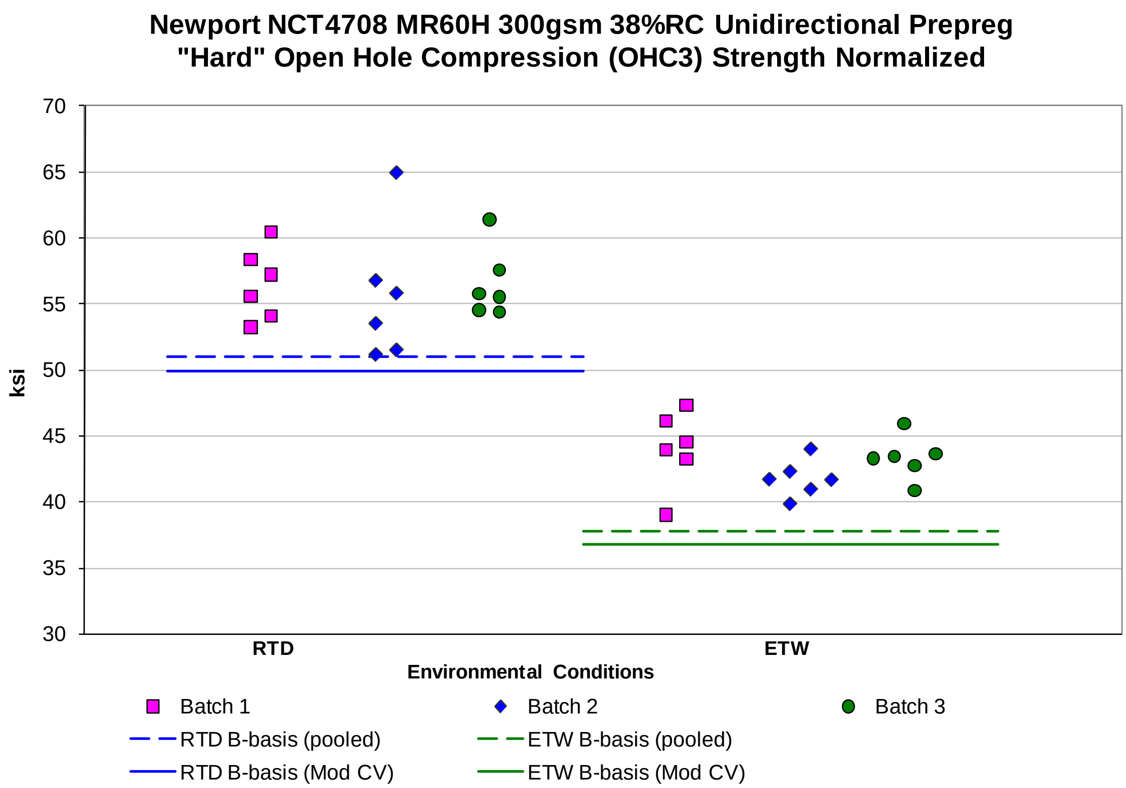

Figure 5-15: Batch plot for OHC3 normalized strength

Open Hole Compression (OHC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	56.23	43.06	56.17	42.88
Stdev	3.46	2.17	3.58	2.20
CV	6.16	5.04	6.38	5.12
Mod CV	7.08	6.52	7.19	6.56
Min	51.21	39.03	50.70	38.41
Max	64.99	47.33	63.53	46.51
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and/or Estimates				
B-basis Value	50.97	37.80	50.75	37.47
A-estimate	47.38	34.22	47.07	33.78
Method	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	49.96	36.79	49.83	36.54
A-estimate	45.69	32.52	45.51	32.23
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 as measured data from the RTD and ETW conditions fail the ADK test, which means that only the ANOVA method can be used to compute basis values for those environments. The as measured ETW did not pass the ADK test even after with the transform for the modified CV method, so modified CV B-values could not be computed for that dataset. A- and B-estimates were computed based on the modified CV method.

The FHC1 normalized data passed the ADK test for both environmental conditions, but the pooled dataset did not pass the normality test so the single point method was used to compute basis values. However, after applying the modified CV transformation, the normalized pooled dataset did pass the normality test and modified CV basis values were computed by pooling the two environments.

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

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.

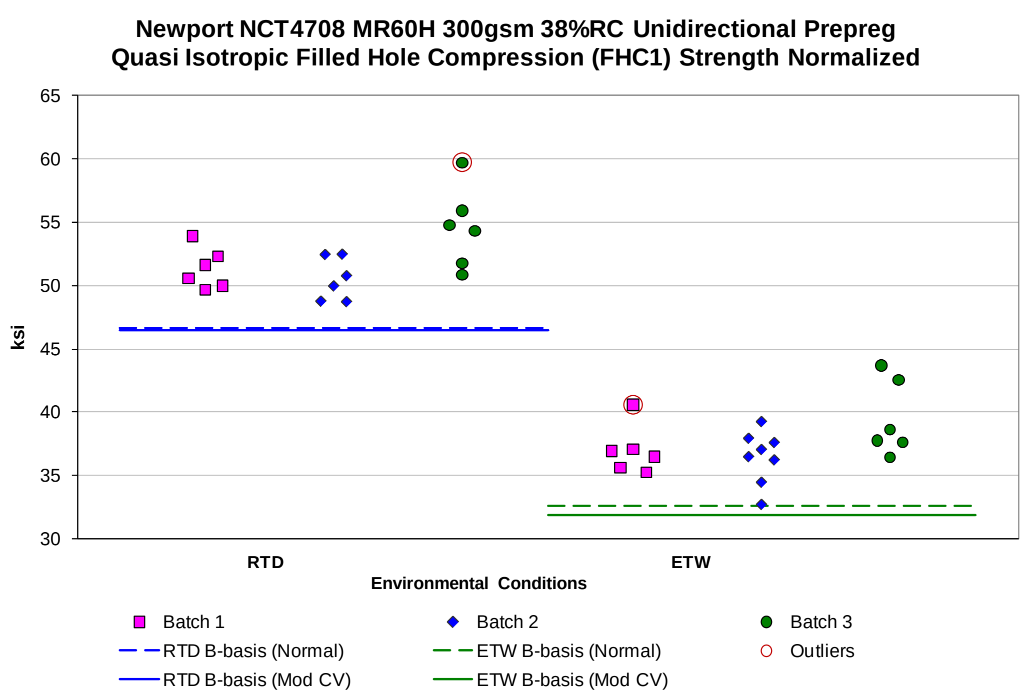

Figure 5-16: Batch plot for FHC1 normalized strength

Filled Hole Compression (FHC1) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	52.14	37.52	51.94	37.46
Stdev	2.78	2.56	3.09	2.86
CV	5.34	6.81	5.96	7.63
Mod CV	6.67	7.41	6.98	7.82
Min	48.72	32.72	47.50	32.24
Max	59.73	43.70	60.30	44.73
No. Batches	3	3	3	3
No. Spec.	18	20	18	20
Basis Values and/or Estimates				
B-basis Value	46.65	32.60		
B-estimate			35.79	25.03
A-estimate	42.76	29.10	24.27	16.16
Method	Normal	Normal	ANOVA	ANOVA
Mod CV Basis Values and/or Estimates				
B-basis Value	46.47	31.90	44.78	
B-estimate				31.82
A-estimate	42.63	28.04	39.72	27.81
Method	pooled	pooled	Normal	Normal

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

5.17 "Soft" Filled Hole Compression (FHC2)

The FHC2 data from the RTD condition fails the ADK test, which means that only the ANOVA method can be used to compute estimates of basis values for that environment. The RTD data fail the ADK test even after applying the transform for the modified CV method, so modified CV basis values cannot be provided. A- and B-estimates for the RTD environment were computed based on the modified CV method.

There is one outlier. The highest value in batch two of the RTD data is an outlier only before pooling the data from the three batches together. It was an outlier in both the as measured and the normalized RTD data. The outlier was retained for this analysis.

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

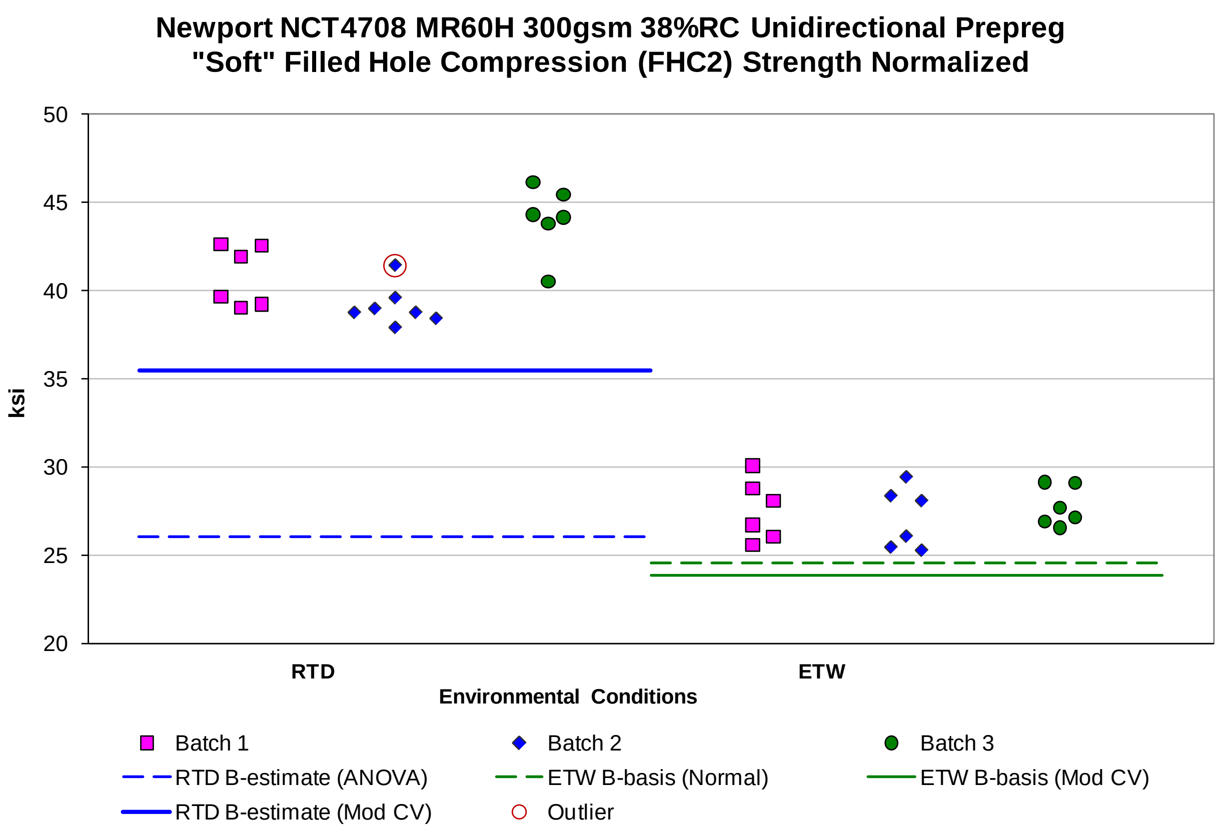

Figure 5-17: Batch plot for FHC2 normalized strength

Filled Hole Compression (FHC2) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	41.24	27.49	41.34	27.49
Stdev	2.60	1.49	2.75	1.61
CV	6.30	5.41	6.64	5.85
Mod CV	7.15	6.71	7.32	6.93
Min	37.92	25.28	38.18	25.26
Max	46.16	30.10	46.85	29.98
No. Batches	3	3	3	3
No. Spec.	19	18	19	18
Basis Values and/or Estimates				
B-basis Value		24.55		24.31
B-estimate	26.07		24.91	
A-estimate	15.25	22.47	13.19	22.06
Method	ANOVA	Normal	ANOVA	Normal
Mod CV Basis Values and/or Estimates				
B-basis Value		23.85		23.73
B-estimate	35.49		35.44	
A-estimate	31.42	21.27	31.26	21.07
Method	Normal	Normal	Normal	Normal

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

5.18 "Hard" Filled Hole Compression (FHC3)

There were no diagnostic test failures in the FHC3 data, so the data could be pooled across the two environments. There were no outliers.

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.

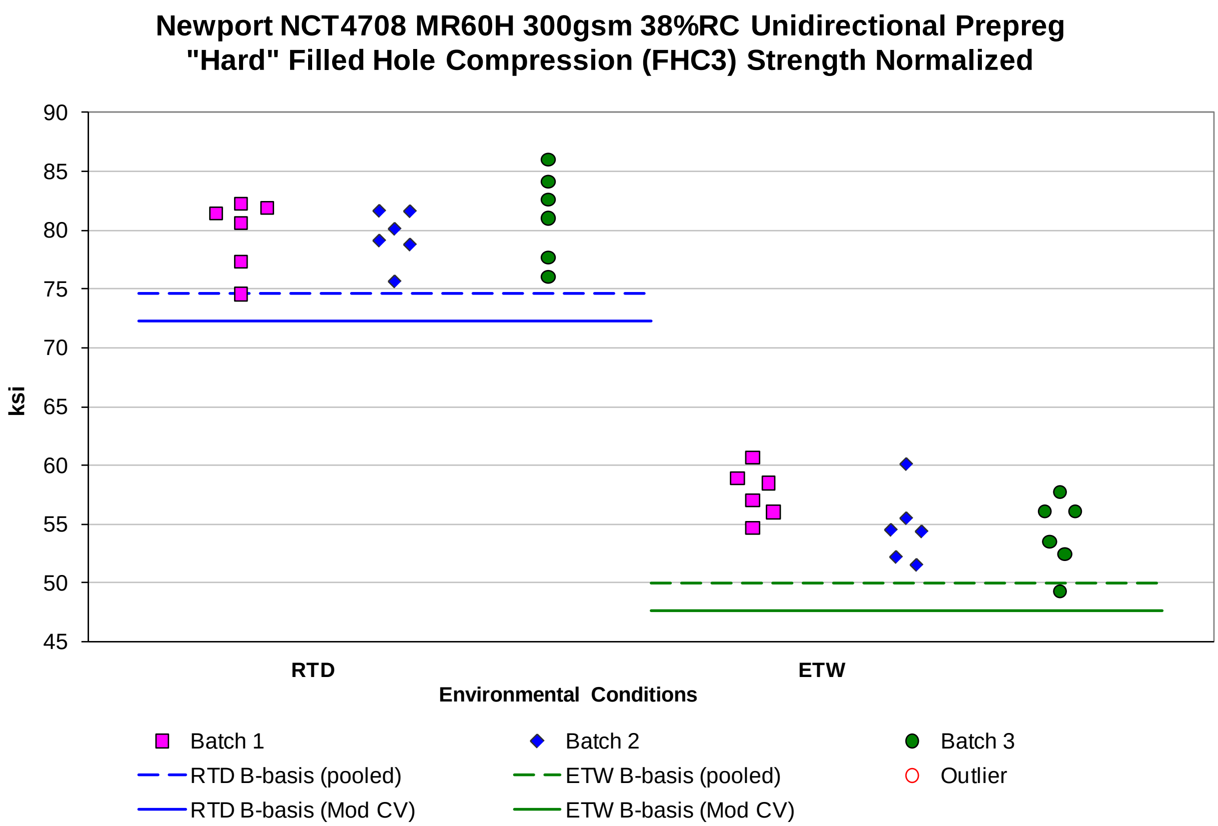

Figure 5-18: Batch plot for FHC3 normalized strength

Filled Hole Compression (FHC3) Strength Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW	RTD	ETW
Mean	80.14	55.53	80.76	55.69
Stdev	3.03	3.05	3.40	2.67
CV	3.78	5.48	4.21	4.80
Mod CV	6.00	6.74	6.11	6.40
Min	74.56	49.31	72.95	50.53
Max	86.03	60.65	87.62	60.19
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and/or Estimates				
B-basis Value	74.61	50.00	75.19	50.12
A-estimate	70.84	46.23	71.40	46.33
Method	pooled	pooled	pooled	pooled
Mod CV Basis Values and/or Estimates				
B-basis Value	72.29	47.68	72.93	47.86
A-estimate	66.95	42.34	67.59	42.52
Method	pooled	pooled	pooled	pooled

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

5.19 Laminate Short Beam Strength (SBS1) Data

The Laminate Short Beam Strength data is not normalized. The data from the ETW condition fails the ADK test, which means that only the ANOVA method can be used to compute estimates of basis values for those environments. However, the ETW data passes the ADK after applying the transform for the modified CV method. The RTD data could be pooled with the ETW data for the computation of the modified CV basis values.

There were two outliers. One outlier was the highest value in batch two of the RTD data. It was an outlier both before and after pooling the data from the three batches together. The lowest value in batch two of the ETW data was an outlier only before pooling the data from the three batches together. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for SBS1 strength data in Table 5-25. The data, B-estimates and B-basis values are shown graphically in Figure 5-19.

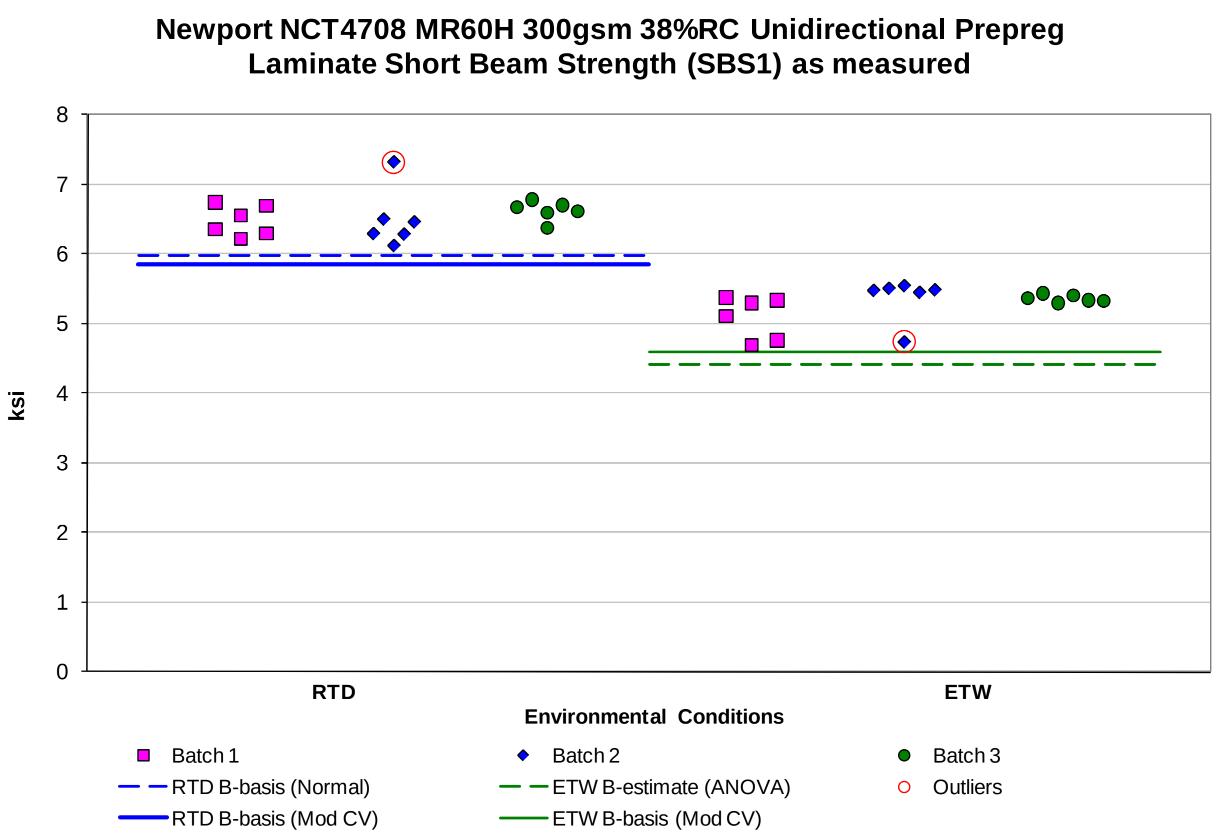

Figure 5-19: Batch plot for SBS1 strength as measured

Laminate Short Beam Strength (SBS1) Basis Values and Statistics		
Env	RTD	ETW
Mean	6.53	5.28
Stdev	0.28	0.27
CV	4.26	5.13
Mod CV	6.13	6.56
Min	6.13	4.69
Max	7.33	5.55
No. Batches	3	3
No. Spec.	18	18
Basis Values and/or Estimates		
B-basis Value	5.98	
B-estimate		4.42
A-estimate	5.59	3.81
Method	Normal	ANOVA
Mod CV Basis Values and/or Estimates		
B-basis Value	5.85	4.59
A-estimate	5.39	4.13
Method	pooled	pooled

Table 5-25: Statistics and Basis Values for SBS1 Strength data as measured

5.20 Quasi Isotropic Single Shear Bearing (SSB1)

The as measured SSB1 2% Offset Strength data from both the RTD and ETW conditions fail the ADK test, which means that only the ANOVA method can be used to compute estimates of basis values for those environments. However, the data from both environments pass the ADK after applying the transform for the modified CV method, so modified CV basis values are provided for that environment. There were no other test failures so pooling was acceptable for the as measured modified CV basis values.

The as measured SSB1 Ultimate Strength data from both the RTD and ETW conditions fail the ADK test, which means that only the ANOVA method can be used to compute estimates of basis values for those environments. However, the data from both environments pass the ADK test after applying the transform for the modified CV method and the two data from the two environments could be pooled together to compute the modified CV basis values.

The normalized SSB1 data had no test failures, so pooling was acceptable for both the 2% Offset Strength and the Ultimate Strength data.

There was one outlier. The lowest value in batch two of the as measured Ultimate Strength data from the ETW environment was an outlier only before pooling the three batches of data together. The outlier was retained for this analysis.

Statistics, basis values and estimates are given for the SSB1 data in Table 5-26. The normalized data and the B-basis values are shown graphically in Figure 5-20.

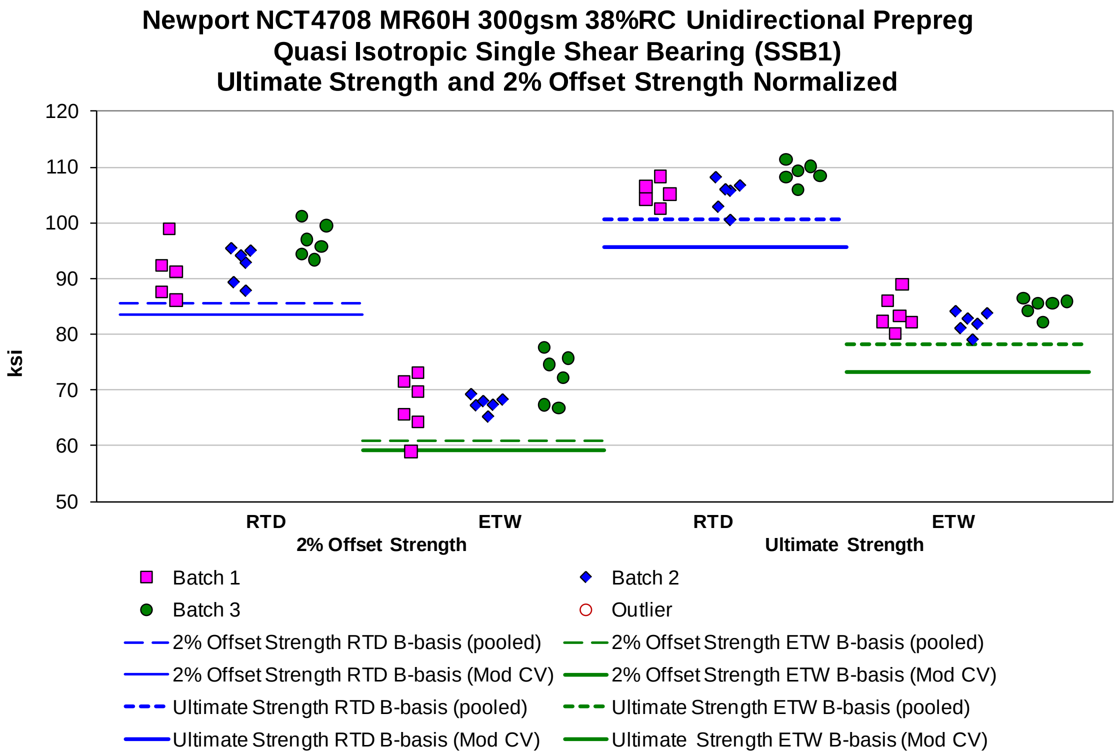

Figure 5-20: Batch plot for SSB1 normalized strength

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	93.66	69.05	106.51	83.65	95.78	70.04	108.91	84.83
Stdev	4.28	4.53	2.83	2.47	5.30	5.01	4.29	2.77
CV	4.57	6.56	2.66	2.96	5.54	7.16	3.94	3.26
Mod CV	6.28	7.28	6.00	6.00	6.77	7.58	6.00	6.00
Min	86.16	58.98	100.57	79.06	87.63	59.64	102.02	79.99
Max	101.10	77.69	111.34	88.94	105.68	79.06	116.38	89.37
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	17	18	17	18	17	18	17	18
Basis Values and/or Estimates								
B-basis Value	85.57	61.00	101.64	78.81				
B-estimate					66.19	48.01	81.82	72.35
A-estimate	80.09	55.51	98.34	75.50	45.08	32.31	62.49	63.46
Method	pooled	pooled	pooled	pooled	ANOVA	ANOVA	ANOVA	ANOVA
Mod CV Basis Values and/or Estimates								
B-basis Value	83.64	59.09	96.00	73.20	84.94	59.26	98.20	74.17
A-estimate	76.86	52.29	88.89	66.08	77.60	51.91	90.95	66.91
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 (SSB2)

The SSB2 2% Offset Strength pooled dataset, both as measured and normalized, failed Levene's test, which means that the variances of the data from the different environmental conditions is too dissimilar for pooling. Therefore, the single point method was used to compute the basis values for 2% Offset Strength. The normalized data passed Levene's test after applying the modified CV transform, so pooling was used to compute the modified CV basis values. The Ultimate Strength data had no test failures, so pooling was appropriate and ASAP was used to compute the basis values.

There was one outlier in the SSB2 data. It was an outlier in the as measured 2% Offset Strength data only. It was the lowest value in batch one from the ETW condition. It was on outlier only after pooling the data from the three batches together.

Statistics, basis values and estimates are given for the SSB2 data in Table 5-27. The normalized data and B-basis values are shown graphically in Figure 5-21.

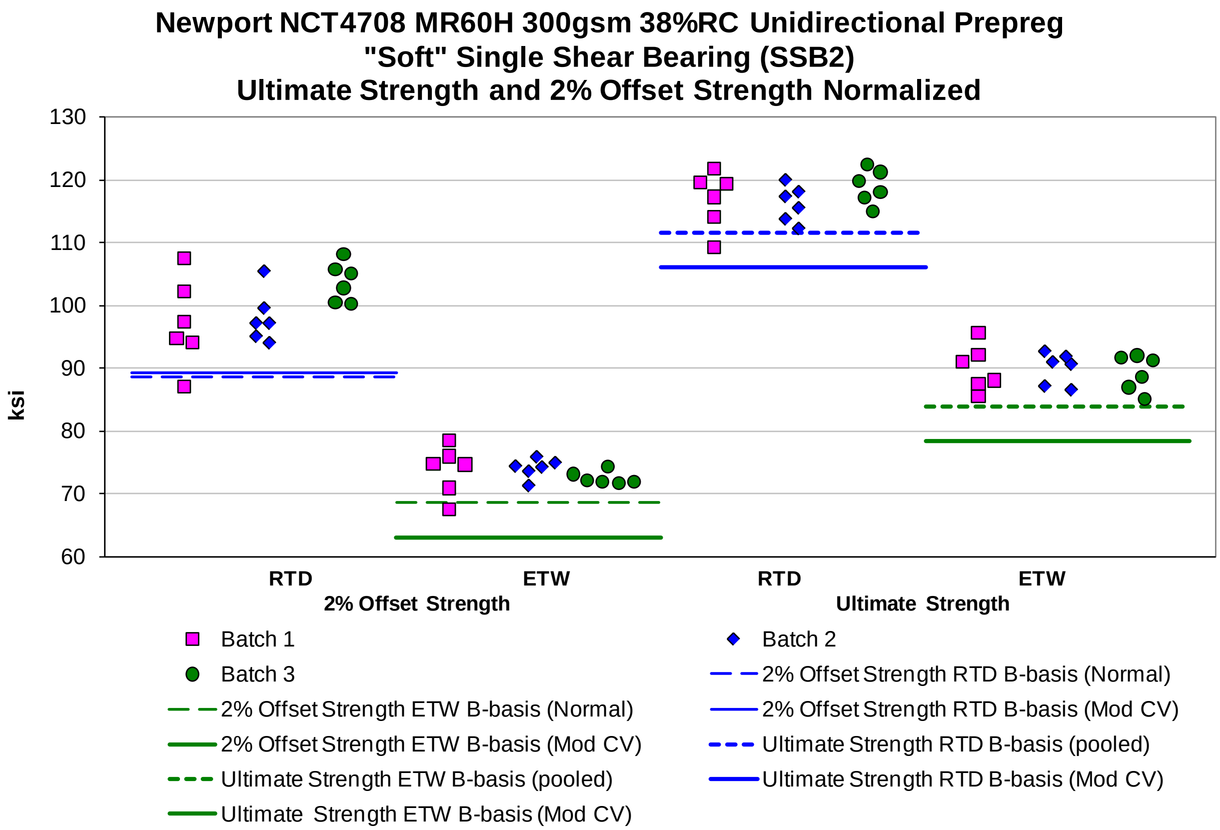

Figure 5-21: Batch plot for SSB2 normalized strength

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	99.64	73.41	117.29	89.72	99.98	73.24	117.62	89.52
Stdev	5.61	2.45	3.51	2.90	7.12	2.68	4.72	3.47
CV	5.63	3.33	2.99	3.23	7.12	3.66	4.02	3.88
Mod CV	6.82	6.00	6.00	6.00	7.56	6.00	6.01	6.00
Min	87.04	67.46	109.28	85.06	83.81	65.54	105.23	83.15
Max	108.16	78.44	122.47	95.67	111.14	77.12	123.81	95.02
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18	18	18
Basis Values and/or Estimates								
B-basis Value	88.57	68.58	111.43	83.86		67.77	110.07	81.98
B-estimate					68.63			
A-estimate	80.72	65.16	107.45	79.87	46.29	61.98	104.94	76.84
Method	Normal	Normal	pooled	pooled	ANOVA	Weibull	pooled	pooled
Mod CV Basis Values and/or Estimates								
B-basis Value	89.22	62.98	105.88	78.31	85.06	NA	106.19	78.09
A-estimate	82.12	55.89	98.12	70.54	74.50	NA	98.41	70.31
Method	pooled	pooled	pooled	pooled	Normal	NA	pooled	pooled

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

5.22 "Hard" Single Shear Bearing (SSB3)

The SSB3 pooled datasets, both as measured and normalized for the 2% Offset Strength and the normalized Ultimate Strength failed Levene's test, which means that the variances of the data from the different environmental conditions is too dissimilar for pooling. Therefore, the single point method was used to compute the basis values for those datasets. However, in all three cases, the data passed Levene's test after applying the modified CV transform, so pooling was used to compute the modified CV basis values.

The as measured Ultimate Strength data failed the ADK test for both the RTD and ETW environmental conditions which means the ANOVA method must be used to estimate basis values. However, when the transform for the modified CV method is used, the data from both those conditions pass the ADK test so modified CV basis values can be computed. Pooling was used to compute the modified CV basis values.

There were three outliers in the SSB3 data. There were two outliers in the as measured 2% Offset strength data. The lowest value in batch three of the RTD condition data and the lowest values in batch two of the ETW condition data were both outliers only for their respective batches, not after pooling the data from the three batches together. The lowest value in batch one of the Ultimate strength data from the ETW condition was an outlier for both the normalized and the as measured data. It was an outlier only after pooling the data from the three batches together. All three outliers were retained for this analysis.

Statistics, basis values and estimates are given for the SSB3 strength data in Table 5-28. The normalized data and B-basis values are shown graphically in Figure 5-22.

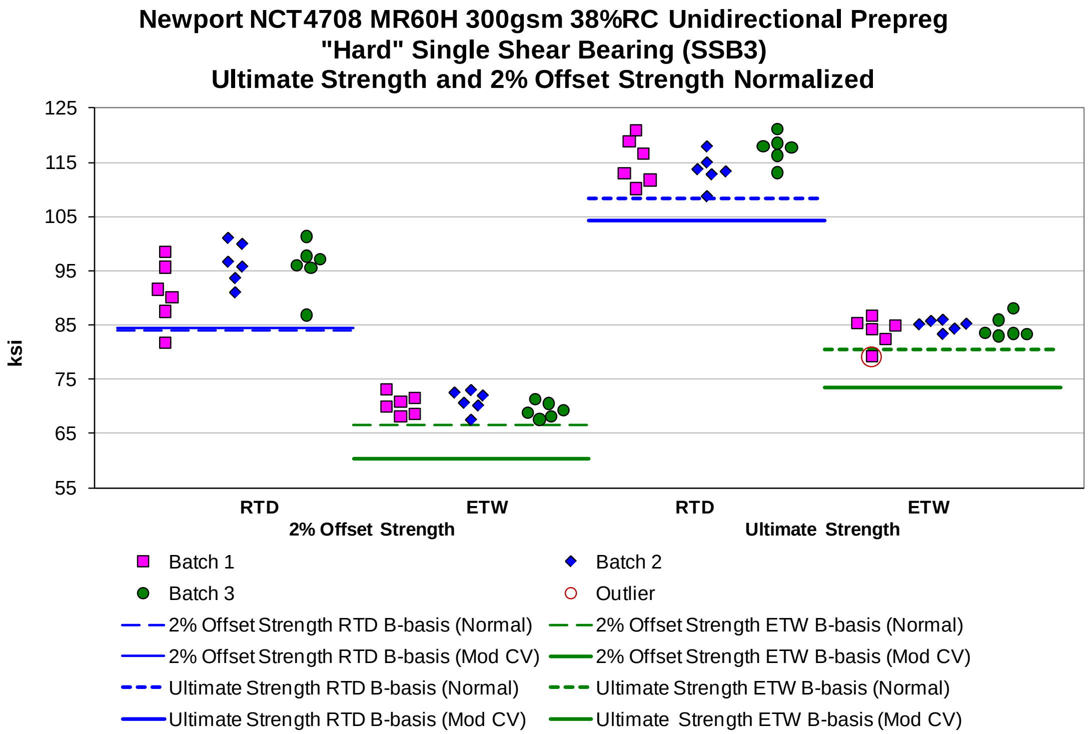

Figure 5-22: Batch plot for SSB3 normalized strength

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	94.33	70.25	115.39	84.45	95.63	70.70	116.95	85.01
Stdev	5.28	1.83	3.55	1.95	6.07	2.34	4.11	3.06
CV	5.59	2.61	3.08	2.31	6.35	3.30	3.52	3.61
Mod CV	6.80	6.00	6.00	6.00	7.18	6.00	6.00	6.00
Min	81.79	67.59	108.76	79.21	81.16	66.27	109.31	76.41
Max	101.32	73.17	121.12	88.00	103.53	73.86	123.52	90.75
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18	18	18
Basis Values and/or Estimates								
B-basis Value	83.91	66.63	108.37	80.60	83.64	66.09		
B-estimate							98.33	69.93
A-estimate	76.53	64.07	103.40	77.87	75.14	62.82	85.05	59.17
Method	Normal	Normal	Normal	Normal	Normal	Normal	ANOVA	ANOVA
Mod CV Basis Values and/or Estimates								
B-basis Value	84.45	60.37	104.34	73.41	85.24	60.31	105.78	73.84
A-estimate	77.72	53.64	96.82	65.88	78.17	53.24	98.18	66.23
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

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

5.23 Compression After Impact (CAI)

The CAI data is normalized so both normalized and as measured statistics are provided. Basis values are not computed for this property. Testing is done only for the RTD condition. However the summary statistics are presented in Table 5-29 and the data are displayed graphically in Figure 5-23.

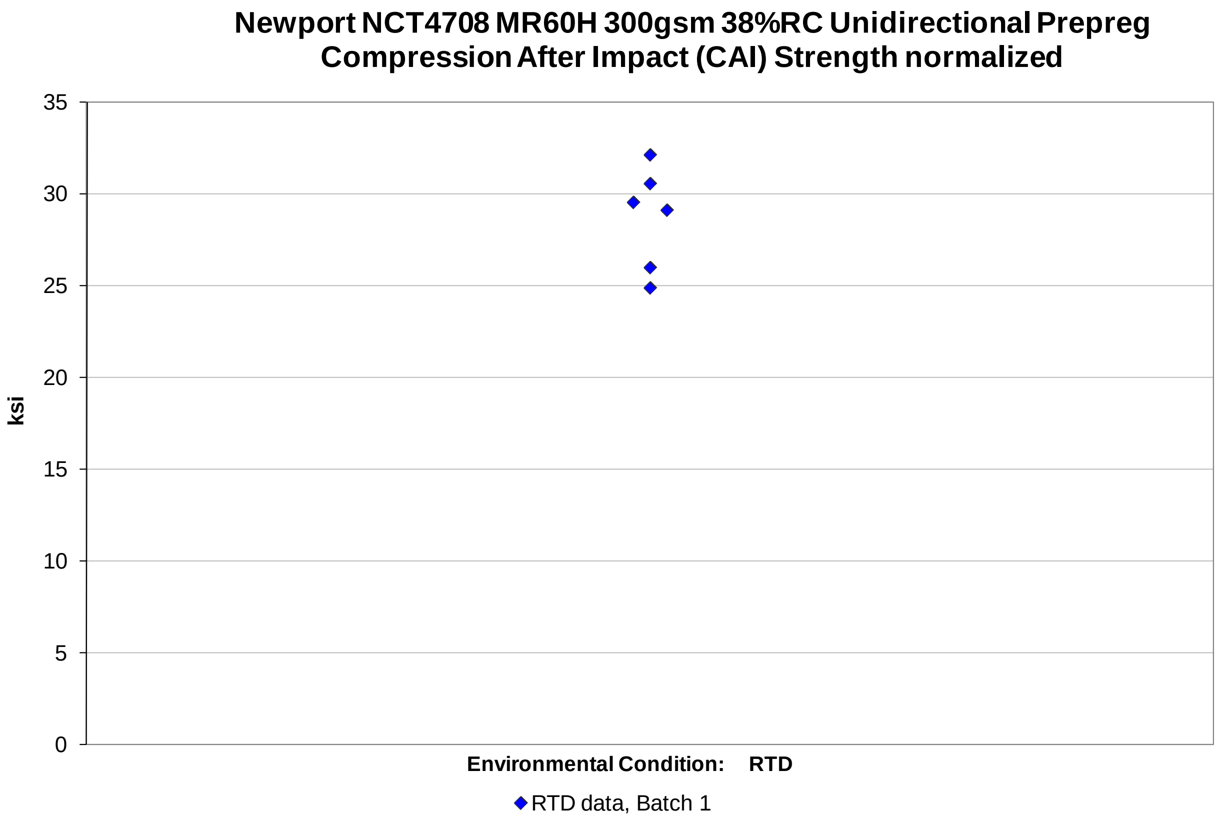

Figure 5-23: Plot for Compression After Impact Normalized Strength

Compression After Impact Strength (ksi)		
	Normalized	As Measured
Env	RTD	RTD
Mean	28.66	27.34
Stdev	2.72	2.60
CV	9.50	9.50
Mod CV	9.50	9.50
Min	24.91	23.77
Max	32.03	30.53
No. Batches	1	1
No. Spec.	6	6

Table 5-29: Statistics from Compression After Impact Strength data

5.24 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 5-30 and the data are displayed graphically in Figure 5-24.

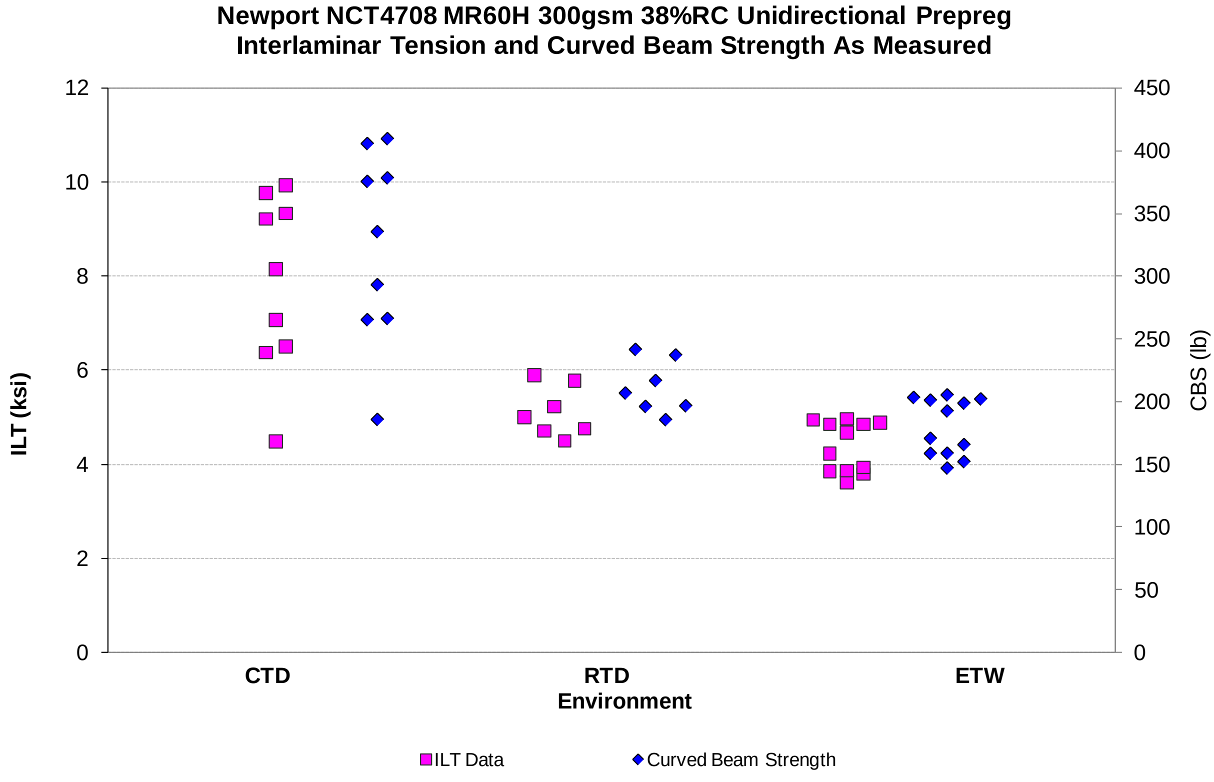

Figure 5-24: Plot ILT and CBS as measured

Property	Interlaminar Strength (ksi)			Curved Beam Strength (lb)		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	7.86	5.11	4.36	323.66	211.56	179.79
Stdev	1.88	0.54	0.54	76.12	21.31	22.68
CV	23.87	10.52	12.27	23.52	10.08	12.62
Mod CV	23.87	10.52	12.27	23.52	10.08	12.62
Min	4.47	4.49	3.60	185.85	185.66	147.19
Max	9.93	5.88	4.96	409.14	241.55	205.38
No. Batches	1	1	1	1	1	1
No. Spec.	9	7	12	9	7	12

Table 5-30: Statistics for ILT and CBS 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 chapter 8. An outlier may be an outlier in the normalized data, the as measured data, or both. A specimen may be an outlier for the batch only (before pooling the three batches within a condition together) or for the condition (after pooling the three batches within a condition together) or both.

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

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-2010-041 N/C.

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
LT	CTD	3	WFJC213B	Not an outlier	351.99	Low	Yes	No
TC	CTD	2	WFZB213B	NA	28.28	Low	Yes	No
IPS 5% Strain	CTD	1	WFNA211B	NA	9.25	High	No	Yes
IPS 5% Strain	CTD	1	WFNA212B	NA	9.36	High	No	Yes
IPS 5% Strain	CTD	3	WFNC111B	NA	8.69	Low	Yes	No
IPS 5% Strain	**ETW**	**1**	**WFNA11BF**	**NA**	**4.30**	**Low**	**Yes**	**Yes**
IPS 0.2% Offset	CTD	2	WFNB113B	NA	8.51	High	No	Yes
IPS 0.2% Offset	ETD	1	WFNA218G	NA	4.48	High	Yes	No
UNC0	RTD	3	WFRC219A	Not an outlier	77.23	High	Yes	No
UNT0	CTD	2	WFPB112B	185.89	Not an outlier	High	Yes	No
UNC1	ETW	1	WFWA21BF	43.02	43.38	High	Yes	No
UNC2	ETW	2	WFXB21AF	28.12	28.68	Low	Yes	No
FHT1	ETW	2	WF4B219F	68.88	69.39	Low	Yes	No
FHT2	ETW	2	WF5B21AF	Not an outlier	36.94	High	Yes	No
FHC1	RTD	3	WF7C213A	59.73	60.30	High	No	Yes
FHC1	ETW	1	WF7A218F	40.60	39.79	High	Yes	No
FHC2	RTD	2	WF8B115A	41.45	42.13	High	Yes	No
OHT3	RTD	3	WFFC216A	Not an outlier	154.39	High	Yes	No
OHT3	CTD	1	WFFA112B	139.75	Not an outlier	High	Yes	No
OHT3	ETW	2	WFFB218F	131.99	Not an outlier	Low	No	Yes
OHC3	RTD	3	WFIC211A	Not an outlier	63.53	High	Yes	No
OHC1	ETW	1	WFGA116F	34.65	Not an outlier	High	No	Yes
SBS1	**RTD**	**2**	**WFqB113A**	**NA**	**7.33**	**High**	**Yes**	**Yes**
SBS1	ETW	2	WFqB217F	NA	4.74	Low	Yes	No
SSB1 Ult. Str.	ETW	2	WFSB117F	Not an outlier	79.99	Low	Yes	No
SSB2 2% offset	ETW	1	WF2A119F	Not an outlier	65.54	Low	No	Yes
SSB3 2% offset	RTD	3	WF3C111A	Not an outlier	89.86	Low	Yes	No
SSB3 2% offset	ETW	2	WF3B218F	Not an outlier	67.46	Low	Yes	No
SSB3 Ult. Str.	ETW	1	WF3A117F	79.21	76.41	Low	No	Yes

Table 6-1: List of outliers

7. References

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