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# Solvay Cytec Cycom EP 2202 IM7G Unitape Gr 190 RC 33%Material Allowables
# Statistical Analysis Report

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# 1. Introduction

This report contains statistical analysis of the Solvay Cytec Cycom EP 2202 IM7G Unitape Gr 190 material property data published in NCAMP Test Report CAM-RP-2014-017 N/C. The lamina and laminate material property data have been generated with NCAMP oversight in accordance with NSP 100 NCAMP Standard Operating Procedures; the test panels and test specimens have been inspected by NCAMP Authorized Inspection Representatives (AIR) and the testing has been witnessed by NCAMP Authorized Engineering Representatives (AER). However, the data may not fulfill all the needs of any specific company's program; specific properties, environments, laminate architecture, and loading situations may require additional testing.

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 220/1 Rev – Initial Release dated March 06, 2012. The qualification test panels were cured in accordance with NCAMP Process Specification 82202 "C" cure cycle Rev - released January 26, 2012. The panels were fabricated at Spirit AeroSystems, Inc. 3801 S Oliver St., Wichita, KS 67278. The NCAMP Test Plan NTP 2201Q1 was used for this qualification program. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas.

Basis numbers are labeled as 'values' when the data meets all the requirements of working draft CMH-17 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 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).

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 220/1. NMS 220/1 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 220/1. NMS 220/*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 |
| Interlaminar Tension | ILT |
| Curved Beam Strength | CBS |
| Compression After Impact | CAI |

**Table 1-1: Test Property Abbreviations**

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

**Table 1-2: Test Property Symbols**

| Environmental Condition | Abbreviation | Temperature |
|---|---|---|
| Cold Temperature Dry | CTD | −65°F |
| Room Temperature Dry | RTD | 70°F |
| Elevated Temperature Dry | ETD | 180°F |
| Elevated Temperature Wet | ETW | 180°F |

**Table 1-3: Environmental Conditions Abbreviations**

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

1 refers to a 25/50/25 layup. This is also referred to as "Quasi-Isotropic"
2 refers to a 10/80/10 layup. This is also referred to as "Soft"
3 refers to a 50/40/10 layup. This is also referred to as "Hard"

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

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2014-017.

## 1.2 Pooling Across Environments

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

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

## 1.3 Basis Value Computational Process

The general form to compute engineering basis values is: $\text{basis value} = \overline{X} - kS$ 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 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.:** $$S = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} \left( X_i - \bar{X} \right)^2}$$ **Equation 2**

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

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.:** $$S_p = \sqrt{\frac{\sum_{i=1}^{k} (n_i - 1) S_i^2}{\sum_{i=1}^{k} (n_i - 1)}}$$ **Equation 4**

Where *k* refers to the number of batches, $S_i$ indicates the standard deviation of $i^{th}$ sample, and $n_i$ refers to the number of specimens in the $i^{th}$ sample.

#### 2.1.2.2 Pooled Coefficient of Variation

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

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

### 2.1.3 Basis Value Computations

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

**Basis Values:**

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

**Equation 6**

#### 2.1.3.1 K-factor computations

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

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

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

Where

r = the number of environments being pooled together

$n_j$= number of data values for environment j

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

$$f = N - r$$

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

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

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

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

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

### 2.1.4 Modified Coefficient of Variation

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

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

This is converted to percent by multiplying by 100%.

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

$$S^* = CV^* \cdot \overline{X}$$ **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 $S_i^* = CV^* \cdot \overline{X}_i$ for each batch. Transform the individual data values ($X_{ij}$) in each batch as follows:

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

$$C_i = \frac{S_i^*}{S_i}$$ **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.

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

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

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

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

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

### 2.1.5 Determination of Outliers

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

$$MNR = \frac{\max\limits_{all\ i}\left|X_i - \bar{X}\right|}{S},\ i = 1 \ldots n$$ **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, n being the total number of data values.

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

### 2.1.6 The k-Sample Anderson Darling Test for Batch Equivalency

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

The k-sample Anderson-Darling test statistic is:

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

Where

$n_i$ = the number of test specimens in each batch

$n = n_1 + n_2 + \ldots + n_k$

$h_j$ = the number of values in the combined samples equal to $z_{(j)}$

$H_j$ = the number of values in the combined samples less than $z_{(j)}$ plus ½ the number of values in the combined samples equal to $z_{(j)}$

$F_{ij}$ = the number of values in the $i^{th}$ group which are less than $z_{(j)}$ plus ½ the number of values in this group which are equal to $z_{(j)}$.

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

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

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

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

With

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

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

### 2.1.7 The Anderson Darling Test for Normality

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

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

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

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

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

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

The Anderson Darling test statistic (AD) is:

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

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

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

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

### 2.1.8 Levene's Test for Equality of Coefficient of Variation

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

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

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

## 2.2 STAT-17

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

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

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

### 2.2.1 Distribution Tests

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

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

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

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

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

### 2.2.2 Computing Normal Distribution Basis Values

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

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

**Table 2-1: K factors for normal distribution**

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

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

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

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

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

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

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

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

### 2.2.2.3 Two-parameter Weibull Distribution

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

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

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

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

#### 2.2.2.3.1 Estimating Weibull Parameters

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

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

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

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

#### 2.2.2.3.2 Goodness-of-fit test for the Weibull distribution

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

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

The Anderson-Darling test statistic is

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

and the observed significance level is

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

where

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

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

#### 2.2.2.3.3 Basis value calculations for the Weibull distribution

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

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

where

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

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

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

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

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

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

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

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

**Table 2-2: Weibull Distribution Basis Value Factors**

#### 2.2.2.4 Lognormal Distribution

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

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

##### 2.2.2.4.1 Goodness-of-fit test for the Lognormal distribution

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

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

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

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

#### 2.2.2.4.2 Basis value calculations for the Lognormal distribution

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

### 2.2.3 Non-parametric Basis Values

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

#### 2.2.3.1 Non-parametric Basis Values for large samples

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

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

For B-basis values:

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

For A-Basis values:

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

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

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

#### 2.2.3.2 Non-parametric Basis Values for small samples

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

The Hanson-Koopmans B-basis value is:

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

The A-basis value is:

$$A = x_{(n)} \left[ \frac{x_{(1)}}{x_{(n)}} \right]^k$$ **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 all 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**

### 2.2.4 Analysis of Variance (ANOVA) Basis Values

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

#### 2.2.4.1 Calculation of basis values using ANOVA

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

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

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

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

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

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

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

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

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

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

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

## 2.3 Single Batch and Two Batch Estimates using Modified CV

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

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

## 2.4 Lamina Variability Method (LVM)

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

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

The LVM B-basis value is then computed as:

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

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

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

With:

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

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

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

## 2.5 0º Lamina Strength Derivation

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

$F^u_{0^\circ} = F^u_{0^\circ/90^\circ} \cdot BF$ where BF is the backout factor.

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

$$BF = \frac{E_1\left[V_0E_2 + (1-V_0)E_1\right] - (\nu_{12}E_2)^2}{\left[V_0E_1 + (1-V_0)E_2\right]\left[V_0E_2 + (1-V_0)E_1\right] - (\nu_{12}E_2)^2}$$ **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
$\nu_{12}$ = major Poisson's ratio of 0º plies from an average of all batches

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

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, if there were no ETD tests run for transverse tension and compression, the value for $E_2$ would not be available. In that case, this 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

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

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

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

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

# 3. Summary of Results

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

## 3.1 NCAMP Recommended B-basis Values

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

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

## NCAMP Recommended B-basis Values for Cytec Cycom EP2202 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 | LC from UNC0** | TT* | TC* | SBS* | IPS* 0.2% Offset | IPS* 5% Strain | UNC0 |
|---|---|---|---|---|---|---|---|---|---|
| CTD (-65º F) | B-basis | 271.897 | 255.771 | 8.932 | 49.453*** | 18.047 | 8.602 | 14.664 | 94.073 |
| | Mean | 439.576 | 281.644 | 11.592 | 52.095 | 19.953 | 9.483 | 16.557 | 103.619 |
| | CV | 10.389 | 6.075 | 12.389 | 2.619 | 6.000 | 6.000 | 6.000 | 6.075 |
| RTD (70º F) | B-basis | 286.611 | 214.501 | 9.052 | 33.608 | 13.694 | 6.127 | 10.241 | 81.051 |
| | Mean | 425.798 | 240.788 | 11.170 | 37.947 | 15.600 | 7.008 | 11.563 | 90.750 |
| | CV | 11.463 | 6.806 | 10.182 | 6.000 | 6.000 | 6.000 | 6.000 | 6.806 |
| ETD (180º F) | B-basis | | NA: I | | NA: I | NA: I | | | NA: I |
| | Mean | | 211.475 | | 29.398 | 12.328 | | | 76.429 |
| | CV | | 5.873 | | 1.016 | 1.730 | | | 5.873 |
| ETW (180º F) | B-basis | 336.584 | 159.580 | NA:A | 20.303 | 8.684 | NA:A | NA:A | 57.223 |
| | Mean | 385.457 | 185.868 | 6.736 | 22.956 | 9.806 | 4.806 | 7.503 | 66.922 |
| | CV | 6.654 | 6.336 | 8.132 | 6.000 | 6.000 | 4.963 | 4.091 | 6.336 |

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

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

## NCAMP Recommended B-basis Values for Cytec Cycom EP2202 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 | SSB Ultimate Strength | SBS1* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 25/50/25 | CTD (-65º F) | B-basis | 70.025 | | 74.391 | | 125.112 | | | | |
| | | Mean | 77.970 | | 82.585 | | 139.581 | | | | |
| | | CV | 6.000 | | 6.000 | | 6.022 | | | | |
| | RTD (75º F) | B-basis | 69.647 | 44.360 | 71.394 | 62.536 | 125.989 | 80.174 | 111.500 | 133.980 | 11.784 |
| | | Mean | 77.592 | 48.922 | 79.588 | 69.032 | 140.459 | 88.676 | 125.894 | 148.180 | 13.273 |
| | | CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.307 | 6.000 | 6.000 | 6.000 |
| | ETW (180º F) | B-basis | 66.480 | 31.800 | 66.316 | 45.335 | 123.286 | 56.050 | 86.565 | 102.618 | 7.854 |
| | | Mean | 74.391 | 36.343 | 74.510 | 51.831 | 137.755 | 64.444 | 97.740 | 116.818 | 8.868 |
| | | CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| 10/80/10 | CTD (-65º F) | B-basis | 49.831 | | 56.463 | | 79.807 | | | | |
| | | Mean | 55.137 | | 62.327 | | 88.217 | | | | |
| | | CV | 6.000 | | 6.000 | | 6.000 | | | | |
| | RTD (75º F) | B-basis | 46.670 | 38.808 | 51.903 | 51.434 | 73.915 | 55.497 | 112.659 | 136.656 | |
| | | Mean | 51.976 | 42.898 | 57.767 | 56.774 | 82.325 | 64.512 | 125.181 | 151.210 | |
| | | CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 7.407 | 6.000 | 6.000 | |
| | ETW (180º F) | B-basis | 40.541 | 29.709 | 42.699 | 38.928 | 63.329 | 39.099 | 80.717 | 106.961 | |
| | | Mean | 45.847 | 33.782 | 48.563 | 44.209 | 71.739 | 44.188 | 93.289 | 121.573 | |
| | | CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.043 | 7.121 | 6.000 | |
| 50/40/10 | CTD (-65º F) | B-basis | 103.417 | | 101.761 | | 226.588 | | | | |
| | | Mean | 116.767 | | 113.350 | | 250.603 | | | | |
| | | CV | 6.000 | | 6.000 | | 6.000 | | | | |
| | RTD (75º F) | B-basis | 105.127 | 52.474 | 102.637 | 77.012 | 212.525 | 102.366 | 115.802 | 137.732 | |
| | | Mean | 118.698 | 58.359 | 114.276 | 85.006 | 236.539 | 124.738 | 127.739 | 152.253 | |
| | | CV | 6.000 | 6.404 | 6.000 | 6.000 | 6.000 | 8.668 | 6.000 | 6.000 | |
| | ETW (180º F) | B-basis | 103.186 | 40.810 | 97.393 | 56.535 | 182.804 | 79.504 | 82.117 | 104.031 | |
| | | Mean | 116.507 | 46.650 | 109.032 | 64.591 | 206.716 | 90.187 | 94.054 | 118.553 | |
| | | CV | 6.000 | 6.238 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | |

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

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

## 3.2 Lamina and Laminate Summary Tables

| | | | | |
|---|---|---|---|---|
| **Prepreg Material:** | EP2202 IM7G Unitape Gr 190 RC 33% | | | **EP2202 IM7G Unitape Gr 190 RC 33% Lamina Properties** |
| **Material Specification:** | NMS 220/1 | | | |
| **Process Specification:** | **NPS 82202** | | | |
| **Fiber:** | IM7G Unitape | **Resin:** | Epoxy EP 2202 | |
| **Tg(dry):** 366.740° F | **Tg(wet):** 288.044° F | **Tg METHOD:** | ASTM D7028 | |
| **PROCESSING:** | | | | |

| | | | |
|---|---|---|---|
| **Date of fiber manufacture** | Jun 2011 - May 2012 | **Date of testing** | Jun 2013 - Feb 2014 |
| **Date of resin manufacture** | Aug 2011 - Aug 2012 | **Date of data submittal** | July 30 2014 |
| **Date of prepreg manufacture** | Aug 2011 - Oct 2012 | **Date of analysis** | Jun 2014 - July 2014 |
| **Date of composite manufacture** | Feb 2012 - Apr 2013 | | |

**LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY**

**Data reported: As-measured followed by normalized values in parentheses, normalizing tply: 0.0072 in**

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

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

| | CTD | | | RTD | | | ETD | | | ETW | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B-Basis | Modified CV B-basis | Mean | B-Basis | Modified CV B-basis | Mean | B-Basis | Modified CV B-basis | Mean | B-Basis | Modified CV B-basis | Mean |
| $F_1^{tu}$ | 271.721 | NA | 444.296 | 280.397 | NA | 430.299 | | | | 349.534 | 338.266 | 388.395 |
| (ksi) | (271.897) | NA | (439.576) | (286.611) | NA | (425.798) | | | | (340.923) | 336.584 | (385.457) |
| $E_1^t$ | | | 22.720 | | | 22.803 | | | | | | 22.423 |
| (Msi) | | | (22.491) | | | (22.582) | | | | | | (22.256) |
| $\nu_{12}^t$ | | | 0.300 | | | 0.317 | | | | | | 0.304 |
| $F_2^{tu}$ (ksi) | 8.932 | NA | 11.592 | 9.052 | NA | 11.170 | | | | 3.020 | NA | 6.736 |
| $E_2^t$ (Msi) | | | 1.434 | | | 1.282 | | | | | | 1.156 |
| $F_1^{cu}$ (ksi) | 263.738 | 257.707 | 284.162 | 223.579 | 217.452 | 244.330 | 188.535 | 181.656 | 211.832 | 166.923 | 160.797 | 187.674 |
| from UNC0* | (262.097) | (255.771) | (281.644) | (220.929) | (214.501) | (240.788) | (189.178) | (181.961) | (211.475) | (166.008) | (159.580) | (185.868) |
| $E_1^c$ | | | 20.779 | | | 20.750 | | | 20.959 | | | 21.609 |
| (Msi) | | | (20.624) | | | (20.459) | | | (20.880) | | | (21.423) |
| $F_2^{cu}$ (ksi) | 49.453 | NA | 52.095 | 36.836 | 33.608 | 37.947 | 28.640 | NA | 29.398 | 22.298 | 20.303 | 22.956 |
| $E_2^c$ (Msi) | | | 1.533 | | | 1.395 | | | 1.313 | | | 1.244 |
| $F_{12}^{s5\%}$ (ksi) | 14.509 | 14.664 | 16.557 | 11.352 | 10.241 | 11.563 | | | | 5.403 | NA | 7.503 |
| $F_{12}^{s0.2\%}$ (ksi) | 8.555 | 8.602 | 9.483 | 6.859 | 6.127 | 7.008 | | | | 3.164 | NA | 4.806 |
| $G_{12}^s$ (Msi) | | | 0.836 | | | 0.663 | | | | | | 0.489 |
| SBS (ksi) | 19.244 | 18.047 | 19.953 | 15.269 | 13.694 | 15.600 | 11.736 | 10.287 | 12.328 | 8.654 | 8.684 | 9.806 |
| UNC0 | 97.190 | 94.979 | 104.732 | 83.955 | 81.708 | 91.617 | 68.334 | 65.812 | 76.937 | 59.594 | 57.347 | 67.256 |
| (ksi) | (96.398) | (94.073) | (103.619) | (83.414) | (81.051) | (90.750) | (68.192) | (65.540) | (76.429) | (59.586) | (57.223) | (66.922) |
| (Msi) | | | 7.659 | | | 7.781 | | | 7.612 | | | 7.744 |
| | | | (7.588) | | | (7.711) | | | (7.546) | | | (7.713) |

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

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

| | | | |
|---|---|---|---|
| **Prepreg Material:** | EP2202 IM7G Unitape Gr 190 RC 33% | | |
| **Material Specification:** | NMS 220/1 | | |
| **Process Specification:** | **NPS 82202** | | |
| **Fiber:** | IM7G Unitape | **Resin:** | Epoxy EP 2202 |
| **Tg(dry):** 366.740° F | **Tg(wet):** 288.044° F | **Tg METHOD:** | ASTM D7028 |
| **PROCESSING:** | | | |

**EP2202 IM7G Unitape Gr 190 RC 33% Laminate Properties**

| | | | |
|---|---|---|---|
| **Date of fiber manufacture** | Jun 2011 - May 2012 | **Date of testing** | Jun 2013 - Feb 2014 |
| **Date of resin manufacture** | Aug 2011 - Aug 2012 | **Date of data submittal** | July 30 2014 |
| **Date of prepreg manufacture** | Aug 2011 - Oct 2012 | **Date of analysis** | Jun 2014 - July 2014 |
| **Date of composite manufacture** | Feb 2012 - Apr 2013 | | |

**LAMINATE MECHANICAL PROPERTY B-BASIS SUMMARY**

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

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

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

| Test | Property | Layup: | | Quasi Isotropic 25/50/25 | | | "Soft" 10/80/10 | | | "Hard" 50/40/10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Test Condition | Unit | B-value | Mod. CV B-value | Mean | B-value | Mod. CV B-value | Mean | B-value | Mod. CV B-value | Mean |
| OHT (normalized) | Strength | CTD | ksi | 74.583 | 70.025 | 77.970 | 51.758 | 49.831 | 55.137 | 105.390 | 103.417 | 116.767 |
| | | RTD | ksi | 74.260 | 69.647 | 77.592 | 50.850 | 46.670 | 51.976 | 104.186 | 105.127 | 118.698 |
| | | ETW | ksi | 71.073 | 66.480 | 74.391 | 42.055 | 40.541 | 45.847 | 100.121 | 103.186 | 116.507 |
| OHC (normalized) | Strength | RTD | ksi | 47.553 | 44.360 | 48.922 | 36.719 | 38.808 | 42.898 | 53.014 | 52.474 | 58.359 |
| | | ETW | ksi | 34.979 | 31.800 | 36.343 | 28.812 | 29.709 | 33.782 | 43.689 | 40.810 | 46.650 |
| UNT (normalized) | Strength | CTD | ksi | 131.632 | 125.112 | 139.581 | 84.570 | 79.807 | 88.217 | 228.146 | 226.588 | 250.603 |
| | Modulus | | Msi | --- | --- | 8.464 | --- | --- | 5.528 | --- | --- | 13.196 |
| | Strength | RTD | ksi | 132.510 | 125.989 | 140.459 | 77.472 | 73.915 | 82.325 | 201.923 | 212.525 | 236.539 |
| | Modulus | | Msi | --- | --- | 8.247 | --- | --- | 5.197 | --- | --- | 13.132 |
| | Strength | ETW | ksi | 129.807 | 123.286 | 137.755 | 63.693 | 63.329 | 71.739 | 169.636 | 182.804 | 206.716 |
| | Modulus | | Msi | --- | --- | 8.146 | --- | --- | 4.816 | --- | --- | 12.933 |
| UNC (normalized) | Strength | RTD | ksi | 82.736 | 80.174 | 88.676 | 56.221 | 55.497 | 64.512 | 102.350 | NA | 124.738 |
| | Modulus | | Msi | --- | --- | 7.758 | --- | --- | 4.977 | --- | --- | 11.930 |
| | Strength | ETW | ksi | 58.579 | 56.050 | 64.444 | 40.748 | 39.099 | 44.188 | 73.065 | 79.504 | 90.187 |
| | Modulus | | Msi | --- | --- | 7.945 | --- | --- | 4.658 | --- | --- | 12.074 |
| FHT (normalized) | Strength | CTD | ksi | 79.717 | 74.391 | 82.585 | 59.083 | 56.463 | 62.327 | 100.877 | 101.761 | 113.350 |
| | | RTD | ksi | 73.472 | 71.394 | 79.588 | 54.523 | 51.903 | 57.767 | 92.280 | 102.637 | 114.276 |
| | | ETW | ksi | 66.325 | 66.316 | 74.510 | 43.454 | 42.699 | 48.563 | 93.045 | 97.393 | 109.032 |
| FHC (normalized) | Strength | RTD | ksi | 58.412 | 62.536 | 69.032 | 52.595 | 51.434 | 56.774 | 80.151 | 77.012 | 85.006 |
| | | ETW | ksi | 47.707 | 45.335 | 51.831 | 41.977 | 38.928 | 44.209 | 61.968 | 56.535 | 64.591 |
| Single Shear Bearing (normalized) | 2% Offset Strength | RTD | ksi | 119.821 | 111.500 | 125.894 | 118.118 | 112.659 | 125.181 | 121.857 | 115.802 | 127.739 |
| | | ETW | ksi | 91.666 | 86.565 | 97.740 | 67.886 | 80.717 | 93.289 | 88.172 | 82.117 | 94.054 |
| | Ultimate Strength | RTD | ksi | 138.846 | 133.980 | 148.180 | 145.540 | 136.656 | 151.210 | 146.761 | 137.732 | 152.253 |
| | | ETW | ksi | 111.902 | 102.618 | 116.818 | 115.880 | 106.961 | 121.573 | 113.060 | 104.031 | 118.553 |
| | Initial Peak | RTD | ksi | --- | --- | --- | --- | --- | --- | 111.041 | 103.412 | 117.532 |
| SBS1 (as-measured) | Strength | RTD | ksi | 12.219 | 11.784 | 13.273 | --- | --- | --- | --- | --- | --- |
| | | ETW | ksi | 7.557 | 7.854 | 8.868 | --- | --- | --- | --- | --- | --- |
| ILT (as-measured) | Strength | CTD | ksi | --- | --- | 6.186 | --- | --- | --- | --- | --- | --- |
| | | RTD | ksi | --- | --- | 4.962 | --- | --- | --- | --- | --- | --- |
| | | ETW | ksi | --- | --- | 4.568 | --- | --- | --- | --- | --- | --- |
| CBS (as-measured) | Strength | CTD | lb | --- | --- | 206.183 | --- | --- | --- | --- | --- | --- |
| | | RTD | lb | --- | --- | 164.398 | --- | --- | --- | --- | --- | --- |
| | | ETW | lb | --- | --- | 153.193 | --- | --- | --- | --- | --- | --- |
| CAI (Normalized) | Strength | RTD | ksi | 37.093 | NA | 50.093 | --- | --- | --- | --- | --- | --- |

**Table 3-4: Summary of Test Results for Laminate Data**

# 4. 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 there was of the data within and between batches. When there was little variation, the batches were graphed from left to right. The environmental conditions were identified by the shape and color of the symbol used to plot the data. Otherwise, the environmental conditions were graphed from left to right and the batches were identified by the shape and color of the symbol.

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

## 4.1 Longitudinal Tension (LT)

None of the datasets passed the normality test, so pooling across environments was not appropriate for either the normalized or the as-measured datasets. The normalized ETW dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. The as-measured ETW dataset failed the normality test, but a B-basis value could be computed using the Weibull distribution. When the ETW datasets, both normalized and as-measured, were transformed according to the assumptions of the modified CV method, they both passed the normality, so the modified CV basis values are provided. The CTD and RTD datasets, both normalized and as-measured, failed all distribution tests, so the non-parametric method was used to compute basis values. Modified CV basis values could not be computed due to the non-normality of those datasets.

There was one outlier. The lowest value in batch three of the CTD condition was an outlier for both batch three and the CTD condition. It was an outlier for both the normalized and as-measured datasets. It was retained for this analysis.

Statistics and basis values are given for strength data in Table 4-1 and for the modulus data in Table 4-2. The data and the B-basis values are shown graphically in Figure 4-1.

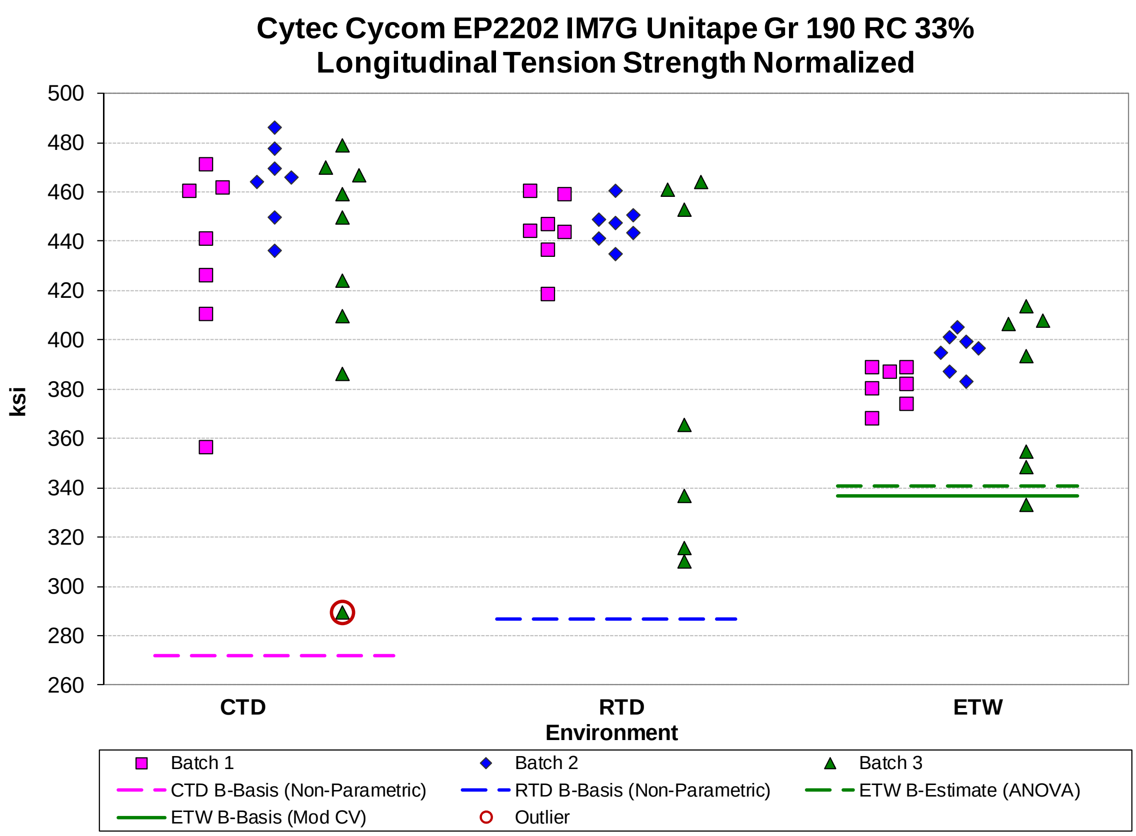


**Figure 4-1 Batch plot for LT strength normalized**

| Longitudinal Tension Strength Basis Values and Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 439.576 | 425.798 | 385.457 | 444.296 | 430.299 | 388.395 |
| Stdev | 45.666 | 48.809 | 20.458 | 46.228 | 51.755 | 21.541 |
| CV | 10.389 | 11.463 | 5.308 | 10.405 | 12.028 | 5.546 |
| Mod CV | 10.389 | 11.463 | 6.654 | 10.405 | 12.028 | 6.773 |
| Min | 289.567 | 309.944 | 333.178 | 289.790 | 305.350 | 332.792 |
| Max | 486.073 | 464.167 | 413.547 | 487.389 | 474.381 | 413.866 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 23 | 21 | 21 | 23 | 21 | 21 |
| B-basis Value | 271.897 | 286.611 | | 271.721 | 280.397 | 349.53 |
| B-Estimate | | | 340.923 | | | |
| A-estimate | 154.436 | 182.531 | 309.164 | 154.193 | 171.377 | 308.821 |
| Method | Non-Parametric | Non-Parametric | ANOVA | Non-Parametric | Non-Parametric | Weibull |
| Modified CV Basis Values and Estimates | | | | | | |
| B-basis Value | NA | NA | 336.584 | NA | NA | 338.266 |
| A-estimate | NA | NA | 301.770 | NA | NA | 302.558 |
| Method | NA | NA | normal | NA | NA | normal |

**Table 4-1: Statistics and Basis values for LT strength**

| Longitudinal Tension Modulus Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 22.491 | 22.582 | 22.256 | 22.720 | 22.803 | 22.423 |
| Stdev | 0.650 | 0.431 | 0.279 | 0.765 | 0.468 | 0.316 |
| CV | 2.890 | 1.909 | 1.255 | 3.368 | 2.053 | 1.409 |
| Mod CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 21.608 | 21.503 | 21.675 | 21.356 | 22.003 | 21.878 |
| Max | 23.882 | 23.492 | 22.662 | 24.410 | 24.078 | 22.981 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 | 21 | 21 |

**Table 4-2: Statistics from LT modulus**

## 4.2 Transverse Tension (TT)

Transverse Tension data is not normalized for unidirectional tape. The ETW dataset failed the Anderson-Darling k-sample test for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

Modified CV basis values could not be provided because the CV was higher than 8% for all conditions. There were no outliers.

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

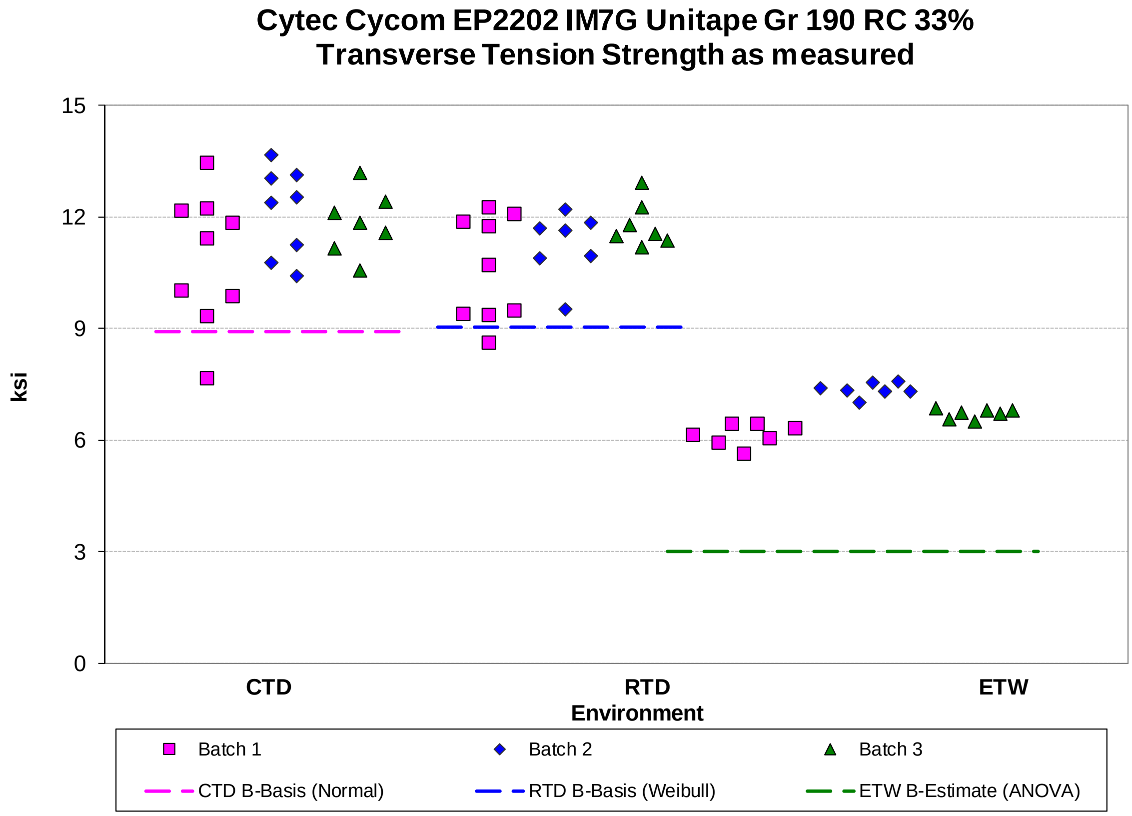


**Figure 4-2: Batch Plot for TT strength as-measured**

| Transverse Tension Strength Basis Values and Statistics | | | |
|---|---|---|---|
| As-measured | | | |
| Env | CTD | RTD | ETW |
| Mean | 11.592 | 11.170 | 6.736 |
| Stdev | 1.436 | 1.137 | 0.548 |
| CV | 12.389 | 10.182 | 8.132 |
| Mod CV | 12.389 | 10.182 | 8.132 |
| Min | 7.678 | 8.620 | 5.630 |
| Max | 13.677 | 12.913 | 7.568 |
| No. Batches | 3 | 3 | 3 |
| No. Spec. | 24 | 23 | 21 |
| Basis Values and Estimates | | | |
| B-basis Value | 8.932 | 9.052 | |
| B-estimate | | | 3.020 |
| A-estimate | 7.025 | 7.088 | 0.367 |
| Method | Normal | Weibull | ANOVA |

**Table 4-3: Statistics and Basis Values for TT Strength data as-measured**

| Transverse Tension Modulus Statistics | | | |
|---|---|---|---|
| | As-measured | | |
| Env | CTD | RTD | ETW |
| Mean | 1.434 | 1.282 | 1.156 |
| Stdev | 0.026 | 0.018 | 0.017 |
| CV | 1.793 | 1.385 | 1.433 |
| Mod CV | 6.000 | 6.000 | 6.000 |
| Min | 1.381 | 1.226 | 1.131 |
| Max | 1.474 | 1.312 | 1.203 |
| No. Batches | 3 | 3 | 3 |
| No. Spec. | 24 | 23 | 25 |

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

## 4.3 Longitudinal Compression (LC)

The strength values for 0° properties are computed via the equation 65 specified in section 2.5. There were no outliers or diagnostic test failures. Pooling was acceptable. The ETD condition lacks sufficient specimens to compute B-basis values so only B-estimates are provided for that condition.

Statistics and B-estimates are given for strength data in Table 4-5 and for the modulus data in Table 4-6. The data and the B-estimates are shown graphically in Figure 4-3.

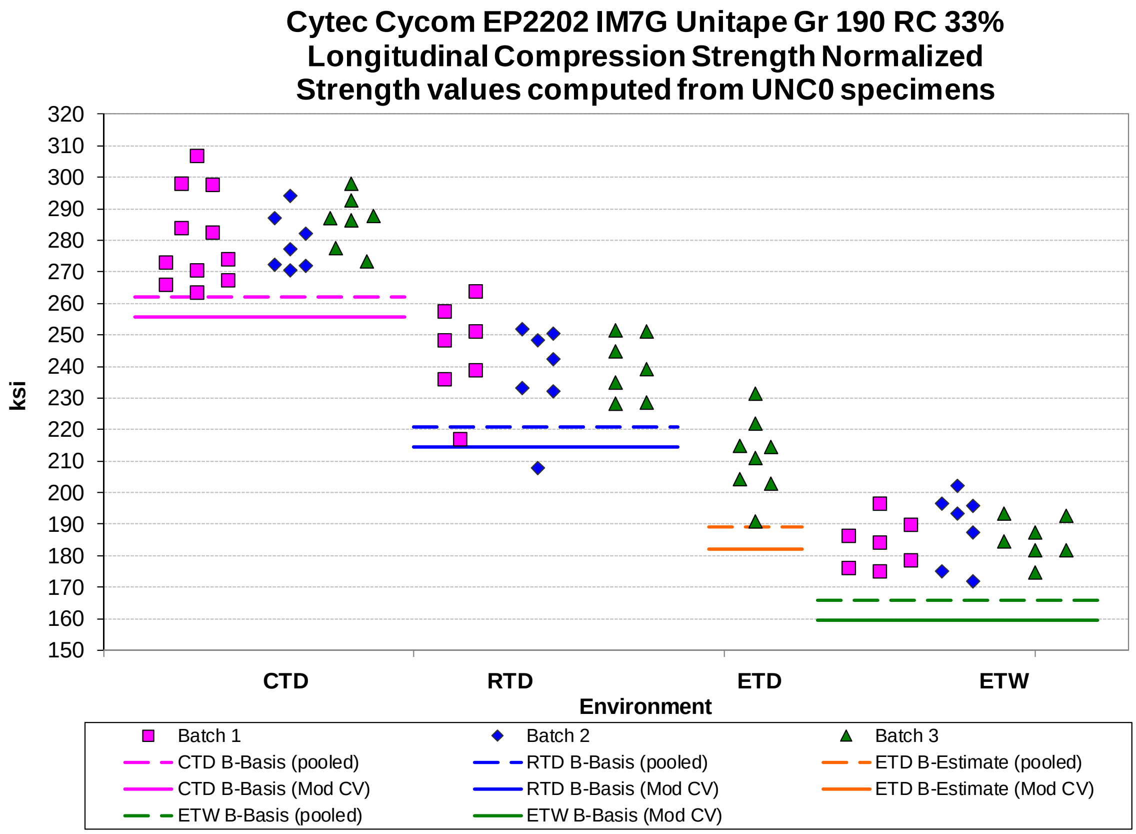


**Figure 4-3 Batch plot for LC strength normalized**

| Longitudinal Compression Strength Basis Values and Statistics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Normalized | | | | As-measured | | | |
| Env | CTD | RTD | ETD | ETW | CTD | RTD | ETD | ETW |
| Mean | 281.644 | 240.788 | 211.475 | 185.868 | 284.162 | 244.330 | 211.832 | 187.674 |
| Stdev | 11.689 | 13.512 | 12.420 | 8.683 | 11.969 | 14.813 | 12.128 | 8.763 |
| CV | 4.150 | 5.612 | 5.873 | 4.672 | 4.212 | 6.063 | 5.725 | 4.669 |
| Mod CV | 6.075 | 6.806 | 6.936 | 6.336 | 6.106 | 7.031 | 6.863 | 6.335 |
| Min | 263.497 | 207.845 | 190.907 | 171.739 | 267.905 | 205.606 | 191.742 | 173.484 |
| Max | 306.827 | 263.914 | 231.549 | 202.061 | 313.141 | 268.997 | 231.265 | 204.367 |
| No. Batches | 3 | 3 | 1 | 3 | 3 | 3 | 1 | 3 |
| No. Spec. | 25 | 21 | 8 | 21 | 25 | 21 | 8 | 21 |
| Basis Value Estimates | | | | | | | | |
| B-basis Value | 262.097 | 220.929 | | 166.008 | 263.738 | 223.579 | | 166.923 |
| B-Estimate | | | 189.178 | | | | 188.535 | |
| A-Estimate | 248.715 | 207.601 | 176.141 | 152.681 | 249.754 | 209.653 | 174.912 | 152.997 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled | pooled | pooled |
| Modified CV Basis Value Estimates | | | | | | | | |
| B-basis Value | 255.771 | 214.501 | | 159.580 | 257.707 | 217.452 | | 160.797 |
| B-Estimate | | | 181.961 | | | | 181.656 | |
| A-Estimate | 238.056 | 196.860 | 164.704 | 141.939 | 239.596 | 199.415 | 164.012 | 142.759 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled | pooled | pooled |

**Table 4-5: Statistics and Basis Values for LC strength derived from UNC0**

| Longitudinal Compression Modulus Statistics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Normalized | | | | As-measured | | | |
| Env | CTD | RTD | ETD | ETW | CTD | RTD | ETD | ETW |
| Mean | 20.624 | 20.459 | 20.880 | 21.423 | 20.779 | 20.750 | 20.959 | 21.609 |
| Stdev | 0.348 | 0.336 | 0.826 | 0.300 | 0.476 | 0.436 | 0.852 | 0.458 |
| CV | 1.685 | 1.640 | 3.954 | 1.399 | 2.291 | 2.103 | 4.067 | 2.120 |
| Mod CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.034 | 6.000 |
| Min | 19.665 | 19.747 | 20.359 | 20.731 | 19.645 | 20.089 | 20.440 | 20.696 |
| Max | 21.217 | 21.044 | 22.986 | 21.904 | 21.709 | 21.612 | 23.151 | 22.595 |
| No. Batches | 3 | 3 | 1 | 3 | 3 | 3 | 1 | 3 |
| No. Spec. | 21 | 21 | 9 | 21 | 21 | 21 | 9 | 21 |

**Table 4-6: Statistics from LC modulus**

## 4.4 Transverse Compression (TC)

Transverse Compression data is not normalized for unidirectional tape. The CTD and ETD datasets did not pass the normality test. The Weibull was the best fit distribution for both of those conditions. The ETD dataset lacked sufficient data for B-basis values. B-estimates only are provided. Pooling was not acceptable due to the failure of Levene's test for equal variances. The CTD and ETD conditions failed the normality test even after the use of the transformation for the modified CV approach. Therefore, CTD and ETD conditions do not have modified CV basis values.

There were four outliers. The lowest value in batch two of the CTD data was an outlier for batch two, but not for the CTD condition. The lowest value in batch three of both the ETD and ETW conditions were outliers for batch three only. (The ETD condition only had data from one batch available.) The largest value in batch one of the ETW dataset was an outlier for batch one, but not for the ETW condition. All four outliers were retained for this analysis.

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

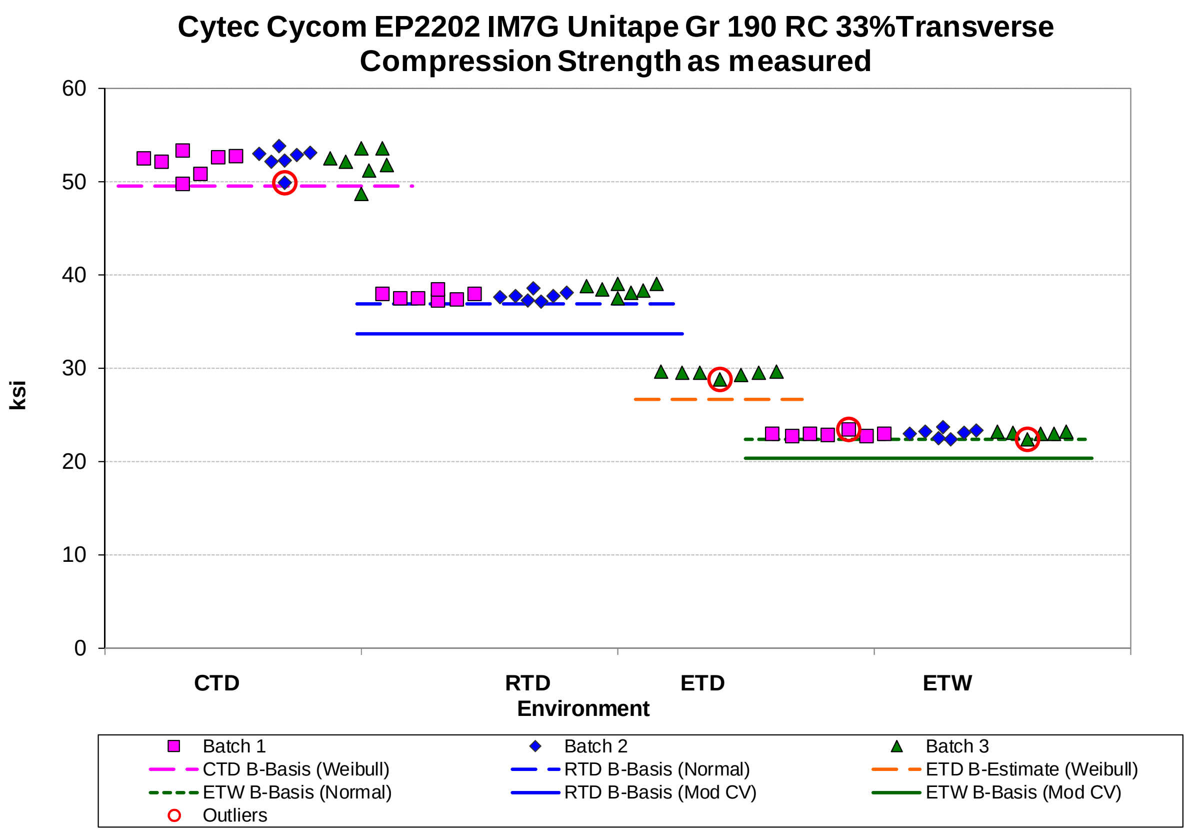


**Figure 4-4: Batch Plot for TC strength as-measured**

| Transverse Compression Strength Basis Values and Statistics | | | | |
|---|---|---|---|---|
| **As-measured** | | | | |
| Env | CTD | RTD | ETD | ETW |
| Mean | 52.095 | 37.947 | 29.398 | 22.956 |
| Stdev | 1.364 | 0.583 | 0.299 | 0.342 |
| CV | 2.619 | 1.537 | 1.016 | 1.490 |
| Mod CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 48.684 | 37.130 | 28.765 | 22.341 |
| Max | 53.821 | 39.045 | 29.611 | 23.670 |
| No. Batches | 3 | 3 | 1 | 3 |
| No. Spec. | 21 | 21 | 7 | 20 |
| **Basis Values and Estimates** | | | | |
| B-basis Value | 49.453 | 36.836 | | 22.298 |
| B-estimate | | | 28.640 | |
| A-estimate | 46.516 | 36.044 | 27.852 | 21.829 |
| Method | Weibull | Normal | Weibull | Normal |
| **Modified CV Basis Values and Estimates** | | | | |
| B-basis Value | NA | 33.608 | NA | 20.303 |
| A-estimate | NA | 30.518 | NA | 18.417 |
| Method | NA | normal | NA | normal |

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

| Transverse Compression Modulus Statistics | | | | |
|---|---|---|---|---|
| | **As-measured** | | | |
| Env | CTD | RTD | ETD | ETW |
| Mean | 1.533 | 1.395 | 1.313 | 1.244 |
| Stdev | 0.046 | 0.019 | 0.013 | 0.021 |
| CV | 3.001 | 1.340 | 1.008 | 1.650 |
| Mod CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 1.420 | 1.361 | 1.299 | 1.209 |
| Max | 1.604 | 1.433 | 1.337 | 1.288 |
| No. Batches | 3 | 3 | 1 | 3 |
| No. Spec. | 21 | 21 | 7 | 20 |

**Table 4-8: Statistics from TC Modulus data**

## 4.5 In-Plane Shear (IPS)

In Plane Shear data is not normalized. The CTD and ETW datasets, both 0.2% offset strength and strength at 5% strain, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When the CTD datasets were transformed according to the assumptions of the modified CV method, they passed the ADK test, so the modified CV basis values are provided. The ETW datasets did not pass the ADK test even after the modified CV transformation so modified CV basis values are not available for the ETW condition. There were no outliers.

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

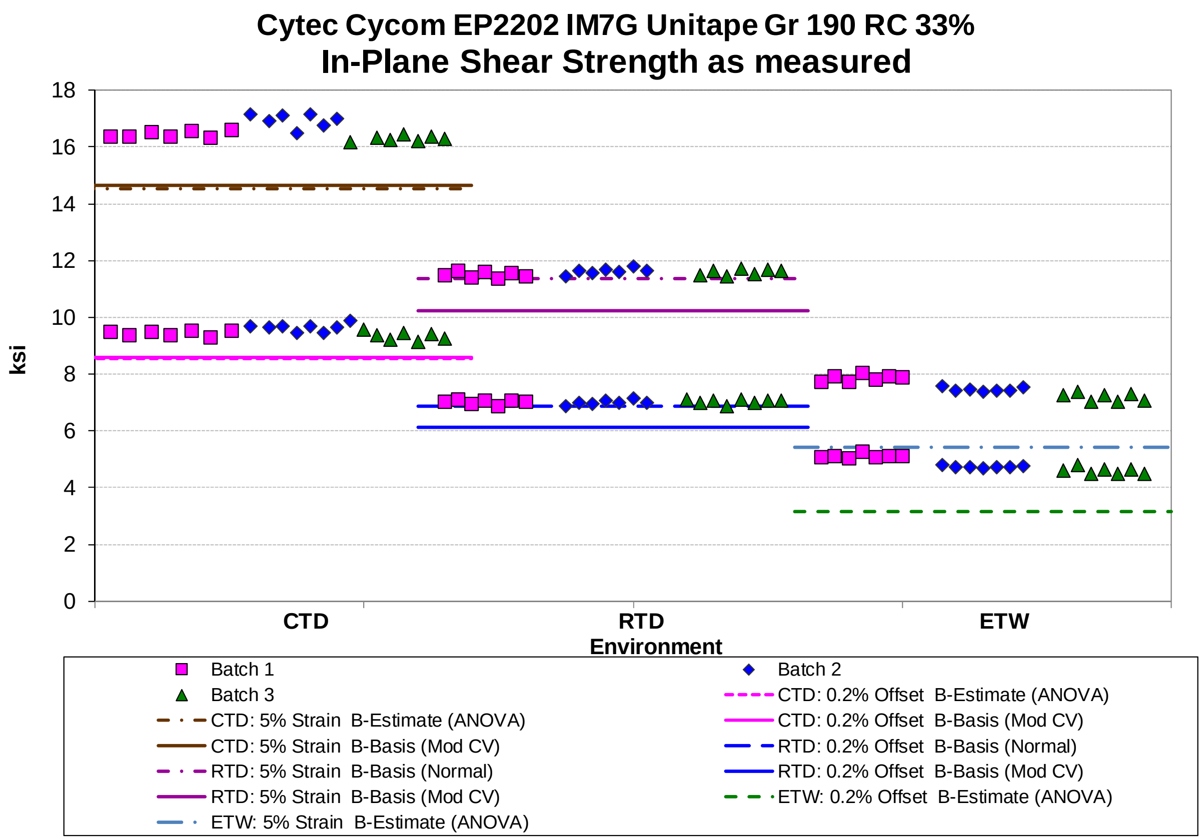


**Figure 4-5: Batch plot for IPS for 0.2% offset strength and strength at 5% strain as-measured**

| In-Plane Shear Strength Basis Values and Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Strength at 5% Strain | | | 0.2% Offset Strength | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 16.557 | 11.563 | 7.503 | 9.483 | 7.008 | 4.806 |
| Stdev | 0.322 | 0.111 | 0.307 | 0.179 | 0.079 | 0.239 |
| CV | 1.945 | 0.958 | 4.091 | 1.885 | 1.127 | 4.963 |
| Mod CV | 6.000 | 6.000 | 6.045 | 6.000 | 6.000 | 6.481 |
| Min | 16.170 | 11.353 | 7.006 | 9.150 | 6.857 | 4.470 |
| Max | 17.157 | 11.776 | 8.037 | 9.892 | 7.136 | 5.257 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 22 | 22 | 21 |
| Basis Values and Estimates | | | | | | |
| B-basis Value | | 11.352 | | | 6.859 | |
| B-estimate | 14.509 | | 5.403 | 8.555 | | 3.164 |
| A-estimate | 13.046 | 11.202 | 3.903 | 7.893 | 6.753 | 1.991 |
| Method | ANOVA | Normal | ANOVA | ANOVA | Normal | ANOVA |
| Modified Basis Values and Estimates | | | | | | |
| B-basis Value | 14.664 | 10.241 | NA | 8.602 | 6.127 | NA |
| A-estimate | 13.315 | 9.299 | NA | 7.995 | 5.520 | NA |
| Method | Normal | Normal | NA | pooled | pooled | NA |

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

| In Plane Shear Modulus Statistics | | | |
|---|---|---|---|
| | Modulus Statistics | | |
| Env | CTD | RTD | ETW |
| Mean | 0.836 | 0.663 | 0.489 |
| Stdev | 0.011 | 0.009 | 0.034 |
| CV | 1.350 | 1.432 | 6.903 |
| Mod CV | 6.000 | 6.000 | 7.452 |
| Min | 0.806 | 0.646 | 0.447 |
| Max | 0.854 | 0.677 | 0.544 |
| No. Batches | 3 | 3 | 3 |
| No. Spec. | 22 | 22 | 21 |

Table 4-10: Statistics from IPS Modulus data

## 4.6 "25/50/25" Unnotched Tension 1 (UNT1)

There were no diagnostic test failures. Pooling across the three conditions was acceptable. There were no outliers.

Statistics, basis values and estimates are given for UNT1 strength data in Table 4-11and for the modulus data in Table 4-12. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-6

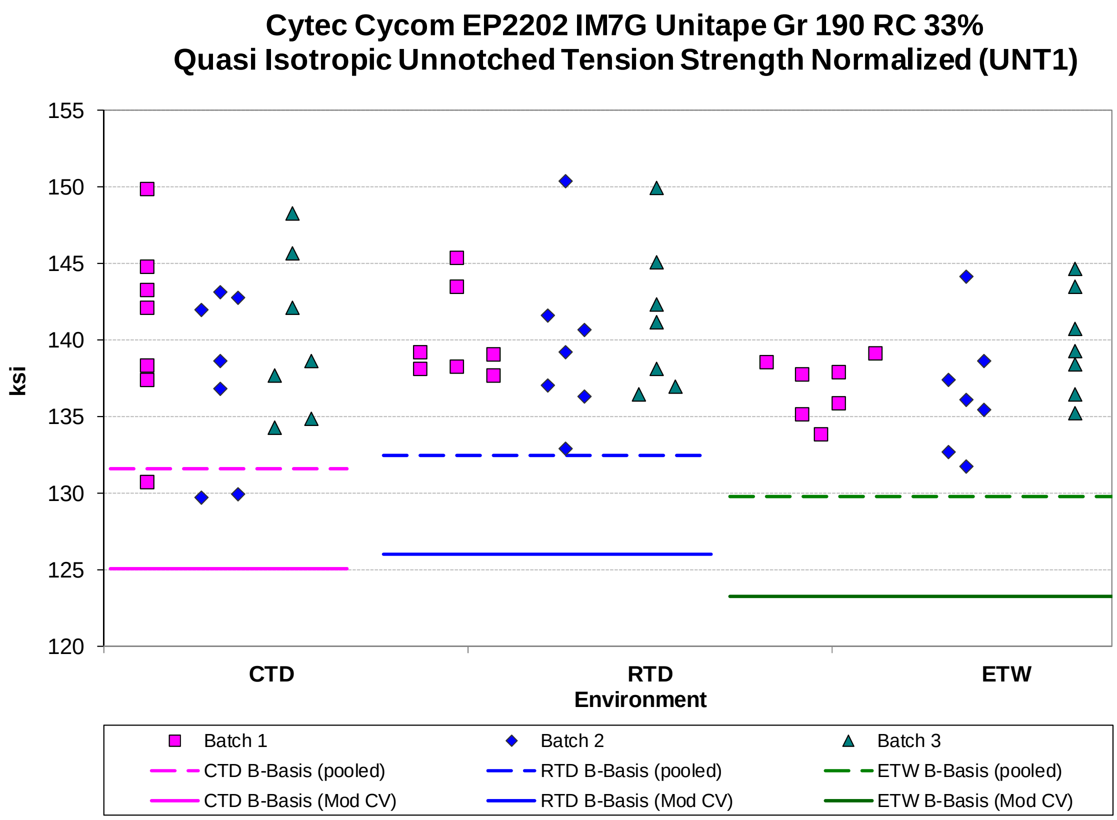


**Figure 4-6: Batch Plot for UNT1 strength normalized**

| Unnotched Tension (UNT1) Strength Basis Values and Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 139.581 | 140.459 | 137.755 | 139.861 | 140.693 | 138.374 |
| Stdev | 5.644 | 4.414 | 3.469 | 5.931 | 4.583 | 3.630 |
| CV | 4.044 | 3.142 | 2.518 | 4.241 | 3.257 | 2.623 |
| Modified CV | 6.022 | 6.000 | 6.000 | 6.120 | 6.000 | 6.000 |
| Min | 129.734 | 132.945 | 131.736 | 129.211 | 132.619 | 131.584 |
| Max | 149.853 | 150.358 | 144.636 | 151.986 | 149.364 | 144.326 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 | 21 | 21 |
| Basis Values and Estimates | | | | | | |
| B-basis Value | 131.632 | 132.510 | 129.807 | 131.545 | 132.377 | 130.058 |
| A-estimate | 126.266 | 127.144 | 124.441 | 125.932 | 126.764 | 124.445 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled |
| Modified CV Basis Values and Estimates | | | | | | |
| B-basis Value | 125.112 | 125.989 | 123.286 | 125.272 | 126.104 | 123.785 |
| A-estimate | 115.344 | 116.221 | 113.518 | 115.424 | 116.256 | 113.937 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled |

Table 4-11: Statistics and Basis Values for UNT1 Strength data

| Unnotched Tension (UNT1) Modulus Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 8.464 | 8.247 | 8.146 | 8.481 | 8.266 | 8.182 |
| Stdev | 0.142 | 0.139 | 0.115 | 0.164 | 0.165 | 0.101 |
| CV | 1.675 | 1.680 | 1.408 | 1.937 | 1.994 | 1.236 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 8.042 | 7.851 | 7.899 | 7.982 | 7.832 | 7.989 |
| Max | 8.688 | 8.610 | 8.370 | 8.707 | 8.558 | 8.361 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 22 | 21 | 21 | 22 | 21 |

Table 4-12: Statistics from UNT1 Modulus data

## 4.7 "10/80/10" Unnotched Tension 2 (UNT2)

The normalized ETW dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. The as-measured ETW dataset failed the normality test, but a B-basis value could be computed using the Weibull distribution. When the ETW datasets, both normalized and as-measured, were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided for that dataset.

The RTD datasets, both normalized and as-measured, and the as-measured ETW dataset failed the normal distribution test. However, all three of those datasets passed the Weibull distribution test, so the Weibull distribution was used to compute basis values. When the datasets were transformed according to the assumptions of the modified CV method, the three conditions could be pooled to compute the modified CV basis values.

There was one outlier. The lowest value in batch one of the RTD condition was an outlier for both batch one and the RTD condition. It was retained for this analysis.

Statistics, basis values and estimates are given for UNT2 strength data in Table 4-13 and for the modulus data in Table 4-14. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-7.

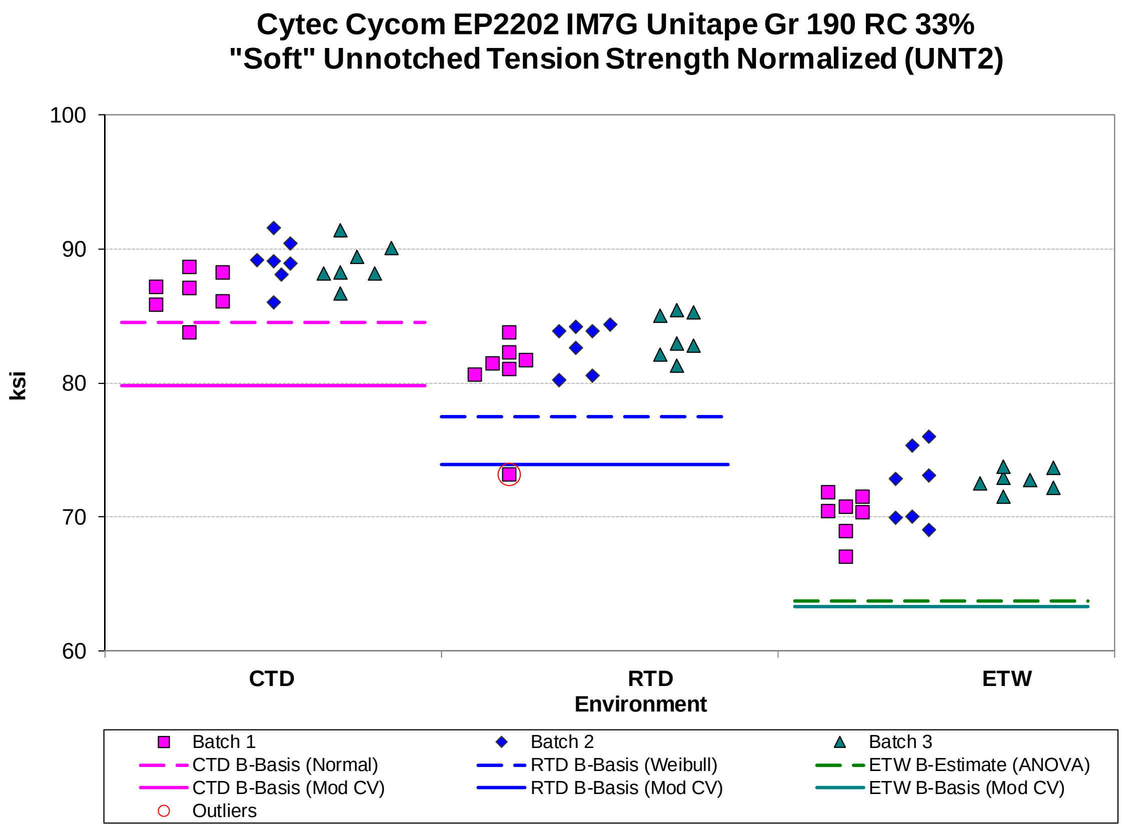


**Figure 4-7: Batch Plot for UNT2 strength normalized**

| Unnotched Tension (UNT2) Strength Basis Values and Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 88.217 | 82.325 | 71.739 | 88.394 | 82.496 | 71.834 |
| Stdev | 1.915 | 2.637 | 2.149 | 1.500 | 2.232 | 1.874 |
| CV | 2.170 | 3.204 | 2.996 | 1.697 | 2.705 | 2.609 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 83.762 | 73.191 | 67.077 | 85.513 | 75.453 | 68.347 |
| Max | 91.556 | 85.422 | 75.987 | 91.061 | 85.456 | 75.178 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 | 21 | 21 |
| Basis Values and Estimates | | | | | | |
| B-basis Value | 84.570 | 77.472 | | 85.536 | 78.316 | 67.287 |
| B-estimate | | | 63.693 | | | |
| A-estimate | 81.970 | 72.153 | 57.951 | 83.499 | 73.680 | 62.427 |
| Method | Normal | Weibull | ANOVA | Normal | Weibull | Weibull |
| Modified CV Basis Values and Estimates | | | | | | |
| B-basis Value | 79.807 | 73.915 | 63.329 | 79.968 | 74.070 | 63.408 |
| A-estimate | 74.130 | 68.237 | 57.652 | 74.280 | 68.382 | 57.720 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled |

**Table 4-13: Statistics and Basis Values for UNT2 Strength data**

| Unnotched Tension (UNT2) Modulus Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 5.528 | 5.197 | 4.816 | 5.540 | 5.208 | 4.822 |
| Stdev | 0.075 | 0.065 | 0.093 | 0.096 | 0.083 | 0.077 |
| CV | 1.358 | 1.252 | 1.941 | 1.729 | 1.597 | 1.592 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 5.394 | 5.094 | 4.670 | 5.421 | 5.103 | 4.681 |
| Max | 5.695 | 5.367 | 5.026 | 5.736 | 5.354 | 4.973 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 | 21 | 21 |

Table 4-14: Statistics from UNT2 Modulus data

## 4.8 "50/40/10" Unnotched Tension 3 (UNT3)

Only the as-measured RTD dataset passed the Anderson Darling k-sample test (ADK test) for batch to batch variability. The remaining datasets did not, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these datasets were transformed according to the assumptions of the modified CV method, they all passed the ADK test, so the modified CV basis values are provided. Pooling the conditions was acceptable to compute the modified CV basis values.

There were three outliers. The lowest values in batch one and batch three of the RTD condition and the lowest value in batch two of the ETW condition were identified as outliers. The lowest value in batch one of the RTD condition was an outlier only for the RTD condition. The outliers in batch three of the RTD condition and batch two of the ETW condition were outliers for their respective batches but not their respective conditions. Outliers were retained for this analysis.

Statistics and basis values are given for UNT3 strength data in Table 4-15 and for the modulus data in Table 4-16. The normalized data and the B-basis values are shown graphically in Figure 4-8.

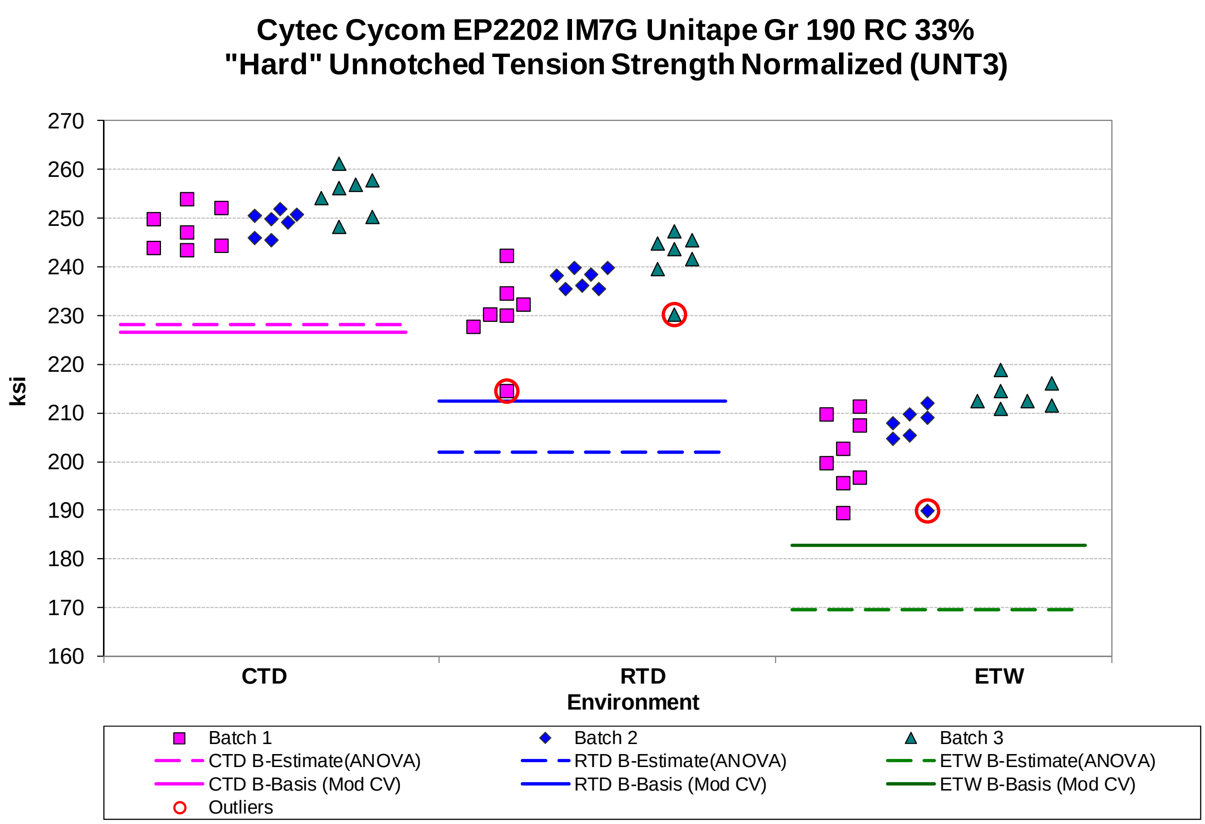


**Figure 4-8: Batch Plot for UNT3 strength normalized**

| Unnotched Tension (UNT3) Strength Basis Values and Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 250.603 | 236.539 | 206.716 | 251.164 | 236.814 | 207.012 |
| Stdev | 4.862 | 7.498 | 8.033 | 5.292 | 6.428 | 7.971 |
| CV | 1.940 | 3.170 | 3.886 | 2.107 | 2.714 | 3.850 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 243.438 | 214.510 | 189.504 | 243.478 | 220.533 | 187.596 |
| Max | 261.317 | 247.236 | 218.869 | 261.479 | 249.204 | 218.616 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 22 | 21 | 21 | 22 |
| Basis Values and Estimates | | | | | | |
| B-basis Value | | | | | 224.569 | |
| B-estimate | 228.146 | 201.923 | 169.636 | 226.406 | | 178.421 |
| A-estimate | 212.116 | 177.214 | 143.160 | 208.734 | 215.840 | 158.005 |
| Method | ANOVA | ANOVA | ANOVA | ANOVA | Normal | ANOVA |
| Modified CV Basis Values and Estimates | | | | | | |
| B-basis Value | 226.588 | 212.525 | 182.804 | 227.110 | 212.760 | 183.061 |
| A-estimate | 210.388 | 196.325 | 166.585 | 210.883 | 196.533 | 166.815 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled |

Table 4-15: Statistics and Basis Values for UNT3 Strength data

| Unnotched Tension (UNT3) Modulus Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 13.196 | 13.132 | 12.933 | 13.226 | 13.153 | 12.951 |
| Stdev | 0.163 | 0.265 | 0.211 | 0.180 | 0.192 | 0.243 |
| CV | 1.238 | 2.022 | 1.635 | 1.360 | 1.462 | 1.877 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 12.951 | 12.813 | 12.624 | 12.987 | 12.760 | 12.627 |
| Max | 13.525 | 13.798 | 13.342 | 13.606 | 13.570 | 13.623 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 24 | 23 | 21 | 24 | 23 |

Table 4-16: Statistics from UNT3 Modulus data

## 4.9 "33/0/67" Unnotched Compression 0 (UNC0)

There were no outliers or diagnostic test failures. Pooling was acceptable. The ETD condition lacks sufficient specimens to compute B-basis values so only B-estimates are provided for that condition.

Statistics and estimates of basis values are given for strength data in Table 4-17 and for the modulus data in Table 4-18. The normalized data and the B-estimates are shown graphically in Figure 4-9.

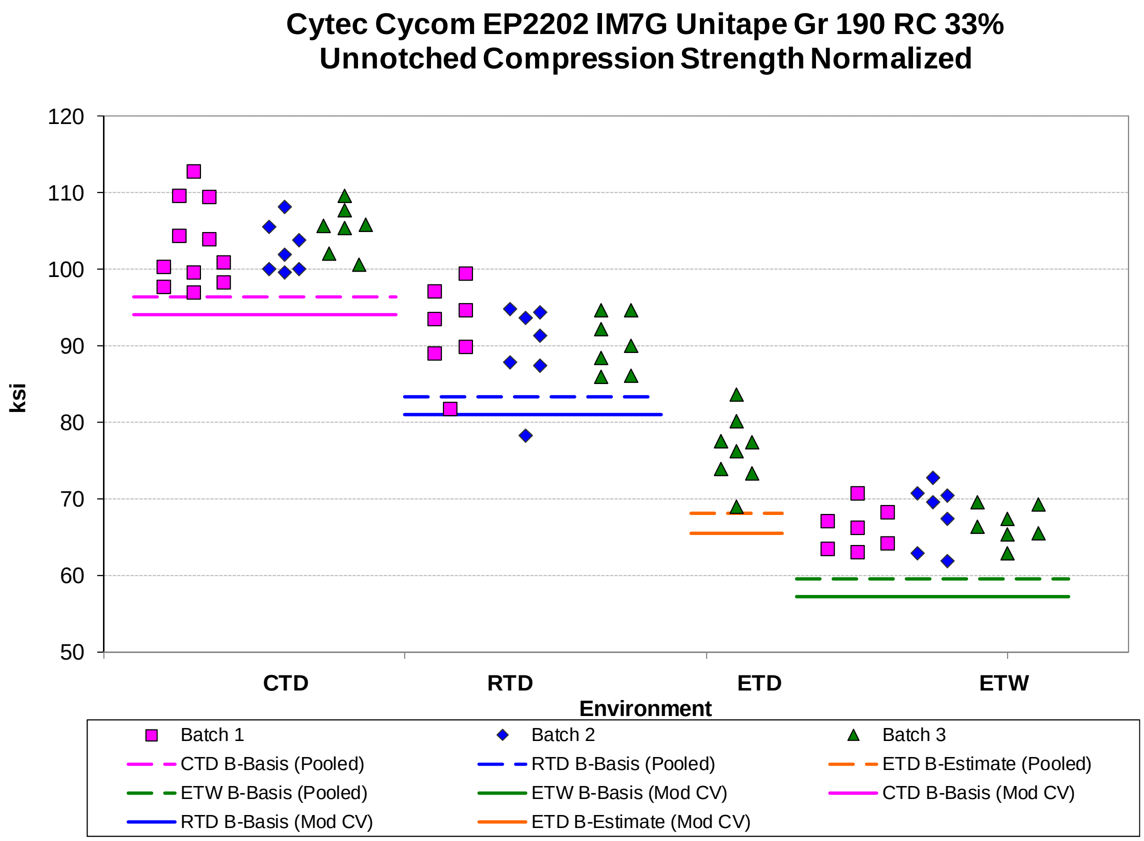


**Figure 4-9: Batch Plot for UNC0 strength normalized**

| Unnotched Compression (UNC0) Strength Basis Values and Statistics | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Normalized | | | | As-measured | | | |
| Env | CTD | RTD | ETD | ETW | CTD | RTD | ETD | ETW |
| Mean | 103.619 | 90.750 | 76.429 | 66.922 | 104.732 | 91.617 | 76.937 | 67.256 |
| Stdev | 4.300 | 5.093 | 4.489 | 3.126 | 4.411 | 5.554 | 4.405 | 3.141 |
| CV | 4.150 | 5.612 | 5.873 | 4.672 | 4.212 | 6.063 | 5.725 | 4.669 |
| Modified CV | 6.075 | 6.806 | 6.936 | 6.336 | 6.106 | 7.031 | 6.863 | 6.335 |
| Min | 96.943 | 78.335 | 68.996 | 61.835 | 98.741 | 77.097 | 69.640 | 62.171 |
| Max | 112.884 | 99.466 | 83.684 | 72.753 | 115.413 | 100.867 | 83.995 | 73.239 |
| No. Batches | 3 | 3 | 1 | 3 | 3 | 3 | 1 | 3 |
| No. Spec. | 25 | 21 | 8 | 21 | 25 | 21 | 8 | 21 |
| Basis Values and Estimates | | | | | | | | |
| B-basis Value | 96.398 | 83.414 | | 59.586 | 97.190 | 83.955 | | 59.594 |
| B-estimate | | | 68.192 | | | | 68.334 | |
| A-estimate | 91.454 | 78.490 | 63.375 | 54.662 | 92.026 | 78.812 | 63.303 | 54.451 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled | pooled | pooled |
| Modified CV Basis Values and Estimates | | | | | | | | |
| B-basis Value | 94.073 | 81.051 | | 57.223 | 94.979 | 81.708 | | 57.347 |
| B-estimate | | | 65.540 | | | | 65.812 | |
| A-estimate | 87.537 | 74.542 | 59.172 | 50.714 | 88.302 | 75.059 | 59.307 | 50.698 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled | pooled | pooled |

Table 4-17: 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 | 7.588 | 7.711 | 7.546 | 7.713 | 7.659 | 7.781 | 7.612 | 7.744 |
| Stdev | 0.151 | 0.144 | 0.049 | 0.133 | 0.203 | 0.176 | 0.036 | 0.155 |
| CV | 1.993 | 1.867 | 0.654 | 1.721 | 2.649 | 2.259 | 0.473 | 2.000 |
| Mod CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 7.315 | 7.495 | 7.442 | 7.530 | 7.247 | 7.491 | 7.541 | 7.508 |
| Max | 7.974 | 8.001 | 7.588 | 7.921 | 8.153 | 8.113 | 7.648 | 8.024 |
| No. Batches | 3 | 3 | 1 | 3 | 3 | 3 | 1 | 3 |
| No. Spec. | 21 | 21 | 7 | 21 | 21 | 21 | 7 | 21 |

Table 4-18: Statistics from UNC0 Modulus data

## 4.10 "25/50/25" Unnotched Compression 1 (UNC1)

There were no diagnostic test failures. Pooling the RTD and ETW condition was acceptable. There was one outlier. The lowest value in batch two of the as-measured RTD condition dataset was an outlier only for batch two, not for the RTD condition and not for the normalized dataset. It was retained for this analysis.

Statistics, basis values and estimates are given for UNC1 strength data in Table 4-19 and for the modulus data in Table 4-20. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-10.

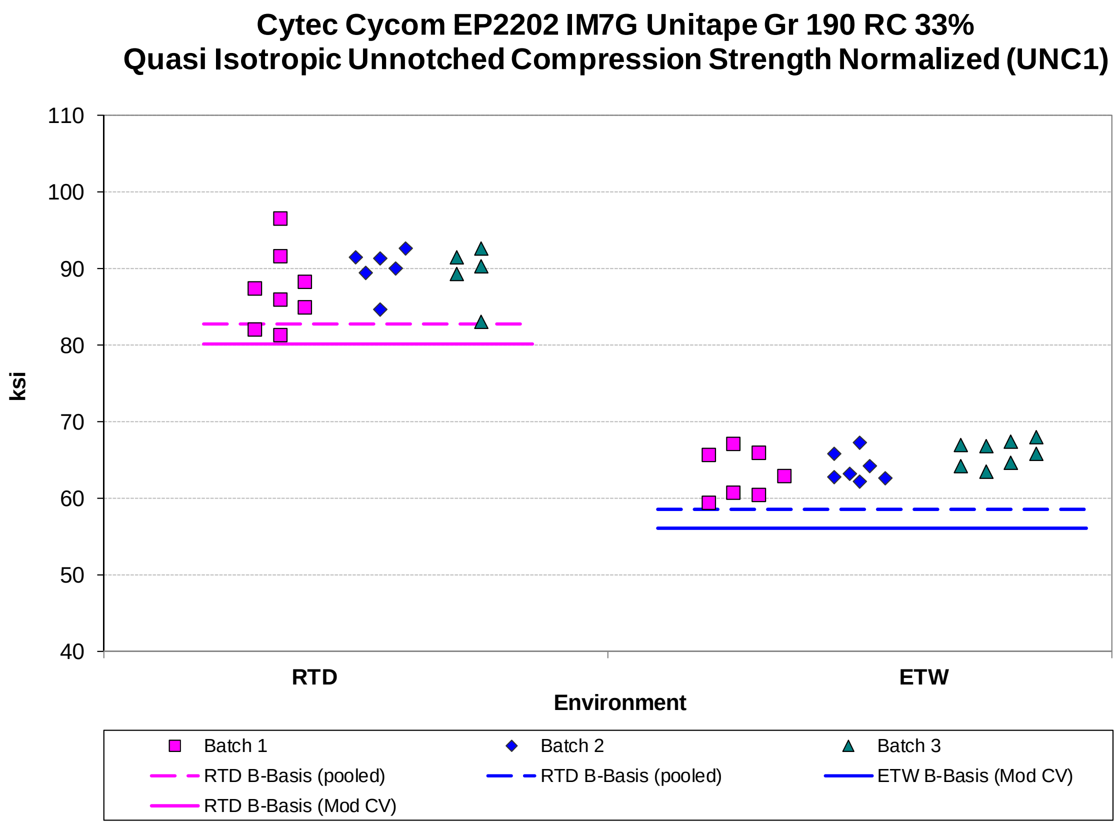


**Figure 4-10: Batch plot for UNC1 strength normalized**

| Unnotched Compression (UNC1) Strength Basis Values and | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 88.676 | 64.444 | 89.850 | 64.984 |
| Stdev | 4.091 | 2.457 | 3.854 | 2.337 |
| CV | 4.613 | 3.813 | 4.289 | 3.597 |
| Modified CV | 6.307 | 6.000 | 6.145 | 6.000 |
| Min | 81.382 | 59.416 | 83.107 | 60.779 |
| Max | 96.623 | 68.055 | 98.635 | 68.775 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 19 | 22 | 19 | 22 |
| Basis Values and Estimates | | | | |
| B-basis Value | 82.736 | 58.579 | 84.238 | 59.443 |
| A-estimate | 78.697 | 54.523 | 80.422 | 55.611 |
| Method | pooled | pooled | pooled | pooled |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 80.174 | 56.050 | 81.392 | 56.633 |
| A-estimate | 74.392 | 50.243 | 75.640 | 50.857 |
| Method | pooled | pooled | pooled | pooled |

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

| Unnotched Compression (UNC1) Modulus | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 7.758 | 7.945 | 7.851 | 8.027 |
| Stdev | 0.090 | 0.207 | 0.083 | 0.210 |
| CV | 1.166 | 2.607 | 1.056 | 2.622 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 7.599 | 7.627 | 7.701 | 7.687 |
| Max | 7.946 | 8.289 | 8.014 | 8.392 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 |

**Table 4-20: Statistics from UNC1 Modulus data**

## 4.11 "10/80/10" Unnotched Compression 2 (UNC2)

The as-measured ETW failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the ETW dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test, so the modified CV basis values are provided.

Pooling the RTD and ETW conditions was not permissible due to the failure of Levene's test of equality of variance. There were no outliers.

Statistics and basis values are given for UNC2 strength data in Table 4-21 and for the modulus data in Table 4-22. The normalized data and the B-basis values are shown graphically in Figure 4-11.

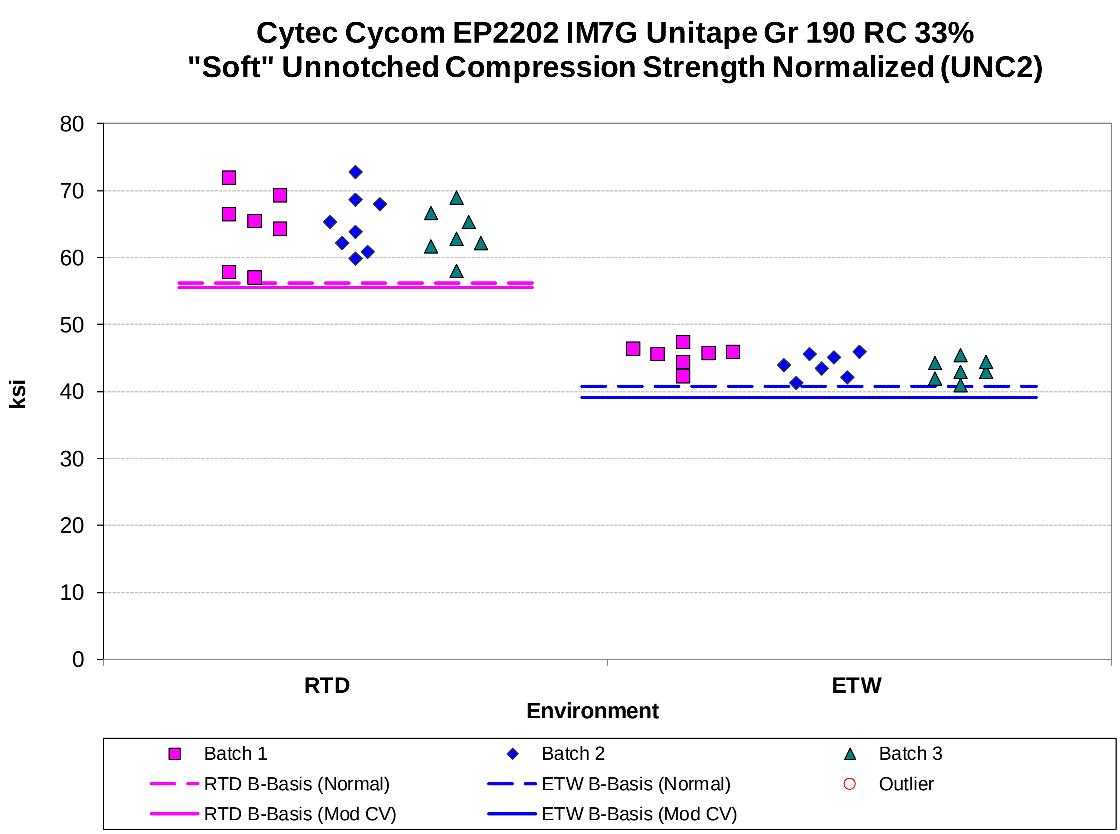


**Figure 4-11: Batch plot for UNC2 strength normalized**

| Unnotched Compression (UNC2) Strength Basis Values and | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 64.512 | 44.188 | 65.165 | 44.575 |
| Stdev | 4.396 | 1.806 | 4.454 | 1.943 |
| CV | 6.814 | 4.087 | 6.835 | 4.359 |
| Modified CV | 7.407 | 6.043 | 7.418 | 6.180 |
| Min | 56.995 | 40.996 | 57.907 | 41.201 |
| Max | 72.731 | 47.382 | 72.938 | 48.134 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 22 | 21 | 22 | 21 |
| Basis Values and Estimates | | | | |
| B-basis Value | 56.221 | 40.748 | 56.765 | |
| B-estimate | | | | 36.594 |
| A-estimate | 50.299 | 38.296 | 50.765 | 30.898 |
| Method | Normal | Normal | Normal | ANOVA |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 55.497 | 39.099 | 56.046 | 39.326 |
| A-estimate | 49.061 | 35.474 | 49.536 | 35.587 |
| Method | normal | normal | normal | normal |

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

| Unnotched Compression (UNC2) Modulus | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 4.977 | 4.658 | 5.030 | 4.699 |
| Stdev | 0.081 | 0.065 | 0.089 | 0.080 |
| CV | 1.637 | 1.397 | 1.766 | 1.709 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 4.742 | 4.547 | 4.754 | 4.534 |
| Max | 5.088 | 4.784 | 5.167 | 4.849 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 |

**Table 4-22: Statistics from UNC2 Modulus data**

## 4.12 "50/40/10" Unnotched Compression 3 (UNC3)

The RTD dataset lacked sufficient valid specimens to compute B-basis values. Therefore, only B-estimates are provided for the RTD condition.

The ETW datasets, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the ETW datasets were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided.

There were no outliers. Statistics, basis values and estimates are given for UNC3 strength data in Table 4-23 and for the modulus data in Table 4-24. The normalized data and the B-basis values are shown graphically in Figure 4-12.

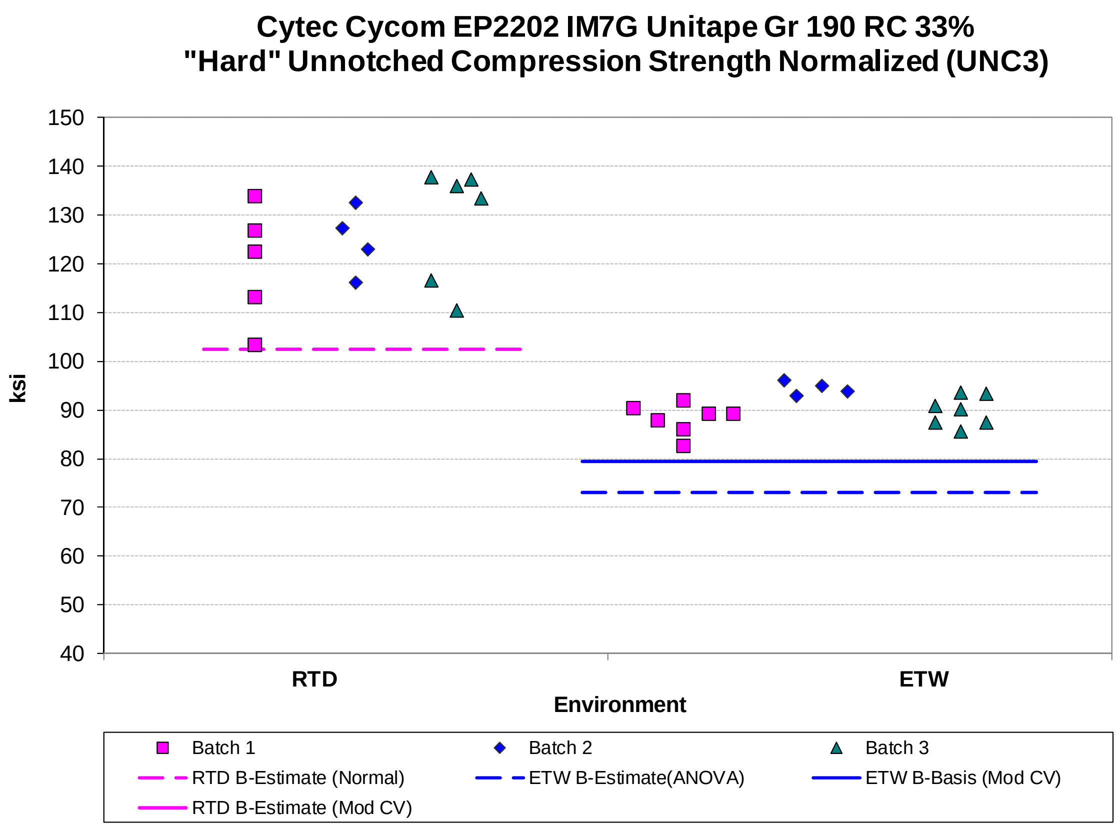


**Figure 4-12: Batch plot for UNC3 strength normalized**

| Unnotched Compression (UNC3) Strength Basis Values and | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 124.738 | 90.187 | 125.938 | 91.406 |
| Stdev | 10.812 | 3.605 | 10.778 | 3.759 |
| CV | 8.668 | 3.998 | 8.558 | 4.112 |
| Modified CV | 8.668 | 6.000 | 8.558 | 6.056 |
| Min | 103.485 | 82.526 | 106.101 | 84.172 |
| Max | 137.855 | 96.080 | 138.738 | 97.962 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 15 | 18 | 15 | 18 |
| Basis Values and Estimates | | | | |
| B-estimate | 102.350 | 73.065 | 103.622 | 72.897 |
| A-estimate | 86.587 | 60.857 | 87.909 | 59.699 |
| Method | Normal | ANOVA | Normal | ANOVA |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | NA | 79.504 | NA | 80.478 |
| A-estimate | NA | 71.947 | NA | 72.747 |
| Method | NA | normal | NA | normal |

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

| Unnotched Compression (UNC3) Modulus | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 11.930 | 12.074 | 12.055 | 12.204 |
| Stdev | 0.247 | 0.156 | 0.282 | 0.185 |
| CV | 2.068 | 1.292 | 2.341 | 1.513 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 11.322 | 11.806 | 11.363 | 11.838 |
| Max | 12.241 | 12.389 | 12.403 | 12.452 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 18 | 18 | 18 | 18 |

**Table 4-24: Statistics from UNC3 Modulus data**

## 4.13 Lamina Short-Beam Strength (SBS)

The Short Beam Strength data is not normalized. The ETD condition had insufficient data to compute B-basis values so only B-estimates are provided. The ETW dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across all four environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. However, after transforming the data to fit the modified CV assumptions, the ETW dataset passed the ADK test and modified CV basis values are provided.

The CTD and RTD datasets could not be pooled due to a failure of Levene's test. However, after applying the transformation of data for the assumptions of the modified CV method, the CTD and RTD conditions could be pooled to compute the modified CV basis values.

There was one outlier. The lowest value in batch two of the CTD condition dataset was an outlier for both batch two and the CTD condition. It was retained for this analysis.

Statistics and basis values are given for SBS data in Table 4-25. The data and the B-basis values are shown graphically in Figure 4-13.

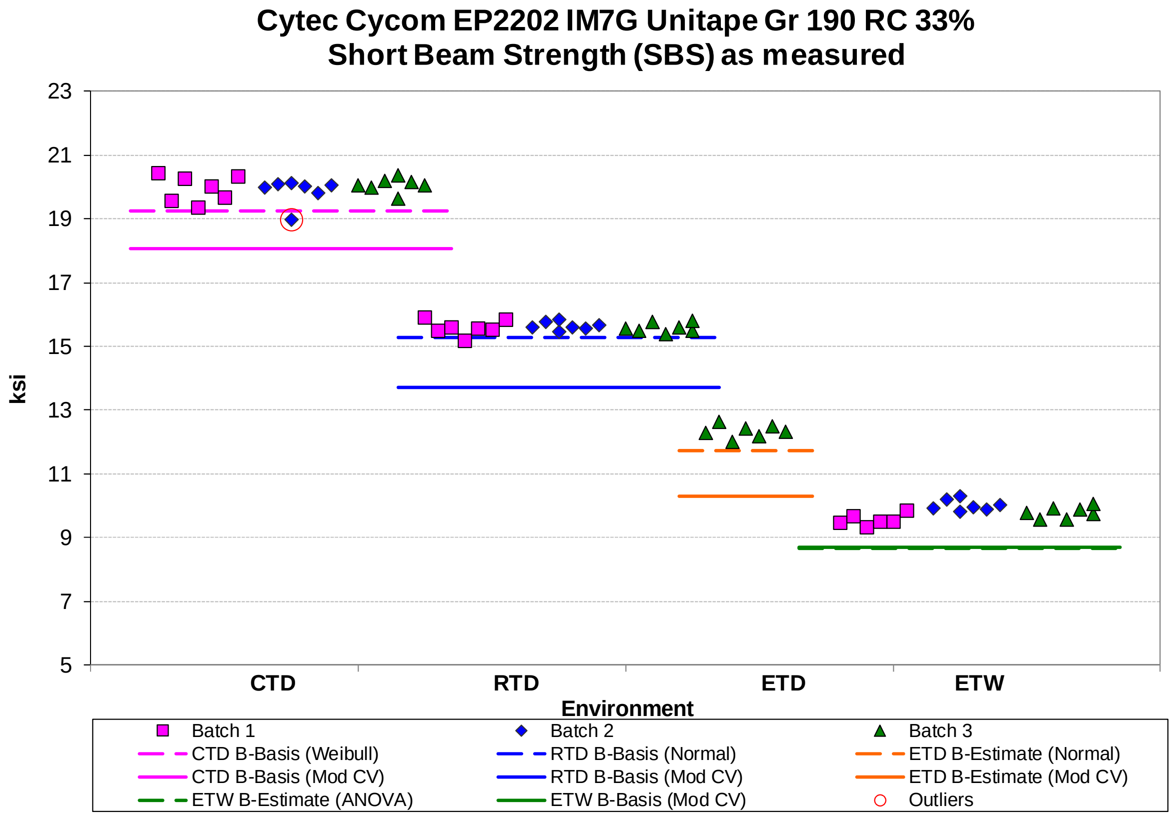


**Figure 4-13: Batch plot for SBS as-measured**

| Short Beam Strength (SBS) Basis Values and Statistics As-measured | | | | |
|---|---|---|---|---|
| Env | CTD | RTD | ETD | ETW |
| Mean | 19.953 | 15.600 | 12.328 | 9.806 |
| Stdev | 0.357 | 0.174 | 0.213 | 0.254 |
| CV | 1.788 | 1.114 | 1.730 | 2.590 |
| Mod CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 18.966 | 15.174 | 11.993 | 9.340 |
| Max | 20.435 | 15.908 | 12.644 | 10.301 |
| No. Batches | 3 | 3 | 1 | 3 |
| No. Spec. | 21 | 21 | 7 | 21 |
| Basis Values and Estimates | | | | |
| B-basis Value | 19.244 | 15.269 | | |
| B-estimate | | | 11.736 | 8.654 |
| A-estimate | 18.443 | 15.033 | 11.319 | 7.831 |
| Method | Weibull | Normal | Normal | ANOVA |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 18.047 | 13.694 | | 8.684 |
| B-estimate | | | 10.287 | |
| A-estimate | 16.737 | 12.384 | 8.890 | 7.886 |
| Method | pooled | pooled | normal | normal |

**Table 4-25: Statistics and Basis Values for SBS data**

## 4.14 Laminate Short-Beam Strength (SBS1)

The Laminate Short Beam strength data is not normalized. The as-measured ETW failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. Pooling was not acceptable because the data failed Levene's test for equality of variance. However, after transforming the data to fit the modified CV assumptions, the RTD dataset passed the normality test and the ETW dataset passed the ADK test so modified CV basis values are provided.

There was one outlier. The lowest value in the batch one of the RTD condition was an outlier for the RTD condition but not for batch one. It was retained for this analysis.

Statistics, estimates and basis values are given for SBS1 strength data in Table 4-26. The data and the B-basis values are shown graphically in Figure 4-14.

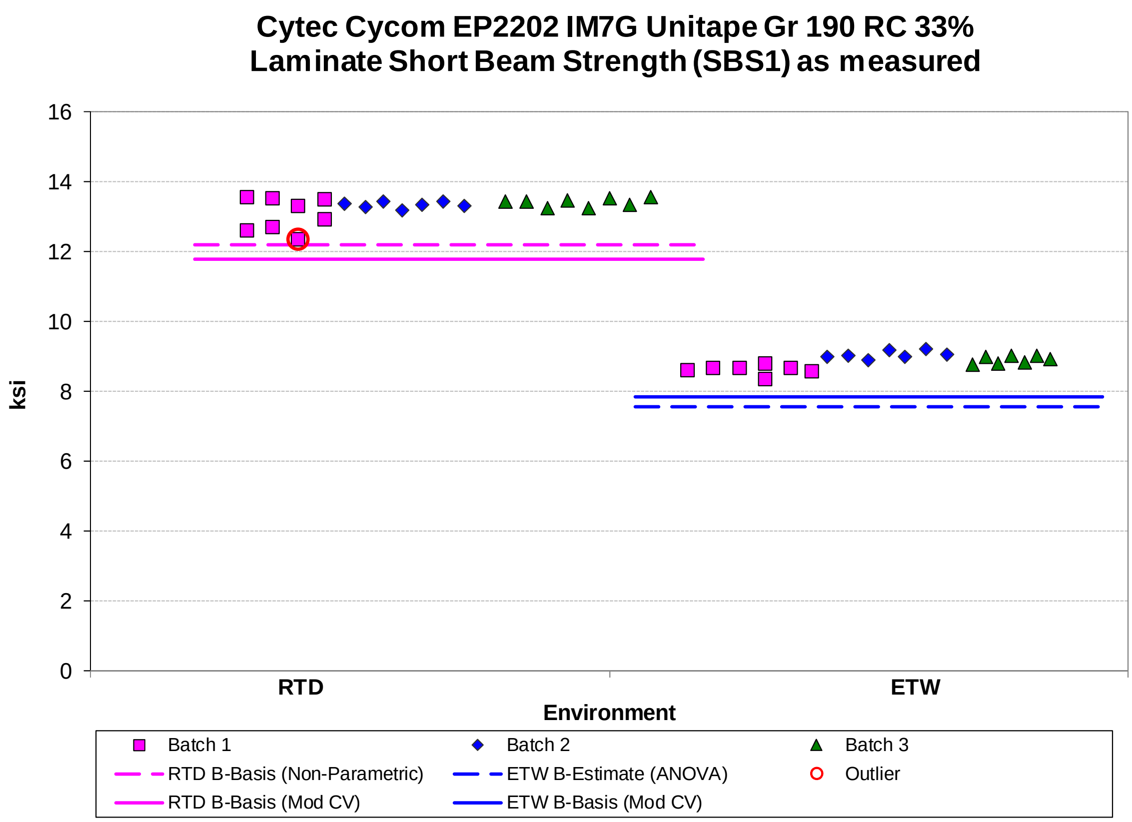


**Figure 4-14: Batch plot for SBS1 strength as-measured**

| Laminate Short Beam Shear Properties (SBS1) Strength (ksi) | | |
|---|---|---|
| | As-measured | |
| Env | RTD | ETW |
| Mean | 13.273 | 8.868 |
| Stdev | 0.320 | 0.214 |
| CV | 2.408 | 2.410 |
| Modified CV | 6.000 | 6.000 |
| Min | 12.355 | 8.365 |
| Max | 13.584 | 9.229 |
| No. Batches | 3 | 3 |
| No. Spec. | 23 | 21 |
| Basis Values and Estimates | | |
| B-basis Value | 12.219 | |
| B-estimate | | 7.557 |
| A-estimate | 11.011 | 6.621 |
| Method | Non-Parametric | ANOVA |
| Modified CV Basis Values and Estimates | | |
| B-basis Value | 11.784 | 7.854 |
| A-estimate | 10.720 | 7.132 |
| Method | normal | normal |

**Table 4-26: Statistics and Basis Values for SBS1 Strength data**

## 4.15 "25/50/25" Open-Hole Tension 1 (OHT1)

The as-measured CTD dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across all three environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. The normalized CTD dataset failed the tests for the normal, Weibull and lognormal distributions, but the non-parametric method could be used to compute basis values. The RTD and ETW conditions could be pooled to compute basis values, and all three conditions could be pooled to compute the modified CV basis values.

There was one outlier. The highest specimen value in batch three of the CTD dataset was an outlier for the CTD condition but not for batch three. It was an outlier for both the normalized and the as-measured datasets. It was retained for this analysis.

Statistics, basis values and estimates are given for OHT1 strength data in Table 4-27. The normalized data, B-basis values and B-estimates are shown graphically in Figure 4-15.

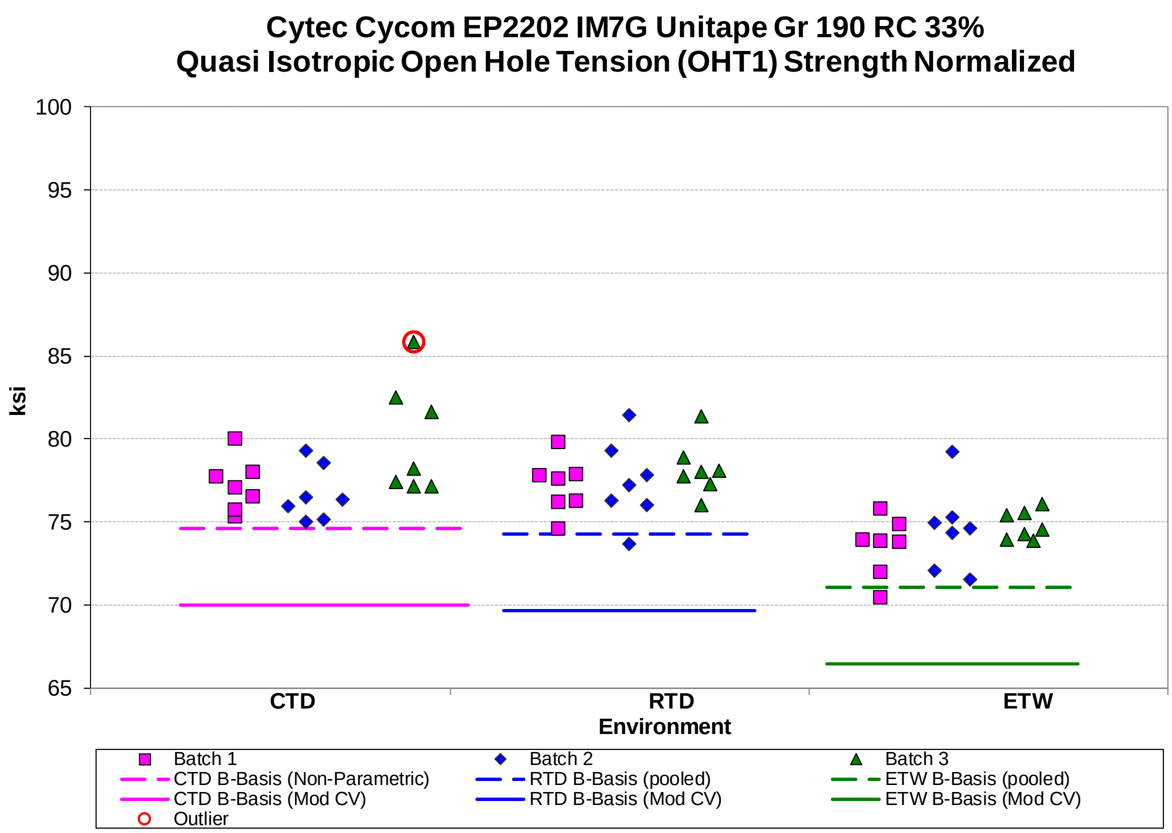


**Figure 4-15: Batch Plot for OHT1 strength normalized**

| Open Hole Tension (OHT1) Strength Basis Values and Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 77.970 | 77.592 | 74.391 | 78.519 | 78.130 | 75.047 |
| Stdev | 2.687 | 1.929 | 1.835 | 2.811 | 2.012 | 1.880 |
| CV | 3.446 | 2.487 | 2.467 | 3.580 | 2.576 | 2.505 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 75.033 | 73.677 | 70.457 | 74.524 | 73.496 | 71.221 |
| Max | 85.857 | 81.418 | 79.207 | 86.382 | 81.978 | 78.627 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 22 | 21 | 21 | 22 |
| Basis Values and Estimates | | | | | | |
| B-basis Value | 74.583 | 74.260 | 71.073 | | 74.685 | 71.616 |
| B-estimate | | | | 65.566 | | |
| A-estimate | 62.881 | 71.973 | 68.782 | 56.320 | 72.321 | 69.248 |
| Method | Non-Parametric | pooled | pooled | ANOVA | pooled | pooled |
| Modified CV Basis Values and Estimates | | | | | | |
| B-basis Value | 70.025 | 69.647 | 66.480 | 70.513 | 70.125 | 67.076 |
| A-estimate | 64.665 | 64.287 | 61.114 | 65.112 | 64.724 | 61.669 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled |

Table 4-27: Statistics and Basis Values for OHT1 Strength data

## 4.16 "10/80/10" Open-Hole Tension 2 (OHT2)

The normalized CTD dataset, the as-measured RTD and the ETW datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When the datasets were transformed according to the assumptions of the modified CV method, they passed the ADK test, so the modified CV basis values are provided. Pooling was not acceptable for computing the modified CV basis values.

There were two outliers. The highest value in batch three of the CTD dataset is an outlier for batch three but not for the CTD condition. The lowest value in batch two of ETW dataset was an outlier for batch two but not for the ETW condition. Both were outliers for their respective batches in both the normalized and the as-measured datasets. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for OHT2 strength data in Table 4-28. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-16.

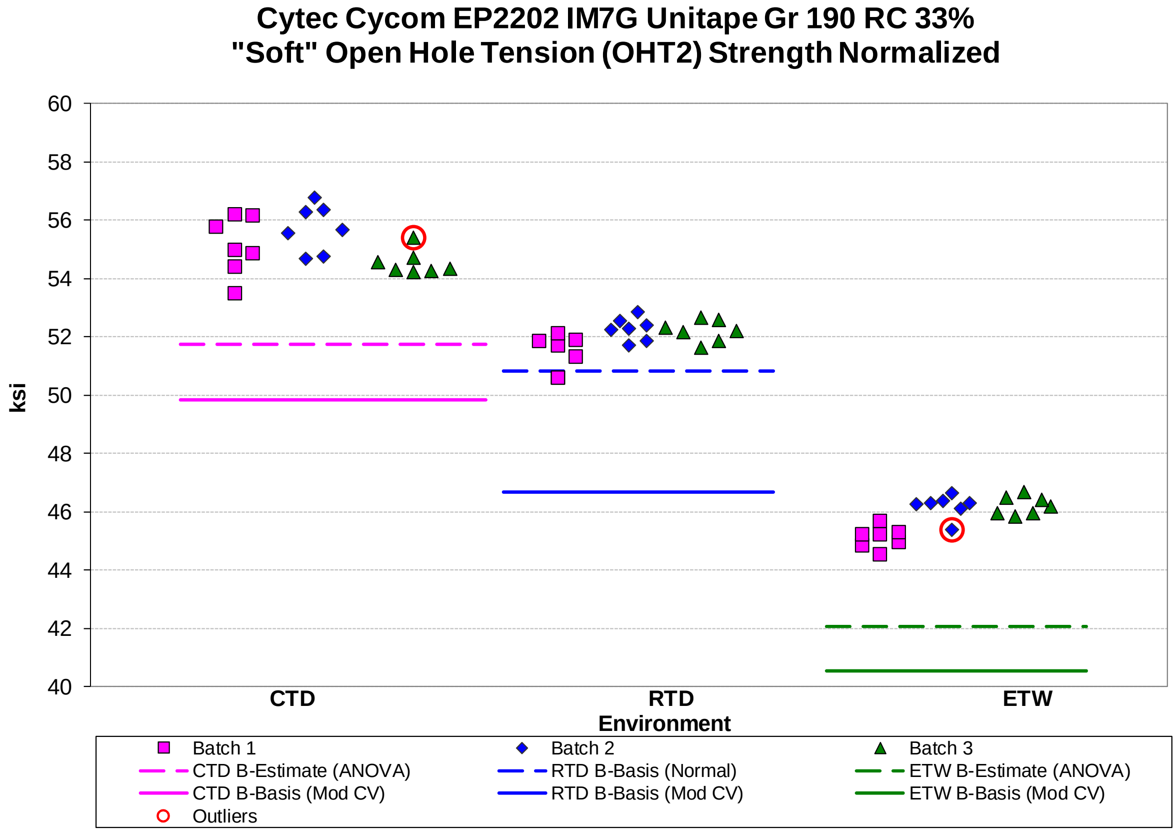


**Figure 4-16: Batch Plot for OHT2 strength normalized**

| Open Hole Tension (OHT2) Strength Basis Values and Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 55.137 | 51.976 | 45.847 | 55.456 | 52.241 | 46.091 |
| Stdev | 0.885 | 0.591 | 0.627 | 0.930 | 0.764 | 0.672 |
| CV | 1.605 | 1.138 | 1.368 | 1.677 | 1.463 | 1.458 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 53.486 | 50.602 | 44.565 | 54.284 | 50.449 | 44.357 |
| Max | 56.785 | 52.843 | 46.677 | 57.245 | 53.285 | 47.346 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 | 21 | 21 |
| Basis Values and Estimates | | | | | | |
| B-basis Value | | 50.850 | | 54.096 | | |
| B-estimate | 51.758 | | 42.055 | | 48.598 | 42.339 |
| A-estimate | 49.347 | 50.047 | 39.348 | 50.634 | 45.999 | 39.661 |
| Method | ANOVA | Normal | ANOVA | Non-Parametric | ANOVA | ANOVA |
| Modified CV Basis Values and Estimates | | | | | | |
| B-basis Value | 49.831 | 46.670 | 40.541 | 50.121 | 46.906 | 40.756 |
| A-estimate | 46.249 | 43.088 | 36.959 | 46.520 | 43.305 | 37.155 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled |

**Table 4-28: Statistics and Basis Values for OHT2 Strength data**

## 4.17 "50/40/10" Open-Hole Tension 3 (OHT3)

All of the OHT3 datasets, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When the OHT3 datasets were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. Pooling was not acceptable for computing the modified CV basis values.

There was one outlier. The lowest value in batch three of the ETW as-measured dataset was an outlier for batch three but not for the ETW condition. It was not an outlier for the normalized dataset. It was retained for this analysis.

Statistics, basis values and estimates are given for OHT3 strength data in Table 4-29. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-17.

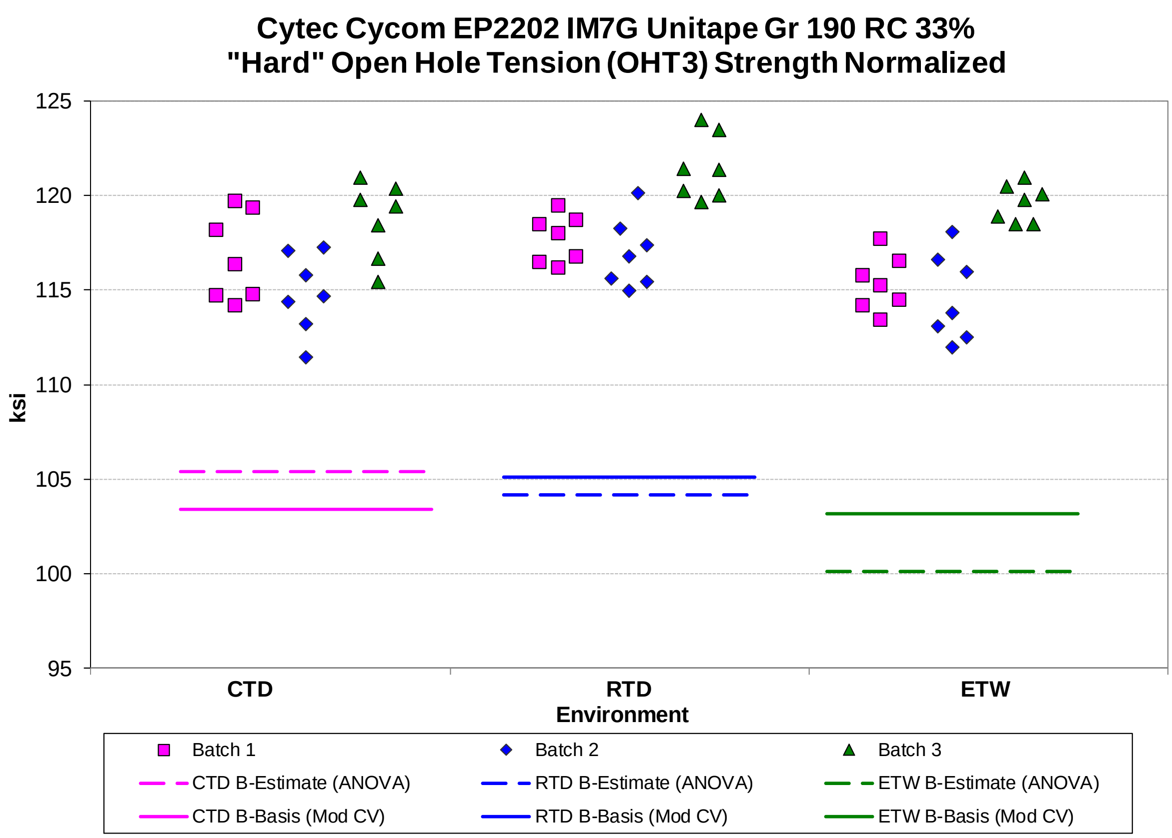


**Figure 4-17: Batch Plot for OHT3 strength normalized**

| Open Hole Tension (OHT3) Strength (ksi) Basis Values and Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 116.767 | 118.698 | 116.507 | 116.554 | 118.769 | 116.830 |
| Stdev | 2.599 | 2.524 | 2.772 | 3.253 | 3.182 | 3.258 |
| CV | 2.226 | 2.126 | 2.379 | 2.791 | 2.679 | 2.788 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 111.462 | 114.991 | 111.950 | 110.756 | 112.734 | 110.872 |
| Max | 120.933 | 123.971 | 120.932 | 121.553 | 124.516 | 121.423 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 | 21 | 21 |
| Basis Value Estimates | | | | | | |
| B-estimate | 105.390 | 104.186 | 100.121 | 98.682 | 98.298 | 96.823 |
| A-estimate | 97.269 | 93.827 | 88.424 | 85.923 | 83.682 | 82.539 |
| Method | ANOVA | ANOVA | ANOVA | ANOVA | ANOVA | ANOVA |
| Modified CV Basis Values and Estimates | | | | | | |
| B-basis Value | 103.417 | 105.127 | 103.186 | 103.228 | 105.190 | 103.472 |
| A-estimate | 93.907 | 95.459 | 93.697 | 93.735 | 95.517 | 93.957 |
| Method | normal | normal | normal | normal | normal | normal |

**Table 4-29: Statistics and Basis Values for OHT3 Strength data**

## 4.18 "25/50/25" Filled-Hole Tension 1 (FHT1)

With the exception of the CTD normalized dataset, all of the remaining FHT1 datasets, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When the FHT1 datasets were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable for computing the modified CV basis values.

There was one outlier. The lowest value in batch one of the RTD condition was an outlier. It was an outlier for batch one but not for the RTD condition in the as-measured dataset. It was an outlier for the RTD condition but not batch one in the normalized dataset. It was retained for this analysis.

Statistics, estimates and basis values are given for FHT1 strength data in Table 4-30. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-18 .

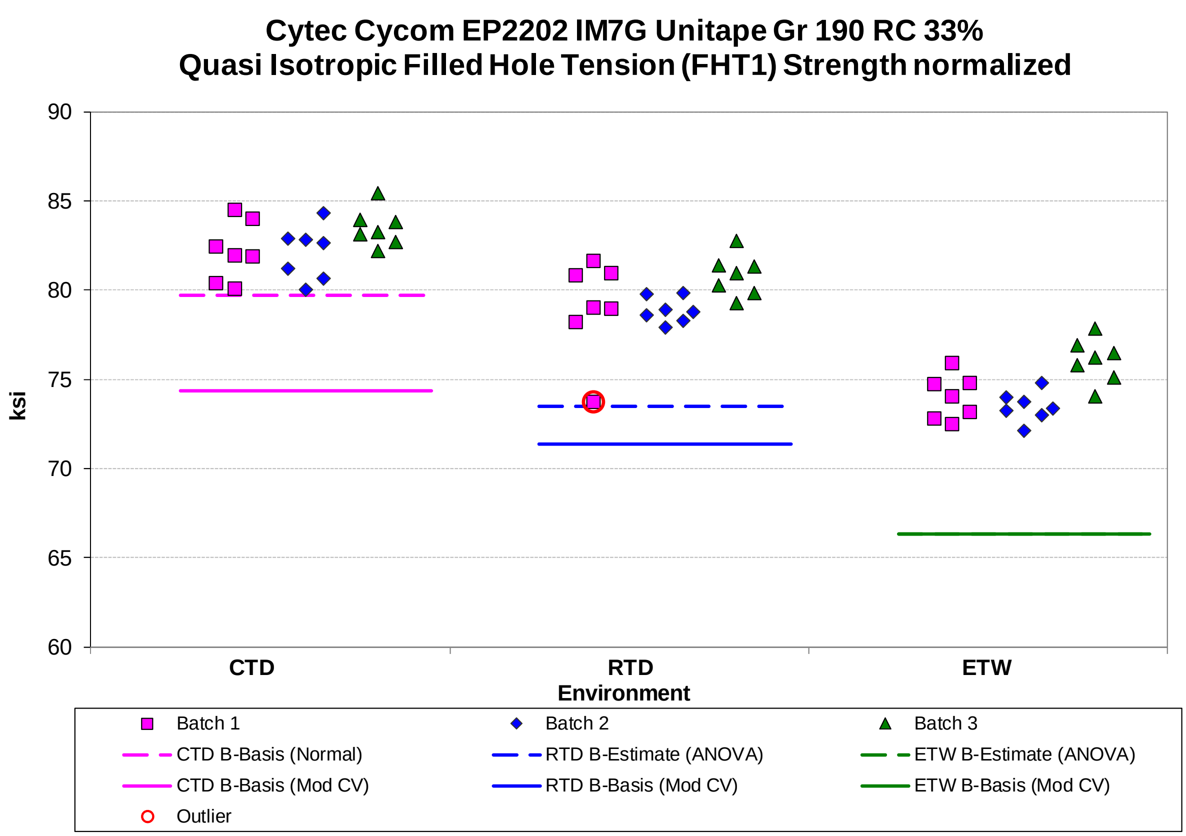


**Figure 4-18: Batch plot for FHT1 strength normalized**

| Filled-Hole Tension (FHT1) Strength Basis Values and Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 82.585 | 79.588 | 74.510 | 82.789 | 79.673 | 74.880 |
| Stdev | 1.506 | 1.866 | 1.563 | 2.195 | 2.458 | 2.098 |
| CV | 1.823 | 2.344 | 2.097 | 2.651 | 3.085 | 2.802 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 79.999 | 73.768 | 72.143 | 78.067 | 75.226 | 71.287 |
| Max | 85.417 | 82.769 | 77.821 | 85.599 | 83.567 | 78.479 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 | 21 | 21 |
| Basis Values and Estimates | | | | | | |
| B-basis Value | 79.717 | | | | | |
| B-estimate | | 73.472 | 66.325 | 70.341 | 66.362 | 61.382 |
| A-estimate | 77.672 | 69.107 | 60.483 | 61.454 | 56.860 | 51.746 |
| Method | Normal | ANOVA | ANOVA | ANOVA | ANOVA | ANOVA |
| Modified CV Basis Values and Estimates | | | | | | |
| B-basis Value | 74.391 | 71.394 | 66.316 | 74.572 | 71.457 | 66.663 |
| A-estimate | 68.859 | 65.863 | 60.784 | 69.026 | 65.910 | 61.116 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled |

**Table 4-30: Statistics and Basis Values for FHT1 Strength data**

## 4.19 "10/80/10" Filled-Hole Tension 2 (FHT2)

The normalized ETW dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the ETW dataset was transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. There were no other diagnostic test failures and pooling was acceptable for computing basis values.

There was one outlier. The largest value in batch three of the ETW condition was an outlier for batch three but not for the ETW condition. It was an outlier for the normalized dataset but not in the as-measured datasets. It was retained for this analysis.

Statistics and basis values are given for FHT2 strength data in Table 4-31. The normalized data and the B-basis values are shown graphically in Figure 4-19.

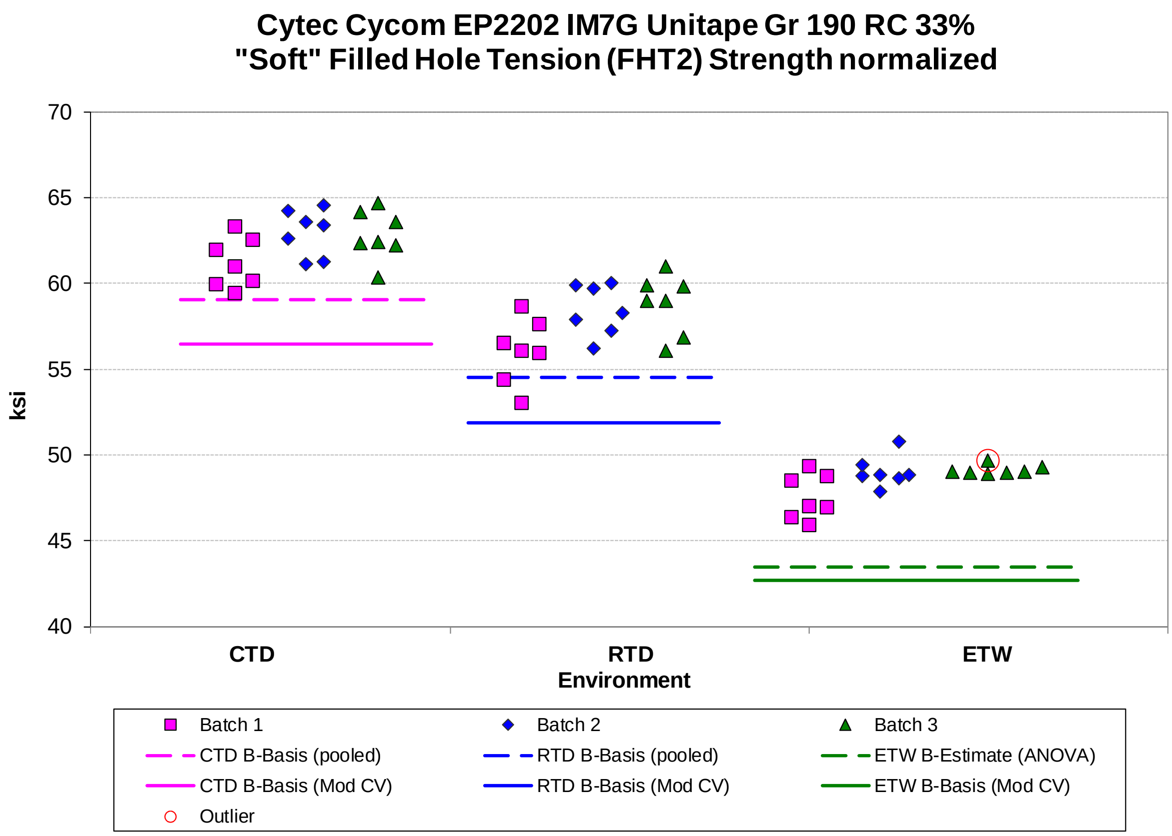


**Figure 4-19: Batch plot for FHT2 strength normalized**

| Filled-Hole Tension (FHT2) Strength Basis Values and Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 62.327 | 57.767 | 48.563 | 62.401 | 57.804 | 48.736 |
| Stdev | 1.572 | 2.054 | 1.142 | 1.600 | 1.870 | 1.001 |
| CV | 2.522 | 3.555 | 2.352 | 2.565 | 3.235 | 2.054 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 59.447 | 53.017 | 45.953 | 59.087 | 54.241 | 46.686 |
| Max | 64.673 | 60.963 | 50.795 | 65.584 | 61.130 | 49.962 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 | 21 | 21 |
| Basis Values and Estimates | | | | | | |
| B-basis Value | 59.083 | 54.523 | | 59.747 | 55.150 | 46.083 |
| B-estimate | | | 43.454 | | | |
| A-estimate | 56.854 | 52.294 | 39.808 | 57.956 | 53.359 | 44.292 |
| Method | pooled | pooled | ANOVA | pooled | pooled | pooled |
| Modified CV Basis Values and Estimates | | | | | | |
| B-basis Value | 56.463 | 51.903 | 42.699 | 56.527 | 51.930 | 42.863 |
| A-estimate | 52.505 | 47.945 | 38.740 | 52.563 | 47.965 | 38.898 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled |

**Table 4-31: Statistics and Basis Values for FHT2 Strength data**

## 4.20 "50/40/10" Filled-Hole Tension 3 (FHT3)

All of the FHT3 datasets, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When the FHT3 datasets were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable for computing the modified CV basis values.

There was one outlier. The lowest value in batch two of the ETW condition was an outlier for batch two but not for the ETW condition. It was an outlier for both the normalized and as-measured datasets. It was retained for this analysis.

Statistics, estimates and basis values are given for FHT3 strength data in Table 4-32. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-20.

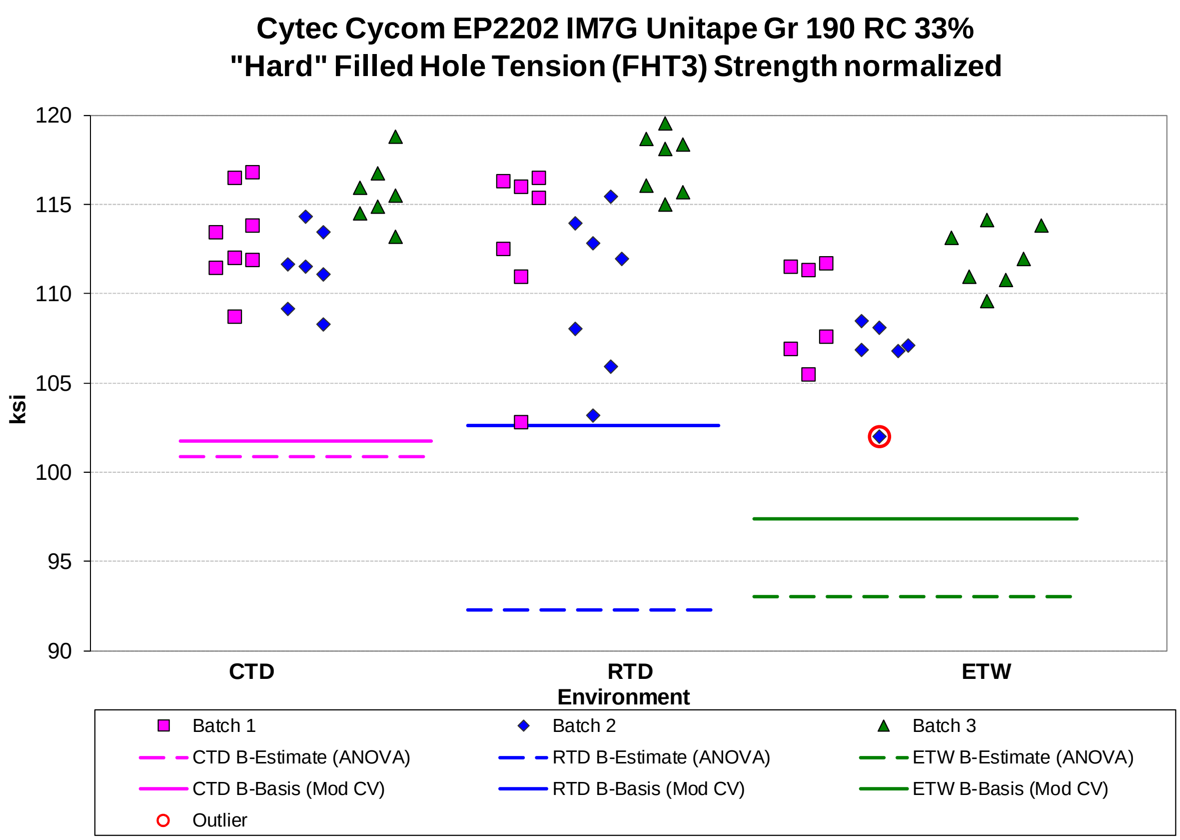


**Figure 4-20: Batch plot for FHT3 strength normalized**

| Filled-Hole Tension (FHT3) Strength Basis Values and Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Normalized | | | As-measured | | |
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 113.350 | 114.276 | 109.032 | 113.895 | 114.660 | 109.662 |
| Stdev | 2.786 | 4.349 | 3.334 | 3.669 | 5.240 | 3.880 |
| CV | 2.458 | 3.806 | 3.058 | 3.222 | 4.570 | 3.538 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.285 | 6.000 |
| Min | 108.288 | 103.163 | 101.982 | 107.147 | 102.699 | 101.046 |
| Max | 118.808 | 119.578 | 114.129 | 119.751 | 121.628 | 114.715 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 22 | 21 | 21 | 22 | 21 | 21 |
| Basis Values and Estimates | | | | | | |
| B-estimate | 100.877 | 92.280 | 93.045 | 92.786 | 83.079 | 88.404 |
| A-estimate | 91.971 | 76.578 | 81.632 | 77.715 | 60.532 | 73.228 |
| Method | ANOVA | ANOVA | ANOVA | ANOVA | ANOVA | ANOVA |
| Modified CV Basis Values and Estimates | | | | | | |
| B-basis Value | 101.761 | 102.637 | 97.393 | 102.061 | 102.776 | 97.778 |
| A-estimate | 93.899 | 94.785 | 89.541 | 94.035 | 94.758 | 89.760 |
| Method | pooled | pooled | pooled | pooled | pooled | pooled |

**Table 4-32: Statistics and Basis Values for FHT3 Strength data**

## 4.21 "25/50/25" Open-Hole Compression 1 (OHC1)

The as-measured datasets, both RTD and ETW, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the as-measured datasets were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. There were no other diagnostic test failures. Pooling the two conditions was acceptable. There were no outliers.

Statistics, estimates and basis values are given for OHC1 strength data in Table 4-33. The normalized data and the B-basis values are shown graphically in Figure 4-21.

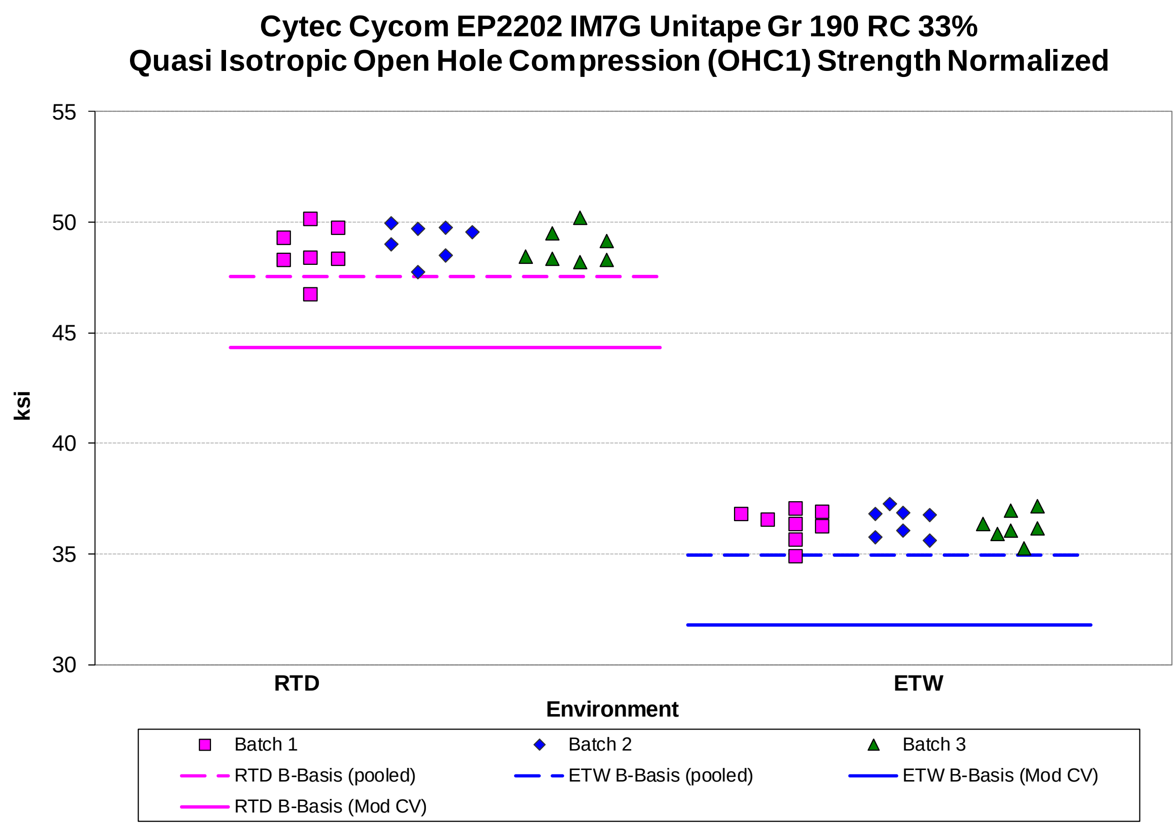


**Figure 4-21: Batch plot for OHC1 strength normalized**

| Open Hole Compression (OHC1) Strength Basis Values and Statistics | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 48.922 | 36.343 | 49.049 | 36.426 |
| Stdev | 0.894 | 0.638 | 1.167 | 0.946 |
| CV | 1.827 | 1.755 | 2.379 | 2.596 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 46.723 | 34.928 | 47.009 | 34.773 |
| Max | 50.194 | 37.253 | 51.238 | 37.901 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 22 | 21 | 22 |
| Basis Values and Estimates | | | | |
| B-basis Value | 47.553 | 34.979 | | |
| B-estimate | | | 43.751 | 31.425 |
| A-estimate | 46.613 | 34.038 | 39.970 | 27.854 |
| Method | pooled | pooled | ANOVA | ANOVA |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 44.360 | 31.800 | 44.476 | 31.871 |
| A-estimate | 41.229 | 28.664 | 41.337 | 28.728 |
| Method | pooled | pooled | pooled | pooled |

**Table 4-33: Statistics and Basis Values for OHC1 Strength data**

## 4.22 "10/80/10" Open-Hole Compression 2 (OHC2)

The normalized datasets, both RTD and ETW, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the normalized datasets were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. There were no other diagnostic test failures. Pooling the two conditions was acceptable. There were no outliers.

Statistics, estimates and basis values are given for OHC2 strength data in Table 4-34. The normalized data and the B-basis values are shown graphically in Figure 4-22.

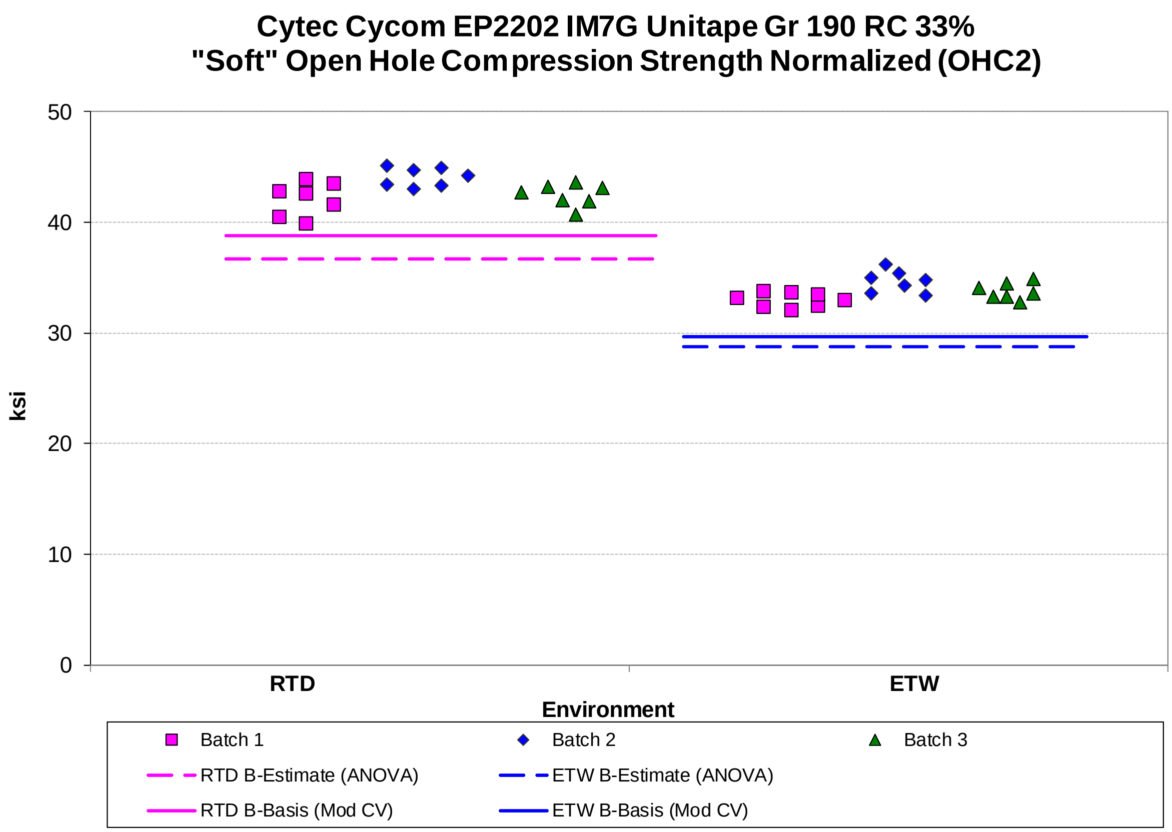


**Figure 4-22: Batch plot for OHC2 strength normalized**

| Open-Hole Compression (OHC2) Strength Basis Values and Statistics | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 42.898 | 33.782 | 43.024 | 33.913 |
| Stdev | 1.412 | 1.041 | 1.101 | 0.836 |
| CV | 3.291 | 3.081 | 2.558 | 2.464 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 39.881 | 32.054 | 40.490 | 32.564 |
| Max | 45.114 | 36.236 | 44.743 | 35.817 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 22 | 21 | 22 |
| Basis Values and Estimates | | | | |
| B-basis Value | | | 41.300 | 32.195 |
| B-estimate | 36.719 | 28.812 | | |
| A-estimate | 32.308 | 25.263 | 40.116 | 31.010 |
| Method | ANOVA | ANOVA | pooled | pooled |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 38.808 | 29.709 | 38.921 | 29.826 |
| A-estimate | 36.001 | 26.898 | 36.104 | 27.005 |
| Method | pooled | pooled | pooled | pooled |

**Table 4-34: Statistics and Basis Values for OHC2 Strength data**

## 4.23 "50/40/10" Open-Hole Compression 3 (OHC3)

The normalized ETW dataset failed all distribution tests, so the non-parametric method was used to compute basis values. The as-measured datasets, both RTD and ETW, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the as-measured datasets were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. Pooling the two conditions was acceptable. There were no outliers.

Statistics, estimates and basis values are given for OHC3 strength data in Table 4-35. The normalized data and the B-basis values are shown graphically in Figure 4-23.

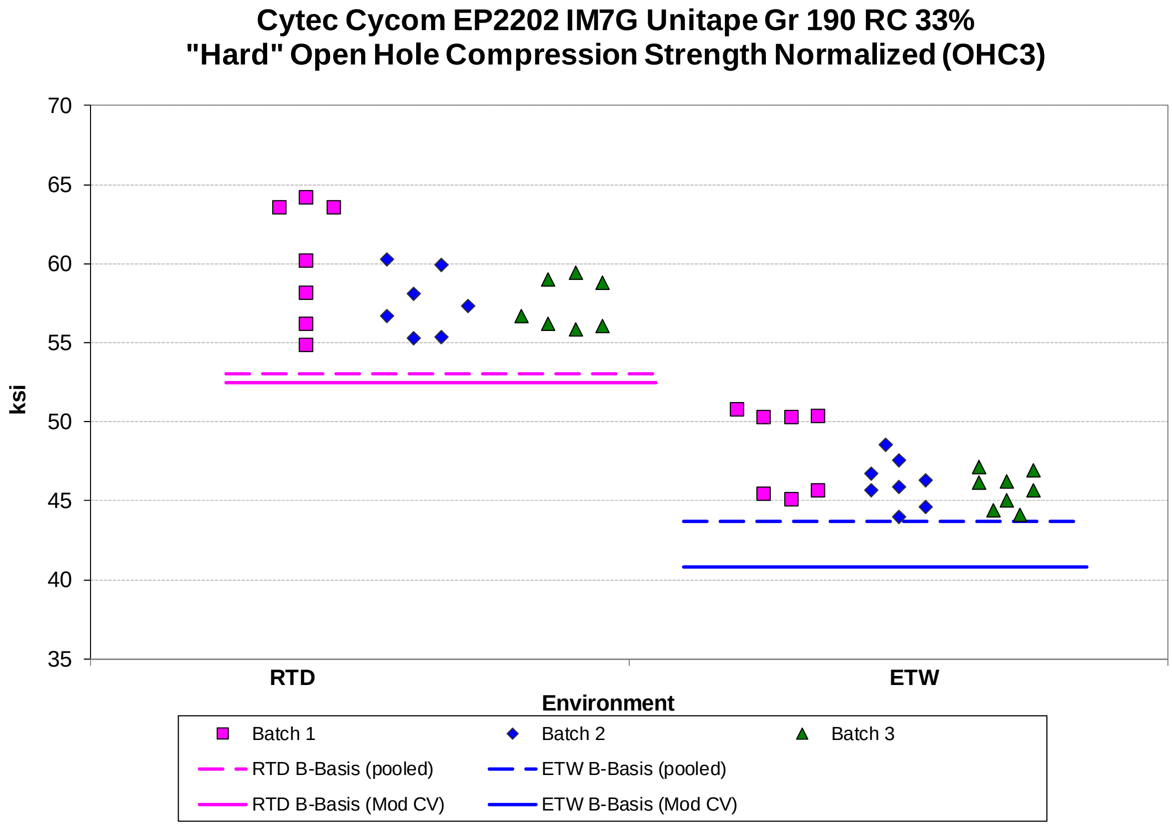


**Figure 4-23: Batch plot for OHC3 strength normalized**

| Open-Hole Compression (OHC3) Strength Basis Values and Statistics | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 58.359 | 46.650 | 58.520 | 46.736 |
| Stdev | 2.806 | 2.088 | 3.440 | 2.480 |
| CV | 4.808 | 4.475 | 5.878 | 5.306 |
| Modified CV | 6.404 | 6.238 | 6.939 | 6.653 |
| Min | 54.874 | 43.960 | 53.614 | 43.063 |
| Max | 64.175 | 50.758 | 65.625 | 51.685 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 23 | 21 | 23 |
| Basis Values and Estimates | | | | |
| B-basis Value | 53.014 | 43.689 | | |
| | | | 42.515 | 33.332 |
| A-estimate | 49.203 | 36.922 | 31.091 | 23.760 |
| Method | Normal | Non-Parametric | ANOVA | ANOVA |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 52.474 | 40.810 | 52.168 | 40.433 |
| A-estimate | 48.439 | 36.765 | 47.812 | 36.066 |
| Method | pooled | pooled | pooled | pooled |

**Table 4-35: Statistics and Basis Values for OHC3 Strength data**

## 4.24 "25/50/25" Filled-Hole Compression 1 (FHC1)

The normalized RTD dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the RTD dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test, so the modified CV basis values are provided.

There were no outliers.

Statistics, estimates and basis values are given for FHC1 strength data in Table 4-36. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-24.

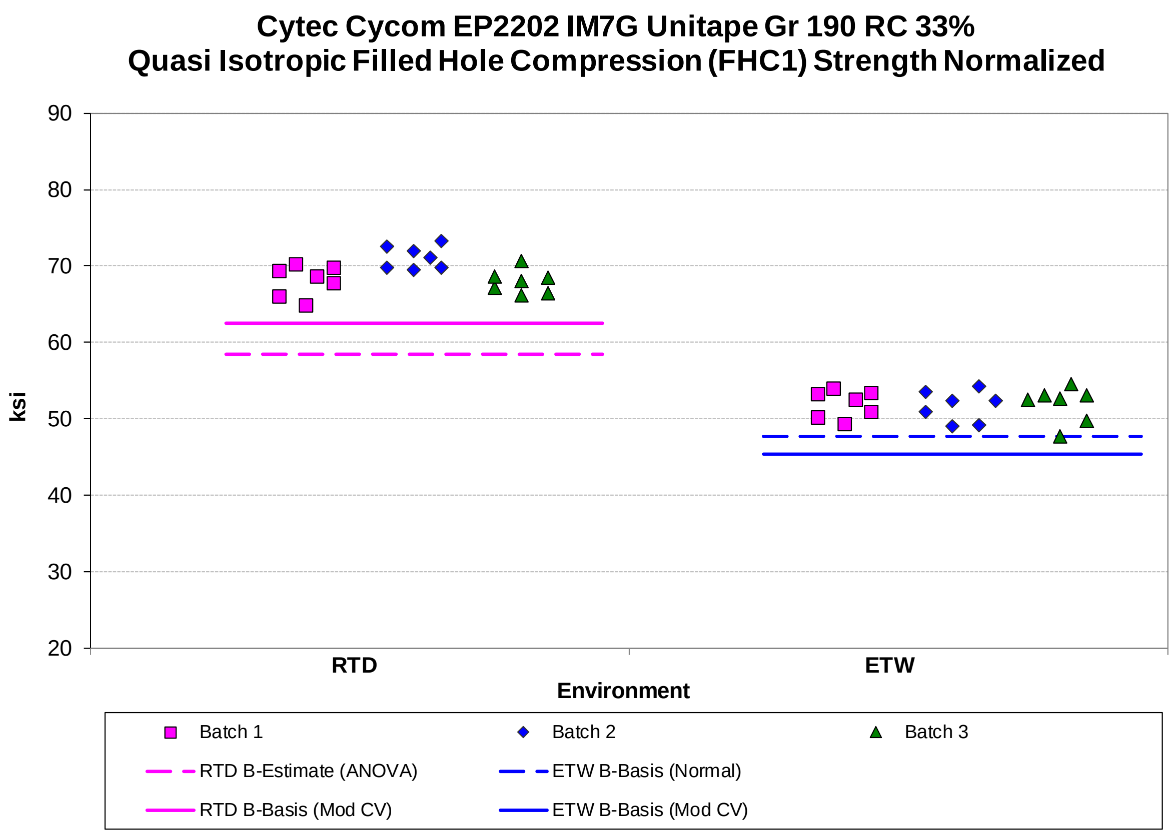


**Figure 4-24: Batch plot for FHC1 strength normalized**

| Filled-Hole Compression (FHC1) Strength Basis Values and Statistics | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 69.032 | 51.831 | 69.210 | 52.075 |
| Stdev | 2.195 | 1.971 | 1.721 | 2.143 |
| CV | 3.180 | 3.803 | 2.487 | 4.115 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.057 |
| Min | 64.814 | 47.705 | 66.455 | 48.081 |
| Max | 73.196 | 54.545 | 71.648 | 55.144 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 |
| Basis Values and Estimates | | | | |
| B-basis Value | | 47.707 | 65.763 | 48.627 |
| B-estimate | 58.412 | | | |
| A-estimate | 50.831 | 43.310 | 63.394 | 46.258 |
| Method | ANOVA | Weibull | pooled | pooled |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 62.536 | 45.335 | 62.669 | 45.534 |
| A-estimate | 58.071 | 40.870 | 58.174 | 41.039 |
| Method | pooled | pooled | pooled | pooled |

Table 4-36: Statistics and Basis Values for FHC1 Strength data

## 4.25 "10/80/10" Filled-Hole Compression 2 (FHC2)

The pooled dataset failed Levene's test but passed with the use of the modified CV transformation, so pooling was acceptable to compute the modified CV basis values.

There was one outlier. The lowest value in batch three of the ETW condition was an outlier for batch three but not for the ETW condition. It was an outlier for both the normalized and the as-measured datasets. It was retained for this analysis.

Statistics, estimates and basis values are given for FHC2 strength data in Table 4-37. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-25.

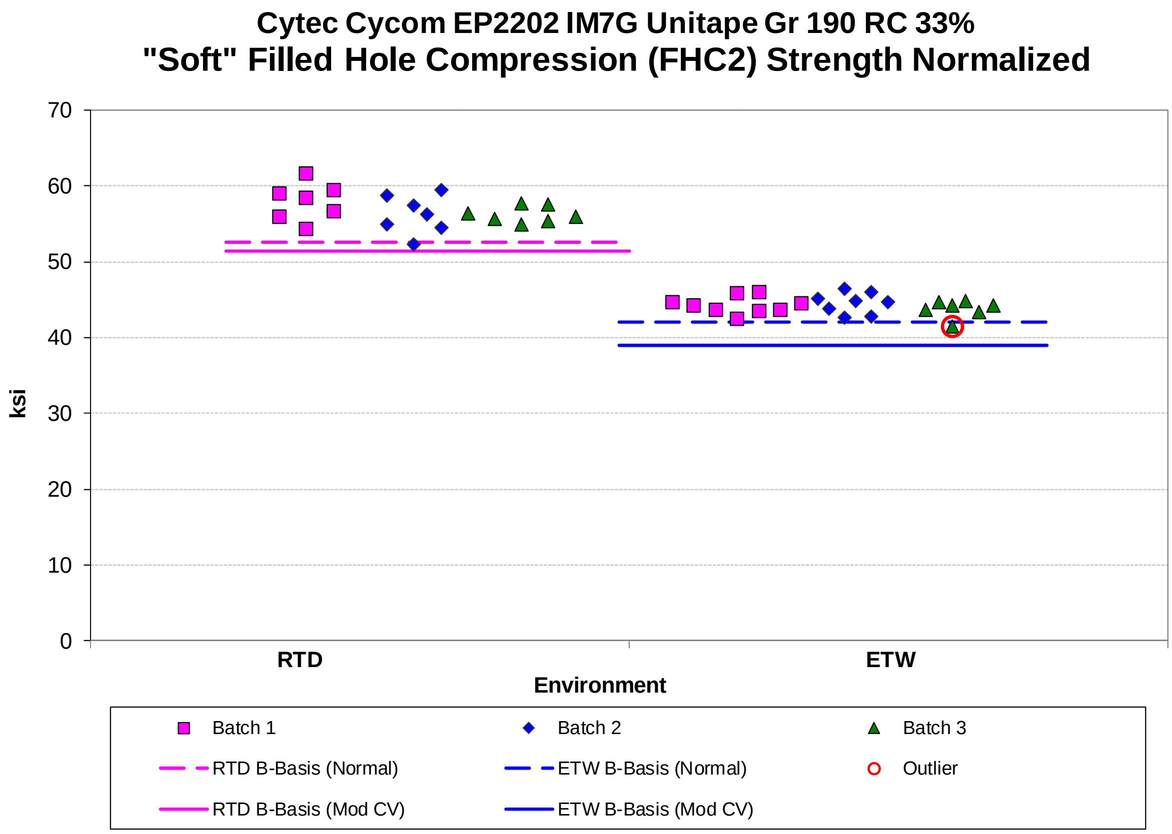


**Figure 4-25: Batch plot for FHC2 strength normalized**

| Filled-Hole Compression (FHC2) Strength Basis Values and Statistics | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 56.774 | 44.209 | 57.001 | 44.383 |
| Stdev | 2.194 | 1.205 | 2.413 | 1.343 |
| CV | 3.864 | 2.726 | 4.234 | 3.026 |
| Modified CV | 6.000 | 6.000 | 6.117 | 6.000 |
| Min | 52.196 | 41.445 | 51.979 | 41.570 |
| Max | 61.638 | 46.401 | 62.389 | 46.694 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 24 | 21 | 24 |
| Basis Values and Estimates | | | | |
| B-basis Value | 52.595 | 41.977 | 52.404 | 41.896 |
| A-estimate | 49.615 | 40.377 | 49.126 | 40.112 |
| Method | Normal | Normal | Normal | Normal |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 51.434 | 38.928 | 51.578 | 39.020 |
| A-estimate | 47.776 | 35.257 | 47.863 | 35.292 |
| Method | pooled | pooled | pooled | pooled |

**Table 4-37: Statistics and Basis Values for FHC2 Strength data**

## 4.26 "50/40/10" Filled-Hole Compression 3 (FHC3)

There were no outliers. The pooled dataset failed Levene's test but passed with the use of the modified CV transformation, so pooling was acceptable to compute the modified CV basis values.

Statistics, estimates and basis values are given for FHC3 strength data in Table 4-38. The normalized data and the B-basis values are shown graphically in Figure 4-26.

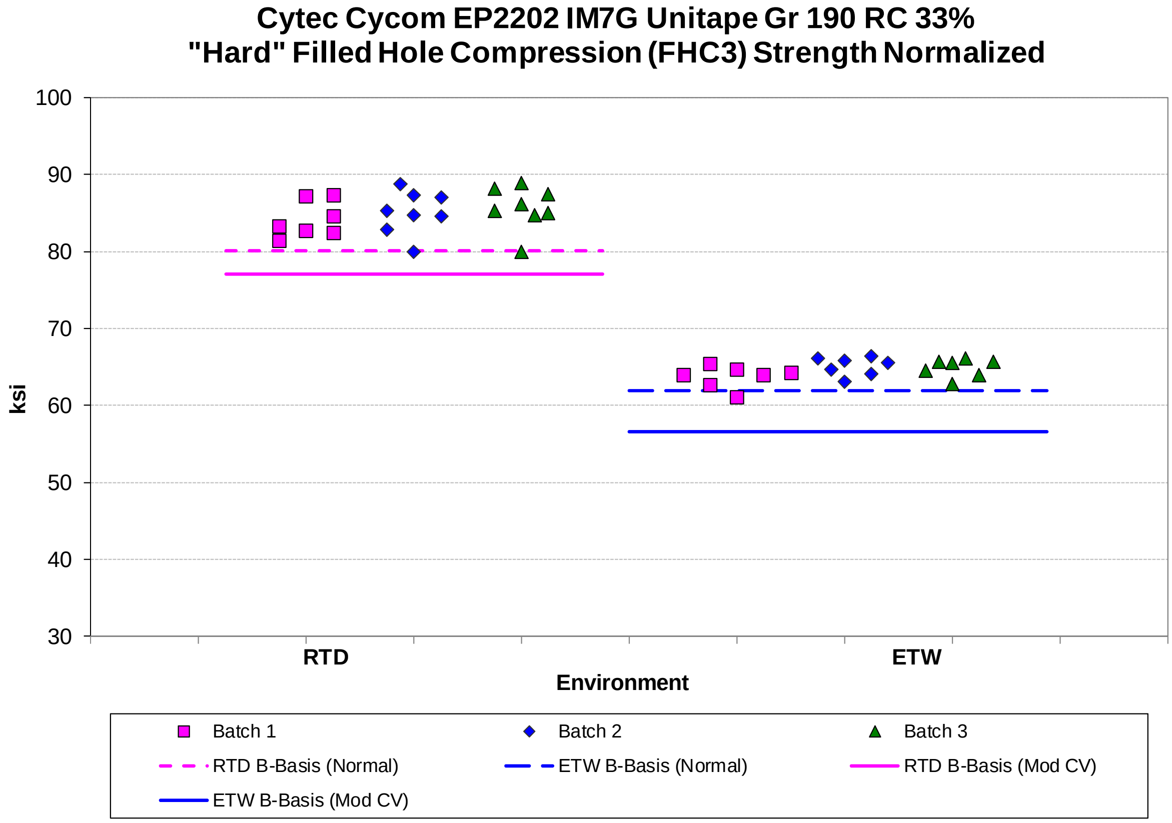


**Figure 4-26: Batch plot for FHC3 strength normalized**

| Filled-Hole Compression (FHC3) Strength Basis Values and Statistics | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 85.006 | 64.591 | 85.503 | 65.067 |
| Stdev | 2.598 | 1.377 | 2.978 | 1.430 |
| CV | 3.056 | 2.132 | 3.483 | 2.198 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 80.011 | 61.124 | 77.902 | 62.387 |
| Max | 88.866 | 66.449 | 89.938 | 67.448 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 23 | 21 | 23 | 21 |
| Basis Values and Estimates | | | | |
| B-basis Value | 80.151 | 61.968 | 79.940 | 62.342 |
| A-estimate | 76.677 | 60.097 | 75.959 | 60.400 |
| Method | Normal | Normal | Normal | Normal |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 77.012 | 56.535 | 77.458 | 56.959 |
| A-estimate | 71.473 | 51.010 | 71.884 | 51.399 |
| Method | pooled | pooled | pooled | pooled |

**Table 4-38: Statistics and Basis Values for FHC3 Strength data**

## 4.27 "25/50/25" Single-Shear Bearing 1 (SSB1)

The as-measured ultimate strength ETW failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the ETW dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test, so the modified CV basis values are provided. The normalized ultimate strength dataset failed Levene's test for equality of variance between the RTD and ETW conditions, so pooling was not acceptable. However, it passed Levene's test after the modified CV transformation was applied, so pooling was acceptable for the modified CV basis values.

The as-measured 2% offset strength RTD and ETW pooled datasets failed the normality test, so pooling was not appropriate for that property. The normalized 2% offset strength datasets passed the normality test so pooling was acceptable, but failed the normality test after the modified CV transformation, so pooling was not used to compute the modified CV basis values.

There were no outliers.

Statistics, estimates and basis values are given for the 2% offset strength data in Table 4-39 and the Ultimate Strength data in Table 4-40. The normalized data and the B-basis values are shown graphically in Figure 4-27.

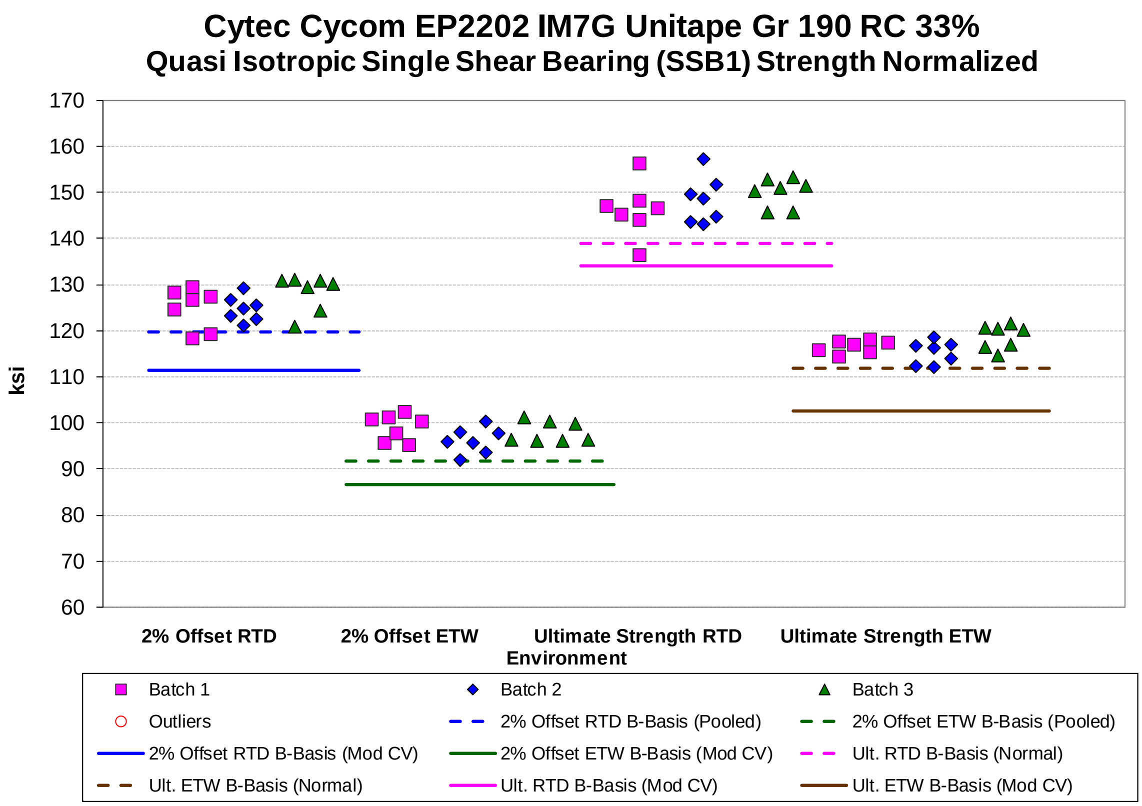


**Figure 4-27: Batch plot for SSB1 strength normalized**

| Single Shear Bearing (SSB1) Strength Basis Values and Statistics for 2% Offset Strength | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 125.894 | 97.740 | 126.055 | 98.214 |
| Stdev | 3.935 | 2.823 | 3.906 | 3.364 |
| CV | 3.126 | 2.888 | 3.098 | 3.425 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 118.393 | 91.971 | 119.693 | 92.024 |
| Max | 131.017 | 102.413 | 131.762 | 104.238 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 |
| Basis Values and Estimates | | | | |
| B-basis Value | 119.821 | 91.666 | 118.614 | |
| B-estimate | | | | 81.027 |
| A-estimate | 115.646 | 87.492 | 113.310 | 68.758 |
| Method | pooled | pooled | Normal | ANOVA |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 111.500 | 86.565 | 111.642 | 86.985 |
| A-estimate | 101.247 | 78.605 | 101.376 | 78.986 |
| Method | normal | normal | normal | normal |

**Table 4-39: Statistics and Basis Values for SSB1 2% Offset Strength data**

| Single Shear Bearing (SSB1) Strength Basis Values and Statistics for Ultimate Strength | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 148.180 | 116.818 | 148.363 | 117.368 |
| Stdev | 4.899 | 2.581 | 4.728 | 2.682 |
| CV | 3.306 | 2.209 | 3.186 | 2.285 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 136.264 | 112.052 | 139.845 | 111.971 |
| Max | 157.306 | 121.481 | 160.066 | 121.079 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 |
| Basis Values and Estimates | | | | |
| B-basis Value | 138.846 | 111.902 | 139.358 | |
| B-estimate | | | | 104.162 |
| A-estimate | 132.192 | 108.397 | 132.937 | 94.735 |
| Method | Normal | Normal | Normal | ANOVA |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 133.980 | 102.618 | 134.127 | 103.132 |
| A-estimate | 124.221 | 92.859 | 124.343 | 93.348 |
| Method | pooled | pooled | pooled | pooled |

**Table 4-40: Statistics and Basis Values for SSB1 Ultimate Strength data**

## 4.28 "10/80/10" Single-Shear Bearing 2 (SSB2)

The 2% offset strength ETW datasets, both normalized and as-measured, and the ultimate strength RTD as-measured dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these datasets were transformed according to the assumptions of the modified CV method, they passed the ADK test, so the modified CV basis values are provided. Pooling was not acceptable for the ultimate strength as-measured datasets due to the pooled data failing the normality test.

There were four outliers, one in each of the four datasets. The largest values in batch three of the ultimate strength datasets, both RTD and ETW, and the largest value in batch one of the 2% offset strength ETW dataset were outliers for their respective batches but not their respective conditions. The largest value in batch two of the 2% offset strength RTD dataset was an outlier for the RTD dataset but not for batch two. All outliers were outliers for both the normalized and as-measured datasets. All four outliers were retained for this analysis.

Statistics, estimates and basis values are given for the 2% offset strength data in Table 4-41 and the Ultimate Strength data in Table 4-42. The normalized data and the B-basis values are shown graphically in Figure 4-28.

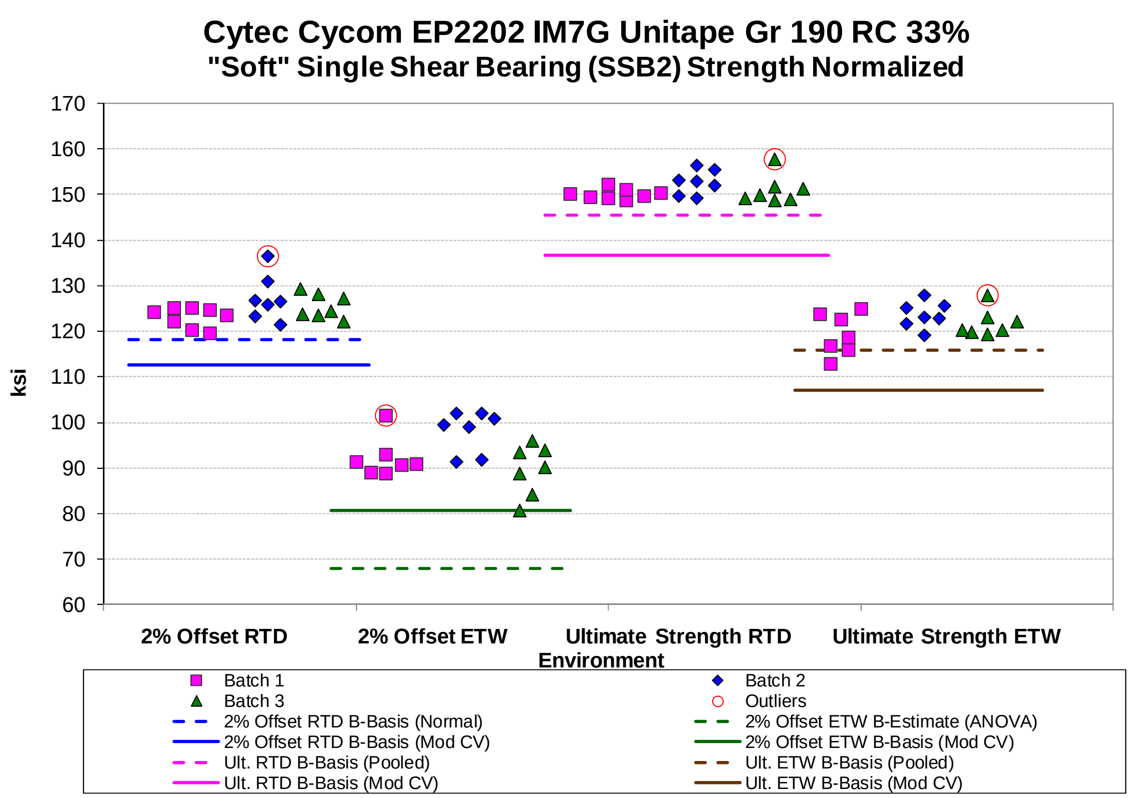


**Figure 4-28: Batch plot for SSB2 strength normalized**

| Single Shear Bearing (SSB2) Strength Basis Values and Statistics for 2% Offset Strength | | | | |
|---|---|---|---|---|
| 2% Offset Strength | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 125.181 | 93.289 | 126.066 | 93.874 |
| Stdev | 3.745 | 5.824 | 3.631 | 6.126 |
| CV | 2.992 | 6.243 | 2.880 | 6.525 |
| Modified CV | 6.000 | 7.121 | 6.000 | 7.263 |
| Min | 119.471 | 80.802 | 121.668 | 80.774 |
| Max | 136.337 | 102.055 | 137.707 | 103.312 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 22 | 21 | 22 | 21 |
| Basis Values and Estimates | | | | |
| B-basis Value | 118.118 | | 119.474 | |
| B-estimate | | 67.886 | | 63.989 |
| A-estimate | 113.074 | 49.755 | 115.009 | 42.657 |
| Method | Normal | ANOVA | LogNormal | ANOVA |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 112.659 | 80.717 | 113.352 | 81.109 |
| A-estimate | 104.017 | 72.086 | 104.578 | 72.347 |
| Method | pooled | pooled | pooled | pooled |

**Table 4-41: Statistics and Basis Values for SSB2 2% Offset Strength data**

| Single Shear Bearing (SSB2) Strength Basis Values and Statistics for Ultimate Strength | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 151.210 | 121.573 | 152.289 | 122.307 |
| Stdev | 2.535 | 3.801 | 2.864 | 3.595 |
| CV | 1.676 | 3.126 | 1.880 | 2.940 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 148.643 | 112.796 | 147.907 | 116.115 |
| Max | 157.670 | 127.908 | 157.899 | 128.192 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 22 | 21 | 22 | 21 |
| Basis Values and Estimates | | | | |
| B-basis Value | 145.540 | 115.880 | | 115.458 |
| B-estimate | | | 140.776 | |
| A-estimate | 141.627 | 111.972 | 132.555 | 110.575 |
| Method | pooled | pooled | ANOVA | Normal |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 136.656 | 106.961 | 135.051 | 108.323 |
| A-estimate | 126.612 | 96.930 | 122.745 | 98.362 |
| Method | pooled | pooled | normal | normal |

**Table 4-42: Statistics and Basis Values for SSB2 Ultimate Strength data**

## 4.29 "50/40/10" Single-Shear Bearing 3 (SSB3)

The only diagnostic test failure was the ultimate strength as-measured RTD and ETW datasets which failed Levene's test of equality of variance and could not be pooled. There was one outlier. The lowest value in batch one on the 2% offset strength RTD condition dataset was an outlier for batch one but not for the RTD condition. It was retained for this analysis.

Initial Peak Strength results were available only for the RTD condition and only for 17 specimens. This is insufficient for B-basis computations, so only B-estimates are provided.

Statistics, estimates and basis values are given for the 2% offset strength data in Table 4-43 and the Ultimate Strength data in Table 4-44. The normalized data and the B-basis values are shown graphically in Figure 4-29.

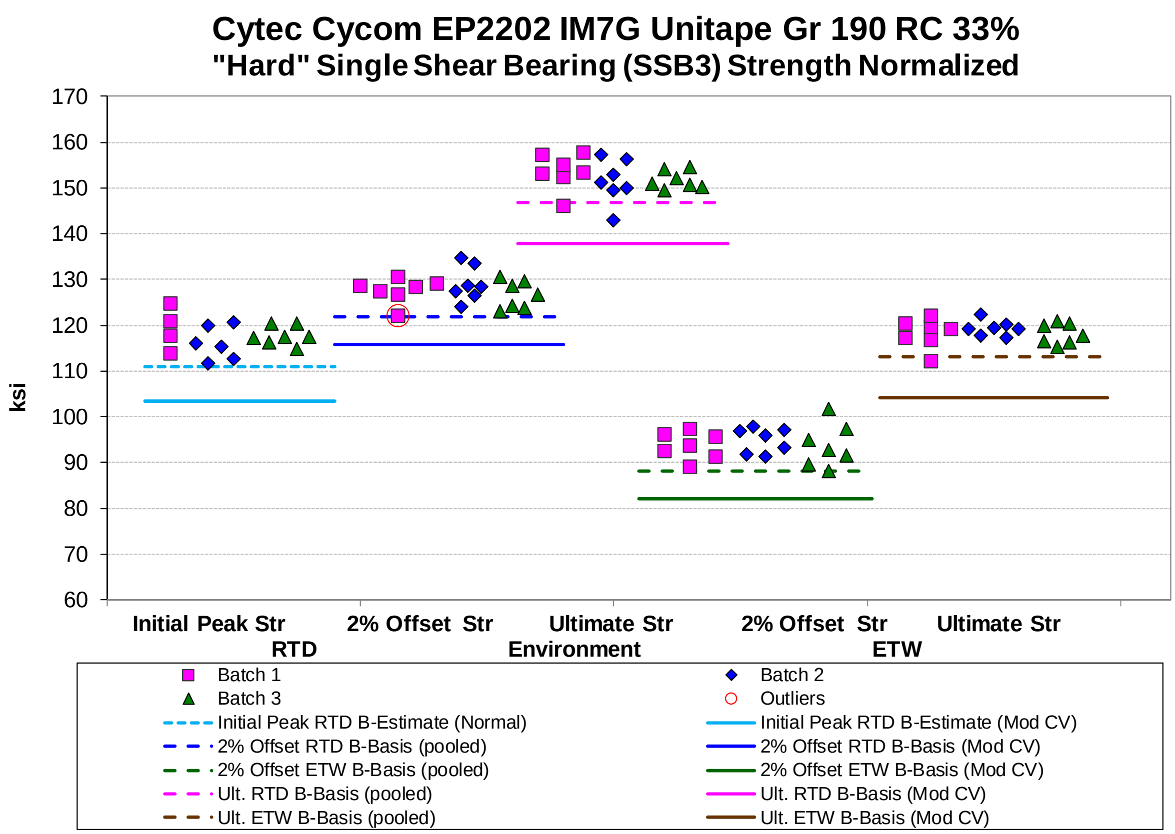


**Figure 4-29: Batch plot for SSB3 strength normalized**

| Single Shear Bearing (SSB3) Strength Basis Values and Statistics for 2% Offset Strength and Initial Peak Strength | | | | | | |
|---|---|---|---|---|---|---|
| | 2% Offset Strength | | | | Initial Peak Strength | |
| | Normalized | | As-measured | | Norm. | As-Meas. |
| Env | RTD | ETW | RTD | ETW | RTD | RTD |
| Mean | 127.739 | 94.054 | 127.999 | 94.153 | 117.532 | 117.479 |
| Stdev | 3.212 | 3.418 | 3.565 | 3.632 | 3.241 | 3.378 |
| CV | 2.514 | 3.634 | 2.786 | 3.858 | 2.758 | 2.876 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 122.072 | 88.141 | 122.345 | 86.894 | 112.223 | 111.603 |
| Max | 134.728 | 101.734 | 134.775 | 100.524 | 122.669 | 124.763 |
| No. Batches | 3 | 3 | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 | 17 | 17 |
| Basis Values and Estimates | | | | | | |
| B-basis Value | 121.857 | 88.172 | 121.615 | 87.769 | | |
| B-estimate | | | | | 111.041 | 110.713 |
| A-estimate | 117.815 | 84.130 | 117.228 | 83.382 | 106.451 | 105.929 |
| Method | pooled | pooled | pooled | pooled | Normal | Normal |
| Modified CV Basis Values and Estimates | | | | | | |
| B-basis Value | 115.802 | 82.117 | 116.041 | 82.195 | | |
| B-estimate | | | | | 103.412 | 103.366 |
| A-estimate | 107.597 | 73.912 | 107.823 | 73.977 | 93.450 | 93.408 |
| Method | pooled | pooled | pooled | pooled | normal | normal |

**Table 4-43: Statistics and Basis Values for SSB3 2% Offset Strength and Initial Peak Strength data**

| Single Shear Bearing (SSB3) Strength Basis Values and Statistics for Ultimate Strength | | | | |
|---|---|---|---|---|
| | Normalized | | As-measured | |
| Env | RTD | ETW | RTD | ETW |
| Mean | 152.253 | 118.553 | 152.574 | 118.674 |
| Stdev | 3.660 | 2.404 | 4.520 | 2.789 |
| CV | 2.404 | 2.028 | 2.962 | 2.350 |
| Modified CV | 6.000 | 6.000 | 6.000 | 6.000 |
| Min | 142.987 | 112.024 | 142.197 | 113.749 |
| Max | 157.627 | 122.291 | 160.317 | 124.144 |
| No. Batches | 3 | 3 | 3 | 3 |
| No. Spec. | 21 | 21 | 21 | 21 |
| Basis Values and Estimates | | | | |
| B-basis Value | 146.761 | 113.060 | 143.964 | 113.361 |
| A-estimate | 142.987 | 109.286 | 137.825 | 109.574 |
| Method | pooled | pooled | Normal | Normal |
| Modified CV Basis Values and Estimates | | | | |
| B-basis Value | 137.732 | 104.031 | 138.028 | 104.128 |
| A-estimate | 127.752 | 94.051 | 128.031 | 94.131 |
| Method | pooled | pooled | pooled | pooled |

**Table 4-44: Statistics and Basis Values for SSB3 Ultimate Strength data**

## 4.30 Compression After Impact 1 (CAI1)

The CAI was tested only at the RTD condition. The datasets, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means the CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. The failed the ADK test even after the modified CV transformation of the data, so modified CV basis values could not be provided.

There were no outliers.

The CAI summary statistics and estimates of the basis values are presented in Table 4-45 and the data are displayed graphically in Figure 4-30.

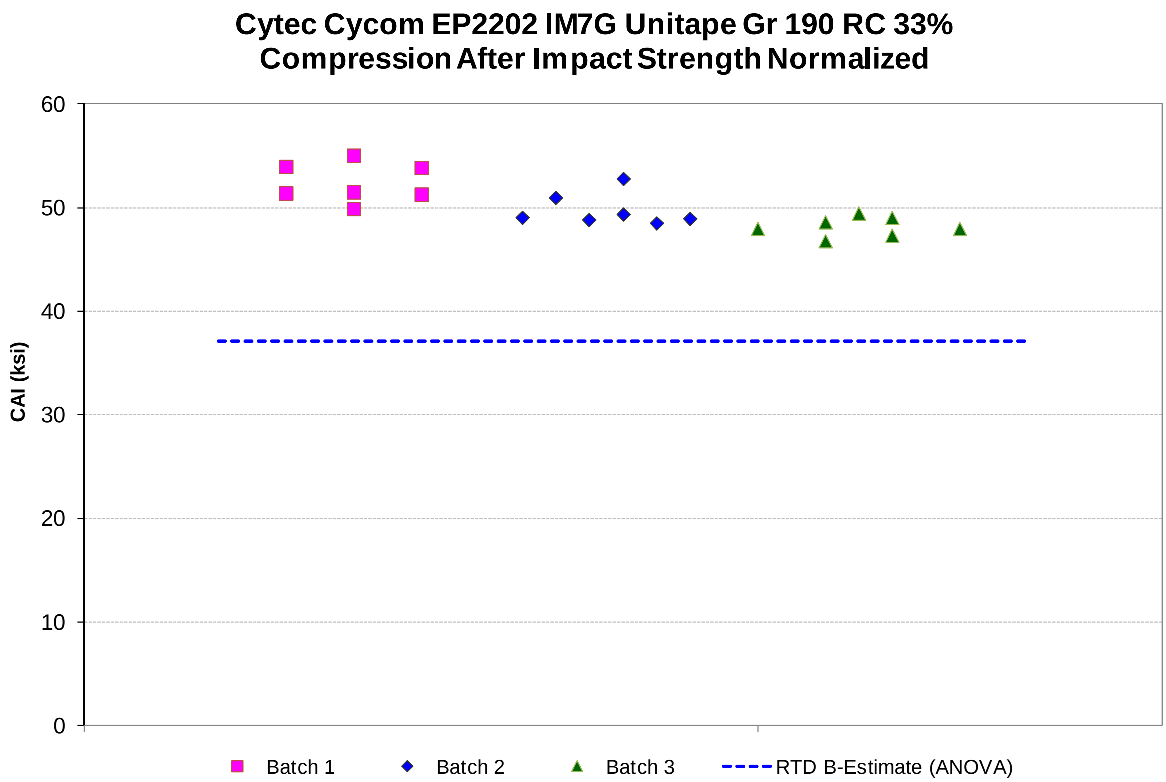


**Figure 4-30: Plot for Compression After Impact strength normalized**

| Compression After Impact Strength (ksi) | | |
|---|---|---|
| | Normalized | As-measured |
| Env | RTD | RTD |
| Mean | 50.093 | 50.313 |
| Stdev | 2.299 | 2.586 |
| CV | 4.589 | 5.139 |
| Modified CV | 6.294 | 6.569 |
| Min | 46.734 | 46.887 |
| Max | 55.016 | 56.153 |
| No. Batches | 3 | 3 |
| No. Spec. | 21 | 21 |
| B-Basis Values Estimates | | |
| B-estimate | 37.093 | 35.159 |
| A-estimate | 27.812 | 24.341 |
| Method | ANOVA | ANOVA |

**Table 4-45: Statistics for Compression After Impact Strength data**

## 4.31 Interlaminar Tension and Curved Beam Strength (ILT and CBS)

The ILT and CBS data is not normalized. There were no outliers. Basis values are not computed for these properties. However the summary statistics are presented in Table 4-46 and the data are displayed graphically in Figure 4-31.

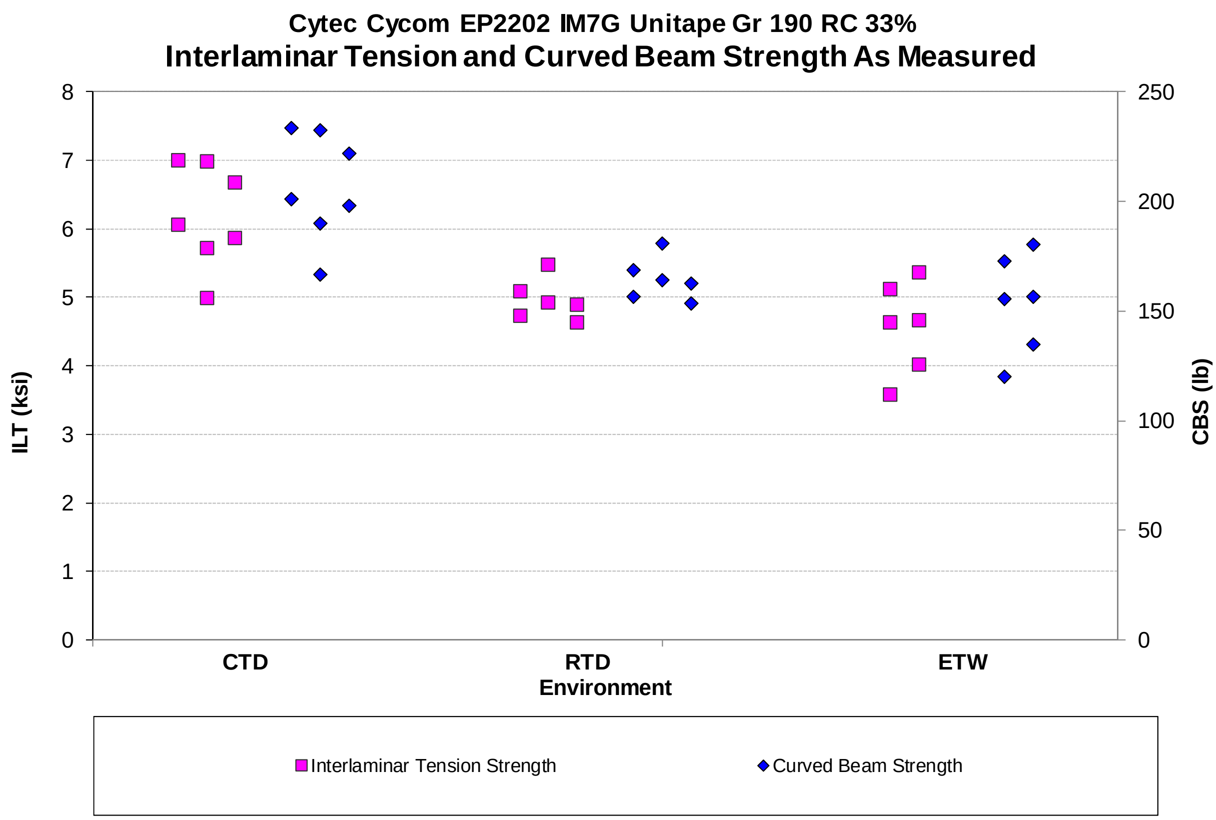


**Figure 4-31: Plot for Curved Beam Strength (CBS) and Interlaminar Tension Strength (ILT)**

| Property | Interlaminar Strength (ksi) | | | Curved Beam Strength (lb) | | |
|---|---|---|---|---|---|---|
| Env | CTD | RTD | ETW | CTD | RTD | ETW |
| Mean | 6.186 | 4.962 | 4.568 | 206.183 | 164.398 | 153.193 |
| Stdev | 0.745 | 0.297 | 0.669 | 24.571 | 9.706 | 22.659 |
| CV | 12.047 | 5.987 | 14.639 | 11.917 | 5.904 | 14.791 |
| Mod CV | 12.047 | 6.993 | 14.639 | 11.917 | 6.952 | 14.791 |
| Min | 4.985 | 4.640 | 3.580 | 166.393 | 153.475 | 119.791 |
| Max | 7.004 | 5.480 | 5.372 | 233.365 | 180.852 | 180.235 |
| No. Batches | 1 | 1 | 1 | 1 | 1 | 1 |
| No. Spec. | 7 | 6 | 6 | 7 | 6 | 6 |

**Table 4-46: Statistics for ILT and CBS Strength data**

# 5. Outliers

Outliers were identified according to the standards documented in section 2.1.5, which are in accordance with the guidelines developed in section 8.3.3 of working draft CMH-17 Rev G. 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-2014-017.

Outliers for which no causes could be identified are listed in Table 5-1. 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 |
|---|---|---|---|---|---|---|---|---|
| SBS | CTD | B | EPAQB116B | NA | 18.966 | Low | Yes | Yes |
| UNT2 | RTD | A | EPABA213A | 73.191 | 75.453 | Low | Yes | Yes |
| UNT3 | RTD | A | EPACA214A | 214.510 | Not an outlier | Low | No | Yes |
| UNT3 | RTD | C | EPACC214A | 230.115 | Not an outlier | Low | Yes | No |
| UNT3 | ETW | B | EPACB219D | 189.767 | 187.596 | Low | Yes | No |
| FHT1 | RTD | A | EPA4A112A | 73.768 | 75.226 | Low | Yes - as meas<br>No - norm | No - as meas<br>Yes - norm |
| FHT2 | ETW | C | EPA5C11ED | 49.669 | Not an outlier | High | Yes | No |
| FHT3 | ETW | B | EPA6B219D | 101.982 | 101.046 | Low | Yes | No |
| OHT1 | CTD | C | EPADC119B | 85.857 | 86.382 | High | No | Yes |
| OHT2 | CTD | C | EPAEC215B | 55.398 | 56.290 | High | Yes | No |
| OHT2 | ETW | B | EPAEB11CD | 45.369 | 44.357 | Low | Yes | No |
| OHT3 | ETW | C | EPAFC11ED | Not an outlier | 117.407 | Low | Yes | No |
| FHC2 | ETW | C | EPA8C217D | 41.445 | 41.570 | Low | Yes | No |
| SBS1 | RTD | A | EPAqA1G1A | NA | 12.355 | Low | No | Yes |
| SSB2 - Ult. Str. | RTD | C | EPA2C112A | 157.670 | 155.848 | High | Yes | No |
| SSB2 - Ult. Str. | ETW | C | EPA2C116D | 127.908 | 126.387 | High | Yes | No |
| SSB2 - 2% Offset | RTD | B | EPA2B114A | 136.337 | 137.707 | High | No | Yes |
| SSB2 - 2% Offset | ETW | A | EPA2A216D | 101.483 | 103.312 | High | Yes | No |
| SSB3 - 2% Offset | RTD | A | EPA3A111A | 122.072 | Not an outlier | Low | Yes | No |
| UNC1 | RTD | B | EPAWB113A | Not an outlier | 85.111 | Low | Yes | No |
| LT | CTD | C | EPAJC116B | 289.567 | 289.790 | Low | Yes | Yes |
| TC | ETD | C | EPAZC21DC | NA | 28.765 | Low | Yes | Yes |
| TC | CTD | B | EPAZB217B | NA | 49.805 | Low | Yes | No |
| TC | ETW | A | EPAZA21ED | NA | 23.448 | High | Yes | No |
| TC | ETW | C | EPAZC11PD | NA | 22.381 | Low | Yes | No |

**Table 5-1: List of Outliers**

# 6. References


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