Solvay Cytec Cycom 5320-1 T650 Unitape Gr 145 Qualification Statistical Analysis Report

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2. Background

Statistical computations are performed with AGATE Statistical Analysis Program (ASAP) when pooling across environments is permissible according to CMH-17 Rev G guidelines. If pooling is not permissible, a single point analysis using STAT17 is performed for each environmental condition with sufficient test results. If the data does not meet 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 CMH STATS and 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: $\bar{X} \quad \sum_{i=1}^{n} \frac{X_i}{n}$ Equation 1

Std. Dev.: Equation 2

% Co. Variation: $\frac{S}{\bar{X}} \quad 100$ Equation

Where k refers to the number of batches,

k_k

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. $w_{ij} = |y_{ij} - \tilde{y}_i|$ An F-test is then performed on the transformed data values as follows:

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

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 α level of confidence, then the data is not rejected as being too different in terms of the coefficient 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 CMH-17 Rev G.

2.2.1 Distribution Tests

In addition to testing

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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 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:

$$k_A \quad 2.326 \quad \exp\{1.34 \quad 0.522 \ln(\quad) \quad 3.87/n \qquad \text{Equation 34}$$

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

$$V_A \approx 6.649 \exp\left(2.55 - 0.526 \ln\left(\frac{4.76}{n}\right)\right)$$ 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 drawn at random from this population falls between a and b $(0 < a < b)$ 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:

thisTf 1 0 0 1 2233.93 Tm [29166731

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 ref 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 equations 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:

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-A basis values for sample size 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:

Equation 50

$$5\ 0\ +n$$

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

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 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, s_i, $\bar{x}_i$, s_i^2 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 th

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

Laminate Strength Tests

B-basis	NA:A		50.344		82.306					
Mean	47.105		56.416		92.513					
CV	5.534		6.000		6.000					
B-basis	NA:A	46.119	51.890	73.794	87.415	82.369	123.999	122.477	137.050	10.649
Mean	49.601	50.894	57.962	81.560	97.622	96.628	136.627	135.155	151.576	13.710
CV	5.909	6.000	6.143	6.299	6.000					

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

3.2 Lamina and Laminate Summary Tables

Prepreg Material: Cytec 5320-1 T650 Unitape Gr 145 RC 33%
Material Specification: NMS 532/5
Process Specification: NPS 85321 Baseline Cure Cycle C

Fiber: T650 Unitape Resin: Cycom 5320-1

Tg(dry): 389.13 °F Tg(wet): 321.79 °F Tg METHOD: ASTM D7028

Date of fiber manufacture	Apr-May 2010	Date of testing	Mar-Oct 2012
Date of resin manufacture	Aug 2010	Date of data submittal	Feb 2013
Date of prepreg manufacture	Aug- Spet 2010	Date of analysis	Feb 2013
Date of composite manufacture	Sept-Dec 2011		

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported: As-measured followed by normalized values in parentheses, normalizing tply: 0.0055 in

Values shown in shaded boxes do not meet CMH17 Rev G requirements and are estimates only
These values may not be used for certification unless specifically allowed by the certifying agency

	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean
	267.069	258.751	292.317	273.756	265.438	299.004	231.005	NA	272.069
	(266.648)	(257.049)	(293.615)	(272.126)	(262.527)	(299.093)	(233.031)	(238.173)	(274.431)
			20.128			20.077			19.892
			(20.214)			(20.082)			(20.084)
ν_{12}^{t}			0.325			0.326			0.337
F_2^{tu} (ksi)	6.882	NA	10.975	8.549	NA	10.096	1.829	NA	4.730
E_2^{t} (Msi)			1.485			1.331			0.840
F_1^{cu} (ksi)	214.981	225.029	251.646	218.929	211.258	237.875	158.181	150.511	177.128
	(228.837)	(224.897)	(251.251)	(214.683)	(210.744)	(237.098)	(156.723)	(152.783)	(179.138)
			17.308			18.356			18.216
			(17.256)			(18.301)			(18.252)
F_2^{cu} (ksi)	47.295	45.422	51.397	37.002	NA	39.751	18.289	17.150	19.364
E_2^{c} (Msi)			1.531			1.427			1.094
	15.217	15.232	17.198	NA	NA	NA	NA	NA	NA
$F_{12}^{s5\%}$ (ksi)	NA	NA	NA	12.793	11.958	13.501	4.755	4.545	5.139
$F_{12}^{s0.2\%}$ (ksi)	10.411	10.224	11.269	7.758	7.075	8.121	2.748	2.675	3.060
G			0.838			0.718			0.325
SBS (ksi)	13.531	16.680	18.126	14.531	14.180	15.639	7.262	6.271	7.722
	84.024	88.051	98.354	85.213	82.207	92.510	60.184	57.178	67.481
	(89.014)	(87.518)	(97.657)	(83.249)	(81.753)	(91.892)	(58.632)	(57.136)	(67.275)
			6.765			7.139			6.940
			(6.707)			(7.093)			(6.855)

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

Table 3-3: Summ ary of Test Results for Lamina Data CTD RTD and ETW2 Conditions

Prepreg Material: Cytec 5320-1 T650 Unitape Gr 145 RC 33%
Material Specification: NMS 532/5
Process Specification: NPS 85321 Baseline Cure Cycle C

Fiber: T650 Unitape Resin: Cycom 5320-1

Tg(dry): 389.13 °F Tg(wet): 321.79 °F Tg METHOD: ASTM D7028

Table 3-4: Summary of Test Results for Lamina Data ETD1 ETW1 and ETD2 Conditions

Prepreg Material: Cytec 5320-1 T650 Unitape Gr 145 RC 33%
Material Specification: NMS 532/5
Process Specification: NPS 85321 Baseline Cure Cycle C

Fiber: T650 Unitape Cycom 5320-1
Tg(dry): 389.13 °F Tg(wet): 321.79 °F Tg METHOD: ASTM D7028

Apr-May 2010
Aug 2010
Aug- Sept 2010
Sept-Dec 2011

Mar-Oct 2012
Feb 2013
Feb 2013

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

Table 3-5: Summary of Test Results for Laminate Data

4. Test Results, Statistics, Basis Values

4.1 Longitudinal Tension (LT)

The LT data is normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. The ETW2 data did not fit any of the tested distributions, so the non-parametric method was used to compute basis values.

The pooled datasets, both normalized and as measured, did not fit the normal distribution, so pooling all four conditions was not acceptable. However, the CTD and RTD could be pooled for both normalized and as-measured datasets. When the data was transformed to meet the assumptions of the modified CV method, all four conditions could be pooled for the normalized dataset but not for the as-measured dataset. There were no outliers.

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.

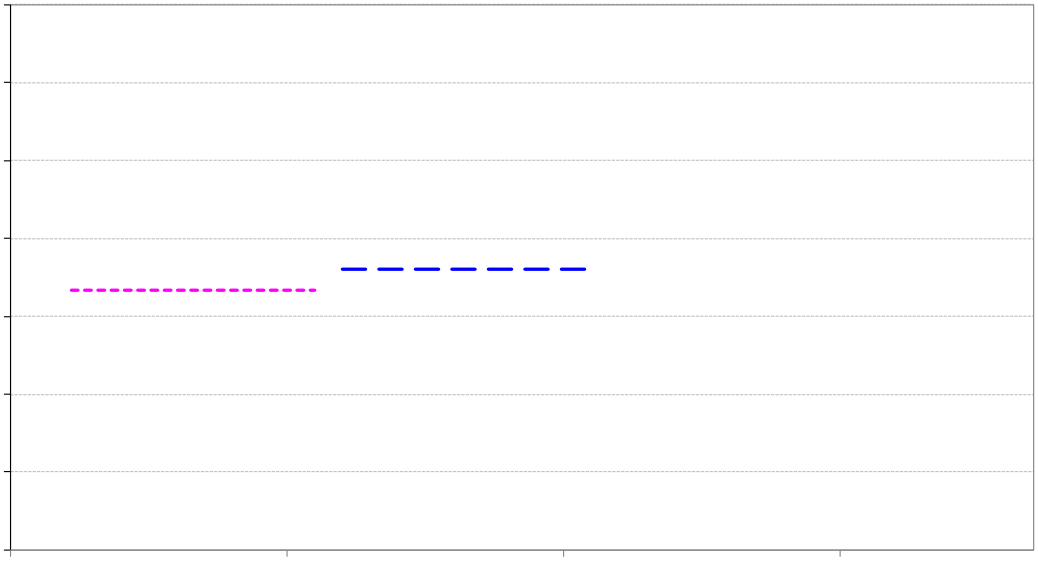

Figure 4-1 Batch plot for LT strength normalized

Env	CTD	RTD	ETW1	ETW2	CTD	RTD	ETW1	ETW2
Mean	293.615	299.093	272.989	274.431	292.317	299.004	276.017	272.069
Stdev	14.557	15.822	24.118	23.422	12.623	15.681	22.869	22.429
CV	4.958	5.290	8.835	8.535	4.318	5.244	8.285	8.244
Mod CV	6.479	6.645	8.835	8.535	6.159	6.622	8.285	8.244
Min	260.542	272.717	241.145	236.839	266.291	269.754	248.616	234.704
Max	323.949	324.928	303.649	312.116	311.839	320.612	305.972	304.278
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	21	8	23	21	21	8	23
B-basis Value	266.648	272.126		233.031	267.069	273.756		231.005
B-estimate			210.303				216.578	
A-estimate	248.115	253.593	166.426	169.429	249.716	256.404	174.975	171.273
Method	pooled	pooled	Normal					

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

Longitudinal Tension Modulus Statistics

Env	CTD	RTD	ETW1	ETW2	CTD	RTD	ETW1	ETW2
Mean	20.214	20.082	20.030	20.084	20.128	20.077	20.263	19.892
Stdev	0.440	0.441	0.614	0.413	0.326	0.264	0.464	0.284
CV	2.175	2.195	3.065	2.056	1.619	1.313	2.291	1.428
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Min	19.248	18.685	18.806	19.202	19.469	19.536	19.670	19.354
Max	20.884	20.860	20.693	20.703	20.620	20.695	20.891	20.546
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	20	7	22	21	20	7	22

Table 4-2: Statistics from LT Modulus data

4.3 Longitudinal Compression (LC)

The strength values for LC properties are computed using equation 65 specified in section 2.5. The ETD1, ETW1, and ETD2 datasets lacked sufficient specimens to meet 17 CMH-17 guidelines, so only estimates are provided for these condition. The normalized data could be pooled across all environmental conditions, but the as-measured data failed Levene's test when all six conditions were included. Conditions RTD through ETW2 could be pooled, but the single point method was used to compute basis values and estimates for the CTD as-measured data. After transforming the data to meet the assumptions of the modified CV method, pooling was acceptable to compute the modified CV basis values and estimates for all conditions for both normalized and as-measured datasets.

There was one outliers. The lowest value in batch six of the ETW2 condition was an outlier for batch six, but not for the ETW2 condition. It was an outlier for both the normalized and as measured datasets. It was retained for this analysis.

4.4 Transverse Compression (TC)

Transverse Compression data is not normalized. The CTD and RTD conditions failed the normality test, but the Weibull distribution fit both datasets sufficiently well to use that method to compute basis values. Both the CTD and RTD datasets failed the normality test even after outliers were removed. After transforming the data to match the assumptions of the modified CV method the CTD dataset passed the normality test but the RTD dataset did not. Modified CV basis values and estimates are provided for the CTD dataset but not the RTD dataset for that reason.

There were three statistical outliers, one in batch five of the CTD dataset and one each in batches four and five of the RTD dataset. All three outliers were outliers only for their respective batches, not for their respective conditions. All three were outliers for being too low. All three 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.

4.5 In-Plane Shear (IPS)

In Plane Shear data is not normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

The CTD condition had no data available for strength at 5% strain due to strain gauge failures prior to 5% being reached. Values are given for the peak shear strength prior to 5% strain. This dataset and the RTD dataset for 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. Where these CTD and RTD datasets were transformed according

Figure 4-5: Batch plot for IPS for 0.2% offset strength as-measured

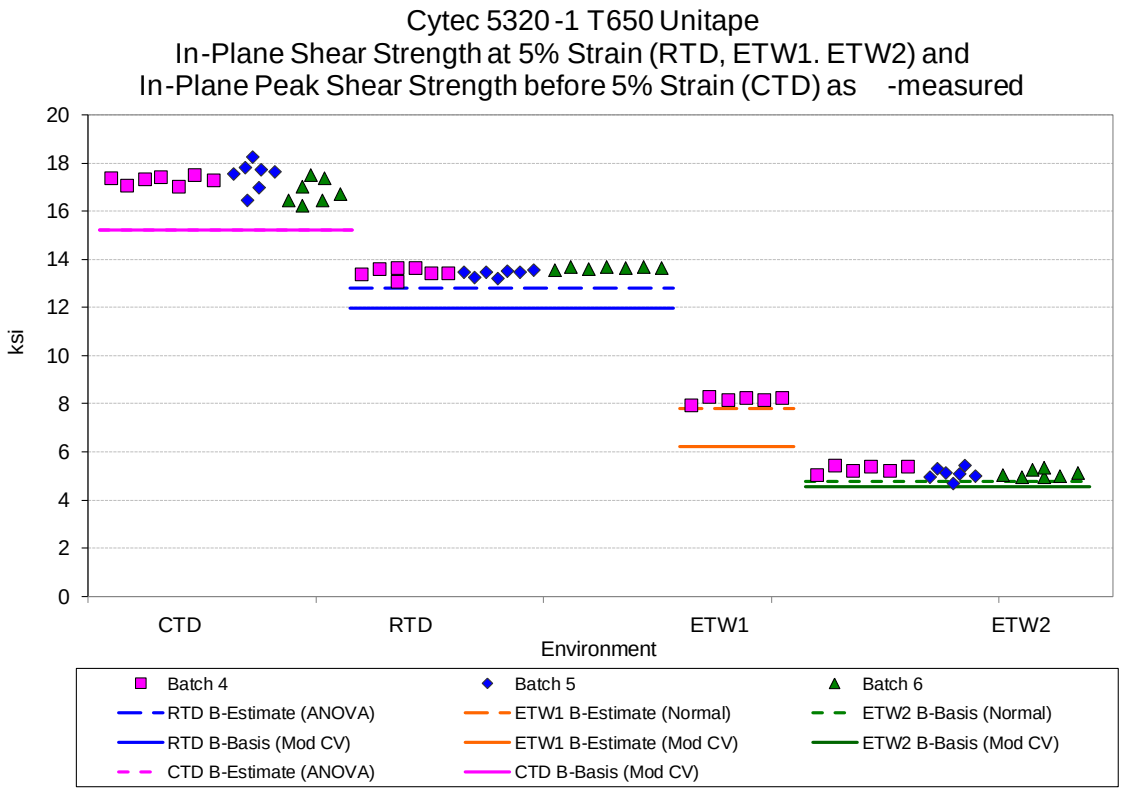

Figure 4-6: Batch plot for IPS for strength at 5% strain and peak strength before 5% strain as-measured

In-Plane Shear Strength Basis Values and Statistics As-Measured								
	Peak before 5% Strain	Strength at 5% Strain			0.2% Offset Strength			
Env	CTD	RTD	ETW1	ETW2	CTD	RTD	ETW1	ETW2
Mean	17.198	13.501	8.165	5.139	11.269	8.121	5.151	3.060
Stdev	0.517	0.173	0.128	0.199	0.451	0.119	0.083	0.167
CV	3.004	1.278	1.568	3.874	3.999	1.468	1.608	5.451
Mod CV	6.000	6.000	8.000	6.000	6.000	6.000	8.000	6.725
Min	16.245	13.055	7.935	4.695	10.639	7.820	5.023	2.668
Max	18.252	13.697	8.297	5.438	12.321	8.430	5.283	3.430
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	21	6	20	21	21	7	23
Basis Values and Estimates								
B-basis Value				4.755	10.411	7.758		2.748
B-estimate	15.217	12.793	7.777				4.921	
A-estimate	13.803	12.287	7.502	4.482	9.799	7.088	4.759	2.525
Method	ANOVA	ANOVA	Normal	Normal	Normal	Non-Parametric	Normal	Normal
Modified Basis Values and Estimates								
B-basis Value	15.232	11.958		4.545	10.224	7.075		2.675
B-estimate			6.197				4.014	
A-estimate	13.831	10.858	4.851	4.123	9.506	6.357	3.235	2.400
Method	Normal	Normal	Normal	Normal	pooled	pooled	Normal	Normal

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

Env	CTD	RTD	ETW1	ETW2
Mean	0.838	0.718	0.547	0.325
Stdev	0.021	0.015	0.010	0.021

Table 4-10: Statistics from IPS Modulus data

Env	CTD	RTD	ETW1	ETW2	CTD	RTD	ETW1	ETW2
Mean	92.513	97.622	105.189	103.351	92.199	97.737	105.614	102.659
Stdev	3.004	2.864	4.501	3.184	3.150	2.671	4.775	3.180
CV	3.247	2.934	4.279	3.081	3.417	2.733	4.521	3.097
Modified CV	6.000	6.000	6.140	6.000	6.000	6.000	6.260	6.000
Min	87.187	92.787	97.105	96.092	87.194	92.616	97.548	94.640
Max	97.145	102.902	112.181	111.772	96.632	103.154	113.558	110.454
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	21	7	21	21	21	7	21
B-basis Value	86.791			97.286	86.675	92.213		97.135
B-estimate		86.272	92.690				99.291	
A-estimate	82.712	78.172	83.897	92.962	82.957	88.495	95.668	93.417
Method	Normal	ANOVA	Normal	Normal	pooled	pooled	pooled	pooled
B-basis Value	82.306	87.415		93.145	81.994	87.532		92.454
B-estimate			93.507				93.934	
A-estimate	75.437	80.546	86.813	86.276	75.127	80.664	87.241	85.586
Method	pooled	pooled	pooled	pooled				

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

Table 4-12: Statistics from UNT1 Modulus data

4.7 ñ10/80/10ò Unnotched Tension 2 (UNT2)

The UNT2 data is normalized. The CTD and ETW2 datasets, both normalized and measured, all 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 modified CV basis values are provided for all datasets. The datasets for all three conditions, both normalized and measured, could be pooled to compute the modified CV basis values.

There was one outlier. The highest value in batch five of the measured ETW2 dataset was an outlier for batch 5 only. It was not an outlier for the ETW2 condition nor was it an outlier for the normalized dataset. The outlier 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 4-8.

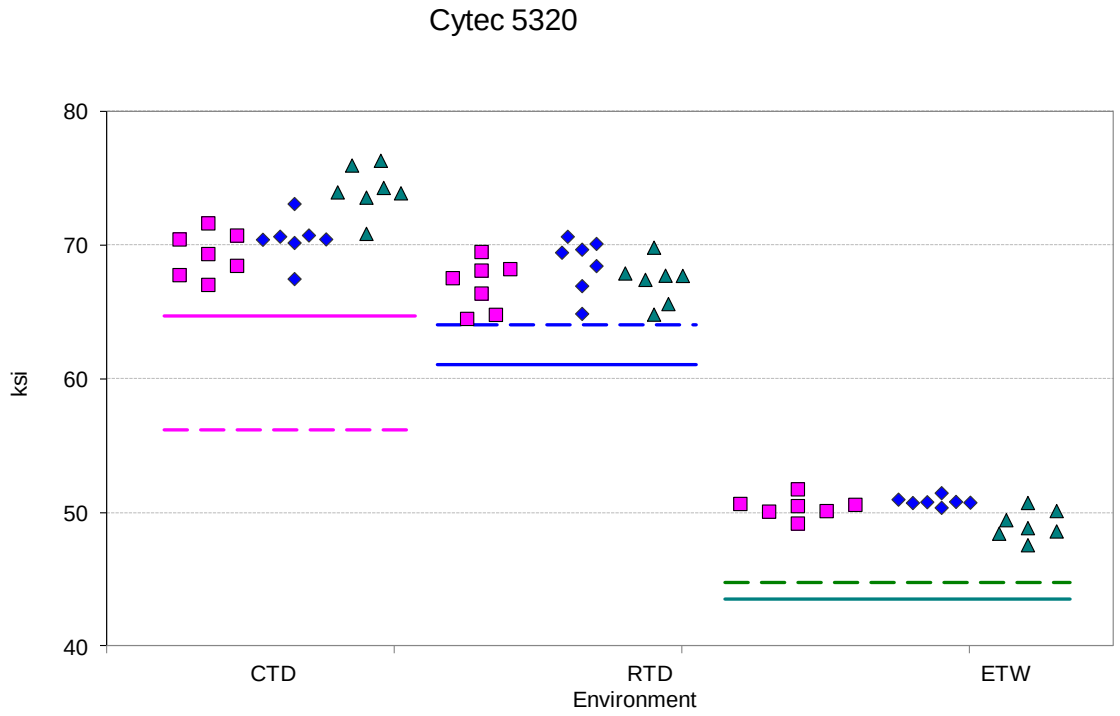

Figure 4-8: Batch Plot for UNT2 strength normalized

Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	71.302	67.633	50.130	70.795	67.581	49.782
Stdev	2.646	1.894	1.062	2.277	1.949	1.223
CV	3.711	2.800	2.119	3.217	2.884	2.456

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

Env	CTD	RTD	ETW2	CTD	RTD	ETW
Mean	5.124	4.917	4.173	5.089	4.914	4.144
Stdev	0.073	0.100	0.096	0.091	0.111	0.105
CV	1.417	2.024	2.298	1.791	2.253	2.527
Modified CV	6.000	6.000	6.000			

Table 4-14: Statistics from UNT2 Modulus data

4.8 ñ50/40/10ò Unnotched Tension 3 (UNT3)

The UNT3 data is normalized. The normalized RTD and ETW2 datasets could be pooled. The CTD datasets, both normalized and measured, and the as-measured ETW2 dataset failed the Anderson Darling k-

Unnotched Tension (UNT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	144.363	153.345	164.899	143.639	152.653	163.352
Stdev	6.768	7.810	6.570	5.800	7.271	7.251
CV	4.688	5.093	3.984	4.038	4.763	4.439
Modified CV	6.344	6.547	6.000	6.019	6.382	6.220
Min	133.118	140.003	152.789	133.604	140.268	148.996
Max	160.869	165.067	176.367	157.692	164.324	174.740
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value		140.549	152.103		138.802	
B-estimate	108.512			119.124		131.324
A-estimate	82.920	131.748	143.302	101.627	128.927	108.464
Method	ANOVA	pooled	pooled	ANOVA	Normal	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	127.579	136.561	148.115	127.145	136.159	146.858
A-estimate	116.248	125.231	136.785	116.011	125.024	135.724
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean						

Table 4-16: Statistics from UNT3 Modulus data

4.9 ñ33/0/67ò Unnotched Compression 0 (UNC0)

The UNC0 data is normalized. The ETD1, ETW1 and ETD2 datasets lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for those conditions. The as

4.10 ñ25/50/25ò Unnotched Compression 1 (UNC1)

The UNC1 data is normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. Pooling was not acceptable for either the normalized or the as-measured data due to the failure of Levene's test for equality of variance. However, the as-measured data passed Levene's test after the modified CV

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Unnotched Compression (UNC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	72.330	43.957	73.618	43.965
Stdev	3.960	1.937	3.344	2.051
CV	5.475	4.408	4.543	4.665
Modified CV	6.737	6.204	6.271	6.332
Min	64.583	40.233	68.731	40.288
Max	77.006	48.163	78.152	47.853
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	64.787	40.266	67.728	40.058
A-estimate	59.409	37.635	58.077	37.273
Method	Normal	Normal	Non-Parametric	Normal
Modified CV Basis Values and Estimates				
B-basis Value	63.044	38.760	NA	38.660
A-estimate	56.429	35.059	NA	34.881
Method	Normal	Normal	NA	Normal

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

Unnotched Compression (UNC2) Modulus Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	4.743	3.932	4.842	3.927
Stdev	0.122	0.136	0.214	0.127
CV	2.581	3.470	4.427	3.236
Modified CV	6.000	6.000	6.214	6.000
Min	4.567	3.725	4.514	3.677
Max	4.953	4.222	5.239	4.175
No. Batches	3	3	3	3
No. Spec.	21	20	21	20

Table 4-22: Statistics from UNC2 Modulus data

4.12 ñ50/40/10ò Unnotched Compression 3 (UNC3)

The UNC3 data is normalized. Pooling was not acceptable for either the normalized or the as measured data due to the failure of Levene's test for equality of variance. The normal distribution method was used to compute basis values and estimates for both conditions. After transforming the data to match the assumptions of the modified CV method, the datasets passed Levene's test and pooling was used to compute the modified CV basis values.

There were no statistical 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 4-13.

Figure 4-13: Batch plot for UNC3 strength normalized

Unnotched Compression (UNC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	129.217	86.522	130.454	86.791
Stdev	4.047	1.998	4.480	1.969
CV	3.132	2.309	3.434	2.269
Modified CV	6.000	6.000	6.000	6.000
Min	121.715	82.166	123.856	82.456
Max	136.286	90.033	142.082	90.281
No. Batches	3	3	3	3
No. Spec.	21	20	21	20
Basis Values and Estimates				
B-basis Value	121.507	82.674	121.919	82.999
A-estimate	116.010	79.936	115.834	80.300
Method	Normal	Normal	Normal	Normal
B-basis Value	117.435	74.689	118.582	74.868
A-estimate	109.327	66.593	110.412	66.711
Method	pooled	pooled	pooled	pooled

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

Unnotched Compression (UNC3) Modulus Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	10.913	10.463	11.041	10.509
Stdev	0.273	0.254	0.264	0.222
CV	2.500	2.423	2.390	2.116
Modified CV	6.000	6.000	6.000	6.000
Min	10.215	9.948	10.493	10.140
Max	11.344	10.994	11.573	10.937
No. Batches	3	3	3	3
No. Spec.	21	21	21	21

Table 4-24: Statistics from UNC3 Modulus data

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

Laminate Short Beam Strength (SBS1) Basis Values and Statistics		
As-measured		
Env	RTD	ETW2
Mean	13.710	7.356
Stdev	0.851	0.382
CV	6.205	5.199
Modified CV	7.102	6.599
Min	11.168	6.943
Max	14.499	8.102
No. Batches	3	3
No. Spec.	21	21
Basis Values and Estimates		
B-basis Value	10.649	
B-estimate		4.875
A-estimate	7.931	3.104
Method	Non-Parametric	ANOVA
Modified CV Estimates of Basis Values		
B-estimate	NA	6.431
A-estimate	NA	5.772
Method	NA	Normal

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

4.15 ñ25/50/25ò Open-Hole Tension1 (OHT1)

The OHT1 data is normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. The CTD and RTD datasets, both normalized and as measured, all failed the Anderson Darling k-sample test (ADK test) for batch to ba

4.16 ñ10/80/10ò Open-Hole Tension 2 (OHT2)

The OHT2 data is normalized. The normalized and measured CTD datasets and 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 the 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 modified CV basis values are provided for those datasets with the exception of the normalized RTD dataset which failed the normality test

The as-measured RTD and ETW2 datasets could be pooled. The as-measured datasets for all three conditions could be pooled to compute the modified CV basis values. Pooling was not acceptable for the normalized modified CV basis values due to non-normality of the pooled dataset.

There were no outliers. 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 4-17.

Figure 4-17: Batch Plot for OHT2 strength normalized

Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	44.056	42.535	35.238	43.732	42.191	34.909
Stdev	0.689	0.530	0.456	0.587	0.499	0.481
CV	1.564	1.245	1.294	1.343	1.183	1.379
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	42.671	41.642	34.532	42.856	41.612	34.139
Max	45.222	43.801	36.087	44.851	43.439	35.727
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
3-basis Value			34.369		41.321	34.039
B-estimate	40.796	40.615		40.891		
A-estimate	38.470	39.245	33.750	38.863	40.724	33.442
Method	ANOVA	ANOVA	Normal	ANOVA	pm 0 0 0 1 242.85 5O7.	

Table 4-28: Statistics and Basis Values for OH T2 Strength data

4.17 ñ50/40/10ò Open-Hole Tension3 (OHT3)

The OHT3 data is normalized. There were no test failures or outliers. Pooling across environments was acceptable. Statistics, basis values and estimates

Open Hole Tension (OHT3) Strength (ksi) Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	65.202	70.597	86.585	64.585	69.906	85.508
Stdev	4.398	3.543	3.128	4.228	3.376	3.062
CV	6.744	5.019	3.612	6.546	4.829	3.581
Modified CV	7.372	6.510	6.000	7.273	6.415	6.000
Min	58.756	63.981	79.852	58.183	64.017	79.014
Max	72.639	75.804	92.821	71.802	74.997	91.001
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	22	21	21	22
Basis Value Estimates						
B-basis Value	58.777	64.172	80.188	58.397	63.718	79.346
A-estimate	54.442	59.838	75.848	54.222	59.543	75.166
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	56.773	62.169	78.192	56.318	61.639	77.276
A-estimate	51.087	56.483	72.500	50.741	56.061	71.692
Method	pooled	pooled	pooled	pooled	pooled	pooled

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

4.18 ñ25/50/25ò Filled-Hole Tension1 (FHT1)

The FHT1 data is normalized. The normalized and measured CTD and RTD 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 all passed the ADK test, so modified CV basis values are provided for those datasets. When all conditions were transformed for the Mod CV method, the datasets, both normalized and as measured, could be pooled across the conditions to compute the modified CV basis values.

There was one outlier. The lowest value in batch five of the RTD condition was an outlier for batch five, but not for the RTD condition. It was an outlier only for the normalized dataset, not for the as-measured 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 4-19.

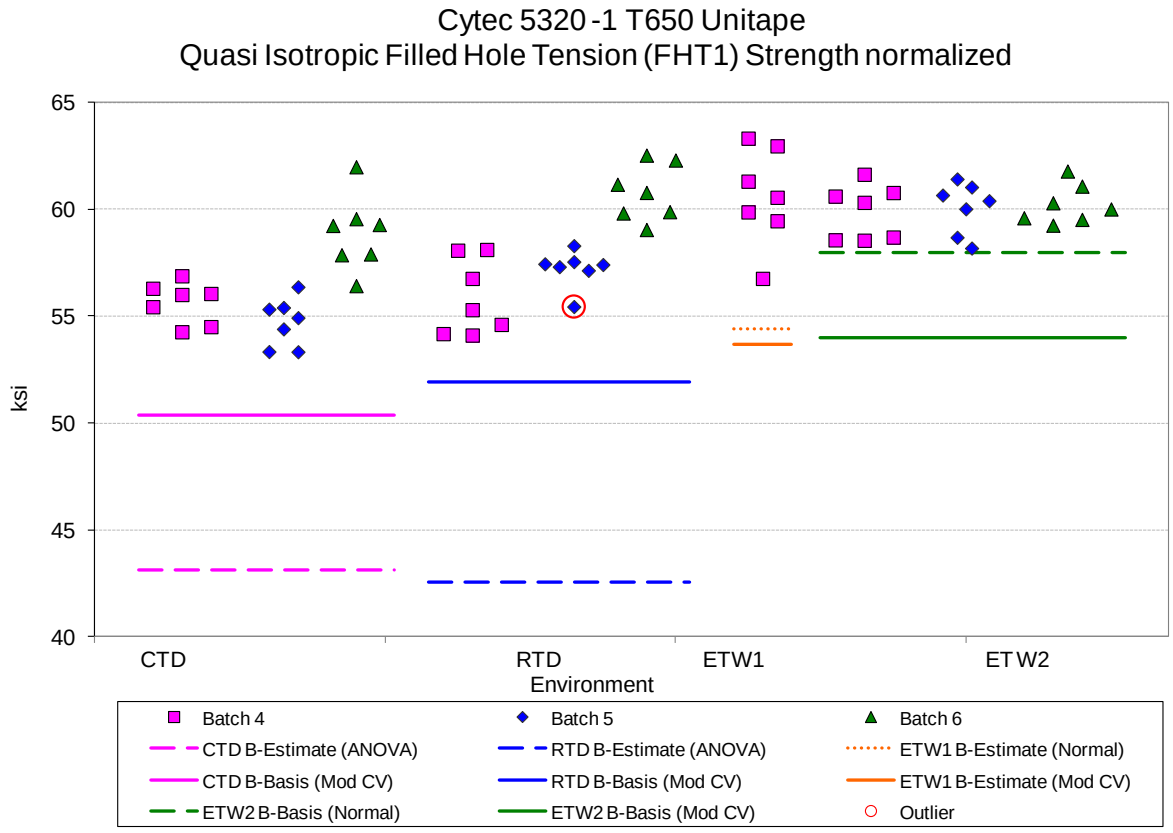

Figure 4-19: Batch plot for FHT 1 strength normalized

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

4.19 ñ10/80/10ò Filled-Hole Tension2 (FHT2)

The FHT2 data is normalized. The normalized and measured CTD datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across all 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 RTD and ETW2 datasets could not be pooled together (normalized and measured) due to a failure of Levene's test for equality of variance.

When the datasets were transformed according to the assumptions of the modified CV method, they all passed the ADK test, so modified CV basis values are provided for those datasets. All three conditions could be pooled to compute the modified CV basis values.

There were no outliers. Statistics and basis values are given for FHT2 strength data in Table

Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	51.295	49.558	39.898	51.297	49.549	39.805
Stdev	1.545	1.447	0.663	1.527	1.425	0.700
CV	3.011	2.919	1.661	2.977	2.875	1.759
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	48.468	46.954	38.453	48.387	46.531	38.135
Max	54.251	52.481	40.970	53.727	52.400	41.201
No. Batches	3	3	3	3	3	3
No. Spec.	20	20	20	20	20	20
B-basis Value		46.772	38.622		46.805	38.457
B-estimate	42.020			42.464		
A-estimate	35.399	44.790	37.713	36.159	44.853	37.497
Method	ANOVA	Normal	Normal			

38.394 38.394

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

4.20 ñ50/40/10ò Filled-Hole Tension3 (FHT3)

The FHT3 data is normalized. The CTD and RTD 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 all 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, the normalized RTD and both the CTD and RTD as-measured datasets passed the ADK test, so modified CV basis values are provided for those datasets. The normalized RTD and ETW2 conditions and all three conditions for the as-measured datasets could be pooled to compute the modified CV basis values.

The normalized CTD dataset did not pass the ADK test after the modified CV transformation of the data so the modified CV basis values for the normalized CTD dataset are considered estimates.

There was one outlier. The highest value in batch six of the as-measured ETW2 condition was an outlier for batch six only, not the ETW2 condition. It was an outlier only for the as-measured dataset, not for the normalized dataset. 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 4-21.

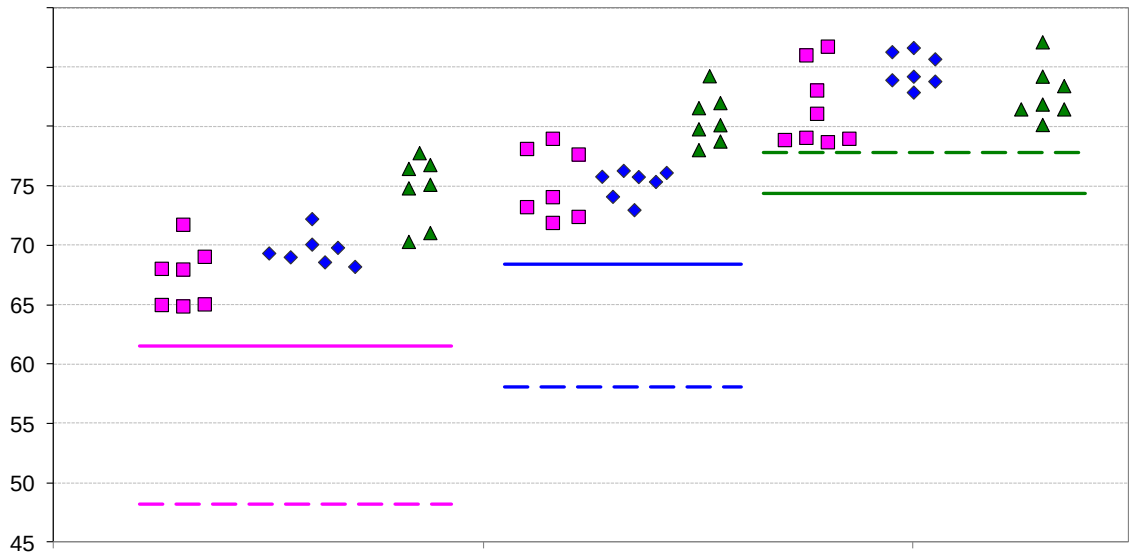

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Figure 4-21: Batch plot for FHT3 strength normalized

Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	70.552	77.031	83.001	70.159	76.861	82.528
Stdev	3.821	3.371	2.765	3.558	3.033	2.702
CV	5.417	4.376	3.331	5.071	3.946	3.274
Modified CV	6.708	6.188	6.000	6.536	6.000	6.000
Min	64.889	71.921	78.716	64.801	72.547	78.292
Max	77.795	84.274	87.128	76.406	83.552	87.230
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	22	21	21	22

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

4.21 [25/50/25] Open-Hole Compression 1 (OHC1)

The OHC1 data is normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. There were no test failures or outliers. Pooling across environments was acceptable.

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 4-22.

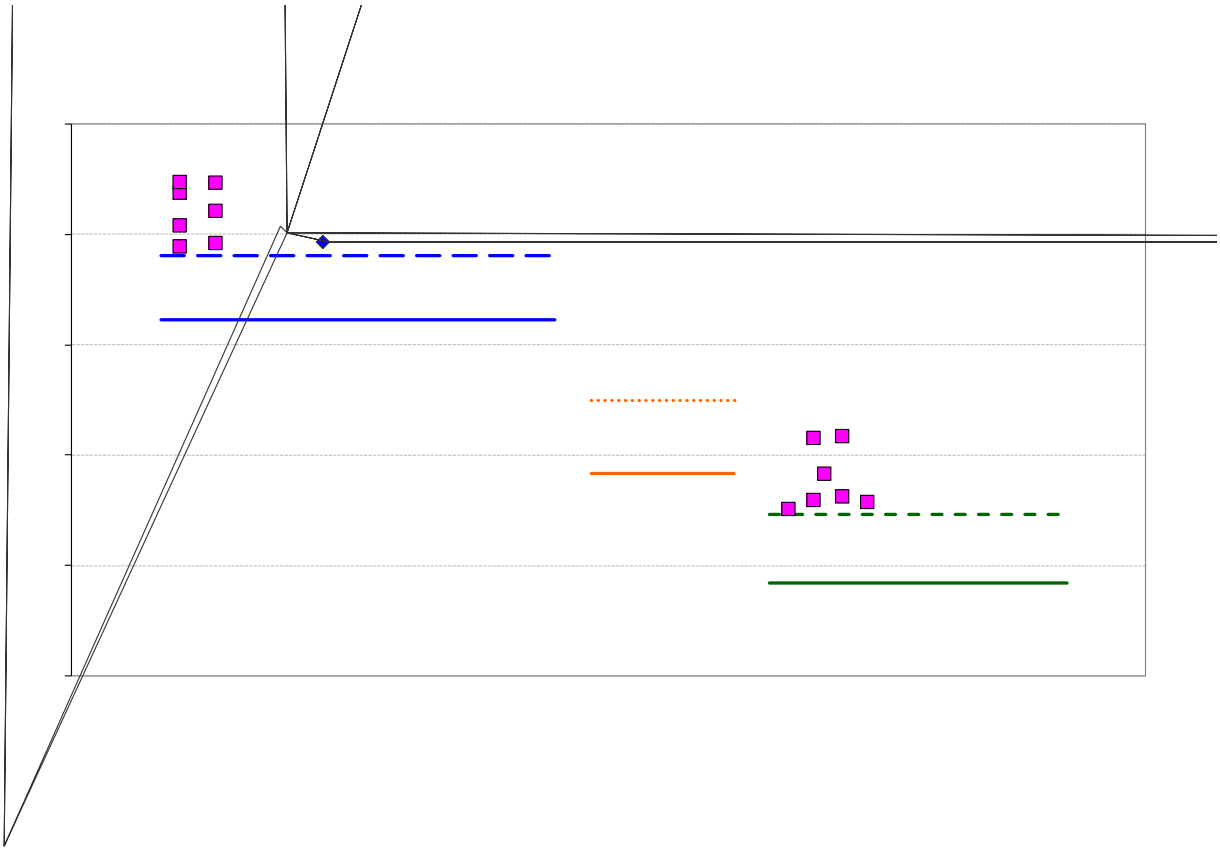

Figure 4-22: Batch plot for OHC1 strength normalized

Env	RTD	ETW1	ETW2	RTD	ETW1	ETW2
Mean	50.894	44.630	39.199	50.684	44.446	39.002
Stdev	0.964	0.667	1.253	0.937	0.630	1.166
CV	1.894	1.495	3.196	1.850	1.418	2.989
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	49.474	43.711	36.300	49.213	43.468	36.542
Max	52.538	45.454	41.327	52.207	45.159	41.000
No. Batches	3	1	3	3	1	3
No. Spec.	21	7	21	21	7	21
B-basis Value	49.015		37.320	48.906		37.224
B-estimate		42.491			42.421	

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

4.22 ñ10/80/10ò Open-Hole Compression 2 (OHC2)

The OHC2 data is normalized. The RTD and ETW 2 datasets, both normalized and 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-17-1G 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 all passed the ADK test, so the modified CV basis values are provided. Pooling was able to be accepted to compute the modified CV basis values.

There were no outliers. Statistics, estimates and basis values are given for OHC2 strength data in Table 4-34. The normalized data and the basis values are shown graphically in Figure 4-23.

Figure 4-23: Batch plot for OHC2 strength normalized

Env	RTD	ETW2	RTD	ETW2
Mean	44.484	32.389	44.400	32.252
Stdev	1.638	0.715	1.648	0.648
CV	3.682	2.208	3.711	2.011
Modified CV	6.000	6.000	6.000	6.000
Min	41.415	30.500	41.462	30.908
Max	47.243	34.082	47.214	33.833
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
B-Estimate	37.204	30.427	36.880	29.981
A-estimate	32.008	29.026	31.512	28.361
Method	ANOVA	ANOVA	ANOVA	ANOVA
B-basis Value	40.343	28.248	40.270	28.122
A-estimate	37.497			

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

4.23 ñ50/40/10ò Open-Hole Compression3 (OHC3)

TheOHC3data /677.5 Tm [o02m -0.00312 Tc[luT1 42li 1 3z1 421 29d. 0 1 93re w1 0 ri4(s)-urs

Env	RTD	ETW2	RTD	ETW2
Mean	66.016	52.759	65.929	52.603
Stdev	1.308	1.652	1.350	1.460
CV	1.982	3.131	2.047	2.776
Modified CV	6.000	6.000	6.000	6.000
Min	63.411	49.810	63.450	49.202
Max	67.837	56.555	68.737	55.537
No. Batches	3	3	3	3
No. Spec.	22	21	22	21
B-basis Value	63.396	50.128	63.452	50.115
A-estimate	61.587	48.322	61.743	48.408
Method	pooled	pooled	pooled	pooled
B-basis Value	59.676	46.394	59.602	46.250
A-estimate	55.301	42.024	55.235	41.889
Method	pooled	pooled	pooled	pooled

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

Env

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

Filled-Hole Compression (FHC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	61.954	41.262	61.727	41.030
Stdev	2.092	1.558	2.070	1.527
CV	3.376	3.777	3.354	3.723
Modified CV	6.000	6.000	6.000	6.000
Min	57.690	39.055	57.455	38.669
Max	65.707	44.671	65.454	44.146
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	58.682	37.991		38.120
B-estimate			52.938	
A-estimate	56.434	35.742	46.664	36.046
Method	pooled	pooled	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-basis Value	56.352	35.660	56.150	35.452
A-estimate	52.502	31.810	52.316	31.619
Method	pooled	pooled	pooled	pooled

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

4.26 ñ50/40/10ò Filled-Hole Compression 3 (FHC3)

The FHC3 data is normalized. There were no test failures in the normalized datasets so pooling the two environmental conditions was acceptable. The measured ETW2 dataset failed the

4.27 ñ25/50/25ò Single-Shear Bearing 1 (SSB1)

The SSB1 data is normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. The ETW2 datasets, both normalized and as measured, for initial peak strength failed the Anderson Darling 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 ETW2 datasets were transformed according to the assumptions of the modified CV method, both normalized and as measured passed the ADK test, so the modified CV basis values are provided.

There were no other diagnostic test failures and no statistical outliers.

Statistics, estimates and basis values are given for the 2% offset strength data in Table 4-39, for the initial peak strength in Table 4-40, and for ultimate strength in Table 4-41. The normalized data and the B-basis values are shown graphically for the 2% offset strength data in Figure 4-28, for the initial peak strength in Figure 4-29, and for ultimate strength in Figure 4-30.

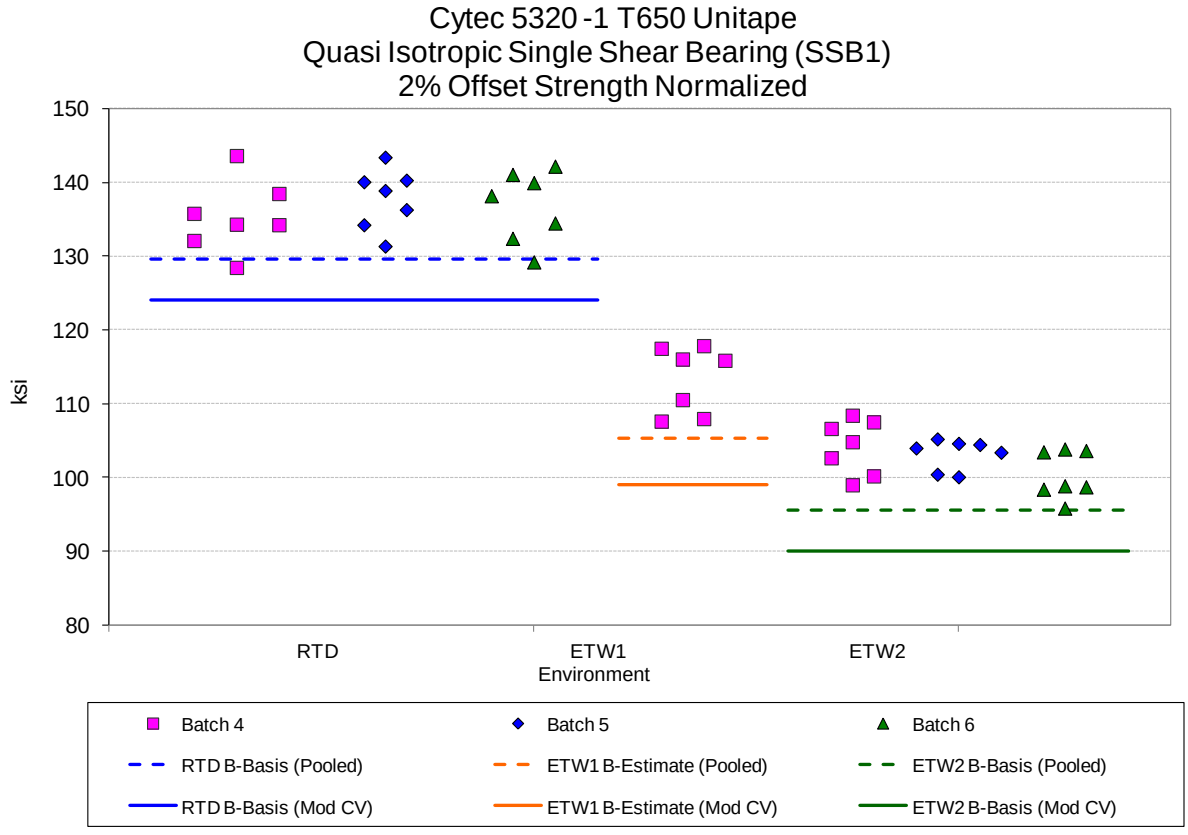

Figure 4-28: Batch plot for SS

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Figure 4-30: Batch plot for SSB1 ultimate strength normalized

Env	RTD	ETW1	ETW2	RTD	ETW1	ETW2
Mean	136.627	113.335	102.565	139.642	114.664	102.719
Stdev	4.488	4.487	3.332	3.555	4.501	3.625
CV	3.285	3.959	3.249	2.546	3.926	3.529
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	128.464	107.615				

Table 4-39: Statistics and Bas is Values for SS B1 2% Offset Strength data

Env	RTD	ETW1	ETW2	RTD	ETW2	RTD
Mean	135.155	114.633	101.299	138.099	115.963	101.461
Stdev	5.466	3.166	4.135	4.824	2.462	4.642
CV	4.044	2.762	4.082	3.493	2.123	4.575
Modified CV	6.022	6.000	6.041	6.000	6.000	6.287
Min	125.560	110.624	93.673	130.606	113.079	93.585
Max	144.899	119.555	107.830	149.632	119.851	110.949
No. Batches	3	1	3	3	1	3
No. Spec.	18	7	21	18	7	21
B-basis Value	124.363			128.575		
B-estimate		105.842	81.955		109.128	78.736
A-estimate	116.716	99.657	68.147	121.827	104.319	62.515
Method	Normal	Normal	ANOVA	Normal	Normal	ANOVA
B-basis Value	122.477		88.800	125.095		88.640
B-estimate		100.41(t)26(e)] TJ ET BT 1 0 0 284.85 69.758 Tmi(7)19(7)] T2A11(				

149 Tj ET 1

Table 4-40: Statistics and Basis Values for SSB1 Initial Peak

Figure 4-32: Batch plot for SSB2 ultimate strength normalized

Single Shear Bearing (SSB2) Strength Basis Values and Statistics								
	Normalized				As-measured			
	2% Offset		Ultimate		2% Offset		Ultimate	
Env	RTD	ETW2	RTD	ETW2	RTD	ETW2	RTD	ETW2
Mean	134.738	101.082	161.861	120.367	135.741	100.954	163.020	120.198
Stdev	3.395	3.065	7.635	4.924	4.266	3.510	7.335	4.906
CV	2.520	3.032	4.717	4.091	3.143	3.476	4.500	4.081
Modified CV	6.000	6.000	6.359	6.046	6.000	6.000	6.250	6.041
Min	127.426	93.513	140.545	114.344	123.515	93.443	145.460	114.038
Max	140.341	105.886	173.405	134.110	141.457	106.759	172.698	135.217
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21	21	21
Basis Values and Estimates								
B-basis Value	128.270		150.466	108.972	127.558		151.952	109.130
B-estimate		87.269				83.235		
A-estimate	123.659	77.410	142.634	101.140	118.587	70.587	144.345	101.523
Method	Normal	ANOVA	pooled	pooled	Weibull	ANOVA	pooled	pooled
Modified CV Basis Values and Estimates								
B-basis Value	122.062	88.406	146.052	104.558	123.011	88.224	147.328	104.506
A-estimate	113.351	79.695	135.187	93.693	114.262	79.475	136.544	93.722
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

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

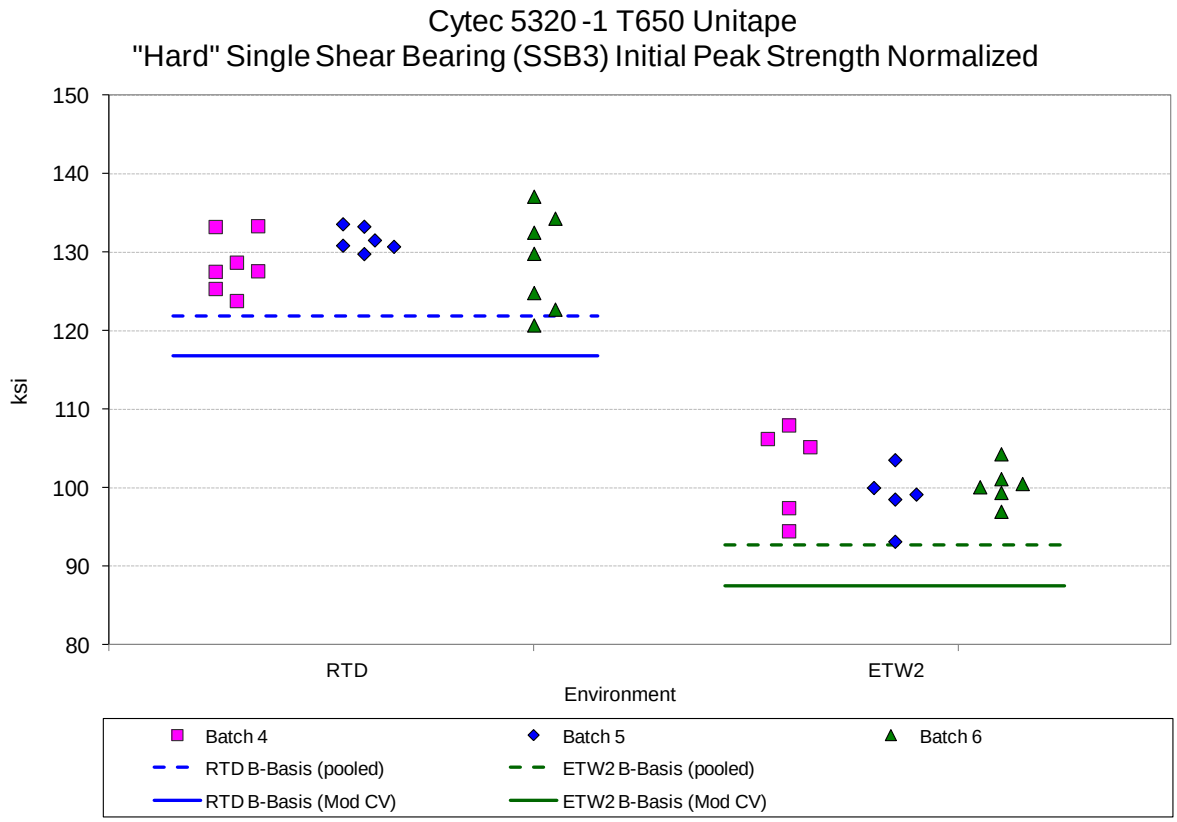

Figure 4-34: Batch plot for SSB3 Initial Peak S trength norm alized

Figure 4-35: Batch plot for SSB3 Ultimate S trength normalized

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

Env	RTD	ETW2	RTD	ETW2
Mean	129.575	100.496	130.664	100.224
Stdev				

Table 4

Env	RTD	ETW2	RTD	ETW2
Mean	145.805	120.521	146.834	120.150
Stdev	5.773	4.251	5.540	4.424
CV	3.959	3.527	3.773	3.682

Table 4-45: Statistics and Basis Values for SSB3 Ultimate Strength data

4.30 Compression After Impact 1 (CAI 1)

CAI1 data is normalized. There were no statistical 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 4-36.

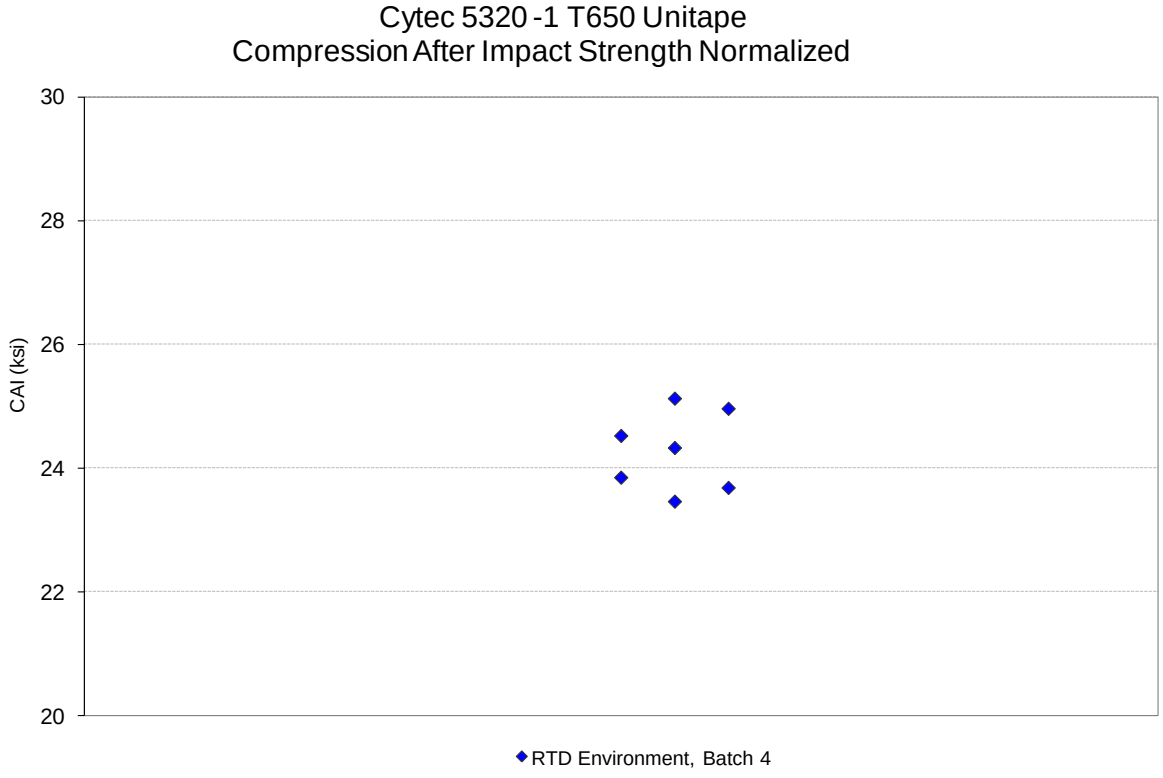

Figure 4-36: Plot for Compression After Impact strength normalized

Compression After Impact Strength (ksi)		
	Normalized	As-measured
Env	RTD	RTD
Mean	24.280	24.270
Stdev	0.639	0.576
CV	2.633	2.374
Modified CV	6.000	6.000
Min	23.466	23.549
Max	25.129	25.044
No. Batches	1	1
No. Spec.	7	7

Table 4-46: 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 statistical outliers. Basis values are not computed for these properties. However the summary statistics are presented in Table 4-47 and the data are displayed graphically in Figure 4-37.

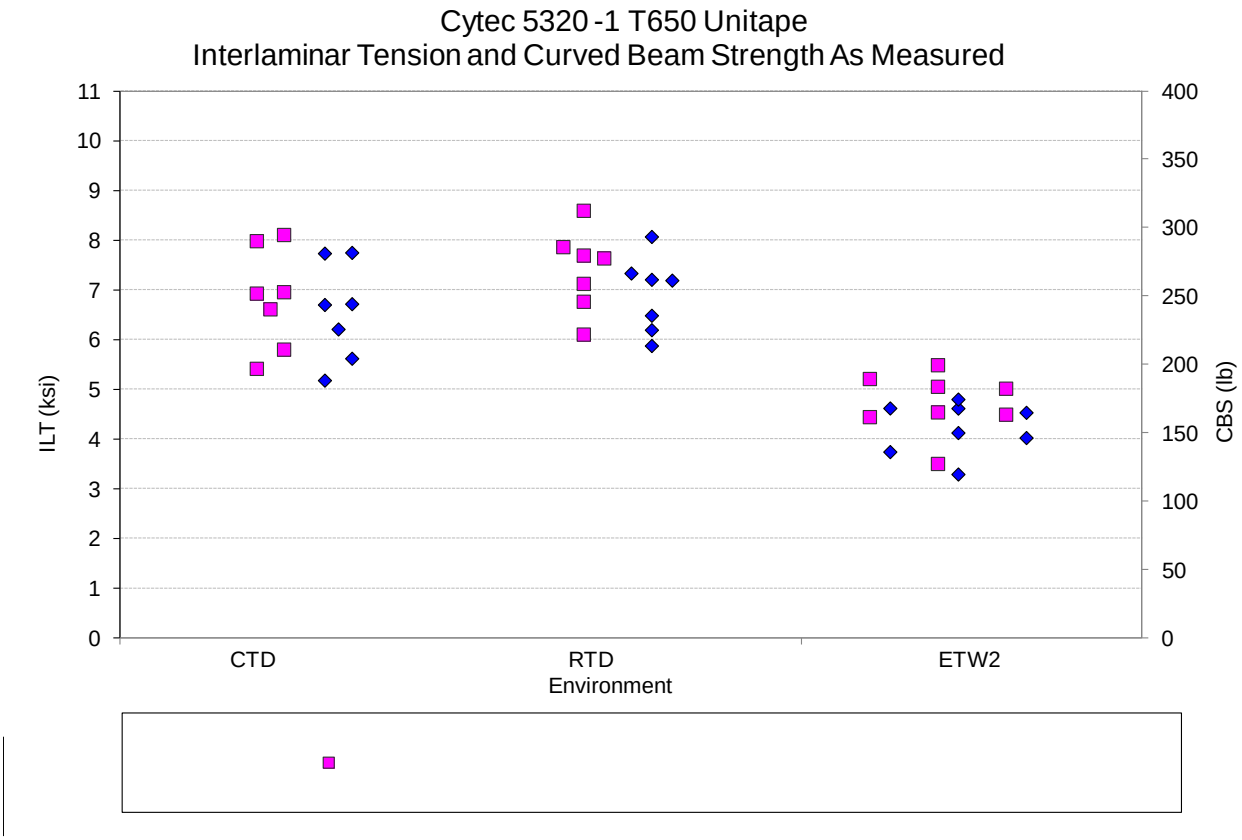

Figure 4-37: Plot for ILT and CBS as-measured

Property	Interlaminar Strength (ksi)			Curved Beam Strength (lb)		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	6.831	7.399	4.719	238.501	251.215	153.369
Stdev	1.008	0.811	0.618	35.617	27.612	18.895
CV	14.761	10.959	13.101	14.934	10.991	12.320
Mod CV	14.761	10.959	13.101	14.934	10.991	12.320
Min	5.416	6.106	3.502	188.327	213.670	119.620
Max	8.110	8.597	5.489	281.814	293.481	174.475
No. Batches	1	1	1	1	1	1
No. Spec.	7	7	8	7	7	8

Table 4-47: Statistics for ILT and CBS Strength data