CYTEC
(Formerly Advanced Composites Group)
MTM45-1/ 12K AS4 145gsm 32%RW
Unidirectional
Qualification Statistical Analysis Report

FAA Special Project Number SP3505WI-Q

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5HY	%\	'DWH	%\	3DJHV 5HYLVHG RU $GGHG
1 &	(OL]DEHWK &ODUNVR		5R\DO /RYLQJIRVV	'RFXPHQW ,QLWLDO 5HOHDVH
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%	(YHO\Q /LDQ		5R\DO /RYLQJIRVV	(GLWRULDO FKDQJHV 8SGDWHG UHIHUHQFH RI ³&0+ ³&0+ *´ 8SGDWHG ,36 GDWD IRU DOO FF DIIHFWHG VHXSGLRQH DQ 7DEO 3J 3J 3J 3J 3J DQG 3J)LJXUHV 3J DQG 3J 6HFWLRQ 3

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1. Introduction

This report contains statistical analysis of ACG MTM45-1/AS4-145-32%RW material property data published in ñMTM45-1 AS4 Data MH Cure Cycle.pdfò, available on the NCAMP website. The lamina and laminate material property data have been generated with FAA oversight through FAA Special Project Number SP3505WI-Q and also meet the requirements outlined in NCAMP Standard Operating Procedure NSP 100.

B-Basis values and A and B-basis estimates were computed using a variety of techniques that are detailed in section 2. Qualification material was procured in accordance with ACG material specification ACGM 1001-11. An equivalent NCAMP Material Specification NMS 451/11 which contains specification limits that are derived from guidelines in DOT/FAA/AR-03/19 has been created. The qualification test panels were fabricated per ACGP1001-02 using ñMHò cure cycle. An equivalent NCAMP Process Specification NPS 81451 with ñMHò cure cycle has been created. The panels were fabricated at Advanced Composites Group, 5350 E. 129th E. Ave. Tulsa, OK 74134 and Solvay, 1440 N Kraemer Blvd, Anaheim, CA 92806. The ACG Test Plan AI/TR/1392 was used for this qualification program. The mechanical testing was performed by ACG at their Tulsa, Oklahoma facility and National Institute for Aviation Research, Wichita State University, Wichita, KS 67260.

Basis numbers are labeled as óvaluesô when the data meets all the requirements of CMH-17-1G. When those requirements are not met, they will be labeled as óestimates.ô 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 Composite Materials Handbook 17 (CMH-17-1G).

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 equire ad ʻ tio o M я ʻ NCe l ɣ ɤ p ʞ b
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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

$$3\,R\,R\,O\,H\,G\;\;6\,W\,S_p\,G\;\;\sqrt{\frac{\sum_{i=1}^{k} n_i\;\;1\;\;S_i^2}{\sum_{i=1}^{k} n_i\;\;1}}$$

Where k refers to the number of batches and n_i refers to the number of specimens in the ith 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

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

$$f = N - r$$

$$q(f) = 1 \quad \frac{2.323}{\sqrt{f}} \quad \frac{1.064}{f} \quad \frac{0.9157}{f\sqrt{f}} \quad \frac{0.6530}{f^2} \qquad (\text{TXDWLRQ}$$

$$b_B(f) \quad \frac{1.1372}{\sqrt{f}} \quad \frac{0.49162}{f} \quad \frac{0.18612}{f\sqrt{f}} \qquad ($$

$$c_B(f) \quad 0.36961 \quad \frac{0.0040342}{\sqrt{f}} \quad \frac{0.71750}{f} \quad \frac{0.19693}{f\sqrt{f}} \qquad (\text{TXDWLRQ}$$

$$b_A(f) \quad \frac{2.0643}{\sqrt{f}} \quad \frac{0.95145}{f} \quad \frac{0.51251}{f\sqrt{f}}$$

$$c_A(f) \quad 0.36961 \quad \frac{0.0026958}{\sqrt{f}} \quad \frac{0.65201}{f} \quad \frac{0.011320}{f\sqrt{f}} \qquad (\text{TXDWLRQ}$$

2.1.4

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$$MNR \quad \frac{\max_{all\ i} \left| X_i \quad \bar{X} \right|}{S}, \ i \quad 1 \quad n$$

$$\sqrt{\ }$$

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2.2.1 Distribution tests

In addition to testing for normality using the Anderson-Darling test (see 2.1.7); Stat-17 also tests to see if the Weibull or Lognormal distribution is a good fit for the data.

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

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

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

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

Norm. Dist. k Factors for N<16F		
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

2.2.2.3.3 Basis value calculations for the Weibull distribution

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

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:

$$z_i \quad \frac{\ln x_i \quad \bar{x}_L}{s_L}, \quad \text{for } i \quad 1, \quad , n \qquad (\text{TXDWLRQ}$$

where $x_{(i)}$ is the ith 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 d0.05, 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 7.

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 m A -fes l ɜ ɤ ɹ
een

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.

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

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				

The following calculations address batch-to-batch variability.

Denote the ratio of mean squares by

$$u \quad \frac{MSB}{MSE}$$

/90 (VWLPDWHG $ %DVLV

2.5

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 CMH-17-1G. 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 CMH-17-1G 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 CMH-17-1G 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

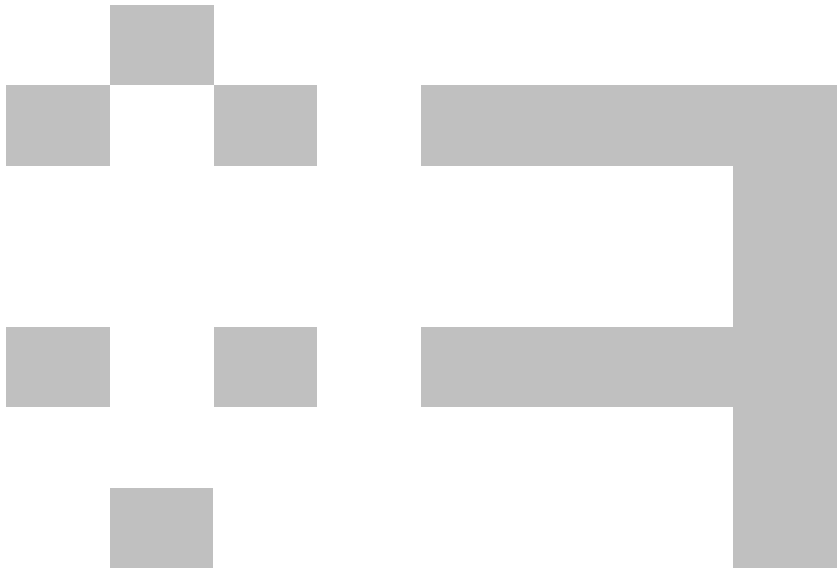
1&$03 5HFRPPHQGHG % EDVLV 9DOXHV IRU
$&* 070 $6 5: 8QLGLUHFWLRQDO
$OO %EDVLV YDOXHV LQ WKLV WDEOH WHVWHG LQ &0+:DQG*UDLQ2ULHQWHG&RPSRVLWH
9DOXHV DUH IRU QRUPDOL]HG GDWD XQOHVV RWKHUZLVH QRWHG
/DPLQD 6WUHQJWK 7HVWV

(QYLURQPHQW		77	7&			,36 2IIVHW6WUDLQ	
B-basis	232.65	207.81	NA: A	33.04	14.41	7.61	12.17
CTD (MWX u l'Mean	263.10	231.81	7.10	38.35	16.35	8.36	13.37
CV	6.99	7.02	14.77	7.00	6.00	6.00	6.00
B-basis	240.01	178.99	NA: A	24.26**	11.16	5.56	8.64
Mean	270.76	202.80	6.92	26.81	12.66	6.31	9.83
CV	6.64	7.68	17.47	4.93	6.00	6.00	6.00
B-basis					8.70	NA:I	NA:I
Mean					9.87	4.91	7.28
CV					6.00	1.68	1.07
B-basis	225.78	111.93	NA: A	13.15	7.32	3.71	5.44
Mean	256.69	135.73	3.99	14.96	8.31	4.16	6.11
CV	7.04	8.49	9.85	6.13	6.00	6.00	6.00
B-basis	237.12	114.32	NA: A	10.90	5.96	2.89	NA:I
Mean	268.04	138.12	3.26	12.30	6.83	3.24	4.79
CV	6.13	9.44	13.32	6.16	6.45	6.00	6.00

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

/ D P L Q D W H 6 W U H Q J W K 7 H V W V

B-basis	51.52	51.76	101.08
Mean	57.49	58.71	113.13
CV	6.00	6.00	6.00



3.2 Lamina and Laminate Summary Tables

Advanced Composites Group - MTM45-1 12K AS4-145 Unidirectional Tape
NMS 451/11 Material Specification
NPS 81451 Process Specification "MH" Cure Cycle

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Advanced Composites Group - MTM48 Ů p! MCG ‘ M · ξ

4.

4.1 Longitudinal (0º) Tension Properties (LT)

The normalized LT data meets all CMH-17-1G requirements for B-basis values. The LT data met all requirements for pooling across all environments.

The as measured LT data could also be pooled across all environments. While the CTD and RTD environments failed the normality test, the pooled dataset passed.

There were four outliers in the LT data. There was one outlier in the RTD condition data. It was an outlier for both the as measured and normalized data. It was on the low side of batch two and was an outlier for the RTD condition but not for batch two. There were two outliers in the ETW condition data. One outlier was on the high side of batch two for the as measured data only. It was an outlier for batch two, but not for the ETW condition. The second outlier in the ETW data was on the low side of batch three. It was an outlier for both the normalized and as measured data. It was an outlier for the ETW condition, but not for batch three. The fourth outlier in the LT data was in the ETW2 condition. It was an outlier only for the as measured data. It was on the low side of batch two and was an outlier for both batch two and the ETW2 condition. All om l e M p γ D ɹ ʻ ʻ d ® ɧ

(QY &7' 57' (7: (7: &7' 57' (7: (7:
0 H D Q
6W G H Y
& 9
0 R G & 9
0 L Q
0 D [
1 R % D W F K H

4.2 Transverse (90º) Tension Properties (TT)

Transverse Tension data is not normalized because it is not a fiber dominated property for unidirectional tape. The strength data could not be pooled as all four conditions failed the ADK test. In addition, all environments have such a large coefficient of variation that the modified CV method would have no effect. This means those datasets require the ANOVA method and with data from less than five batches available it is an estimate only and may result in overly conservative basis values. An override of the ADK test results is not appropriate due to the batches showing trends across the environments; batch two has lowest mean for all four environments while batch three has the highest mean for all for environments. Estimates were also computed using the normal distribution method, but caution is advised with these estimates. There were no outliers.

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

4.3

/RQJLWXGLQDO &RPSUHVVLRQ 6WUHQJWK NVL								
1RUPDOL]HG					$V 0HDVXUHG			
(QY	&7'	57'	(7:	(7:	&7'	57'	(7:	(7:
0HDQ								
6WGHY								
&9								
0RG &9								
0LQ								
0D[								
1	R			%	D	W	F	K H
1	R			6	S	H	F	
%DVLV 9DOXHV DQG RU (VWLPDWHV								
% EDVLV 9DOXH								
$ HVWLPDWH								
0HWKRG	SRROHG	SRROHG	SRROHG	SRROHG	SRROHG	SRROHG	SRROHG	SRROHG
0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV								
% EDVLV 9DOXH								
$ HVWLPDWH								
0HWKRG	SRROHG	SRROHG	SRROHG	SRROHG	SRROHG	SRROHG	SRROHG	SRROHG

7DEOH 6WDWLVWLFV DQG %RUD/&L 6WUHQJWK GDWD

/RQJLWXGLQDO &RPSUHVVLRQ 0RGXOXV PVL								
1RUPDOL]HG					$V 0HDVXUHG			
(QY	&7'	57'	(7:	(7:	&7'	57'	(7:	(7:
0HDQ								
6WGHY								
&9								
0RG &9								
0LQ								
0D[								
1	R			%	D	W	F	K H
1R 6SHF								

7DEOH 6WDWLVWLFV IURP /& PRGXOXV GDWD

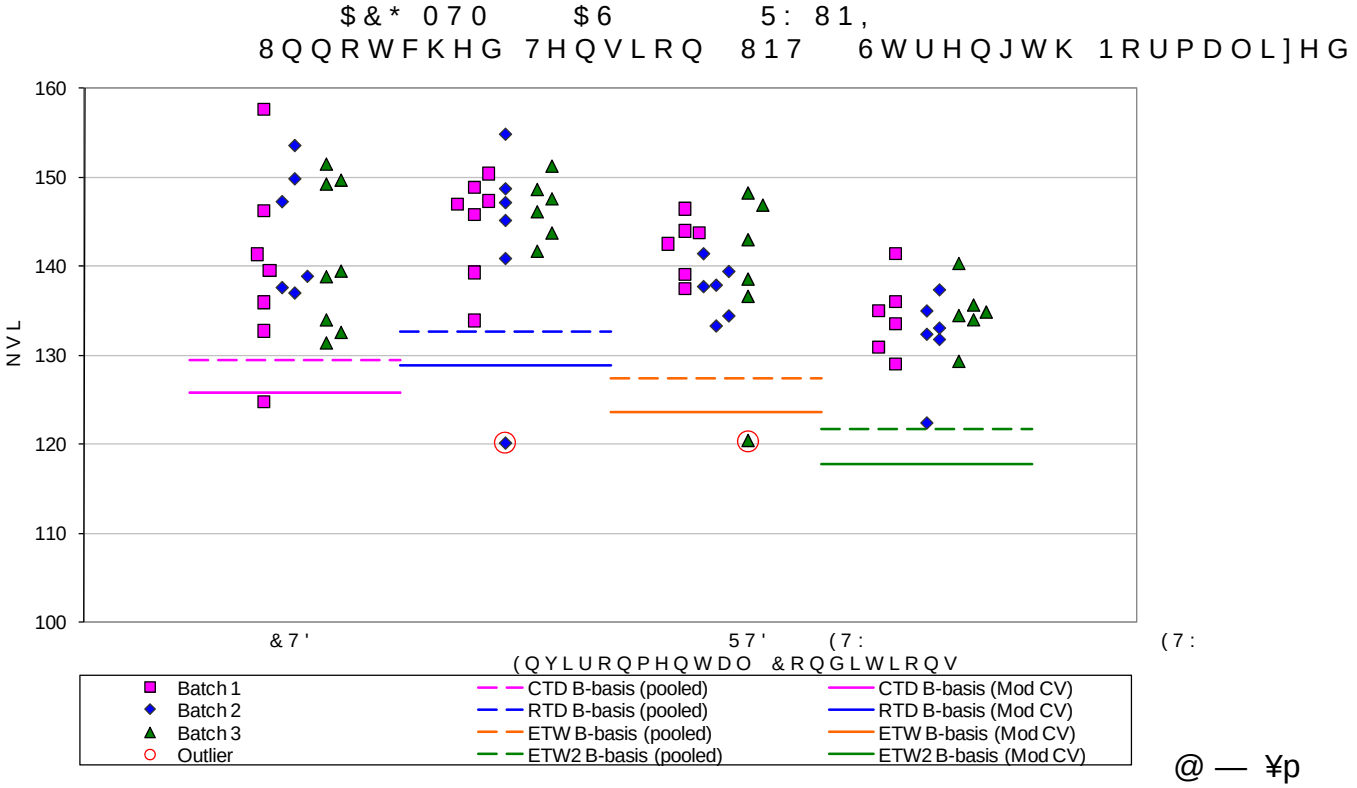
(QY &7' 57' (7: (7: &7' 57' (7: (7:
0 H D Q
6 W G H Y
& 9
0 R G & 9
0 L Q
0 D [
1 R % D W F K H

4.5 Unnotched Tension Properties (UNT0)

Pooling across the environments was acceptable for both the normalized and the as measured data. The normalized and the as measured RTD data and the as measured CTD data did not pass the normality test, but the pooled dataset for both the normalized and the as measured data did pass the normality test.

There were four outliers in the LT data. There was one outlier in the RTD condition data. It was an outlier for both the as measured and normalized data. It was on the low side of batch two and was an outlier for both batch and condition in the normalized data. It was an outlier for the condition, but not the batch in the as measured data. There were two outliers in the ETW condition data. One outlier was on the high side of batch two for the as measured data only. It was an outlier for batch two, but not for the ETW condition. The second outlier in the ETW data was on the low side of batch three. It was an outlier for both the normalized and as measured data. It was an outlier for the ETW condition, but not for batch three. The fourth outlier in the LT data was in the ETW2 condition. It was an outlier only for the as measured data. It was on the low side of batch two and was an outlier for both batch two and the ETW2 condition. All four outliers were retained for this analysis.

Statistics and basis values are given for the UNT0 strength data in Table 4-7 and for the modulus data in Table 4-8. The normalized data and the B-basis values are shown graphically in Figure 4-5.



@ — ¥p

(QY &7' 57' (7: (7: &7' 57' (7: (7:
0HDQ
6WGHY
&9
0RGLILHG &9
0LQ
0D[
1 R % D W F K H
1 R 6 S H F

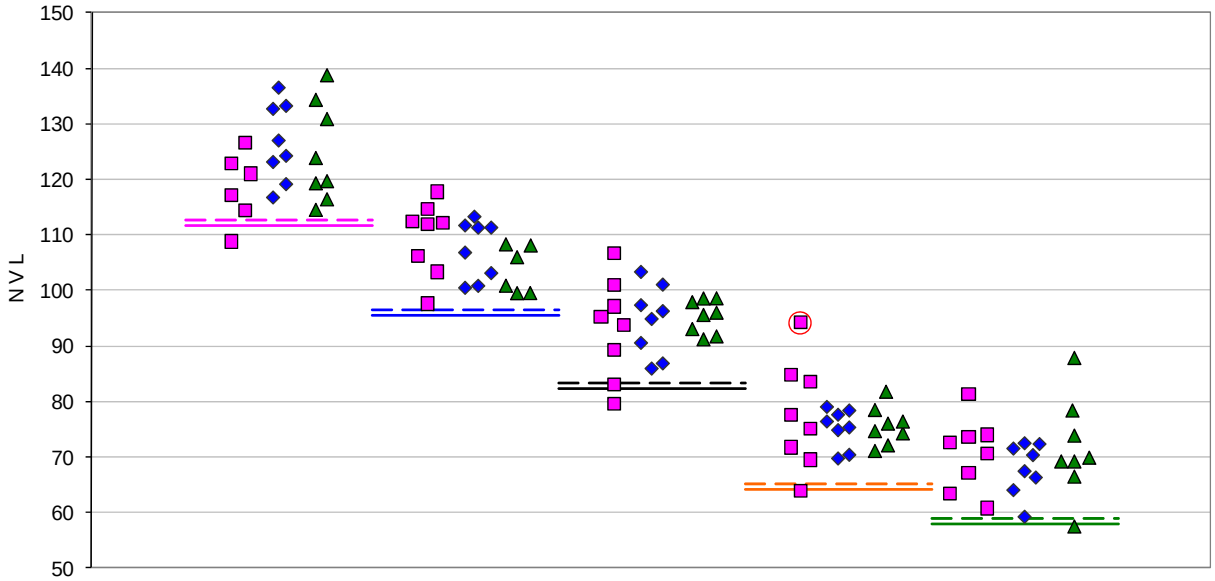
% EDVLV 9DOXH
$ HVWLPDWH
0HWKRG SRROHG SRROHG SRROHG SRROHG SRROHG SRROHG

% EDVLV 9DOXH
$ HVWLPDWH €

4.6 Unnotched Compression Properties (UNC0)

The UNC0 normalized strength data meets all CMH-17-1G requirements for pooling. There was one outlier in batch one on the high side in the ETW environment. It was an outlier after pooling for the ETW condition, but not batch one. It was an outlier in both the normalized and as measured data. It was retained for this analysis.

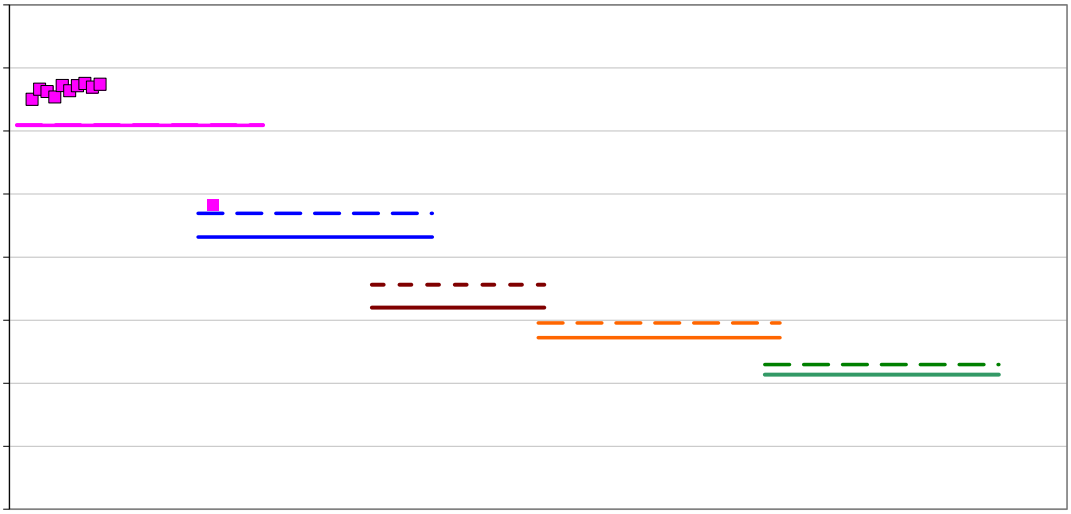
Statistics and basis values are given for the UNC0 strength data in Table 4-9. Statistics for the modulus data are given in Table 4-10. The normalized data and the B-basis values are shown graphically in Figure 4-6.



4.7 In-Plane Shear Properties (IPS)

The In-Plane Shear data is not normalized. Data is reported on three properties: 0.2% Offset Strength, Strength at 5% Strain and Modulus. The ETD condition lacks sufficient specimens to compute B-basis values so only B-estimates are provided for that condition.

The 0.2% Offset Strength (RTD) and Strength at 5% Strain (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-17-1G guidelines required using the



,Q 3ODQH 6KHDU ,36 6WUHQJWK DW 6WUDLQ NVL					
(QY	&7'	57'	(7'	(7:	(7:
0HDQ					
6WGHY					
&9					
0RG &9					
0LQ					
0D[					
1R %DWFKHV					
1	R			6	S H F
%DVLV 9DOXHV DQG RU (VWLPDWHV					
% EDVLV 9DOXH					
% HVWLPDWH					
$ HVWLPDWH					
0HWKRG	129	129	1RUPDO	1RUPDO	1RUPDO
0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV					
% EDVLV 9DOXH					
% HVWLPDWH					
$ HVWLPDWH					
0HWKRG	SRROHG	SRROHG	1RUPDO	1RUPDO	1RUPDO

7DEOH 6WDWLVW9DOXHVGIRUDV36 6WUHQJWKGDW

,Q 3ODQH 6KHDU ,36 2IIVHW 6WUHQJWK NVL					
(QY	&7'	57'	(7'	(7:	(7:
0HDQ					
6	W	G	H	Y	
&9					
0RG &9					
0	L	Q			
0	D	[			
1R %DWFKHV					
1	R			6	S H F
%DVLV 9DOXHV DQG RU (VWLPDWHV					
% EDVLV 9DOXH					
% HVWLPDWH					
$ HVWLPDWH					
0HWKRG	1RUPDO	129	1RUPDO	1RUPDO	1RUPDO
0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV					
% EDVLV 9DOXH					
% HVWLPDWH					
$ HVWLPDWH					
0HWKRG	SRROHG	SRROHG	1RUPDO	1RUPDO	1RUPDO

7DEOH 6WDWLVW9DOXHVGIRUDV36 HQJIWKWD6WU

,Q 3ODQH 6KHDU ,36 0RGXOXV 0VL					
(QY	&7'	57'	(7'	(7:	(7:
0HDQ					
6WGHY					
&9					
0RG &9					
0LQ					
0D[					
1R %DWFKHV					
1	R			6	S H F

7DEOH 6WDWLVWLFV RI 0RGXOXV GDWD

4.8

6KRUW %HDP 6WUHQJWK 6%6 DV PHDVXUHG NVL

Env	&7'	57'	(7'	(7:	(7:
0HDQ					
6	W	G	H	Y	
&9					
0RG &9					
0LQ					
0D[					
1R %DWFKHV					
1	R		6	S	H F

% EDVLV 9DOXH

% HVWLPDWH

$ HVWLPDWH

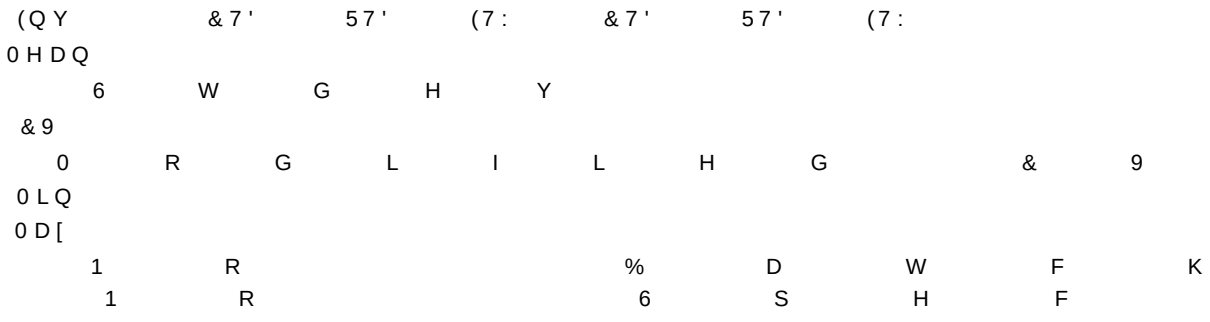
0HWKRG	1RUPDO	129	1RUPDO	129	129

% EDVLV 9DOXH

$ HVWLPDWH

0HWKRG	1RUPDO	1RUPDO	1RUPDO	1RUPDO	1RUPDO

(QY &7' 57' (7: &7' 57' (7:
0HDQ
6 W G H Y


(Q Y & 7 ' 5 7 ' (7 : & 7 ' 5 7 ' (7 :
0 H D Q
6 W G H Y
& 9
0 R G L I L H G & 9
0 L Q
0 D [
1 R % D W F K
1 R 6 S H F

5.1.3 “Hard” Unnotched Tension (UNT3)

This property had data from only

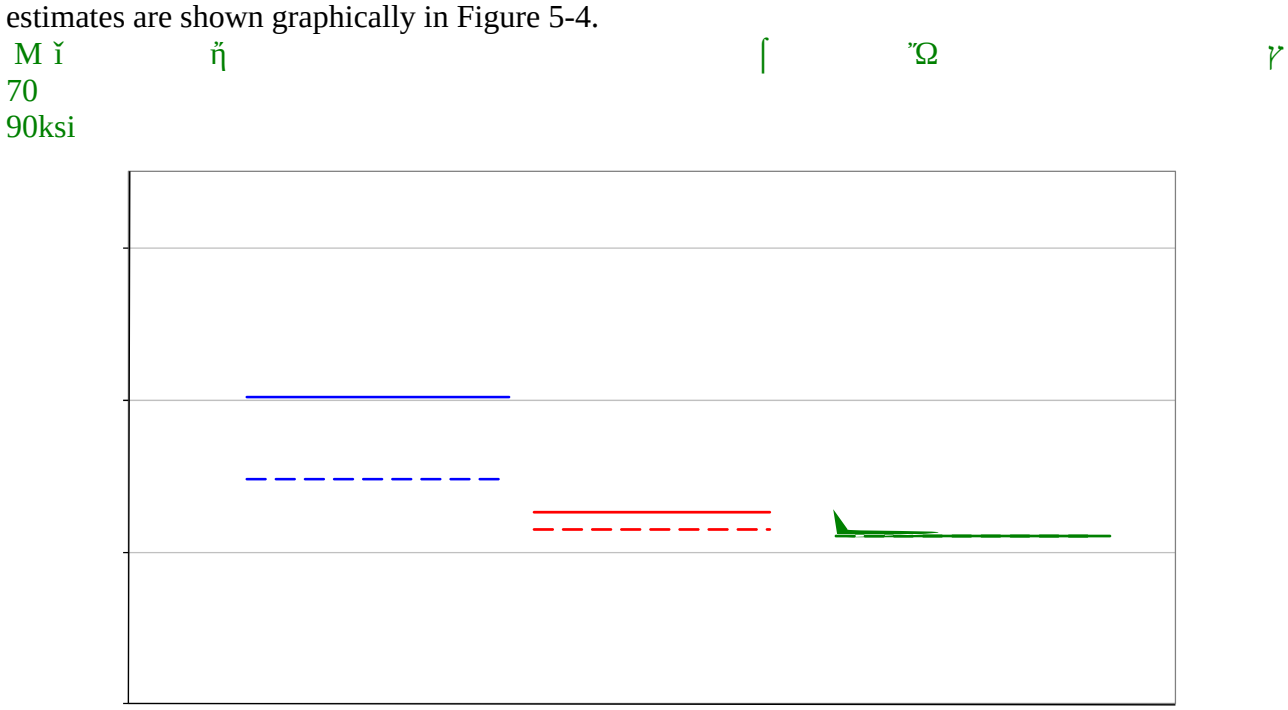
(QY &7' 57' (7: &7' 57' (7:
0HDQ
6WGHY
&9
0RG &9
0LQ
0D[

5.2 Unnotched Compression Properties

5.2.1 Quasi Isotropic Unnotched Compression (UNC1)

The UNC1 as measured strength data could be pooled, but the UNC1 normalized strength data could not be pooled because the normalized data from the RTD environment did not pass the ADK test and required an ANOVA analysis. Since ANOVA is not recommended for samples with fewer than 5 batches, these values are considered estimates and may be overly conservative. However, under the assumptions of the modified CV, the data from the RTD environment passed the ADK test and pooling was permissible. The ETW environment only had data from one batch available and thus is an estimate.

There were no outliers. Statistics and basis values are given for the strength data in Table 5-7 and the modulus data in Table 5-8. The normalized strength data, B-basis values and B-estimates are shown graphically in Figure 5-4.



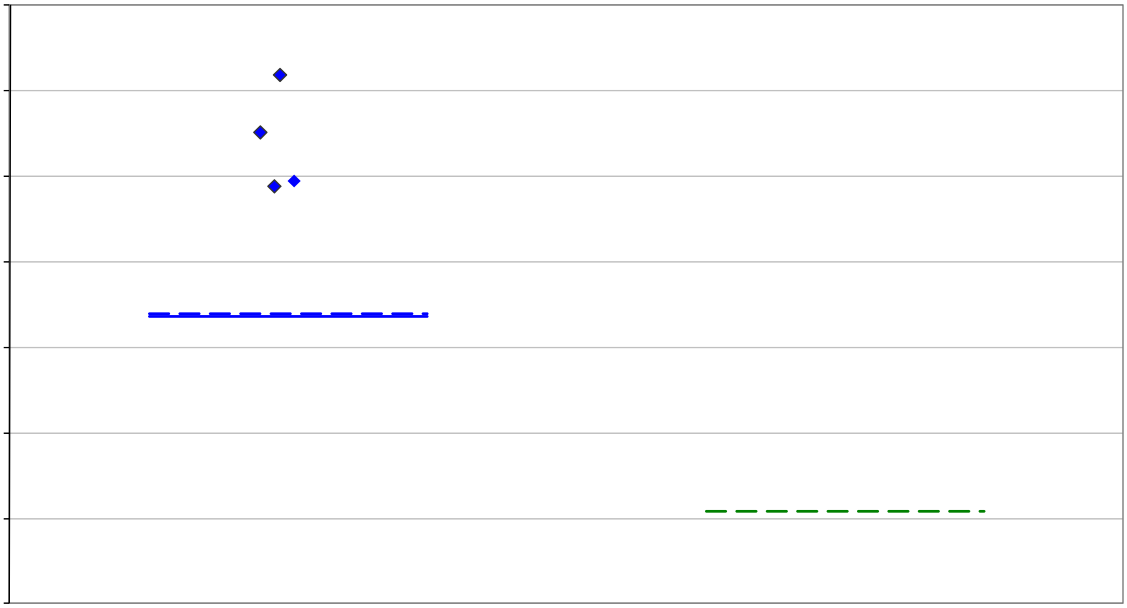
/DPLQDWH 8QQRWFKHG &RPSUHVVLRQ 81& 6WUHQJWK NV						
1RUPDOL]HG				$V 0HDVXUHG		
(QY	57'	(7:	(7:	57'	(7:	(7:
0HDQ						
6	W	G	H	Y		
&9						
0	R	G L	I	L	H	G & 9
0LQ						
0D[						
1	R			%	D	W F K
1	R			6	S	H F
%DVLV 9DOXHV DQG RU (VWLPDWHV						
% EDVLV 9DOXH						
% HVWLPDWH						
$ HVWLPDWH			1$			
0HWKRG	129	/90	1RUPDO	SRROHG	SRROHG	SRROHG
0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV						
% EDVLV 9DOXH						
% HVWLPDWH						
$ HVWLPDWH						
0HWKRG	SRROHG	SRROHG	SRROHG	SRROHG	SRROHG	SRROHG SF

7DEOH 6WDWLVWLFDO 9DOXHV DQG %DVLV IRU 6WUHQJWK GDWD

/DPLQDWH 8QQRWFKHG &RPSUHVVLRQ 81& 0RGXOXV PVL						
1RUPDOL]HG				$V 0HDVXUHG		
(QY	57'	(7:	(7:	57'	(7:	(7:
0HDQ						
6	W	G	H	Y		
&9						
0RG &9						
0	L	Q				
0	D	[				
1	R			%	D	W F K
1	R			6	S	H F

5.2.2 "Soft" Unnotched Compression (UNC2)

This property had data from only one batch available, thus all basis values are estimates. Modified CV values are not available for the ETW2 condition due to the large CV of the LC lamina data for the ETW2 condition which was used to compute the LVM B-estimate. Statistics and B-estimates are given for the strength data in Table 5-9 and the modulus data in Table 5-10. The normalized strength data and B-estimates are shown graphically in Figure 5-5.



/DPLQDWH 8QQRWFKHG &RPSUHVVLRQ 81& 6WUHQJWK N				
1RUPDOL]HG			$V 0HDVXUHG	
(QY	57'	(7:	57'	(7:
0HDQ				
6	W	G	H	Y
&9				
0	R	G L	I	L H G &
0LQ				
0D[				
1R %DWFKHV				
1R 6SHF				
%DVLV 9DOXHV DQG RU (VWLPDWHV				
% HVWLPDWH				
0HWKRG	/90	/90	/90	/90
0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV				
% HVWLPDWH			1$	1$
0HWKRG	/90	1$	/90	1$

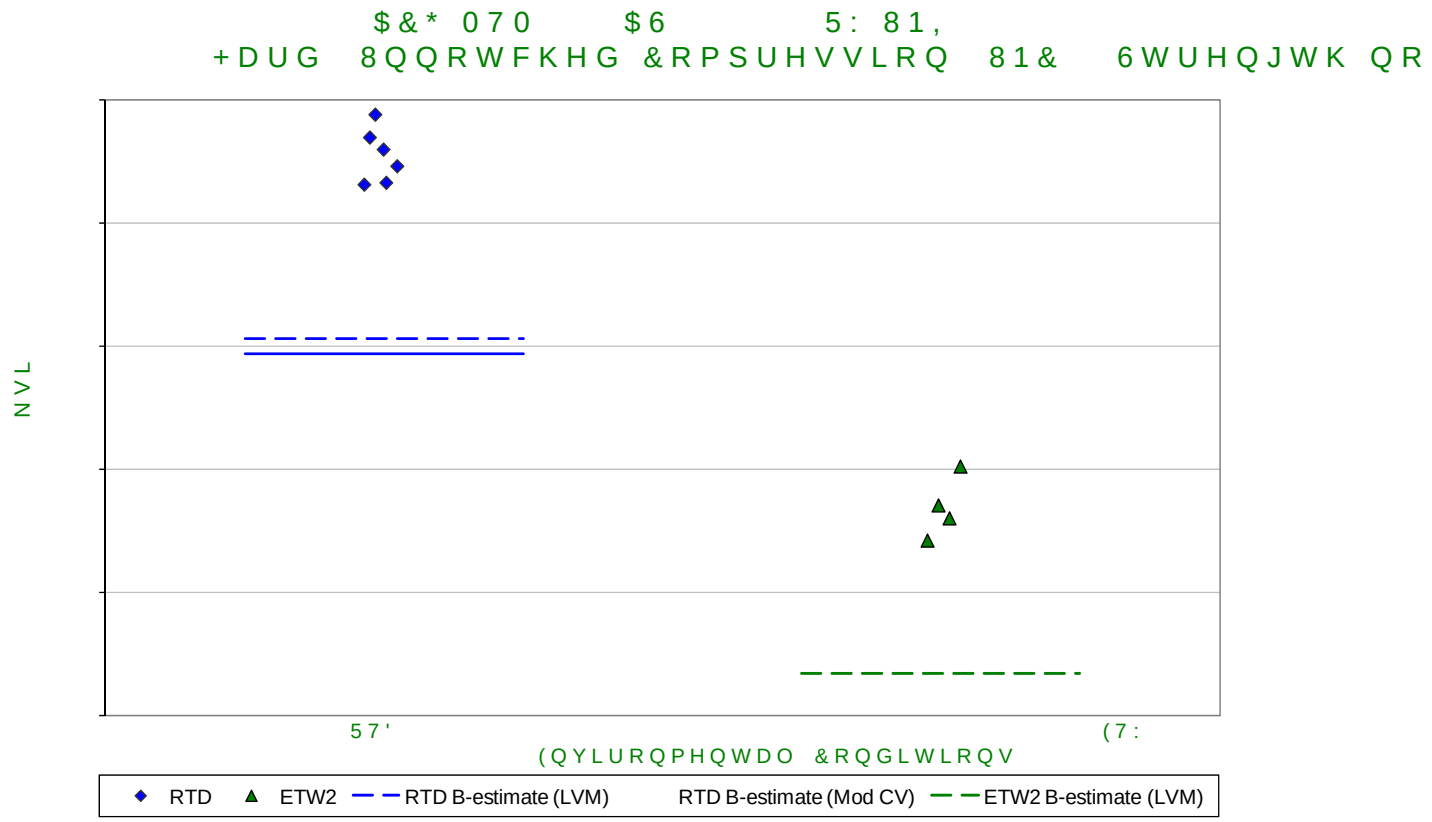
7DEOH 6WDWLVWLFV 9DOXHV GRU %DVLV 6WUHQJWK GDWD

/DPLQDWH 8QQRWFKHG &RPSUHVVLRQ 81& 0RGXOXV PVL				
1RUPDOL]HG			$V 0HDVXUHG	
(QY	57'	(7:	57'	(7:
0HDQ				
6	W	G	H	Y
&9				
0RG &9				
0	L	Q		
0	D	[		
1R %DWFKHV				
1R 6SHF				

7DEOH 6WDWLVWLFV 9DOXHV GRU %DVLV 6WUHQJWK GDWD

5.2.3 "Hard" Unnotched Compression (UNC3)

60 This property had data from only one batch available, thus all basis values are estimates. Modified CV values are not available for the ETW2 condition due to the large CV of the LC lamina data for the ETW2 condition which was used to compute the LVM B-estimate. Statistics and B-estimates are given for the strength data in Table 5-11 and the modulus data in Table 5-12. The normalized strength data and B-estimates are shown graphically in Figure 5-6.



/DPLQDWH 8QQRWFKHG &RPSUHVVLRQ 81& 6WUHQJWK NV				
1RUPDOL]HG			$V 0HDVXUHG	
(QY	57'	(7:	57'	(7:
0HDQ				
6WGHY				
&9				
0RGLILHG &9				
0LQ				
0D[				
1R %DWFKHV				
1R 6SHF				
%DVLV 9DOXHV DQG RU (VWLPDWHV				
% HVWLPDWH				
0HWKRG	/90	/90	/90	/90
0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV				
% HVWLPDWH			1$	1$
0HWKRG	/90	1$	/90	1$

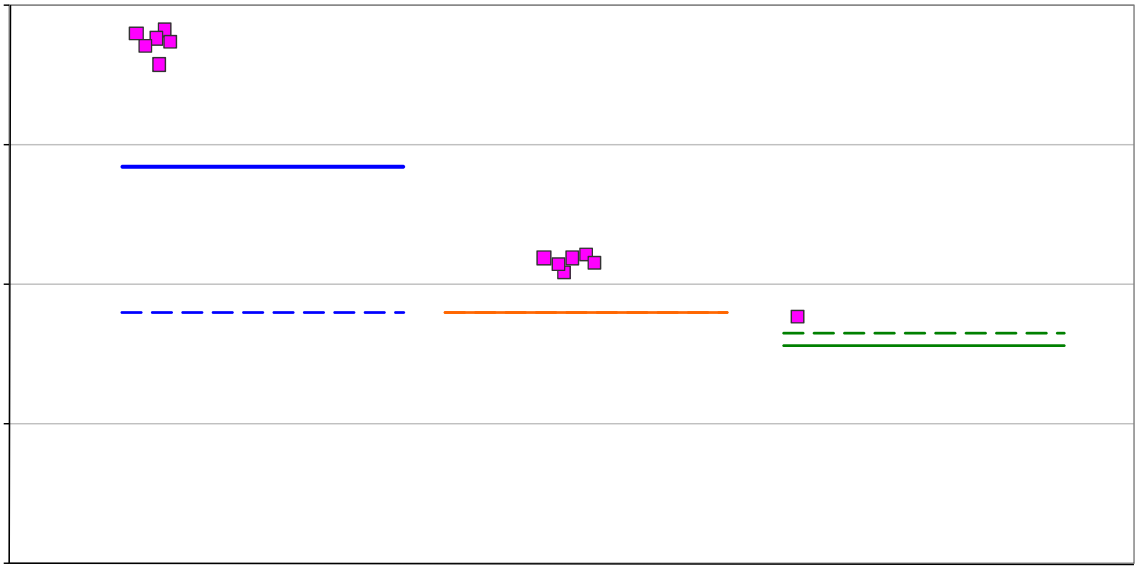
7DEOH 6WDWLVWLFDO 9DOXHV &RPSDULVRQ 6WUHQJWK GDWD

/DPLQDWH 8QQRWFKHG &RPSUHVVLRQ 81& 0RGXOXV PVL				
1RUPDOL]HG			$V 0HDVXUHG	
(QY	57'	(7:	57'	(7:
0HDQ				
6WGHY				
&9				
0RG &9				
0LQ				
0D[				
1R %DWFKHV				
1R 6SHF				

5.3 Laminate Short Beam Shear Properties (LSBS)

The LSBS data is not normalized. Only the data for the ETW2 condition meets all requirements of CMH-17-1G. The RTD data does not pass the ADK test, even after the transformation to fit the assumptions of the modified CV approach. It required an ANOVA analysis and since ANOVA is not recommended for samples with fewer than 5 batches, these values are considered estimates and may be overly conservative. B-estimates computed using the modified CV method are provided for the RTD environment.

There was insufficient data for the ETW condition. There were no outliers. Statistics, basis values and estimates are given for the LSBS data in Table 5-13. The strength data, B-basis values and B-estimates are shown graphically in Figure 5-7.



/DPLQDWH 6KRUW %HDP /6%6 6WUHQJWK NVL

(QY	57'	(7:	(7:
0HDQ			
6	W	G	H
&9			
0RG &9			
0	L	Q	
0D[			
1R %DWFKHV			
1	R		

Y

6 S H F

%DVLV 9DOXHV DQG RU (VWLPDWHV

% EDVLV 9DOXH	
% HVWLPDWH	
$ HVWLPDWH	1$
0HWKRG	129 /90 1RUPDO

0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV

% EDVLV 9DOXH			
% HVWLPDWH			
$ HVWLPDWH		1$	
0HWKRG	1RUPDO	/90	1RUPDO

5.4 Open Hole Tension Properties

5.4.1 Quasi Isotropic Open Hole Tension (OHT1)

The as measured OHT1 strength data met all requirements for pooling across environments, but the normalized OHT1 strength data could not be pooled because the RTD data failed the Anderson-Darling k-sample test for batch to batch variability. Since the RTD data failed the ADK test it requires the ANOVA method to compute basis values, but with data from only three batches, these values are considered estimates and may result in overly conservative basis values. The normalized RTD data does pass the normality test and passed the ADK test under the modified CV transformation, so the modified CV values are provided. There was insufficient data for the ETW condition so only estimates are provided.

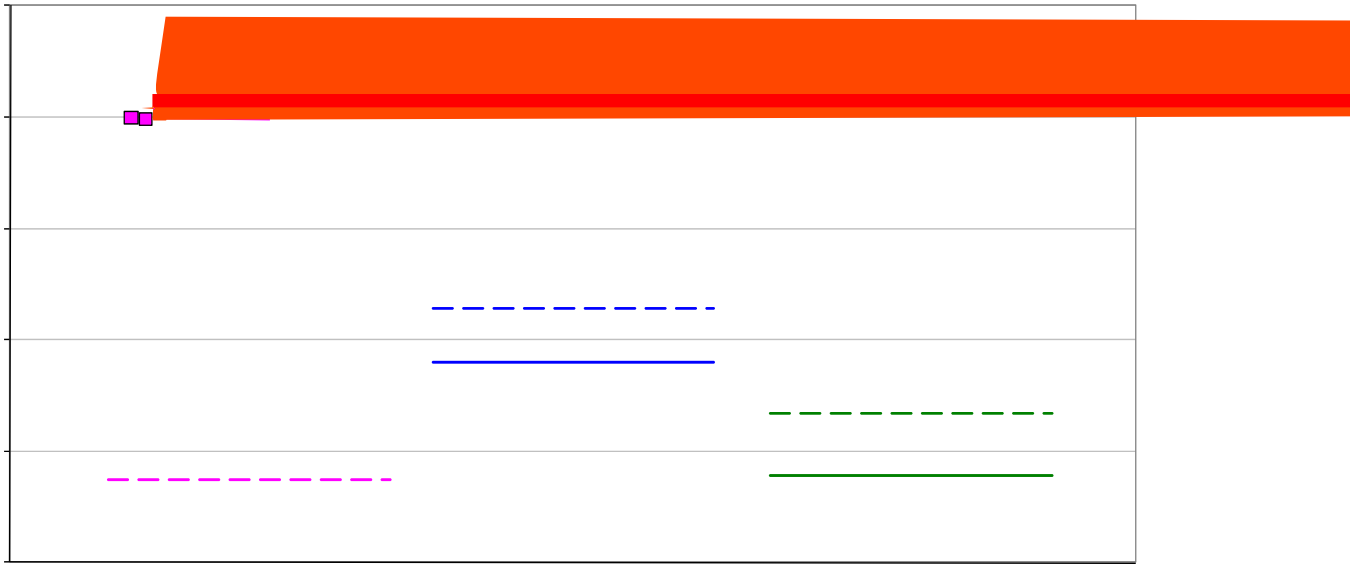
There was an outlier on the high side of batch one of the ETW2 data. The normalized value was an outlier both for batch one and for the ETW2 condition while the as measured value was only an outlier for batch one. There was an outlier on the high side of batch two of the as measured RTD data. It was an outlier only for batch two and not for the RTD condition.

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

5.4.2 "Soft" Open Hole Tension (OHT2)

The data from the CTD condition, both normalized and as measured, did not pass the ADK test or the normality test. Since the CTD data failed the ADK test it requires the ANOVA method to compute basis values, but with data from only three batches, these values are considered estimates and may result in overly conservative basis values. Since the CTD data fails the normality test, modified CV estimates of basis values cannot be provided. The RTD and ETW2 environments had insufficient data for publication in the handbook, so only estimates are provided.

There was one outlier on the low side of batch one in the normalized CTD data. It was an outlier only for batch one, not for the CTD condition. Statistics, A- and B-estimates are given for the strength data in Table 5-15. The normalized strength data and B-estimates are shown graphically in Figure 5-9.

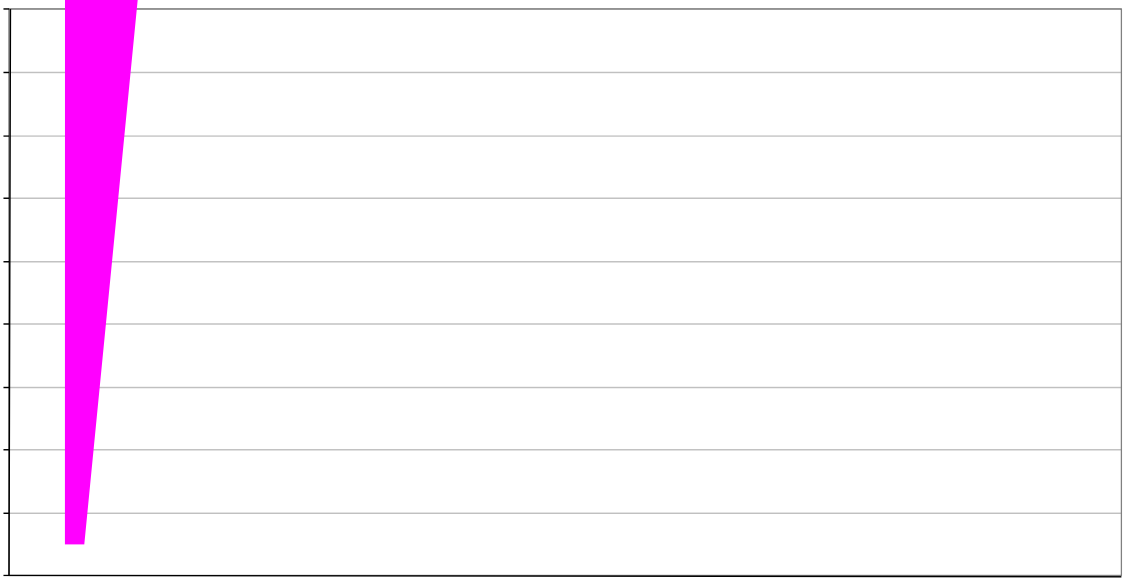


/DPLQDWH 2SHQ +ROH 7HQVLRQ 2+7 6WUHQJWK NVL						
1RUPDOL]HG				$V 0HDVXUHG		
(QY	&7'	57'	(7:	&7'	57'	(7:
0HDQ						
6	W	G	H	Y		
&9						
0	R	G L	I	L	H	G & 9
0LQ						
0D[						
1	R			%	D	W F K
1	R			6	S	H F
%DVLV 9DOXHV DQG RU (VWLPDWHV						
% HVWLPDWH						
$ HVWLPDWH			1$	1$		1$ 1$
0HWKRG	129	/90	/90	129	/90	/90
0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV						
% HVWLPDWH		1$			1$	
$ HVWLPDWH		1$	1$	1$	1$	1$ 1$
0HWKRG	1$	/90	/90	1$	/90	/90

5.4.3 "Har Hole Tension (OHT3)

Only the CTD eets the requirements of CMH-17-1G. The normalized CTD data did not pass the ADK t requires the ANOVA method to compute basis values, but with data from only three ba ese values are considered estimates and may result in overly conservative basis values. r, the normalized CTD data did pass the ADK test after the modified CV transform and ed CV basis values are provided.

The RTD and environments had insufficient data for publication in the handbook, so only estimates are ed. There were no outliers. Statistics, basis values and estimates are given for the streng in Table 5-16. The normalized strength data, B-basis values and B-estimates are graphically in Figure 5-10.



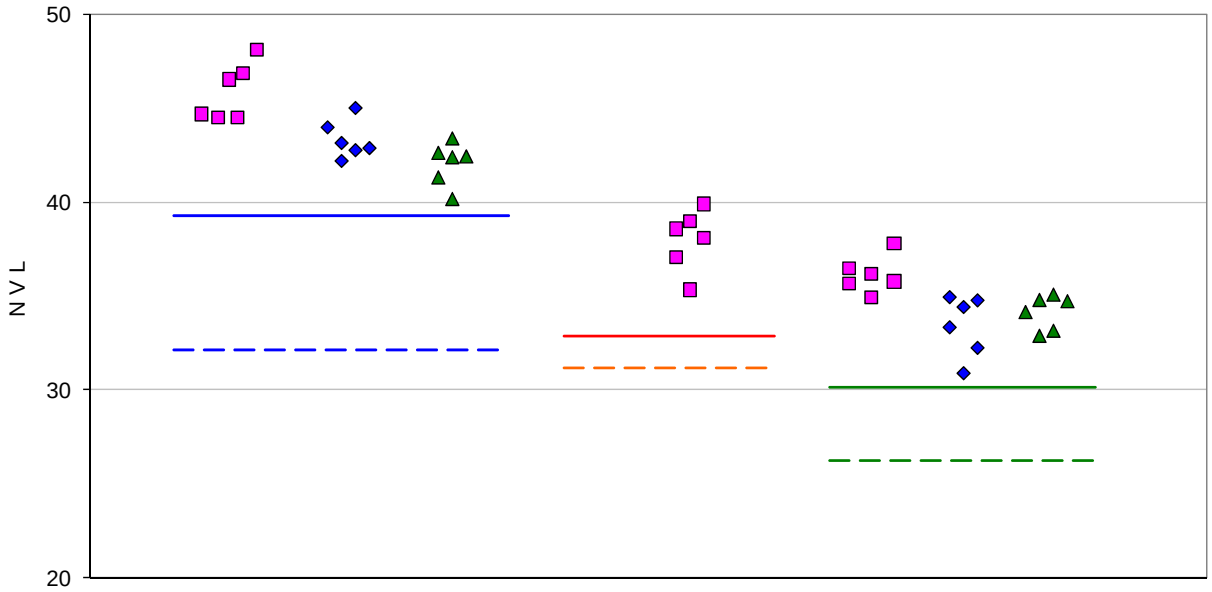
(QY &7' 57' (7: &7' 57' (7:
0HDQ
6WGHY
&9
0RGLILHG &9
0LQ
0D[
1 R % D W F K
1 R 6 S H F
% EDVLV 9DOXH

5.5 Open Hole Compression Properties

5.5.1 Quasi Isotropic Open Hole Compression (OHC1)

The normalized RTD and ETW2 data did not pass the ADK test and required an ANOVA analysis to compute basis values, but with data from only three batches, these values are considered estimates and may result in overly conservative basis values.. However, those datasets did pass the ADK test after the modified CV transform and modified CV basis values are provided. Pooling was acceptable for the modified CV approach. The ETW condition has insufficient data for publishable basis values. Estimates only are provided.

There were no outliers. Statistics, basis values and estimates are given for the strength data in Table 5-17 . The normalized strength data, B-basis values and B-estimates are shown graphically in Figure 5-11.



/DPLQDWH 2SHQ +ROH &RPSUHVVLRQ 2+& 6WUHQJWK NV

1RUPDOL]HG $V 0HDVXUHG

(QY	57'	(7:	(7:	57'	(7:	(7:
0HDQ						
6 W G H Y						
&9						
0 R G L I L H G &9						
0LQ						
0D[						
1 R %D W F K						
1 R 6 S H F						

%DVLV 9DOXHV DQG RU (VWLPDWHV

% EDVLV 9DOXH						
% HVWLPDWH						
$ HVWLPDWH		1$				
0HWKRG	129	/90	129	SROHG	SROHG	SROHG

0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV

% EDVLV 9DOXH						
% HVWLPDWH						
$ HVWLPDWH						
0HWKRG	SROHG	SROHG	SROHG	SROHG	SROHG	SR

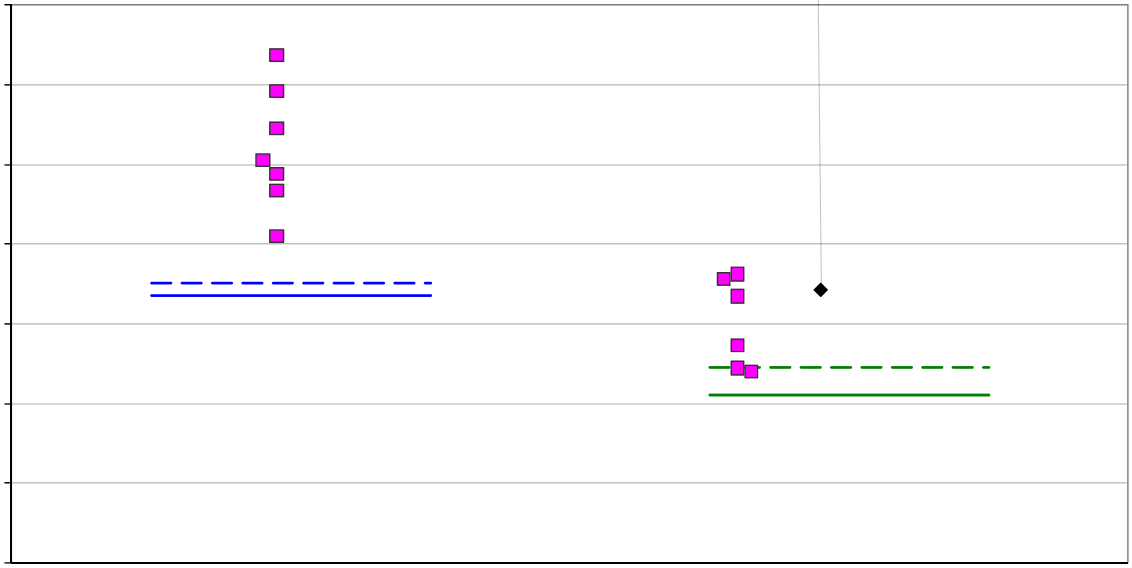
5.5.2 “Soft” Open Hole Compression (OHC2)

/DPLQDWH 2SHQ +ROH &RPSUHVVLRQ 2+& 6WUHQJWK NV				
1RUPDOL]HG			$V 0HDVXUHG	
(QY	57'	(7:	57'	(7:
0HDQ				
6	W	G	H	Y
&9				
0	R	G L	I	L H G &
0LQ				
0D[				
1R %DWFKHV				
1	R			6 S H F
%DVLV 9DOXHV DQG RU (VWLPDWHV				
% EDVLV 9DOXH				
% HVWLPDWH				
$ HVWLPDWH		1$		1$
0HWKRG	/90	1RUPDO	/90	1RUPDO
0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV				
% EDVLV 9DOXH				
% HVWLPDWH				
$ HVWLPDWH		1$		1$
0HWKRG	/90	1RUPDO	/90	1RUPDO

7DEOH 6WDWLVWLFDO 9DOXHV RI %DVLV 6WUHQJWK GDWD

5.5.3 “Hard” Open Hole Compression (OHC3)

There were no outliers or test failures. The RTD data is insufficient to generate basis values that meet the requirements of CMH-17-1G so only estimates are provided for that condition. The ETW2 as measured data does not fit a normal distribution, so no modified CV basis values are provided for that dataset. Statistics, basis values and estimates are given for the strength data in Table 5-19. The normalized strength data, B-basis values and B-estimates are shown graphically in Figure 5-13.



5.6 Filled Hole Tension Properties

5.6.1 Quasi Isotropic Filled Hole Tension (FHT1)

The data from the CTD environment meets all requirements of CMH-17-1G. The RTD data is insufficient to generate basis values that meet the requirements of CMH-17-1G so only estimates

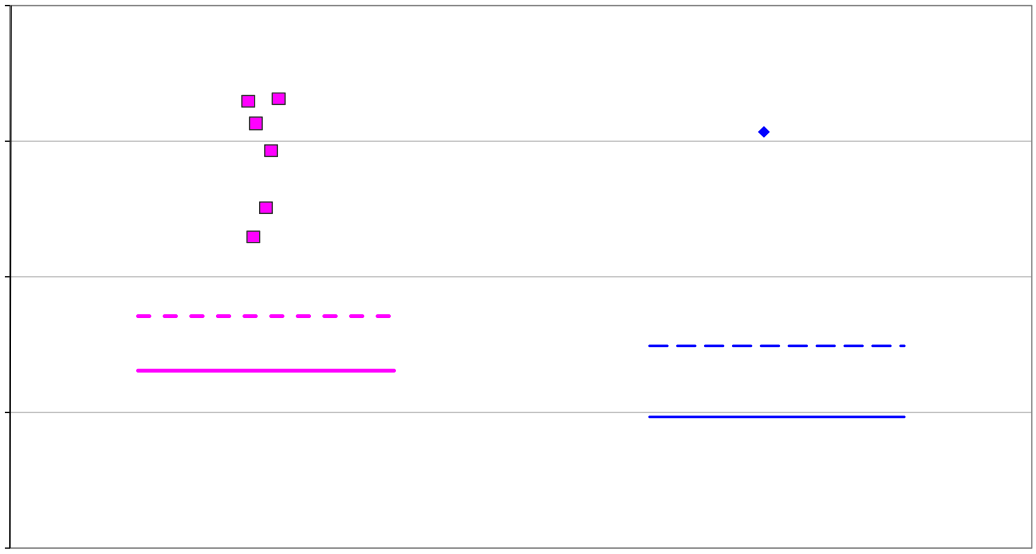
/DPLQDWH)LOOHG +ROH 7HQVLRQ				
1RUPDOL]HG			$V 0	
(QY	&7'	57'	&7'	57'
0HDQ				
6	W	G	H	Y
&9				
0	R	G L	I	L
0LQ				
0D[				
1R %DWFKHV				
1	R			6 S H F

%DVLV 9DOXHV DQG RU (VWLPDWHV				
% EDVLV 9DOXH				
% HVWLPDWH				
$ HVWLPDWH			1$	1$
0HWKRG	1RUPDO		/90	1RUPDO /90

0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV				
% EDVLV 9DOXH				
% HVWLPDWH				
$ HVWLPDWH			1$	1$
0HWKRG	1RUPDO		/90	1RUPDO /90

5.6.3 "Hard" Filled Hole Tension (FHT3)

This property had data from only one batch available, thus all basis values are estimates. Statistics and B-estimates are given for the strength data in Table 5-22. The normalized strength data and B-estimates are shown graphically in Figure 5-16.



5.7

/DPLQDWH)LOOHG +ROH &RPSUHVVLRQ)+& 6WUHQJWK
1RUPDOL]HG $V 0HDVXUHG
(QY 57' (7: 57' (7:
0HDQ
6 W G H Y
&9
0RGLILHG &9
0LQ
0D[
1R %DWFKHV
1 R 6 S H F
%DRP€
% EDVLV 9DOXH
% HVWLPDWH
$ HVWLPDWH 1$ 1$
0HWKRG /90 1RUPDO /90 129

% EDVLV 9DOXH
% HVWLPDWH 1$
$ HVWLPDWH 1$ 1$ 1$
0HWKRG /90 1RUPDO /90 1$

5.7.2 “Soft” Filled Hole Compression (FHC2)

The data for the ETW2 environment meets all requirements of CMH-17-1G. The as measured ETW2 data did not fit a normal distribution, so modified CV basis values are not provided for that condition. The RTD data is insufficient to generate basis values that meet the requirements of CMH-17-1G so only estimates are provided for that condition.

There was one outlier on the low side of batch two in the as measured ETW2 dataset. It was an outlier only for batch two, not the ETW2 condition. It was retained for this analysis.

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

(QY 57' (7: 57' (7:
0 H D Q
6 W G H Y

/DPLQDWH)LOOHG +ROH &RPSUHVVLRQ)+& 6WUHQJWK

1RUPDOL]HG $V 0HDVXUHG

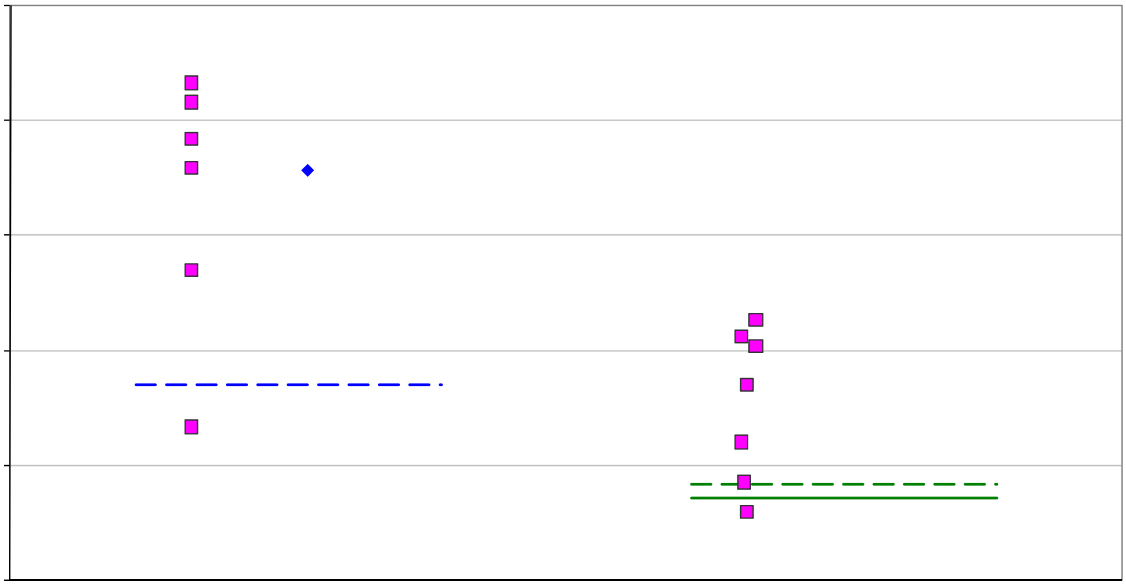
(QY	57'	(7:	57'	(7:
0HDQ				
6WGHY				
&9				
0RGLILHG &9				
0LQ				
0D[				
1R %DWFKHV				
1R 6SHF				

%DVLV 9DOXHV DQG RU (VWLPDWHV

% EDVLV 9DOXH				
% HVWLPDWH				
$ HVWLPDWH	1$		1$	
0HWKRG	/90	1RUPDO	/90	1RUPDO

0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV

% EDVLV 9DOXH		1$		1$
% HVWLPDWH				
$ HVWLPDWH	1$	1$	1$	1$
0HWKRG	/90	1$	/90	1$



3LQ %HDULQJ 3URSHUWLHV 3%			2IIVHW 6WUHQJWK NV	
1RUPDOL]HG			$V 0HDVXUHG	
(QY	57'	(7:	57'	(7:
0HDQ				
6	W	G	H	Y
&9				
0	R	G L	I	L H G &
0LQ				
0D[				
1R %DWFKHV				
1	R			6 S H F
%DVLV 9DOXHV DQG RU (VWLPDWHV				
% EDVLV 9DOXH				
$ HVWLPDWH				
0HWKRG	1RUPDO		1RUPDO	:HLEXOO 1RUPDO
0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV				
% EDVLV 9DOXH		1$		1$
$ HVWLPDWH		1$		1$
0HWKRG	1$		QRUPDO	1$ QRUPDO

7DEOH 6WDWLVWLFDO 9DOXHV IRU %DVLV 2I 2WKHU 6WUHQ

3LQ %HDULQJ 3% 8OWLPDWH 6WUHQJWK NVL				
1RUPDOL]HG			$V 0HDVXUHG	
(QY	57'	(7:	57'	(7:
0HDQ				
6	W	G	H	Y
&9				
0	R	G L	I	L H G &
0LQ				
0D[				
1R %DWFKHV				
1	R			6 S H F
%DVLV 9DOXHV DQG RU (VWLPDWHV				
% EDVLV 9DOXH				
% HVWLPDWH				
$ HVWLPDWH				
0HWKRG	129	1RUPDO	SRROHG	SRROHG
0RGLILHG &9 %DVLV 9DOXHV DQG RU (VWLPDWHV				
% EDVLV 9DOXH				
$ HVWLPDWH				
0HWKRG	SRROHG	SRROHG	SRROHG	SRROHG

7DEOH 6WDWLVWLFDO 9DOXHV DQG RU %DVLV 8OWLPDWH 6WUHQJ

5.8.2 “Soft” Pin Bearing (PB2)

The ETW2 data meets all requirements of CMH-17-1G. The RTD dat

(QY 57' (7: 57' (7:

October 20, 2023

3LQ %HDULQJ 3URSHUWLHV 3 BRSH PW P'p@O

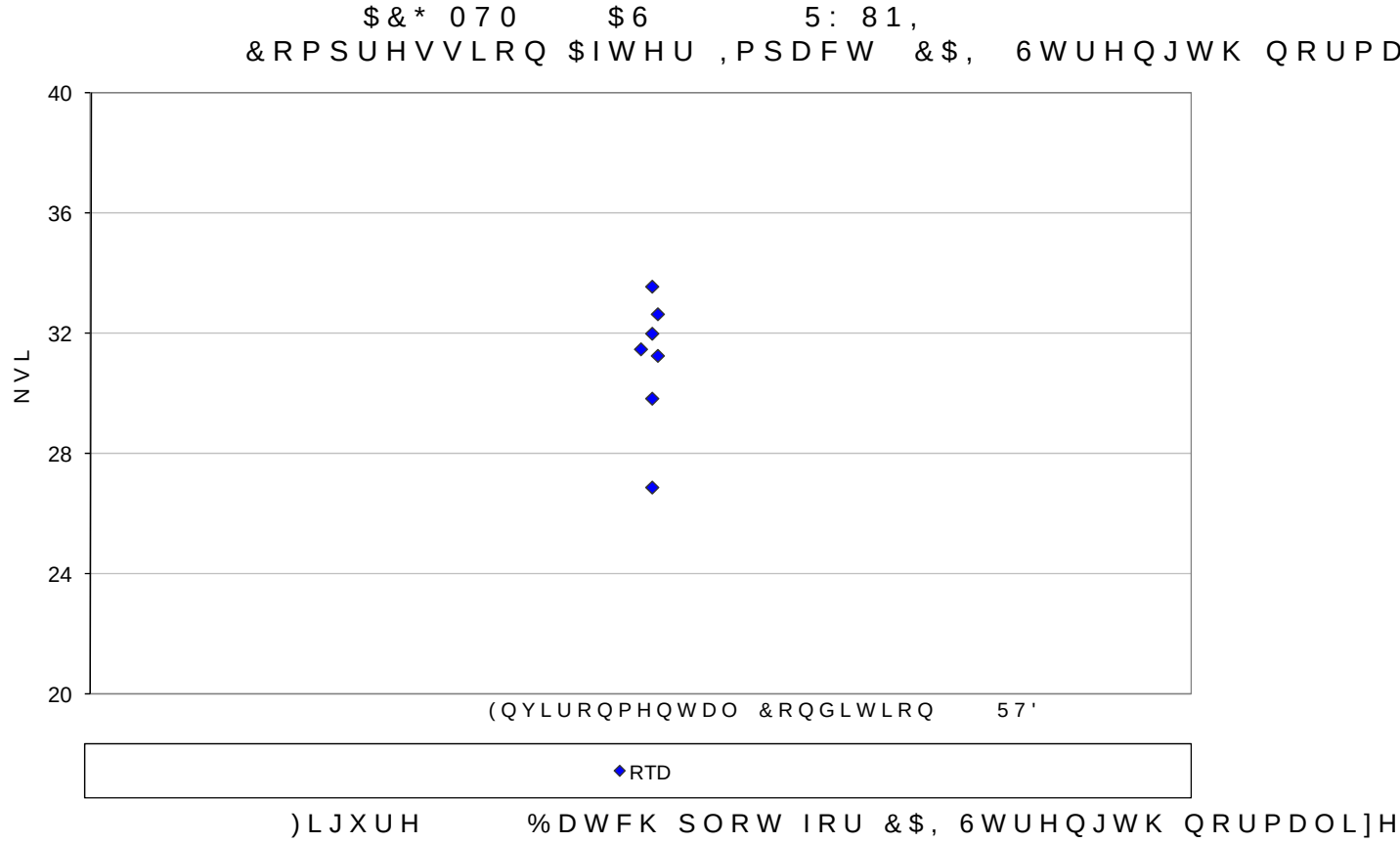
(QY	57'	(7:	57'	(7:
0HDQ				
6	W	G	H	Y
&9				
0RGLILHG &9				
0LQ				
0D[				
1R %DWFKHV				
1R 6SHF				

% EDVLV 9DOXH				
% HVWLPDWH				
$ HVWLPDWH	1$		1$	
0HWKRG	/90	1RUPDO	/90	1RUPDO

% EDVLV 9DOXH				
% HVWLPDWH				
$ HVWLPDWH	1$		1$	
0HWKRG	/90	1RUPDO	/90	1RUPDO

5.9 Compression After Impact Properties (CAI)

Basis values are not computed for this property. However the summary statistics are presented in Table 5-32. The normalized strength data are shown graphically in Figure 5-26.



)LJXUH %DWFK SORW IRU &$, 6WUHQJWK QRUPDOL]H

57' (QY 0HDQ	1RUPDOL]HG 6W G P H Y	$V PHDVXUHG	1RUPDOL]HG	$V PHDVXUHG
° P	6 W	G	P H	Y

6. Outliers

Outliers were identified according to the standards documented in section 2.1.5, which are in accordance with the guidelines developed in CMH-17-1G section 8.3.3. An outlier may be an outlier in the normalized data, the as measured data, or both. A specimen may be an outlier for the batch only (before pooling the three batches within a condition together) or for the condition (after pooling the three batches within a condition together) or both.

Approximately 5 out of 100 specimens will be identified as outliers due to the expected random

7. References

1. Snedecor, G.W. and Cochran, W.G., Statistical Methods, 7th ed., The Iowa State University Press, 1980, pp. 252-253.
2. Stefansky, W., "Rejecting Outliers in Factorial Designs," Technometrics, Vol. 14,