



Evaluation of Fire-Retardant Treated Laminated Veneer Lumber

Final Report – Part 1 of 2 USDA Joint Venture Agreement 16-JV-11111135-079

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Executive Summary

This report contains test results for the fire-retardant-treatment (FRT) and hygrothermal effects on laminated veneer lumber (LVL). This is the first part of the collaborative research project between APA – The Engineered Wood Association, Tacoma, WA, and USDA Forest Products Laboratory (FPL), Madison, WI. The second part of this project is related to FRT structural glued laminated timber (glulam) and the results are provided in a separate research report.

Selected mechanical properties, including tension, edgewise bending, and edgewise shear of the FRT LVL treated with the American Wood Protection Association (AWPA) P49 fire retardant were evaluated in this study. The combined FRT and hygrothermal effects on the LVL volume effect factor were also evaluated. These results are used to support the development of an ASTM standard for FRT LVL.

This work was a joint research project of APA – The Engineered Wood Association and the USDA FPL. This research was supported in part by funds provided by the USDA FPL, which is acknowledged and greatly appreciated by the project team. The project team also appreciated the contribution of Arch Wood Protection Inc. for providing the P49 fire-retardant treatment.

Table of Contents

1. Introduction	4
2. Objective.....	4
3. Materials	4
4. Methods.....	6
4.1 Tension Tests.....	6
4.2 Edgewise Bending Tests	6
4.3 Edgewise Block Shear Tests	7
4.4 Gluebond Durability Tests	7
5. Results and Discussion.....	7
5.1 Tension	7
5.2 Edgewise Bending.....	8
5.2.1 Bending Volume Effect	8
5.3 Edgewise Block Shear.....	11
5.4 Adhesive Durability (Six-Cycle Short Span Bending)	11
5.5 Combined FRT and Hygrothermal Effects	12
6. Acknowledgements.....	13
7. References	13
Appendix A. Tension Test Results	14
Appendix B. Edgewise Bending Test Results.....	19
Appendix C. Edgewise Block Shear Test Results	30
Appendix D. Adhesive Durability Test Results.....	39

1. Introduction

Interests in using engineered wood products in Type III construction in the U.S. have been rising in recent years. The wood industry has been heavily engaged in the promotion of multi-family and light commercial construction in which wood-frame Type III construction predominates. Type III construction, based on the definition of the International Building Code (IBC) is “that type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of any material permitted by this code,” except that fire-retardant-treated (FRT) wood framing complying with the IBC is permitted within exterior wall assemblies of a 2-hour rating or less.

As part of the Type III construction, the exterior bearing walls of wood-frame construction must be FRT wood with a 2-hour fire rating, and the floor framing is required to be 1-hour fire rated. At the intersection of the 2-hour wall and 1-hour floor, where the floor framing is attached to the wall with joist hangers, a popular solution is to use solid structural rimboard or header to provide the needed load transfer mechanism. Due to the requirement for continuity on the 2-hour fire rating, the rimboard or wall header is a good fit for structural glued laminated timber (glulam) and structural composite lumber (SCL) products. Unfortunately, this market demand has faced a strong technical challenge due to the lack of consensus-based evaluation standards or product specifications for FRT glulam and SCL. ASTM and AWPA have published FRT test standards and FRT product specifications for lumber and plywood, but not glulam and SCL. For SCL, due to the different treatment requirements and the market size, this study focused on laminated veneer lumber (LVL).

2. Objective

The objective of this work was to develop ASTM standards for the evaluation of fire-retardant treated (FRT) LVL in support of wood-frame construction, especially in Type III construction. In this study, fire-retardant treatment was performed by a treater using the American Wood Protection Association (AWPA) P49 standard, *Standard for Fire Retardant FR-1*. Full scale tension and edgewise bending tests and also block shear tests were conducted on matched samples for 3100F_b-2.0E LVL to evaluate both fire-retardant treatment and hygrothermal effects. In addition, full-size LVL specimens of four different sizes were tested in edgewise bending after fire-retardant treatment to evaluate the FRT effect on the LVL volume effect under hygrothermal conditions. Adhesive durability tests were conducted on untreated materials to evaluate the LVL bond durability.

3. Materials

3100F_b-2.0E LVL billets at a nominal thickness of 1-3/4 inches were shipped by a commercial LVL plant to the APA Research Center in Tacoma, Washington in August 2016. These materials were cut based on the test plan shown in Tables 1 through 3. After being prepared, groups TTA, TTH, TBA, TBH1, TBH2, TBH3, and TBH4 were shipped to a fire-retardant treatment company for AWPA P49 treatment. After being treated, these materials were shipped back to APA. Then groups UTA, TTA, UBA, and TBA were conditioned at standard conditions (68 ± 11°F and 65 ± 5% relative humidity) in accordance with ASTM D5456, *Standard Specification for Evaluation of Structural Composite Lumber Products*. All the other groups, i.e. UTH, TTH, UBH1, TBH1, UBH2, TBH2, UBH3, TBH3, UBH4, and TBH4, were shipped to the USDA Forest Products Laboratory (FPL) for hygrothermal conditioning (150 + 4°F and 50% or higher relative humidity for 108 ± 3 days in accordance with ASTM D5664, *Standard Test Method for Evaluating the Effects of Fire-Retardant Treatments and Elevated Temperatures on Strength Properties of Fire-Retardant Treated Lumber*), and testing. Included in this study were

four different LVL sizes that were tested in edgewise bending after fire-retardant treatment to study the volume effect for untreated and treated LVL.

Table 1. Tension tests

Type ^(a)	Quantity	Treatment	Conditioning	Dimension	Test Lab
UTA (Untreated Control)	30	NA	Standard	1-3/4 inches x 5-1/2 inches x 9 feet	APA
TTA (Treated and Matched with UTA)	30	P49			
UTH (Untreated Control)	30	NA	Hygrothermal		FPL
TTH (Treated and Matched with UTH)	30	P49			

^(a) First letter: U (untreated) or T (treated); Second letter: T (tension); Third letter: A (standard condition) or H (hygrothermal condition)

Table 2. Edgewise bending tests

Type ^(a)	Quantity	Treatment	Conditioning	Dimension	Test Lab
UBA (Untreated Control)	30	NA	Standard	1-3/4 inches x 3-1/2 inches x 6 feet	APA
TBA (Treated and Matched with UBA)	30	P49			
UBH1 (Untreated Control Size 1)	30	NA	Hygrothermal	1-3/4 inches x 3-1/2 inches x 6 feet	FPL
TBH1 (Treated Size 1 and Matched with UBH1)	30	P49			
UBH2 (Untreated Control Size 2)	30	NA		1-3/4 inches x 5-1/2 inches x 8 feet	
TBH2 (Treated Size 2 and Matched with UBH2)	30	P49			
UBH3 (Untreated Control Size 3)	30	NA		1-3/4 inches x 7-1/4 inches x 12 feet	
TBH3 (Treated Size 3 and Matched with UBH3)	30	P49			
UBH4 (Untreated Control Size 4)	30	NA		1-3/4 inches x 9-1/4 inches x 14 feet	
TBH4 (Treated Size 4 and Matched with UBH4)	30	P49			

^(a) First letter: U (untreated) or T (treated); Second letter: B (bending); Third letter: A (standard condition) or H (hygrothermal condition)

Table 3. Edgewise block shear tests

Type ^(a)	Quantity	Treatment	Conditioning	Dimension	Test Lab
USA (Untreated Control)	30	NA	Standard	1-3/4 inches x 1-3/4 inches x 3 inches	APA
TSA (Treated and Matched with USA)	30	P49			
TSH (Treated and Matched with UTH)	30	P49	Hygrothermal		FPL

^(a) First letter: U (untreated) or T (treated); Second letter: S (shear); Third letter: A (standard condition) or H (hygrothermal condition)

4. Methods

4.1 Tension Tests

The tension tests were conducted in accordance with Section 6.5.2 of ASTM D5456, using a 4-ft gauge length. Untreated (UTA and UTH) and treated (TTA and TTH) samples were tested under both standard and hygrothermal conditions.

4.2 Edgewise Bending Tests

The edgewise bending tests were conducted in accordance with Section 6.5.1 of ASTM D5456 as shown in Figure 1. The neutral axis deflection at mid-span was measured using a linear potentiometer. The total applied load and mid-span deflection were recorded by a computer data acquisition system. Dimensions for the specimens are listed in Table 4. Treated (TBA) and untreated (UBA) samples were tested to evaluate the fire-retardant treatment effect on LVL bending properties under standard conditions. Four different sizes of treated and untreated samples (UBH1 and TBH1, UBH2 and TBH2, UBH3 and TBH3, and UBH4 and TBH4) have been tested to evaluate the influence of the fire-retardant treatment on the volume effect under hygrothermal conditions.

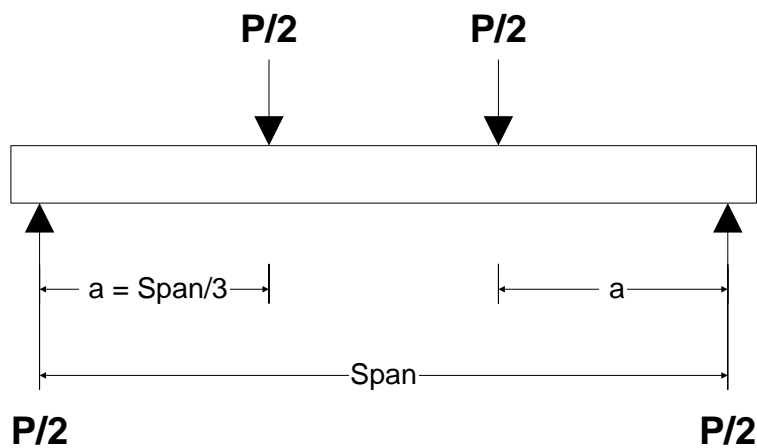


Figure 1. Schematic diagram of edgewise bending test

Table 4. Test configuration for edgewise bending tests

Type	Nominal Depth (inch)	Span L (in.)	a (in.)	Span/Depth
UBA and TBA	3-1/2	63	21	18.0 : 1
UBH1 and TBH1	3-1/2	60	20	17.1 : 1
UBH2 and TBH2	5-1/2	90	30	16.4 : 1
UBH3 and TBH3	7-1/4	126-3/4	42-1/4	17.5 : 1
UBH4 and TBH4	9-1/4	162	154	17.5 : 1

The modulus of rupture (MOR) and the modulus of elasticity (MOE) for each specimen were calculated using the actual dimensions recorded at the time of test based on the following equations:

$$MOR = \frac{3 P_{ult} a}{b h^2} \dots\dots\dots (1)$$

$$MOE = \frac{\theta a (3 L^2 - 4 a^2)}{4 b h^3} \dots\dots\dots (2)$$

Where:

- MOR = modulus of rupture (psi)
- MOE = apparent modulus of elasticity (psi)
- P_{ult} = ultimate total load excluding the dead weight of the specimens (lbf)
- a = distance between the reaction point to the nearest loading point (in.)
- b = measured beam width (in.)
- h = measured beam depth (in.)
- L = test span (in.), and
- θ = slope of load vs. deflection plot below the proportional limit (lbf/in.)

4.3 Edgewise Block Shear Tests

Longitudinal shear strength in the L-Y plane (edgewise or joist orientation) was tested by conducting block shear tests in accordance with ASTM D5456 and D143. Untreated (USA) and treated (TSA and TSH) samples were tested under both standard and hygrothermal conditions.

4.4 Gluebond Durability Tests

Gluebond durability of the untreated LVL was tested in accordance with the six-cycle short-span bending test method of Section A4.2 of ASTM D5456. The specimens were subjected to six vacuum-pressure-soak cycles and in the final cycle, they were dried to a moisture content that was within $\pm 2\%$ of the control group. The specimens were then tested in a flatwise short-span bending configuration.

5. Results and Discussion

5.1 Tension

Tension test results are summarized in Table 5. Individual test results are given in Appendix A.

Table 5. Summary of tension test results for untreated and treated specimens

	UTA	TTA	UTH	TTH
Number of specimens	32	32	32	32
Mean (psi)	6,968	6,174	6,617	5,718
Maximum (psi)	7,988	7,332	7,795	6,954
Minimum (psi)	6,048	4,974	5,049	4,500
COV	0.069	0.096	0.096	0.097
LTL (normal distribution) (psi)	6,078	5,068	5,432	4,682
LTL (lognormal distribution) (psi)	6,120	5,129	5,477	4,730

5.2 Edgewise Bending

Results of the edgewise bending tests are summarized in Tables 6 through 8. Individual test results are given in Appendix B.

Table 6. Summary of edgewise bending properties under standard conditions

	UBA		TBA	
	MOE	MOR	MOE	MOR
Number of specimens	32	32	32	32
Mean (psi)	2.11 x 10 ⁶	10,076	1.93 x 10 ⁶	9,017
Maximum (psi)	2.25 x 10 ⁶	12,313	2.03 x 10 ⁶	10,550
Minimum (psi)	2.00 x 10 ⁶	8,110	1.82 x 10 ⁶	7,754
COV	0.032	0.079	0.034	0.072
LTL (normal distribution) (psi)	--	8,590	--	7,807
LTL (lognormal distribution) (psi)	--	8,681	--	7,870

Table 7. Summary of edgewise bending MOR^(a) under hygrothermal conditions

	Test Depth (in.)			
	3-1/2 (UBH1)	5-1/2 (UBH2)	7-1/4 (UBH3)	9-1/4 (UBH4)
Number of specimens	31	32	32	31
Mean (psi)	9,818	9,097	8,498	7,915
Maximum (psi)	11,547	10,804	9,766	9,602
Minimum (psi)	8,496	7,406	7,111	6,156
COV	0.070	0.087	0.073	0.096
LTL (normal distribution) (psi)	8,541	7,630	7,345	6,506
LTL (lognormal distribution) (psi)	8,602	7,693	7,379	6,583

^(a) MOE data were not available.

Table 8. Summary of edgewise bending MOR^(a) under hygrothermal conditions

	Test Depth (in.)			
	3-1/2 (TBH1)	5-1/2 (TBH2)	7-1/4 (TBH3)	9-1/4 (TBH4)
Number of specimens	32	32	31	31
Mean (psi)	8,634	7,673	7,414	6,758
Maximum (psi)	9,891	9,134	9,033	8,360
Minimum (psi)	7,447	6,335	6,458	3,676
COV	0.069	0.085	0.075	0.126
LTL (normal distribution) (psi)	7,520	6,459	6,383	5,174
LTL (lognormal distribution) (psi)	7,568	6,539	6,446	5,118

^(a) MOE data were not available.

5.2.1 Bending Volume Effect

The bending volume effect parameter (K_d) takes the form of:

$$K_d = \left(\frac{d_1}{d}\right)^{2/m} = \left(\frac{d_1}{d}\right)^{1/n} \dots\dots\dots (3)$$

Where:

- K_d = volume effect parameter
- d_1 = base depth (inches)
- d = any depth (inches)
- n = $m/2$ coefficient determined following Annex A1, ASTM D5456
- = 4.8 (UBH) and 4.1 (TBH) based on the empirical procedure
- = 7.3 (UBH) and 7.8 (TBH) based on theoretical procedure.

The volume effect parameter was determined following Annex A1 of ASTM D5456. The base bending depth was 3.5 inches. Figures 2 and 3 are plots of both the empirical (following least-square regression technique per section A1.4.2 of ASTM D5456) and the theoretical (as determined by lower-tail Weibull analysis as covered in section A1.4.3 of ASTM D5456) bending volume effect parameters. The empirical procedure for determining the volume effect exponent “n” was deemed “acceptable” based on Sections A1.4.5 and A1.4.5.1 of ASTM D5456.

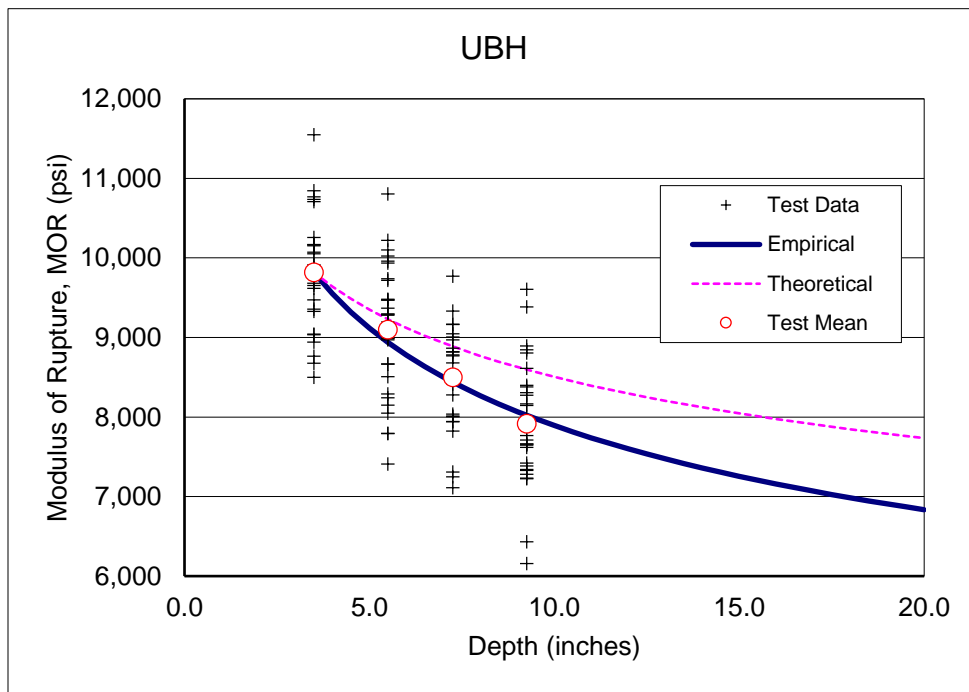


Figure 2. Empirical and theoretical edgewise bending volume effect for untreated specimens

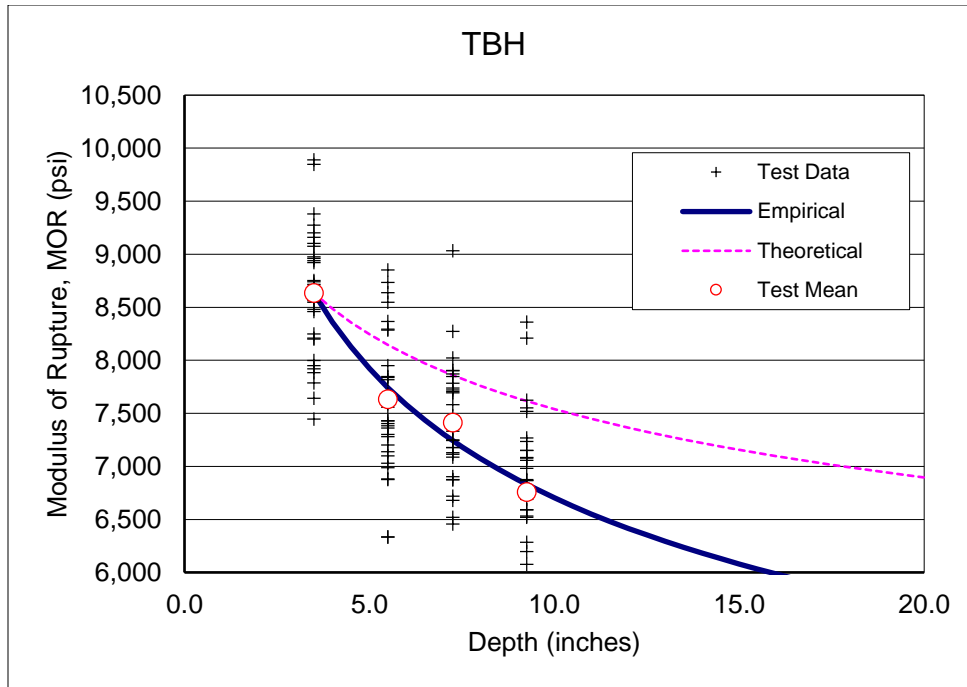


Figure 3. Empirical and theoretical edgewise bending volume effect for treated specimens

Based on APA Technical Report T2008P-113, factor n in the edgewise bending volume effect parameter K_d ($K_d = (d_1/d)^{1/n}$) for untreated 3,100F_b-2.0E LVL under standard conditions is 5.4. From this study, n is 4.8 and 4.1 for untreated (UBH) and treated (TBH) 3,100F_b-2.0E LVL under hygrothermal conditions, respectively. The average edgewise bending MOR for untreated and treated samples under standard and hygrothermal conditions are listed in Table 9 and shown in Figure 4. The average bending strength decreased for about 7 to 11 percent for untreated samples after hygrothermal treatment. Then it decreased again for 12 to 16 percent after the fire-retardant treatment.

Table 9. Average edgewise bending MOR

Depth (in.)	Untreated MOR (psi) under standard conditions	Untreated MOR (psi) under hygrothermal conditions	Untreated MOR under hygrothermal conditions/ Untreated MOR under standard conditions	Treated MOR (psi) under hygrothermal conditions	Treated MOR (psi) under hygrothermal conditions/ Untreated MOR under hygrothermal conditions	Treated MOR under hygrothermal conditions/ Untreated MOR under standard conditions
2-1/2	11,461	--	--	--	--	--
3-1/2	10,579	9,818	0.93	8,634	0.88	0.82
5-1/2	--	9,097	--	7,673	0.84	--
7-1/4	9,556	8,498	0.89	7,414	0.87	0.78
9-1/4	--	7,915	--	6,758	0.85	--
11-7/8	8,331	--	--	--	--	--

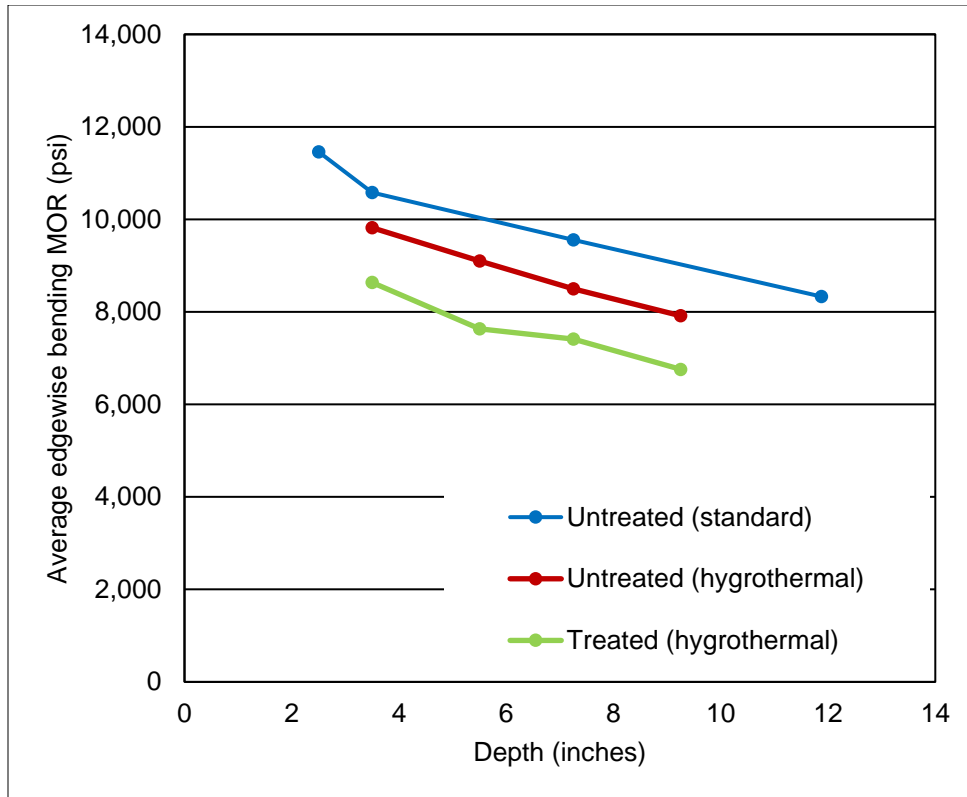


Figure 4. Average edgewise bending MOR for untreated and treated LVL under standard and hygrothermal conditions

5.3 Edgewise Block Shear

Tests results for longitudinal shear strength in the L-Y plane (edgewise or joist orientation) are summarized in Table 10. Individual test results are given in Appendix C.

Table 10. Summary of edgewise block shear results under standard and hygrothermal conditions

	USA	TSA	TSH
Number of specimens	35	35	156
Mean (psi)	1,020	933	813
Maximum (psi)	1,245	1,167	1,001
Minimum (psi)	813	639	585
COV	0.104	0.144	0.101
LTL (normal distribution) (psi)	824	685	671
LTL (lognormal distribution) (psi)	838	702	677

5.4 Adhesive Durability (Six-Cycle Short Span Bending)

Detailed test results for adhesive durability tests on untreated LVL are provided in Appendix D. The ratio of the average cycled failure load divided by the control failure load was 0.89.

5.5 Combined FRT and Hygrothermal Effects

Fire-retardant treatment and hygrothermal effects for tension, bending, and shear properties are listed in Tables 11 through 14.

Table 11. Fire-retardant treatment effect under standard conditions

	Tension		Edgewise Bending MOR		Edgewise Bending MOE		Edgewise Block Shear	
	UTA	TTA	UBA	TBA	UBA	TBA	USA	TSA
Number of specimens	32	32	32	32	32	32	35	35
Mean (psi)	6,968	6,174	10,076	9,017	2.11 x 10 ⁶	1.93 x 10 ⁶	1,020	933
COV	0.069	0.096	0.079	0.072	0.032	0.034	0.104	0.144
LTL (lognormal) (psi)	6,120	5,129	8,681	7,870	--	--	838	702
Treatment effect (mean)	--		--		0.91		--	
Treatment effect (LTL)	0.84		0.91		--		0.84	

Table 12. Fire-retardant treatment effect under hygrothermal conditions

	Tension		Edgewise Bending MOR	
	UTH	TTH	UBH1	TBH1
Number of specimens	32	32	31	32
Mean (psi)	6,617	6,954	9,818	8,634
COV	0.096	0.097	0.070	0.069
LTL (lognormal) (psi)	5,477	4,730	8,602	7,568
Treatment effect (LTL)	0.86		0.88	

Table 13. Hygrothermal effect for untreated and treated LVL

	Tension				Edgewise Bending MOR				Edgewise Block Shear	
	Untreated		Treated		Untreated		Treated		Treated	
	UTA	UTH	TTA	TTH	UBA	UBH1	TBA	TBH1	TSA	TSH
N	32	32	32	32	32	31	32	32	35	156
Mean (psi)	6,968	6,617	6,174	6,954	10,076	9,818	9,017	8,634	933	813
COV	0.069	0.096	0.096	0.097	0.079	0.070	0.072	0.069	0.144	0.101
LTL (lognormal) (psi)	6,120	5,477	5,129	4,730	8,681	8,602	7,870	7,568	702	677
Hygrothermal effect (LTL)	0.89		0.92		0.99		0.96		0.96	

Table 14. The combined hygrothermal and fire-retardant treatment effects

	Tension		Edgewise Bending MOR		Edgewise Block Shear	
	UTA	TTH	UBA	TBH1	USA	TSH
N	32	32	32	32	35	156
Mean (psi)	6,968	6,954	10,076	8,634	1,020	813
COV	0.069	0.097	0.079	0.069	0.104	0.101
LTL (lognormal) (psi)	6,120	4,730	8,681	7,568	838	677
Hygrothermal + treatment effects (LTL)	0.77		0.87		0.81	

6. Acknowledgements

This work was a joint research project of APA – The Engineered Wood Association and the USDA Forest Products Laboratory. This research was supported in part by funds provided by the USDA Forest Products Laboratory (16-JV-11111135-079), which is acknowledged and greatly appreciated by the project team. The project team also appreciated the contribution of Arch Wood Protection Inc. and Viance, LLC for providing the fire-retardant treatments for this project.

7. References

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- 4) ASTM International. 2010. *Standard Test Method for Evaluating the Effects of Fire-Retardant Treatments and Elevated temperatures on Strength Properties of Fire-Retardant Treated Lumber. ASTM D5664-10*. West Conshohocken, PA.
- 5) International Code Council. 2018. *International Building Code*. Country Club Hills, IL.

Appendix A. Tension Test Results

LVL tension tests (UTA)

Material: 1-3/4" 3,100Fb-2.0E LVL (untreated)

Test lab: APA Research Center, Tacoma, WA

Conditions: Standard conditions

Specimen Number	Width (in.)	Thickness (in.)	D ^(a) (pcf)	MC (%)	Max Load (lbf)	Tension ^(b) (psi)	Lognormal Tension
1	5.569	1.725	34.7	10.0	72,173	7,513	8.92
2	5.466	1.746	35.9	9.7	65,147	6,828	8.83
3	5.495	1.737	37.4	9.5	75,631	7,924	8.98
4	5.555	1.749	38.5	9.6	60,964	6,275	8.74
5	5.563	1.737	38.6	9.3	65,206	6,748	8.82
6	5.549	1.727	38.6	9.6	66,740	6,963	8.85
7	5.563	1.743	39.0	9.6	60,711	6,261	8.74
8	5.524	1.736	38.5	9.4	68,330	7,127	8.87
9	5.548	1.717	36.9	9.7	62,594	6,573	8.79
10	5.553	1.732	37.4	9.6	67,152	6,984	8.85
11	5.562	1.764	34.7	9.7	74,558	7,599	8.94
12	5.557	1.742	38.5	10.1	68,788	7,106	8.87
13	5.551	1.712	36.2	9.5	70,006	7,369	8.91
14	5.562	1.714	38.4	9.4	64,849	6,804	8.83
15	5.570	1.750	35.3	9.6	72,694	7,460	8.92
16	5.564	1.744	38.3	9.1	64,517	6,648	8.80
17	5.580	1.745	37.2	9.2	72,013	7,395	8.91
18	5.559	1.752	35.3	9.5	71,977	7,390	8.91
19	5.575	1.782	38.3	9.2	72,228	7,269	8.89
20	5.559	1.750	35.8	9.4	65,872	6,772	8.82
21	5.576	1.724	37.2	9.2	66,371	6,904	8.84
22	5.570	1.760	35.2	9.4	59,275	6,048	8.71
23	5.574	1.792	39.6	8.7	79,768	7,988	8.99
24	5.563	1.752	35.8	9.4	67,035	6,880	8.84
25	5.566	1.766	35.1	9.3	62,216	6,330	8.75
26	5.552	1.734	34.9	9.3	66,186	6,875	8.84
27	5.570	1.744	38.6	9.0	70,762	7,286	8.89
28	5.563	1.735	37.0	9.1	63,458	6,577	8.79
29	5.563	1.763	35.7	9.0	62,909	6,414	8.77
30	5.565	1.732	33.5	9.5	62,871	6,525	8.78
31	5.575	1.745	38.5	9.0	71,251	7,325	8.90
32	5.559	1.729	36.5	9.2	65,603	6,827	8.83
Total no. of observations			32	32	32	32	32
Mean			36.9	9.4	67,495	6,968	8.85
Maximum			39.6	10.1	79,768	7,988	8.99
Minimum			33.5	8.7	59,275	6,048	8.71
COV			0.043	0.031	0.071	0.069	0.008
K for 5 th percentile with 75% confidence						1.860	1.860
Lower tolerance limit (LTL)						6,078	6,120
LTL/2.1						2,894	2,914

^(a) Density based on weight and volume at test.

^(b) Tension tested at a 4-ft gauge length.

LVL tension tests (TTA)
Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)
Test lab: APA Research Center, Tacoma, WA
Conditions: Standard conditions

Specimen Number	Width (in.)	Thickness (in.)	D ^(a) (pcf)	MC (%)	Max Load (lbf)	Tension ^(b) (psi)	Lognormal Tension
1	5.516	1.789	37.4	13.0	59,775	6,059	8.71
2	5.537	1.826	35.4	12.6	62,807	6,211	8.73
3	5.549	1.809	38.1	12.2	59,169	5,895	8.68
4	5.593	1.818	38.1	12.5	51,487	5,064	8.53
5	5.598	1.786	40.7	12.1	64,862	6,486	8.78
6	5.576	1.803	38.8	12.2	73,703	7,332	8.90
7	5.585	1.812	38.2	12.5	59,075	5,839	8.67
8	5.593	1.796	40.1	12.9	49,944	4,974	8.51
9	5.588	1.792	36.3	12.7	70,327	7,023	8.86
10	5.592	1.785	36.4	12.5	53,980	5,407	8.60
11	5.584	1.871	36.6	12.4	67,239	6,438	8.77
12	5.600	1.801	38.3	12.0	56,687	5,621	8.63
13	5.583	1.791	39.5	12.8	55,210	5,522	8.62
14	5.599	1.784	36.8	12.9	65,244	6,534	8.78
15	5.600	1.807	36.5	12.2	71,123	7,029	8.86
16	5.609	1.814	38.8	12.9	64,724	6,360	8.76
17	5.634	1.797	37.6	13.1	64,231	6,346	8.76
18	5.636	1.808	35.1	12.7	71,585	7,026	8.86
19	5.609	1.819	39.9	11.8	69,735	6,835	8.83
20	5.591	1.822	37.9	11.2	60,487	5,939	8.69
21	5.628	1.794	36.7	12.2	64,377	6,378	8.76
22	5.654	1.833	36.1	13.5	60,614	5,848	8.67
23	5.635	1.834	40.4	12.8	72,781	7,043	8.86
24	5.616	1.810	37.2	12.6	67,759	6,665	8.80
25	5.617	1.824	36.7	13.2	55,806	5,447	8.60
26	5.614	1.801	37.2	13.5	61,119	6,044	8.71
27	5.596	1.806	38.4	11.6	59,406	5,878	8.68
28	5.602	1.778	39.0	12.8	64,826	6,510	8.78
29	5.621	1.842	36.5	14.1	57,326	5,536	8.62
30	5.614	1.806	35.4	13.0	63,773	6,291	8.75
31	5.628	1.834	39.0	12.7	62,641	6,069	8.71
32	5.597	1.781	38.6	12.6	58,974	5,916	8.69
Total no. of observations			32	32	32	32	32
Mean			37.7	12.6	62,525	6,174	8.72
Maximum			40.7	14.1	73,703	7,332	8.90
Minimum			35.1	11.2	49,944	4,974	8.51
COV			0.040	0.045	0.098	0.096	0.011
K for 5 th percentile with 75% confidence						1.860	1.860
Lower tolerance limit (LTL)						5,068	5,129
LTL/2.1						2,413	2,442

^(a) Density based on weight and volume at test.

^(b) Tension tested at a 4-ft gauge length.

LVL tension tests (UTH)

Material: 1-3/4" 3,100Fb-2.0E LVL (untreated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Specimen Number	Width (in.)	Thickness (in.)	Max Load (lbf)	Tension ^(a) (psi)	Lognormal Tension
1	5.527	1.752	60,080	6,205	8.73
2	5.527	1.722	67,381	7,080	8.86
3	5.504	1.738	51,313	5,364	8.59
4	5.528	1.727	71,977	7,539	8.93
5	5.510	1.735	64,844	6,783	8.82
6	5.530	1.734	74,747	7,795	8.96
7	5.527	1.748	64,648	6,691	8.81
8	5.514	1.740	71,740	7,477	8.92
9	5.526	1.711	57,914	6,125	8.72
10	5.529	1.735	69,898	7,287	8.89
11	5.509	1.767	70,348	7,227	8.89
12	5.547	1.753	59,686	6,138	8.72
13	5.522	1.730	62,417	6,534	8.78
14	5.535	1.720	53,970	5,669	8.64
15	5.530	1.753	70,684	7,291	8.89
16	5.536	1.746	61,850	6,399	8.76
17	5.547	1.740	66,790	6,920	8.84
18	5.535	1.772	66,564	6,787	8.82
19	5.538	1.785	69,382	7,019	8.86
20	5.526	1.750	65,108	6,733	8.81
21	5.533	1.727	66,968	7,008	8.85
22	5.549	1.773	70,950	7,212	8.88
23	5.531	1.777	70,629	7,186	8.88
24	5.529	1.763	62,730	6,435	8.77
25	5.537	1.753	58,582	6,035	8.71
26	5.521	1.728	59,639	6,251	8.74
27	5.535	1.760	60,212	6,181	8.73
28	5.518	1.736	64,217	6,704	8.81
29	5.520	1.756	57,700	5,953	8.69
30	5.518	1.722	61,544	6,477	8.78
31	5.530	1.746	48,754	5,049	8.53
32	5.527	1.752	60,080	6,205	8.73
Total no. of observations			32	32	32
Mean			63,855	6,617	8.79
Maximum			74,747	7,795	8.96
Minimum			48,754	5,049	8.53
COV			0.098	0.096	0.011
K for 5 th percentile with 75% confidence				1.860	1.860
Lower tolerance limit (LTL)				5,432	5,477
LTL/2.1				2,587	2,608

^(a) Tension tested at a 4-ft gauge length.

LVL tension tests (TTH)

Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Specimen Number	Width (in.)	Thickness (in.)	Max Load (lbf)	Tension ^(a) (psi)	Lognormal Tension
1	5.475	1.765	58,636	6,068	8.71
2	5.528	1.795	60,327	6,080	8.71
3	5.529	1.784	54,030	5,478	8.61
4	5.570	1.797	59,900	5,984	8.70
5	5.531	1.784	60,232	6,104	8.72
6	5.452	1.778	54,274	5,599	8.63
7	5.528	1.787	50,890	5,152	8.55
8	5.503	1.778	62,115	6,348	8.76
9	5.446	1.777	52,471	5,422	8.60
10	5.501	1.802	47,605	4,802	8.48
11	5.506	1.790	52,501	5,327	8.58
12	5.447	1.799	54,130	5,524	8.62
13	5.491	1.781	47,399	4,847	8.49
14	5.471	1.769	48,730	5,035	8.52
15	5.492	1.793	54,777	5,563	8.62
16	5.487	1.785	56,204	5,738	8.65
17	5.494	1.804	62,582	6,314	8.75
18	5.495	1.803	62,348	6,293	8.75
19	5.484	1.835	61,519	6,113	8.72
20	5.486	1.787	58,818	6,000	8.70
21	5.497	1.774	67,808	6,954	8.85
22	5.522	1.798	59,853	6,028	8.70
23	5.484	1.815	64,079	6,438	8.77
24	5.522	1.810	56,839	5,687	8.65
25	5.504	1.830	45,328	4,500	8.41
26	5.514	1.779	51,521	5,252	8.57
27	5.596	1.788	61,775	6,174	8.73
28	5.547	1.782	48,387	4,895	8.50
29	5.501	1.829	59,177	5,882	8.68
30	5.492	1.790	52,657	5,356	8.59
31	5.485	1.772	57,857	5,953	8.69
32	5.475	1.765	58,636	6,068	8.71
Total no. of observations			32	32	32
Mean			56,357	5,718	8.65
Maximum			67,808	6,954	8.85
Minimum			45,328	4,500	8.41
COV			0.098	0.097	0.012
K for 5 th percentile with 75% confidence				1.860	1.860
Lower tolerance limit (LTL)				4,682	4,730
LTL/2.1				2,230	2,252

^(a) Tension tested at a 4-ft gauge length.

Appendix B. Edgewise Bending Test Results

LVL edgewise bending tests (UBA)
Material: 1-3/4" 3,100Fb-2.0E LVL (untreated)
Test lab: APA Research Center, Tacoma, WA
Conditions: Standard condition
Span = 63 in., a = 21 in.

Specimen Number	Depth (in.)	Width (in.)	D ^(a) (pcf)	MC (%)	Max Load (lbf)	Slope (lbf/in.)	MOE (x 10 ⁶ psi)	MOR (psi)	Lognormal MOR
1	3.565	1.722	37.0	9.1	3,628	3,061	2.09	10,443	9.25
2	3.561	1.761	35.1	9.3	3,224	3,036	2.03	9,095	9.12
3	3.542	1.730	37.0	9.2	3,297	2,922	2.02	9,571	9.17
4	3.553	1.741	38.6	8.9	3,536	3,150	2.15	10,135	9.22
5	3.548	1.729	36.5	9.3	3,283	3,057	2.11	9,503	9.16
6	3.550	1.768	35.5	9.5	3,398	3,044	2.05	9,607	9.17
7	3.569	1.748	36.7	8.7	3,647	2,991	2.00	10,319	9.24
8	3.559	1.733	38.1	8.4	3,445	3,134	2.14	9,887	9.20
9	3.547	1.712	37.9	8.9	3,466	3,105	2.16	10,137	9.22
10	3.546	1.764	38.6	8.4	4,335	3,329	2.25	12,313	9.42
11	3.555	1.734	38.8	9.0	3,700	3,094	2.12	10,638	9.27
12	3.553	1.761	38.9	9.3	3,459	3,141	2.12	9,802	9.19
13	3.554	1.704	38.7	9.2	3,392	3,098	2.16	9,927	9.20
14	3.557	1.756	39.0	8.9	3,776	3,294	2.22	10,709	9.28
15	3.553	1.716	38.0	8.9	3,556	3,086	2.13	10,343	9.24
16	3.558	1.758	39.1	9.4	3,772	3,199	2.15	10,677	9.28
17	3.553	1.764	38.8	9.4	3,960	3,144	2.12	11,203	9.32
18	3.559	1.741	36.4	9.1	3,550	2,943	2.00	10,142	9.22
19	3.556	1.737	37.2	9.2	3,542	3,177	2.17	10,158	9.23
20	3.557	1.731	36.3	9.2	3,429	3,049	2.08	9,864	9.20
21	3.550	1.756	38.8	9.3	3,264	3,105	2.10	9,292	9.14
22	3.567	1.747	37.4	8.9	3,722	3,119	2.09	10,549	9.26
23	3.562	1.728	38.8	9.1	3,452	3,272	2.23	9,920	9.20
24	3.563	1.753	37.6	8.9	3,269	3,092	2.08	9,253	9.13
25	3.542	1.716	38.7	8.9	2,771	2,884	2.01	8,110	9.00
26	3.530	1.723	37.5	8.9	3,434	3,151	2.21	10,076	9.22
27	3.552	1.728	37.0	8.7	3,431	2,941	2.02	9,913	9.20
28	3.532	1.748	37.1	9.1	3,162	3,065	2.12	9,135	9.12
29	3.543	1.707	38.4	8.6	3,580	2,942	2.06	10,525	9.26
30	3.522	1.724	38.1	8.8	4,034	3,076	2.17	11,885	9.38
31	3.502	1.740	37.0	8.6	3,212	2,929	2.09	9,483	9.16
32	3.514	1.747	37.0	8.8	3,364	3,045	2.14	9,824	9.19
No. of tests			32	32	32		32	32	32
Mean			37.7	9.0	3,503		2.11	10,076	9.21
Max.			39.1	9.5	4,335		2.25	12,313	9.42
Min.			35.1	8.4	2,771		2.00	8,110	9.00
COV			0.028	0.031	0.082		0.032	0.079	0.009
K for 5 th percentile with 75% confidence								1,860	1,860
Lower tolerance limit (LTL)								8,590	8,681
LTL/2.1								4,091	4,134

^(a) Density based on weight and volume at test.

LVL edgewise bending tests (TBA)
Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)
Test lab: APA Research Center, Tacoma, WA
Conditions: Standard condition
Span = 63 in., a = 21 in.

Specimen Number	Depth (in.)	Width (in.)	D ^(a) (pcf)	MC (%)	Max Load (lbf)	Slope (lbf/in.)	MOE (x 10 ⁶ psi)	MOR (psi)	Lognormal MOR
1	3.579	1.813	38.2	11.9	3,292	3,030	1.94	8,931	9.10
2	3.595	1.804	36.0	11.8	3,086	2,906	1.85	8,339	9.03
3	3.579	1.785	38.0	11.5	3,375	3,074	2.00	9,300	9.14
4	3.577	1.779	36.7	12.0	3,092	3,004	1.96	8,557	9.05
5	3.588	1.823	38.3	12.0	3,270	2,937	1.86	8,777	9.08
6	3.575	1.800	37.5	12.0	2,994	2,825	1.83	8,200	9.01
7	3.603	1.789	38.9	11.8	3,625	3,085	1.96	9,834	9.19
8	3.557	1.798	37.1	11.9	3,809	3,026	1.99	10,550	9.26
9	3.578	1.789	39.3	12.2	3,031	2,916	1.90	8,338	9.03
10	3.573	1.792	37.7	12.0	3,432	3,122	2.03	9,452	9.15
11	3.604	1.821	38.4	11.9	3,452	3,007	1.88	9,194	9.13
12	3.572	1.806	37.2	11.5	3,658	3,141	2.03	10,000	9.21
13	3.591	1.816	38.7	11.9	3,278	3,101	1.96	8,820	9.08
14	3.567	1.786	38.0	11.7	3,388	3,071	2.02	9,394	9.15
15	3.575	1.845	38.9	11.8	3,346	3,167	2.00	8,941	9.10
16	3.578	1.825	38.1	11.8	3,587	3,152	2.01	9,671	9.18
17	3.593	1.820	37.5	12.0	2,892	2,947	1.86	7,754	8.96
18	3.583	1.837	37.6	11.9	3,210	2,978	1.88	8,576	9.06
19	3.553	1.836	36.8	12.1	3,096	2,891	1.87	8,417	9.04
20	3.562	1.819	38.5	11.9	3,264	3,065	1.99	8,910	9.09
21	3.586	1.853	37.0	12.0	3,437	2,953	1.84	9,087	9.11
22	3.604	1.838	37.6	11.9	3,112	3,019	1.87	8,212	9.01
23	3.566	1.809	36.9	11.8	3,612	3,007	1.95	9,892	9.20
24	3.584	1.821	37.3	12.0	3,713	3,149	2.00	10,001	9.21
25	3.583	1.832	37.8	12.0	3,288	2,938	1.86	8,809	9.08
26	3.569	1.833	36.4	12.0	2,998	2,851	1.82	8,090	9.00
27	3.582	1.786	38.5	12.0	3,209	2,972	1.93	8,822	9.09
28	3.583	1.817	38.3	11.5	3,477	3,111	1.98	9,390	9.15
29	3.564	1.820	37.9	11.9	3,364	2,972	1.92	9,167	9.12
30	3.554	1.832	36.0	12.0	3,325	2,872	1.86	9,052	9.11
31	3.566	1.829	37.4	11.8	3,552	2,985	1.92	9,622	9.17
32	3.542	1.806	37.7	11.7	3,036	2,884	1.91	8,441	9.04
No. of tests			32	32	32		32	32	32
Mean			37.7	11.9	3,322		1.93	9,017	9.10
Max.			39.3	12.2	3,809		2.03	10,550	9.26
Min.			36.0	11.5	2,892		1.82	7,754	8.96
COV			0.022	0.014	0.070		0.034	0.072	0.008
K for 5 th percentile with 75% confidence								1.860	1.860
Lower tolerance limit (LTL)								7,807	7,870
LTL/2.1								3,718	3,748

^(a) Density based on weight and volume at test.

LVL edgewise bending tests (UBH1)

Material: 1-3/4" 3,100Fb-2.0E LVL (untreated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Span = 60 in., a = 20 in.

Specimen Number	Depth (in.)	Width (in.)	Max Load (lbf)	Slope (lbf/in.)	MOE (x 10 ⁶ psi)	MOR (psi)	Lognormal MOR
UBH1_01	3.558	1.738	3,315	3,979	2.34	9,041	9.11
UBH1_02	3.555	1.759	3,214	4,127	2.40	8,674	9.07
UBH1_03	3.546	1.746	3,518	4,248	2.51	9,615	9.17
UBH1_04	3.546	1.738	3,609	4,274	2.54	9,909	9.20
UBH1_05	3.563	1.730	3,611	4,079	2.40	9,865	9.20
UBH1_06	3.545	1.767	3,144	4,307	2.52	8,496	9.05
UBH1_07	3.557	1.775	3,280	4,118	2.37	8,763	9.08
UBH1_08	3.550	1.741	3,925	4,576	2.70	10,733	9.28
UBH1_09	3.547	1.716	3,554	4,297	2.58	9,878	9.20
UBH1_10	3.551	1.751	4,249	4,573	2.68	11,547	9.35
UBH1_11	3.553	1.753	3,493	4,155	2.43	9,470	9.16
UBH1_12	3.552	1.757	3,632	4,334	2.53	9,831	9.19
UBH1_13	3.558	1.713	3,543	4,258	2.54	9,804	9.19
UBH1_14	3.619	1.769	3,727	4,664	2.56	9,652	9.17
UBH1_15	3.549	1.728	3,906	4,519	2.69	10,767	9.28
UBH1_16	3.549	1.741	3,912	4,310	2.55	10,705	9.28
UBH1_17	3.555	1.770	3,790	4,465	2.58	10,167	9.23
UBH1_19	3.564	1.740	3,703	4,678	2.73	10,052	9.22
UBH1_20	3.563	1.740	3,737	4,215	2.46	10,151	9.23
UBH1_21	3.553	1.752	3,448	4,275	2.50	9,355	9.14
UBH1_22	3.551	1.750	3,561	4,257	2.50	9,682	9.18
UBH1_23	3.556	1.734	3,587	4,489	2.65	9,817	9.19
UBH1_24	3.543	1.745	3,404	4,271	2.53	9,324	9.14
UBH1_25	3.535	1.720	3,236	4,401	2.66	9,032	9.11
UBH1_26	3.559	1.719	3,721	4,244	2.52	10,255	9.24
UBH1_27	3.538	1.723	3,653	4,237	2.55	10,162	9.23
UBH1_28	3.546	1.741	3,957	4,453	2.64	10,844	9.29
UBH1_29	3.540	1.705	3,587	4,041	2.46	10,072	9.22
UBH1_30	3.544	1.726	3,230	4,436	2.66	8,940	9.10
UBH1_31	3.533	1.751	3,609	4,131	2.46	9,906	9.20
UBH1_32	3.600	1.745	3,713	4,117	2.33	9,852	9.20
No. of tests			31		31	31	31
Mean			3,599		2.53	9,818	9.19
Max.			4,249		2.73	11,547	9.35
Min.			3,144		2.33	8,496	9.05
COV			0.069		0.043	0.070	0.008
K for 5 th percentile with 75% confidence						1.864	1.864
Lower tolerance limit (LTL)						8,541	8,602
LTL/2.1						4,067	4,096

LVL edgewise bending tests (TBH1)

Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Span = 60 in., a = 20 in.

Specimen Number	Depth (in.)	Width (in.)	Max Load (lbf)	Slope (lbf/in.)	MOE (x 10 ⁶ psi)	MOR (psi)	Lognormal MOR
TBH1_01	3.581	1.796	3,445	4,145	2.31	8,976	9.10
TBH1_02	3.557	1.817	2,929	4,006	2.25	7,643	8.94
TBH1_03	3.553	1.779	3,353	4,279	2.47	8,959	9.10
TBH1_04	3.544	1.793	3,213	4,049	2.33	8,561	9.06
TBH1_05	3.603	1.796	2,894	3,994	2.19	7,447	8.92
TBH1_06	3.570	1.802	3,017	3,890	2.18	7,882	8.97
TBH1_07	3.572	1.780	3,744	4,269	2.42	9,891	9.20
TBH1_08	3.569	1.766	3,352	3,999	2.29	8,939	9.10
TBH1_09	3.562	1.806	3,264	4,104	2.31	8,548	9.05
TBH1_10	3.555	1.775	3,070	4,176	2.41	8,211	9.01
TBH1_11	3.575	1.821	3,390	4,110	2.27	8,739	9.08
TBH1_12	3.572	1.804	3,482	4,081	2.28	9,076	9.11
TBH1_13	3.581	1.825	3,399	4,209	2.31	8,715	9.07
TBH1_14	3.575	1.801	3,336	4,104	2.29	8,696	9.07
TBH1_15	3.568	1.841	3,391	4,254	2.34	8,681	9.07
TBH1_16	3.587	1.796	3,330	4,082	2.27	8,646	9.06
TBH1_17	3.571	1.816	3,056	3,837	2.13	7,918	8.98
TBH1_18	3.546	1.828	3,249	4,154	2.34	8,480	9.05
TBH1_19	3.566	1.795	3,568	4,303	2.43	9,380	9.15
TBH1_20	3.544	1.791	3,413	4,118	2.38	9,104	9.12
TBH1_21	3.563	1.816	3,363	4,090	2.29	8,751	9.08
TBH1_22	3.545	1.881	3,067	4,321	2.37	7,786	8.96
TBH1_23	3.565	1.795	3,483	3,978	2.25	9,159	9.12
TBH1_24	3.545	1.807	3,727	4,237	2.42	9,848	9.19
TBH1_25	3.566	1.808	3,241	4,143	2.32	8,458	9.04
TBH1_26	3.568	1.806	3,065	3,951	2.22	7,998	8.99
TBH1_27	3.576	1.792	3,150	4,116	2.31	8,248	9.02
TBH1_28	3.559	1.820	3,427	4,050	2.27	8,921	9.10
TBH1_29	3.571	1.819	3,170	4,154	2.31	8,199	9.01
TBH1_30	3.545	1.819	3,028	3,920	2.23	7,948	8.98
TBH1_31	3.571	1.814	3,575	4,266	2.38	9,274	9.13
TBH1_32	3.576	1.813	3,555	3,997	2.22	9,201	9.13
N			32		32	32	32
Mean			3,305		2.31	8,634	9.06
Max.			3,744		2.47	9,891	9.20
Min.			2,894		2.13	7,447	8.92
COV			0.066		0.034	0.069	0.008
K for 5 th percentile with 75% confidence						1.860	1.860
Lower tolerance limit (LTL)						7,520	7,568
LTL/2.1						3,581	3,604

LVL edgewise bending tests (UBH2)

Material: 1-3/4" 3,100Fb-2.0E LVL (untreated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Span = 90 in., a = 30 in.

Specimen Number	Depth (in.)	Width (in.)	Max Load (lbf)	Slope (lbf/in.)	MOE (x 10 ⁶ psi)	MOR (psi)	Lognormal MOR
UBH2_01	5.457	1.767	4,818	4,506	2.44	8,240	9.02
UBH2_02	5.506	1.753	4,751	4,513	2.39	8,045	8.99
UBH2_03	5.520	1.794	5,636	4,805	2.47	9,279	9.14
UBH2_04	5.496	1.773	5,635	4,432	2.34	9,470	9.16
UBH2_05	5.531	1.789	6,039	4,799	2.46	9,931	9.20
UBH2_06	5.510	1.744	5,728	4,669	2.48	9,736	9.18
UBH2_07	5.507	1.782	5,520	4,781	2.49	9,193	9.13
UBH2_08	5.473	1.758	4,560	4,468	2.41	7,793	8.96
UBH2_09	5.501	1.769	4,930	4,581	2.42	8,289	9.02
UBH2_10	5.513	1.727	5,239	4,419	2.37	8,984	9.10
UBH2_11	5.443	1.751	5,358	4,590	2.52	9,295	9.14
UBH2_12	5.500	1.721	5,189	4,421	2.40	8,970	9.10
UBH2_13	5.486	1.768	5,376	4,574	2.43	9,093	9.12
UBH2_14	5.497	1.749	6,001	4,790	2.56	10,219	9.23
UBH2_15	5.571	1.756	5,247	4,619	2.36	8,665	9.07
UBH2_16	5.562	1.745	5,101	4,456	2.30	8,505	9.05
UBH2_17	5.505	1.745	5,708	4,536	2.42	9,715	9.18
UBH2_18	5.497	1.727	5,254	4,607	2.49	9,061	9.11
UBH2_19	5.498	1.771	5,630	4,636	2.45	9,465	9.16
UBH2_20	5.485	1.737	5,864	4,888	2.65	10,098	9.22
UBH2_21	5.510	1.756	6,400	5,016	2.65	10,804	9.29
UBH2_22	5.513	1.767	4,862	4,344	2.28	8,147	9.01
UBH2_23	5.507	1.731	5,528	4,896	2.63	9,477	9.16
UBH2_24	5.527	1.774	5,593	4,814	2.50	9,288	9.14
UBH2_25	5.516	1.773	4,439	4,838	2.52	7,406	8.91
UBH2_26	5.532	1.780	5,243	5,015	2.58	8,663	9.07
UBH2_27	5.551	1.767	5,436	4,819	2.48	8,986	9.10
UBH2_28	5.523	1.767	5,610	4,517	2.36	9,368	9.15
UBH2_29	5.504	1.724	5,777	4,751	2.57	9,956	9.21
UBH2_30	5.512	1.792	4,712	4,649	2.40	7,789	8.96
UBH2_31	5.513	1.778	5,501	4,866	2.54	9,162	9.12
UBH2_32	5.494	1.768	5,943	5,086	2.69	10,022	9.21
N			32		32	32	32
Mean			5,395		2.47	9,097	9.11
Max.			6,400		2.69	10,804	9.29
Min.			4,439		2.28	7,406	8.91
COV			0.085		0.042	0.087	0.010
K for 5 th percentile with 75% confidence						1.860	1.860
Lower tolerance limit (LTL)						7,630	7,693
LTL/2.1						3,633	3,664

LVL edgewise bending tests (TBH2)

Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Span = 90 in., a (in.) = 30 in.

Specimen Number	Depth (in.)	Width (in.)	Max Load (lbf)	Slope (lbf/in.)	MOE (x 10 ⁶ psi)	MOR (psi)	Lognormal MOR
TBH2_01	5.514	1.850	5,228	4,796	2.40	8,366	9.03
TBH2_02	5.485	1.830	4,673	4,505	2.32	7,638	8.94
TBH2_03	5.515	1.825	4,503	4,244	2.15	7,301	8.90
TBH2_04	5.553	1.839	5,504	4,856	2.39	8,735	9.08
TBH2_05	5.541	1.825	4,950	4,758	2.38	7,951	8.98
TBH2_06	5.586	1.845	5,020	4,592	2.22	7,848	8.97
TBH2_07	5.492	1.822	4,786	4,325	2.22	7,838	8.97
TBH2_08	5.543	1.810	4,589	4,630	2.33	7,427	8.91
TBH2_09	5.522	1.834	4,741	4,814	2.42	7,630	8.94
TBH2_10	5.471	1.853	4,241	4,487	2.30	6,881	8.84
TBH2_11	5.483	1.824	4,683	4,630	2.39	7,685	8.95
TBH2_12	5.500	1.810	4,598	4,643	2.39	7,558	8.93
TBH2_13	5.580	1.881	4,738	4,758	2.26	7,281	8.89
TBH2_14	5.471	1.807	4,562	4,496	2.36	7,592	8.93
TBH2_15	5.554	1.821	5,335	4,751	2.36	8,549	9.05
TBH2_16	5.531	1.774	4,481	4,280	2.21	7,430	8.91
TBH2_17	5.624	1.841	5,589	4,748	2.25	8,638	9.06
TBH2_18	5.526	1.807	3,884	4,428	2.25	6,335	8.75
TBH2_19	5.445	1.797	4,383	4,823	2.58	7,405	8.91
TBH2_20	5.563	1.837	5,233	4,668	2.29	8,285	9.02
TBH2_21	5.465	1.849	4,797	4,764	2.45	7,818	8.96
TBH2_22	5.537	1.837	4,443	5,008	2.49	7,099	8.87
TBH2_23	5.428	1.802	4,211	4,449	2.40	7,139	8.87
TBH2_24	5.487	1.805	4,349	4,332	2.26	7,202	8.88
TBH2_25	5.556	1.817	4,601	4,369	2.18	7,382	8.91
TBH2_26	5.442	1.844	4,239	4,180	2.18	6,986	8.85
TBH2_27	5.498	1.797	5,513	4,760	2.47	9,134	9.12
TBH2_28	5.522	1.803	4,497	4,701	2.40	7,361	8.90
TBH2_29	5.508	1.811	5,405	4,687	2.40	8,853	9.09
TBH2_30	5.490	1.805	4,250	4,446	2.31	7,030	8.86
TBH2_31	5.522	1.791	5,033	4,592	2.36	8,294	9.02
TBH2_32	5.535	1.819	4,257	4,535	2.28	6,875	8.84
N			32		32	32	32
Mean			4,729		2.33	7,673	8.94
Max.			5,589		2.58	9,134	9.12
Min.			3,884		2.15	6,335	8.75
COV			0.093		0.043	0.085	0.009
K for 5 th percentile with 75% confidence						1.860	1.860
Lower tolerance limit (LTL)						6,459	6,539
LTL/2.1						3,076	3,114

LVL edgewise bending tests (UBH3)

Material: 1-3/4" 3,100Fb-2.0E LVL (untreated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Span = 126-3/4 in., a = 42-1/4 in.

Specimen Number	Depth (in.)	Width (in.)	Max Load (lbf)	Slope (lbf/in.)	MOE (x 10 ⁶ psi)	MOR (psi)	Lognormal MOR
UBH3_01	7.310	1.770	6,315	3,749	2.25	8,488	9.05
UBH3_02	7.290	1.760	5,375	3,822	2.33	7,305	8.90
UBH3_03	7.310	1.760	5,927	3,784	2.29	8,012	8.99
UBH3_04	7.320	1.740	6,223	3,919	2.39	8,485	9.05
UBH3_05	7.360	1.730	6,248	3,854	2.32	8,476	9.04
UBH3_06	7.310	1.770	6,157	3,887	2.34	8,276	9.02
UBH3_07	7.390	1.800	6,936	3,804	2.18	8,970	9.10
UBH3_08	7.340	1.750	6,678	4,090	2.46	9,005	9.11
UBH3_09	7.310	1.750	5,330	3,737	2.27	7,245	8.89
UBH3_10	7.320	1.760	6,910	3,959	2.38	9,315	9.14
UBH3_11	7.350	1.750	6,529	4,075	2.44	8,779	9.08
UBH3_12	7.290	1.750	6,194	3,953	2.42	8,467	9.04
UBH3_14	7.330	1.790	6,007	3,900	2.30	7,939	8.98
UBH3_13	7.350	1.760	5,939	3,842	2.28	7,941	8.98
UBH3_15	7.320	1.740	6,502	3,914	2.38	8,865	9.09
UBH3_16	7.310	1.760	6,422	4,015	2.43	8,680	9.07
UBH3_17	7.320	1.780	5,869	3,829	2.28	7,822	8.96
UBH3_18	7.320	1.780	5,335	3,883	2.31	7,111	8.87
UBH3_19	7.340	1.750	6,707	3,998	2.40	9,043	9.11
UBH3_20	7.320	1.750	6,759	3,905	2.36	9,164	9.12
UBH3_21	7.320	1.740	6,719	3,845	2.34	9,162	9.12
UBH3_22	7.370	1.770	6,670	3,937	2.31	8,819	9.08
UBH3_23	7.330	1.800	7,099	3,981	2.33	9,331	9.14
UBH3_24	7.330	1.750	7,224	4,018	2.42	9,766	9.19
UBH3_25	7.300	1.730	6,142	3,797	2.34	8,469	9.04
UBH3_26B	7.310	1.770	6,260	3,905	2.35	8,413	9.04
UBH3_27	7.320	1.760	5,937	3,856	2.32	8,003	8.99
UBH3_28	7.310	1.780	6,596	3,836	2.29	8,816	9.08
UBH3_29	7.310	1.760	5,945	3,851	2.33	8,036	8.99
UBH3_30	7.330	1.760	6,285	3,918	2.35	8,449	9.04
UBH3_31	7.300	1.740	6,200	3,789	2.33	8,501	9.05
UBH3_32	7.320	1.760	6,502	3,862	2.32	8,765	9.08
N			32		32	32	32
Mean			6,311		2.34	8,498	9.04
Max.			7,224		2.46	9,766	9.19
Min.			5,330		2.18	7,111	8.87
COV			0.075		0.025	0.073	0.008
K for 5 th percentile with 75% confidence						1.860	1.860
Lower tolerance limit (LTL)						7,345	7,379
LTL/2.1						3,498	3,514

LVL edgewise bending tests (TBH3)

Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Span = 126-3/4 in., a = 42-1/4 in.

Specimen Number	Depth (in.)	Width (in.)	Max Load (lbf)	Slope (lbf/in.)	MOE (x 10 ⁶ psi)	MOR (psi)	Lognormal MOR
TBH3_01	7.310	1.870	6,210	3,685	2.10	7,901	8.97
TBH3_02	7.260	1.810	5,013	3,669	2.20	6,679	8.81
TBH3_03	7.250	1.760	5,388	3,474	2.15	7,404	8.91
TBH3_04	7.270	1.780	5,087	3,754	2.28	6,874	8.84
TBH3_05	7.270	1.770	5,330	3,714	2.27	7,243	8.89
TBH3_06	7.310	1.820	4,987	3,630	2.12	6,519	8.78
TBH3_07	7.190	1.760	5,922	3,722	2.36	8,274	9.02
TBH3_08	7.270	1.780	5,701	3,833	2.33	7,704	8.95
TBH3_09	7.260	1.800	5,357	3,628	2.19	7,178	8.88
TBH3_10	7.280	1.800	5,931	3,788	2.27	7,904	8.98
TBH3_11	7.310	1.800	5,955	4,022	2.38	7,871	8.97
TBH3_12	7.280	1.830	4,927	3,759	2.21	6,458	8.77
TBH3_13	7.250	1.780	5,335	3,723	2.28	7,249	8.89
TBH3_14	7.290	1.740	6,571	4,110	2.53	9,033	9.11
TBH3_15	7.270	1.800	5,335	3,861	2.32	7,128	8.87
TBH3_16	7.330	1.830	5,480	3,728	2.15	7,085	8.87
TBH3_17	7.290	1.810	5,736	3,840	2.28	7,581	8.93
TBH3_18	7.310	1.820	5,139	3,858	2.25	6,718	8.81
TBH3_19	7.290	1.810	6,070	3,789	2.25	8,022	8.99
TBH3_21	7.280	1.820	5,398	3,869	2.29	7,114	8.87
TBH3_22	7.310	1.820	5,921	3,792	2.22	7,739	8.95
TBH3_23	7.300	1.790	5,518	3,850	2.30	7,353	8.90
TBH3_24	7.290	1.800	5,809	3,820	2.28	7,719	8.95
TBH3_25	7.330	1.780	5,170	3,771	2.23	6,872	8.84
TBH3_26	7.280	1.880	5,746	3,841	2.20	7,332	8.90
TBH3_27	7.270	1.810	5,627	3,827	2.29	7,477	8.92
TBH3_28	7.270	1.810	5,195	3,889	2.32	6,903	8.84
TBH3_29	7.290	1.760	5,661	3,986	2.43	7,694	8.95
TBH3_30	7.280	1.790	5,855	3,958	2.38	7,846	8.97
TBH3_31	7.330	1.810	5,491	3,780	2.20	7,178	8.88
TBH3_32	7.270	1.810	5,856	3,789	2.26	7,782	8.96
N			31		31	31	31
Mean			5,572		2.27	7,414	8.91
Max.			6,571		2.53	9,033	9.11
Min.			4,927		2.10	6,458	8.77
COV			0.070		0.040	0.075	0.008
K for 5 th percentile with 75% confidence						1.864	1.864
Lower tolerance limit (LTL)						6,383	6,446
LTL/2.1						3,040	3,070

LVL edgewise bending tests (UBH4)

Material: 1-3/4" 3,100Fb-2.0E LVL (untreated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Span = 162 in., a = 54 in.

Specimen Number	Depth (in.)	Width (in.)	Max Load (lbf)	Slope (lbf/in.)	MOE (x 10 ⁶ psi)	MOR (psi)	Lognormal MOR
UBH4_02	9.155	1.743	7,156	3,497	2.37	7,935	8.98
UBH4_03	9.131	1.763	8,023	3,565	2.40	8,842	9.09
UBH4_04	9.173	1.767	5,902	3,373	2.24	6,431	8.77
UBH4_05	9.140	1.757	7,802	3,605	2.43	8,611	9.06
UBH4_06	9.223	1.766	7,101	3,600	2.35	7,658	8.94
UBH4_07D	9.128	1.781	5,639	3,336	2.23	6,156	8.73
UBH4_08	9.181	1.765	6,779	3,445	2.28	7,382	8.91
UBH4_09B	9.122	1.757	7,115	3,559	2.42	7,884	8.97
UBH4_10	9.103	1.728	6,390	3,246	2.25	7,229	8.89
UBH4_11	9.124	1.749	6,886	3,570	2.43	7,661	8.94
UBH4_12	9.088	1.740	6,510	3,367	2.33	7,338	8.90
UBH4_13A	9.124	1.753	6,601	3,511	2.39	7,328	8.90
UBH4_14	9.026	1.748	7,270	3,472	2.45	8,270	9.02
UBH4_15	9.191	1.753	8,047	3,560	2.37	8,803	9.08
UBH4_16	9.180	1.745	6,557	3,284	2.20	7,223	8.89
UBH4_17	9.118	1.741	7,420	3,438	2.36	8,305	9.02
UBH4_18	9.121	1.731	6,470	3,288	2.27	7,278	8.89
UBH4_19A	9.151	1.770	7,255	3,498	2.33	7,930	8.98
UBH4_20A	9.058	1.736	6,720	3,334	2.34	7,643	8.94
UBH4_21	9.173	1.772	8,838	3,720	2.46	9,602	9.17
UBH4_22	9.115	1.814	7,596	3,615	2.38	8,165	9.01
UBH4_23	9.158	1.721	6,920	3,612	2.47	7,767	8.96
UBH4_24	9.116	1.797	7,378	3,466	2.31	8,004	8.99
UBH4_25	9.129	1.778	7,662	3,693	2.47	8,376	9.03
UBH4_26	9.078	1.775	6,959	3,598	2.45	7,707	8.95
UBH4_27	9.158	1.780	8,647	3,673	2.43	9,383	9.15
UBH4_28	9.107	1.762	8,021	3,654	2.49	8,892	9.09
UBH4_29	9.122	1.728	6,585	3,498	2.41	7,420	8.91
UBH4_30	9.116	1.797	7,019	3,498	2.33	7,615	8.94
UBH4_31	9.139	1.771	7,667	3,621	2.43	8,397	9.04
UBH4_32	9.114	1.775	7,411	3,358	2.26	8,142	9.00
N			31		31	31	31
Mean			7,172		2.37	7,915	8.97
Max.			8,838		2.49	9,602	9.17
Min.			5,639		2.20	6,156	8.73
COV			0.100		0.034	0.096	0.011
K for 5 th percentile with 75% confidence						1.864	1.864
Lower tolerance limit (LTL)						6,506	6,583
LTL/2.1						3,098	3,135

LVL edgewise bending tests (TBH4)

Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Span = 162 in., a = 54 in.

Specimen Number	Depth (in.)	Width (in.)	Max Load (lbf)	Slope (lbf/in.)	MOE (x 10 ⁶ psi)	MOR (psi)	Lognormal MOR
TBH4_02	8.958	1.784	7,253	3,294	2.33	8,208	9.01
TBH4_03	9.010	1.808	5,973	3,379	2.31	6,592	8.79
TBH4_04	8.947	1.812	6,251	3,203	2.24	6,981	8.85
TBH4_05	8.970	1.834	6,878	3,533	2.42	7,550	8.93
TBH4_06	8.953	1.809	6,401	3,146	2.19	7,151	8.88
TBH4_07	8.996	1.812	6,580	3,271	2.25	7,269	8.89
TBH4_08	9.040	1.821	6,000	3,237	2.18	6,532	8.78
TBH4_09	8.985	1.786	6,281	3,245	2.27	7,057	8.86
TBH4_10	8.978	1.793	5,529	3,079	2.15	6,198	8.73
TBH4_11	8.988	1.781	3,265	3,340	2.34	3,676	8.21
TBH4_12X	8.968	1.791	5,091	3,213	2.25	5,726	8.65
TBH4_13	9.005	1.790	6,152	3,338	2.31	6,866	8.83
TBH4_14	8.989	1.825	6,449	3,362	2.30	7,085	8.87
TBH4_15	8.962	1.811	6,174	3,334	2.32	6,877	8.84
TBH4_16	8.918	1.815	6,307	3,162	2.22	7,079	8.86
TBH4_17R	9.033	1.809	5,274	3,252	2.21	5,788	8.66
TBH4_18	8.992	1.791	6,034	3,191	2.22	6,750	8.82
TBH4_19	9.010	1.870	6,308	3,386	2.24	6,732	8.81
TBH4_20RR	8.970	1.787	5,848	3,880	2.72	6,589	8.79
TBH4_21R	8.941	1.804	5,594	3,299	2.32	6,283	8.75
TBH4_22X	8.980	1.833	6,196	3,257	2.22	6,790	8.82
TBH4_23	8.923	1.796	6,310	3,287	2.33	7,149	8.87
TBH4_24X	8.932	1.858	6,120	3,260	2.23	6,689	8.81
TBH4_25	8.973	1.858	6,942	3,435	2.32	7,517	8.92
TBH4_26R	8.979	1.810	7,530	3,341	2.31	8,360	9.03
TBH4_27	8.945	1.832	6,898	3,466	2.39	7,624	8.94
TBH4_28	9.072	1.814	6,008	3,454	2.31	6,520	8.78
TBH4_29	9.011	1.787	6,480	3,208	2.22	7,234	8.89
TBH4_30	8.980	1.841	5,197	3,201	2.17	5,671	8.64
TBH4_31	9.038	1.813	5,554	3,399	2.30	6,075	8.71
TBH4_32R	8.980	1.814	6,201	3,265	2.25	6,868	8.83
N			31		31	31	31
Mean			6,099		2.28	6,758	8.81
Max.			7,530		2.72	8,360	9.03
Min.			3,265		2.15	3,676	8.21
COV			0.126		0.045	0.126	0.016
K for 5 th percentile with 75% confidence						1.864	1.864
Lower tolerance limit (LTL)						5,174	5,118
LTL/2.1						2,464	2,437

Appendix C. Edgewise Block Shear Test Results

LVL edgewise block shear tests (USA)
 Material: 1-3/4" 3,100Fb-2.0E LVL (untreated)
 Test lab: APA Research Center, Tacoma, WA
 Conditions: Standard conditions

Specimen Number	Length (in.)	Width (in.)	Max Load (lbf)	Shear Strength (psi)
1	2.250	1.730	4,486	1,152
2	2.268	1.734	4,016	1,021
3	2.267	1.762	4,135	1,035
4	2.302	1.761	4,214	1,040
5	2.290	1.762	3,966	983
6	2.292	1.755	3,633	903
7	2.301	1.766	4,090	1,006
8	2.297	1.746	4,607	1,149
9	2.300	1.746	4,589	1,143
10	2.303	1.743	4,223	1,052
11	2.300	1.739	3,788	947
12	2.302	1.750	4,302	1,068
13	2.288	1.758	4,968	1,235
14	2.289	1.761	3,720	923
15	2.298	1.756	3,818	946
16	2.301	1.732	4,059	1,018
17	2.300	1.733	3,729	935
18	2.296	1.746	3,899	973
19	2.317	1.754	3,551	874
20	2.300	1.713	3,520	894
21	2.286	1.729	3,823	967
22	2.291	1.738	4,513	1,133
23	2.292	1.760	3,818	946
24	2.300	1.732	4,034	1,013
25	2.292	1.721	4,199	1,065
26	2.289	1.754	3,265	813
27	2.283	1.765	3,625	899
28	2.297	1.709	3,604	918
29	2.294	1.713	3,576	910
30	2.285	1.722	3,920	996
31	2.289	1.728	4,458	1,127
32	2.298	1.748	4,508	1,122
33	2.298	1.748	5,001	1,245
34	2.302	1.729	4,304	1,081
35	2.295	1.761	4,706	1,164
No. of tests				35
Mean				1,020
Maximum				1,245
Minimum				813
COV				0.104
K for 5 th percentile with 75% confidence				1.849
Lower tolerance limit (LTL)				824 ^(a)
LTL/3.15				262

^(a) Based on a normal distribution (838 psi based on a lognormal distribution).

LVL edgewise block shear tests (TSA)
 Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)
 Test lab: APA Research Center, Tacoma, WA
 Conditions: Standard conditions

Specimen Number	Length (in.)	Width (in.)	Max Load (lbf)	Shear Strength (psi)
1	2.306	1.781	4,030	981
2	2.311	1.811	4,351	1,040
3	2.265	1.799	3,702	908
4	2.245	1.797	3,444	854
5	2.287	1.827	3,111	744
6	2.310	1.800	3,301	794
7	2.304	1.803	4,561	1,098
8	2.184	1.749	4,448	1,164
9	2.234	1.784	4,106	1,030
10	2.038	1.767	3,099	860
11	2.304	1.794	4,039	977
12	2.264	1.787	3,606	891
13	2.309	1.807	4,486	1,075
14	2.305	1.818	3,170	757
15	2.300	1.730	3,898	980
16	2.308	1.786	3,873	940
17	2.164	1.877	4,003	985
18	2.288	1.819	3,479	836
19	2.309	1.802	3,525	847
20	2.298	1.833	3,023	718
21	2.305	1.820	3,489	832
22	2.306	1.806	4,734	1,137
23	2.304	1.809	3,848	923
24	2.305	1.732	4,213	1,055
25	2.304	1.722	2,843	717
26	2.306	1.805	4,135	993
27	2.308	1.823	3,607	857
28	2.309	1.817	3,954	942
29	2.279	1.794	2,615	639
30	2.307	1.830	4,702	1,114
31	2.305	1.778	3,728	910
32	2.303	1.793	4,818	1,167
33	2.307	1.807	3,602	864
34	2.309	1.781	4,297	1,045
35	2.304	1.815	4,121	985
No. of tests				35
Mean				933
Maximum				1,167
Minimum				639
COV				0.144
K for 5 th percentile with 75% confidence				1.849
Lower tolerance limit (LTL)				685 ^(a)
LTL/3.15				218

^(a) Based on a normal distribution (702 psi based on a lognormal distribution).

LVL edgewise block shear tests (TSH)

Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Specimen Number	Length (in.)	Width (in.)	Max Load (lbf)	Shear Strength (psi)
TSH TTH-01	1.762	2.519	3,561	802
TSH TTH-02	1.760	2.496	3,550	808
TSH TTH-03	1.757	2.534	3,050	685
TSH TTH-04	1.759	2.492	3,776	861
TSH TTH-05	1.757	2.494	4,013	916
TSH TTH-06	1.756	2.520	3,937	890
TSH TTH-07	1.756	2.511	3,791	860
TSH TTH-08	1.758	2.512	3,926	889
TSH TTH-09	1.748	2.501	3,776	864
TSH TTH-10	1.726	2.561	3,854	872
TSH TTH-11	1.753	2.495	3,710	848
TSH TTH-12	1.753	2.514	4,037	916
TSH TTH-13	1.754	2.508	3,723	846
TSH TTH-14	1.750	2.499	4,006	916
TSH TTH-15	1.758	2.508	4,414	1,001
TSH TTH-16	1.759	2.524	4,408	993
TSH TTH-17	1.755	2.490	3,001	687
TSH TTH-18	1.758	2.505	3,680	836
TSH TTH-19	1.757	2.514	3,839	869
TSH TTH-20	1.760	2.513	3,577	809
TSH TTH-21	1.761	2.516	3,302	745
TSH TTH-22	1.753	2.433	3,282	770
TSH TTH-23	1.748	2.509	4,129	941
TSH TTH-24	1.749	2.492	3,524	808
TSH TTH-25	1.757	2.527	4,000	901
TSH TTH-26	1.756	2.524	3,700	835
TSH TTH-27	1.750	2.503	3,604	823
TSH TTH-28	1.762	2.490	3,752	855
TSH TTH-29	1.757	2.502	3,727	848
TSH TTH-30	1.754	2.513	3,907	886
TSH TTH-31	1.756	2.494	4,179	954
TSH TTH-32	1.762	2.505	4,394	995
No. of tests				32
Mean				860
Maximum				1,001
Minimum				685
COV				0.089
K for 5 th percentile with 75% confidence				1.860
Lower tolerance limit (LTL)				718
LTL/3.15				228

LVL edgewise block shear tests (TSH)

Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Specimen Number	Length (in.)	Width (in.)	Max Load (lbf)	Shear Strength (psi)
TSH TBH1-01	1.776	2.261	3,144	783
TSH TBH1-02	1.764	2.247	2,765	698
TSH TBH1-03	1.767	2.155	2,865	753
TSH TBH1-04	1.769	2.313	3,567	872
TSH TBH1-05	1.770	2.272	3,129	778
TSH TBH1-06	1.773	2.221	2,733	694
TSH TBH1-07	1.776	2.241	3,413	857
TSH TBH1-08	1.777	2.246	2,601	652
TSH TBH1-09	1.776	2.278	3,298	815
TSH TBH1-10	1.771	2.264	3,248	810
TSH TBH1-11	1.768	2.266	3,134	782
TSH TBH1-12	1.764	2.279	3,877	965
TSH TBH1-13	1.780	2.246	3,557	890
TSH TBH1-14	1.761	2.244	3,080	779
TSH TBH1-15	1.766	2.231	2,844	722
TSH TBH1-16	1.768	2.244	2,774	699
TSH TBH1-17	1.772	2.233	3,274	828
TSH TBH1-18	1.772	2.238	3,349	844
TSH TBH1-19	1.773	2.251	3,658	916
TSH TBH1-20	1.763	2.248	3,264	824
TSH TBH1-21	1.763	2.250	2,928	738
TSH TBH1-22	1.770	2.263	2,931	732
TSH TBH1-23	1.766	2.234	2,815	713
TSH TBH1-24	1.770	2.242	3,106	783
TSH TBH1-25	1.777	2.236	2,931	738
TSH TBH1-26	1.776	2.237	3,249	818
TSH TBH1-27	1.772	2.258	2,919	730
TSH TBH1-28	1.772	2.238	3,601	908
TSH TBH1-29	1.775	2.245	2,430	610
TSH TBH1-30	1.773	2.269	2,782	691
TSH TBH1-31	1.771	2.249	3,492	877
No. of tests				31
Mean				784
Maximum				965
Minimum				610
COV				0.106
K for 5 th percentile with 75% confidence				1.864
Lower tolerance limit (LTL)				629
LTL/3.15				200

LVL edgewise block shear tests (TSH)

Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Specimen Number	Length (in.)	Width (in.)	Max Load (lbf)	Shear Strength (psi)
TSH TBH2-01	1.773	2.269	3,161	786
TSH TBH2-02	1.772	2.281	3,080	762
TSH TBH2-03	1.769	2.271	2,755	686
TSH TBH2-04	1.776	2.266	2,890	718
TSH TBH2-05	1.774	2.285	3,252	802
TSH TBH2-06	1.774	2.271	3,065	761
TSH TBH2-07	1.768	2.363	2,649	634
TSH TBH2-08A	1.775	2.270	3,526	875
TSH TBH2-09	1.777	2.269	3,151	782
TSH TBH2-10	1.770	2.276	2,358	585
TSH TBH2-11	1.775	2.265	3,323	826
TSH TBH2-12	1.769	2.266	3,007	750
TSH TBH2-13	1.772	2.273	3,097	769
TSH TBH2-14	1.769	2.273	3,381	841
TSH TBH2-15	1.766	2.278	3,206	797
TSH TBH2-16	1.775	2.276	3,029	750
TSH TBH2-17	1.772	2.269	2,819	701
TSH TBH2-18	1.762	2.281	3,529	878
TSH TBH2-19	1.776	2.270	3,502	869
TSH TBH2-20	1.767	2.270	3,254	811
TSH TBH2-21	1.770	2.267	3,328	829
TSH TBH2-22	1.787	2.274	3,080	758
TSH TBH2-23	1.774	2.285	2,956	729
TSH TBH2-24	1.762	2.269	3,619	905
TSH TBH2-25	1.773	2.266	3,425	853
TSH TBH2-26	1.772	2.270	3,668	912
TSH TBH2-27	1.770	2.268	3,405	848
TSH TBH2-28	1.769	2.273	3,263	811
TSH TBH2-29	1.769	2.273	3,610	898
TSH TBH2-30	1.771	2.290	3,478	858
TSH TBH2-31	1.774	2.269	3,466	861
TSH TBH2-32	1.771	2.276	3,115	773
No. of tests				32
Mean				794
Maximum				912
Minimum				585
COV				0.097
K for 5 th percentile with 75% confidence				1.860
Lower tolerance limit (LTL)				651
LTL/3.15				207

LVL edgewise block shear tests (TSH)

Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Specimen Number	Length (in.)	Width (in.)	Max Load (lbf)	Shear Strength (psi)
TSH TBH3-01	1.764	2.247	3,243	818
TSH TBH3-02	1.743	2.244	3,538	905
TSH TBH3-03	1.756	2.240	3,298	838
TSH TBH3-04	1.752	2.263	3,450	870
TSH TBH3-05	1.760	2.268	3,219	806
TSH TBH3-06	1.757	2.253	3,298	833
TSH TBH3-07	1.758	2.258	3,523	887
TSH TBH3-08	1.778	2.520	3,703	826
TSH TBH3-09	1.756	2.255	3,281	829
TSH TBH3-10	1.758	2.254	2,915	736
TSH TBH3-11	1.755	2.237	2,685	684
TSH TBH3-12	1.757	2.257	3,006	758
TSH TBH3-13	1.756	2.256	2,579	651
TSH TBH3-15	1.760	2.250	3,550	896
TSH TBH3-16	1.755	2.265	2,780	699
TSH TBH3-18	1.750	2.249	2,663	677
TSH TBH3-20	1.760	2.254	2,926	737
TSH TBH3-21	1.759	2.249	3,704	936
TSH TBH3-22	1.753	2.250	3,465	878
TSH TBH3-23	1.759	2.249	3,578	905
TSH TBH3-24	1.756	2.249	3,503	887
TSH TBH3-25	1.773	2.244	3,682	925
TSH TBH3-26	1.773	2.242	3,766	948
TSH TBH3-27	1.756	2.247	3,019	765
TSH TBH3-28	1.753	2.251	2,986	757
TSH TBH3-29	1.753	2.228	2,871	735
TSH TBH3-30	1.749	2.258	3,272	828
TSH TBH3-31	1.772	2.256	3,144	787
TSH TBH3-32	1.756	2.257	3,604	909
No. of tests				29
Mean				818
Maximum				948
Minimum				651
COV				0.103
K for 5 th percentile with 75% confidence				1.873
Lower tolerance limit (LTL)				659
LTL/3.15				209

LVL edgewise block shear tests (TSH)

Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)

Test lab: Forest Products Laboratory, Madison, WI

Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Specimen Number	Length (in.)	Width (in.)	Max Load (lbf)	Shear Strength (psi)
TSH TBH4-01	1.779	2.524	3,352	747
TSH TBH4-02	1.781	2.535	3,200	709
TSH TBH4-03	1.778	2.526	3,481	775
TSH TBH4-04	1.779	2.536	3,259	722
TSH TBH4-05	1.778	2.541	3,677	814
TSH TBH4-06	1.778	2.531	3,232	718
TSH TBH4-07	1.780	2.515	3,636	812
TSH TBH4-08	1.785	2.532	4,443	983
TSH TBH4-09	1.778	2.532	3,656	812
TSH TBH4-10	1.786	2.517	3,229	718
TSH TBH4-11	1.783	2.526	3,366	747
TSH TBH4-12	1.768	2.524	4,066	911
TSH TBH4-13	1.779	2.524	3,738	832
TSH TBH4-14	1.778	2.529	4,041	899
TSH TBH4-15	1.778	2.549	3,534	780
TSH TBH4-16	1.762	2.551	4,002	890
TSH TBH4-17	1.759	2.255	2,978	751
TSH TBH4-18	1.779	2.518	3,745	836
TSH TBH4-19	1.782	2.524	3,710	825
TSH TBH4-20	1.776	2.523	3,389	756
TSH TBH4-21	1.774	2.537	3,521	782
TSH TBH4-22	1.777	2.496	3,861	871
TSH TBH4-23	1.761	2.569	3,756	830
TSH TBH4-24	1.775	2.529	3,895	868
TSH TBH4-25	1.771	2.530	3,433	766
TSH TBH4-26	1.785	2.514	4,102	914
TSH TBH4-27	1.779	2.515	3,479	778
TSH TBH4-28	1.779	2.525	3,320	739
TSH TBH4-29	1.783	2.525	3,982	884
TSH TBH4-30	1.782	2.531	3,167	702
TSH TBH4-31	1.775	2.532	3,692	821
TSH TBH4-32	1.780	2.527	4,045	899
No. of tests				32
Mean				809
Maximum				983
Minimum				702
COV				0.089
K for 5 th percentile with 75% confidence				1.860
Lower tolerance limit (LTL)				676
LTL/3.15				215

LVL edgewise block shear tests (TSH)
 Material: 1-3/4" 3,100Fb-2.0E LVL (P49 treated)
 Test lab: Forest Products Laboratory, Madison, WI
 Conditions: Hygrothermal conditioning and re-conditioned to standard conditions

Combined Statistics

	Shear Strength
No. of tests	156
Mean	813
Maximum	1,001
Minimum	585
COV	0.101
K for 5 th percentile with 75% confidence	1.734
Lower tolerance limit (LTL)	671 ^(a)
LTL/3.15	213

^(a) Based on a normal distribution (677 psi based on a lognormal distribution).

Appendix D. Adhesive Durability Test Results

LVL adhesive durability tests

Material: 1-3/4" 3,100Fb-2.0E LVL (UBA, untreated)

Test lab: APA Research Center, Tacoma, WA

Specimen Number	Failure Load (lbf)	Moisture Content (%)	Width in.	Thickness in.	Shear Strength psi
Control Specimens					
1	2,375	5.5	1.688	1.750	402
2	2,408	5.6	1.688	1.750	408
3	3,083	5.7	1.688	1.750	522
4	2,069	5.8	1.688	1.750	350
5	2,576	5.6	1.688	1.750	436
6	3,000	5.0	1.688	1.750	508
7	2,907	5.7	1.688	1.750	492
8	2,551	5.7	1.688	1.750	432
9	2,639	5.2	1.688	1.750	447
10	2,507	5.8	1.688	1.750	424
Count	10	10			10
Min	2,069	5.0			350
Max	3,083	5.8			522
Mean	2,611	5.6			442
COV (%)	11.9	4.8			11.9
6-Cycle VPS Specimens (Tested Redry)					
1	2,312	6.4	1.688	1.750	391
2	2,114	6.5	1.688	1.750	358
3	2,691	6.8	1.688	1.750	456
4	2,024	6.9	1.688	1.750	343
5	2,535	6.5	1.688	1.750	429
6	2,282	4.5	1.688	1.750	386
7	2,243	6.7	1.688	1.750	380
8	2,197	6.7	1.688	1.750	372
9	2,442	6.4	1.688	1.750	414
10	2,415	6.9	1.688	1.750	409
Count	10	10			10
Min	2,024	4.5			343
Max	2,691	6.9			456
Mean	2,325	6.5			394
COV (%)	8.6	10.8			8.6

Difference in MC: 0.9

Mean Ratio of Cycled/Control: **0.89**