Qualification Testing of E21M1
Grade SPF-S Cross Laminated Timber

University of Maine's Advanced Structures and Composites Center
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1. EXECUTIVE SUMMARY

The primary objective of this project is to introduce two new grades of cross laminated timber (CLT) using machine stress rated (MSR) grades of SPF-S lumber as noted in the qualification test plan (Appendix A), approved by APA via email on June 16, 2020. The two grades being proposed are "E21" utilizing 1650f-1.5E SPF-S MSR lumber in the longitudinal layers and "E21M1" utilizing 2100f-1.8E SPF-S MSR lumber in the longitudinal layers. Both of these grades use No. 3 SPF-S lumber in the transverse layers. Lumber was shipped from Maine to the SmartLam, LLC facility in Columbia Falls, MT for conditioning and CLT manufacturing. After CLT manufacturing and specimen preparation, materials were shipped to the Advanced Structures and Composites Center (ASCC), at the University of Maine, for testing which occurred from December 2020 – May 2021. The ASCC is an ISO 17025-accredited laboratory (TL-255), by the International Accreditation Service (IAS), and has PRG 320 listed within its Scope of Accreditation. Testing of finger-joint strength and durability was conducted at the SmartLam, LLC facility, while adhesive face bond and flatwise mechanical properties were evaluated at the ASCC in accordance with ANSI/APA PRG 320-2019. The empirical test data justified the analytically-derived design values for the E21M1 CLT grade using standard engineering formulae based on the shear-analogy model and Appendix X3 of ANSI/APA PRG 320 using the lamination design values per the National Design Specification (NDS). In addition, the adhesive face bond test results met the criteria noted in ANSI/APA PRG 320. As such, it is the author's conclusion that these two new E21 and E21M1 grades of CLT are qualified for use at the SmartLam, LLC, Columbia Falls, MT facility. This effort was funded by USDA Agricultural Research Service project # 0204-41510-001-68S, whose objective was to encourage CLT manufacturing in Maine.

2. OVERVIEW

2.1. Introduction

The test protocol described herein assumes the following:

- The qualification of the "E21M1" CLT layup made of 2100f-1.8E SPF-S MSR lumber in the longitudinal layers and No. 3 SPF-S lumber in the transverse layers will justify the qualification of the "E21" CLT layup made of 1650f-1.5E SPF-S MSR lumber in the longitudinal direction and No. 3 SPF-S lumber in the transverse direction without additional qualification tests.
- The end joint testing (described in Section 6.3.2 of ANSI/APA PRG 320-2019) of nominal 2x6 2100f-1.8E SPF-S MSR lumber will justify narrower lumber widths and lower lumber grades, such that other criteria noted in ANSI/APA PRG 320-2019 are met. As such, end joint testing on 1650f-1.5E SPF-S MSR lumber or No. 3 SPF-S lumber with the same or narrower widths is not required.
- Qualification testing of 3-alt and 7-maxx CLT will justify all intermediate depths. The CLT layups are as described below in Table 1.

Table 1. Layups of E21M1 3-alt and 7-maxx CLT.

CLT Grade/ Layup	t_p (in.)	Lamination Thickness (in.) in CLT Layup				
		//	⊥	//	⊥	//
E21M1/ 3-alt	4-1/8	1-3/8	1-3/8	1-3/8		
E21M1/ 7-maxx	9-5/8	1-3/8 x 2	1-3/8	1-3/8	1-3/8	1-3/8 x 2

The qualification tests were conducted at the Advanced Structures and Composites Center (ASCC) at the University of Maine, Orono, ME and at SmartLam, LLC's manufacturing facility in Columbia Falls, MT.

2.2. Qualification Tests

The CLT was evaluated for the following properties:

- Glue Bond Quality/Durability
  - Delamination of adhesive face bond: glue bond delamination properties were evaluated in accordance with Section 8.2.6 of ANSI/APA PRG 320-2019
  - Block shear of adhesive face bond: block shear tests were conducted in accordance Section 8.2.5 of ANSI/APA PRG 320-2019
  - Finger-joint adhesive tensile strength: full-size end-joint tension tests were conducted in accordance with Section 6.3.2(b) of ANSI/APA PRG 320-2019
  - Finger-joint durability: glue bond delamination properties were evaluated in accordance with Section 8.2.6 of ANSI/APA PRG 320-2019
- Mechanical Properties
  - Flatwise bending stiffness (EI) and moment capacity were evaluated in accordance with Sections 8.5.3.1 and 8.5.3.2 of ANSI/APA PRG 320-2019
  - Flatwise shear stiffness (GA) and capacity were evaluated with Sections 8.5.4.1 and 8.5.4.2 of ANSI/APA PRG 320-2019

Note: Edgewise properties (bending and shear stiffness and capacity) were not evaluated as part of the work described herein.

2.3. Design Values

Design values for the E21 and E21M1 grades were derived using standard engineering formulae based on the Shear-Analogy Model (Gagnon and Popovski, 2011) and Appendix X3 of ANSI/APA PRG 320 using the lamination design values for the species/grades listed in the National Design Specification (NDS). In addition, the calculated moment capacities in the major strength direction were further multiplied by a factor of 0.85 for conservatism per Equation X3-1 ASD in ANSI/APA PRG 320-2019. The NDS/ASD reference design values of the laminations used in the new E21 and E21M1 grades are shown in Table 2. The analytically-derived CLT design properties for the E21M1 3-alt and 7-maxx layups are shown in Table 3.

As specified in PRG 320, when calculating CLT design properties, the transverse E of the lamination is assumed to be E/30, the longitudinal G of the lamination is assumed to be E/16, and the transverse G of the lamination is assumed to be longitudinal G/10.

Table 2. ASD Reference Design Values for Laminations Used in E21 and E21M1 CLT

CLT Grade	Laminations Used in Major Strength Direction						Laminations Used in Minor Strength Direction					
	F_b (psi)	E (10^6 psi)	F_t (psi)	F_c (psi)	F_v (psi)	F_s (psi)	F_b (psi)	E (10^6 psi)	F_t (psi)	F_c (psi)	F_v (psi)	F_s (psi)
E21	1,650	1.5	1,020	1,700	150	50	450	1.0	200	575	135	45
E21M1	2,100	1.8	1,575	1,875	150	50	450	1.0	200	575	135	45

Table 3. ASD Reference Design Values for 3-alt and 7-maxx E21M1 CLT

CLT Grade/ Layup	t_p (in.)	Lamination Thickness (in.) in CLT Layup					Major Strength Direction				Minor Strength Direction			
		//	⊥	//	⊥	//	$(F_bS)_{eff,f,0}$ (lbf-ft/ft of width)	$(EI)_{eff,f,0}$ (10^6 lbf-in.^{2}/ft of width)	$(GA)_{eff,f,0}$ (10^6 lbf/ft of width)	$V_{s,0}$ (10^6 lbf/ft of width)	$(F_bS)_{eff,f,90}$ (lbf-ft/ft of width)	$(EI)_{eff,f,90}$ (10^6 lbf-in.^{2}/ft of width)	$(GA)_{eff,f,90}$ (10^6 lbf/ft of width)	$V_{s,90}$ (10^6 lbf/ft of width)
E21M1 3-alt	4-1/8	1-3/8	1-3/8	1-3/8			4,875	122	0.39	1,490	140	2.6	0.63	550
E21M1 7-maxx	9-5/8	1-3/8 x 2	1-3/8	1-3/8	1-3/8	1-3/8 x 2	25,500	1,486	1.2	3,475	1,230	68	1.4	1,650

3. MATERIAL DESCRIPTION

In May 2017, four units of 2100f-1.8E SPF-S MSR 2x6 lumber, and 7 units of "PMO" SPF-S 2x6 lumber, were shipped from Maibec Lumber Co., Masardis, ME and Pleasant River Lumber Co., Moose River, Maine, respectively, to SmartLam, LLC, Columbia Falls, Montana for conditioning and CLT manufacturing. Note: Both lumber suppliers are certified by the Northeastern Lumber Manufacturers Association (NELMA).

Due to several factors, including the decision by SmartLam, LLC to commission a new manufacturing facility shortly after this project was initiated, CLT manufacturing did not occur until 2020.

The "PMO" term stands for "Planar Mill Out". This category of lumber supplied by Pleasant River Lumber Company is defined as anything lower than No. 2 grade. Since the PRG 320 standard requires a minimum grade of No. 3 lumber in the transverse direction, University of Maine contracted the Western Wood Products Association (WWPA) to identify No. 3 grade boards from the PMO at the SmartLam, LLC facility on June 17th, 2020. Only No. 3 grade boards were used. Documentation of the PMO regrading is provided in Appendix B.

Six SPF-S E21M1 CLT billets (two 3-layer and four 7-layer) were manufactured at SmartLam, LLC, Columbia Falls, MT in August and October 2020. The production details, including billet sizes and cutting diagrams, are described in the APA Witness Reports and other supplemental documents, presented in Appendix B.

The CLT billets were shipped to the ASCC in Orono, Maine after manufacture for moisture conditioning and testing which occurred from December 2020 – May 2021. Figure 1 is an illustration of the flatwise major and minor strength axes.

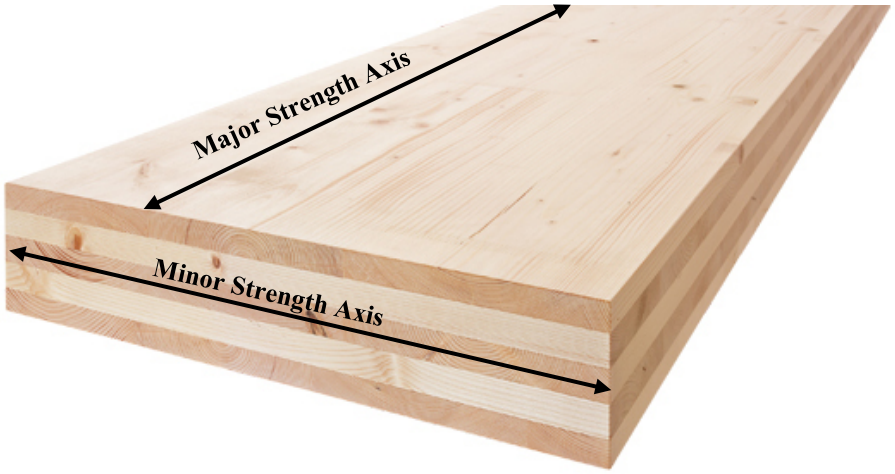

Figure 1. Orientation of axes in CLT.

Figure 2. CLT arriving at the ASCC from SmartLam, LLC.

4. TESTS METHODS AND DATA ANALYSIS

4.1. Qualification of Finger-Joints

In July 2020, prior to the CLT manufacturing, end joint tension and delamination testing were conducted at the SmartLam, LLC facility under APA witness. The qualification plan (Appendix C) prepared by SmartLam, LLC and APA notes that the qualification testing was required for the approval of a new adhesive system, a new finger-jointing and planning line at the manufacturing facility being commissioned, and new lumber species/grades being used, i.e., 2100f-1.8E SPF-S MSR lumber.

4.1.1. Basis

- Section 6.3.2 of ANSI/APA PRG 320-2019

4.1.2. Testing Facility and Condition

- After manufacturing, finger-jointed 2100f-1.8E SPF-S MSR lumber was evaluated at the SmartLam, LLC manufacturing facility in July 2020 under APA witness.
- The tensile specimens were tested in the as-manufactured moisture condition, while the delamination specimens were evaluated following a vacuum-pressure-soak (VPS).

4.1.3. Test Methods

- Tension testing followed Section 6.3.2 of ANSI/APA PRG 320-2019
- Delamination testing followed Section 8.2.6(b) of ANSI/APA PRG 320-2019

4.1.4. Results

Individual test results are presented in Appendix C. Based on the test data, the derived allowable tensile strength of the finger-joints (2,005 psi) exceeded the NDS published tension design value of 1,575 psi for the 2100f-1.8E SPF-S MSR lumber. In addition, all of the tested durability specimens had a delamination of less than 5%. As such, it was concluded that the finger-jointed lumber met the acceptance criteria.

4.2. Plant pre-qualification of adhesive face bond

All tests listed in Table 4 were conducted at the Advanced Structures and Composites Center in Orono, Maine in December 2021.

Table 4. Summary table for CLT face bond testing.

CLT Layup	Test	Specimen dimensions			Number of specimens
		L (in.)	w (in.)	h (in.)	
3-alt	Delamination	3	3	4-1/8	6
	Block shear	1-1/2	2	4-1/8	6
7-maxx	Delamination	3	3	9-5/8	6
	Block shear	1-1/2	2	9-5/8	6

4.2.1. Block Shear

4.2.1.1. Basis

- Section 8.2.5 of ANSI/APA PRG 320-2019

4.2.1.2. Testing Facility and Condition

- After manufacturing, CLT billets were shipped to the Advanced Structures and Composites Center, University of Maine, Orono, ME for block shear testing. The specimen cutting diagrams, showing the location of the 2’ x 2’ blocks, from which shear specimens were taken from, are included in Appendix B.
- The specimens were tested in the as-received moisture condition.

4.2.1.3. Test Methods

- Tested at a loading rate of 0.50 ± 0.05 inch/min.

4.2.1.4. Results

Individual test results are presented in Appendix D. The average wood failure for 3-alt CLT was 100%. The average wood failure for 7-maxx CLT was 97%, with 100% of the specimens having an associated wood failure of 60% or greater. As such, the acceptance criteria of Section 6.3.3(a) of ANSI/APA PRG 320-2019 were met for the SPF-S CLT.

4.2.2. Delamination

4.2.2.1. Basis

- Section 8.2.6 of ANSI/APA PRG 320-2019

4.2.2.2. Testing Facility and Condition

- After manufacturing, CLT billets were shipped to the Advanced Structures and Composites Center, University of Maine, Orono, ME for delamination testing. The specimen cutting diagrams, showing the location of the 2' x 2' blocks, from which delamination specimens were taken from, are included in Appendix B.
- The specimens were evaluated after moisture cycling.

4.2.2.3. Test Methods

- Moisture cycling followed Section 8.2.6(b) of ANSI/APA PRG 320-2019.

4.2.2.4. Results

Individual test results are presented in Appendix D. The average delamination of all bondlines in each specimen for 3-alt and 7-maxx CLT was less than 5%. As such, the acceptance criterion of Section 6.3.3(b) of ANSI/APA PRG 320-2019 was met for the SPF-S CLT.

4.3. Mechanical Property Evaluation

All tests listed in Table 5 were conducted at the Advanced Structures and Composites Center in Orono, Maine from December 2020 through May 2021.

Table 5. Summary table for "E21M1" CLT mechanical properties testing.

CLT layout	Test	Orientation	# of specimens	Specimen dimensions				
				Length (in.) (as prepared by SmartLam, LLC)	Width (in.)	Depth (in.)	Tested Span, l (in.)	l/d
3-alt	Flatwise bending	Longitudinal	10	132	12	Actual billet thickness	123-3/4	30
		Transverse	10	96	12		74-1/4	18
	Flatwise shear strength	Longitudinal	10	28	12		23-7/8	5.8
		Transverse	10	28	12		23-7/8	5.8
	Flatwise shear modulus	Longitudinal	12	132[(a)]	12		See Table 7	See Table 7
		Transverse	12	96[(a)]	12			
7-maxx	Flatwise bending	Longitudinal	10	300	12	Actual billet thickness	280-3/4	29
		Transverse	10	204	12		173-1/4	18
	Flatwise shear	Longitudinal	10	60	12		50-3/8	5.2
		Transverse	10	60	12		50-3/8	5.2
	Flatwise shear modulus	Longitudinal	12	300[(a)]	12		See Table 7	See Table 7
		Transverse	12	204[(a)]	12			

[(a)] Flatwise bending specimens were non-destructively tested for shear modulus prior to the destructive bending tests.

4.3.1. Flatwise Bending

4.3.1.1. Basis

- Section 8.5.3 of ANSI/APA PRG 320-2019

4.3.1.2. Testing Facility and Condition

- After manufacturing, CLT billets were shipped to the Advanced Structures and Composites Center, University of Maine, Orono, ME for moisture conditioning and testing. The cutting diagrams, showing the location of the specimens within the larger CLT billets, are included in Appendix B.
- The specimens were tested at as-received conditions from March through May 2021.

4.3.1.3. Test Methods

Flatwise bending tests were conducted in both the major and minor strength directions in accordance with the third-point load method of Section 4 through 12 of ASTM D198-15 using a nominal specimen width of 12 inches. The on-center span was 30 times the specimen depth for the tests in the major strength direction and 18 times the specimen depth for the testing in the minor strength direction (Table 5).

Bearing plates measured 4 inches and 9 inches in length for the 3-alt and 7-maxx CLT, respectively, and were of a sufficient width and thickness to provide a firm bearing surface and a uniform bearing stress across the width of the specimen, thus complying with Section 7.2.1 of ASTM D198. Bearing and load points were configured such that unrestricted longitudinal deformation and rotation of the specimen was allowed via reaction-alignment-rockers and rollers of both one end plate and one load point. The load heads had a radius of curvature of 16 inches, which complied with the ASTM D198-15, Section 7.3.1 requirement that the loading surface of the blocks have a radius of curvature equal to two to four times the specimen depth for the 3-alt CLT and fell only slightly out of the range for the 7-maxx CLT.

Midspan deflection was measured in relation to the neutral axis using a HGSI linear potentiometer having a 4-inch stroke (AS#2761, verified on April 7, 2021) and yoke system for the 3-alt CLT. Three linear potentiometers were used for the 7-maxx CLT; two HGSI 1-inch stroke linear potentiometers were used at the neutral axis at the reactions (AS#2768 and AS#3329, verified on April 7, 2021) and an additional HGSI linear potentiometer having a 4-inch stroke (AS#2761, verified on April 7, 2021) was used at the neutral axis at the midspan. Load was recorded using a Honeywell 250 kN load cell (SN 3175-50K/1201361_AS#650, calibrated on December 12, 2019). Load was applied using position control at rates such that the average time to maximum load was 4 minutes or greater.

At the conclusion of the testing, a small cross-section of each specimen was removed and used for as-tested density determination and moisture content measurement in accordance with ASTM D4442, Method B. The moisture content specimen was taken from the interior of the beam, i.e., not the end, as close to the failure zone as practical.

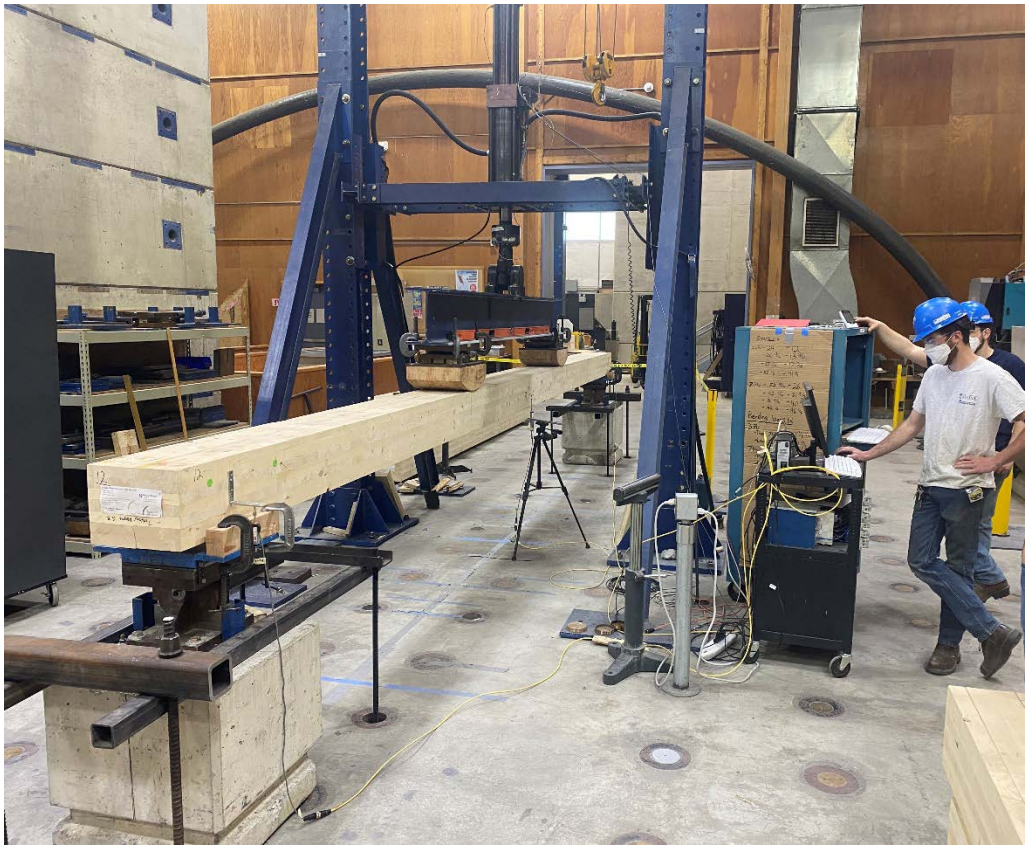

Figure 5. Flatwise bending tests.

4.3.1.4. Results

Individual test results are presented in Appendix E, while summary statistics of the testing is presented as Table 6. The average EI values from the testing exceed the analytically-derived design values for both the 3-alt and 7-maxx CLT. In addition, the allowable moment capacity, based on the lower tolerance limit (5^{th} percentile with 75% confidence) divided by 2.1 exceeded the analytically-derived design values for both the 3-alt and 7-maxx CLT.

Table 6. Flatwise bending stiffness and strength summary statistics.

CLT Layup	3-alt				7-maxx			
Orientation	Longitudinal		Transverse		Longitudinal		Transverse	
	F_bS (lbf-ft/ft)	EI (10^6 lbf-in.^{2}/ft)	F_bS (lbf-ft/ft)	EI (10^6 lbf-in.^{2}/ft)	F_bS (lbf-ft/ft)	EI (10^6 lbf-in.^{2}/ft)	F_bS (lbf-ft/ft)	EI (10^6 lbf-in.^{2}/ft)
N	10	10	10	10	10	10	10	10
Mean	19,194	**134**	2,465	**5.6**	72,492	**1,647**	16,685	**126**
Maximum	21,735	141	3,579	6.5	80,349	1,720	19,313	138
Minimum	16,910	127	1,918	4.5	58,354	1,495	11,611	117
COV	0.094	0.033	0.212	0.102	0.094	0.041	0.133	0.057
K	2.104		2.104		2.104		2.104	
LTL[(a)]	15,387		1,368		58,101		12,016	
LTL/2.1	**7,327**		**651**		**27,667**		**5,722**	
Requirement	**4,875**	**122**	**140**	**2.6**	**25,500**	**1,486**	**1,230**	**68**

(a) Lower tolerance limit (5th percentile with 75% confidence) based on normal distribution.

4.3.2. Flatwise Shear Modulus

4.3.2.1. Basis

- Section 8.5.4 of ANSI/APA PRG 320-2019

4.3.2.2. Testing Facility and Condition

- After manufacturing, CLT billets were shipped to the Advanced Structures and Composites Center, University of Maine, Orono, ME for moisture conditioning and testing. The cutting diagrams, showing the location of the specimens within the larger CLT billets, are included in Appendix B.
- The specimens were tested at as-received conditions from March through April 2021.

4.3.2.3. Test Methods

Flatwise shear modulus tests were conducted in both the major and minor strength directions in accordance with the center point load method of Section 45 through 51 of ASTM D198 using a nominal specimen width of 12 inches. Testing was conducted at four different spans as shown in Table 7 for each of the CLT layups. Span:depth ratios of 5.5, 6.5, 8.5, and 20.0 were used to meet the $(d/l)^2$ requirements of Section 50.2 of ASTM D198. In one case, however, this was not possible due to equipment limitations; the shortest span tested on the 3-alt layup was 24-1/2 inches, corresponding to a span:depth ratio of 5.9. This minor deviation was approved by APA staff prior to testing, and was expected to have minimal, if any, effect on the results.

Bearing plates measured 4 inches and 9 inches in length for the 3-alt and 7-maxx CLT, respectively, were of a sufficient width and thickness to provide a firm bearing surface and a uniform bearing stress across the width of the specimen, thus complying with Section 7.2.1 of ASTM D198. Bearing and load points were configured such that unrestricted longitudinal deformation and rotation of the specimen was allowed via reaction-alignment-rockers and rollers of both one end plate and the load point.

Midspan deflection was measured in relation to the neutral axis using an HGSI linear potentiometer having a 4-inch stroke (AS#2761, verified on April 7, 2021) and yoke system for the 3-alt CLT, and three of the four tested spans for the 7-maxx CLT. Three linear potentiometers were used for the longest span of the 7-maxx CLT; two HGSI 1-inch stroke linear potentiometers were used at the neutral axis at the reactions (AS#2768 and AS#3329, verified on April 7, 2021) and an additional HGSI linear potentiometer having a 4-inch stroke (AS#2761, verified on April 7, 2021) was used at the neutral axis at the midspan. Load was recorded using a Honeywell 250 kN load cell (SN 3175-50K/1201361_AS#650, calibrated on December 12, 2019). Load was applied at rates such that the average time to the designated proof load was approximately three minutes.

Table 7. Flatwise shear modulus test spans for the 3-alt and 7-maxx CLT layups.

CLT Layup	Depth, d (in.)	Span, l (in.)	l/d	$(d/l)^2$
3-alt	4-1/8	24-1/2	5.9	0.0283
		26-13/16	6.5	0.0237
		35-1/16	8.5	0.0138
		82-1/2	20	0.0025
7-maxx	9-5/8	52-15/16	5.5	0.0331
		62-9/16	6.5	0.0237
		81-13/16	8.5	0.0138
		192-1/2	20	0.0025

4.3.2.4. Results

Shear modulus, G, was determined by plotting $1/E_{app}$ (where E_{app} is the apparent modulus of elasticity calculated under center point loading) versus $(d/l)^2$ for each span tested. As indicated in Appendix X4 of ASTM D198, shear modulus is proportional to the slope of the best-fit line between these points.

Plots of $1/E_{app}$ versus $(d/l)^2$ are shown in Figures 2 and 3 for the 3-alt layup tested in the major and minor strength directions, respectively. Similarly, Figures 4 and 5 present $1/E_{app}$ versus $(d/l)^2$ the 7-maxx layup tested in the major and minor strength directions, respectively. Derived G and GA_{eff} values, from the plots, are summarized in Table 8. Based on these data, the effective shear stiffness of both CLT layups, in both strength directions, exceed the analytically-derived design values.

Table 8. Flatwise shear modulus test results.

	3-alt		7-maxx	
	Major axis	Minor axis	Major axis	Minor axis
Slope:	2.533E-05	4.926E-05	2.699E-05	8.078E-05
Y-intercept:	5.172E-07	1.172E-05	5.183E-07	6.827E-06
r^2:	0.998	0.709	0.990	0.953
MOE_{sf} (psi)	1,933,659	85,350	1,929,515	146,486
G (psi):	4.737E+04	2.436E+04	4.446E+04	1.486E+04
GA_{eff} (lbf/ft of width):	**2.337E+06**	**1.180E+06**	**5.105E+06**	**1.694E+06**
Requirement	**0.39E+06**	**0.63E+06**	**1.2E+06**	**1.4E+06**

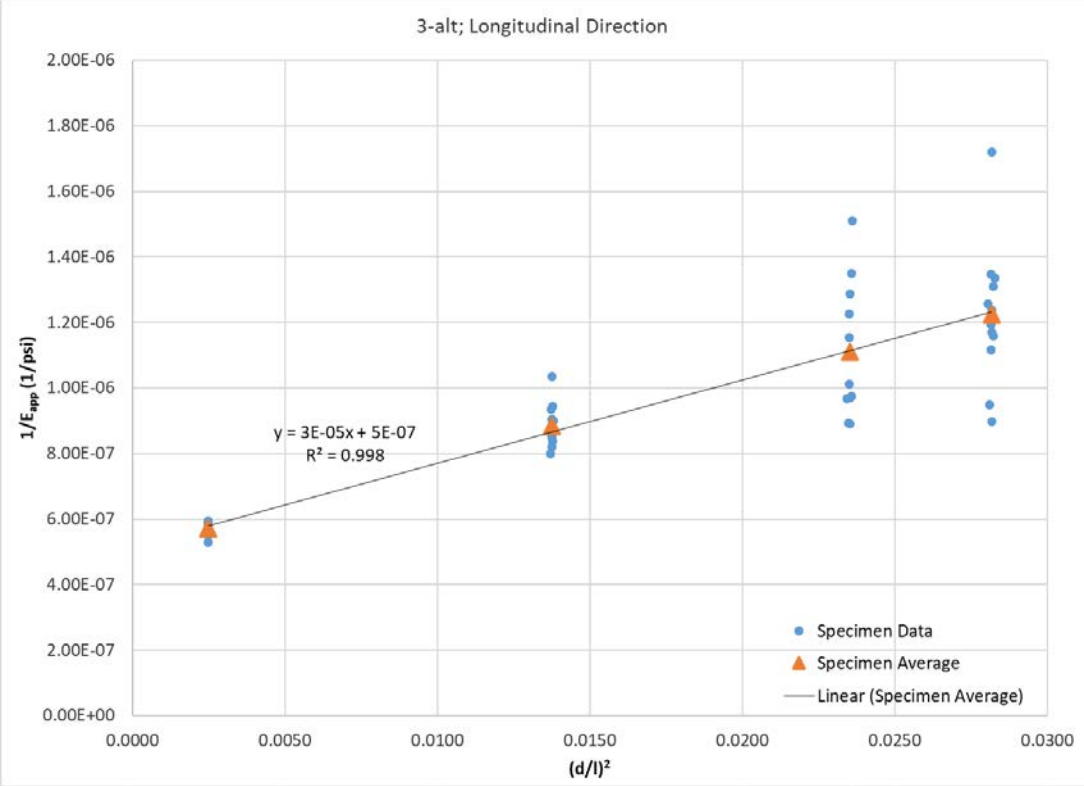

Figure 6. Shear modulus test data for the 3-alt CLT in the major strength direction.

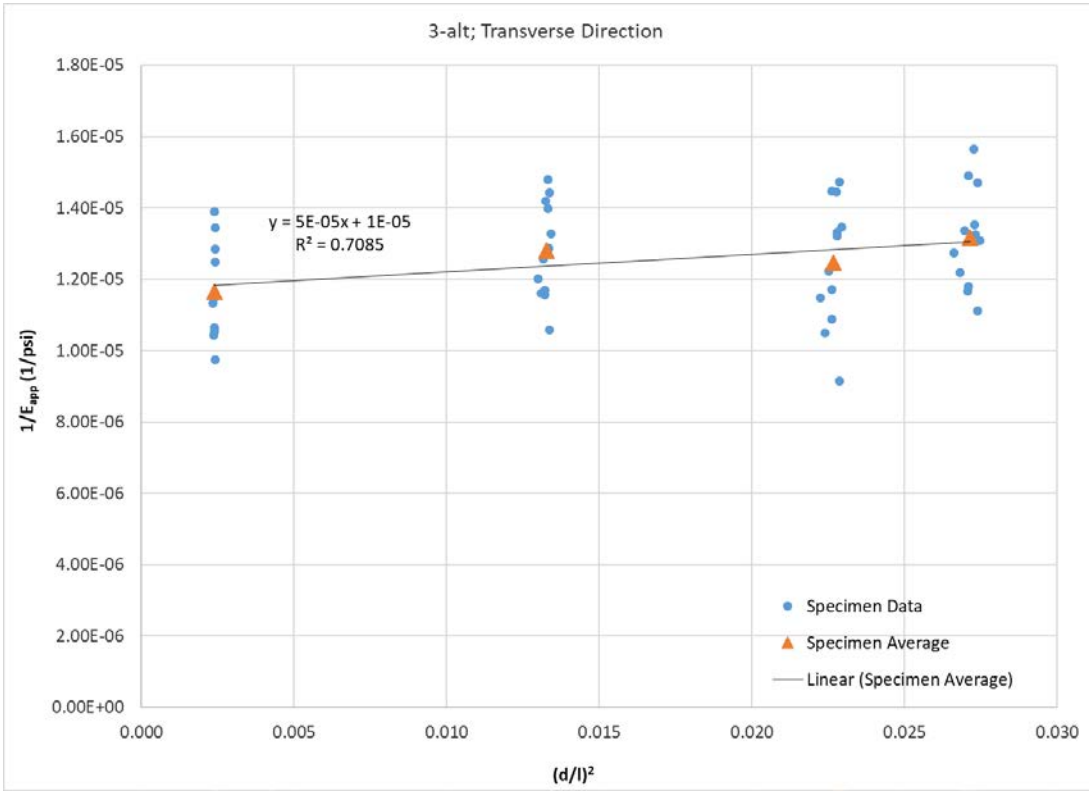

Figure 7. Shear modulus test data for the 3-alt CLT in the minor strength direction.

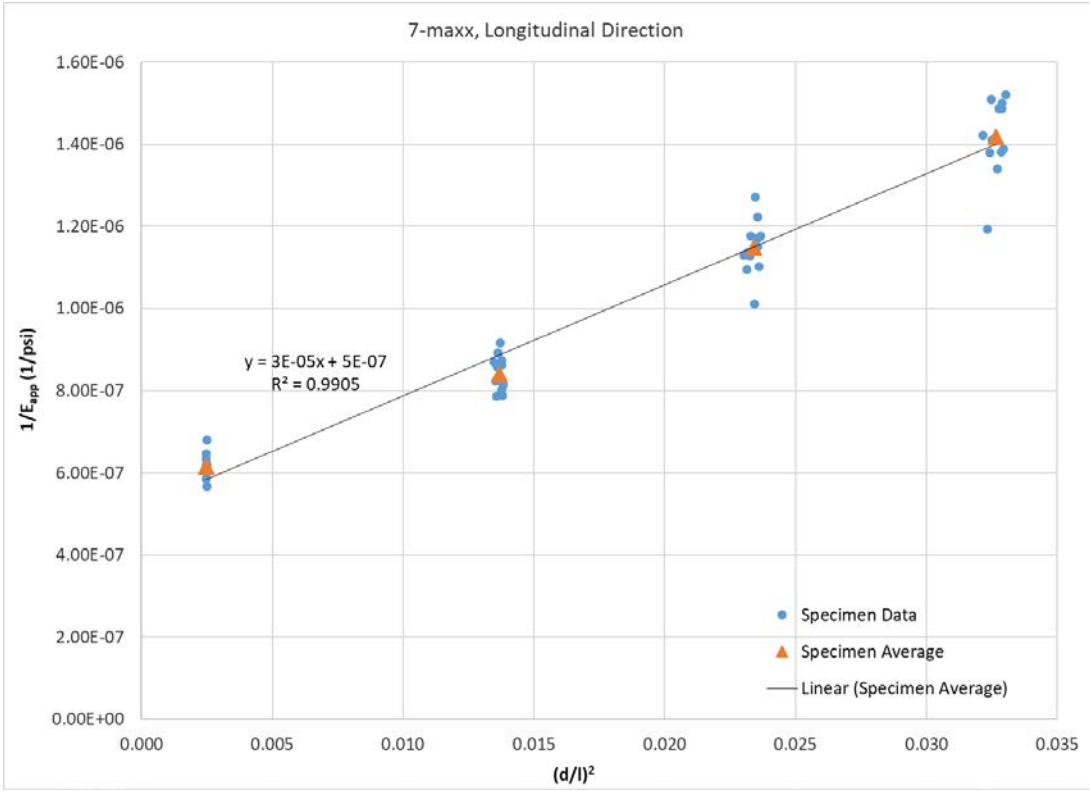

Figure 8. Shear modulus test data for the 7-maxx CLT in the major strength direction.

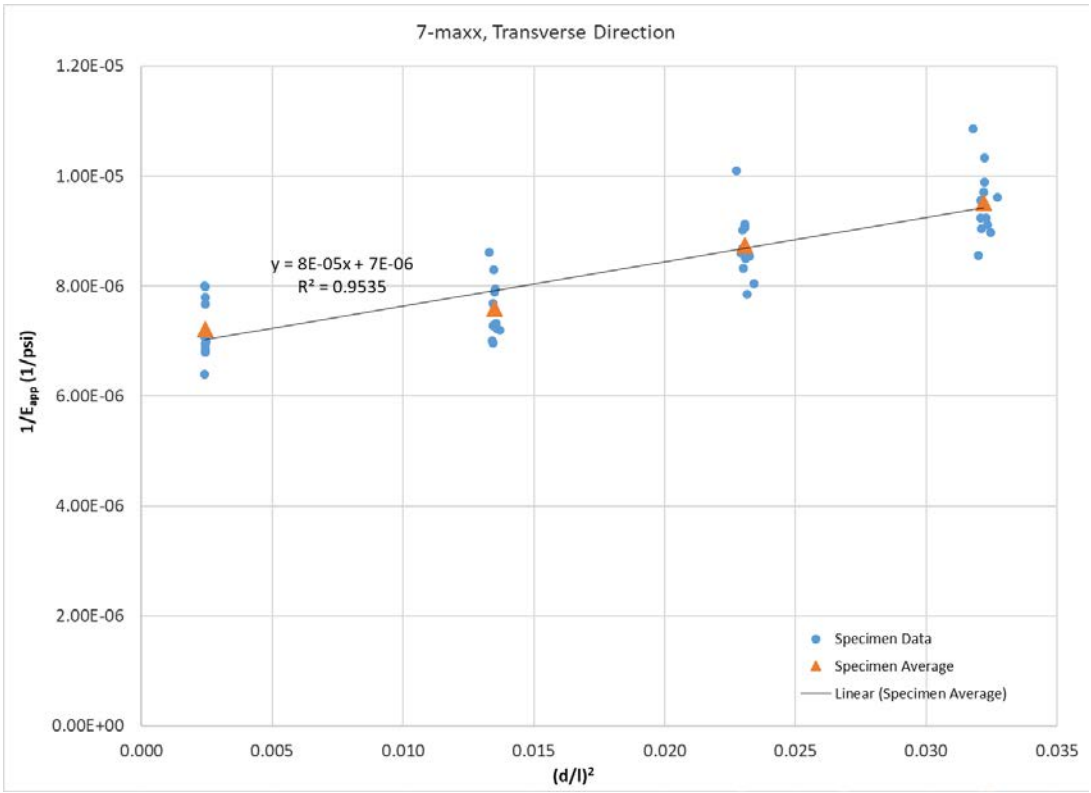

Figure 9. Shear modulus test data for the 7-maxx CLT in the minor strength direction.

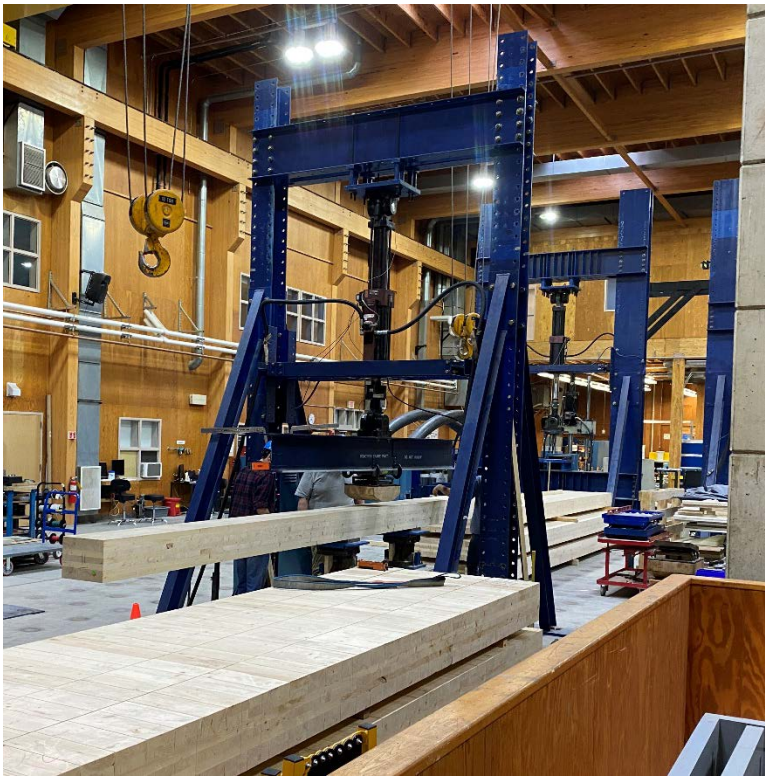

Figure 10. Flatwise shear modulus tests.

4.3.3. Flatwise Shear Strength

4.3.3.1. Basis

- Section 8.5.4 of ANSI/APA PRG 320-2019

4.3.3.2. Testing Facility and Condition

- After manufacturing, CLT billets were shipped to the Advanced Structures and Composites Center, University of Maine, Orono, ME for moisture conditioning and testing. The cutting diagrams, showing the location of the specimens within the larger CLT billets, are included in Appendix B.
- The specimens were tested at as-received conditions in December 2020.

4.3.3.3. Test Methods

Flatwise shear tests were conducted in both the major and minor strength directions in accordance with the center-point load method of Section 4 through 12 of ASTM D198 using a nominal specimen width of 12 inches. The on-center span was 5.8 times the specimen depth for the 3-alt CLT tests and 5.2 times the specimen depth for the 7-maxx CLT, thus complying with the ANSI/APA PRG 320-2019 requirement in Section 8.5.4.1 that the on-center span be equal to 5 to 6 times the specimen depth.

Bearing plates measured 4 inches and 9 inches for the 3-alt and 7-maxx CLT, respectively. All specimens were prepared such that there were no overhangs. Load was measured via an Instron 500 kN load cell (SN #2527-125/13356_AS#110, calibrated on October, 22 2020).

At the conclusion of the testing, a small cross-section of each specimen was removed and used for as-tested density determination and moisture content measurement in accordance with ASTM D4442, Method B. The moisture content specimen was taken from the interior of the beam, i.e., not the end, as close to the failure zone as practical.

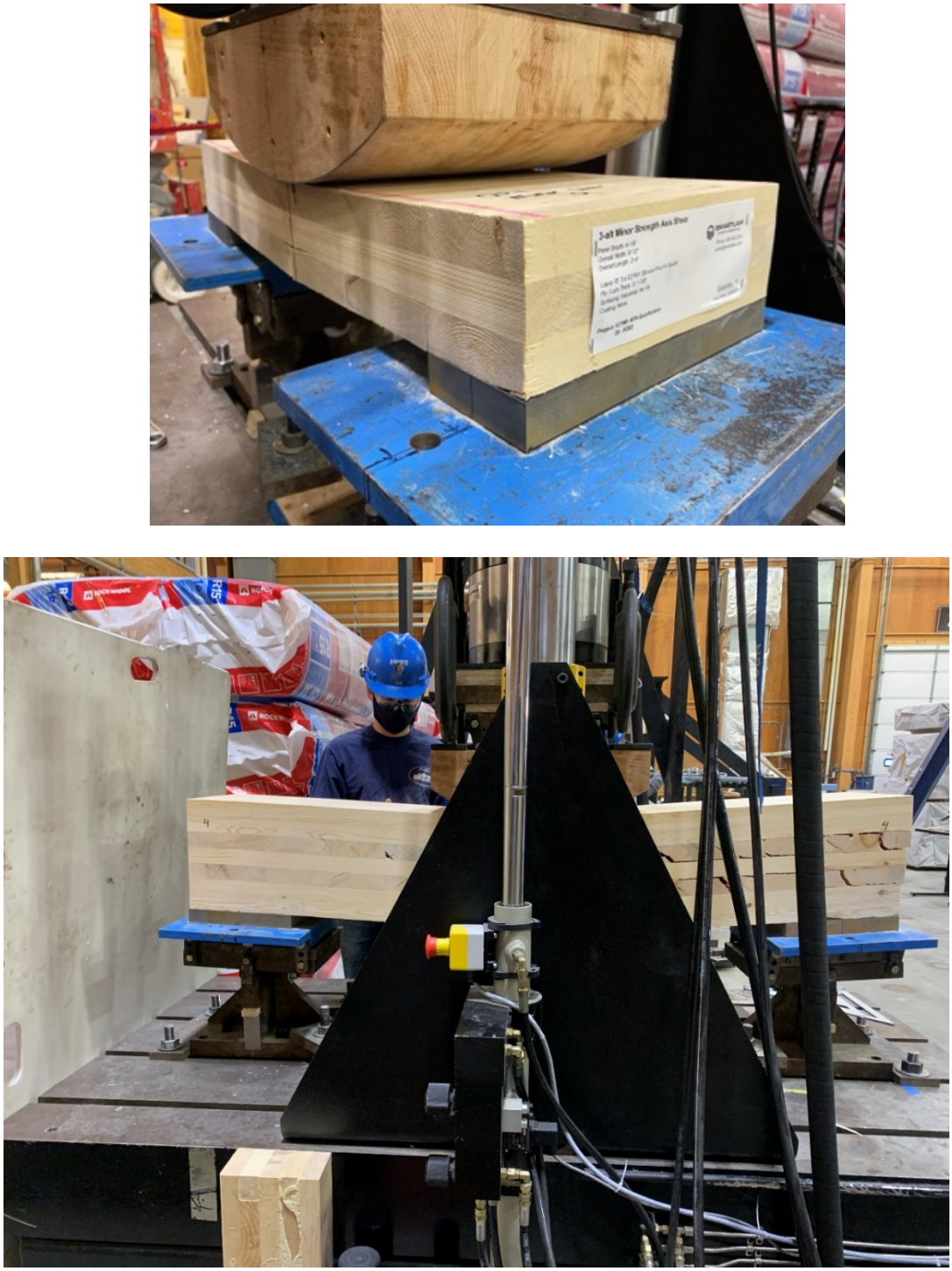

Figure 11. Flatwise shear modulus tests; 3-alt, minor strength direction (top) and 7-maxx, major strength direction (bottom).

4.3.3.4. Results

Individual test results are presented in Appendix G, while summary statistics of the testing is presented as Table 9. The allowable shear capacity, based on the lower tolerance limit (5th percentile with 75% confidence) divided by 2.1 exceeded the analytically-derived design values for both the 3-alt and 7-maxx CLT.

Table 9. Flatwise bending stiffness and strength summary statistics.

CLT Layup	3-alt		7-maxx	
Orientation	Longitudinal	Transverse	Longitudinal	Transverse
N	10	10	10	10
Mean	13,483	4,098	25,813	7,752
Maximum	14,982	5,226	27,627	8,899
Minimum	11,755	2,392	24,046	6,844
COV	0.071	0.274	0.049	0.069
K	2.104	2.104	2.104	2.104
LTL[(a)]	11,483	1,734	23,168	6,632
LTL/2.1	**5,468**	**826**	**11,032**	**3,158**
Requirement	**1,490**	**550**	**3,475**	**1,650**

[(a)] Lower tolerance limit (5th percentile with 75% confidence) based on normal distribution.

5. CONCLUSIONS

E21M1 CLT, comprised of 2100f-1.8E SPF-S MSR lumber in the longitudinal layers and No. 3 SPF-S lumber in the transverse layers, in both 3- alt and 7-maxx layups, was manufactured by SmartLam, LLC and sent to the Advanced Structures and Composites Center (ASCC), located at the University of Maine, for qualification testing. Testing of finger-joint strength and durability was conducted at the SmartLam, LLC facility, while adhesive face bond and flatwise mechanical properties were evaluated at the ASCC in accordance with ANSI/APA PRG 320-2019. The empirical test data justified the analytically-derived design values for this CLT grade using standard engineering formulae based on the shear-analogy model and Appendix X3 of ANSI/APA PRG 320 using the lamination design values per the National Design Specification (NDS). In addition, the adhesive face bond test results met the criteria noted in ANSI/APA PRG 320. As such, it is the author's conclusion that the E21 and E21M1 grades of CLT are qualified for use at the SmartLam, LLC, Columbia Falls, MT facility.

6. REFERENCES

ANSI/APA. 2019. *PRG 320 Standard for Performance-Rated Cross-Laminated Timber*. APA – The Engineered Wood Association. Tacoma, WA.

ANSI/AWC. 2018. *National Design Specification for Wood Construction*. American Wood Council. Leesburg, VA.

ASTM D4442. 2020. *D4442-20. Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials.* American Society of Testing and Materials (ASTM). West Conshohocken, PA.

ASTM D198. 2015. *D198-15. Standard Test Methods of Static Tests of Lumber in Structural Sizes*. American Society of Testing and Materials (ASTM). West Conshohocken, PA.
National Design Specification

Gagnon, S. and M. Popovski. 2011. Structural Design of Cross-Laminated Timber Elements. In: Chapter 3, CLT Handbook. FPInnovations, Canada

7. APPENDICES

Appendix A. Qualification Test Plan
(4 pages)

Proposed Qualification Testing Plan for "E21" and "E21M1" CLT grades for SmartLam LLC, Columbia Falls, MT

May 9, 2017
Revised: June 11, 2020

Objective

To qualify two new "E" grades using SPF-S MSR lumber. The two grades being proposed would be "E21" utilizing 1650f-1.5E SPF-S MSR lumber in the longitudinal layers and "E21M1" utilizing 2100f-1.8E SPF-S MSR lumber in the longitudinal layers. Both of these grades will use No. 3 SPF-S lumber in the transverse layers.

The test protocol described herein assumes the following:

- The qualification of the "E21M1" CLT layup made of 2100f-1.8E SPF-S MSR lumber will justify the qualification of the "E21" CLT layup made of 1650f-1.5E SPF-S MSR lumber without additional qualification tests because SmartLam has qualified for the V4M1 grade of CLT.
- The end joint testing (described in Section 6.4.2 of ANSI/APA PRG 320) of nominal 2x6 2100f-1.8E SPF-S MSR lumber will justify narrower lumber widths and lower lumber grades. As such, end joint testing on 1650f-1.5E SPF-S MSR lumber or No. 3 SPF-S lumber with the same or narrower widths is not required.
- Qualification testing of 3-alt and 7-maxx CLT will justify all intermediate depths.
  - 3-alt: L – T – L
  - 7-maxx: L – L – T – L – T – L – L
  - L = longitudinal direction, T = transverse direction
- All testing will be conducted at the Advanced Structures & Composites Center at the University of Maine, APA's lab in Tacoma, WA, or at SmartLam's facilities in Columbia Falls, MT. UMaine's ISO 17025 Scope of Accreditation currently contains ASTM D198, D4761, D5456, ANSI/AITC A190.1, AITC T107, T110, T119, and PRG 320.

Manufacturing and Component Requirements

- Lumber:
  - Longitudinal layers: 2100f-1.8E SPF-S MSR lumber.
    Finished dimensions: width 5.25", thickness 1-3/8"
  - Transverse layers: No. 3 SPF-S
    Finished dimensions: width 5.25", thickness 1-3/8"
  - The moisture content of the lumber at the time of CLT manufacturing shall be 12 ± 3%.
- Adhesives: Adhesives shall meet PRG 320 requirements.

- Layup: The arrangement of orthogonal layers shall be provided to APA and then specified in the in-plant manufacturing standard.

Witness Requirements:

Material sampling, end joint and CLT manufacturing, and portions of the testing shall be witnessed by an APA auditor who should prepare and submit a detailed witness report to technical services staff at APA.

Test Requirements

1. Plant pre-qualification of adhesive face bond

Two 3-alt and two 7-maxx panels measuring 2' x 2' (minimum) will be manufactured by SmartLam. These panels will: (a) be of the same approximate length and width at the time of pressing, (b) be pressed individually and (c) be taken from the approximate geometric center of a larger panel. From each 2' x 2' panel, three delamination ("D") and three block shear specimens ("B") will be cut (Figure 1). Testing will follow PRG 320-2019 and will be conducted at the Advanced Structures & Composites Center at the University of Maine.

Table 1. Summary table for CLT face bond testing.

CLT	Test	Specimen dimension			Number of specimens
		L (in.)	w (in.)	h (in.)	
3-alt	Delamination	3	3	4-1/8	6
	Block shear	Figure 4 of PRG 320-2019	Figure 4 of PRG 320-2019	4-1/8	6
7-maxx	Delamination	3	3	9-5/8	6
	Block shear	Figure 4 of PRG 320-2019	Figure 4 of PRG 320-2019	9-5/8	6

BLOCK SHEAR ("B") AND DELAMINATION ("D") SPECIMEN LOCATIONS
a = 4 ± 1 inches, L_1 = 24 to 36 inches, and L_2 = 24 to 36 inches (1 inch = 25.4 mm)

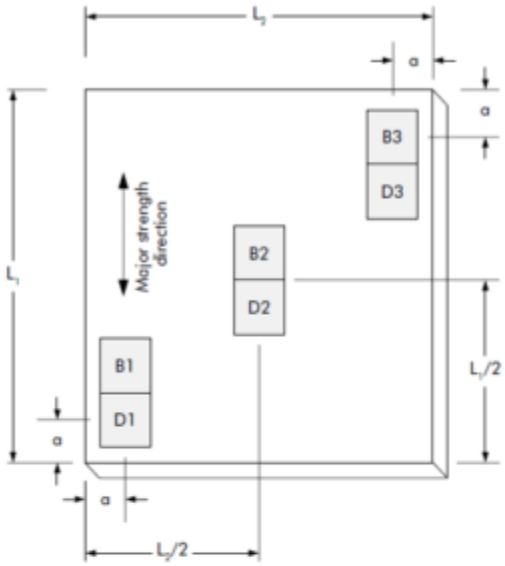

Figure 1. Block shear ("B") and delamination ("D") specimen locations

2. End joints in laminations

End (finger) joint tension and durability testing will be carried out per Section 6.3.2 of PRG 320-2019.

Tension testing of 30 pieces from 2100f-1.8E SPF-S MSR finger-jointed lumber. Note: testing on 1650f-1.5E SPF-S MSR lumber or No. 3 graded lumber are not required since a higher grade will be tested. Nominal 2" x 6" lumber will be used of for these tests. Actual dimensions will be 1.5" x 5.5". Use of wider lumber, e.g., nominal 2"x8", in production will be pending successful testing of the wider finger-jointed lumber. End joint durability (5 tests) will also be evaluated per Section 6.3.2(c) of PRG 320-2019. All finger jointing manufacturing and testing will be done at SmartLam under APA witness.

3. Mechanical properties qualifications

Flatwise bending tests will be conducted in both the major and minor strength directions in accordance with the third point load method of Section 4 through 12 of ASTM D198 or Section 8 of ASTM D4761 using a specimen width of not less than 12 inches. The on-center span will be approximately 30 times the specimen depth for the tests in the major strength direction and approximately 18 times the specimen depth for the testing in the minor direction.

Flatwise shear stiffness tests shall be conducted in both major and minor strength directions in accordance with Sections 45 through 52 of ASTM D198. Flatwise shear tests shall be conducted

in both major and minor strength directions in accordance with the center-point load method of Sections 4 through 12 of ASTM D198 or Section 7 of ASTM D4761 using a specimen width of not less than 12 inches and the on-center span equal to 5 to 6 times the specimen depth. The bearing length will be sufficient to avoid bending failure, but not greater than the specimen depth. All specimens will be cut to length with no overhang allowed.

Table 2. Summary table for "E21M1" CLT mechanical properties testing.

CLT layout	Test	Orientation	# of specimens	Specimen dimensions				
				Length (in.) (as prepared by SmartLam)	Width (in.)	Depth (in.)	Tested Span, ℓ (in.)	ℓ/d
3-alt	Flatwise bending	Longitudinal	10	132	12	Actual panel thickness	123-3/4	30
		Transverse	10	96	12		74-1/4	18
	Flatwise shear strength	Longitudinal	10	28	12		23-7/8	5.8
		Transverse	10	28	12		23-7/8	5.8
	Flatwise shear modulus	Longitudinal	10	132[a]	12		See footnote (b)	See footnote (b)
		Transverse	10	96[a]	12			
7-maxx	Flatwise bending	Longitudinal	10	300	12	Actual panel thickness	280-3/4	29
		Transverse	10	204	12		173-1/4	18
	Flatwise shear	Longitudinal	10	60	12		50-3/8	5.2
		Transverse	10	60	12		50-3/8	5.2
	Flatwise shear modulus	Longitudinal	10	300[a]	12		See footnote (c)	See footnote (c)
		Transverse	10	204[a]	12			

[a] Flatwise bending specimens will be non-destructively tested for shear modulus prior to the destructive bending tests.

[b] Flatwise shear modulus testing on the 3-alt layup will be as shown below

CLT Layup	Depth, d (in.)	Span, ℓ (in.)	ℓ/d	$(d/\ell)^2$
3-alt	4-1/8	22-11/16	5.5	0.0331
		26-13/16	6.5	0.0237
		35-1/16	8.5	0.0138
		82-1/2	20	0.0025

[c] Flatwise shear modulus testing on the 7-maxx layup will be as shown below

CLT Layup	Depth, d (in.)	Span, ℓ (in.)	ℓ/d	$(d/\ell)^2$
7-maxx	9-5/8	52-15/16	5.5	0.0331
		62-9/16	6.5	0.0237
		81-13/16	8.5	0.0138
		192-1/2	20	0.0025

Tentative Timeline

1. April-May 2017 – Lumber shipped from Maine to SmartLam in MT.
2. July 2020 - CLT panels produced (APA witness needed).
3. July-August 2020 – SmartLam cuts specimens from billets and ships them to Maine for testing.
4. October – November 2020 – UMaine conducts testing.
5. November – December 2020 – UMaine analyzes test data and prepares test report.
6. December 2020 – SmartLam prepares submission to APA.

Appendix B. APA Witness Report & Billet Cutting Diagram
(13 pages)

Witness Report

APA Mill 1131 – SmartLam North America, Columbia Falls, MT

Mill Facility Columbia Falls, MT

SPFs CLT panel Manufacture for E21M1 Qualification in collaboration with the Advanced Structures and Composites Center at the U. of Maine

☒ New Witness Report	☐ Continuation	Original Date of Witnessing: 8-11-20
Product to be sent for testing: ☐ Yes ☒ No Date: Click here to enter a date.		Sent to: ☐ Tacoma ☐ Atlanta ☒ Other: tested at the U. of Maine

Type of Witnessing Conducted (check all that apply)		
☐ In-plant Adhesive	☒ In-plant Manufacturing	☒ Qualification
☐ In-plant Approval	☐ In-plant Test Witness	☐ Requalification
☐ In-plant E-Rater	☐ Other:	

Witness Date(s):	8/10/2020	Start Time(s):	: 08:00	End Time(s):	: 10:00
Witness Date(s):	8/11/2020	Start Time(s):	: 08:00	End Time(s):	: 12:00
Witness Date(s):	8/12/2020	Start Time(s):	: 08:00	End Time(s):	: 10:00

On the dates of August 10 through 12, 2020 I witnessed the manufacture of CLT panels for qualification conducted at SmartLam North America, Columbia Falls, MT. All of the witnessing for this qualification was conducted by recorded video capture and also mill provided photographic and process document evidence.

The purpose of this qualification was to qualify CLT layups for E21M1 grades utilizing previously qualified "SPFs" (SPF-South) lumber species per PRG 30 criteria.

My contacts for this qualification were Robert Tudhope Vice President of Product development, Scott Blair Quality Control Manager and Benjamin Herzog, Wood Technologist at the Advanced Structures and Composites Center at the U. of Maine. APA TSD staff collaborated with staff from the Advanced Structures and Composites Center at the U. of Maine developed a qualification plan (on file) and it formed the basis of this qualification.

7011 South 19th Street • Tacoma, WA 98466-5333 • Phone: (253) 565-6600 • Fax: (253) 565-7265 • www.apawood.org

Raw materials used for assembly:

- SPFs (SPF-South) 2x6" 2100Fb-1.8e lumber supplied by Maibec Lumber of Maine.
- SPFs (SPF-South) #3 2x6" lumber supplied by Maibec as graded from the supplied material. (Photographic evidence was provided for confirmation of species and grade at end of this report)
- Henkel Loctite HB X032 Purbond adhesive with Henkel Loctite PR 3105 Purbond adhesion promoter. Valid COA's were provided for confirmation by mill staff for both components.

Assembly Process:

- Lumber was sorted and graded prior to the assembly process. A special grade was conducted to develop the #3 grade in advance of this qualification. The mill conducted grading for the 2100Fb material on August 6-7,2020. Provided video evidence of typical grading activity confirmed measurements of dimensional tolerances as well as moisture content checks made with a Wagner hand held moisture meter.
- Assembly of the finger joints was conducted on August 10-12th. The assembly was witnessed via captured video. The mill utilized its new finger joint operation in the assembly of the horizontal joints.
- The observed moisture content as witnessed via provided documentation by the auditor was at 10% and met mill QM guidelines as well as ANSI / APA PRG 320 Standard for Performance - Rated Cross-Laminated Timber (Standard).
- Lumber temperatures ranged from 77 to 81°F at time of manufacture.
- Provided mill process control documentation indicated an adhesive spread of the HB X032 to be at the 100-160g/m² as recommended by the adhesive vendor Henkel. Similarly, the adhesion promoter was documented at 1.5g L/ft.
- End joints are ambient cured. After end jointing, the lams are planed to the required thickness of 1-3/8" and cut to the desired length for the testing machine. Documentation of process control checks for thickness (per the QM) of planed lams was observed at the stacking station with planed thickness ranging from 1.376-1.379". This thickness was verified via provided process control documentation.
- CLT panels for test specimens were assembled on August 10,11 and 12th. Layups included both 3 and 7 ply configurations. Panels were manufactured using both the alternate and transverse configurations of the plies per the qualification plan. Four (4) 7-ply panels: 2 consisting of L-L-T-L-T-L-L plies, and 2 consisting of T-T-L-T-L-T-T plies. Two (2)3-ply panels were manuafctured consisting of one (1) L-T-L layup and one (1) T-L-T layup manufactured.

Sampling and testing:

- Captured video witnessing was conducted of the production process consisting of approximately 1 hour. Video of the end joint assembly and pressing operations was provided to the auditor for review. In addition, photos of panels produced were provided.
- Panels were to be processed for test specimens by the mill utilizing a mill staff created cutting diagram.
- Test specimens were to be forwarded to the Advanced Structures and Composites Center at the U. of Maine for testing.

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Trademark Example:

SPFs 2100Fb-1.8e

Pete Cuff Western Coordinator
ASQ/CQA

Witness Report

APA Mill 1131 – SmartLam North America, Columbia Falls, MT

Mill Facility Columbia Falls, MT

SPFs CLT panel Manufacture for E21M1 Qualification in collaboration with the Advanced Structures and Composites Center at the U. of Maine

☐ New Witness Report	☒ Continuation	Original Date of Witnessing: 8-11-20
Product to be sent for testing: ☐ Yes ☒ No Date: Click here to enter a date.		Sent to: ☐ Tacoma ☐ Atlanta ☒ Other: tested at the U. of Maine

Type of Witnessing Conducted (check all that apply)		
☐ In-plant Adhesive	☒ In-plant Manufacturing	☒ Qualification
☐ In-plant Approval	☐ In-plant Test Witness	☐ Requalification
☐ In-plant E-Rater	☐ Other:	

Witness Date(s):	10/19/2020	Start Time(s):	: 08:00	End Time(s):	: 10:00
Witness Date(s):	10/20/2020	Start Time(s):	: 08:00	End Time(s):	: 12:00

On the dates of October 19 through October 20, 2020 I witnessed the manufacture of CLT panels for qualification conducted at SmartLam North America, Columbia Falls, MT. This witnessing documentation is a continuation of the project initially started and documented on August 8 through August 12,2020. The witnessing for this qualification was conducted remotely via use of recorded video capture and mill provided emails of photographic and process document evidence.

The purpose of this qualification was to qualify CLT layups for E21M1 grades utilizing previously qualified "SPFs" (SPF-South) lumber species per PRG 320 criteria.

My contacts for this qualification were Robert Tudhope Vice President of Product development, Scott Blair Quality Control Manager and Benjamin Herzog, Wood Technologist at the Advanced Structures and Composites Center at the U. of Maine. APA TSD staff collaborated with staff from the Advanced Structures and Composites Center at the U. of Maine developed a qualification plan (on file) and it formed the basis of this qualification.

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Raw materials used for assembly:

- SPFs (SPF-South) 2x6", 2100Fb-1.8e lumber supplied by Vaagen Lumber.
  (Photographic evidence was provided for confirmation of species and grade at end of this report)
- SPFs (SPF-South) 2x6", #3 grade lumber supplied by Vaagen as graded from supplied lumber material.
- Henkel Loctite HB X202 Purbond adhesive with Henkel Loctite PR 3105 Purbond adhesion promoter for face bonding.
- Henkel Loctite HB X032 Purbond adhesive for finger joint bonding.
- Valid COA's were provided for confirmation by mill staff for both components.

Assembly Process:

- Lumber was sorted and graded prior to the assembly process. A special grade was conducted to develop the #3 grade in advance of this qualification. The mill conducted grading for the Vaagen 2100Fb material on October 14,2020. Provided video evidence of typical grading activity confirmed measurements of dimensional tolerances as well as moisture content checks made with a Wagner hand held moisture meter.
- Assembly of the finger joints was conducted on October 19th. The assembly was witnessed via captured video. The mill utilized its horizontal finger joint operation in the assembly of the joints.
- The observed moisture content as witnessed via provided documentation to the auditor was at 13% and met mill QM guidelines as well as ANSI / APA PRG 320 Standard for Performance - Rated Cross-Laminated Timber (Standard).
- Lumber temperatures ranged from 70 to 71°F at time of manufacture.
- Provided mill process control documentation for finger joint manufacture indicated an adhesive spread of the HB X032 to be at the 100-160g/m² as recommended by the adhesive vendor Henkel. Similarly, the adhesion promoter was documented at 1.5g L/ft.
- End joints are ambient cured. After end jointing, the lams are planed to the required thickness of 1-3/8" and cut to the desired length for the panel assembly. Documentation of process control checks for thickness (per the QM) of planed lams was observed at the stacking station with planed thickness ranging from 1.378-1.380". This thickness was verified via provided process control documentation.
- Documented spread rate for panel assembly was 13.8-13.9 g/ft^2. Lamina temps were at 70-71°F. The manufacturing facility was at 70°F ambient temperature with 66% relative humidity. Assembly times of the panels ranged from 8-11 minutes with total press times of 70 minutes under pressure. All aspects of the assembly process were deemed typical of SmartLam CLT production.
- CLT panels for test specimens were assembled on October 19,2020. Layups included both 3 and 7 ply configurations. Panels were manufactured using transverse alternate and transverse MAXX configurations of the plies per the qualification plan. Three (3) panels were produced in total; two (2) 7-ply panels consisting of a T-T-L-T-L-T-T ply orientation and one(1) 3-ply panel consisting of a T-L-T ply orientation. The #3 lumber grade was used in both layups for the longitudinal direction plies.

Sampling and testing:

- Captured video witnessing was conducted of the production process consisting of approximately 1 hour. Video of the end joint assembly, planning process and pressing operations were provided to the auditor for review and verification. In addition, photos of panel layups produced were provided.
- Panels were to be processed for test specimens by the mill utilizing a mill staff created cutting diagram.
- Test specimens were to be forwarded to the Advanced Structures and Composites Center at the U. of Maine for testing.

Trademark Example:

SPF-south 2100Fb-1.8e

Pete Cuff, Western Coordinator
ASQ/CQA

This report is a result of direct observation made by an auditor from APA – The Engineered Wood Association (APA), a certification body accredited by Standards Council of Canada and inspection agency accredited by International Accreditation Services. The products or processes described in this witness report may contain products or processes outside the scope of APA accreditation or which may undergo secondary processing outside the scope of APA accreditation.

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WESTERN WOOD PRODUCTS ASSOCIATION
1500 SW First Avenue, Suite 870 Portland, Oregon 97201
503-224-3930 Fax: 503-224-3935 www.wwpa.org

June 30, 2020

Mr. Robert Tudhope
610 3rd St. West,
Columbia Falls, Montana 59912

On June 17th, our Lumber Inspector, Gary Mathews, sorted and identified the following pieces out of 756 pieces of 2x6x16' identified as Planer Mill Outs.

128 pieces made the grade of No. 2. (Identified with red end paint and a black vertical crayon mark.)

614 pieces made the grade of No. 3. (Identified with red end paint.)

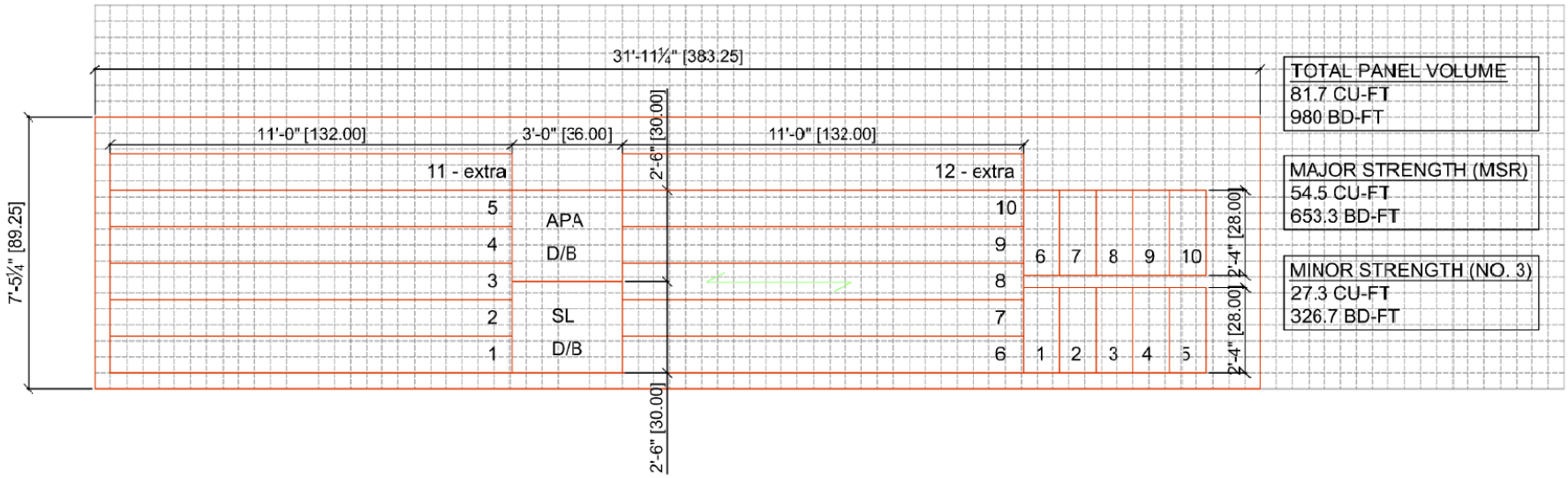
19 pieces made the grade of economy. (Identified with green end paint.)

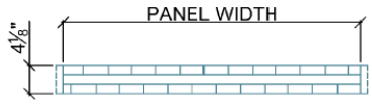
The stock was marked with a HT stamp, however no consideration was given to moisture content due to the age of the stock.

WWPA is a rules-writing agency accredited by the American Lumber Standard Committee (ALSC) and adheres to the *Voluntary Product Standard PS 20-15* published by the U.S. Department of Commerce. The lumber inspected and identified listed above complies with the National Grading Rule for dimension lumber and section 62.00 of WWPA *Western Lumber Grading Rules 2017*.

Sincerely,

Pete Austin
Director, Quality Standards





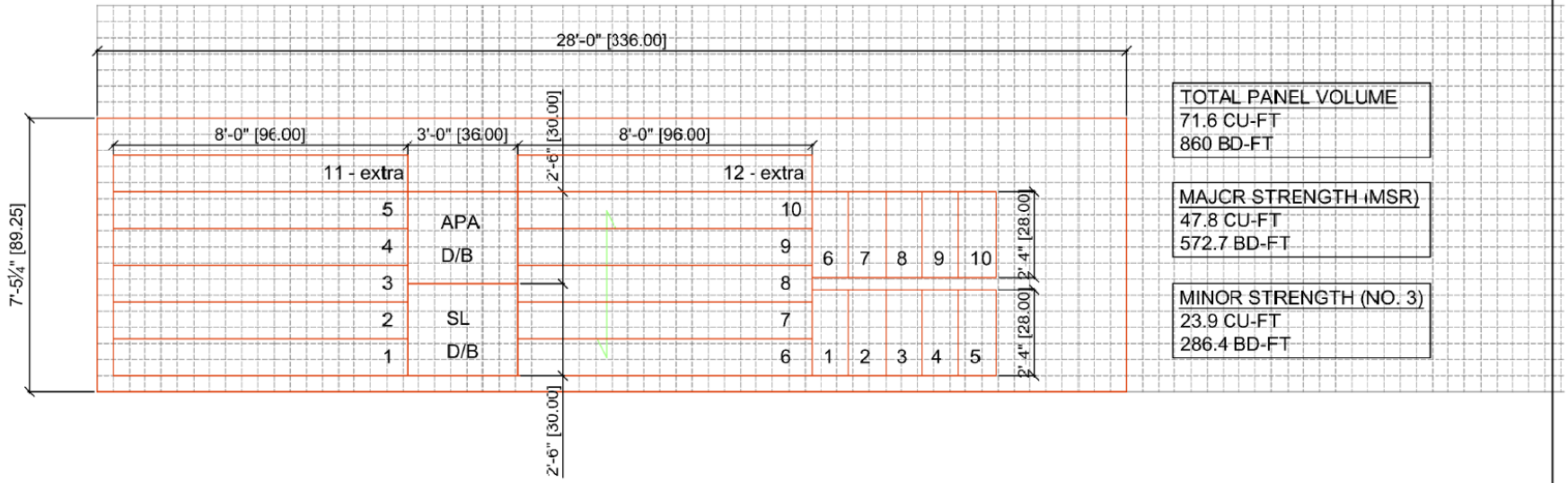
3 ply alt major PROFILE

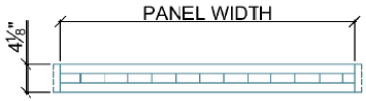
BENDING SPECIMEN NOTES:

1. BACKGROUND LIGHT LINES INDICATE 2x6 BOARD LAYOUT (5.25" WIDE)
2. DIMENSIONS SHOWN DO NOT INCLUDE KERF FOR SAW BLADE. VERIFY SPECIMEN IS 12" WIDE.
3. SHEAR AND DELAMINATION SAMPLE SHALL BE TAKEN FROM THE BENDING SPECIMEN PANEL. SAMPLES CAN BE 24" TO 36" SQUARE.

INDICATES MAJOR STRENGTH DIRECTION

SMARTLAM | NORTH AMERICA | 6 0 3rd Stree West Columbia Falls, MT 59912 (406) 892-2241 www.smartlam.com	Smartlam Qualification Drawing CLT Grade: E21M1 (Spruce Pine Fir South) Major Strength Direction: 2x6 MSR (2,100 Fb, 1.8E) Minor Strength Direction: 2x6 Visual Grade No. 3 Mechanical Property Test Sample	3 ply alt Major Bending Minor Shear Block Shear & Delam	EQUIPMENT: Minda Press	DATE: 06.29.2020 SHEET: QP-1





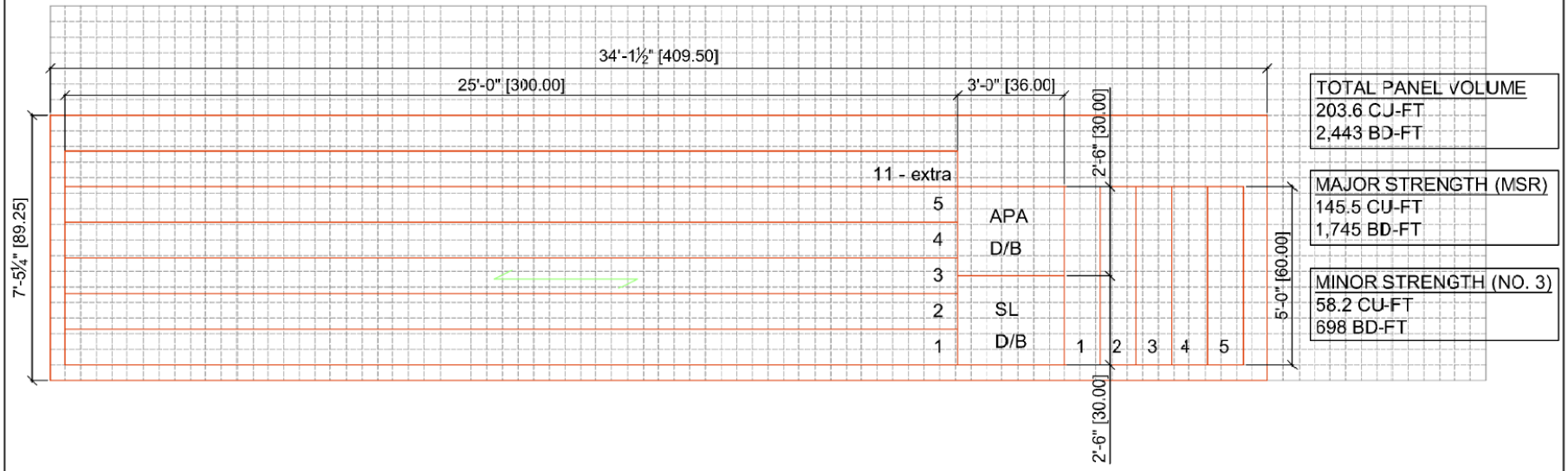
3 ply alt minor PROFILE

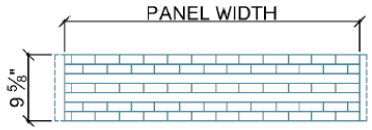
BENDING SPECIMEN NOTES:

1. BACKGROUND LIGHT LINES INDICATE 2x6 BOARD LAYOUT (5.25" WIDE)
2. DIMENSIONS SHOWN DO NOT INCLUDE KERF FOR SAW BLADE. VERIFY SPECIMEN IS 12" WIDE.
3. SHEAR AND DELAMINATION SAMPLE SHALL BE TAKEN FROM THE BENDING SPECIMEN PANEL. SAMPLES CAN BE 24" TO 36" SQUARE.

INDICATES MAJOR STRENGTH DIRECTION

SMARTLAM | NORTH AMERICA | 6 0 3rd Stree West Columbia Falls, MT 59912 (406) 892-2241 www.smartlam.com	Smartlam Qualification Drawing CLT Grade: E21M1 (Spruce Pine Fir South) Major Strength Direction: 2x6 MSR (2,100 Fb, 1.8E) Minor Strength Direction: 2x6 Visual Grade No. 3 Mechanical Property Test Sample	3 ply alt - transverse Minor Bending Major Shear Block Shear & Delam	EQUIPMENT: Minda Press	DATE: 06.29.2020 SHEET: QP-2





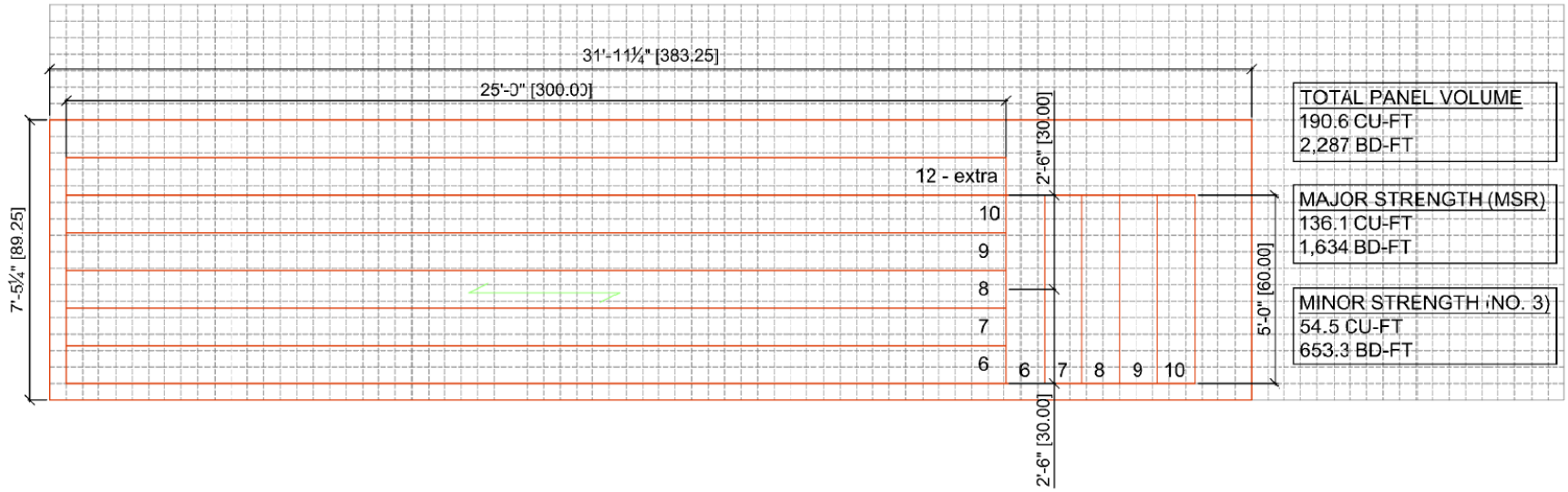
7 ply maxx major PROFILE

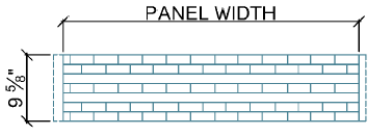
BENDING SPECIMEN NOTES:

1. BACKGROUND LIGHT LINES INDICATE 2x6 BOARD LAYOUT (5.25" WIDE)
2. DIMENSIONS SHOWN DO NOT INCLUDE KERF FOR SAW BLADE. VERIFY SPECIMEN IS 12" WIDE.
3. SHEAR AND DELAMINATION SAMPLE SHALL BE TAKEN FROM THE BENDING SPECIMEN PANEL. SAMPLES CAN BE 24" TO 36" SQUARE.

INDICATES MAJOR STRENGTH DIRECTION

SMARTLAM [NORTH AMERICA] 600 3rd Street West Columbia Falls, MT 59912 (406) 892-2241 www.smartlam.com	Smartlam Qualification Drawing CLT Grade: E21M1 (Spruce Pine Fir South) Major Strength Direction: 2x6 MSR (2,100 Fb, 1.8E) Minor Strength Direction: 2x6 Visual Grade No. 3 Mechanical Property Test Sample	7 ply maxx Major Bending Minor Shear Block Shear & Delam	EQUIPMENT: Minda Press	DATE: 06.29.2020 SHEET: QP-3





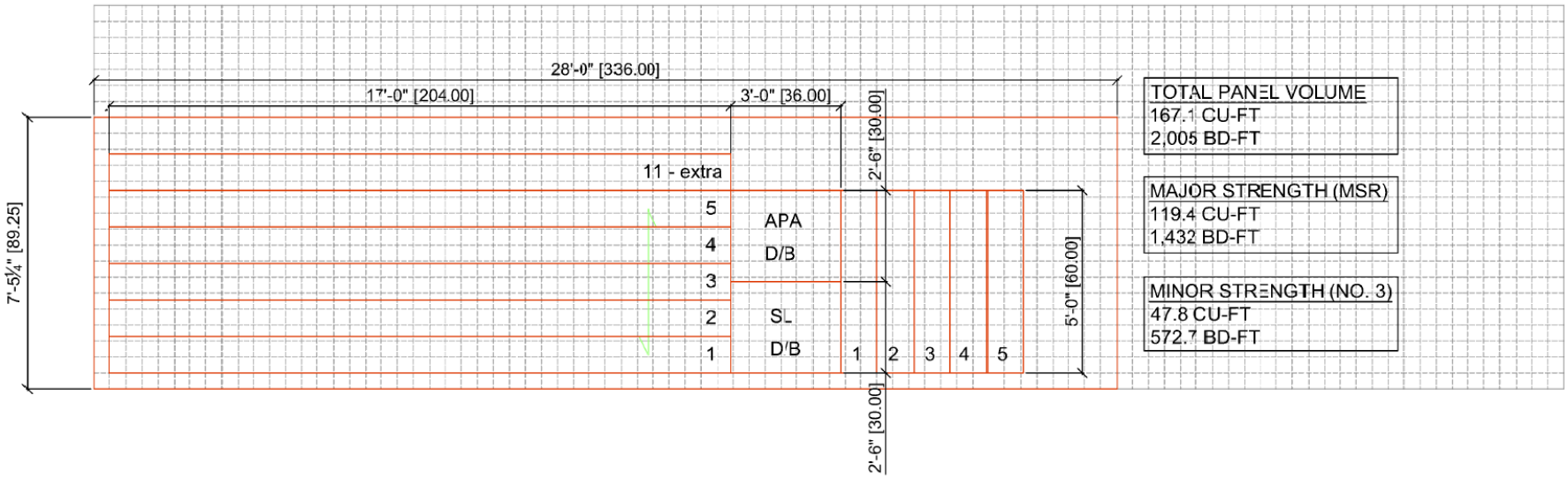
7 ply maxx major PROFILE

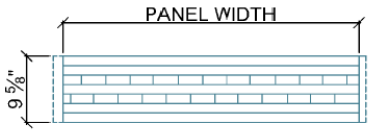
BENDING SPECIMEN NOTES:

1. BACKGROUND LIGHT LINES INDICATE 2x6 BOARD LAYOUT (5.25" WIDE)
2. DIMENSIONS SHOWN DO NOT INCLUDE KERF FOR SAW BLADE. VERIFY SPECIMEN IS 12" WIDE.
3. SHEAR AND DELAMINATION SAMPLE SHALL BE TAKEN FROM THE BENDING SPECIMEN PANEL. SAMPLES CAN BE 24" TO 36" SQUARE.

INDICATES MAJOR STRENGTH DIRECTION

SMARTLAM NORTH AMERICA 600 3rd Street West Columbia Falls, MT 59912 (406) 892-2241 www.smartlam.com	Smartlam Qualification Drawing CLT Grade: E21M1 (Spruce Pine Fir South) Major Strength Direction: 2x6 MSR (2,100 Fb, 1.8E) Minor Strength Direction: 2x6 Visual Grade No. 3 Mechanical Property Test Sample	7 ply maxx Major Bending Minor Shear	EQUIPMENT: Minda Press	DATE: 06.29.2020 SHEET: QP-4





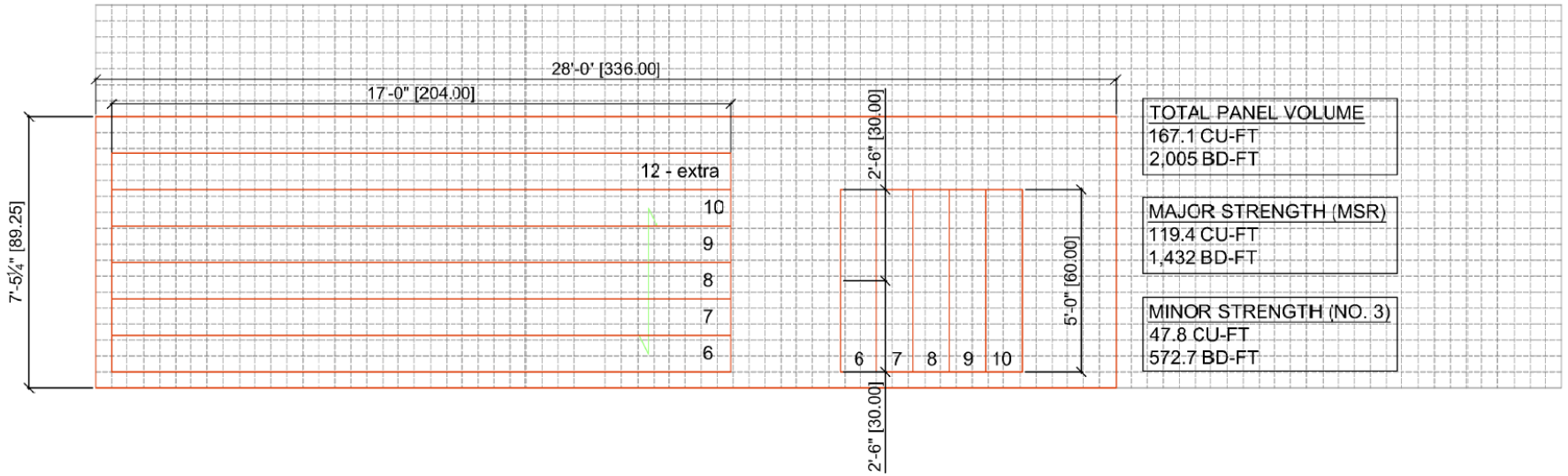
7 ply maxx minor PROFILE

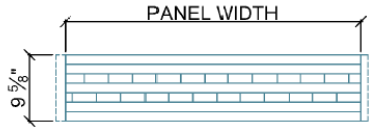
BENDING SPECIMEN NOTES:

1. BACKGROUND LIGHT LINES INDICATE 2x6 BOARD LAYOUT (5.25" WIDE)
2. DIMENSIONS SHOWN DO NOT INCLUDE KERF FOR SAW BLADE. VERIFY SPECIMEN IS 12" WIDE.
3. SHEAR AND DELAMINATION SAMPLE SHALL BE TAKEN FROM THE BENDING SPECIMEN PANEL. SAMPLES CAN BE 24" TO 36" SQUARE.

INDICATES MAJOR STRENGTH DIRECTION

SMARTLAM NORTH AMERICA 6 0 3rd Stree West Columbia Falls, MT 59912 (406) 892-2241 www.smartlam.com	Smartlam Qualification Drawing CLT Grade: E21M1 (Spruce Pine Fir South) Major Strength Direction: 2x6 MSR (2,100 Fb, 1.8E) Minor Strength Direction: 2x6 Visual Grade No. 3 Mechanical Property Test Sample	7 ply maxx - transverse Minor Bending Major Shear Block Shear & Delam	EQUIPMENT: Minda Press	DATE: 06.29.2020 SHEET: QP-5





7 ply maxx minor PROFILE

BENDING SPECIMEN NOTES:

1. BACKGROUND LIGHT LINES INDICATE 2x6 BOARD LAYOUT (5.25" WIDE)
2. DIMENSIONS SHOWN DO NOT INCLUDE KERF FOR SAW BLADE. VERIFY SPECIMEN IS 12" WIDE.
3. SHEAR AND DELAMINATION SAMPLE SHALL BE TAKEN FROM THE BENDING SPECIMEN PANEL. SAMPLES CAN BE 24" TO 36" SQUARE.

INDICATES MAJOR STRENGTH DIRECTION

SMARTLAM [NORTH AMERICA] 600 3rd Street West Columbia Falls, MT 59912 (406) 892-2241 www.smartlam.com	Smartlam Qualification Drawing CLT Grade: E21M1 (Spruce Pine Fir South) Major Strength Direction: 2x6 MSR (2,100 Fb, 1.8E) Minor Strength Direction: 2x6 Visual Grade No. 3 Mechanical Property Test Sample	7 ply maxx - transverse Minor Bending Major Shear	EQUIPMENT: Minda Press	DATE: 06.29.2020 SHEET: QP-6

Appendix C. Finger-joint Qualification Plan and Results
(3 pages)

Qualification Testing Plan for SmartLam Finger Joints

(Using HB X Adhesive and the New Finger Jointing and Planning Line at Mill #1131)

June 12, 2020

Checklist for required test data

Test	
End joint tension (Moisture content & specific gravity)	Nominal 2 x 6 or 2x8
End joint delamination	Nominal 2 x 6 or 2x8

Manufacturing requirements:

Lumber grades:

- Nominal 2 x 8 Select Structural Hem-fir lumber
- Nominal 2 x 8 Select Structural Douglas fir-Larch lumber
- Nominal 2 x 6 2100f-1.8E Spruce-pine-fir South MSR lumber

Moisture content:

- The moisture content of the lumber at the time of finger joint manufacturing shall be 12 ± 3%.

Adhesives: Henkel Loctite HB X032 adhesive and Loctite PR3105 Purbond primer.

Witness requirements:

Material sampling, end joint manufacturing, and testing shall be witnessed by an APA auditor who should prepare and submit a detailed witness report to technical services staff.

Test Plan

End joints in laminations:

- Tensile strength: Tension with 2-ft gauge length. Sampled from the same production as the CLT panels. Record the failure mode and the % of wood failure of each specimen. 30 tension tests for nominal 2 x 8 Select Structural Hem-fir lumber. 30 tension tests for nominal 2 x 8 Select Structural Douglas fir-Larch lumber. 30 tension tests for nominal 2 x 6 2100f-1.8E Spruce-pine-fir South MSR lumber.

- Durability of end joint gluebond: Cut individual end joints to exposure the end joint in section. After one complete cycle, record % of delamination. 5 delamination tests for nominal 2 x 8 Select Structural Hem-fir lumber. 5 delamination tests for nominal 2 x 8 Select Structural Douglas fir-Larch lumber. 5 delamination tests for nominal 2 x 6 2100f-1.8E Spruce-pine-fir South MSR lumber.

Objective: End-joint tensile strength qualification
Plant: SmartLam North America, Columbia Falls, MT
Grade: 2100f-1.8E SPF-S MSR lumber
Manufacturing date: July 29, 2020
Test lab: SmartLam North America, Columbia Falls, MT
Test date: July 30, 2020
Test witnessed by: APA staff (Pete Cuff)
Referenced test methods: PRG 320-2019
Guage length: 24 in.

Test Results

#	Thickness (in.)	Width (in.)	P_{ult} (lbf)	F_t (psi)	MC (%)	Wood Failure (%)	Failure Mode
1	1.379	5.268	44,000	6,057	12	100	5
2	1.376	5.256	36,500	5,047	10	85	4
3	1.377	5.258	36,000	4,972	10	85	4
4	1.371	5.258	34,800	4,827	10	85	4
5	1.377	5.250	38,300	5,298	12	85	5
6	1.377	5.260	41,500	5,730	10	90	4
7	1.380	5.252	34,100	4,705	13	90	5
8	1.380	5.252	33,400	4,608	14	90	4
9	1.378	5.260	33,800	4,663	11	90	5
10	1.367	5.250	37,300	5,197	10	90	4
11	1.375	5.258	34,700	4,800	11	95	4
12	1.378	5.259	35,700	4,926	12	80	5
13	1.373	5.256	38,800	5,377	10	95	5
14	1.373	5.254	40,000	5,545	10	95	5
15	1.371	5.261	39,000	5,407	10	95	4
16	1.370	5.258	42,500	5,900	10	85	5
17	1.369	5.250	34,500	4,800	10	85	5
18	1.368	5.257	37,600	5,228	15	90	5
19	1.369	5.260	39,200	5,444	14	90	5
20	1.370	5.260	34,200	4,746	10	90	5
21	1.372	5.254	29,100	4,037	10	90	5
22	1.375	5.257	36,800	5,091	14	90	5
23	1.373	5.257	32,400	4,489	10	90	5
24	1.369	5.260	35,100	4,874	10	90	4
25	1.372	5.250	36,600	5,081	10	85	5
26	1.373	5.261	31,400	4,347	10	90	5
27	1.365	5.258	41,700	5,810	13	90	5
28	1.375	5.250	39,600	5,486	11	90	5
29	1.369	5.252	38,400	5,341	12	85	5
30	1.372	5.250	42,100	5,845	13	90	5
Total no. of observations				30	30	30	
Mean				5,123	11	89	
Maximum				6,057	15	100	
Minimum				4,037	10	80	
Std Dev				488	1.6	4.1	
COV (%)				9.5	14.2	4.6	
K				1.869			
Lower tolerance limit (LTL), normal distribution				4,211			
LTL, lognormal distribution				4,261			
LTL (normal)/2.1				2,005			
LTL (lognormal)/2.1				2,029			
Requirement				1,575			

Objective: End-joint durability
Plant: SmartLam North America, Columbia Falls, MT
Grade: 2100f-1.8E SPF-S MSR lumber
Manufacturing date: July 29, 2020
Test lab: SmartLam North America, Columbia Falls, MT
Test date: July 31, 2020
Test witnessed by: APA staff (Pete Cuff)
Referenced test methods: PRG 320-2019

Test Results

Specimen #	Pre Wt.	Final Wt.	% Wt.Change	Lines Open	Total Lines	% Delam
1-A	161.40	162.30	-0.01	1.75	56.79	3%
1-B	140.20	152.30	-0.09	1.5	56.79	3%
2-A	170.40	181.60	-0.07	0	56.79	0%
2-B	167.90	176.00	-0.05	0	56.79	0%
3-A	180.20	191.20	-0.06	0.625	56.79	1%
3-B	183.50	189.60	-0.03	0	56.79	0%
4-A	189.30	192.60	-0.02	0	56.79	0%
4-B	184.50	179.20	0.03	1.125	56.79	2%
5-A	186.60	198.60	-0.06	0	56.79	0%
5-B	185.30	193.60	-0.04	0	56.79	0%

Appendix D. Face Bond Tests: Block Shear & Cyclic Delamination
(2 pages)

Objective: face lamination qualification tests (shear)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: October 19-20, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: December 11, 2020
Referenced test methods: PRG 320
Test conditions: As-received

CLT Layup	Billet #	Specimen	Bondline	Avg. Length (in.)	Average Width (in.)	Wood Failure, WF (%)	Avg WF (%)	Avg WF (%)
3-alt	Billet 1	1-SW	1	1.469	1.974	100	100	100
			2	1.449	1.986	100		
		1-C	1	1.460	1.980	100	100	
			2	1.467	1.976	100		
		1-NE	1	1.478	1.942	100	100	
			2	1.460	1.962	100		
	Billet 2	2-SW	1	1.498	2.271	100	100	
			2	1.507	2.265	100		
		2-C	1	1.505	2.254	100	100	
			2	1.498	2.262	100		
		2-NE	1	1.522	2.277	100	100	
			2	1.518	2.284	100		
7-maxx	Billet 1	3-SW	1	1.523	2.244	100	93	97
			2	1.519	2.259	95		
			3	1.524	2.254	95		
			4	1.525	2.261	95		
			5	1.535	2.253	75		
			6	1.538	2.248	100		
		3-C	1	1.526	2.254	100	98	
			2	1.519	2.272	95		
			3	1.500	2.270	100		
			4	1.493	2.253	90		
			5	1.507	2.255	100		
			6	1.515	2.258	100		
		3-NE	1	1.479	2.260	100	92	
			2	1.477	2.265	80		
			3	1.453	2.257	100		
			4	1.468	2.251	70		
			5	1.473	2.242	100		
			6	1.483	2.235	100		
	Billet 2	4-SW	1	1.484	2.038	100	100	
			2	1.480	2.034	100		
			3	1.479	2.038	100		
			4	1.479	2.013	100		
			5	1.480	2.008	100		
			6	1.482	2.002	100		
		4-C	1	1.491	2.036	100	100	
			2	1.497	2.036	100		
			3	1.504	2.031	100		
			4	1.503	2.025	100		
			5	1.500	2.019	100		
			6	1.499	2.016	100		
		4-NE	1	1.508	2.228	100	100	
			2	1.498	2.236	100		
			3	1.491	2.234	100		
			4	1.496	2.227	100		
			5	1.505	2.238	100		
			6	1.506	2.244	100		

Objective: face lamination qualification tests (cyclic delamination)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: October 19-20, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: December 9, 2020
Referenced test methods: PRG 320
Test conditions: As-received

				Bondline Length (in.)					Delamination (in.)					% Delam	
CLT Layup	Billet #	Specimen #	Bondline #	Front	Right	Back	Left	Total	Front	Right	Back	Left	Total	Bondline	Specimen
3-alt	Billet 1	1-SW	1	2.964	2.944	2.983	2.960	11.851	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%
			2	2.966	2.954	2.965	2.967	11.851	0.000	0.000	0.000	0.000	0.000	0.0%	
		1-C	1	2.949	2.972	2.951	2.956	11.827	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%
			2	2.946	2.959	2.949	2.940	11.793	0.000	0.000	0.000	0.000	0.000	0.0%	
		1-NE	1	2.968	2.955	2.972	2.953	11.847	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%
			2	2.993	2.963	2.987	2.959	11.902	0.000	0.000	0.000	0.000	0.000	0.0%	
	Billet 2	2-SW	1	3.011	2.998	3.012	2.995	12.015	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%
			2	3.019	2.998	3.017	3.000	12.034	0.000	0.000	0.000	0.000	0.000	0.0%	
		2-C	1	3.012	3.028	3.018	3.023	12.080	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%
			2	3.027	3.004	3.030	3.017	12.077	0.000	0.000	0.000	0.000	0.000	0.0%	
		2-NE	1	3.036	3.046	3.039	3.035	12.155	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%
			2	3.036	3.034	3.039	3.035	12.143	0.000	0.000	0.000	0.000	0.000	0.0%	
7-maxx	Billet 1	3-SW	1	2.998	3.007	3.003	3.016	12.023	0.000	0.000	0.000	0.000	0.000	0.0%	0.7%
			2	2.980	3.022	2.984	3.026	12.011	0.000	0.000	0.000	0.000	0.000	0.0%	
			3	2.990	3.012	2.997	3.024	12.023	0.000	0.000	0.000	0.500	0.500	4.2%	
			4	2.989	3.003	2.990	3.031	12.012	0.000	0.000	0.000	0.000	0.000	0.0%	
			5	2.994	3.023	3.004	3.032	12.052	0.000	0.000	0.000	0.000	0.000	0.0%	
			6	2.994	3.024	3.001	3.026	12.044	0.000	0.000	0.000	0.000	0.000	0.0%	
		3-C	1	3.019	3.079	3.019	3.076	12.191	0.000	0.000	0.000	0.000	0.000	0.0%	0.8%
			2	3.032	3.081	3.030	3.080	12.223	0.000	0.600	0.000	0.000	0.600	4.9%	
			3	3.040	3.077	3.038	3.075	12.229	0.000	0.000	0.000	0.000	0.000	0.0%	
			4	3.020	3.073	3.023	3.074	12.189	0.000	0.000	0.000	0.000	0.000	0.0%	
			5	3.029	3.071	3.022	3.065	12.186	0.000	0.000	0.000	0.000	0.000	0.0%	
			6	3.020	3.060	3.019	3.056	12.155	0.000	0.000	0.000	0.000	0.000	0.0%	
		3-NE	1	3.026	3.016	3.008	2.987	12.036	0.000	0.000	0.000	0.000	0.000	0.0%	0.6%
			2	3.020	3.035	3.000	3.006	12.060	0.000	0.000	0.000	0.000	0.000	0.0%	
			3	3.028	3.045	3.006	3.024	12.102	0.000	0.000	0.000	0.000	0.000	0.0%	
			4	3.023	3.049	2.989	3.023	12.083	0.000	0.000	0.000	0.000	0.000	0.0%	
			5	3.003	3.053	2.982	3.006	12.043	0.000	0.400	0.000	0.000	0.400	3.3%	
			6	3.003	3.036	2.979	3.014	12.032	0.000	0.000	0.000	0.000	0.000	0.0%	
	Billet 2	4-SW	1	3.208	2.987	3.202	2.994	12.390	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%
			2	3.211	2.995	3.210	2.993	12.408	0.000	0.000	0.000	0.000	0.000	0.0%	
			3	3.208	3.001	3.210	2.998	12.416	0.000	0.000	0.000	0.000	0.000	0.0%	
			4	3.232	3.006	3.225	3.003	12.465	0.000	0.000	0.000	0.000	0.000	0.0%	
			5	3.226	3.010	3.218	3.008	12.462	0.000	0.000	0.000	0.000	0.000	0.0%	
			6	3.223	3.019	3.213	3.016	12.470	0.000	0.000	0.000	0.000	0.000	0.0%	
		4-C	1	3.025	3.050	3.020	3.048	12.142	0.000	0.000	0.000	0.000	0.000	0.0%	0.7%
			2	3.039	3.052	3.033	3.051	12.174	0.000	0.000	0.000	0.000	0.000	0.0%	
			3	3.043	3.057	3.042	3.057	12.198	0.000	0.000	0.500	0.000	0.500	4.1%	
			4	3.027	3.059	3.067	3.056	12.209	0.000	0.000	0.000	0.000	0.000	0.0%	
			5	2.996	3.059	3.030	3.057	12.141	0.000	0.000	0.000	0.000	0.000	0.0%	
			6	2.962	3.063	3.015	3.065	12.105	0.000	0.000	0.000	0.000	0.000	0.0%	
		4-NE	1	3.122	3.039	3.118	3.036	12.315	0.000	0.000	0.000	0.000	0.000	0.0%	0.0%
			2	3.118	3.039	3.115	3.051	12.323	0.000	0.000	0.000	0.000	0.000	0.0%	
			3	3.105	3.066	3.106	3.067	12.342	0.000	0.000	0.000	0.000	0.000	0.0%	
			4	3.068	3.079	3.079	3.069	12.294	0.000	0.000	0.000	0.000	0.000	0.0%	
			5	3.084	3.080	3.082	3.078	12.323	0.000	0.000	0.000	0.000	0.000	0.0%	
			6	3.093	3.089	3.085	3.074	12.340	0.000	0.000	0.000	0.000	0.000	0.0%	

Appendix E. Flatwise Bending Test Results
(4 pages)

Objective: 3-alt CLT qualification tests (flatwise bending - major strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: March 10-11, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received
Specimen length: 132 in.

Test Results

#	h (in.)	b (in.)	L (in.)	a (in.)	P_{ult} (lbf)	θ (lbf/in.)	D[(a)] (pcf)	F_bS[(b)] (lbf-ft/ft)	EI (10^6 lbf-in.^{2}/ft)	MC (%)	Failure Mode
1	4.111	11.982	123.75	41.25	12,044	4,060	33.4	20,885	137	8.3	Tension - FJ
2	4.120	11.955	123.75	41.25	9,863	3,907	29.7	17,152	132	8.9	Tension - FJ, Knot
3	4.111	11.968	123.75	41.25	10,224	4,025	29.4	17,754	136	8.9	Tension/Shear
4	4.113	11.977	123.75	41.25	11,589	3,888	29.4	20,091	131	9.2	Tension - FJ (multiple)
5	4.112	11.933	123.75	41.25	10,953	4,158	30.2	19,070	141	9.2	Tension/Shear
6	4.105	11.992	123.75	41.25	11,080	3,930	30.6	19,197	132	9.2	Tension - Knot
7	4.108	11.946	123.75	41.25	9,718	3,811	28.9	16,910	129	9.2	Tension - FJ
8	4.117	11.923	123.75	41.25	12,485	4,113	30.1	21,735	139	9.1	Tension/Shear
9	4.112	11.992	123.75	41.25	12,441	3,945	27.6	21,524	133	8.7	Tension/Shear
10	4.112	11.953	123.75	41.25	10,139	3,760	29.1	17,628	127	8.4	Tension - FJ (multiple)
Total no. of observations							10	10	10	10	
Mean							29.8	19,194	134	8.9	
Maximum							33.4	21,735	141	9.2	
Minimum							27.6	16,910	127	8.3	
COV							0.050	0.094	0.033	0.039	
K								2.104			
Lower tolerance limit (LTL) based on normal distribution								15,387			
LTL based on lognormal distribution								15,684			
LTL (normal)/2.1								7,327			
LTL (lognormal)/2.1								7,468			
Requirement[(c)]								4,875	122		

[(a)] D is based on weight and volume at test.

[(b)] Bending moment includes beam weight.

[(c)] LTL/2.1 for F_bS and mean for EI.

Objective: 3-alt CLT qualification tests (flatwise bending - minor strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: March 16-17, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received
Specimen length: 96 in.

Test Results

#	h (in.)	b (in.)	L (in.)	a (in.)	P_{ult} (lbf)	θ (lbf/in.)	D[(a)] (pcf)	F_bS[(b)] (lbf-ft/ft)	EI (10^6 lbf-in.^{2}/ft)	MC (%)	Failure Mode
1	4.023	11.965	74.25	24.75	2,140	727	30.4	2,262	5.3	8.9	Bottom layer boards separated then middle layer broke in tension
2	4.033	11.962	74.25	24.75	2,916	850	28.4	3,062	6.2	9.0	Did not break
3	4.034	11.973	74.25	24.75	1,825	614	30.8	1,935	4.5	9.2	Bottom layer boards separated then middle layer broke in tension @ FJ
4	4.055	11.992	74.25	24.75	3,418	896	32.0	3,579	6.5	10.0	Did not break
5	4.032	11.958	74.25	24.75	2,194	766	30.1	2,318	5.6	9.3	Bottom layer boards separated then middle layer broke @ section of soft rot
6	4.013	11.515	74.25	24.75	2,018	766	31.2	2,219	5.8	8.8	Bottom layer boards separated then middle layer broke in tension
7	4.048	11.957	74.25	24.75	2,257	708	28.6	2,382	5.2	9.0	Bottom layer boards separated then middle layer broke in tension
8	4.061	11.954	74.25	24.75	2,096	731	32.7	2,222	5.3	9.1	Bottom layer boards separated then middle layer broke in tension @ knot
9	4.055	11.993	74.25	24.75	1,811	788	30.6	1,918	5.7	9.5	Bottom layer boards separated then middle layer broke in tension
10	4.049	11.962	74.25	24.75	2,608	749	31.5	2,749	5.5	9.2	Did not break
Total no. of observations							10	10	10	10	
Mean							30.6	2,465	5.6	9.2	
Maximum							32.7	3,579	6.5	10.0	
Minimum							28.4	1,918	4.5	8.8	
COV							0.045	0.212	0.102	0.038	
K								2.104			
Lower tolerance limit (LTL) based on normal distribution								1,368			
LTL based on lognormal distribution								1,598			
LTL (normal)/2.1								651			
LTL (lognormal)/2.1								761			
Requirement[(c)]								140	2.6		

[(a)] D is based on weight and volume at test.

[(b)] Bending moment includes beam weight.

[(c)] LTL/2.1 for F_bS and mean for EI.

Objective: 7-maxx CLT qualification tests (flatwise bending - major strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: May 3-5, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received
Specimen length: 300 in.

Test Results

#	h (in.)	b (in.)	L (in.)	a (in.)	P_{ult} (lbf)	θ (lbf/in.)	D[(a)] (pcf)	F_bS[(b)] (lbf-ft/ft)	EI (10^6 lbf-in.^{2}/ft)	MC (%)	Failure Mode
1	9.623	11.953	280.75	93.58	17,169	4,188	29.3	68,823	1,651	9.4	Tension @ FJ's
2	9.610	11.942	280.75	93.58	16,641	4,359	31.4	66,923	1,720	9.4	Tension @ FJ's
3	9.574	11.947	280.75	93.58	19,436	4,353	30.0	77,759	1,717	8.7	Tension @ FJ and knots
4	9.601	11.936	280.75	93.58	18,204	4,321	30.1	73,016	1,706	8.9	Tension @ FJ and knots
5	9.494	11.960	280.75	93.58	19,246	4,268	30.6	76,959	1,682	8.7	Tension @ knot
6	9.542	11.959	280.75	93.58	18,600	4,126	32.1	74,526	1,626	8.8	Tension @ FJ's
7	9.531	11.967	280.75	93.58	19,910	4,217	30.0	79,477	1,661	8.8	Tension @ FJ's
8	9.584	11.969	280.75	93.58	14,515	4,091	29.4	58,354	1,611	9.4	Tension @ FJ and knots
9	9.598	11.978	280.75	93.58	20,170	3,801	28.4	80,349	1,495	9.2	Tension @ FJ
10	9.517	11.957	280.75	93.58	17,151	4,072	29.8	68,738	1,605	8.7	Tension @ FJ and knots
Total no. of observations					10	10	10	10	10	10	
Mean					18,104	4,180	30.1	72,492	1,647	9.0	
Maximum					20,170	4,359	32.1	80,349	1,720	9.4	
Minimum					14,515	3,801	28.4	58,354	1,495	8.7	
COV					0.097	0.040	0.035	0.094	0.041	0.034	
K								2.104			
Lower tolerance limit (LTL) based on normal distribution								58,101			
LTL (normal)/2.1								27,667			
Requirement[(c)]								25,500	1,486		

[(a)] D is based on weight and volume at test.

[(b)] Bending moment includes beam weight.

[(c)] LTL/2.1 for F_bS and mean for EI.

Objective: 7-maxx CLT qualification tests (flatwise bending - minor strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: April 28, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received
Specimen length: 204 in.

Test Results

#	h (in.)	b (in.)	L (in.)	a (in.)	P_{ult} (lbf)	θ (lbf/in.)	D[(a)] (pcf)	F_bS[(b)] (lbf-ft/ft)	EI (10^6 lbf-in.^{2}/ft)	MC (%)	Failure Mode
1	9.470	11.982	173.25	57.75	6,992	1,495	33.2	17,533	138.2	8.3	Tension failure under northern load head, no visible defects
2	9.483	11.985	173.25	57.75	6,418	1,279	32.6	16,132	118.2	9.3	Tension failure between load heads, no visible defects
3	9.522	11.985	173.25	57.75	7,576	1,415	31.3	18,901	130.8	8.7	Tension failure under both load heads, knots at both breaks
4	9.536	11.981	173.25	57.75	7,728	1,434	33.2	19,313	132.5	10.0	Tension failure between load heads, no visible defects
5	9.574	11.986	173.25	57.75	7,388	1,388	33.9	18,505	128.3	10.1	Tension failure under southern load head, finger joints at break
6	9.483	11.999	173.25	57.75	6,552	1,309	35.7	16,504	120.8	8.5	Tension failure under southern load head, no defects visible
7	9.503	11.986	173.25	57.75	6,555	1,350	31.0	16,432	124.8	8.1	Tension failure between load heads, no visible defects
8	9.499	12.002	173.25	57.75	4,535	1,285	34.0	11,611	118.5	7.9	Complete tension failure, broken at finger joints and knot clusters
9	9.510	11.984	173.25	57.75	6,024	1,262	31.4	15,163	116.6	9.0	Complete tension failure, broken at knot clusters
11	9.488	11.983	173.25	57.75	6,670	1,395	33.0	16,752	128.9	8.8	Tension failure under northern load head, finger joints at break
Total no. of observations					10	10	10	10	10	10	
Mean					6,644	1,361	32.9	16,685	125.8	8.9	
Maximum					7,728	1,495	35.7	19,313	138.2	10.1	
Minimum					4,535	1,262	31.0	11,611	116.6	7.9	
COV					0.139	0.056	0.044	0.133	0.057	0.083	
K								2.104			
Lower tolerance limit (LTL) based on normal distribution								12,016			
LTL (normal)/2.1								5,722			
Requirement[(c)]								1,230	68		

[(a)] D is based on weight and volume at test.

[(b)] Bending moment includes beam weight.

[(c)] LTL/2.1 for F_bS and mean for EI.

Appendix F. Flatwise Shear Modulus Test Results
(20 pages)

Objective: 3-alt CLT qualification tests (flatwise shear modulus - major strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: February 12, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E (psi)	1/E (1/psi)
1	4.111	11.982	82.5	20.068	0.0025	10,780	126.3	1,817,836	5.50E-07
2	4.120	11.955	82.5	20.027	0.0025	10,115	118.8	1,698,956	5.89E-07
3	4.111	11.968	82.5	20.071	0.0025	10,549	123.7	1,781,616	5.61E-07
4	4.113	11.977	82.5	20.061	0.0025	10,091	118.3	1,700,507	5.88E-07
5	4.112	11.933	82.5	20.063	0.0025	10,304	121.2	1,743,496	5.74E-07
6	4.105	11.992	82.5	20.100	0.0025	10,408	121.8	1,762,047	5.68E-07
7	4.108	11.946	82.5	20.083	0.0025	10,269	120.7	1,740,705	5.74E-07
8	4.117	11.923	82.5	20.039	0.0025	11,205	131.9	1,890,648	5.29E-07
9	4.112	11.992	82.5	20.066	0.0025	10,527	123.2	1,773,127	5.64E-07
10	4.112	11.953	82.5	20.063	0.0025	9,971	117.1	1,684,305	5.94E-07
11	4.117	11.942	82.5	20.039	0.0025	10,180	119.7	1,714,815	5.83E-07
12	4.113	11.956	82.5	20.058	0.0025	10,462	122.8	1,765,484	5.66E-07
Total no. of observations					12	12	12	12	12
Mean					0.0025	10,405	122.1	1,756,128	5.70E-07
Maximum					0.0025	11,205	131.9	1,890,648	5.94E-07
Minimum					0.0025	9,971	117.1	1,684,305	5.29E-07
COV					0.002	0.033	0.033	0.033	0.032

Objective: 3-alt CLT qualification tests (flatwise shear modulus - major strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: February 19, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E (psi)	1/E (1/psi)
1	4.111	11.982	35 1/16	8.529	0.0137	87,794	79.0	1,136,528	8.80E-07
2	4.120	11.955	35 1/16	8.511	0.0138	86,233	77.7	1,111,933	8.99E-07
3	4.111	11.968	35 1/16	8.530	0.0137	93,975	84.6	1,218,409	8.21E-07
4	4.113	11.977	35 1/16	8.526	0.0138	90,294	81.2	1,168,046	8.56E-07
5	4.112	11.933	35 1/16	8.527	0.0138	74,397	67.2	966,347	1.03E-06
6	4.105	11.992	35 1/16	8.542	0.0137	96,206	86.5	1,250,310	8.00E-07
7	4.108	11.946	35 1/16	8.535	0.0137	82,280	74.2	1,070,650	9.34E-07
8	4.117	11.923	35 1/16	8.517	0.0138	92,186	83.3	1,194,052	8.37E-07
9	4.112	11.992	35 1/16	8.528	0.0138	90,430	81.3	1,169,252	8.55E-07
10	4.112	11.953	35 1/16	8.527	0.0138	85,335	76.9	1,106,561	9.04E-07
11	4.117	11.942	35 1/16	8.517	0.0138	81,989	74.0	1,060,236	9.43E-07
12	4.113	11.956	35 1/16	8.525	0.0138	90,873	81.9	1,177,182	8.49E-07
Total no. of observations					12	12	12	12	12
Mean					0.0138	87,666	79.0	1.14E+06	8.84E-07
Maximum					0.0138	96,206	86.5	1.25E+06	1.03E-06
Minimum					0.0137	74,397	67.2	9.66E+05	8.00E-07
COV					0.002	0.069	0.068	0.069	0.073

Objective: 3-alt CLT qualification tests (flatwise shear modulus - major strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: February 26, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

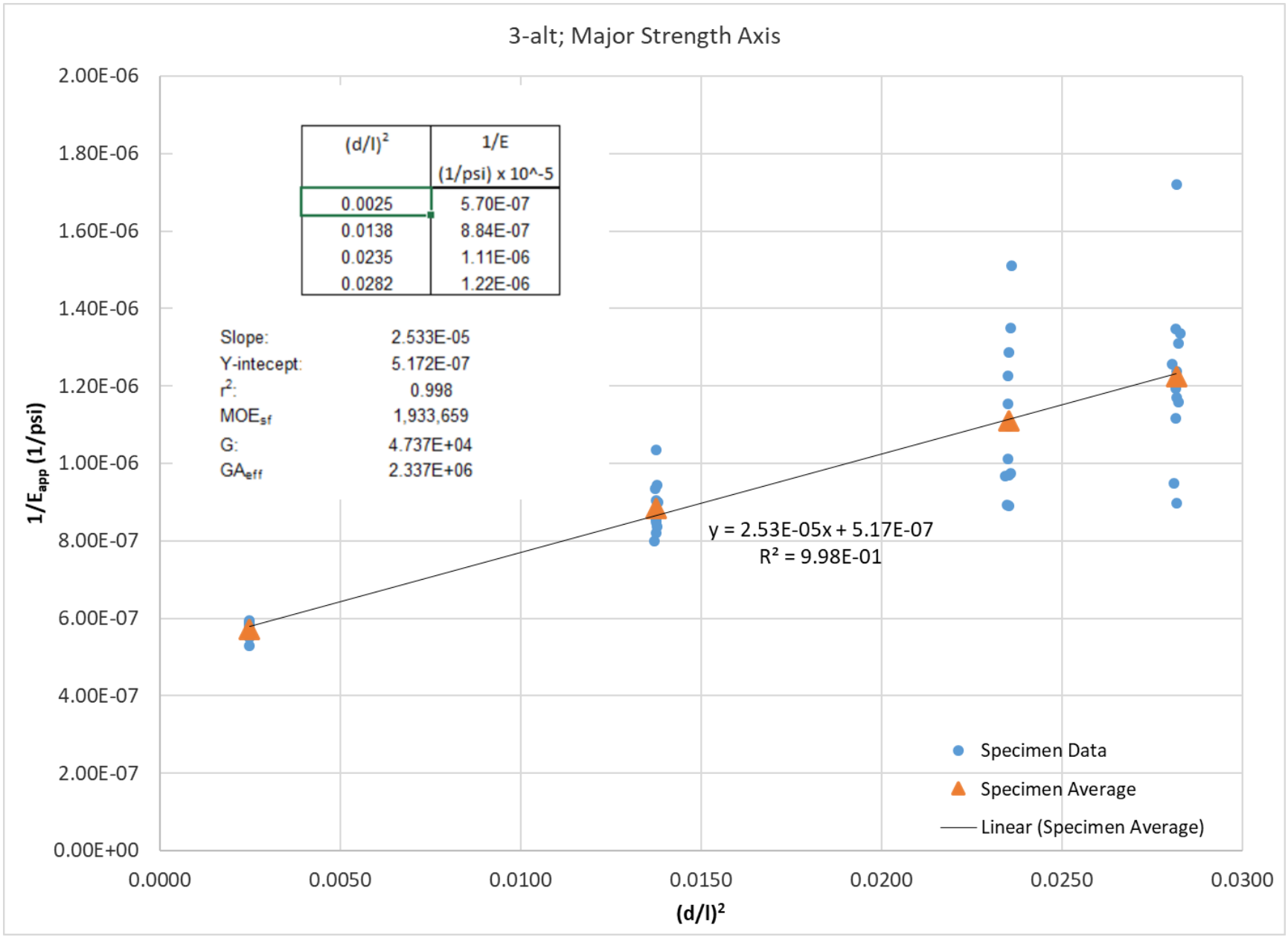
Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E	1/E (1/psi)
1	4.111	11.982	26 13/16	6.522	0.0235	140,953	56.7	815,969	1.23E-06
2	4.120	11.955	26 13/16	6.509	0.0236	114,753	46.3	661,686	1.51E-06
3	4.111	11.968	26 13/16	6.523	0.0235	149,599	60.2	867,345	1.15E-06
4	4.113	11.977	26 13/16	6.520	0.0235	178,416	71.8	1,032,097	9.69E-07
5	4.112	11.933	26 13/16	6.521	0.0235	133,742	54.0	776,834	1.29E-06
6	4.105	11.992	26 13/16	6.532	0.0234	177,763	71.4	1,033,092	9.68E-07
7	4.108	11.946	26 13/16	6.527	0.0235	192,427	77.6	1,119,706	8.93E-07
8	4.117	11.923	26 13/16	6.513	0.0236	177,354	71.7	1,027,265	9.73E-07
9	4.112	11.992	26 13/16	6.521	0.0235	171,079	68.8	989,177	1.01E-06
10	4.112	11.953	26 13/16	6.521	0.0235	193,798	78.1	1,123,784	8.90E-07
11	4.117	11.942	26 13/16	6.513	0.0236	128,030	51.7	740,362	1.35E-06
12	4.113	11.956	26 13/16	6.519	0.0235	157,539	63.5	912,592	1.10E-06
Total no. of observations				12	12	12	12	12	12
Mean				6.5200	0.0235	159,621	64.3	924,992	1.11E-06
Maximum				6.5325	0.0236	193,798	78.1	1,123,784	1.51E-06
Minimum				6.5087	0.0234	114,753	46.3	661,686	8.90E-07
COV				0.001	0.002	0.164	0.163	0.165	0.178

Objective: 3-alt CLT qualification tests (flatwise shear modulus - major strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: March 5, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E	1/E (1/psi)
1	4.111	11.982	24 1/2	5.960	0.0282	168,076	51.6	742,316	1.35E-06
2	4.120	11.955	24 1/2	5.947	0.0283	170,076	52.3	748,197	1.34E-06
3	4.111	11.968	24 1/2	5.960	0.0281	189,395	58.2	837,759	1.19E-06
4	4.113	11.977	24 1/2	5.957	0.0282	183,178	56.2	808,438	1.24E-06
5	4.112	11.933	24 1/2	5.958	0.0282	131,199	40.4	581,403	1.72E-06
6	4.105	11.992	24 1/2	5.969	0.0281	179,550	55.0	796,102	1.26E-06
7	4.108	11.946	24 1/2	5.964	0.0281	237,141	73.0	1,052,764	9.50E-07
8	4.117	11.923	24 1/2	5.951	0.0282	172,629	53.2	762,856	1.31E-06
9	4.112	11.992	24 1/2	5.959	0.0282	202,925	62.2	895,155	1.12E-06
10	4.112	11.953	24 1/2	5.958	0.0282	251,574	77.4	1,112,975	8.98E-07
11	4.117	11.942	24 1/2	5.951	0.0282	195,523	60.2	862,614	1.16E-06
12	4.113	11.956	24 1/2	5.957	0.0282	193,350	59.5	854,516	1.17E-06
Total no. of observations				12	12	12	12	12	12
Mean				5.9576	0.0282	189,551	58.3	837,925	1.22E-06
Maximum				5.9691	0.0283	251,574	77.4	1,112,975	1.72E-06
Minimum				5.9473	0.0281	131,199	40.4	581,403	8.98E-07
COV				0.001	0.002	0.167	0.167	0.168	0.171


3-alt; Major Strength Axis
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1.80E-06
1.60E-06
1.40E-06
1.20E-06
1.00E-06
8.00E-07
6.00E-07
4.00E-07
2.00E-07
0.00E+00
1/Eapp (1/psi)
0.0000
0.0050
0.0100
0.0150
0.0200
0.0250
0.0300
(d/l)2
(d/l)2
1/E (1/psi) x 10^-5
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5.70E-07
0.0138
8.84E-07
0.0235
1.11E-06
0.0282
1.22E-06
Slope:
2.533E-05
Y-intecept:
5.172E-07
r2:
0.998
MOEsf
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G:
4.737E+04
GAeff
2.337E+06
y = 2.53E-05x + 5.17E-07
R² = 9.98E-01
Specimen Data
Specimen Average
Linear (Specimen Average)

Objective: 3-alt CLT qualification tests (flatwise shear modulus - minor strength direction)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: February 12, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E (psi)	1/E (1/psi)
1	4.023	11.965	82.5	20.507	0.0024	482	5.7	86,800	1.15E-05
2	4.033	11.962	82.5	20.456	0.0024	525	6.2	93,972	1.06E-05
3	4.034	11.973	82.5	20.454	0.0024	403	4.7	71,919	1.39E-05
4	4.055	11.992	82.5	20.345	0.0024	584	6.8	102,467	9.76E-06
5	4.032	11.958	82.5	20.464	0.0024	530	6.2	94,889	1.05E-05
6	4.013	11.515	82.5	20.561	0.0024	508	6.2	95,914	1.04E-05
7	4.048	11.957	82.5	20.380	0.0024	440	5.2	77,803	1.29E-05
8	4.061	11.954	82.5	20.318	0.0024	495	5.8	86,894	1.15E-05
9	4.055	11.993	82.5	20.348	0.0024	456	5.3	80,092	1.25E-05
10	4.049	11.962	83.5	20.622	0.0024	474	5.8	86,880	1.15E-05
11	3.998	11.938	82.5	20.635	0.0023	480	5.6	88,242	1.13E-05
12	4.046	11.917	82.5	20.391	0.0024	418	4.9	74,349	1.35E-05
Total no. of observations				12	12	12	12	12	12
Mean				20.457	0.002	483	5.7	86,685	1.17E-05
Maximum				20.635	0.002	584	6.8	102,467	1.39E-05
Minimum				20.318	0.002	403	4.7	71,919	9.76E-06
COV				0.005	0.010	0.105	0.106	0.107	0.110

Objective: 3-alt CLT qualification tests (flatwise shear modulus - minor strength direction)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: February 18, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E	1/E (1/psi)
1	4.023	11.965	35 1/16	8.716	0.0132	5,749	5.2	79,524	1.26E-05
2	4.033	11.962	35 1/16	8.694	0.0132	6,231	5.6	85,573	1.17E-05
3	4.034	11.973	35 1/16	8.693	0.0132	5,135	4.6	70,434	1.42E-05
4	4.055	11.992	35 1/16	8.647	0.0134	7,012	6.3	94,501	1.06E-05
5	4.032	11.958	35 1/16	8.697	0.0132	6,291	5.7	86,519	1.16E-05
6	4.013	11.515	35 1/16	8.738	0.0131	5,945	5.6	86,123	1.16E-05
7	4.048	11.957	35 1/16	8.662	0.0133	5,268	4.7	71,575	1.40E-05
8	4.061	11.954	35 1/16	8.635	0.0134	5,594	5.0	75,330	1.33E-05
9	4.055	11.993	35 1/16	8.648	0.0134	5,142	4.6	69,325	1.44E-05
10	4.049	11.962	35 1/16	8.660	0.0133	5,722	5.2	77,654	1.29E-05
11	3.998	11.938	35 1/16	8.770	0.0130	5,893	5.3	83,242	1.20E-05
12	4.046	11.917	35 1/16	8.666	0.0133	4,951	4.5	67,605	1.48E-05
Total no. of observations				12	12	12	12	12	12
Mean				8.685	0.013	5,744	5.2	78,950	1.28E-05
Maximum				8.770	0.013	7,012	6.3	94,501	1.48E-05
Minimum				8.635	0.013	4,951	4.5	67,605	1.06E-05
COV				0.005	0.009	0.103	0.103	0.106	0.105

Objective: 3-alt CLT qualification tests (flatwise shear modulus - minor strength direction)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: February 23, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

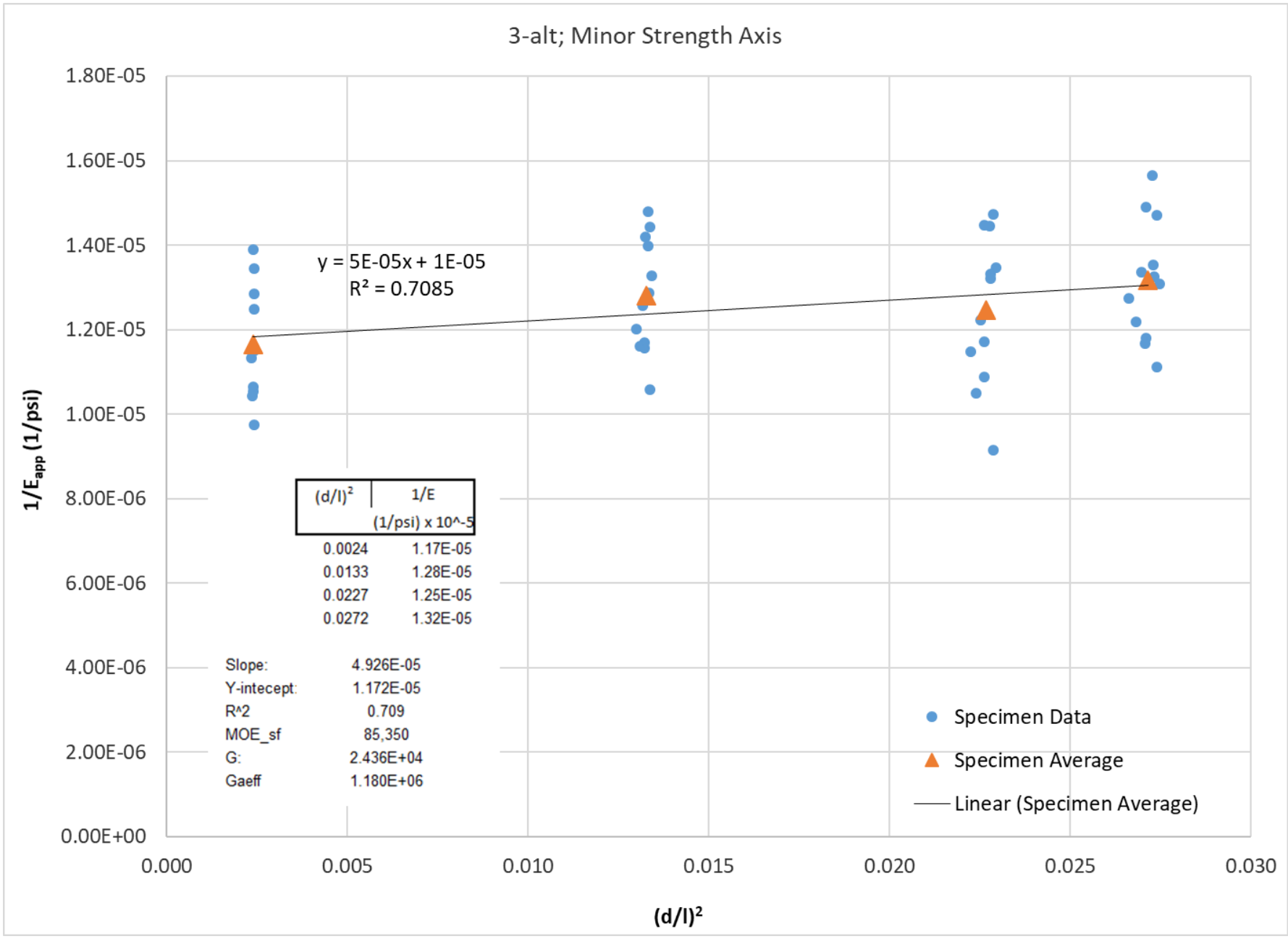
Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E	1/E (1/psi)
1	4.023	11.965	26 13/16	6.665	0.0225	13,227	5.3	81,821	1.22E-05
2	4.033	11.962	26 13/16	6.648	0.0226	14,954	6.0	91,844	1.09E-05
3	4.034	11.973	26 13/16	6.647	0.0226	11,269	4.5	69,119	1.45E-05
4	4.055	11.992	26 13/16	6.612	0.0229	18,119	7.3	109,198	9.16E-06
5	4.032	11.958	26 13/16	6.651	0.0226	13,879	5.6	85,358	1.17E-05
6	4.013	11.515	26 13/16	6.682	0.0224	14,709	6.2	95,287	1.05E-05
7	4.048	11.957	26 13/16	6.624	0.0228	12,460	5.0	75,708	1.32E-05
8	4.061	11.954	26 13/16	6.603	0.0229	12,334	5.0	74,270	1.35E-05
9	4.055	11.993	26 13/16	6.613	0.0229	11,264	4.5	67,911	1.47E-05
10	4.049	11.962	26 13/16	6.622	0.0228	12,380	5.0	75,131	1.33E-05
11	3.998	11.938	26 13/16	6.706	0.0222	13,780	5.6	87,044	1.15E-05
12	4.046	11.917	26 13/16	6.627	0.0228	11,335	4.6	69,206	1.44E-05
Total no. of observations				12	12	12	12	12	12
Mean				6.642	0.023	13,309	5.4	81,825	1.25E-05
Maximum				6.706	0.023	18,119	7.3	109,198	1.47E-05
Minimum				6.603	0.022	11,264	4.5	67,911	9.16E-06
COV				0.005	0.009	0.149	0.151	0.153	0.141

Objective: 3-alt CLT qualification tests (flatwise shear modulus - minor strength direction)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: March 8, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E	1/E (1/psi)
1	4.023	11.965	24 1/2	6.090	0.0270	15,847	4.9	74,791	1.34E-05
2	4.033	11.962	24 1/2	6.075	0.0271	18,098	5.6	84,802	1.18E-05
3	4.034	11.973	24 1/2	6.074	0.0271	14,336	4.4	67,084	1.49E-05
4	4.055	11.992	24 1/2	6.042	0.0274	19,569	6.0	89,980	1.11E-05
5	4.032	11.958	24 1/2	6.077	0.0271	18,269	5.6	85,722	1.17E-05
6	4.013	11.515	24 1/2	6.106	0.0268	16,613	5.3	82,108	1.22E-05
7	4.048	11.957	24 1/2	6.052	0.0273	15,938	4.9	73,881	1.35E-05
8	4.061	11.954	24 1/2	6.034	0.0275	16,638	5.1	76,437	1.31E-05
9	4.055	11.993	24 1/2	6.043	0.0274	14,775	4.5	67,958	1.47E-05
10	4.049	11.962	24 1/2	6.051	0.0273	16,305	5.0	75,495	1.32E-05
11	3.998	11.938	24 1/2	6.128	0.0266	16,276	5.0	78,437	1.27E-05
12	4.046	11.917	24 1/2	6.055	0.0273	13,715	4.2	63,888	1.57E-05
Total no. of observations				12	12	12	12	12	12
Mean				6.069	0.027	16,365	5.0	76,715	1.32E-05
Maximum				6.128	0.027	19,569	6.0	89,980	1.57E-05
Minimum				6.034	0.027	13,715	4.2	63,888	1.11E-05
COV				0.005	0.009	0.103	0.103	0.104	0.106


3-alt; Minor Strength Axis
y = 5E-05x + 1E-05
R² = 0.7085
1.80E-05
1.60E-05
1.40E-05
1.20E-05
1.00E-05
8.00E-06
6.00E-06
4.00E-06
2.00E-06
0.00E+00
1/Eapp (1/psi)
0.000
0.005
0.010
0.015
0.020
0.025
0.030
(d/l)²
(d/l)² | 1/E (1/psi) x 10^-5
0.0024 | 1.17E-05
0.0133 | 1.28E-05
0.0227 | 1.25E-05
0.0272 | 1.32E-05
Slope: 4.926E-05
Y-intecept: 1.172E-05
R^2 0.709
MOE_sf 85,350
G: 2.436E+04
Gaeff 1.180E+06
Specimen Data
Specimen Average
Linear (Specimen Average)

Objective: 7-maxx CLT qualification tests (flatwise shear modulus - major strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: March 22, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E (psi)	1/E (1/psi)
1	9.623	11.953	192 1/2	20.005	0.0025	9,615	1,434.5	1,610,085	6.21E-07
2	9.610	11.942	192 1/2	20.031	0.0025	10,483	1,565.4	1,763,823	5.67E-07
3	9.574	11.947	192 1/2	20.108	0.0025	10,042	1,499.0	1,708,356	5.85E-07
4	9.601	11.936	192 1/2	20.051	0.0025	9,666	1,444.3	1,632,076	6.13E-07
5	9.494	11.960	192 1/2	20.277	0.0024	9,447	1,408.7	1,646,473	6.07E-07
6	9.542	11.959	192 1/2	20.174	0.0025	9,205	1,372.7	1,579,953	6.33E-07
7	9.531	11.967	192 1/2	20.197	0.0025	9,592	1,429.3	1,650,905	6.06E-07
8	9.584	11.969	192 1/2	20.086	0.0025	9,556	1,423.8	1,617,390	6.18E-07
9	9.598	11.978	192 1/2	20.056	0.0025	8,740	1,301.3	1,471,782	6.79E-07
10	9.599	11.979	192 1/2	20.055	0.0025	9,871	1,469.5	1,661,679	6.02E-07
11	9.517	11.957	192 1/2	20.227	0.0024	9,551	1,424.6	1,652,717	6.05E-07
12	9.544	11.953	192 1/2	20.170	0.0025	9,015	1,345.0	1,547,112	6.46E-07
Total no. of observations				12	12	12	12	12	12
Mean				20.120	0.002	9,565	1,426.5	1,628,529	6.15E-07
Maximum				20.277	0.002	10,483	1,565.4	1,763,823	6.79E-07
Minimum				20.005	0.002	8,740	1,301.3	1,471,782	5.67E-07
COV				0.004	0.009	0.048	0.048	0.046	0.047

Objective: 7-maxx CLT qualification tests (flatwise shear modulus - major strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: April 5th, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E	1/E (1/psi)
1	9.623	11.953	81 13/16	8.502	0.0138	95,568	1,094.6	1,228,533	8.14E-07
2	9.610	11.942	81 13/16	8.513	0.0138	98,184	1,125.5	1,268,209	7.89E-07
3	9.574	11.947	81 13/16	8.546	0.0137	96,937	1,110.8	1,265,950	7.90E-07
4	9.601	11.936	81 13/16	8.521	0.0138	96,093	1,102.2	1,245,476	8.03E-07
5	9.494	11.960	81 13/16	8.618	0.0135	85,974	984.1	1,150,196	8.69E-07
6	9.542	11.959	81 13/16	8.574	0.0136	88,375	1,011.7	1,164,486	8.59E-07
7	9.531	11.967	81 13/16	8.584	0.0136	96,339	1,102.1	1,272,915	7.86E-07
8	9.584	11.969	81 13/16	8.536	0.0137	84,015	960.9	1,091,580	9.16E-07
9	9.598	11.978	81 13/16	8.524	0.0138	88,461	1,011.1	1,143,511	8.74E-07
10	9.599	11.979	81 13/16	8.523	0.0138	89,645	1,024.5	1,158,492	8.63E-07
11	9.517	11.957	81 13/16	8.596	0.0135	91,465	1,047.2	1,214,924	8.23E-07
12	9.544	11.953	81 13/16	8.572	0.0136	84,999	973.5	1,119,789	8.93E-07
Total no. of observations				12	12	12	12	12	12
Mean				8.551	0.014	91,338	1,045.7	1,193,672	8.40E-07
Maximum				8.618	0.014	98,184	1,125.5	1,272,915	9.16E-07
Minimum				8.502	0.013	84,015	960.9	1,091,580	7.86E-07
COV				0.004	0.009	0.056	0.056	0.053	0.053

Objective: 7-maxx CLT qualification tests (flatwise shear modulus - major strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: March 28, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

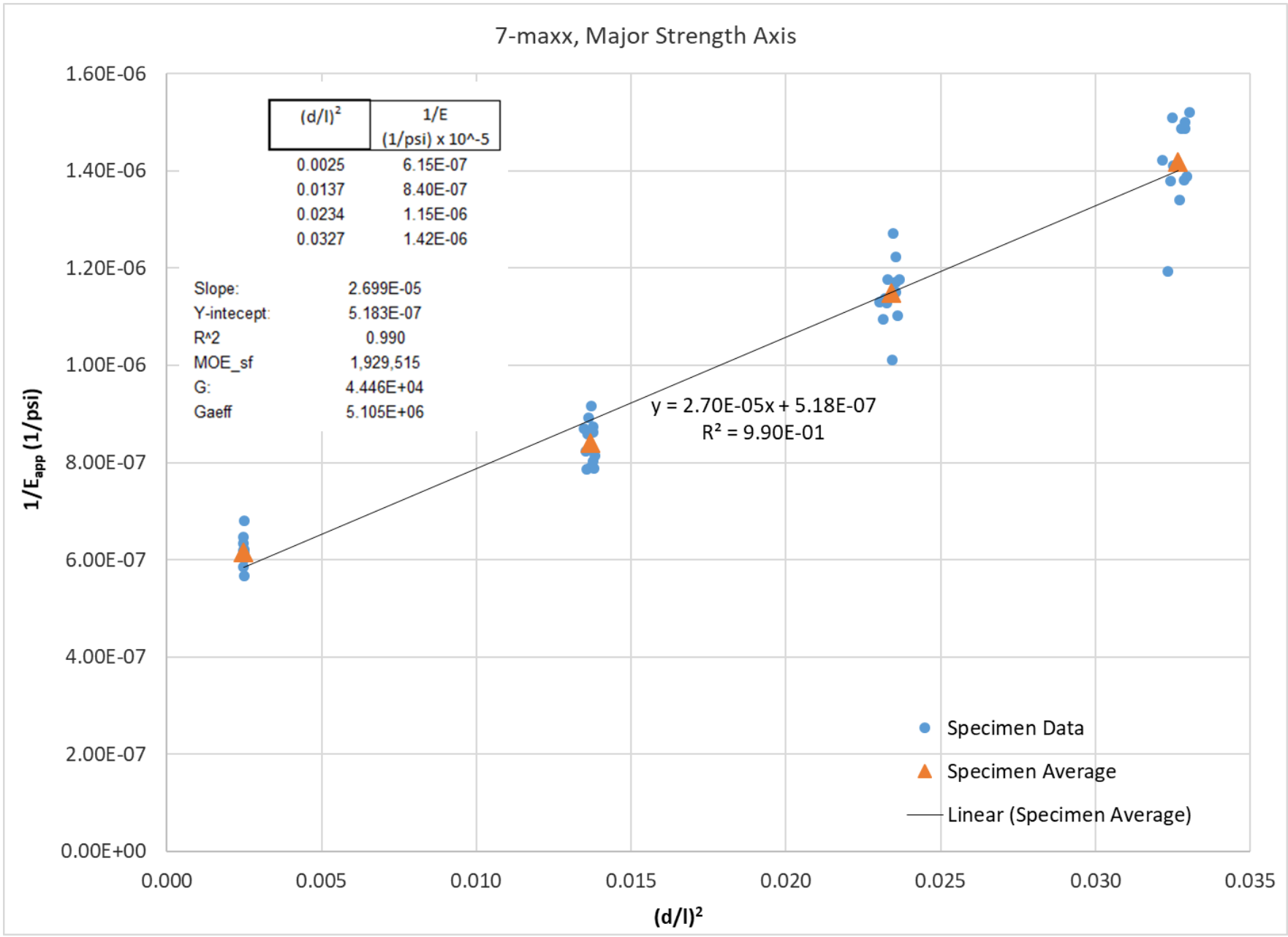
Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E	1/E (1/psi)
1	9.623	11.953	62 9/16	6.502	0.0237	147,920	757.6	850,326	1.18E-06
2	9.610	11.942	62 9/16	6.510	0.0236	157,154	805.6	907,736	1.10E-06
3	9.574	11.947	62 9/16	6.535	0.0234	169,328	867.7	988,875	1.01E-06
4	9.601	11.936	62 9/16	6.516	0.0235	149,958	769.2	869,153	1.15E-06
5	9.494	11.960	62 9/16	6.590	0.0230	147,848	756.8	884,514	1.13E-06
6	9.542	11.959	62 9/16	6.557	0.0233	150,322	769.5	885,745	1.13E-06
7	9.531	11.967	62 9/16	6.564	0.0232	148,729	760.8	878,775	1.14E-06
8	9.584	11.969	62 9/16	6.528	0.0235	135,316	692.1	786,203	1.27E-06
9	9.598	11.978	62 9/16	6.518	0.0235	147,825	755.6	854,518	1.17E-06
10	9.599	11.979	62 9/16	6.518	0.0235	141,375	722.5	817,003	1.22E-06
11	9.517	11.957	62 9/16	6.574	0.0231	153,769	787.3	913,368	1.09E-06
12	9.544	11.953	62 9/16	6.555	0.0233	144,164	738.3	849,300	1.18E-06
Total no. of observations				12	12	12	12	12	12
Mean				6.539	0.023	149,476	765.3	873,793	1.15E-06
Maximum				6.590	0.024	169,328	867.7	988,875	1.27E-06
Minimum				6.502	0.023	135,316	692.1	786,203	1.01E-06
COV				0.004	0.009	0.056	0.057	0.058	0.057

Objective: 7-maxx CLT qualification tests (flatwise shear modulus - major strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: March 24, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E	1/E (1/psi)
1	9.623	11.953	52 15/16	5.501	0.0330	188,801	585.8	657,525	1.52E-06
2	9.610	11.942	52 15/16	5.509	0.0330	205,691	638.8	719,778	1.39E-06
3	9.574	11.947	52 15/16	5.530	0.0327	210,868	654.6	746,054	1.34E-06
4	9.601	11.936	52 15/16	5.514	0.0329	191,394	594.7	672,050	1.49E-06
5	9.494	11.960	52 15/16	5.576	0.0322	194,148	602.1	703,675	1.42E-06
6	9.542	11.959	52 15/16	5.548	0.0325	185,485	575.3	662,130	1.51E-06
7	9.531	11.967	52 15/16	5.554	0.0324	202,500	627.6	724,863	1.38E-06
8	9.584	11.969	52 15/16	5.524	0.0328	191,068	592.1	672,542	1.49E-06
9	9.598	11.978	52 15/16	5.515	0.0329	206,708	640.1	723,900	1.38E-06
10	9.599	11.979	52 15/16	5.515	0.0329	190,465	589.7	666,831	1.50E-06
11	9.517	11.957	52 15/16	5.562	0.0323	232,848	722.3	837,912	1.19E-06
12	9.544	11.953	52 15/16	5.547	0.0325	198,465	615.8	708,333	1.41E-06
Total no. of observations				12	12	12	12	12	12
Mean				5.533	0.033	199,870	619.9	707,966	1.42E-06
Maximum				5.576	0.033	232,848	722.3	837,912	1.52E-06
Minimum				5.501	0.032	185,485	575.3	657,525	1.19E-06
COV				0.004	0.009	0.066	0.066	0.071	0.066


7-maxx, Major Strength Axis
(d/l)²
1/E (1/psi) x 10^-5
0.0025
6.15E-07
0.0137
8.40E-07
0.0234
1.15E-06
0.0327
1.42E-06
Slope:
2.699E-05
Y-intecept:
5.183E-07
R^2
0.990
MOE_sf
1,929,515
G:
4.446E+04
Gaeff
5.105E+06
y = 2.70E-05x + 5.18E-07
R² = 9.90E-01
Specimen Data
Specimen Average
Linear (Specimen Average)
1/Eapp (1/psi)
(d/l)²
1.60E-06
1.40E-06
1.20E-06
1.00E-06
8.00E-07
6.00E-07
4.00E-07
2.00E-07
0.00E+00
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035

Objective: 7-maxx CLT qualification tests (flatwise shear modulus - minor strength direction)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: March 23, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E (psi)	1/E (1/psi)
1	9.470	11.982	192 1/2	20.327	0.0024	893	132.9	156,450	6.39E-06
2	9.483	11.985	192 1/2	20.301	0.0024	809	120.4	141,232	7.08E-06
3	9.522	11.985	192 1/2	20.217	0.0024	835	124.3	143,944	6.95E-06
4	9.536	11.981	192 1/2	20.188	0.0025	856	127.5	147,003	6.80E-06
5	9.574	11.986	192 1/2	20.107	0.0025	844	125.6	143,108	6.99E-06
6	9.483	11.999	192 1/2	20.299	0.0024	806	119.9	140,556	7.11E-06
7	9.503	11.986	192 1/2	20.258	0.0024	739	110.0	128,224	7.80E-06
8	9.499	12.002	192 1/2	20.265	0.0024	722	107.3	125,203	7.99E-06
9	9.510	11.984	192 1/2	20.242	0.0024	754	112.2	130,458	7.67E-06
10	9.488	11.983	192 1/2	20.290	0.0024	826	123.0	144,030	6.94E-06
11	9.503	11.984	192 1/2	20.258	0.0024	841	125.1	145,842	6.86E-06
12	9.436	11.984	192 1/2	20.401	0.0024	706	105.0	125,019	8.00E-06
Total no. of observations				12	12	12	12	12	12
Mean				20.263	0.002	803	119.4	139,256	7.21E-06
Maximum				20.401	0.002	893	132.9	156,450	8.00E-06
Minimum				20.107	0.002	706	105.0	125,019	6.39E-06
COV				0.004	0.007	0.073	0.073	0.071	0.072

Objective: 7-maxx CLT qualification tests (flatwise shear modulus - minor strength direction)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: February 19, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E	1/E (1/psi)
1	9.470	11.982	81 13/16	8.639	0.0134	10,616	121.3	142,819	7.00E-06
2	9.483	11.985	81 13/16	8.628	0.0134	9,707	110.9	130,036	7.69E-06
3	9.522	11.985	81 13/16	8.592	0.0135	10,313	117.8	136,467	7.33E-06
4	9.536	11.981	81 13/16	8.580	0.0136	10,505	120.0	138,449	7.22E-06
5	9.574	11.986	81 13/16	8.545	0.0137	10,667	121.8	138,831	7.20E-06
6	9.483	11.999	81 13/16	8.627	0.0134	10,260	117.1	137,267	7.29E-06
7	9.503	11.986	81 13/16	8.610	0.0135	9,520	108.7	126,733	7.89E-06
8	9.499	12.002	81 13/16	8.613	0.0135	9,053	103.3	120,480	8.30E-06
9	9.510	11.984	81 13/16	8.603	0.0135	9,470	108.2	125,786	7.95E-06
10	9.488	11.983	81 13/16	8.623	0.0134	10,725	122.5	143,477	6.97E-06
11	9.503	11.984	81 13/16	8.610	0.0135	9,922	113.3	132,093	7.57E-06
12	9.436	11.984	81 13/16	8.670	0.0133	8,541	97.6	116,127	8.61E-06
Total no. of observations				12	12	12	12	12	12
Mean				8.612	0.013	9,942	113.5	132,380	7.59E-06
Maximum				8.670	0.014	10,725	122.5	143,477	8.61E-06
Minimum				8.545	0.013	8,541	97.6	116,127	6.97E-06
COV				0.004	0.007	0.070	0.070	0.066	0.068

Objective: 7-maxx CLT qualification tests (flatwise shear modulus - minor strength direction)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: February 24, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

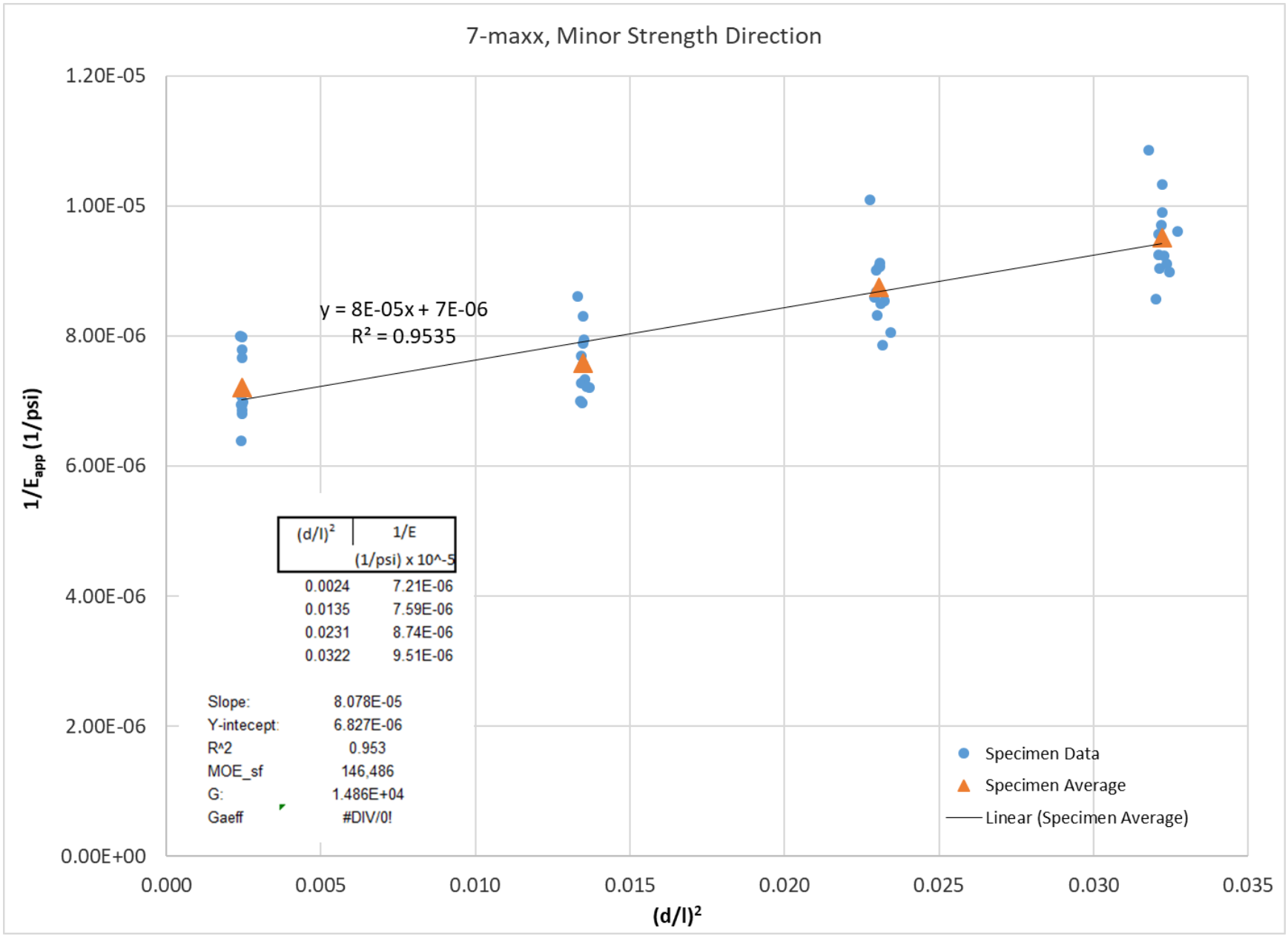
Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E	1/E (1/psi)
1	9.470	11.982	62 9/16	6.606	0.0229	19,324	98.7	116,254	8.60E-06
2	9.483	11.985	62 9/16	6.598	0.0230	18,525	94.6	110,976	9.01E-06
3	9.522	11.985	62 9/16	6.571	0.0232	21,511	109.9	127,296	7.86E-06
4	9.536	11.981	62 9/16	6.561	0.0232	19,860	101.5	117,047	8.54E-06
5	9.574	11.986	62 9/16	6.535	0.0234	21,344	109.0	124,221	8.05E-06
6	9.483	11.999	62 9/16	6.597	0.0230	19,257	98.3	115,214	8.68E-06
7	9.503	11.986	62 9/16	6.584	0.0231	18,519	94.6	110,238	9.07E-06
8	9.499	12.002	62 9/16	6.586	0.0231	18,532	94.5	110,287	9.07E-06
9	9.510	11.984	62 9/16	6.579	0.0231	19,794	101.1	117,567	8.51E-06
10	9.488	11.983	62 9/16	6.594	0.0230	20,090	102.6	120,190	8.32E-06
11	9.503	11.984	62 9/16	6.584	0.0231	18,407	94.0	109,587	9.13E-06
12	9.436	11.984	62 9/16	6.630	0.0227	16,292	83.2	99,059	1.01E-05
Total no. of observations				12	12	12	12	12	12
Mean				6.585	0.023	19,288	98.5	114,828	8.74E-06
Maximum				6.630	0.023	21,511	109.9	127,296	1.01E-05
Minimum				6.535	0.023	16,292	83.2	99,059	7.86E-06
COV				0.004	0.007	0.073	0.073	0.065	0.067

Objective: 7-maxx CLT qualification tests (flatwise shear modulus - minor strength direction)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: March 25, 2021
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received

Test Results

#	d (in.)	b (in.)	L (in.)	L/d	$(d/l)^2$	θ (lbf/in.)	EI (10^6 lbf-in.^{2}/ft)	E	1/E (1/psi)
1	9.470	11.982	52 15/16	5.590	0.0320	32,039	99.2	116,769	8.56E-06
2	9.483	11.985	52 15/16	5.583	0.0321	28,807	89.1	104,548	9.56E-06
3	9.522	11.985	52 15/16	5.560	0.0324	30,603	94.7	109,714	9.11E-06
4	9.536	11.981	52 15/16	5.552	0.0324	31,190	96.6	111,361	8.98E-06
5	9.574	11.986	52 15/16	5.529	0.0327	29,501	91.3	104,020	9.61E-06
6	9.483	11.999	52 15/16	5.582	0.0321	29,844	92.2	108,174	9.24E-06
7	9.503	11.986	52 15/16	5.571	0.0322	28,020	86.7	101,047	9.90E-06
8	9.499	12.002	52 15/16	5.573	0.0322	28,581	88.3	103,046	9.70E-06
9	9.510	11.984	52 15/16	5.567	0.0323	30,090	93.1	108,272	9.24E-06
10	9.488	11.983	52 15/16	5.580	0.0321	30,494	94.4	110,520	9.05E-06
11	9.503	11.984	52 15/16	5.571	0.0322	26,837	83.1	96,795	1.03E-05
12	9.436	11.984	52 15/16	5.610	0.0318	24,997	77.4	92,077	1.09E-05
Total no. of observations				12	12	12	12	12	12
Mean				5.572	0.032	29,250	90.5	105,529	9.51E-06
Maximum				5.610	0.033	32,039	99.2	116,769	1.09E-05
Minimum				5.529	0.032	24,997	77.4	92,077	8.56E-06
COV				0.004	0.007	0.067	0.067	0.064	0.066


7-maxx, Minor Strength Direction
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1.00E-05
8.00E-06
6.00E-06
4.00E-06
2.00E-06
0.00E+00
1/Eapp (1/psi)
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
(d/l)2
y = 8E-05x + 7E-06
R² = 0.9535
(d/l)²
1/E
(1/psi) x 10^-5
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7.21E-06
0.0135
7.59E-06
0.0231
8.74E-06
0.0322
9.51E-06
Slope:
8.078E-05
Y-intecept:
6.827E-06
R^2
0.953
MOE_sf
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G:
1.486E+04
Gaeff
#DIV/0!
Specimen Data
Specimen Average
Linear (Specimen Average)

Appendix G. Flatwise Shear Strength Test Results
(4 pages)

Objective: 3-alt CLT qualification tests (flatwise shear - major strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: October 19-20, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: December 16, 2020
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received
Specimen length: 28 in.

Test Results

#	b (in.)	h (in.)	L (in.)	P_{ult} (lbf)	V_s (lbf)	V_s (lbf/ft)	D[(a)] (pcf)	MC (%)	Failure Mode
1	11.938	4.094	24.000	26,237	13,118	13,187	32.8	12.5	Rolling shear in the cross layer
2	11.938	4.125	24.000	25,792	12,896	12,963	33.3	12.1	
3	11.938	4.094	24.000	23,388	11,694	11,755	34.6	12.5	
4	11.969	4.125	24.000	25,822	12,911	12,944	31.5	12.7	
5	11.938	4.063	24.000	29,809	14,905	14,982	32.1	12.9	
6	11.938	4.094	24.000	28,559	14,279	14,354	33.7	13.5	
7	11.969	4.063	24.000	29,190	14,595	14,633	33.1	13.3	
8	11.969	4.094	24.000	26,482	13,241	13,276	32.4	13.4	
9	11.938	4.094	24.000	26,148	13,074	13,142	33.0	12.6	
10	11.938	4.063	24.000	27,057	13,528	13,599	32.5	12.7	
Total no. of observations						10	10	10	
Mean						13,483	32.9	12.8	
Maximum						14,982	34.6	13.5	
Minimum						11,755	31.5	12.1	
COV						0.071	0.026	0.035	
K						2.104			
Lower tolerance limit (LTL) based on normal distribution						11,483			
LTL (normal)/2.1						5,468			
Requirement[(b)]						1,490			

[(a)] D is based on weight and volume at test.

[(b)] LTL/2.1 for V_s.

Objective: 3-alt CLT qualification tests (flatwise shear - minor strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: December 16-17, 2020
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received
Specimen length: 28 in.

Test Results

#	b (in.)	h (in.)	L (in.)	P_{ult} (lbf)	V_s (lbf)	V_s (lbf/ft)	D[(a)] (pcf)	MC (%)	Failure Mode
1	11.938	4.094	24.000	10,240	5,120	5,147	30.9	11.2	Bottom layer boards separated then bending failure in the middle layer.
2	11.938	4.094	24.000	10,397	5,199	5,226	29.5	10.9	
3	11.938	4.125	24.000	5,161	2,581	2,594	31.3	10.5	
4	11.969	4.094	24.000	4,772	2,386	2,392	30.5	10.7	
5	11.969	4.094	24.000	6,552	3,276	3,285	29.9	10.8	
6	11.938	4.125	24.000	10,323	5,162	5,189	29.0	10.6	
7	11.938	4.063	24.000	10,116	5,058	5,085	34.2	10.8	
8	11.969	4.094	24.000	8,026	4,013	4,024	33.5	10.6	
9	12.000	4.125	24.000	6,645	3,322	3,322	31.8	10.7	
10	11.969	4.125	24.000	9,412	4,706	4,718	30.0	11.0	
Total no. of observations						10	10	10	
Mean						4,098	31.1	10.8	
Maximum						5,226	34.2	11.2	
Minimum						2,392	29.0	10.5	
COV						0.274	0.055	0.018	
K						2.104			
Lower tolerance limit (LTL) based on normal distribution						1,734			
LTL (normal)/2.1						826			
Requirement[(b)]						550			

[(a)] D is based on weight and volume at test.

[(b)] LTL/2.1 for V_s.

Objective: 7-maxx CLT qualification tests (flatwise shear - major strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: October 19-20, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: December 17-18, 2020
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received
Specimen length: 60 in.

Test Results

#	b (in.)	h (in.)	L (in.)	P_{ult} (lbf)	V_s (lbf)	V_s (lbf/ft)	D[(a)] (pcf)	MC (%)	Failure Mode
1	11.938	9.594	51.000	52,560	26,280	26,416	32.8	13.9	Rolling shear in the cross layers
2	11.985	9.625	51.000	55,182	27,591	27,627	32.9	13.5	
3	11.938	9.563	51.000	52,143	26,072	26,207	35.3	13.7	
4	11.969	9.625	51.000	55,087	27,544	27,615	34.8	14.5	
5	12.000	9.500	51.000	51,200	25,600	25,600	35.3	13.4	
6	12.000	9.625	51.000	48,549	24,274	24,274	33.8	13.0	
7	11.993	9.594	51.000	48,061	24,031	24,046	32.7	12.5	
8	12.000	9.625	51.000	52,679	26,340	26,340	33.1	13.3	
9	12.000	9.625	51.000	49,704	24,852	24,852	31.4	13.2	
10	11.969	9.563	51.000	50,178	25,089	25,154	32.2	12.7	
Total no. of observations						10	10	10	
Mean						25,813	33.4	13.4	
Maximum						27,627	35.3	14.5	
Minimum						24,046	31.4	12.5	
COV						0.049	0.040	0.044	
K						2.104			
Lower tolerance limit (LTL) based on normal distribution						23,168			
LTL (normal)/2.1						11,032			
Requirement[(b)]						3,475			

[(a)] D is based on weight and volume at test.

[(b)] LTL/2.1 for V_s.

Objective: 7-maxx CLT qualification tests (flatwise shear - minor strength axis)
Plant: SmartLam, Columbia Falls, MT
Grade: E21M1
Manufacturing date: August 10-12, 2020
Test lab: Advanced Structures & Composites Center, Orono, ME
Test date: December 18-21, 2020
Referenced test methods: PRG 320 and ASTM D198
Test conditions: As-received
Specimen length: 60 in.

Test Results

#	b (in.)	h (in.)	L (in.)	P_{ult} (lbf)	V_s (lbf)	V_s (lbf/ft)	D[(a)] (pcf)	MC (%)	Failure Mode
1	11.985	9.594	51.000	15,302	7,651	7,661	29.5	10.0	Bottom layer boards separated then bending failure in the middle layer.
2	11.969	9.563	51.000	15,147	7,574	7,593	30.4	11.0	
3	11.938	9.625	51.000	15,011	7,505	7,544	31.0	10.4	
4	12.000	9.500	51.000	14,700	7,350	7,350	31.2	10.3	
5	11.969	9.532	51.000	16,191	8,096	8,117	30.4	11.3	
6	12.000	9.563	51.000	13,687	6,844	6,844	30.0	10.7	
7	12.000	9.563	51.000	15,856	7,928	7,928	30.3	10.5	
8	11.938	9.532	51.000	15,405	7,702	7,742	28.8	10.9	
9	11.938	9.563	51.000	17,705	8,853	8,899	30.0	10.7	
10	11.969	9.625	51.000	15,645	7,822	7,843	29.8	10.3	
Total no. of observations						10	10	10	
Mean						7,752	30.1	10.6	
Maximum						8,899	31.2	11.3	
Minimum						6,844	28.8	10.0	
COV						0.069	0.023	0.037	
K						2.104			
Lower tolerance limit (LTL) based on normal distribution						6,632			
LTL (normal)/2.1						3,158			
Requirement[(b)]						1,650			

[(a)] D is based on weight and volume at test.

[(b)] LTL/2.1 for V_s.