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**ADVANCING ENHANCED WOOD
MANUFACTURING INDUSTRIES
IN LAOS AND AUSTRALIA**

Mechanical Property Testing of Laminated Veneer Lumber (LVL) and Plywood for Burapha Ltd

Written by Adam Faircloth and Tony Dakin – March 2020

VALTIP 3

This publication has been compiled by Adam Faircloth and Tony Dakin, Forest Product Innovations, Department of Agriculture and Fisheries.

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1. Introduction

The work described in this report has been conducted by the Engineering Laboratory of the Salisbury Research Facility, Forest Product Innovations – a Queensland Government research facility operated by the Department of Agriculture and Fisheries (DAF). DAF conducted testing to determine the mechanical properties of laminated veneer lumber (LVL), cross-banded LVL (LVB) and plywood manufactured by Burapha Ltd, as part of the Australian Centre for International Agricultural Research (ACIAR) project FST/2016/151: Advancing enhanced wood manufacturing in Laos and Australia.

Sample material, provided by the manufacturer, was tested in accordance with the Australian Standard AS/NZS 4357.2:2006 and European Standard EN 13393:2001 for bending strength and stiffness (MOR and MOE) of LVL and LVB, a modified test method from AS 2269.1:2012 for MOR and MOE of plywood, AS/NZS 2098.2:2012 for the bond quality between glue lines (all samples), and AS/NZS 1080.1:2012 for moisture content percentage (all samples).

This report describes the samples, outlines the testing methods used and presents a summary of the test results. Detailed results are included as appendices to this report.

2. Testing Proposal

As part of an ACIAR joint research and development (R&D) project with DAF, Burapha is a registered partner looking to expand their production, improve quality and begin exporting their product.

During a visit to Burapha's facilities by DAF project staff, an initial batch of LVL, LVB and plywood was manufactured (Batch 1) for mechanical testing to evaluate potential production practices and products. A subsequent batch of LVL and LVB was produced by Burapha and shipped to DAF for assessment (Batch 2). The LVL and plywood was manufactured from the K7 hybrid, which is a hybrid between *Eucalyptus camaldulensis* x *Eucalyptus deglupta*. A range of construction strategies and adhesives were used in preparation of the samples, and remain proprietary to Burapha. Both batches of samples were assessed using the following method:

- Acoustic assessment of the boards to approximate their stiffness non-destructively;
- Bending Stiffness and Strength testing to appropriate standards;
- Bond Quality Assessment in accordance with AS/NZS 2098.2; and,
- Moisture Content Percentage assessment in accordance with AS/NZS 1080.1.

Details of the test material supplied and test sample preparation is included in Section 3. The test methods employed are described in detail in Section 4, including any deviations from Standard procedure.

3. Sample Preparation

Test material was supplied by Burapha in 2 batches, the first was produced and shipped in October 2019 and the second in January 2020.

Table 1 summarises the quantity and dimensions of material supplied.

Table 1: Nominal dimensions and number of samples.

Test Batch	Product Type	Quantity	Nominal Width (mm)	Nominal Thickness (mm)	Nominal Length (mm)
Batch 1	Plywood	2	100	8	600
	LVL	2	100	9	600
		2	100	10	600
		2	100	12	600
		2	100	12	600
	LVB	2	100	9	600
		2	100	10	600
		2	100	12	600
	Batch 2	LVL	1	100	6
1			100	10	900
1			100	12	900
1			100	24	1100
1			100	36	1100
LVB		1	100	6	900
		1	100	12	900

All test material lengths were supplied with a label to allow Burapha to trace test results back to the proprietary manufacturing parameters. This label was transposed to all sub samples cut by DAF. Upon receipt, the sample material was stored in a constant environment chamber, set to 20°C and 65% relative humidity, until a constant equilibrium moisture content of 12% was achieved. A sample for MOE/MOR and Bond Quality testing was then cut from each sample. The 24 and 36 mm LVL MOE/MOR samples from Batch 2 were also ripped longitudinally to provide 2 test specimens.

Table 2 summarises the final array of test specimens.

A sample for the confirmation testing of Moisture Content was taken from each MOE/MOR specimen after testing, as described in Section 4.4.

Table 2: Final specimens for testing

Test Batch	Product Type	Test Type	Quantity	Nominal Width (mm)	Nominal Thickness (mm)	Nominal Length (mm)
Batch 1	Plywood	MOE/MOR	2	100	8	400
		Bond Quality	2	100	8	100
	LVL	MOE/MOR	2	100	9	400
		Bond Quality	2	100	9	100
		MOE/MOR	2	100	10	400
		Bond Quality	2	100	10	100
		MOE/MOR	2	100	12	400
		Bond Quality	2	100	12	100
	LVB	MOE/MOR	2	100	9	400
		Bond Quality	2	100	9	100
		MOE/MOR	2	100	10	400
		Bond Quality	2	100	10	100
		MOE/MOR	2	100	12	400
		Bond Quality	2	100	12	100
Batch 2	LVL	MOE/MOR	1	100	6	800
		Bond Quality	1	100	6	100
		MOE/MOR	1	100	10	800
		Bond Quality	1	100	10	100
		MOE/MOR	1	100	12	800
		Bond Quality	1	100	12	100
		MOE/MOR	2	50	24	1000
		Bond Quality	1	100	24	100
		MOE/MOR	2	50	36	100
		Bond Quality	1	100	36	100
	LVB	MOE/MOR	1	100	6	800
		Bond Quality	1	100	6	100
		MOE/MOR	1	100	12	800
		Bond Quality	1	100	12	100

4. Test Methods

4.1 Acoustic Assessment

Acoustic analysis was conducted on the test material supplied to DAF prior to any static assessment taking place. The material was tested using a laboratory scale acoustic measurement device BING, which analyses the vibration of the timber after being impacted; from this signal data the elastic modulus (MOE) of the board can be approximated. The setup used consisted of one similar to the configuration displayed in Figure 1.



Figure 1: Acoustic assessment of LVL sample.

The boards were tested at their supplied dimensions, prior to being cut into final test specimens. The samples were tested in both the longitudinal and transverse directions of the boards. The results were used to help identify any abnormalities in the data collected from subsequent testing. Following acoustic analysis the samples were prepared for testing of their mechanical properties in accordance with the relevant standards, as discussed in Sections 2 and 3.

4.2 Bending Stiffness and Strength (MOE and MOR)

Bending Stiffness and Strength testing was conducted using a number of different methods depending on the requirements of Burapha, and in some cases the limitations of available test equipment. The various test methods are summarised in following sections. Table 3 indicates the test method conducted for each sample type.

Table 3: MOE/MOR test method conducted by sample type

Test Batch	Product Type	Test Method	Orientation
Batch 1	Plywood	Modified AS/NZS 2269.1	Flatwise
	LVL	AS/NZS 4357.2	Flatwise
	LVB	AS/NZS 4357.2	Flatwise
Batch 2	6, 10 & 12mm LVL	EN 13393	Flatwise
	24 & 36mm LVL	AS/NZS 4357.2	Edgewise
	LVB	EN 13393	Flatwise

4.2.1 4-point Bending Test to AS/NZS 4357.2

Figure 2 shows the arrangement of the 4-point bending test method in accordance with AS/NZS 4357.2. As detailed in Table 3, tests were conducted in both edgewise and flatwise orientations. In all cases, a test span of 18x the depth of the sample was adopted. Testing was conducted on a Shimadzu AG-X universal test machine, with a 100kN load cell. The displacement was measured using highly precise digital imaging cameras (DIC) capable of recording displacement and accounting for any rotational affects that may occur during the test.

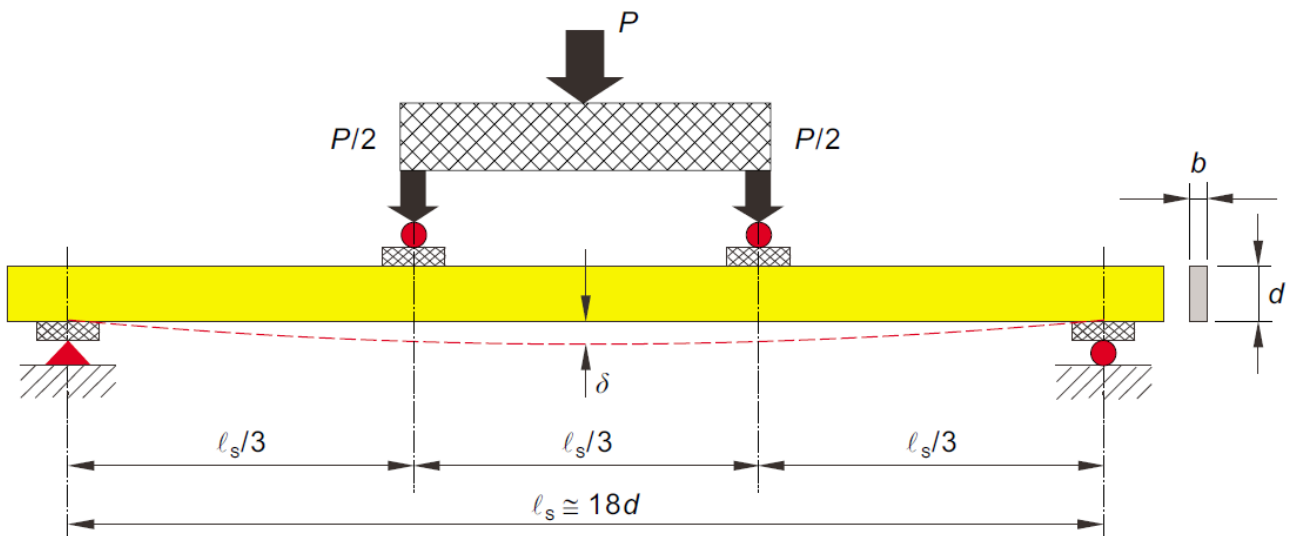


Figure 2: Bending test setup (AS/NZS 4357.2).

Load was applied at a constant rate and the resulting load-displacement curve plotted, until rupture of the specimen occurred. The applied load at time of failure was recorded, along with the cross sectional dimensions of the sample adjacent to the failure location (measured using calibrated digital callipers). The location of failure initiation within the span was also noted.

Modulus of Elasticity (MOE), was determined from the following equation:

$$MOE = \frac{23 \times L^3}{1296 \times I} \times \frac{\Delta F}{\Delta D}$$

Where I is the moment of inertia of the sample calculated in accordance with AS/NZS 2269.0 using information provided by Burapha, L is the lower span, and $\frac{\Delta F}{\Delta D}$ is the slope of the elastic portion of the load versus displacement curve.

The Bending Strength, or Modulus of Rupture (MOR), is determined from the following equation:

$$f'_b = \frac{F_{ult} \times L}{6 \times z}$$

Where F_{ult} is the maximum load at the point of failure, z is the section modulus of the sample calculated in accordance with AS/NZS 2269.0 using information provided by Burapha, and L is the lower span.

Test results are summarised in Section 5, with full results contained as appendices.

4.2.2 3-point Bending Test to EN 13393

In addition to testing conducted by DAF, Burapha has also had material assessed by a 3rd party testing agency. Burapha requested that DAF replicate some of this testing. The 3rd party testing agency adopted a 3-point bending test method in accordance with EN 13393:2001. The general arrangement of the 3-point test is shown in Figure 3.

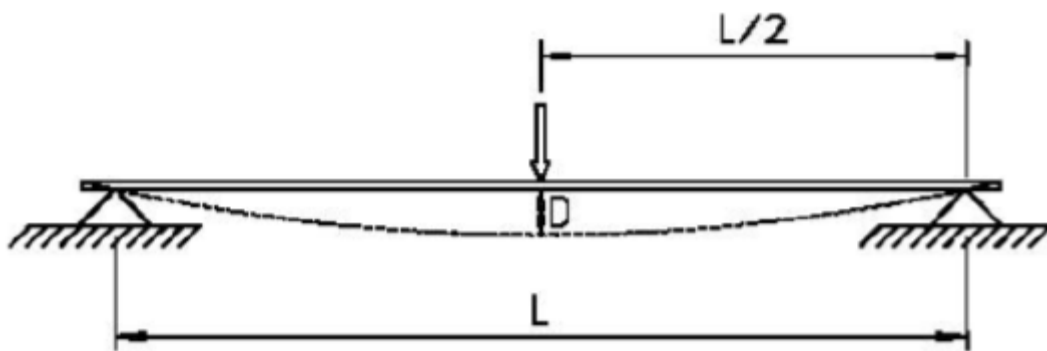


Figure 3: 3-point bending test setup

Testing was conducted on a Shimadzu AG-X universal test machine, with a 100kN load cell. The displacement was measured using a highly precise DIC system. A fixed test span of 500mm was adopted in all cases regardless of specimen type and depth. Load was applied at a constant rate and the resulting load-displacement curve plotted, until rupture of the specimen occurred. The applied load at time of failure was recorded, along with the cross sectional dimensions of the sample adjacent to the failure location (measured using calibrated digital callipers). The location of failure initiation within the span was also noted.

In alignment with the 3rd party test report, Bending Stiffness (S) was determined using the following equation:

$$S = \frac{L^3}{48} \times \frac{\Delta F}{\Delta D}$$

Where $L = 500\text{mm}$, and $\frac{\Delta F}{\Delta D}$ is the slope of the elastic portion of the load versus displacement curve.

This Bending Stiffness value was also reported as a MOE result, calculated using the following equation:

$$MOE = \frac{S}{I}$$

Where I is the moment of inertia of the sample calculated in accordance with AS/NZS 2269.0 using information provided by Burapha.

The 3rd party test agency reported Bending Strength simply as the applied load at time of failure of the test specimen. These failure loads were also converted to a MOR result using the following equation:

$$f'_b = \frac{F_{ult} \times L}{4 \times z}$$

Where F_{ult} is the maximum load at the point of failure, z is the section modulus of the sample calculated in accordance with AS/NZS 2269.0 using information provided by Burapha, and $L = 500\text{mm}$.

Test results are summarised in Section 5, with full results contained as appendices.

4.2.3 Modified AS/NZS 2269.1 Plywood Bending Test

The standard bending test for plywood, in accordance with AS/NZS 2269.1:2012, is a 4-point test similar to the setup shown in Figure 2. Specific to the plywood test, samples are typically 300mm wide and tested over a span of 48x times the thickness of the sheet. Due to the size of material supplied by Burapha and limitations of the DAF test equipment, some modifications to this standard method were adopted. A 3-point bending test was conducted, as per the setup shown in Figure 3. Specimens were 100mm wide, as supplied, and tested over a span of 48x their nominal thickness.

Testing was conducted on a Shimadzu AG-X universal test machine, with a 100kN load cell. The displacement was measured using a highly precise DIC system. Load was applied at a constant rate and the resulting load-displacement curve plotted, until rupture of the specimen occurred. The applied load at time of failure was recorded, along with the cross sectional dimensions of the sample adjacent to the failure location (measured using calibrated digital callipers). The location of failure initiation within the span was also noted.

Modulus of Elasticity (MOE), was determined from the following equation:

$$MOE = \frac{L^3}{48 \times I} \times \frac{\Delta F}{\Delta D}$$

Where I is the moment of inertia of the sample calculated in accordance with AS/NZS 2269.0 using information provided by Burapha, L is the lower span, and $\frac{\Delta F}{\Delta D}$ is the slope of the elastic portion of the load versus displacement curve.

The Bending Strength, or Modulus of Rupture (MOR), is determined from the following equation:

$$f'_b = \frac{F_{ult} \times L}{4 \times z}$$

Where F_{ult} is the maximum load at the point of failure, z is the section modulus of the sample calculated in accordance with AS/NZS 2269.0 using information provided by Burapha, and L is the lower span.

Test results are summarised in Section 5, with full results contained as appendices.

4.3 Bond Quality Assessment

The Australian Standards AS/NZS 4357.0:2005 *Structural laminated veneer lumber (LVL) – Specifications* and AS/NZS 2269.0:2012 *Plywood – Structural – Specifications* specify that the bonding between plies of products needs to be of varying classes depending on the required durability, when tested in accordance with AS/NZS 2098.2:2012. This standard test method involves the pre-conditioning of the test samples before chiselling apart the glue lines and assessing the bond quality. The pre-conditioning process varies depending on the bond durability class targeted. Burapha provided samples targeting Type A and Type C classes. Testing was conducted as per Table 4.

Table 4: Target Bond Type of test samples

Test Batch	Product Type	Bond Type
Batch 1	Plywood	Type A
	LVL	Type A
	LVB	Type A
Batch 2	6, 10 & 12mm LVL	Type A
	24 & 36mm LVL	Type C
	LVB	Type A

All test specimens were 100x100mm. The pre-conditioning process for each bond class is described in Table 5.

Table 5: Bond type pre-condition process as per AS/NZS 2098.2

Bond Type	Pre-conditioning Process
Type A	Samples are steamed for 6 hrs at 135°C within a pressurised vessel (autoclave) at 200kPa
Type C	Samples are submerged in water at a temperature of 70°C for a period of 3 hrs using a hot water bath

At the completion of the pre-conditioning cycle, samples of all bond classes are tested using the following procedure:

- After the pre-conditioning period the samples are submerged into room temperature water until the samples are cooled to ambient temperature.

- The test pieces are kept wet until testing, and must be tested within 24 hrs of removal from pre-conditioning.
- Veneers are levered apart by using a pneumatic chisel at each glueline, perpendicular to the grain direction.
- Once the samples are chiselled the veneers are dried, after which assessment takes place as detailed below.

The bond quality is assessed based on the amount wood fibre on the surface of the two separated veneers following chiselling. Each glueline is assigned a “Bond quality score” based on the percentage area of the separated veneers containing wood fibre. Bond quality values are assigned as per .

Estimated wood-failure, %	Bond quality value
0 to 5	0
6 to 15	1
16 to 25	2
26 to 35	3
36 to 45	4
46 to 55	5
56 to 65	6
66 to 75	7
76 to 85	8
86 to 95	9
96 to 100	10

Figure 4: Bond quality scale (AS/NZS 2098.2).

In order for samples to meet the requirements of the bond class, the average bond quality value of all gluelines must be 5 or higher, and the minimum bond quality value for an individual glueline must be 2 or higher.

4.4 Moisture Content

After completion of the above MOE/MOR tests, a section of each specimen was cut off for measurement of moisture content (MC), according to the methods of AS/NZS 2098.1. MC test pieces of full cross section, approximately 25mm long, were taken from the timber close to the failure. The oven dry method was used to measure moisture content of the samples. The procedure outlined above is depicted in Figure 5 below.

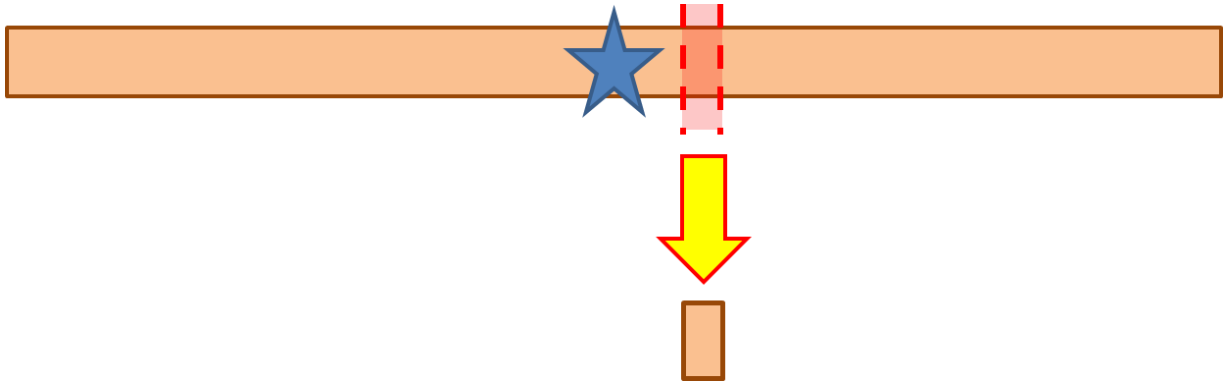


Figure 5: MC sample taken from failed board.

The MC specimens were weighed and then submitted to a drying cycle for 24 hrs at 103°C. After the first 24 hr period, the samples were weighed and returned to the drying oven for an additional 8 hrs. The weight was taken a second time and the difference between successive oven dried weights determined; if the difference is greater than 0.1% the samples are to be placed in the drying oven for another 4 to 6 hr period or until the difference is $\leq 0.1\%$ as outlined by AS/NZS 2098.1. Once drying is complete, the moisture content percentage for each sample is calculated using the following equation:

$$MC\% = \frac{(m_i - m_{OD})}{m_{OD}} \times 100$$

Where m_i is the initial mass of the specimen, and m_{OD} is the final oven dry mass of the sample.

5. Results Summary

5.1 Bending Stiffness and Strength (MOE and MOR)

5.1.1 Batch 1 Results

Table 6 includes a summary of the results obtained from Bending Stiffness and Strength testing, conducted on Batch 1 samples as described in Section 4.2. Full results are included as Appendices A & B.

Table 6: Measured dimensions and results of Bending Stiffness and Strength testing, Batch 1.

Sample Type	Test Method	Orientation	Sample Number	Width (mm)	Thickness (mm)	MOE (MPa)	Bending Strength (MPa)
Plywood	Modified AS/NZS 2269.1	Flatwise	3-PLY-1	100.68	4.65	14727	121.4
			3-PLY-8	100.07	4.74	15272	126.1
LVL	AS/NZS 4357.2	Flatwise	9-LVL-7	101.83	10.38	15285	77.4
			9-LVL-8	100.94	10.43	13969	79.3
			10-LVL-3	100.78	11.37	12838	87.0
			10-LVL-5	101.19	11.34	12242	87.4
			12-LVL-3	102.27	13.69	8229	69.6
			12-LVL-5	101.87	13.60	8806	74.6
LVB	AS/NZS 4357.2	Flatwise	9-LVB-2	100.75	10.34	10020	68.5
			9-LVB-8	100.04	9.98	13469	63.7
			10-LVB-1	99.33	11.47	11746	73.7
			10-LVB-8	99.38	11.49	10938	76.6
			12-LVB-7	101.72	13.64	7901	58.0
			12-LVB-8	101.52	13.74	7421	52.7

As can be seen in Table 6, relatively consistent results were achieved by similar samples of all types, indicating a reasonable level of reliability and quality in the production process. However, given that the production parameters of the test material are proprietary to Burapha, it is difficult to comment on the expectedness or appropriateness of the results attained. The achievement of lower results for LVB, as compared to LVL of the same thickness, is expected due to the reduced number of veneers in the cross section running parallel to the span direction.

Overall, the MOE and Bending Strength values of the plywood tested meet the requirements of F17 grade as per AS1720.1:2010. For the LVL and LVB samples, all Bending Strength results achieve F17 whilst the MOEs range from approximately F7 to F17 depending on the specimen type.

Potentially of note is the mode of failure observed in the 12mm LVB samples. As shown in Figure 6, specimens appeared to exhibit a shearing type failure at the interface between perpendicularly orientated veneers. This is further evidenced in Bond Quality results contained in Section 5.2 and may go some way to explain the achievement of comparatively low mechanical property results achieved by these samples.



Figure 6: (left) 12-LVB-7 failure, (right) 12-LVB-8 failure.

5.1.2 Batch 2 Results

Table 7 includes a summary of the results obtained from Bending Stiffness and Strength testing in accordance with EN 13393, conducted on Batch 2 samples as described in Section 4.2. Full results are included as Appendix C.

Table 7: Measured dimensions and results of Bending Stiffness and Strength testing to EN 13393, Batch 2.

Sample Type	Test Method	Orientation	Sample Number	Width (mm)	Thickness (mm)	Bending Stiffness (N.m ²)	MOE (MPa)	Failure Load (N)	MOR (MPa)
LVL	EN 13393	Flatwise	16-6-LVL-9	100.0	6.50	40.4	17638	604	107.2
			16-10-LVL-6	100.0	10.19	139.7	15848	1571	113.5
			16-12-LVL-6	100.0	12.02	222.0	15340	1764	91.6
LVB	EN 13393	Flatwise	16-6-LVB-5	100.0	6.85	36.4	17334	929	190.9
			16-12-LVB-7	100.0	12.17	167.5	14271	982	64.2

As was the case for Batch 1 testing, the results for samples look to increase proportionally with panel thickness, and the expected reduction in performance for LVB specimens, as compared to LVL of the same thickness, occurred. However, both the Bending Stiffness and Strength achieved by the 12mm LVB sample appear comparatively low. Upon further inspection, it appears that failure of this specimen initiated from a localised area of poor bonding, as shown in Figure 7, likely causing these results. Bond Quality results indicate that the overall adhesion of this sample was adequate.

When converted to MOE and MOR values, all samples meet the requirements of F17 grade as per AS1720.1:2010, and are comparable to commercially available LVL.

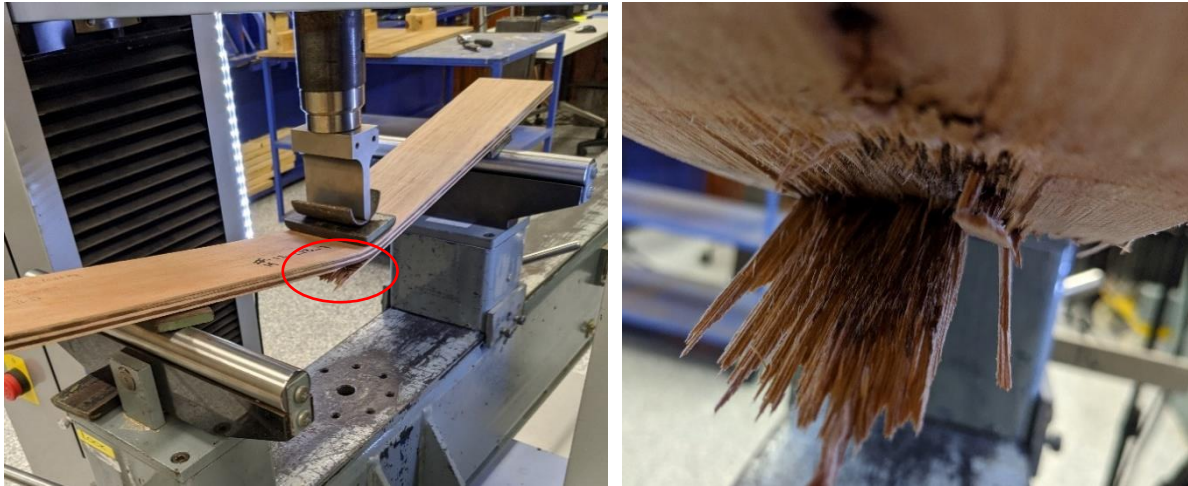


Figure 7: Specimen 16-12-LVB-7 bending test failure mode.

Table 8 includes a summary of the results obtained from Bending Stiffness and Strength testing in accordance with AS/NZS 4357.2, conducted on Batch 2 samples as described in Section 4.2. Full results are included as Appendix D.

Table 8: Measured dimensions and results of Bending Stiffness and Strength testing to AS/NZS 4357.2, Batch 2.

Sample Type	Test Method	Orientation	Sample Number ¹	Width (mm)	Thickness (mm)	MOE (MPa)	Bending Strength (MPa)
LVL	AS/NZS 4357.2	Edgewise	1-12-LVL	49.0	23.49	15532	85.2
			2-12-LVL	49.0	23.60	15309	91.7
			1-18-LVL	42.5	35.70	14110	86.6
			2-18-LVL	49.0	35.80	15253	90.2

¹ Samples 12-LVL and 18-LVL were ripped longitudinally to provide 2x matched samples for testing

As indicated in Table 8, consistent results were achieved across both the 24mm and 36mm LVL samples. The MOE and Bending Strength values meet the requirements of F17 grade as per AS1720.1:2010, and are comparable to commercially available LVL.

5.2 Bond Quality Assessment Results

5.2.1 Batch 1 Results

Table 9 contains a summary of the results from the Type A bond quality assessment conducted on Batch 1 samples in accordance with the test method outlined in Section 4.3. Full results are contained as Appendix E.

Table 9: Bond Quality Assessment, Batch 1.

Sample Type	Bond Class	Sample Number	Average Bond Quality Value	Minimum Bond Quality Value	Pass / Fail
Plywood	Type A	3-PLY-1	3	2	FAIL
		3-PLY-8	4	4	FAIL
LVL	Type A	9-LVL-7	7	6	PASS
		9-LVL-8	8	7	PASS
		10-LVL-3	7	7	PASS
		10-LVL-5	7	5	PASS
		12-LVL-3	7	5	PASS
		12-LVL-5	7	6	PASS
LVB	Type A	9-LVB-2	8	8	PASS
		9-LVB-8	7	5	PASS
		10-LVB-1	7	6	PASS
		10-LVB-8	8	6	PASS
		12-LVB-7	7	5	PASS
		12-LVB-8	7	5	PASS

All Batch 1 samples achieved the requirements of a Type A Bond, with the exception of the plywood specimens. As shown in Figure 8, limited fibre failure was witnessed in the bond lines for the plywood specimens. This can typically be caused by a lack of adhesive, inadequate pressure application or pre-curing of the adhesive prior to pressure application.



Figure 8: 3-PLY-1 Bond Quality test specimen showing low fibre failure.

The impact of the variation in Bond Quality in LVL and LVB samples is discussed in Section 5.1.

5.2.2 Batch 2 Results

Table 10 contains a summary of the results from the Type A bond quality assessment conducted on Batch 2 samples in accordance with the test method outlined in Section 4.3. Full results are contained as Appendix F.

Table 10: Bond Quality Assessment, Batch 2 Type A.

Sample Type	Bond Class	Sample Number	Average Bond Quality Value	Minimum Bond Quality Value	Pass / Fail
LVL	Type A	16-6-LVL-9	6	4	PASS
		16-10-LVL-6	9	7	PASS
		16-12-LVL-6	5	3	PASS
LVB	Type A	16-6-LVB-5	6	4	PASS
		16-12-LVB-7	7	6	PASS

As shown in Table 10, all LVL and LVB samples achieved the requirements of a Type A bond. A localised area of poor adhesion was identified in Sample 16-12-LVB-7 during mechanical property testing. This was further witnessed during Bond Quality testing, as can be seen in Figure 9.



Figure 9: 16-12-LVB-7 Bond Quality test specimen showing an area of poor adhesion.

Table 11 contains a summary of the results from the Type C bond quality assessment conducted on Batch 2 samples in accordance with the test method outlined in Section 4.3. Full results are contained as Appendix G.

Table 11: Bond Quality Assessment, Batch 2 Type C.

Sample Type	Bond Class	Sample Number ¹	Average Bond Quality Value	Minimum Bond Quality Value	Pass / Fail
LVL	Type C	1-12-LVL	7	4	PASS
		2-12-LVL	6	4	PASS
		1-18-LVL	7	6	PASS
		2-18-LVL	7	5	PASS

¹Samples 12-LVL and 18-LVL were ripped longitudinally to provide 2x matched samples for testing

Whilst some variability between gluelines was observed, all samples met the requirements of Type C bonding.

5.3 Moisture Content Percentage

5.3.1 Batch 1 Results

Table 12 contains the moisture content percentages for the test specimens, as per the outlined test method contained in Section 4.4. Full results are contained in Appendix H. Given preconditioning of the test samples, results were very consistent around the targeted 12% equilibrium moisture content, as expected.

Table 12: Oven dry moisture content percentage of test specimens, Batch 1.

Sample Type	Sample Number	Moisture Content (%)
Plywood	3-PLY-1	11.5
	3-PLY-8	11.0
LVL	9-LVL-7	11.6
	9-LVL-8	11.1
	10-LVL-3	13.2
	10-LVL-5	10.9
	12-LVL-3	11.1
	12-LVL-5	11.8
LVB	9-LVB-2	11.4
	9-LVB-8	11.4
	10-LVB-1	11.2
	10-LVB-8	11.4
	12-LVB-7	11.1
	12-LVB-8	11.4

5.3.2 Batch 2 Results

Table 13 contains the moisture content percentages for the test specimens, as per the outlined test method contained in Section 4.4. Full results are contained in Appendix I. Given preconditioning of the test samples, results were very consistent around the targeted 12% equilibrium moisture content, as expected.

Table 13: Oven dry moisture content percentage of test specimens, Batch 2.

Sample Type	Sample Number	Moisture Content (%)
LVL	16-6-LVL-9	11.5
	16-10-LVL-6	10.9
	16-12-LVL-6	11.0
	1-12-LVL	11.0
	2-12-LVL	11.2
	1-18-LVL	13.1
	2-18-LVL	12.8
LVB	18-12-LVB-7	11.9
	18-12-LVB-7	11.1

6. Conclusion

Testing was conducted on EWP samples manufactured and supplied by Burapha Ltd. Bending Stiffness and Strength testing was conducted in accordance with, or based upon, AS/NZS 4357.2, AS/NZS 2269.1 or EN 13393. AS/NZS 2098.2 was adopted for Bond Quality Assessment and AS/NZS 1080.1 for determining the Moisture Content of the specimens. This report contains a summary of the testing and results obtained, with full data located in the appendices.

MOE and MOR testing yielded relatively consistent results across all samples of the same type, across both test batches. The expected differences were typically seen between samples of different thickness and different construction (LVL vs LVB samples). This indicates a reasonable level of reliability and quality in the production process. However, given that the production parameters of the test material are proprietary to Burapha, it is difficult to comment on the expectedness or appropriateness of the results attained. It was noted, however, that all samples (LVL and LVB) tested as a part of Batch 2 met the requirements of F17 grade in accordance with AS 1720.1.

Bond Quality testing indicated that all LVL and LVB samples in both batches achieved the requirements of the desired bond class. Some variability in quality between gluelines, and localised areas of poor adhesion, were observed, and the impact of such on mechanical properties identified where appropriate. Plywood samples supplied in Batch 1 did not meet Type A bond requirements. The inspection of test specimens indicated limited amounts of fibre failure in the gluelines. This can typically be caused by a lack of adhesive, inadequate pressure application or pre-curing of the adhesive prior to pressure application.

The test results contained in this report are indicative of the tested material as selected and supplied by the client. It is important to note that the results achieved were based upon a very small number of test samples. Decisions as to the materials representativeness, and hence, the appropriateness of the test results, are the responsibility of the manufacturer.

7. References

Standards Australia. (2006). *AS/NZS 4357.2 Structural laminated veneer lumber (LVL) – Determination of Structural Properties – Test methods*. Standards Australia

Standards Australia. (2012). *AS/NZS 2269.1 Plywood – Structural – Determination of structural properties – test methods*. Standards Australia

Standards Australia. (2012). *AS/NZS 2098.2 Methods of test for veneer and plywood – Bond quality of plywood (chisel test)*. Standards Australia

Standards Australia. (2012). *AS/NZS 1080.1 Timber – Methods of test – Moisture Content*. Standards Australia

Standards Australia. (2010). *AS 1720.1 Timber Structures – Part 1: Design methods*. Standards Australia

CIRAD (2018). *Beam Identification by Non-destructive Grading (BING)*. Centre for International Agricultural Research and Development.

Appendix A – Bending Stiffness and Strength Test Results – Batch 1 Plywood



3-Point Bending Test for Modulus of Elasticity and Modulus of Rupture

The Results herein apply only to this sample of specimens as provided by client.

Report Number	Report Date	Client	Testing Machine	Deflection Device	Capacity	Test Date	Product Name
04-19	9/03/2020	BURAPHA	AG-100X	Digital Imaging System	100kN	27/02/2020	Plywood

Name	Thickness	Width	Lower span	Upper Span	Slope	Max Force	MoE	MoR
					Force 200 - 2000N			
unit	mm	mm	mm	mm	N/mm	N	Mpa	Mpa
3-PLY-1	4.65	100.68	144	N/A	191.76	1173.46	14727	121.4
3-PLY-8	4.74	100.07	144	N/A	209.90	1260.70	15272	126.1

* All cross sectional dimensions have been recorded using ENG.49 digital vernier calipers,

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Appendix B – Bending Stiffness and Strength Test Results – Batch 1 LVL/LVB



Modulus of Elasticity and Modulus of Rupture to AS/NZS 4357.2



The Results herein apply only to this sample of specimens as provided by client.

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Report Number	Report Date	Client	Testing Machine	Deflection Device	Capacity	Test Date	Product Name
04-19	9/03/2020	BURAPHA	AG-100X	Digital Imaging System	100kN	27/02/2020	LVL & LVB - Batch 1

Name	Thickness	Width	Lower span	Upper Span	Slope	Max Force	MoE	MoR
					Force 200 - 2000N			
unit	mm	mm	mm	mm	N/mm	N	Mpa	Mpa
9-LVB-2	10.34	100.75	162	54	1018.81	3740.26	10020	68.5
9-LVB-8	9.98	100.04	162	54	1193.89	3138.75	13469	63.7
9-LVL-7	10.38	101.83	162	54	1922.57	5242.14	15285	77.4
9-LVL-8	10.43	100.94	162	54	1766.96	5372.43	13969	79.3
10-LVB-1	11.47	99.33	180	60	1295.87	4879.60	11746	73.7
10-LVB-8	11.49	99.38	180	60	1214.27	5092.46	10938	76.6
10-LVL-3	11.37	100.78	180	60	1531.15	6300.07	12838	87.0
10-LVL-5	11.34	101.19	180	60	1454.47	6316.04	12242	87.4
12-LVB-7	13.64	101.72	216	72	849.17	4522.07	7901	58.0
12-LVB-8	13.74	101.75	216	72	817.63	4183.59	7421	52.7
12-LVL-3	13.69	102.27	216	72	1006.05	6179.09	8229	69.6
12-LVL-5	13.60	101.87	216	72	1051.48	6507.49	8806	74.6

* All cross sectional dimensions have been recorded using ENG.49 digital vernier calipers,

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Appendix C – Bending Stiffness and Strength Test Results – Batch 2 EN 13393



Bending Stiffness and Strength to EN 13393

The Results herein apply only to this sample of specimens as provided by client.

Report Number	Report Date	Client	Testing Machine	Deflection Device	Capacity	Test Date	Product Name
04-19	9/03/2020	BURAPHA	AG-100X	Digital Imaging System	100kN	27/02/2020	LVL and LVB - Batch 2

Name	Thickness	Width	Lower span	Upper Span	Slope	Max Force	Bending Stiffness
					Force 200 - 2000N		
unit	mm	mm	mm	mm	N/mm	N	N.m ²
16-12-LVL-6	12.0	100.0	500	N/A	85.25	1764.22	222.0
16-10-LVL-6	10.2	100.0	500	N/A	53.66	1570.86	139.7
16-6-LVL-9	6.5	100.0	500	N/A	15.50	603.82	40.4
16-6-LVB-5	6.9	100.0	500	N/A	13.99	929.10	36.4
16-12-LVB-7	12.2	100.0	500	N/A	64.32	981.81	167.5

* All cross sectional dimensions have been recorded using ENG.49 digital vernier calipers,

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Testing Officer: A. Faircloth

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Appendix D – Bending Stiffness and Strength Test Results – Batch 2 AS/NZS 4357.2



Modulus of Elasticity and Modulus of Rupture to AS/NZS 4357.2



The Results herein apply only to this sample of specimens as provided by client.

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Report Number	Report Date	Client	Testing Machine	Deflection Device	Capacity	Test Date	Product Name
04-19	9/03/2020	BURAPHA	AG-100X	Digital Imaging System	100kN	27/02/2020	LVL - Batch 2

Name	Thickness	Width	Lower span	Upper Span	Slope	Max Force	MoE	MoR
					Force 200 - 2000N			
unit	mm	mm	mm	mm	N/mm	N	Mpa	Mpa
1-1-LVL-18	35.7	48.0	900	300	358.82	7918.66	14110	86.6
2-1-LVL-18	35.8	49.0	900	300	413.80	8614.41	15253	90.2
1-2-LVL-12	23.5	49.0	900	300	276.48	5340.43	15532	85.2
2-2-LVL-12	23.6	49.0	900	300	273.79	5776.50	15309	91.7

* All cross sectional dimensions have been recorded using ENG.49 digital vernier calipers,

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Appendix E – Bond Quality Test Results – Batch 1



Bond Quality of Veneer and Plywood to AS/NZS 2098.2



The results reported herein apply only to this sample of specimens
as provided by client.

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Product	LVL, Ply, LVB - Batch 1	Report No.	04-19
Bond Type	A Bond	Date of Issue	9/03/2020
Test Type	Chisel Test - 6hr Steam	Client	BURAPHA

Sample No.	Date Tested	Score for Glueline No.						Average	Result
		1	2	3	4	5	6		
3-PLY-1	27/02/2020	3	2					3	FAIL
3-PLY-8	27/02/2020	4	4					4	FAIL
9-LVB-2	27/02/2020	8	8	8	8			8	PASS
9-LVB-8	27/02/2020	8	7	5	7			7	PASS
9-LVL-7	27/02/2020	9	7	6	6			7	PASS
9-LVL-8	27/02/2020	9	7	8	8			8	PASS
10-LVB-1	27/02/2020	7	7	7	6	8	8	7	PASS
10-LVB-8	27/02/2020	8	7	8	6	8	8	8	PASS
10-LVL-3	27/02/2020	8	7	7	7	8	7	7	PASS
10-LVL-5	27/02/2020	6	7	7	7	5	7	7	PASS
12-LVB-7	27/02/2020	8	5	7	8	8	8	7	PASS
12-LVB-8	27/02/2020	8	8	5	7	6	7	7	PASS
12-LVL-3	27/02/2020	8	7	8	7	5	7	7	PASS
12-LVL-5	27/02/2020	8	7	8	6	6	7	7	PASS

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Appendix F – Bond Quality Test Results – Batch 2 Type A



Bond Quality of Veneer and Plywood to AS/NZS 2098.2

The results reported herein apply only to this sample of specimens
as provided by client.



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Product	LVL and LVB - Batch 2	Report No.	04-19
Bond Type	A Bond	Date of Issue	9/03/2020
Test Type	Chisel Test - 6hr Steam	Client	BURAPHA

Sample No.	Date Tested	Score for Glue Line No.				Average	Result
		1	2	3	4		
16-12-LVL-6	27/02/2020	7	5	3	5	5	PASS
16-10-LVL-6	27/02/2020	9	7	9	9	9	PASS
16-6-LVL-9	27/02/2020	8	6	5	5	6	PASS
16-6-LVB-5	27/02/2020	8	6	4	4	6	PASS
16-12-LVB-7	27/02/2020	8	7	6	7	7	PASS

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Appendix G – Bond Quality Test Results – Batch 2 Type C



Bond Quality of Veneer and Plywood to AS/NZS 2098.2

The results reported herein apply only to this sample of specimens
as provided by client.

Product	LVL - Batch 2	Report No.	04-19
Bond Type	C Bond	Date of Issue	9/03/2020
Test Type	Chisel Test - Hot Water	Client	BURAPHA

Sample No.	Date Tested	Score for Glueline No.																	Average	Result
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
1-2-LVL-12	27/02/2020	9	7	7	7	8	8	6	4	4	4	8						7	PASS	
2-2-LVL-12	27/02/2020	7	6	8	8	7	4	4	6	6	7	7						6	PASS	
1-1-LVL-18	27/02/2020	7	8	8	7	8	7	9	6	8	6	6	7	8	8	8	8	7	7	PASS
2-1-LVL-18	27/02/2020	6	9	8	8	5	6	8	6	9	7	7	8	8	8	8	8	8	7	PASS

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Appendix H – Moisture Content Test Results – Batch 1



Moisture Content to AS/NZS 1080.1:2012 and AS/NZS 2098.1:2006 and Density^[1]

The results reported herein apply only to this sample
of specimens as provided by client.



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Report Number	Test Date	Report Date	Client	Product	Balance	Callipers	Drying Oven	Comments
04-19	3/03/2020	09/03/2020	BURAPHA	LVL, LVB and Ply	ENG.42	ENG.48	ENG.63/ ENG.64	Batch 1
Initial Weight - Date & Time			Check 1 - Date & Time	Check 2 - Date & Time				
2/03/2020			3/03/2020	3/03/2020				

Sample ID	Thickness	Width	Length	Initial Weight	Check1 (-24hrs)	Check2 ^[2] (-6hrs)	Oven dry Weight	MC	Density ^[1]
Unit	mm	mm	mm	g	g	g	g	%	kg/m ³
3-PLY-1	4.70	100.72	25.97	7.72	6.93	6.92	6.92	11.5	628
3-PLY-8	4.73	100.95	25.60	7.51	6.77	6.76	6.76	11.1	614
9-LVB-2	10.41	100.02	25.48	15.31	13.75	13.74	13.74	11.4	577
9-LVB-8	10.33	100.26	25.82	16.80	15.09	15.08	15.08	11.4	628
9-LVL-7	10.51	102.31	25.77	17.41	15.62	15.61	15.61	11.6	628
9-LVL-8	10.51	101.41	25.81	16.84	15.17	15.15	15.15	11.2	612
10-LVB-1	11.57	99.34	25.66	19.23	17.33	17.29	17.29	11.2	652
10-LVB-8	11.50	99.66	25.70	20.01	17.97	17.96	17.96	11.4	679
10-LVL-3	11.45	100.70	25.86	19.52	17.24	17.24	17.24	13.2	655
10-LVL-5	11.60	101.38	25.79	19.72	17.80	17.79	17.79	10.9	650
12-LVB-7	13.67	101.83	26.96	24.73	22.28	22.27	22.27	11.1	659
12-LVB-8	13.85	101.79	26.54	23.43	21.04	21.04	21.04	11.4	626
12-LVL-3	13.84	102.46	25.60	23.75	21.40	21.38	21.38	11.1	654
12-LVL-5	13.67	102.42	25.60	23.29	20.85	20.83	20.83	11.8	650

Notes: [1] Density measurement to AS 1080.3 not covered by Scope of Accreditation
[2] No reduction in mass is achieved when 2nd weight is within 0.2% (1080.1) or 0.1% (2098.1) of 1st weight

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Appendix I – Moisture Content Test Results – Batch 2



Moisture Content to AS/NZS 1080.1:2012 and AS/NZS 2098.1:2006 and Density^[1]

The results reported herein apply only to this sample
of specimens as provided by client.



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Report Number	Test Date	Report Date	Client	Product	Balance	Callipers	Drying Oven	Comments
04-19	3/03/2020	09/03/2020	BURAPHA	LVL and LVB	ENG.42	ENG.48	ENG.63/ ENG.64	Batch 2
Initial Weight - Date & Time		Check 1 - Date & Time	Check 2 - Date & Time					
2/03/2020		3/03/2020	3/03/2020					

Sample ID	Thickness	Width	Length	Initial Weight	Check1 (-24hrs)	Check2 ^[2] (-6hrs)	Oven dry Weight	MC	Density ^[1]
Unit	mm	mm	mm	g	g	g	g	%	kg/m ³
16-12-LVL-6	12.04	100.36	26.48	20.87	18.81	18.80	18.80	11.0	652
16-10-LVL-6	10.03	100.49	26.46	19.11	17.25	17.23	17.23	10.9	716
16-6-LVL-9	6.45	100.80	26.55	13.36	12.00	11.98	11.98	11.5	774
16-6-LVB-5	6.73	99.59	26.69	14.52	13.00	12.98	12.98	11.9	811
16-12-LVB-7	11.87	100.17	26.39	22.24	20.06	20.03	20.03	11.1	709
1-1-LVL-18	35.65	47.18	25.99	28.88	25.55	25.54	25.54	13.1	661
2-1-LVL-18	35.78	49.24	26.22	30.75	27.29	27.26	27.26	12.8	666
1-2-LVL-12	23.59	49.32	26.26	19.07	17.18	17.17	17.17	11.0	624
2-2-LVL-12	23.50	49.46	26.84	19.43	17.48	17.48	17.48	11.2	623

Notes: [1] Density measurement to AS 1080.3 not covered by Scope of Accreditation
[2] No reduction in mass is achieved when 2nd weight is within 0.2% (1080.1) or 0.1% (2098.1) of 1st weight

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