Northland Regional Council
Kawa Poplar testing

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Report information sheet

Report title	Northland Regional Council Kawa Poplar testing
Authors	Doug Gaunt, Bruce Davy
Client	Northland Regional Council
Client contract number	
MBIE contract number	If applicable
PAD output number	00000
Signed off by	Doug Gaunt
Date	July 2021
Confidentiality requirement	Confidential (for client use only)
Intellectual property	
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Published by: Scion, Private Bag 3020, Rotorua 3046, New Zealand. www.scionresearch.com

Executive summary

Objective

To determine the characteristic bending strength and stiffness stresses for a sample of 90 x 45 Kawa Poplar as supplied by Northland Regional Council.
To explore the difference in timber properties via small clear testing looking at different trees and different sample positions within the tree

Key results - Characteristic bending strength and stiffness testing

1. On the basis of the bending stiffness and strength testing the 90 x 45 Kawa Poplar could be assigned the SG10 grade (limited by bending stiffness).

Key results – Small Clear testing

1. In terms of bending strength/stiffness and nominal density properties the inner wood specimens show up as being lower than the outer wood properties.
2. In terms of bending strength/stiffness and nominal density the inner wood properties show increases with increasing log number, this trend is not as obvious with the outer wood specimens
3. There doesn’t appear to be any significant differences between trees in terms of bending strength/stiffness and nominal density.

Northland Regional Council - Kawa Poplar testing

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Objective

Characteristic bending strength and stiffness testing

To determine the characteristic bending strength and stiffness stresses for a 31 piece sample of 90 x 45 Kawa Poplar as supplied by Northland Regional Council.

The timber was supplied dry and planar gauged to 90x45 in 2.0m lengths.

Ideally to determine characteristic properties we need to test full dimension timber, covering a range of structural sizes in bending, tension, compression and shear. This would require a large volume of timber and for tension testing long lengths. However, 90% of the span tables in NZS3604 are governed by bending strength and stiffness

Thus, as a start on this process it was suggested that only bending strength and stiffness be tested for.

Small clear testing

To explore the difference in timber properties via small clear testing looking at difference trees and different sample positions within the tree

Materials and methods

Characteristic bending strength and stiffness testing

- All the timber was then tested for bending strength and stiffness as a joist (on edge) in accordance with AS/NZS4063.1:2010 & AS/NZS4063.2:2010 over a span to depth ratio of equal to 18:1 at 1620mm. The test pieces were tested in their dry gauged state.
- All the bending testing was undertaken in our Grade 1 Baldwin Universal test machine. The strength testing was completed in the Timber Engineering laboratory of Scion, Rotorua over the period 22nd - 23rd March 2021.

Density and Moisture content

- From all the bending test samples a short cross section was then cut from an undamaged clear wood section close to the failure point of each test specimen for density, moisture content determination
- Moisture content was measured using the oven drying method.
- Nominal density was calculated for each section from the oven dry weight over volume at test.
- Density at test was calculated for each section from the test weight over volume at test.

Small clear testing

Small Clear bending specimens were cut from;

- Seven trees (4, 5, 7, 8, 9, 12 & 17)
- from up to 5 logs
- Inner and outer positions from pith to bark (I & O)
- With three replicates at each position (1, 2 & 3) .
- The specimens were produced by Dean Satchell

The specimens were initially cut to 25x25x500mm then air dried, following air drying the were machined down to 20x20x500mm and supplied to Scion. On receipt the specimens were then conditioned at 20°C and 65% RH until ready for testing.

The 20 x 20 x 500mm small clear specimens were tested for bending strength and stiffness over a span of 280mm with a centre point load, the growth rings were aligned as much as possible with the direction of loading, in accordance with ASTM D143-94. The testing being undertaken in our Grade 1 Instron Universal test machine in the Composites laboratory of Scion, Rotorua, New Zealand.

From the small clear bending testing we calculated;

- Fibre stress at Proportional limit (FSPL), this is point at which linear elastic behaviour ends.
- Fibre stress at maximum load (MoR)
- Modulus of elasticity (MoE), bending stiffness

After testing, the entire sample was used for determination of density and moisture content

- Moisture content was measured using the oven drying method.
- Nominal density was calculated for each test specimen from the oven dry weight over volume at test.
- Density at test was calculated for each test specimen from the test weight over volume at test

Using this information, a series of plots were prepared (Figures 1-6) exploring the relationship between the small clear test values and, sample height within tree, tree, variation between replicates. The limited number of specimens means only trends can be noted without statistical confirmation.

Results and Discussion

Characteristic Timber Testing

The characteristic strength and stiffness properties have been calculated using the calculations and procedures set out in AS/NZS4063.2:2010.

Table 1 shows the characteristic strength and stiffness values for the 90x45 Kawa Poplar timber along with a statistical summary.

Table 2 lists the New Zealand characteristic grade stresses for the SG visual grades

Table 3 shows a statistical summary of the moisture content and density testing.

Appendix A lists the raw test data collected.

***Table 1**: Kawa Poplar Characteristic Bending Strength/Stiffness & Density properties*

Kawa Poplar	90x45			
	Bending Stiffness MoEj (GPa)	**Bending Strength MoRj (MPa)**	**Density at Test kg/m^3**	**Nominal Density kg/m^3**
Mean	10.76	59.13	475.93	429.73
Minimum	6.88	33.37	395.15	358.13
Maximum	13.04	74.34	566.88	511.20
Range	6.16	40.97	171.74	153.08
Standard Deviation	1.33	11.25	35.96	32.36
Coefficient of Variation	12.38%	19.02%	7.56%	7.53%
Count	31	31	31	31
Characteristic Strength (MPa)		**45.09**	**471.2**	**425.7**
Characteristic Stiffness (GPa)	**10.58**			
Assigned Grade	**SG10**	**SG10**		

***Table 2:** Characteristic stresses for SG visually graded timber NZS3603 A4*

1. Moisture Content – Dry (m/c = 16%)					
Radiata pine and Douglas Fir	**Bending Strength MPa**	**Compression Strength MPa**	**Tension Strength MPa**	**Bending Stiffness GPa**	**Lower bound Bending Stiffness GPa**
SG10 (Dry)	20.0	20.0	8.0	10.0	6.7
SG8 (Dry)	14.0	18.0	6.0	8.0	5.6
SG 6 (Dry)	10.0	16.0	4.0	6.0	4.0
2. Moisture Content – Green (m/c = 25%)					
SG 10 (Wet)	15	14.0	5.0	8.0	5.6
SG 8 (Wet)	11.7	12.0	4.0	6.5	4.4
SG 6 (Wet)	7.5	11.0	3.0	4.8	3.2

Note:

- The shear strength for dry Radiata pine shall be taken as fs = 3.8 MPa.

Table 3: Statistical Summary of Density and Moisture content results

	Moisture Content %	Density at Test kg/m³	Nominal Density kg/m³
Mean	10.75	475.93	429.73
Minimum	8.73	395.15	358.13
Maximum	12.13	566.88	511.20
Range	3.40	171.74	153.08
Standard Deviation	0.65	35.96	32.36
Coefficient of Variation	6.04%	7.56%	7.53%
Count	31	31	31

Small clear testing

The following Figures 1, 2 & 3 show the relationship between

1. Log number and Modulus of Elasticity (Bending Stiffness)
2. Log number and Modulus of Rupture (Bending strength)
3. Log number and Nominal density.

In these Figures the data points to the left of the log number are the inner wood specimens with the data points to the right being the outer wood specimens

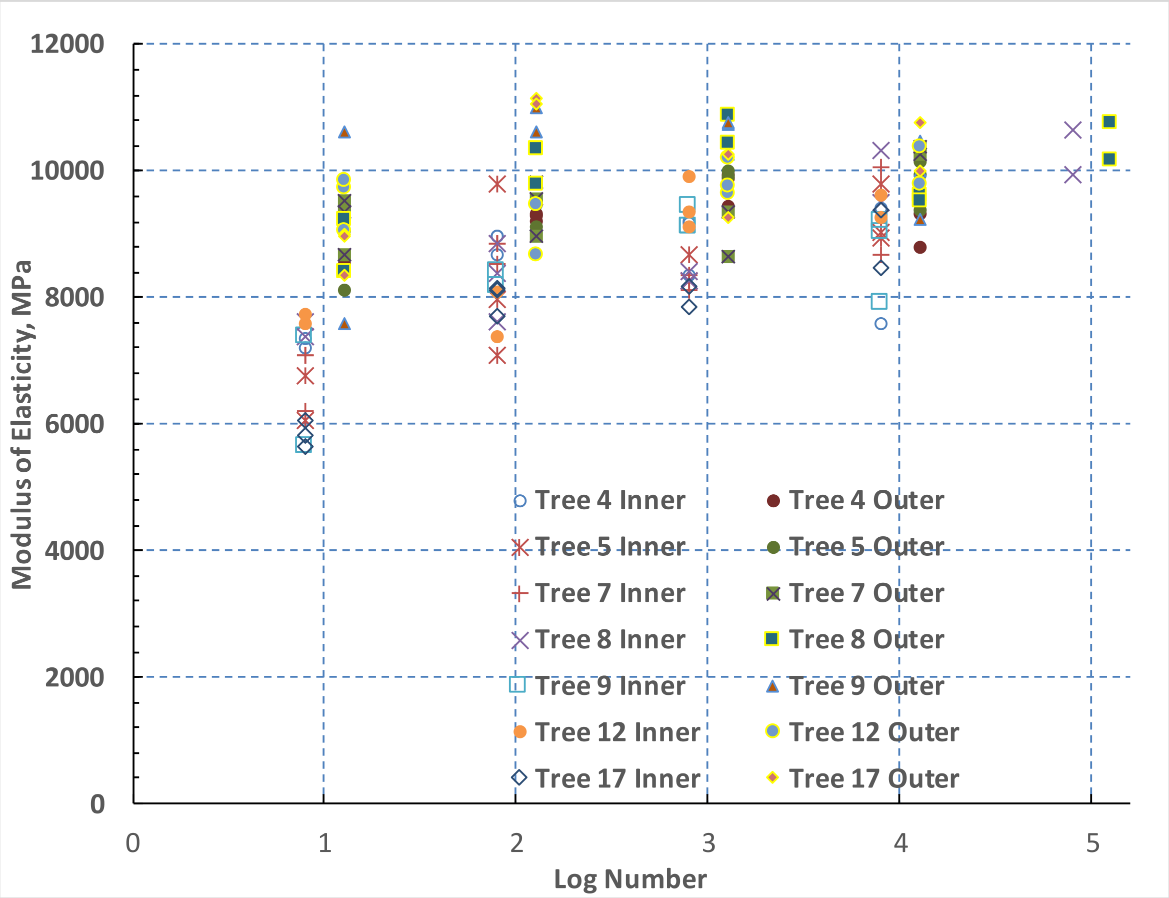


Figure 1: *Log number versus Modulus of Elasticity (Bending Stiffness)*

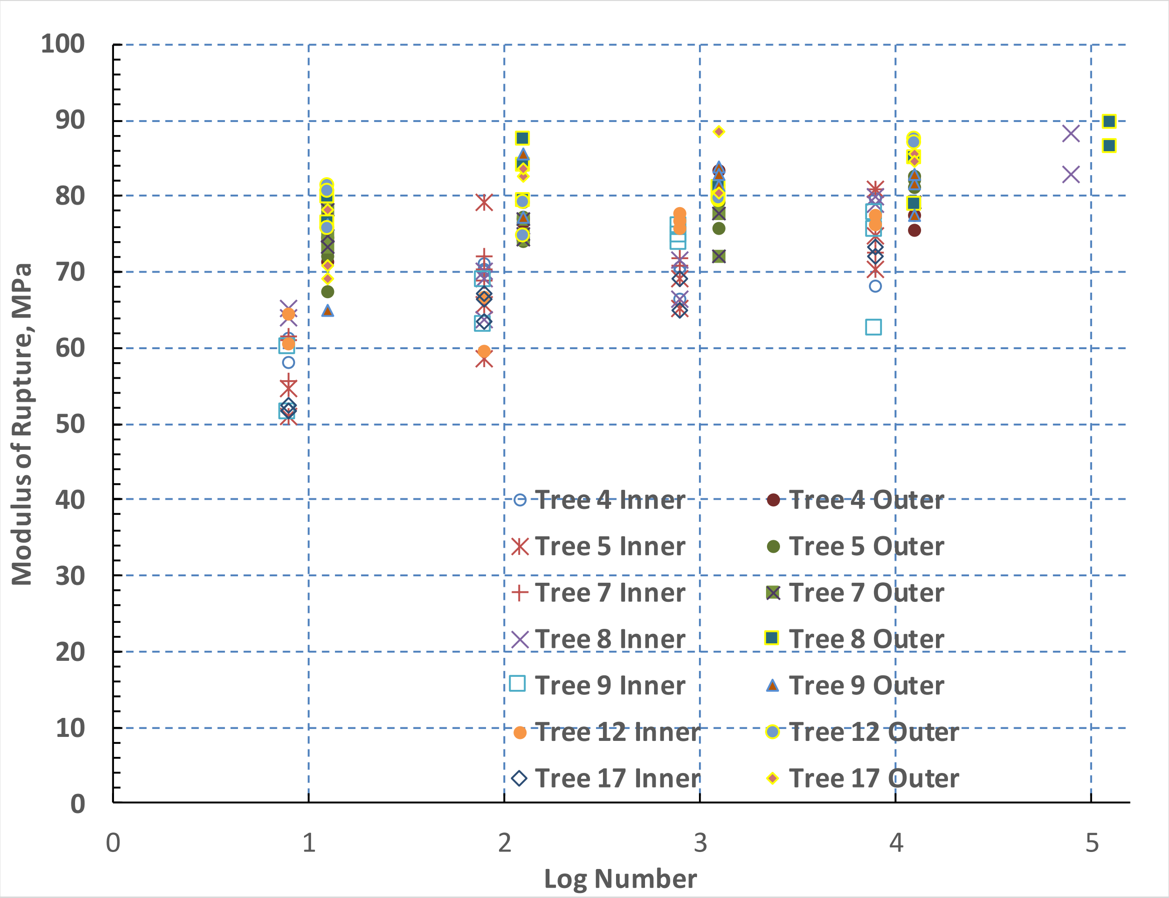


Figure 2: *Log number versus Modulus of Rupture (Bending strength)*

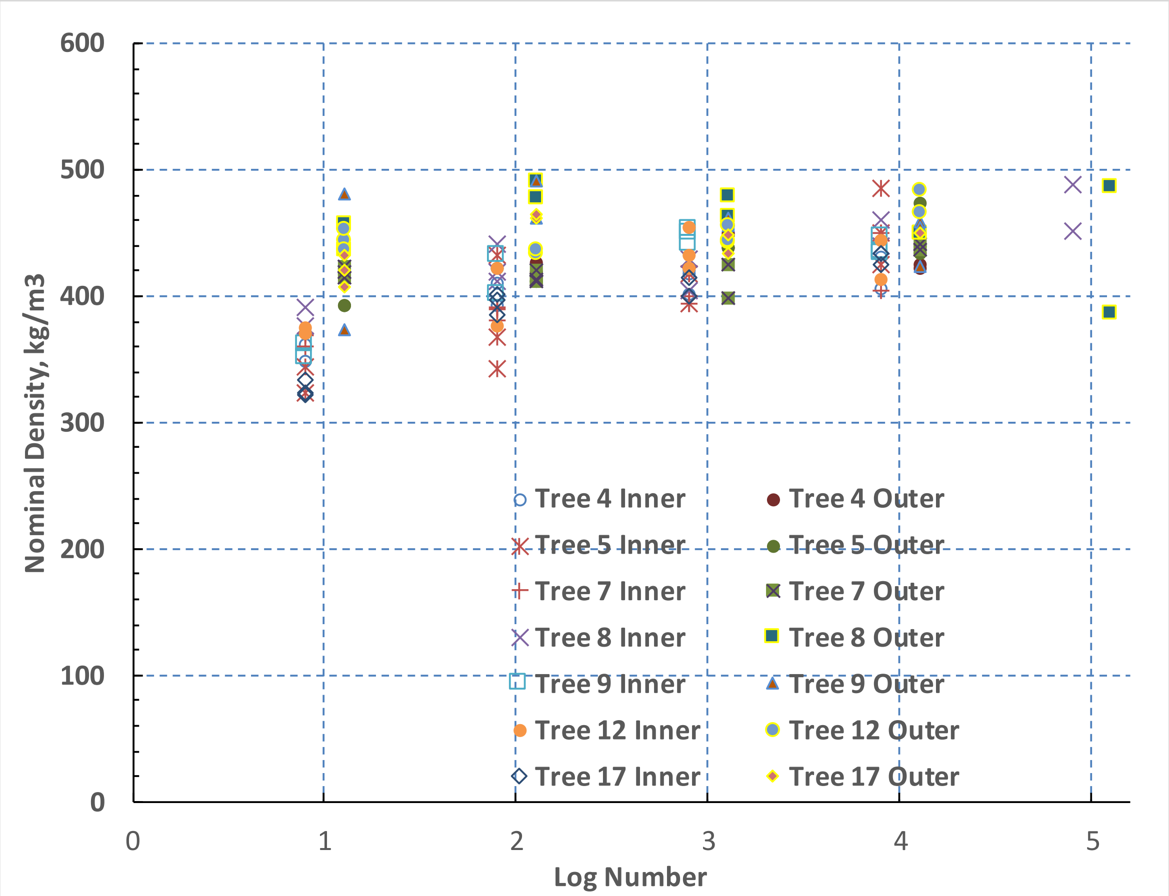


Figure 3: *Log number versus Nominal Density*

Observations from Figures 1, 2 & 3.

1. For all three properties the inner wood specimens show up as being lower than the outer wood properties.
2. The inner wood properties show increases with increasing log number, this trend is not as obvious with the outer wood specimens.

The following Figures 4, 5 & 6 show the relationship between;

1. Tree number and Modulus of Elasticity (Bending Stiffness)
2. Tree number and Modulus of Rupture (Bending strength)
3. Tree number and Nominal density.

In these Figures the data points to the left of the tree number are the inner wood specimens with the data points to the right being the outer wood specimens, with the data combining the 5 logs.

Figure 6: *Tree number versus Modulus of Elasticity (Bending Stiffness)*

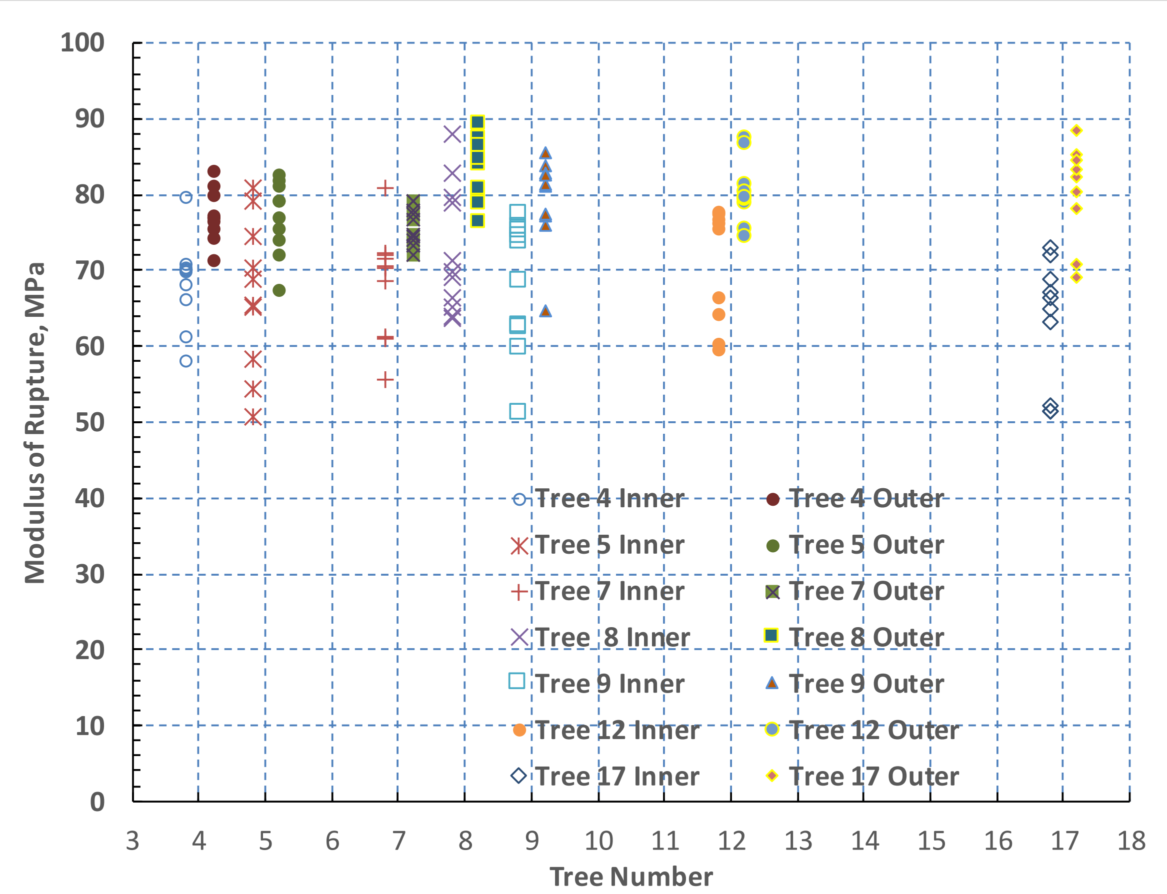


Figure 5: *Tree number versus Modulus of Rupture (Bending strength*

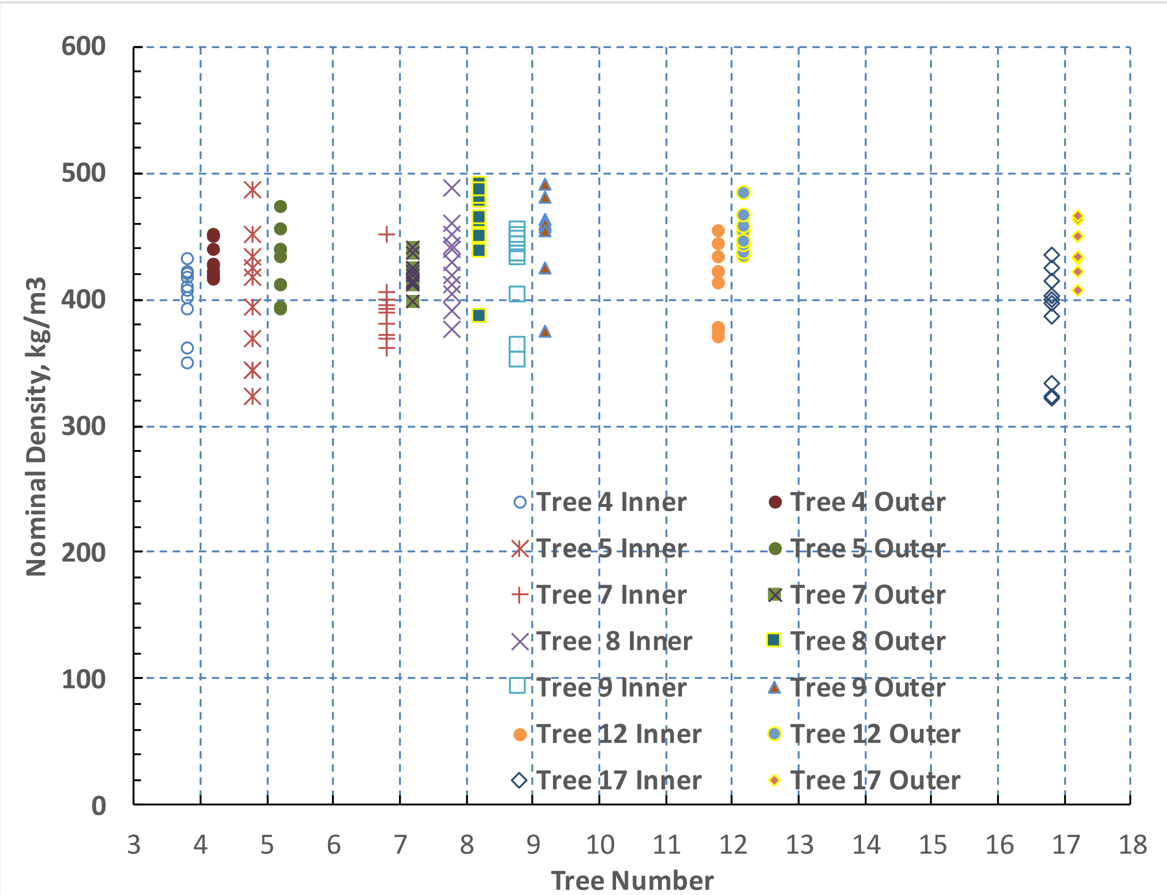


Figure 6: *Tree number versus Nominal Density*

Observations from Figures 4, 5 & 6.

There doesn’t appear to be any significant differences between trees for the three properties.

Conclusions

- On the basis of the bending stiffness and strength testing the 90 x 45 Kawa Poplar could be assigned the SG10 grade (limited by bending stiffness).
- In terms of bending strength/stiffness and nominal density properties the inner wood specimens show up as being lower than the outer wood properties.
- In terms of bending strength/stiffness and nominal density the inner wood properties show increases with increasing log number, this trend is not as obvious with the outer wood specimens
- There doesn’t appear to be any significant differences between trees in terms of bending strength/stiffness and nominal density

References

1. AS/NZS4063.1:2010, Characterization of structural timber Part 1: Test methods. Standards Australia/Standards New Zealand.

2. AS/NZS4063.2:2010, Characterization of structural timber Part 1: Determination of characteristic values. Standards Australia/Standards New Zealand.

3. ASTM D143-94 (Reapproved 2000), Standard Test Methods for Small Clear Specimens of Timber

Appendix A 90x45 Kawa Poplar - Test data

Lab No.	Board Reference	Width (mm)	Depth (mm)	MoEj (GPa)	MoRj (MPa)	Moisture Content (%)	Density at Test kg/m^3	Nominal Density kg/m^3
287288	4 1 1	45.83	90.36	9.06	53.28	10.34	395.15	358.13
287289	4 3 1	45.66	90.28	10.63	57.59	10.71	516.21	466.26
287290	4 3 2	46.21	90.94	9.51	54.59	11.01	425.75	383.51
287291	4 3 3	46.01	90.20	11.62	48.47	10.53	489.37	442.75
287292	4 4 1	45.87	90.61	11.39	42.07	10.55	464.50	420.17
287293	5 3 1	45.95	90.83	11.40	71.32	10.45	480.12	434.72
287294	5 3 2	45.80	91.02	10.37	47.82	10.99	445.19	401.13
287295	5 3 3	46.17	90.68	10.93	50.34	10.58	419.77	379.60
287296	7 4 1	46.07	90.83	11.89	73.46	9.52	514.41	469.69
287297	8 2 1	45.82	90.83	8.52	42.80	10.96	460.25	414.80
287298	8 2 2	45.92	90.89	8.44	37.32	11.77	460.15	411.68
287299	8 2 3	46.24	90.60	10.53	45.64	12.13	497.35	443.56
287300	8 2 4	46.12	90.63	13.04	70.96	11.30	494.41	444.20
287301	8 2 5	46.10	90.73	10.15	66.40	10.86	466.33	420.65
287302	8 2 6	45.92	87.82	10.69	66.57	11.16	530.21	476.96
287303	8 3 1	46.27	90.30	10.92	68.71	10.81	452.27	408.16
287304	8 3 2	46.40	90.66	11.32	62.74	10.76	487.56	440.20
287305	8 3 3	46.20	90.81	11.90	70.65	10.96	483.24	435.50
287306	9 2 1	46.39	91.12	11.72	65.90	10.20	458.83	416.36
287307	9 2 2	45.97	90.98	12.54	59.63	10.89	566.88	511.20
287308	11 1 1	46.19	90.72	9.84	60.43	10.45	510.42	462.13
287309	11 1 2	46.15	90.57	6.88	33.37	10.84	409.16	369.15
287310	12 3 1	46.00	90.87	11.97	70.20	11.61	475.22	425.79
287311	12 3 2	46.39	90.64	11.88	74.34	11.69	508.28	455.08
287312	15 2 1	46.29	91.31	10.22	61.74	11.23	458.97	412.64
287313	17 1 1	46.28	90.55	12.54	67.67	10.24	498.28	452.00
287314	17 2 1	46.22	90.54	10.11	50.25	10.50	482.76	436.90
287315	17 3 1	46.00	90.22	9.95	64.45	10.40	463.47	419.79
287316	17 4 1	46.17	90.57	11.52	61.55	10.21	471.30	427.65
287317	17 3 2	46.18	91.10	11.27	67.50	10.91	503.35	453.85
287288	4 1 1	45.83	90.36	10.71	65.13	8.73	464.75	427.43

Appendix B Kawa Poplar small clear - Data

Appendix B: Kawa Poplar small clear - Test data

Lab No:	Tree No:	Log No:	Inner Outer I/O	Replicate	Moisture Content %	Density at test kg/m^3	Nominal Density kg/m^3	FSPL MPa	MoE MPa	MoR MPa	Failure mode
287465	4	1	I	1	14.6	414.3	361.6	25.93	7361	61.25	3
287466	4	1	I	2	14.5	399.3	348.8	25.93	7219	58.08	3
287470	4	2	I	1	14.4	448.4	391.9	29.92	8990	70.19	3
287471	4	2	I	2	14.4	469.3	410.0	30.00	8693	70.07	3
287472	4	2	I	3	14.5	482.7	421.7	29.00	8991	70.94	3
287476	4	3	I	1	14.7	482.2	420.3	31.03	9217	69.93	4
287477	4	3	I	2	14.6	459.9	401.4	27.33	8376	66.23	3
287478	4	3	I	3	14.5	478.3	417.6	29.16	9192	70.41	4
287481	4	4	I	1	14.5	465.5	406.4	30.98	7606	68.07	3
287482	4	4	I	2	14.4	493.4	431.2	33.31	9428	79.69	3
287463	4	1	O	1	14.4	477.7	417.5	31.73	9332	74.39	3
287464	4	1	O	2	14.3	474.3	415.1	30.58	8529	71.28	4
287467	4	2	O	1	14.4	476.7	416.5	32.72	9310	76.47	4
287468	4	2	O	2	14.4	488.2	426.8	33.15	9341	76.93	4
287469	4	2	O	3	14.4	478.8	418.6	35.89	9229	76.87	4
287473	4	3	O	1	14.3	501.5	438.8	34.64	9463	79.97	4
287474	4	3	O	2	14.3	515.0	450.4	35.79	9957	83.17	4
287475	4	3	O	3	14.4	513.4	448.9	35.66	9892	81.25	4
287479	4	4	O	1	14.3	482.2	421.8	31.33	8801	75.52	4
287480	4	4	O	2	14.3	486.5	425.5	34.91	9337	77.32	4
287485	5	1	I	1	14.5	369.7	323.0	21.95	6059	50.85	3
287486	5	1	I	2	14.4	393.4	344.0	20.79	6772	54.46	3
287490	5	2	I	1	14.2	494.1	432.7	38.35	9806	79.12	4
287491	5	2	I	2	14.3	392.2	343.2	23.97	7107	58.37	3
287492	5	2	I	3	14.2	420.1	367.9	29.63	7968	65.50	3
287495	5	3	I	1	14.3	449.8	393.6	31.55	8682	68.94	4
287496	5	3	I	2	14.3	477.2	417.4	27.53	8286	65.11	3
287500	5	4	I	1	14.3	485.3	424.5	29.51	9039	70.33	3
287501	5	4	I	2	14.1	514.4	450.6	30.90	8956	74.62	3
287502	5	4	I	3	14.1	554.4	486.1	35.19	9811	80.84	4
287483	5	1	O	1	14.2	448.9	392.9	28.65	8137	67.43	3
287484	5	1	O	2	14.2	447.7	392.1	30.41	9079	72.00	3
287487	5	2	O	1	14.1	469.0	411.1	33.28	9495	79.11	4
287488	5	2	O	2	14.1	469.6	411.5	31.50	9530	77.10	3
287489	5	2	O	3	14.0	468.5	411.1	33.49	9130	73.98	4
287493	5	3	O	1	14.3	520.4	455.5	31.82	10016	75.57	4
287494	5	3	O	2	14.2	501.0	438.7	36.01	9937	79.17	4
287497	5	4	O	1	14.2	495.2	433.6	30.20	10166	82.00	4
287498	5	4	O	2	14.1	501.1	439.0	34.33	9948	81.06	4
287499	5	4	O	3	14.3	540.5	473.0	45.78	9395	82.64	4
287506	7	1	I	1	14.6	423.0	369.2	26.67	7083	61.34	3
287507	7	1	I	2	14.7	425.7	371.2	25.45	7085	61.02	3
287508	7	1	I	3	14.8	414.1	360.8	25.03	6223	55.61	3
287512	7	2	I	1	14.5	435.4	380.4	23.15	8531	68.70	4
287513	7	2	I	2	14.4	448.3	391.8	25.39	8861	72.07	3
287514	7	2	I	3	14.2	444.8	389.5	29.43	8877	70.37	3
287517	7	3	I	1	14.4	457.3	399.8	29.67	8132	70.64	3
287518	7	3	I	2	14.4	451.4	394.6	30.82	8368	71.66	3
287521	7	4	I	1	14.2	462.3	404.9	25.12	8684	72.45	4
287522	7	4	I	2	14.1	514.0	450.4	33.02	10059	80.93	4
287503	7	1	O	1	14.3	473.5	414.4	31.58	8693	74.59	4
287504	7	1	O	2	14.2	484.6	424.2	33.64	9534	78.01	4
287505	7	1	O	3	14.2	478.6	419.1	31.08	9361	73.22	4
287509	7	2	O	1	14.2	471.9	413.3	30.74	8988	74.09	3
287510	7	2	O	2	14.1	469.3	411.4	31.52	9563	74.88	4
287511	7	2	O	3	14.1	480.4	421.0	31.93	9839	76.86	4
287516	7	3	O	2	14.2	455.5	398.7	35.17	9370	77.50	3
287519	7	4	O	1	14.1	498.0	436.3	31.34	8648	72.03	3
287520	7	4	O	2	14.1	502.6	440.5	28.42	10381	79.18	3

Appendix B: Kawa Poplar small clear - Test data (cont)

Lab No:	Tree No:	Log No:	Inner Outer I/O	Replicate	Moisture Content %	Density at test kg/m³	Nominal Density kg/m³	FSPL MPa	MoE MPa	MoR MPa	Failure mode
287525	8	1	I	1	14.8	448.9	391.0	27.52	7396	63.90	5
287526	8	1	I	2	14.6	431.6	376.5	28.73	7634	65.19	3
287530	8	2	I	1	14.5	479.4	418.7	25.17	7640	63.70	4
287531	8	2	I	2	14.6	471.8	411.8	28.49	8403	69.10	3
287532	8	2	I	3	14.4	505.6	441.8	29.61	8855	69.96	4
287535	8	3	I	1	14.5	491.8	429.6	31.62	8435	71.46	5
287536	8	3	I	2	14.5	462.6	404.0	23.37	8282	66.43	3
287539	8	4	I	1	14.4	503.1	439.7	31.93	9512	78.84	4
287540	8	4	I	2	14.2	524.8	459.7	32.34	10327	79.78	3
287543	8	5	I	1	14.3	515.6	451.3	30.67	9950	82.78	2
287544	8	5	I	2	14.1	557.0	488.0	35.35	10649	88.07	3
287523	8	1	O	1	14.5	500.2	437.0	33.77	9235	76.38	4
287524	8	1	O	2	14.4	522.9	457.2	38.85	8413	79.92	3
287527	8	2	O	1	14.3	545.5	477.3	33.96	10362	84.00	3
287528	8	2	O	2	14.2	546.1	478.0	32.60	9795	79.36	4
287529	8	2	O	3	14.1	560.7	491.3	40.22	10374	87.43	4
287533	8	3	O	1	14.2	548.0	480.0	33.45	10887	80.08	4
287534	8	3	O	2	14.2	529.3	463.6	33.61	10454	81.01	5
287537	8	4	O	1	14.1	514.2	450.6	37.18	9640	84.93	3
287538	8	4	O	2	14.3	514.5	450.2	32.99	9547	78.93	4
287541	8	5	O	1	14.1	441.2	386.6	36.92	10182	86.52	3
287542	8	5	O	2	14.1	554.7	486.1	36.61	10784	89.53	3
287547	9	1	I	1	14.5	401.5	350.7	21.62	5655	51.28	0
287548	9	1	I	2	14.4	414.5	362.4	25.24	7400	59.85	3
287551	9	2	I	1	14.2	458.8	401.7	26.71	8421	62.80	0
287552	9	2	I	2	14.3	493.3	431.8	28.07	8185	68.77	3
287556	9	3	I	1	14.3	514.2	449.9	30.44	9139	74.62	4
287557	9	3	I	2	14.5	519.3	453.6	30.43	9130	73.76	3
287558	9	3	I	3	14.2	504.4	441.7	32.49	9444	75.88	5
287562	9	4	I	1	14.3	510.3	446.3	26.18	7922	62.43	5
287563	9	4	I	2	14.4	498.2	435.5	29.83	9037	75.35	4
287564	9	4	I	3	14.2	496.0	434.3	31.61	9205	77.60	4
287545	9	1	O	1	14.3	427.3	373.7	31.16	7609	64.74	3
287546	9	1	O	2	13.6	546.5	480.9	32.17	10620	76.13	3
287549	9	2	O	1	13.9	559.5	491.3	38.68	10998	85.56	3
287550	9	2	O	2	13.9	526.5	462.2	32.94	10624	77.24	0
287553	9	3	O	1	14.1	520.9	456.4	34.54	10287	83.75	3
287554	9	3	O	2	14.2	527.6	462.2	34.08	10742	82.82	4
287555	9	3	O	3	14.0	522.0	457.9	33.16	10765	81.21	3
287559	9	4	O	1	14.3	524.7	459.3	32.88	10484	81.52	4
287560	9	4	O	2	14.2	518.5	454.2	34.32	10010	82.68	4
287561	9	4	O	3	14.1	484.1	424.1	30.36	9234	77.43	4
287568	12	1	I	1	14.4	428.7	374.7	29.06	7731	64.33	3
287569	12	1	I	2	14.4	423.2	370.1	25.27	7584	60.33	3
287572	12	2	I	1	14.4	482.4	421.7	28.64	8097	66.54	4
287573	12	2	I	2	14.4	430.9	376.7	25.17	7395	59.47	3
287577	12	3	I	1	14.5	520.0	454.2	31.45	9934	75.58	3
287578	12	3	I	2	14.5	495.5	432.9	32.82	9371	76.64	3
287579	12	3	I	3	14.4	483.2	422.2	33.05	9131	77.65	3
287582	12	4	I	1	14.4	507.3	443.5	33.03	9639	77.37	3
287583	12	4	I	2	14.3	472.5	413.4	34.00	9265	76.20	3
287565	12	1	O	1	14.1	507.5	444.6	36.56	9742	81.42	3
287566	12	1	O	2	14.5	499.6	436.5	33.45	9067	75.58	3
287567	12	1	O	3	14.4	517.7	452.7	35.32	9876	80.54	3
287570	12	2	O	1	14.2	494.6	433.3	33.61	8680	74.60	5
287571	12	2	O	2	14.1	498.4	436.8	33.52	9482	79.05	4
287574	12	3	O	1	14.3	521.7	456.4	34.37	10204	79.34	4
287575	12	3	O	2	14.2	505.2	442.5	35.22	9667	79.80	3
287576	12	3	O	3	14.2	507.6	444.4	33.85	9784	79.64	3
287580	12	4	O	1	14.3	552.8	483.8	43.80	9792	87.47	3
287581	12	4	O	2	14.2	532.1	465.8	40.64	10386	86.89	3

Appendix B: Kawa Poplar small clear - Test data (cont)

Lab No:	Tree No:	Log No:	Inner Outer I/O	Replicate	Moisture Content %	Density at test kg/m^3	Nominal Density kg/m^3	FSPL MPa	MoE MPa	MoR MPa	Failure mode
287588	17	1	I	2	14.4	369.3	322.8	23.84	5823	51.58	3
287589	17	1	I	3	14.4	381.4	333.5	22.22	6067	52.33	4
287592	17	2	I	1	14.2	440.4	385.6	26.17	7722	63.35	2
287593	17	2	I	2	14.2	453.5	397.1	29.12	8140	66.33	3
287594	17	2	I	3	14.2	459.0	402.1	29.19	8158	67.13	3
287597	17	3	I	1	14.2	473.5	414.6	29.14	8175	69.01	3
287598	17	3	I	2	14.3	456.4	399.5	26.62	7870	64.89	3
287601	17	4	I	1	14.4	485.9	424.6	28.83	8466	72.05	4
287602	17	4	I	2	14.3	496.2	434.1	24.89	9402	73.18	4
287584	17	1	O	1	14.1	492.8	431.9	35.52	9016	78.15	5
287585	17	1	O	2	14.2	465.3	407.5	31.68	8348	69.12	3
287586	17	1	O	3	14.2	480.9	421.3	30.31	8973	70.76	5
287590	17	2	O	1	13.8	526.1	462.1	33.57	11169	82.50	4
287591	17	2	O	2	13.9	529.9	465.3	35.80	11079	83.48	4
287595	17	3	O	1	14.3	495.2	433.1	32.10	9262	80.33	3
287596	17	3	O	2	14.2	512.9	449.0	35.83	10261	88.44	3
287599	17	4	O	1	14.2	513.3	449.5	35.66	10012	85.43	4
287600	17	4	O	2	14.2	513.4	449.4	29.20	10773	84.50	4

Appendix C: ASTM Failure Modes

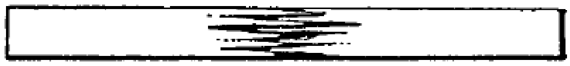
Table C1: *ASTM Failure Modes*

ASTM Code	Type of Failure	Scion Code
(e)	Compression	0
(f)	Horizontal Shear	1
(d)	Brash Tension	2
(a)	Simple Tension	3
(c)	Splintering Tension	4
(b)	Cross Grain Tension	5

Figure C1: *ASTM Failure Modes*

(*a*) Simple Tension.
(Side View)

(*b*) Cross-Grain Tension.*
(Side View)



(*c*) Splintering Tension.
(View of Tension Surface)

(*d*) Brash Tension.
(View of Tension Surface)

(*e*) Compression.
(Side View)

(*f*) Horizontal Shear.
(Side View)