C. x ovensii Bending Strength and Stiffness

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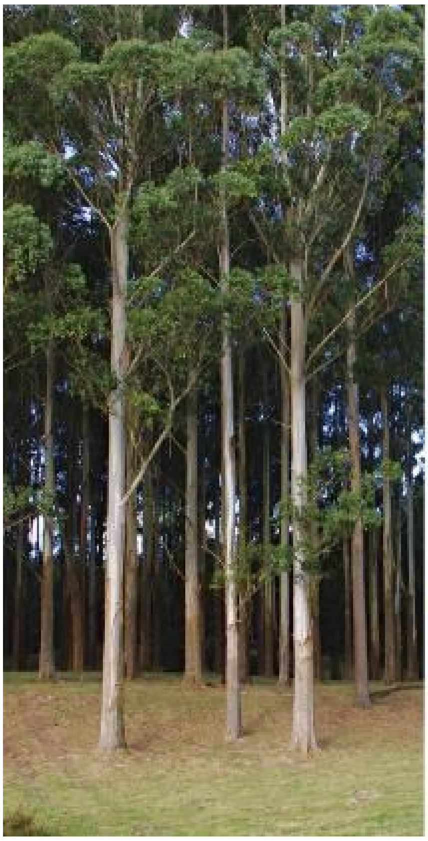

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EXECUTIVE SUMMARY

In terms of bending stiffness, the *C. ovensii* achieved the SG6 structural grade, in terms of bending strength, the *C. ovensii* achieved the SG10 structural grade resulting in an overall grade of SG6.

To assign a full structural grade the other strength properties tension, compression and shear need to be evaluated.

From the small clear testing there were very few obvious trends between height in tree, modulus of elasticity, modulus of rupture and nominal density across the inner and outer wood samples for the five trees assessed.

INTRODUCTION

The timber from the 2019-2020 cypress sawing study was used from the determination of characteristic design properties. It needs to be noted that these properties may or may not be appropriate for all cypress grown in New Zealand when we consider different sites, different genetics, different silviculture, and different rotation ages.

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. Tension and compression strength is required in trusses, shear strength can be important in short span heavily lintels and bearers.

It was therefore suggested as a start that only bending strength and stiffness is assessed.

Small clear testing was also be undertaken in order to better understand the variation in stiffness and strength according to radial position and vertical position in the tree.

Objective

- To determine the characteristic bending strength and stiffness design stresses for *C. x ovensii*.
- Small clear bending testing to determine variation in stiffness and strength between trees and between positions in the tree.

TIMBER SELECTION

Characteristic bending testing

Ruapehu Sawmills supplied Scion with 49 pieces of rough-sawn 100x50mm *C. ovensii.*

A further 13 pieces of rough-sawn 100x25mm of *C. ovensii* No 1 Framing timber from a previous sawing study (Sargent & Stovold, 2021; Stovold, et al., 2019) were also tested. Boards from five trees included in this sawing study were selected for the small clear testing.

Small clear testing

Small clear bending specimens were cut from;

- Five trees (17, 19, 27, 31 & 32)
- From 3 height positions within the tree (approximately 1, 7 &12m from the ground)
- Inner and outer positions from pith to bark (I & O)
- With two replicates at each position (A & B).

The specimens were cut to 20x20x500mm after the boards had been air dried and left to equilibrate in the Scion Timber Workshop. The specimens were then conditioned at 20°C and 65% RH until ready for testing.

CHARACTERISTIC TIMBER TESTING

Bending Strength and Stiffness Test Results

The 100x50 and 100x25 timber was visually graded into the visual framing grades, Engineering, No 1 Framing, No 2 Framing and Box, then the timber was tested for bending strength and stiffness as a joist, in accordance with AS/NZS4063.1:2010 with the testing being undertaken in our Grade-1 Baldwin Universal test machine in the Timber Engineering laboratory of Scion, Rotorua, New Zealand.

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

The following Table 1 shows the characteristic strength and stiffness values for the No 1 Framing and better *C. ovensii* timber along with a statistical summary. This Table also lists the characteristic density information.

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

Appendices A and B list the raw test data collected.

***Table 1**: No 1 Framing Bending Strength and Stiffness properties*

	No 1 Framing *C. ovensii*			
	Bending Stiffness MoEj (GPa)	**Bending Strength MoRj (MPa)**	**Density at Test kg/m^3**	**Nominal Density kg/m^3**
Mean	7.69	50.47	489.53	434.64
Minimum	5.35	16.88	398.64	353.75
Maximum	9.69	71.68	553.55	493.46
Range	4.35	54.79	154.92	139.71
Standard Deviation	1.02	13.20	34.58	31.18
Coefficient of Variation	13.25%	26.14%	7.06%	7.17%
Count	44	44	44	44
Characteristic Strength (MPa)		**28.02**	**485**	**431**
Characteristic Stiffness (GPa)	**7.58**			
Assigned Grade	**SG 6**	**SG 10**		

***Table 2:** Characteristic stresses for SG 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
Verified Heartland	14	16	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.

Density and Moisture content

- From the bending test samples a short cross section was then cut from an undamaged clearwood section close to the failure point of each test specimen for density, moisture content.
- 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.

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

Table 3: *Statistical Summary of Density and Moisture content results*

	Moisture Content %	Density at Test kg/m^3	Nominal Density kg/m^3
Mean	12.80	487.36	432.12
Minimum	11.22	398.64	353.75
Maximum	14.88	576.59	508.47
Range	3.66	177.95	154.72
Standard Deviation	0.89	36.43	32.78
Coefficient of Variation	6.93%	7.48%	7.58%
Count	61	61	61

SMALL CLEAR TIMBER TESTING

Bending Strength and Stiffness Test Results

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.

Appendix C list the raw test data collected.

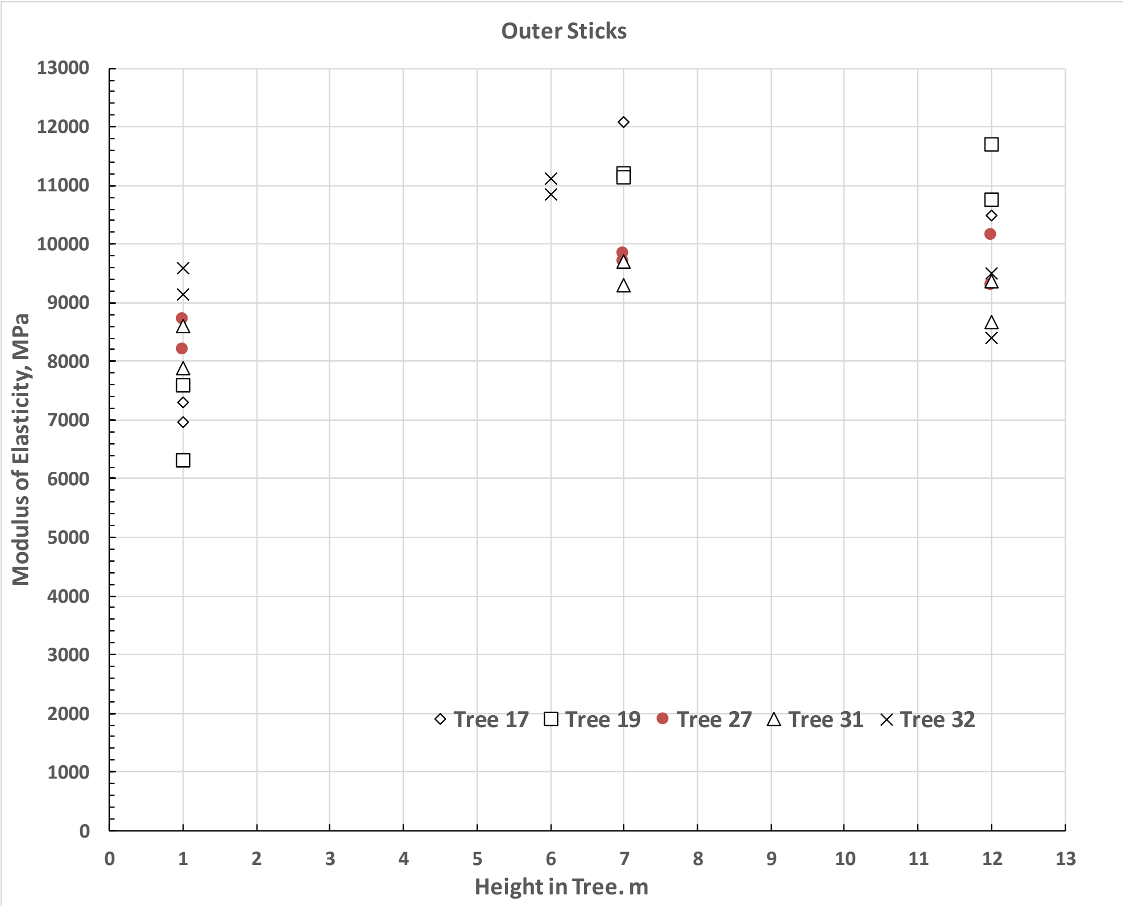

Figure 1: *Outerwood specimens - Height in Tree vs Modulus of Elasticity*

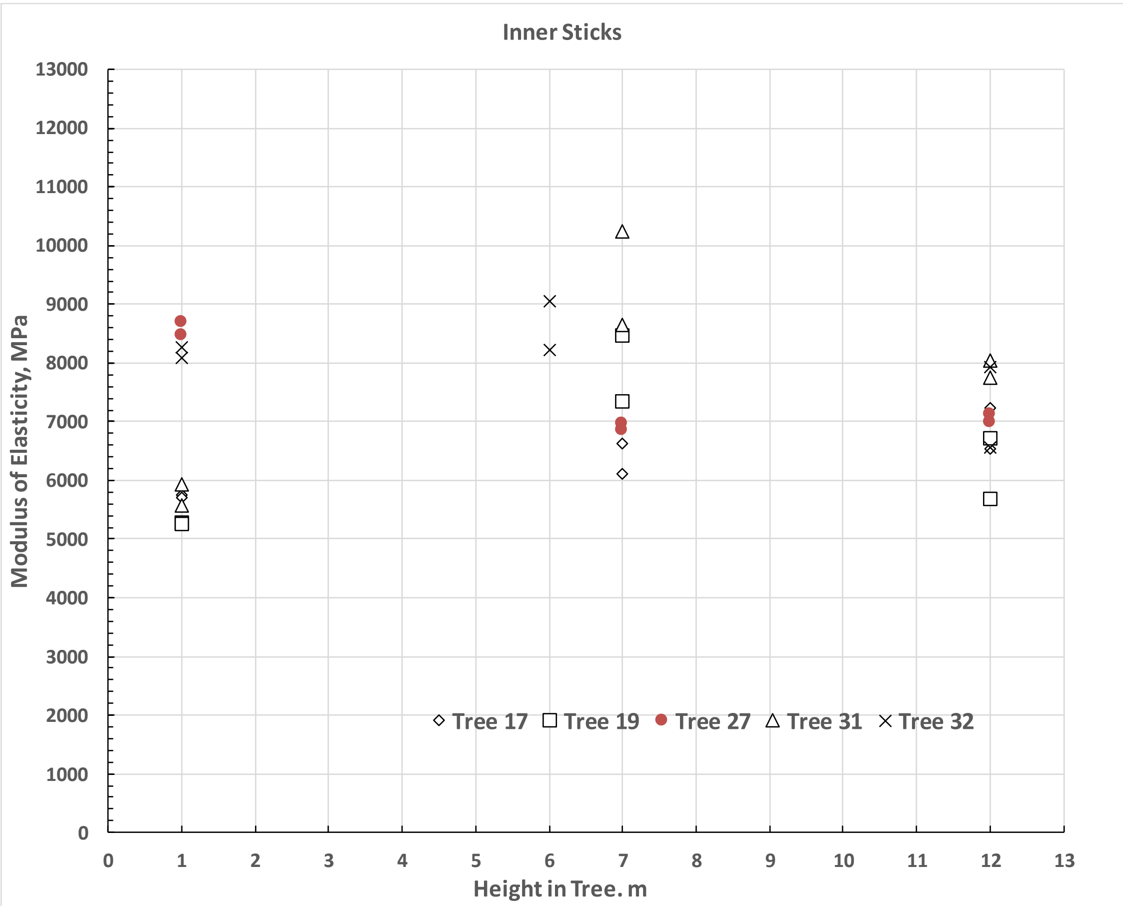

Figure 2: *Innerwood specimens - Height in Tree vs Modulus of Elasticity*

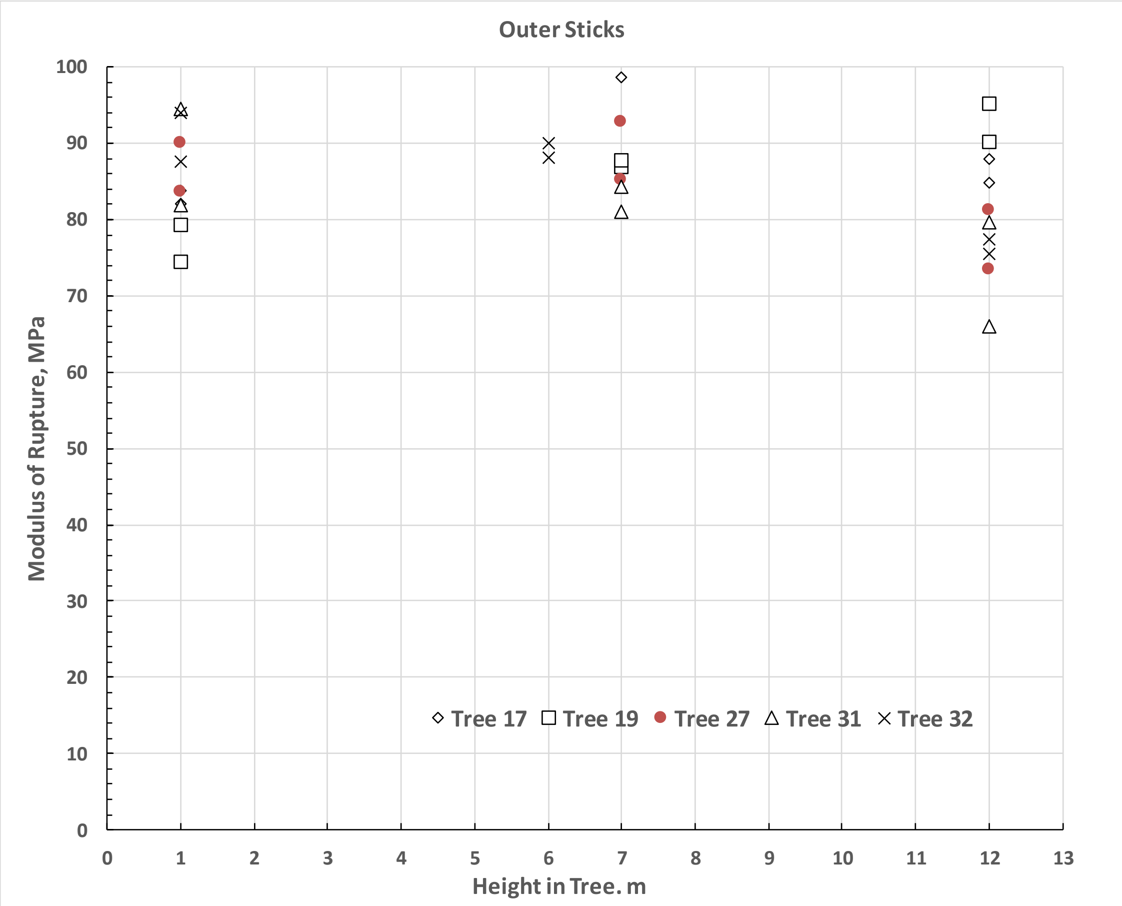

***Figure 3**: Outerwood specimens - Height in Tree vs Modulus of Rupture*

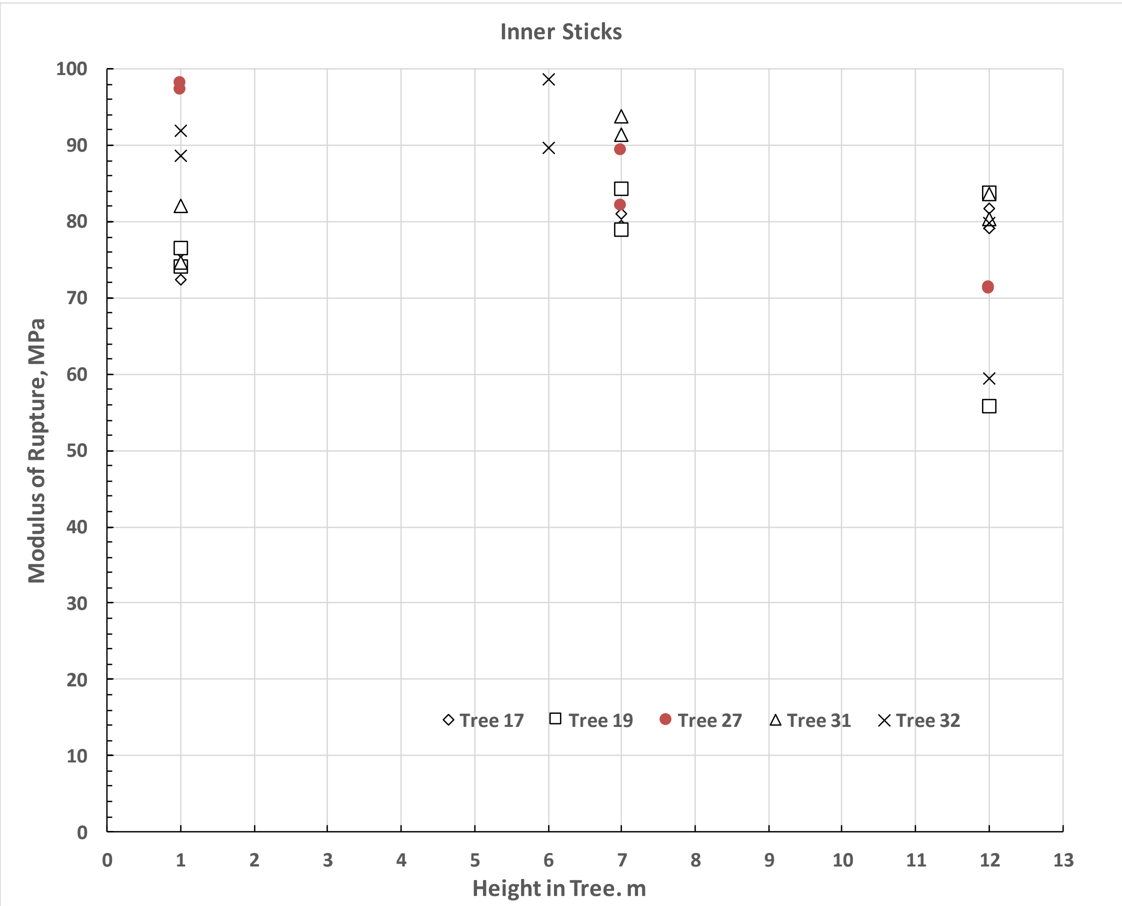

***Figure 4**: Innerwood specimens - Height in Tree vs Modulus of Rupture*

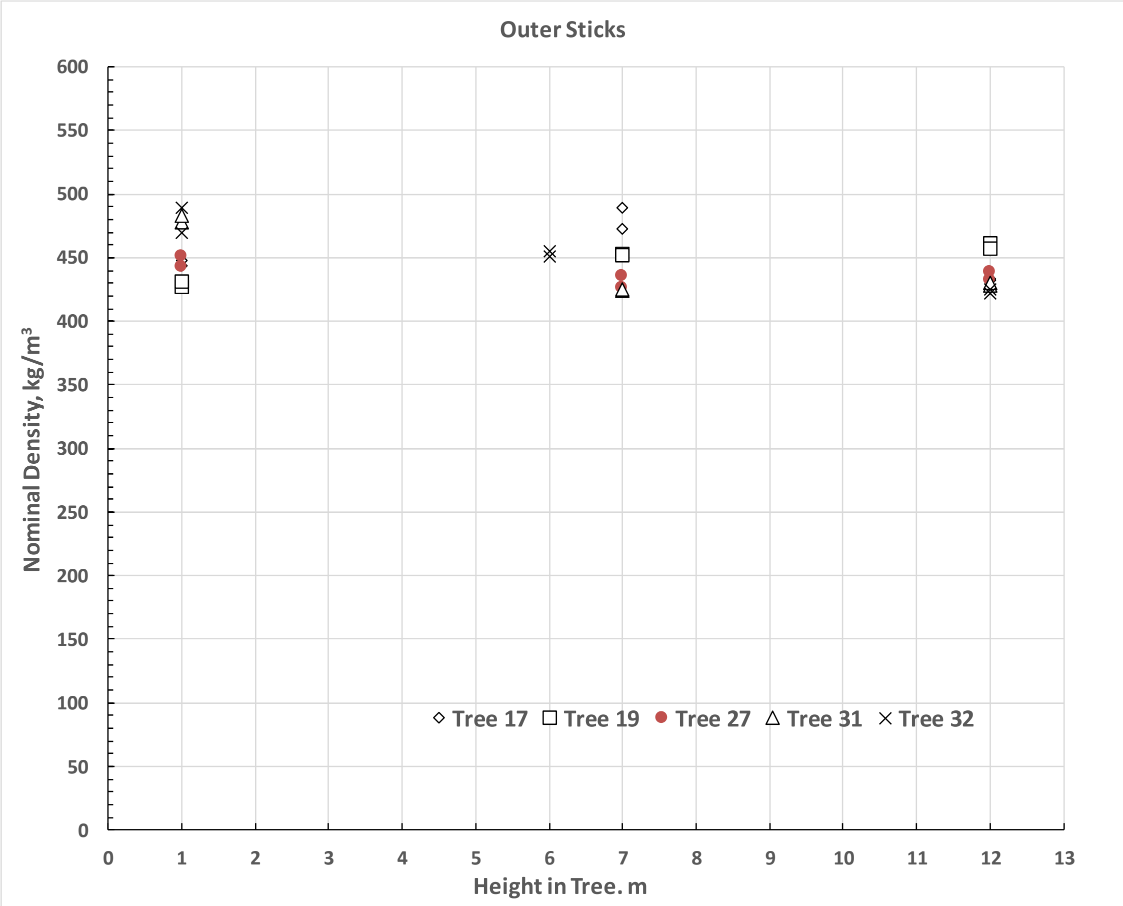

***Figure 5**: Outerwood specimens - Height in Tree vs Nominal Density*

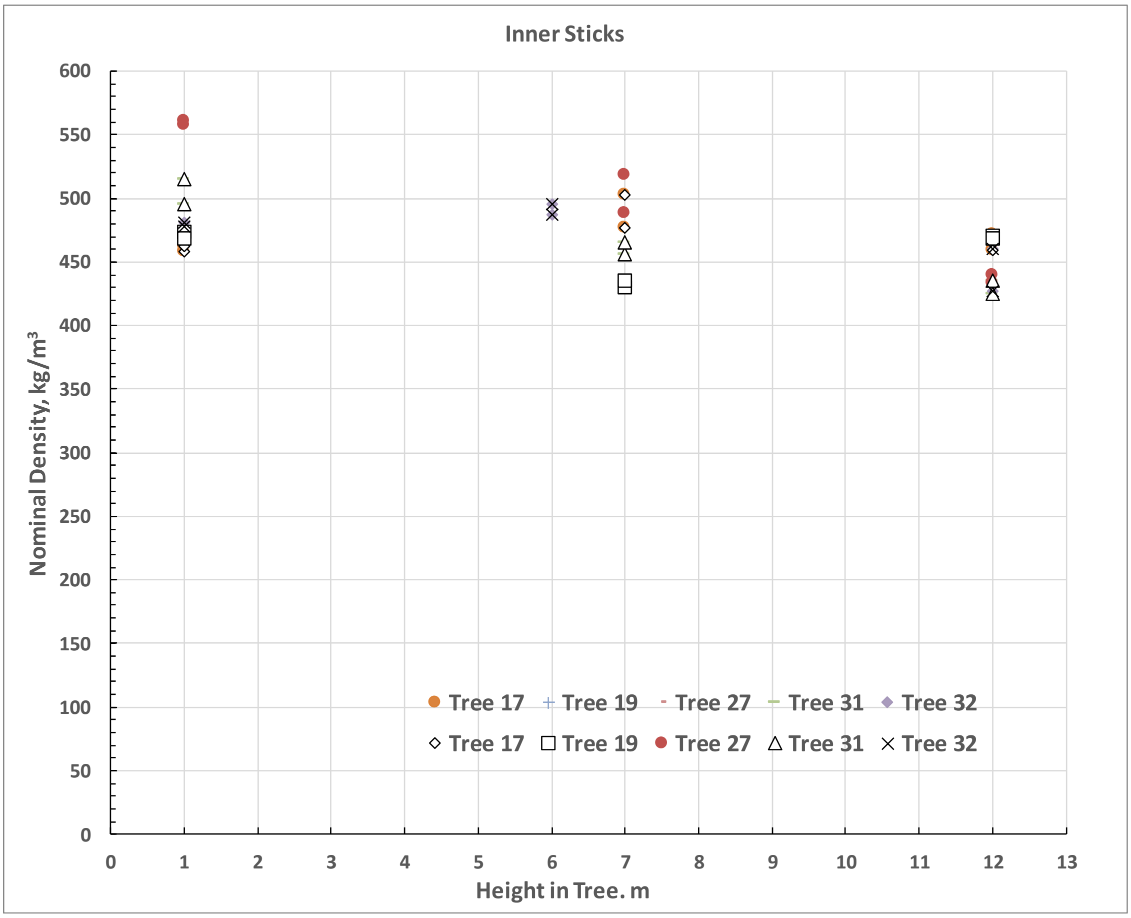

***Figure 6**: Innerwood specimens - Height in Tree vs Nominal Density*

Observations from Figure 1 – 6

- Looking at all the trees Modulus of Elasticity is highest at an average level in the outerwood sticks at the 7m tree height, this trend is not so obvious in the inner wood sticks.
- There an approximately 50% variation in Modulus of Elasticity at the 1, 7 & 12m heights for both the outer and innerwood specimens.
- Looking at all the trees Modulus of Rupture at an average level appears fairly constant in the outerwood sticks across the three heights for the outer wood sticks,
- Looking at all the trees Modulus of Rupture at an average level appears lowest in the innerwood sticks at the 12m height,
- Looking at all the trees the nominal density at an average level appears fairly constant in the outerwood sticks across the three heights
- Looking at all the trees the nominal density at an average level appears shows a decreasing trend with tree height in the innerwood sticks.

CONCLUSION

1. In terms of bending stiffness, the *C. ovensii* achieved the SG6 structural grade, in terms of bending strength, the *C. ovensii* achieved the SG10 structural grade resulting in an overall grade of SG6.
2. To assign a full structural grade the other strength properties tension, compression and shear need to be evaluated.
3. From the small clear testing there were very few obvious trends between height in tree, modulus of elasticity, modulus of rupture and nominal density across the inner and outer wood samples for the five trees assessed.
4. Modulus of Elasticity is often higher in the small clears then the structural timber this commonly occurs with small clear testing and there will also be an impact from the different trees used for the production of the structural timber.
5. Bending strength is higher in small clear testing due to the small size, the absence of strength reducing defects like knots and sloping grain.

ACKNOWLEDGEMENTS

Ruapehu Sawmills for supplying the 100x50mm structural timber

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

4. Sargent, R., & Stovold, G. T. (2021). SWP-T116 Grade recoveries from sawing 22-year-old unpruned cypress clones. Report prepared for the Specialty Wood Products Partnership. Scion, Rotorua.
5. Stovold, T., Sargent, R., & Satchell, D. (2019). SWP-FN084 Sawing Cypress Clones - Green recovery. File Note prepared for the Specialty Wood Products Partnership. Scion, Rotorua.

APPENDICES

Appendix A: Scion Hybrid *C. ovensii* Test data

Lab No.	Board Reference	Visual Grade	Width (mm)	Depth (mm)	MoEj (GPa)	MoRj (MPa)	Moisture Content (%)	Density at Test kg/m^3	Nominal Density kg/m^3
286637	25143	1F	28.31	101.18	7.67	53.49	12.89	471.75	417.90
286633	25174	1F	24.29	101.15	7.65	30.65	12.90	502.66	445.21
286595	42993	2F	41.88	101.04	5.47	36.26	14.30	517.65	452.90
286590	43005	1F	40.35	101.79	6.90	42.65	13.55	480.99	423.60
286588	43006	1F	41.33	101.24	8.04	51.89	13.06	524.21	463.66
286636	43058	2F	26.36	106.58	5.92	38.88	12.66	503.19	446.66
286602	42847-1	2F	52.03	101.32	5.11	37.06	14.09	493.44	432.49
286596	42847-2	1F	52.59	101.32	7.15	59.94	14.61	518.63	452.52
286589	42847-3	1F	50.93	100.91	7.69	51.21	14.48	516.77	451.42
286639	42861-S	2F	30.89	101.52	6.18	25.11	13.16	476.15	420.77
286634	42875-L	1F	24.82	101.39	9.69	59.46	12.40	520.34	462.92
286635	42875-S	1F	25.34	101.25	9.50	48.53	12.80	487.78	432.43
286643	42884-L	2F	25.16	101.70	6.56	61.44	13.40	576.59	508.47
286642	42884-S	2F	25.04	101.06	7.18	56.77	13.04	532.31	470.92
286644	42958-L	1F	24.65	101.46	8.80	66.03	12.66	500.18	443.99
286645	42958-S	1F	24.63	101.31	9.15	51.10	13.07	510.19	451.21
286641	42968-L	1F	24.04	101.28	8.27	54.90	13.05	515.50	456.01
286638	42969-S	2F	23.86	100.06	8.50	28.53	12.88	508.32	450.33
286640	42977-L	1F	25.94	100.51	5.89	37.86	13.19	491.39	434.15

Appendix B: *C. ovensii* Test data

Lab No.	Board Reference	Visual Grade	Width (mm)	Depth (mm)	MoEj (GPa)	MoRj (MPa)	Moisture Content (%)	Density at Test kg/m^3	Nominal Density kg/m^3
286608	OV-10	Eng	50.18	99.94	7.81	59.97	11.95	480.45	429.16
286614	OV-10	1F	50.08	98.85	9.23	38.42	11.48	465.88	417.92
286627	OV-11	2F	52.71	98.61	5.76	38.76	12.14	522.67	466.09
286619	OV-12	1F	53.21	101.25	6.39	57.97	12.46	541.13	481.17
286611	OV-13	1F	53.76	88.33	6.87	58.49	11.45	524.89	470.95
286617	OV-13	1F	55.12	90.46	8.13	62.13	11.77	526.66	471.18
286621	OV-14	1F	50.56	98.37	9.19	34.32	12.05	495.77	442.46
286626	OV-14	Eng	50.37	98.51	7.16	56.93	11.39	457.81	411.00
286585	OV-15	1F	56.11	100.35	6.77	28.46	12.65	441.70	392.10
286592	OV-15	2F	52.64	100.80	6.10	23.36	13.20	434.68	383.99
286598	OV-15	1F	56.27	101.22	5.94	37.24	13.85	456.91	401.33
286604	OV-15	2F	52.39	101.47	5.65	22.70	13.36	499.85	440.92
286584	OV-16	1F	53.77	100.46	8.13	55.25	11.99	421.53	376.39
286591	OV-16	1F	54.47	101.54	7.01	21.07	13.32	424.05	374.19
286597	OV-16	2F	55.42	101.67	6.33	22.66	13.38	420.03	370.47
286603	OV-16	2F	55.43	100.43	6.22	24.03	13.64	439.13	386.41
286587	OV-17	2F	55.91	102.01	4.26	10.93	13.36	435.94	384.55
286594	OV-17	Box	56.38	101.73	4.10	10.40	14.15	499.48	437.55
286600	OV-17	1F	56.16	101.87	5.35	33.72	14.06	503.34	441.28
286606	OV-17	1F	54.87	101.69	6.39	16.88	13.48	441.74	389.26
286586	OV-18	1F	53.17	100.27	7.35	52.77	12.41	451.20	401.41
286593	OV-18	2F	52.92	100.92	5.74	14.97	13.96	416.20	365.20
286599	OV-18	Eng	55.03	101.41	8.08	51.45	12.69	398.64	353.75
286605	OV-18	1F	54.60	101.03	6.89	57.37	14.88	456.55	397.40
286601	OV-19	Eng	49.08	101.15	7.35	54.02	12.39	467.87	416.29
286607	OV-19	1F	48.84	101.66	8.51	61.31	12.68	492.05	436.68
286624	OV-20	Eng	52.61	101.21	7.99	71.68	12.51	467.82	415.81
286630	OV-20	Eng	51.10	101.67	9.57	71.42	11.92	481.84	430.53
286612	OV-21	Eng	47.83	99.43	7.07	48.52	13.12	493.17	435.98
286618	OV-21	1F	51.57	100.50	8.17	58.28	13.26	504.55	445.47
286625	OV-22	1F	49.82	101.68	8.26	67.17	12.54	515.34	457.90
286631	OV-22	Eng	49.37	102.00	6.65	45.77	12.83	495.40	439.08
286613	OV-23	Eng	51.13	101.62	7.27	66.16	12.17	516.65	460.58
286632	OV-25	Eng	54.00	101.58	7.53	46.18	12.76	471.89	418.49
286609	OV-5	1F	47.66	97.09	7.45	62.06	11.61	542.55	486.10
286615	OV-5	2F	46.98	97.01	7.79	43.30	11.22	492.78	443.06
286610	OV-6	2F	51.24	97.34	6.74	39.98	11.79	500.05	447.33
286616	OV-6	2F	51.11	96.27	7.44	37.02	11.48	505.54	453.48
286623	OV-7	1F	54.98	99.96	8.88	38.11	11.96	469.71	419.53
286629	OV-7	1F	51.95	99.05	8.50	61.56	11.44	475.35	426.55
286622	OV-8	1F	53.06	91.52	7.45	49.53	12.18	553.55	493.46
286628	OV-8	1F	49.70	99.15	7.42	60.07	11.39	478.44	429.51
286620	OV-9	1F	49.78	97.09	7.11	28.79	11.60	533.70	478.21

Appendix C: Small Clear Data

Lab No.	Bar Code	Tree	Height in Tree (m)	Inner/ Outer (I/O	Replicate (A/B)	FSPL (MPa)	MoR (MPa)	MoE (MPa)	Moisture Content (%)	Test Density kg/m^3	Nominal Density kg/m^3
287637	42993	17	1	O	A	44.80	83.83	7315	13.34	507.67	447.91
287638	42993	17	1	O	B	43.87	82.11	6984	13.45	503.97	444.22
287639	42933	17	1	I	A	36.92	72.41	5756	14.93	526.87	458.42
287640	42933	17	1	I	B	37.53	75.94	5703	14.93	531.16	462.17
287641	43050	17	12	O	A	40.62	87.92	10764	14.59	496.70	433.46
287642	43050	17	12	O	B	38.97	84.82	10511	14.79	496.79	432.80
287643	43066	17	7	O	A	47.18	102.25	12095	14.99	562.18	488.90
287644	43066	17	7	O	B	45.32	98.62	12095	15.26	545.18	473.02
287645	43066	17	7	I	A	40.19	80.98	6120	14.85	577.72	503.01
287646	43066	17	7	I	B	44.77	79.52	6633	14.57	546.55	477.03
287647	43050	17	12	I	A	41.63	79.11	6538	14.37	539.67	471.87
287648	43050	17	12	I	B	42.16	81.75	7230	14.44	525.88	459.51
287649	42098	19	1	I	A	38.86	76.63	5291	14.56	543.30	474.25
287650	42098	19	1	I	B	36.69	74.18	5267	14.65	537.15	468.53
287651	42098	19	1	O	A	40.59	79.26	7613	13.78	486.48	427.58
287652	42098	19	1	O	B	38.01	74.48	6334	13.65	489.77	430.94
287653	43038	19	12	I	A	44.16	83.79	6720	14.53	538.81	470.47
287654	43038	19	12	I	B	34.91	55.76	5683	14.62	536.81	468.33
287655	43038	19	12	O	A	45.38	95.21	11716	14.69	529.09	461.31
287656	43038	19	12	O	B	42.56	90.26	10776	14.96	525.08	456.75
287657	43041	19	7	I	A	41.20	78.97	7337	14.26	491.53	430.18
287658	43041	19	7	I	B	41.94	84.26	8460	14.34	497.89	435.45
287659	43041	19	7	O	A	42.06	86.85	11226	14.61	519.24	453.06
287660	43041	19	7	O	B	39.83	87.80	11151	14.83	518.97	451.95
287661	42967	27	1	I	A	52.41	97.20	8703	14.39	638.16	557.91
287662	42967	27	1	I	B	50.36	98.04	8469	13.81	638.42	560.93
287663	42967	27	1	O	A	43.12	83.54	8210	13.85	504.39	443.03
287664	42967	27	1	O	B	44.17	90.05	8720	13.99	514.21	451.11
287665	25166	27	12	I	A	39.19	71.42	6996	14.76	504.04	439.21
287666	25166	27	12	I	B	40.12	71.19	7128	14.72	497.48	433.64

Appendix C: Small Clear Data (continued)

Lab No.	Bar Code	Tree	Height in Tree (m)	Inner/ Outer (I/O	Replicate (A/B)	FSPL (MPa)	MoR (MPa)	MoE (MPa)	Moisture Content (%)	Test Density kg/m3	Nominal Density kg/m3
287667	25166	27	12	O	A	35.16	73.36	10157	14.51	502.02	438.42
287668	25166	27	12	O	B	40.37	81.12	9301	14.61	495.21	432.09
287669	43077	27	7	I	A	42.01	89.32	6954	14.72	594.69	518.38
287670	43077	27	7	I	B	44.35	82.06	6851	14.64	560.27	488.71
287671	43077	27	7	O	A	39.11	85.10	9722	14.10	486.14	426.08
287672	43077	27	7	O	B	41.23	92.79	9854	13.75	494.86	435.05
287673	42884	31	1	I	A	40.96	74.62	5934	13.88	587.12	515.55
287674	42884	31	1	I	B	38.80	82.09	5567	13.73	563.84	495.77
287675	42884	31	1	O	A	17.60	81.90	7899	13.87	544.42	478.13
287676	42884	31	1	O	B	45.72	94.47	8609	13.86	549.69	482.77
287677	25056	31	7	I	A	56.17	91.35	8656	14.88	524.56	456.63
287678	25056	31	7	I	B	43.98	93.81	10237	14.84	534.49	465.41
287679	25056	31	7	O	A	34.12	84.27	9712	14.90	487.44	424.23
287680	25056	31	7	O	B	30.78	81.09	9306	15.01	489.20	425.35
287681	25089	31	12	I	A	39.13	80.35	7754	14.95	488.58	425.05
287682	25089	31	12	I	B	44.86	83.55	8043	14.96	500.15	435.05
287683	25089	31	12	O	A	30.80	66.07	8686	14.63	490.90	428.27
287684	25089	31	12	O	B	39.16	79.65	9375	14.67	493.06	429.96
287685	25021	32	1	I	A	46.92	91.85	8256	13.93	544.16	477.63
287686	25021	32	1	I	B	44.83	88.69	8089	13.73	547.16	481.11
287687	25021	32	1	O	A	43.72	87.55	9595	14.31	536.35	469.19
287688	25021	32	1	O	B	48.42	93.97	9162	13.52	555.67	489.47
287689	43081	32	6	I	A	48.78	98.58	9051	14.23	565.66	495.21
287690	43081	32	6	I	B	46.56	89.69	8213	14.23	555.98	486.73
287691	43081	32	6	O	A	43.59	90.07	11123	14.59	521.31	454.95
287692	43081	32	6	O	B	42.31	88.18	10867	14.56	516.02	450.45
287693	25007	32	12	I	A	34.56	59.51	6567	14.82	528.17	459.99
287694	25007	32	12	I	B	41.25	79.85	7922	14.88	490.33	426.82
287695	25007	32	12	O	A	41.84	77.40	9517	15.27	486.91	422.42
287696	25007	32	12	O	B	35.42	75.47	8407	15.38	491.00	425.54