Lusitanica and Lawson Cypress Testing for Compression, Tension and Shear Strength and Flexural Strength and Stiffness

Prepared For

New Zealand Farm Forestry Association

By
Dr. David M. Carradine
Adjunct Fellow
University of Canterbury
Department of Civil and Natural Resources Engineering

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1. Introduction

In order to assess the suitability of using New Zealand grown timber species for structural strength and stiffness properties for possible inclusion within the New Zealand Building Code, Lusitanica and Lawson Cypress species were tested in the Structures Laboratories of the Civil and Natural Resources Engineering Department at the University of Canterbury in Christchurch. Testing to evaluate compression, tension, and shear strength, along with flexural strength (Modulus of Rupture) and stiffness (Modulus of Elasticity) were conducted in accordance with AS/NZS 4063.1:2010, Characterization of structural timber. Evaluation of moisture content using oven dry methods was also conducted from samples cut from all tested specimens. Testing was performed under the direct supervision of Dr. David Carradine at the request of the New Zealand Farm Forestry Association. Described in this report are the specimens tested, methods for testing, results and conclusions based on the generated mechanical property data for these species.

2. Specimens and Specimen Preparation

All timber testing was done with specimens having an approximate cross section of 45 mm x 90 mm and differing lengths according to testing required. All specimens were prepared by Dean Satchell of New Zealand Farm Forest Association with guidance from Dr. David Carradine. Specimens were kiln dried, graded, cut to length and dimensions obtained prior to arrival at the University of Canterbury (UC). Specimen lengths for testing were taken from requirements in Section 2 of AS/NZS 4063.1 and are provided in Table 1 for the different testing configurations. All test specimens were stored inside for at least several hours prior to testing, and usually for several days, therefore none of the specimens had a temperature less than 15°C at the time of testing.

Table 1. Test Specimen Dimensions for and AS/NZS 4063.1 Requirements

Test	Overall Length (mm)	Test or Span Length (mm)	Overall Length Criteria from Standard	Test Length Criteria from Standard
Flexure	1800	1620	20 x depth	18 x depth
Shear	720	540	8 x depth	6 x depth
Tension	≥3750	2800*	NA	≥8 x depth + 2000
Compression	360	360	4 x depth	4 x depth

*Distance between tension grips

Grading was performed by Dean Satchell for all tested specimens and the grade used was Farm Forestry Timbers, No. 1 Structural. This grade has the following limitations:

- Structural timber shall be dry to 18% moisture content or below.
- **Distortion**
    - Bow maximum: 40/1
    - Crook maximum: 200/1
    - Twist minimal
    - Cup: 75/1
- **Knots, holes, voids, bark-inclusion, bark-pockets, resin pockets, pith, decay, wane, sloping grain greater than 1/10 (including sloping grain surrounding spike knots*) and other weakness-causing defect:**
    - Not more than 1/3 of cross section in combination up to 150 mm board;
    - Not more than 1/4 of cross section in combination for larger than 150 mm board.
    - No voids (Voids include holes, bark-pockets, resin pockets and bark inclusion) longer than the width of the face of the piece. Where bark inclusion and associated voids do not exceed 5% of the cross section the length is not restricted.
    - Checks, collapse and pith are not restricted.
    - Pith includes surrounding wood to a radius of 10 mm.
    - Wane and skip are to be kept to a minimum. No more than 5% of cross section.
    - Splits not allowed. Shakes not allowed.
    - Maximum sloping grain: 1 in 10
- **Spike knots**: The length of the longest edge (i.e. as seen on the face of the piece and where adjacent sloping grain is greater than 1 in 10) of a spike knot must not be greater than 75% of the width of the face of the piece. Where structural members are of square cross section this does not apply.
- Sapwood shall be treated to h1.2.

Lawsons Cypress samples all came from Ruapehu sawmills based at Raetahi. The material was randomly selected and all came from central North Island trees and from a range of ages. Much of the material sampled was central wood from smaller diameter trees. The Lusitanica Cypress was sourced from Mac Direct, Auckland. The material was randomly selected from stacked air-dried timber of diverse North Island origins. All timber was air dry then kiln dried before sampling.

3. Testing Methods

Testing for flexure, shear, tension and compression were conducted according to appropriate sections of AS/NZS 4063.1. Details of the different tests are described below, but all specimens were loaded uniformly using either displacement or load control to achieve failures in between 2 and 5 minutes. In a few cases specimens were much weaker or stronger than anticipated and resulted in failure times that fell outside of this range. Prior to testing all specimens were weighed so that density could be calculated.

Photos were taken during and after testing to document specific characteristics of specimens and to help identify failure modes. All instrumentation used to obtain load and displacement data were calibrated prior to testing to ensure accurate results during testing. For all testing configurations, immediately following testing, a small sample (approximately 25 mm along the longitudinal direction) was cut from each specimen for evaluation of oven dry moisture content.

3.1 Flexure Testing

Flexure testing was conducted to determine the strength or Modulus of Rupture (MOR) and the stiffness or Modulus of Elasticity (MOE) of both species according to methods described in Section 2.4 of AS/NZS 4063.1. Specimens were simply supported over a span of 1620 mm using rocking supports with rollers on each end to avoid any resistance to bending deformation. Specimens were tested in an edgewise manner with the 90 mm depth placed vertically. Loads were applied using a spreader bar to apply 2 point loads at a span of 540 mm at a displacement controlled rate of 10 mm per minute. The testing frame was an Instron machine located in the Model Structures Laboratory at the University of Canterbury. In order to obtain measurements of beam mid-span neutral axis deflection throughout testing, a yoke was fabricated, as shown in Figure 1, which was supported on pins installed at neutral axis height directly above the supports, and with a linear potentiometer attached to the yoke and a pin installed at neutral axis height at beam mid-span. Applied loads and mid-span neutral axis deflections were obtained at a rate of 2 samples per second and were recorded using a computer controlled data acquisition system. Data from flexure testing was sufficient to calculate the MOE and MOR for all specimens tested using equations provided in Section 2.4 of AS/NZS 4063.1.

3.2 Shear Testing

Shear testing was conducted to determine the beam shear strength of both species according to methods described in Section 2.7 of AS/NZS 4063.1. Specimens were simply supported over a span of 540 mm using one pinned and one rocking support with bearing plates between the specimen and the supports to distribute reaction forces at the supports. Specimens were tested in an edgewise manner with the 90 mm depth placed vertically. Loads were applied using a steel-bearing plate with rounded edges to avoid stress concentrations and at a displacement controlled rate of 5 mm per minute. The testing frame was an Instron machine located in the Model Structures Laboratory at the University of Canterbury. A typical shear test specimen is shown in Figure 2 in the test apparatus. Applied loads were obtained at a rate of 2 samples per second and were recorded using a computer controlled data acquisition system. Data from shear testing was sufficient to calculate the beam shear strength for all specimens tested using equations provided in Section 2.7 of AS/NZS 4063.1. Failures for shear were primarily in bending but values were conservatively taken as if they had been shear failures and were calculated using the shear strength equation.

Figure 1. Typical Testing Configuration for Flexure Specimens (Note: Deflection Yoke Shown in Lower Right Removed as Specimens Neared Failure)

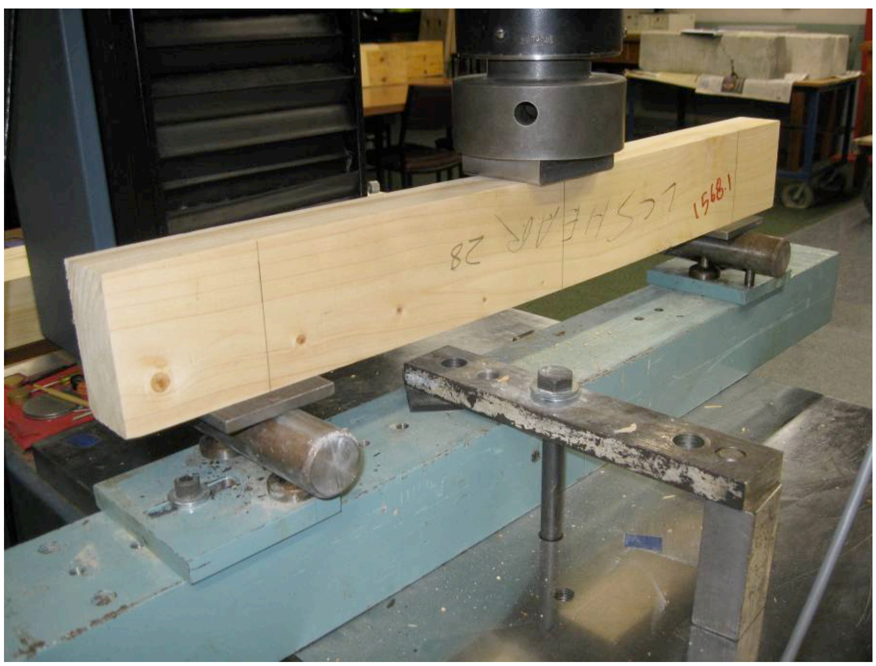

Figure 2. Typical Testing Configuration for Beam Shear Specimens

3.3 Tension Testing

Tension testing was performed to determine the tension strength parallel-to-grain of both species according to methods described in Section 2.5 of AS/NZS 4063.1. Specimens were loaded in tension through the cross-section using a specially designed testing machine shown in Figure 3. Specimens were gripped at each end using 500 mm long hydraulic grips that were adjusted using the pressure so that the specimens would not slip during testing but would also not be crushed by the grips. No specimens were crushed during testing, but one specimen did slip in the grips after exceeding 160 kN of load and needed to have the pressure increased in order to fail it. The distance between the grips was 2800 mm. Loads were applied by elongating the specimens by moving one of the grips while the other remained stationary. The testing machine was bolted to the strong floor in the Structures Extension Laboratory at the University of Canterbury. Applied loads were obtained at a rate of 1 sample per second and were recorded using a computer controlled data acquisition system. Data from tension testing was sufficient to calculate the tension strength parallel-to-grain for all specimens tested using equations provided in Section 2.5 of AS/NZS 4063.1.

Figure 3. Typical Testing Configuration for Tension Parallel-to-Grain Specimens

3.4 Compression Testing

Compression testing was performed to determine bearing strength parallel-to-grain of both species according to methods described in Section 2.9 of AS/NZS 4063.1. Specimens were loaded in compression through the cross-section using a dedicated compression testing machine as shown in Figure 4 which was equipped with a spherical loading platen on the top to ensure a uniform distribution of load over then ends of the specimens. Loads were applied by compressing the specimens by moving one of the platens while the other remained stationary at a rate of 1kN per second. The testing machine was located in the Structures Extension Laboratory at the University of Canterbury. Applied loads were obtained at a rate of 20 samples per second and were recorded using a computer controlled data acquisition system that was integrated within the test machine. Data from compression testing was sufficient to calculate the bearing strength parallel-to-grain for all specimens tested using equations provided in Section 2.9 of AS/NZS 4063.1.

Figure 4. Typical Testing Configuration for Compression Parallel-to-Grain Specimens

3.5 Moisture Content Evaluation

All tested specimens were also evaluated for moisture content (MC) immediately following mechanical property testing. After each test, smaller specimens, approximately 25 mm along the longitudinal direction, were cut from each specimen for evaluation of oven dry moisture content according to ASTM D 4442 - 92 (Reapproved 2003) *Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials*. MC specimens were weighed after being cut then placed in an oven at approximately 103° C and weighed at regular time intervals, usually 48 hours to determine when they no longer were losing weight. Once the weights stabilized they were considered to be "oven dry" and a final weight was obtained to allow for MC using the following equation from ASTM D 4442 – 92 (2003), Section 6.5.1:

$$MC = [(A-B)/B] \times 100\%,$$

where,

MC = moisture content as a percentage,
A = original mass (g), and
B = oven dry mass (g).

4. Data and Results

Data recorded from flexure, shear, tension and compression testing were sufficient to allow for calculation of MOR, MOE, beam shear strength, tension strength parallel-to-grain and bearing strength parallel-to-grain, respectively, using equations provided in Section 2 of AS/NZS 4063.1 for Lusitanica and Lawson Cypress timber species. Moisture content was also evaluated for samples cut from all tested specimens. In addition, failure modes for the different test configurations were recorded and discussed in this section. Omitted specimens were those deemed to be out of grade.

4.1 Flexure Testing Results

Load data from a load cell installed within the testing frame, and mid-span, neutral axis deflection data were analyzed from each specimen to obtain values for modulus of elasticity (MOE), modulus of rupture (MOR), and maximum applied load. A linear estimation of slope from the load versus displacement data between 10 and 40 percent of the maximum load was used to calculate the modulus of elasticity (MOE) of each specimen according to Equation 2.4.3(1) from AS/NZS 4063.1. Failures were due primarily to fracture of the fibers on the tension face of specimens near the mid-span of the beams and always within the area between the loading span. In some cases it was also noted that compression buckling of fibers near the region of the load application occurred, but this was not considered the primary failure mode. Table 2 and Table 3 provide data from flexure testing for Lusitanica and Lawson Cypress, respectively, including maximum applied loads, MOR, MOE, density and moisture content (MC). Lower 5% values were calculated using Excel.

Table 2. Data and Analyses for Lusitanica Flexure Testing

Specimen	Maximum Load (kN)	MOR (MPa)	MOE (GPa)	Density (kg/m^3)	MC (%)
LUB1	7.72	35.89	11.6	434	13.7%
LUB2	6.04	27.24	8.4	454	13.7%
LUB3	6.18	28.03	8.1	467	12.6%
LUB4	6.00	27.65	9.6	432	12.5%
LUB5	8.93	40.49	11.3	430	12.1%
LUB6	13.52	61.29	13.5	450	15.5%
LUB7	14.77	67.04	19.1	403	12.8%
LUB8	11.58	52.49	6.7	483	15.4%
LUB9	10.42	47.27	9.0	444	13.8%
LUB10	12.16	55.09	8.7	455	14.4%
LUB11	10.19	47.36	6.6	484	13.6%
LUB12	11.53	52.69	6.8	446	15.0%
LUB13	15.29	68.61	9.7	460	15.1%
LUB14	6.49	30.31	8.2	386	13.4%
LUB15	8.42	38.11	9.5	443	15.4%
LUB16	6.00	26.78	7.3	437	14.5%
LUB17	10.70	48.66	10.9	491	13.8%
LUB18	8.14	37.30	10.5	501	14.1%
LUB19	6.74	31.01	9.2	514	14.5%
LUB20	6.20	27.91	9.4	435	14.4%
LUB21	12.32	55.07	10.0	415	13.3%
LUB22	10.00	45.92	10.6	509	13.7%
LUB23	11.39	51.92	5.4	454	14.0%
LUB24	10.56	49.42	7.8	422	14.0%
LUB25	9.56	43.26	9.5	450	13.9%
LUB26	6.04	26.96	6.1	509	16.1%
LUB27	7.11	33.33	6.8	507	15.0%
LUB28	9.82	45.09	9.3	441	14.6%
LUB29	8.94	40.12	10.7	433	12.6%
LUB30	6.55	29.01	7.9	463	12.8%
LUB31	6.88	30.89	5.0	423	13.5%
LUB32	7.11	32.23	7.4	476	13.5%
LUB33	8.86	40.02	9.7	426	14.0%
LUB34	6.01	27.33	7.5	399	13.7%
LUB35	10.30	46.34	10.1	452	13.4%
Average	**9.10**	**41.38**	**9.09**	**452**	**14.0%**
St. Dev.	**2.64**	**11.95**	**2.55**	**33**	**0.9%**
COV	**29.03%**	**28.88%**	**28.06%**	**7.19%**	**6.77%**
Lower 5%	**6.01**	**27.16**	**5.85**	**402**	**12.5%**

Table 3. Data and Analyses for Lawson Cypress Flexure Testing

Specimen	Maximum Load (kN)	MOR (MPa)	MOE (GPa)	Density (kg/m^3)	MC (%)
LCB1	9.51	41.24	8.9	514	17.2%
LCB2	10.64	45.86	12.4	578	21.9%
LCB3	7.97	34.37	6.8	590	19.1%
LCB4	11.88	50.88	9.0	547	17.0%
LCB5	8.91	38.30	7.7	565	18.0%
LCB6	9.14	39.54	4.9	563	18.2%
LCB7	8.08	34.77	4.5	513	17.8%
LCB8	8.25	35.33	8.3	540	16.3%
LCB9	15.65	67.41	11.4	491	18.7%
LCB10	9.51	41.17	10.5	575	18.8%
LCB11	6.81	29.40	9.4	521	18.8%
LCB12	8.28	35.73	8.3	558	20.5%
LCB13	7.05	30.42	4.8	581	18.5%
LCB14	7.49	32.24	7.0	547	18.8%
LCB15	7.89	33.88	10.9	492	19.6%
LCB16	8.63	37.32	8.4	616	18.7%
LCB17	9.33	40.29	7.9	540	18.9%
LCB18	9.87	42.43	7.7	595	18.8%
LCB19	8.93	38.68	9.1	528	17.3%
LCB20	8.63	37.35	3.6	582	19.5%
LCB22	13.30	57.34	10.7	564	17.8%
LCB23	8.88	38.12	9.2	468	18.1%
LCB24	11.90	51.28	11.5	492	18.3%
LCB25	8.09	34.75	6.6	558	17.8%
LCB26	7.66	33.38	10.4	541	18.0%
LCB27	9.80	42.08	8.3	517	17.5%
LCB28	8.89	38.42	6.3	528	18.0%
LCB29	12.18	52.63	10.9	523	19.5%
LCB30	6.92	29.86	7.3	528	16.8%
LCB31	6.17	26.70	7.8	513	16.8%
LCB32	8.86	38.50	9.6	546	17.7%
LCB33	9.11	39.18	8.8	473	16.6%
LCB34	12.02	51.81	12.4	525	17.4%
LCB35	9.87	42.38	9.0	540	15.6%
Average	**9.30**	**40.09**	**8.5**	**540**	**18.2%**
St. Dev.	**2.00**	**8.58**	**2.2**	**35**	**1.2%**
COV	**21.48%**	**21.40%**	**0.3**	**6.49%**	**6.70%**
Lower 5%	**6.88**	**29.70**	**4.7**	**485**	**16.5%**

4.2 Shear Testing Results

Load data from a load cell installed within the testing frame were analyzed from each specimen to obtain values for beam shear strength according to Equation 2.7 from AS/NZS 4063.1. Failures were due primarily flexure with approximately 10% of specimens failing in shear. Tables 4 and 5 provide data from shear testing for Lusitanica and Lawson Cypress, respectively, including maximum applied loads, beam shear strength, density and moisture content (MC). Lower 5% values were calculated using Excel.

Table 4. Data and Analyses for Lusitanica Shear Testing

Specimen	Maximum Load (kN)	Beam Shear Strength (MPa)	Density (kg/m^3)	MC (%)
LUS1	20.29	3.80	447	14.6%
LUS2	24.06	4.53	441	14.6%
LUS3	26.27	4.96	460	14.5%
LUS4	28.87	5.48	496	14.7%
LUS5	28.22	5.26	487	14.0%
LUS6	18.34	3.44	423	13.3%
LUS7	23.93	4.44	419	12.3%
LUS8	34.85	6.61	521	15.2%
LUS10	30.04	5.66	447	14.2%
LUS11	28.35	5.32	461	13.6%
LUS12	28.48	5.37	446	13.9%
LUS13	25.10	4.75	562	25.4%
LUS14	28.48	5.37	453	13.1%
LUS15	28.48	5.35	469	13.5%
LUS16	33.94	6.39	476	13.7%
LUS17	30.30	5.71	510	14.5%
LUS18	30.17	5.71	494	14.6%
LUS19	20.94	3.99	511	14.1%
LUS20	27.57	5.16	495	14.2%
LUS21	19.38	3.65	428	12.6%
LUS22	22.50	4.23	413	12.9%
LUS23	29.91	5.62	514	14.2%
LUS24	28.48	5.34	451	13.7%
LUS25	28.22	5.30	440	13.8%
LUS26	31.21	5.90	504	13.9%
LUS27	30.43	5.73	509	14.7%
LUS28	28.48	5.40	471	13.3%
LUS29	29.78	5.65	473	13.6%
LUS30	20.42	3.83	482	13.4%
LUS31	29.26	5.51	464	14.2%
LUS32	29.00	5.50	476	13.7%
LUS33	29.65	5.54	482	14.0%
LUS34	10.66	1.98	470	13.7%
Average	**26.79**	**5.04**	**473**	**14.2%**
St. Dev.	**4.96**	**0.94**	**33**	**2.1%**
COV	**18.52%**	**18.68%**	**7.02%**	**14.71%**
Lower 5%	**18.96**	**3.56**	**422**	**12.8%**

Table 5. Data and Analyses for Lawson Cypress Shear Testing

Specimen	**Maximum Load (kN)**	**Beam Shear Strength (MPa)**	**Density (kg/m^3)**	**MC (%)**
LCS1	22.76	4.09	537	23.5%
LCS2	22.50	4.08	462	19.2%
LCS3	27.70	5.00	599	24.0%
LCS4	26.66	4.82	572	20.8%
LCS5	27.96	5.02	629	19.8%
LCS6	13.26	2.42	540	21.3%
LCS7	25.36	4.57	534	21.2%
LCS8	22.76	4.09	581	22.7%
LCS9	27.31	4.93	532	21.3%
LCS10	30.43	5.50	605	22.8%
LCS11	26.27	4.74	543	20.8%
LCS12	24.71	4.44	572	21.7%
LCS13	24.84	4.47	524	20.0%
LCS14	30.56	5.54	606	24.1%
LCS15	27.31	4.92	565	21.0%
LCS16	21.85	4.05	500	19.4%
LCS17	26.40	4.76	597	21.9%
LCS18	23.93	4.34	516	22.4%
LCS19	24.58	4.44	470	19.1%
LCS20	21.98	3.97	573	21.3%
LCS21	22.37	4.05	485	19.0%
LCS22	29.13	5.27	591	22.1%
LCS23	23.41	4.22	521	20.0%
LCS24	31.86	5.75	538	21.2%
LCS25	29.00	5.37	552	18.5%
LCS26	24.06	4.33	674	25.0%
LCS27	22.76	4.11	651	21.1%
LCS28	23.41	4.21	522	21.4%
LCS29	18.60	3.36	504	22.1%
LCS30	20.03	3.61	493	19.9%
LCS31	28.61	5.15	597	22.7%
LCS32	18.73	3.41	506	21.5%
LCS33	30.56	5.52	540	22.4%
LCS34	23.54	4.23	618	20.7%
LCS35	20.03	3.61	490	22.5%
Average	**24.72**	**4.47**	**553**	**21.4%**
St. Dev.	**3.98**	**0.72**	**51**	**1.5%**
COV	**16.11%**	**16.10%**	**9.31%**	**7.16%**
Lower 5%	**18.69**	**3.39**	**481**	**19.1%**

4.3 Tension Testing Results

Load data from a load cell installed within the tension testing machine were analyzed from each specimen to obtain values for tension strength parallel-to-grain according to Equation 2.5 from AS/NZS 4063.1. Tension failures were due primarily to defects in the timber, but in some cases attributed to pure tension failure of the wood fibres. Tables 6 and 7 provide data from tension testing for Lusitanica and Lawson Cypress, respectively, including maximum applied loads, tension strength parallel-to-grain, density and moisture content (MC). Lower 5% values were calculated using Excel.

Table 6. Data and Analyses for Lusitanica Tension Testing

Specimen	Maximum Load (kN)	Tension Strength (MPa)	Density (kg/m^3)	MC (%)
LUST1	59.4	15.04	497	12.5%
LUST2	56.7	14.30	477	13.2%
LUST3	124.0	31.20	532	12.7%
LUST4	61.6	15.62	535	12.6%
LUST5	107.9	27.22	464	12.8%
LUST6	70.9	17.57	479	12.5%
LUST7	185.6	46.62	552	12.8%
LUST8	69.7	17.45	507	13.3%
LUST9	115.8	28.86	429	12.7%
LUST10	34.0	8.51	438	13.0%
LUST11	139.6	35.27	508	13.2%
LUST12	91.2	23.06	436	12.1%
LUST13	59.0	15.12	515	13.3%
LUST14	66.3	16.91	463	11.2%
LUST15	150.4	38.05	565	12.0%
LUST16	70.2	17.87	524	12.7%
LUST17	40.1	10.00	458	13.5%
LUST18	82.9	20.73	484	13.5%
LUST19	48.0	12.16	497	13.0%
LUST20	128.9	32.71	446	13.3%
LUST21	78.6	19.63	432	12.5%
LUST22	98.8	24.82	448	12.8%
LUST23	62.2	15.81	447	12.4%
LUST24	140.4	35.81	444	12.1%
LUST25	92.4	23.48	430	11.8%
LUST26	51.2	13.01	522	12.5%
LUST27	55.4	13.85	438	12.8%
LUST28	42.2	10.71	482	12.7%
LUST29	135.3	34.52	511	12.1%
LUST30	34.6	8.80	444	13.1%
LUST31	134.1	34.28	511	12.3%
LUST32	149.7	37.64	430	11.7%
LUST33	118.9	30.20	435	12.9%
LUST34	76.4	19.50	509	11.9%
LUST35	100.6	25.91	492	12.0%
Average	**89.5**	**22.64**	**480**	**12.6%**
St. Dev.	**39.2**	**9.91**	**39**	**0.5%**
COV	**43.76%**	**43.77%**	**8.19%**	**4.35%**
Lower 5%	**38.5**	**9.64**	**430**	**11.8%**

Table 7. Data and Analyses for Lawson Cypress Tension Testing

Specimen	Maximum Load (kN)	Tension Strength (MPa)	Density (kg/m^3)	MC (%)
LAWT1	96.9	23.80	525	15.3%
LAWT2	56.5	13.63	486	14.8%
LAWT3	135.3	33.14	551	15.5%
LAWT4	100.4	24.83	496	13.6%
LAWT5	59.2	14.61	548	15.0%
LAWT6	76.0	18.68	541	13.4%
LAWT7	89.1	21.50	606	14.5%
LAWT8	165.6	40.55	524	14.7%
LAWT9	91.8	22.22	479	15.2%
LAWT10	86.8	21.38	591	14.5%
LAWT11	114.1	27.72	575	18.8%
LAWT12	76.1	18.58	547	15.4%
LAWT13	106.1	26.04	571	16.4%
LAWT14	113.5	27.51	551	14.7%
LAWT15	66.8	16.25	605	14.2%
LAWT16	70.3	17.20	531	15.3%
LAWT17	129.3	31.37	452	14.6%
LAWT18	94.3	23.03	536	15.9%
LAWT19	131.0	32.16	505	15.6%
LAWT20	95.4	23.26	509	15.6%
LAWT22	118.8	29.76	495	14.0%
LAWT23	99.5	24.21	534	16.4%
LAWT24	81.5	19.76	544	15.1%
LAWT25	154.7	37.84	538	17.4%
LAWT26	150.3	36.65	460	15.3%
LAWT27	57.4	14.14	574	16.4%
LAWT28	97.4	24.25	584	16.0%
LAWT30	60.7	14.81	511	14.3%
LAWT32	84.3	20.66	543	15.9%
LAWT33	49.2	12.00	504	16.0%
Average	**96.9**	**23.72**	**534**	**15.3%**
St. Dev.	**30.5**	**7.48**	**40**	**1.1%**
COV	**31.50%**	**31.55%**	**7.42%**	**7.23%**
Lower 5%	**56.9**	**13.86**	**469**	**13.8%**

4.4 Compression Testing Results

Load data from a load cell installed within the compression testing machine were analyzed from each specimen to obtain values for bearing strength parallel-to-grain according to Equation 2.9 from AS/NZS 4063.1. Tables 8 and 9 provide data from compression testing for Lusitanica and Lawson Cypress, respectively, including maximum applied loads, bearing strength parallel-to-grain, density and moisture content (MC). Lower 5% values were calculated using Excel. Compression failures were due to crushing and buckling of the timber fibres, and in some cases this was accompanied by splitting of the specimens perpendicular-to-grain, typically around knots, as shown in Figure 5.

Table 8. Data and Analyses for Lusitanica Compression Testing

Specimen	Maximum Load (kN)	Bearing Strength (MPa)	Density (kg/m^3)	MC (%)
LUSC1	145.1	27.35	500	12.2%
LUSC2	104.4	19.88	456	11.8%
LUSC3	152.1	28.87	434	12.6%
LUSC4	133.5	24.94	488	12.6%
LUSC5	126.4	23.60	510	12.7%
LUSC6	175.0	33.28	417	12.3%
LUSC7	156.0	29.13	474	12.6%
LUSC8	140.4	26.40	408	11.8%
LUSC9	123.9	23.62	408	11.8%
LUSC10	171.6	32.67	428	12.4%
LUSC11	130.6	24.61	456	12.6%
LUSC12	167.8	31.57	453	12.5%
LUSC13	126.3	23.88	414	12.2%
LUSC14	115.9	21.88	502	13.1%
LUSC15	118.3	22.64	476	11.9%
LUSC16	165.8	31.45	438	11.8%
LUSC17	149.0	28.90	514	11.6%
LUSC18	194.7	36.59	438	11.4%
LUSC19	211.6	40.28	523	11.5%
LUSC20	137.2	26.34	474	11.4%
LUSC21	125.8	23.87	528	11.3%
LUSC22	100.9	19.11	487	11.7%
LUSC23	101.7	19.25	466	12.0%
LUSC24	123.5	23.93	456	11.9%
LUSC25	173.8	32.94	461	11.9%
LUSC26	164.9	31.18	474	12.1%
LUSC27	154.7	30.04	518	11.3%
LUSC28	231.1	45.06	567	11.3%
LUSC29	175.1	33.17	504	11.6%
LUSC30	205.0	39.32	534	11.3%
Average	**150.1**	**28.52**	**474**	**12.0%**
St. Dev.	**33.0**	**6.38**	**41**	**0.5%**
COV	**21.98%**	**22.38%**	**8.65%**	**4.25%**
Lower 5%	**102.9**	**19.54**	**411**	**11.3%**

Table 9. Data and Analyses for Lawson Cypress Compression Testing

Specimen	Maximum Load (kN)	Bearing Strength (MPa)	Density (kg/m^3)	MC (%)
LAWC1	104.2	19.46	590	13.9%
LAWC2	138.9	26.69	466	12.5%
LAWC3	182.8	33.69	506	12.6%
LAWC4	140.4	26.05	479	15.0%
LAWC5	139.6	25.49	568	12.5%
LAWC6	172.6	31.72	516	13.9%
LAWC7	164.0	30.02	492	13.4%
LAWC8	178.1	32.82	556	13.9%
LAWC9	153.7	28.21	514	13.4%
LAWC10	144.6	27.01	513	13.2%
LAWC11	144.0	26.70	528	12.1%
LAWC12	146.8	26.82	540	14.5%
LAWC13	163.9	30.45	482	12.0%
LAWC14	164.6	30.84	490	13.1%
LAWC15	141.8	25.88	469	14.0%
LAWC16	151.5	27.93	646	13.6%
LAWC17	156.7	29.54	493	13.0%
LAWC18	117.0	21.46	638	16.3%
LAWC19	149.4	27.86	477	12.7%
LAWC20	182.7	33.97	453	12.6%
LAWC21	171.8	32.06	471	12.5%
LAWC22	165.7	31.29	481	12.4%
LAWC23	147.3	27.66	481	12.5%
LAWC24	149.9	27.55	443	12.9%
LAWC25	197.4	36.38	571	13.5%
LAWC26	137.7	25.27	546	13.8%
LAWC27	149.4	27.56	511	14.0%
LAWC28	164.1	30.00	629	13.2%
LAWC29	177.2	33.19	454	12.4%
LAWC30	132.1	24.62	664	16.9%
LAWC31	152.4	28.29	553	13.1%
LAWC32	164.6	30.08	556	12.3%
LAWC33	171.7	31.76	456	13.0%
Average	**155.1**	**28.74**	**522**	**13.4%**
St. Dev.	**19.3**	**3.58**	**60**	**1.1%**
COV	**12.47%**	**12.46%**	**11.44%**	**8.25%**
Lower 5%	**126.0**	**23.36**	**454**	**12.2%**

Figure 5. Example of Crushing and Splitting Failure Observed in Some Compression Parallel-to-Grain Specimens

4.5 Results Summary

Data from all tests were analyzed as previously described with results detailed in previous sections. Table 10 provides a summary of test results from all configurations for both species.

Table 10. Summary of Data and Analyses for Lawson Cypress and Lusitanica Mechanical Property Testing

Lawson Cypress					
	Shear (MPa)	MOR (MPa)	MOE (GPa)	Compression (MPa)	Tension (MPa)
Average	4.47	40.09	8.54	28.74	23.72
Standard Deviation	0.72	8.58	2.20	3.58	7.48
COV	16.1%	21.4%	25.8%	12.5%	31.5%
Lower 5%	3.39	29.70	4.71	23.36	13.86
Average MC	21.4%	18.2%	18.2%	13.4%	15.3%
Lusitanica					
	Shear (MPa)	MOR (MPa)	MOE (GPa)	Compression (MPa)	Tension (MPa)
Average	5.04	41.38	9.09	28.52	22.64
Standard Deviation	0.94	11.95	2.55	6.38	9.91
COV	18.7%	28.9%	28.1%	22.4%	43.8%
Lower 5%	3.56	27.16	5.85	19.54	9.64
Average MC	14.2%	14.0%	14.0%	12.0%	12.6%

5. Comparisons and Conclusions

Testing was conducted to assess mechanical properties for MOR, MOE, shear beam strength, tension strength parallel-to-grain and compressive bearing strength parallel-to-grain according to methods described in AS/NZS 4063.1:2010 of Lusitanica and Lawson Cypress timber. All tested timber was graded and supplied by Dean Satchell of the New Zealand Farm Forest Association. Previous sections describe testing, results, and typical failure modes for the different configurations. Adequate sample set sizes were tested to allow for statistical analyses of the results for determining average and characteristic (lower 5th percentile) strength and stiffness values.

In order to compare these species with currently accepted species mechanical properties, Table 11 provides published values for characteristic stresses for visually graded Radiata Pine and Douglas Fir taken from NZS3603:1993 Table 2.2 which was updated as part of Amendment 4 in March 2005. The comparisons show that Lawson Cypress has greater stress values than all No. 1 Framing Radiata Pine values except beam shear strength, where it is 0.4 MPa lower. In comparison to No. 1 Framing Douglas Fir, Lawson Cypress has greater stress values for all listed mechanical properties. Lusitanica has greater stress values than all No. 1 Framing Radiata Pine values except beam shear strength, where it is 0.2 MPa lower. In comparison to No. 1 Framing Douglas Fir, Lusitanica has greater stress values for all listed mechanical properties. In Table 11 it can also be seen that except for shear, both Lusitanica and Lawson Cypress have strength and stiffness values that are greater than Radiata Pine Grade VG8 and Douglas Fir Grade VG8. Both tested species have greater shear strength that Douglas Fir for all grades.

In terms of beam shear strength, it is reiterated that the testing method acknowledges that in cases where the failure of shear specimens is not shear, but rather bending, the calculation of maximum shear stress will be conservative. It was observed that approximately 90% of shear specimens failed in bending, thus the beam shear strength of Lawson Cypress and Lusitanica are likely to be equivalent to all grades of Radiata Pine, but this would require some additional testing to validate.

It was also noted that the moisture content values obtained for the Lawson Cypress specimens all tended to be higher than those for Lusitanica, and this was particularly evident for shear and flexure specimens. It is was noted during grading that the Lawson Cypress samples were greasy to the touch and emitted a distinct odour, and it was postulated that some extractives could have been dried off during the later process of oven drying, resulting in the higher moisture content values because the oven dried specimens would weigh less with both the water and extractives gone.

Table 11. Comparisons of Lawson Cypress and Lusitanica Characteristic Mechanical Properties with Visually Graded Dry Radiata Pine and Douglas Fir No. 1 Framing from NZS 3603:1993 Table 2.2 (Amendment 4, March 2005).

Species (Grade)	Shear (MPa)	MOR (MPa)	MOE* (GPa)	Compression (Mpa)	Tension (Mpa)
Lawson Cypress	3.4	29.7	8.5	23.4	13.9
Lusitanica	3.6	27.2	9.1	19.5	9.6
Radiata Pine (No. 1 Framing)	3.8	10.0	6.0	15.0	4.0
Douglas Fir (No. 1 Framing)	3.0	10.0	6.0	15.0	4.0
Radiata Pine (VSG8)	3.8	14.0	8.0	18.0	6.0
Douglas Fir (VSG8)	3.0	14.0	8.0	18.0	6.0

*Average values of MOE are provided for Lusitanica and Lawson Cypress

Based on testing conducted and subsequent analyses, it is proposed that the strength and stiffness values provided for Lusitanica and Lawson Cypress through this testing programme would be suitable for use by engineers for the design of timber structures.