MECHANICAL PROPERTIES OF LAMINATED VENEER LUMBER (LVL) MADE OF SECONDARY QUALITY OAK AND BEECH: THE EFFECT OF VENEER THICKNESS

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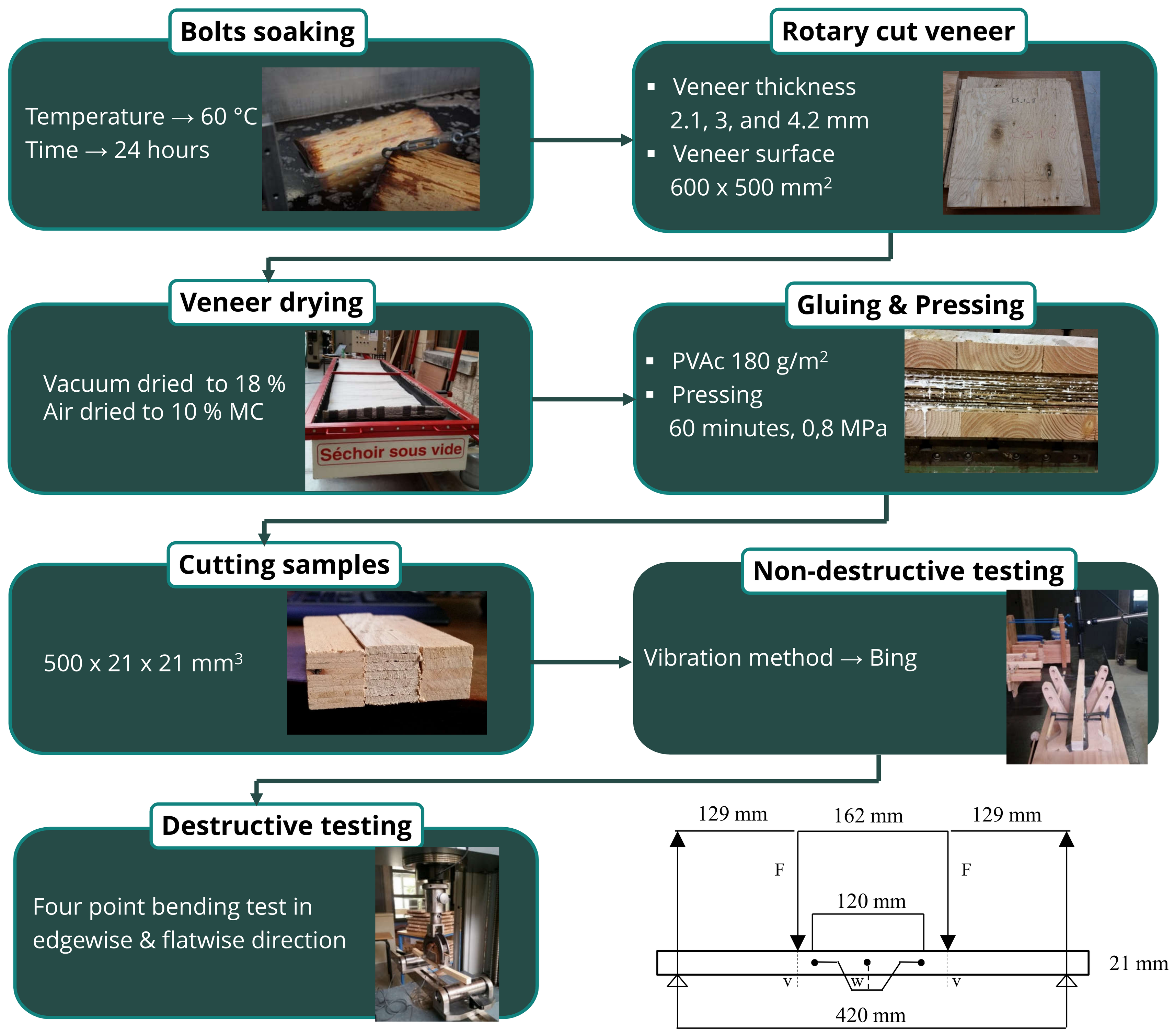
ABSTRACT

The first objective of this work was to evaluate the mechanical properties of laminated veneer lumber (LVL) made of secondary quality beech and oak. The second objective of this paper was to study the influence of veneer thickness on LVL mechanical properties and to propose an adapted veneer thickness that provides optimum mechanical properties. Forty-eight LVL boards were manufactured from three different veneer thickness and glued using polyvinyl acetate (PVAc). Static MOE, Dynamic MOE, MOR, and shear modulus were measured using destructive and non-destructive methods. The shear modulus was decreasing with the increase of veneer thickness. The LVL made of 3 mm thick veneer provide the optimum mechanical properties for both hardwood species. This choice was made by considering the measured mechanical properties and its variation.

INTRODUCTION

Young thinning, top wood and early harvested wood are secondary resources that have great potentials for high-value applications. The presence of various wood defects such as knots, grain deviation, juvenile wood, and reaction wood is restricting the utilization of this resources for structural application. Laminated Veneer Lumber (LVL) is a wood-engineered product manufactured from rotary peeled veneer glued together with the grain orientated mostly parallel to the board length. LVL is usually used for the structural and nonstructural application such as flooring, furniture, and construction. Compared to solid wood, LVL has fewer defects, more stable in dimension, available in large dimension, and provide higher stiffness and strength compared to solid wood. The first objective of this work was to evaluate the mechanical properties of the LVL made of secondary quality beech and oak. Most of the previous studies in hardwood LVL were performed using knot-free veneer. Another objective was to study the effect of veneer thickness on LVL mechanical properties and to propose an adapted veneer thickness that gives optimum mechanical properties. A compromise between the lathe checks properties generated from veneering and the knot proportion from secondary quality veneer was expected.

MATERIALS AND METHODS



Test arrangement for 4 point bending test

RESULTS

LVL mechanical properties measured using destructive test

Veneer (mm)	LVL density (kg/m³)		Local MOE (GPa)		Local SMOE (MNm/kg)		Global SMOE (MNm/kg)		MOR (MPa)		SMOR (MPa)	
	fw	ew	fw	ew	fw	ew	fw	ew	fw	ew	fw	ew
Oak												
2.1	753.2	748.3	10.5^{a}	10.6^{a}	14.0^{a}	14.1^{a}	12.3^{a}	13.2^{ac}	59.3^{ac}	61.9^{bc}	0.08^{ac}	0.08^{ac}
	(30.2)	(29.6)	(1.8)	(1.7)	(2.5)	(2.3)	(2.2)	(1.6)	(12.2)	(9.3)	(0.02)	(0.01)
3	752.5	754.4	13.4^{bc}	13.6^{c}	17.8^{bc}	18.1^{c}	14.1^{bc}	14.7^{c}	63.4^{c}	68.2^{c}	0.08^{ac}	0.09^{c}
	(36.9)	(37.2)	(1.8)	(1.8)	(2.6)	(2.8)	(2.5)	(1.6)	(14.1)	(10.2)	(0.02)	(0.01)
4.2	733.1	726.2	10.6^{a}	11.1^{ab}	13.9^{a}	15.4^{ab}	11.6^{a}	12.9^{ac}	51.1^{a}	53.3^{ab}	0.07^{a}	0.07^{ab}
	(32.8)	(39.1)	(2.5)	(2.6)	(4.7)	(4.1)	(3.2)	(1.9)	(11.1)	(11.2)	(0.02)	(0.02)
Beech												
2.1	736.5	732.7	10.6^{a}	10.1^{a}	14.3^{a}	13.7^{a}	12.7^{abc}	12.1^{a}	68.4^{ab}	62.9^{a}	0.09^{a}	0.07^{a}
	(31.6)	(35.6)	(1.4)	(1.5)	(1.7)	(1.8)	(1.2)	(1.1)	(9.2)	(8.4)	(0.01)	(0.01)
3	749.3	768.3	13.2^{bc}	12.8^{b}	17.7^{b}	16.4^{ab}	14.8^{d}	13.6^{bd}	72.0^{ab}	72.2^{ab}	0.10^{a}	0.09^{a}
	(63.8)	(68.4)	(2.3)	(1.9)	(3.4)	(3.7)	(2.3)	(3.1)	(12.1)	(20.2)	(0.02)	(0.02)
4.2	707.8	700.1	13.8^{cd}	13.9^{d}	18.8^{b}	18.4^{b}	13.8^{bd}	13.7^{ad}	64.2^{ab}	65.0^{ab}	0.09^{a}	0.09^{a}
	(34.4)	(35.0)	(2.6)	(1.7)	(5.84)	(6.5)	(1.3)	(0.8)	(11.8)	(5.6)	(0.02)	(0.01)

Different letters on the top of the numbers signifies statistically different populations, based on posthoc Tukey's HSD tests ($p < 0.05$).

Linear regression equations and correlation coefficients (y = global MOE, x = dynamic MOE, r^2 = coefficient of determination)

Veneer (mm)	Flatwise		Edgewise	
	linear equation	r^2	linear equation	r^2
Oak				
2.1	y=4480+0.364x	0.12	y=469+0.75x	0.9
3	y=668+0.70x	0.23	y=-4140+1.08x	0.82
4.2	y=498+0.72x	0.37	y=-1810+0.93x	0.85
Beech				
2.1	y=2280+0.62x	0.56	y=85.6+0.79x	0.9
3	y=2410+0.648	0.82	y=890+0.74x	0.84
4.2	y=678+0.75x	0.67	y=2470+0.57x	0.66

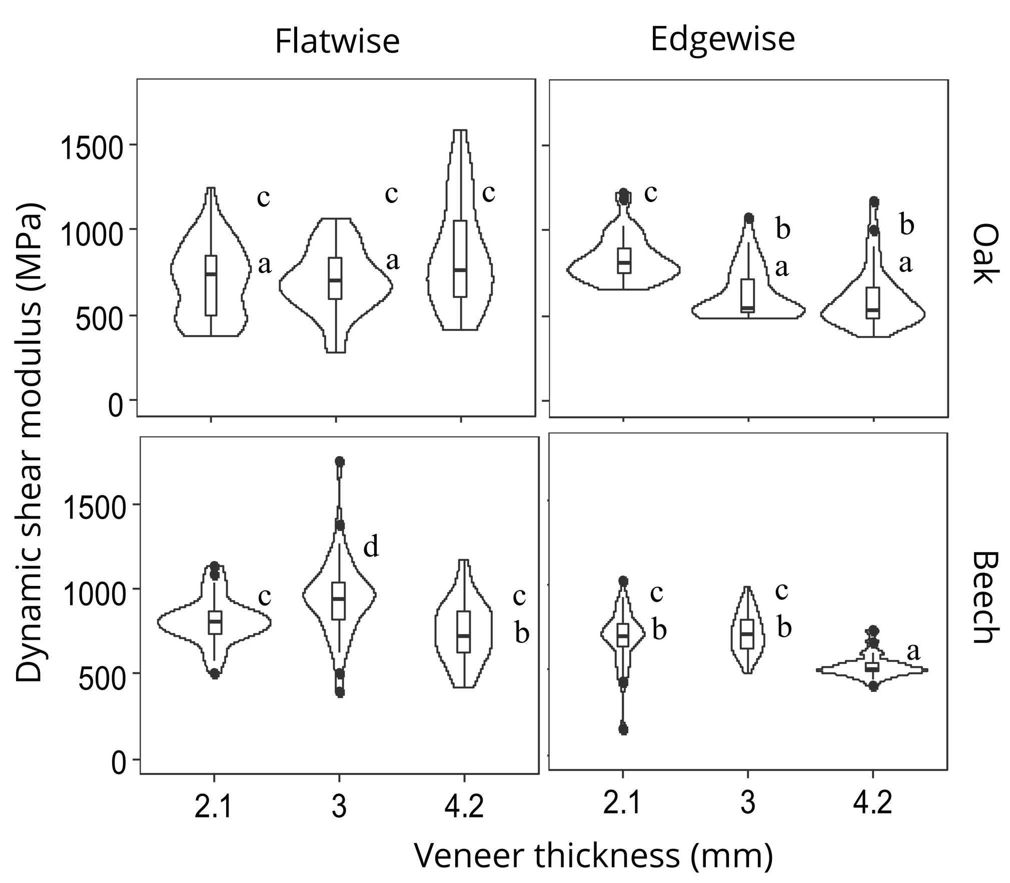
Linear regression equations and correlation coefficients (y =MOR, x = dynamic MOE, r^2 = coefficient of determination)

Species	Test direction	Linear equation	r^2
Oak	Flatwise	y= 0.0038x + 8.61	0.22
	Edgewise	y= 0.0057 - 12.97	0.59
Beech	Flatwise	y=0.0039x + 20.27	0.38
	Edgewise	y=0.0040x + 17.23	0.80

Linear regression equations and correlation coefficients (y =MOR, x = global MOE, r^2 = coefficient of determination)

Veneer (mm)	Flatwise		Edgewise	
	linear equation	r^2	linear equation	r^2
Oak				
2.1	y=-6.53+0.007x	0.81	y=-2.89+0.006x	0.68
3	y=-7.13+0.006x	0.74	y=-30.9+0.008x	0.88
4.2	y=9.68+0.004	0.37	y=-15.9+0.007x	0.78
Beech				
2.1	y=7.7+0.006	0.35	y=-3.22+0.007x	0.76
3	y=3.27+0.006	0.68	y=0.411+0.006x	0.80
4.2	y=-24.8+0.00911	0.33	y=27.6+0.003x	0.17

Dynamic shear modulus of beech and oak LVL by different veneer thickness and testing direction



CONCLUSIONS

Different veneer thickness inside the LVL generated different mechanical properties. The shear modulus was decreasing with the increase of veneer thickness. LVL made from 3 mm thick veneer produce the optimum MOE and MOR in both species on both test direction. This choice was made by considering the measured mechanical properties and its variation. Dynamics MOE has a more significant correlation with MOE global than MOE local. MOR has a higher correlation with MOE global.

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