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A COMPARATIVE STUDY ON SOME MECHANICAL PROPERTIES OF STRUCTURAL COMPOSITE LUMBERS (SCL) PRODUCED FROM POPLAR (*Populus Tremula* L.) PAPELS

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Abstract

In this study, it was aimed to determine some mechanical properties of Laminated Veneer Lumber (LVL), Parallel Strand Lumber (PSL) and Laminated Strand Lumber (LSL), which are called structural composite lumbers (SCL). For this purpose, SCLs were produced from poplar (*Populus tremula* L.) strands. In the tests, modulus of rupture (MOR) and modulus of elasticity (MOE) according to TS EN 310, compression strength parallel to grain according to TS 2595, dynamic bending (shock) strength in accordance with TS 2477, tensile strength parallel to surface and perpendicular to surface according to procedure of ASTM D 1037-06a were determined. The differences of MOR, compression strength and dynamic bending strength values were statistically significant. Better mechanical properties were obtained in LVL samples. These results showed that the usage of PSL and LSL can be an alternative to LVL in furniture production and building sector. But especially in load bearing application, the usage of LVL was advised for not only its better mechanical properties, but also its easier manufacturing process. Although manufacturing process of LSL or PSL is more complex, the possibility of usage of waste of veneer industry makes them a cost-effective alternative to LVL and solid timber.

Key Words: Wood materials, Structural composite lumbers (SCL), mechanical properties, laminated wood material Laminated Veneer Lumber (LVL), Paralel Strand Lumber (PSL), Laminated Strand Lumber (LSL)

1. Introduction

Wood material is one of the oldest construction materials in the building sector, and has been widely used to build a variety of structures because of its availability in most parts of the world and its light weight, compared to materials such as concrete and steel [1]. Worldwide economic growth and development have generated unprecedented needs for covered forest products such as pulp and paper composite boards, plywood and lumber [2]. Long and curved forms may not be manufactured from solid wood due to production difficulties and economic reasons [3]. Furthermore, the diminished supplies of larger dimension timbers have created high pricing. Throughout this change, the industry is forced to identify alternative lignocellulosic sources, and make improvements in traditional production methods [2]. These developments paved the way for production of structural composite lumbers.

Structural composite lumber is often referred to as SCL. Product examples include laminated veneer lumber (LVL), parallel strand lumber (PSL), and laminated strand lumber (LSL) [4]. The manufacture of these products essentially requires the use of exterior grade wood adhesives such as phenol–formaldehyde (PF) resin, resorcinol–formaldehyde (RF) resin, or melamine–formaldehyde (MF) resins. They are mainly used due to their high moisture resistance in outdoor environment [5].

LVL has been developed as an alternative to solid wood. It has large surfaces, and is produced from small sized veneers by bonding. Detailed information on production techniques, technological properties, advantages and disadvantages of these types of panel products can be found in literatures [6, 7].

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LSL is a composite structural material consisting of oriented wood flakes that are glued and compressed to form panels up to 90 mm thick. This material is an attractive alternative to solid sawn lumber, because it has stronger properties than solid lumber of the same species as well as less variability. It can be produced from smaller diameter and low-quality trees, thereby reducing our dependence on old growth forests. LSL can be produced for specific final properties by controlling variables related to the stranded lumber, the resins, and the pressing cycle. The material properties of LSL are dependent on the density of the panel, the strand species, and the orientation of strands [8].

PSL is made from 3-mm thick veneers, which is cut as 100–300 mm in length and 20 mm in width. Adhesive is applied, and blocks are pressed under high pressure in a continuous process. Beams of desired dimensions are cut from the blocks. LSL is similar to PSL; however, long and slender strands are cut directly from whole logs in special machines equipped with rotating knives. LVL is closely related to plywood, and is produced in larger quantities than PSL and LSL [4].

Most of the previous researches about SCLs have been focused on LVLs. Hunt and Suddarth [9], Hoover et al. [10], McNatt et al. [11] and Moses et al [12] studied on the effects of strand orientation on the properties of SCLs. Gupta and Siler [13], Hindman et al [14], Harrison and Hindman [15] and Yeong and Hindman [16] investigated the elastic constant of SCLs. According to these studies, elastic properties of SCLs were affected by the size of the specimen, strand orientation and, the type of bending test set up.

Physical and mechanical properties of SCLs are affected strongly by strand dimensions and geometry. The technological properties of SCLs are important for their application. In this study, it was aimed to determine some physical and mechanical properties of SCLs (LVL, PSL and LSL), produced from poplar (*Populus tremula* L.) strands. For this purpose, humidity, density, modulus of rupture (MOR) and modulus of elasticity (MOE), compression strength parallel to grain, dynamic bending (shock) strength, tensile strength parallel to surface and perpendicular to surface of timbers were determined.

2. Material and Method

In this study, to manufacture SCLs poplar (*Populus tremula* L.) veneers were supplied from SETA Inc. in Tokat in Turkey. Commercial grade phenol formaldehyde (PF) adhesive, which was supplied from Polisan in Izmit in Turkey was used. According to the producer, the density of the PF adhesive was between 1.195 and 1.205 kg/m^3 at 20 °C, its viscosity was 250–500 mPa s (cP) at 20 °C, its gel time was 10–20 s and its pH was 10.5–13.

2.2. Method

2.2.1. Preparation of test samples

The veneers were acclimatized for 2 months at 55 ± 2 °C and % 6 ± 1 relative humidity to 3 % equilibrium moisture of content. The veneers having 3 mm thicknesses were used for making six-layered LVLs. The adhesive was spread on one surface of veneers by using a roll. The spreading rate of adhesive was 6% by weight in proportion to dry veneer weight to manufacture LVLs. Veneers were bonded at 180 ± 3 °C under 30 kg/cm^2 pressure for 7 minutes according to ASTM D 5456 [17] by using a laboratory scale hydraulic-press.

PSLs were produced from 3 mm thick veneers cut as 600 mm in length and 20 mm in width. LSLs were made from 1.2 mm thick veneers cut as 300 mm in length and 20 mm in width. The pressing conditions for both PSLs and LSLs were the same with LVLs samples. Before preparing the test specimens SCLs were acclimatized at 20 °C and 65% relative humidity.

2.2.2. Test method

TS 2471 and TS 2472 standards were used to determine moisture contents (MC) and the specific gravity values of SCLs. [18, 19]
Modulus of rupture (MOR) and modulus of elasticity (MOE), compression strength parallel to grain, dynamic bending (shock) strength, tensile strength parallel and perpendicular to surface were carried out according to EN 310, TS 2595, TS 2477, and ASTM D 1037-06a standarts, respectively[20,21,22,23]. All tests were conducted using a computer controlled universal testing machine.

2.2.3. Statistical Evaluation

The comparison of some technological properties of SCLs, depended on the results of analyses of variance (ANOVA). When the difference between groups was found to be significant, Duncan Test was used to determine the difference between means at prescribed level of α=0.05. Statistical values, which are ANOVA, Mean, Standard deviation values were calculated by the SPSS 15 software.

3. Results and Discussion

Specific gravity and moisture of content values of LVL, LSL and PSL samples were given in Table 1.

Table 1. Physical properties of SCLs

SCL	Specific Gravity (g/cm^3)	Moisture of Content (%)
Control	0.34	11.51
PSL	0.44	8.13
LSL	0.50	8.34
LVL	0.40	8.00

Table 2 Summarizes the mechanical properties of SCLs and solid poplar wood

Table 2. Mechanical properties of SCLs

Properties of SCLs		Control	LVL	LSL	PSL
Modulus of rupture (N/mm^2)	Mean	58.26	64.51	61.83	60.23
	SD	(3.63)	(5.93)	(3.37)	(5.22)
	P=0.03	b	a	ab	ab
Modulus of elasticity (N/mm^2)	Mean	7863.21	7907.20	8022.48	7864.55
	SD	(384.24)	(914.87)	(405.81)	(591.45)
	P=0.98	-	-	-	-
Compression Strength parallel to grain (N/mm^2)	Mean	33.63	49.87	41.91	43.85
	SD	(3.53)	(2.50)	(4.49)	(2.45)
	P=0.00	c	a	b	b
Dynamic bending (shock) strength (kgm/cm^2)	Mean	0.34	0.46	0.40	0.50
	SD	(0.09)	(0.05)	(0.07)	(0.03)
	P=0.00	d	b	c	a
Tensile strength parallel to surface (N/mm^2)	Mean	25.87	25.97	26.04	25.88
	SD	(1.62)	(1.32)	(1.24)	(2.46)
	P=0.99	-	-	-	-
Tensile strength perpendicular to surface (N/mm^2)	Mean	757.34	805.01	775.88	796.66
	SD	(129.55)	(101.06)	(78.41)	(98.19)
	P=0.73	-	-	-	-

Control: Solid poplar wood.
P: probability values according to results of variance analysis.
lowercase letters indicates homogeneity groups according to Duncan test. Same letters indicate same homogeneity groups.

In the comparisons of the average value of MOR in Table 2, the highest value was obtained in LVL samples as 64.51 N/mm^2. But, there was not an important difference statistically between LVL, LSL or PSL samples. Also the difference between control samples and PSL or LSL samples was not important. The highest MOE was obtained in LSL samples as 8022.48 N/mm^2. But there was not statistically a significant difference between SCLs or control samples (P=0.98). Colak et al.[24], Aydın et al. [25], Kilic and Celebi [26]; and Hindman et al., 2006 [14] reported various MOR and MOE values for LVL samples, but it is not proper to compare these results because of variety of sample and test set up. Hindman et al. [14] reported that MOE for LSL as 12600 N/mm^2 and MOE for PSL as 12400 N/mm^2, but these results are not comparable owing to different samples sizes.

Compression strength is a reaction against forces aimed at squeezing and crushing the wood material. Among the structural system elements of construction, such as upright wooden beams, props, the perpendicular components of wooden window joining, furniture legs, and perpendicular space-dividing panels are the elements subjected to compression load [26]. The highest compression strength parallel to grain value was obtained in LVL samples as 49.87 N/mm^2, and the lowest value was obtained in control samples as 33.63 N/mm^2. It was due to lower density of control samples. Existence of adhesive line in samples increased the compression strength of SCLs. There was not a statistically significant difference between PSL and LSL for compression strength although they were higher than control samples. It may be due to relatively small test samples for SCLs. Compression strength of LVL was higher than that of LSL and PSL. It may be caused by splice line of strands in PSL or SCL. Kilic and Celebi [26] reported 51.02 N/mm^2 in compression strength for composite beech and poplar LVL bonded with PVAc adhesive. Similarly Aydin et al. [25] reported 55.3 N/mm^2 for beech LVL bonded with urea formaldehyde adhesive. These results are higher than that of this study because of higher densities of both LVL samples in these previous studies. Also it is incomparable these values because of the differences in structure of samples and test conditions.

When the SCLs were evaluated among themselves, the highest value of dynamic bending (shock) strength was found for PSL as 0.50 kgm/cm^2, whereas the lowest value was found for control samples as 0.34 kgm/cm^2. It was observed that there is statistically a significant difference in all SCLs and control samples. Higher densities of SCLs caused an increase in dynamic bending strength. Although the density of LSL was higher than that of PSL, dynamic bending strength of PSL was higher than that of LSL. It may be caused by longer and thicker strand of PSL samples. No information was found in the literature about dynamic bending strength of SCLs to compare the results obtained in this study.

In the comparisons of the average value of tensile strength parallel to surface, there was not found any statistically significant differences among the SCLs (P=0.99). All the results were almost the same. It can be said that tensile strength parallel to surface of SCLs is mainly depend on tensile strength of poplar wood itself. In point of tensile strength perpendicular to surface, although there were differences among SCLs, these differences were statistically not important (P=0.73). It may be due to good bonding for all the SCL samples.

4. Conclusion

Mechanical properties of structural composite lumbers were higher than that of solid trembling poplar. It is determined that differences of modulus of elasticity, tensile strength parallel to surface and tensile strength perpendicular to surface were statistically not important. But it can be said that LVL has better mechanical properties than the others. These results showed that the usage PSL and LSL can be an alternative to LVL in furniture production and building sector. But especially in load bearing application, the usage of LVL is advised for not only its better mechanical properties but also its easier manufacturing process. Waste of timber or veneer industry may be use the produce LSL or PSL. This possibility may make them a cheaper alternative to LVL.

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