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MANUFACTURING OF PARALLEL STRAND LUMBER (PSL) FROM ROTARY PEELED HYBRID POPLAR I-214 VENEERS WITH PHENOL FORMALDEHYDE AND UREA FORMALDEHYDE ADHESIVES

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ABSTRACT

Hybrid poplars are becoming an alternative raw material for structural applications due to their availability, treatability and prices. Advance technology of structural composite lumber (Laminated veneer lumber, laminated strand lumber and parallel strand lumber) manufacturing process may use hybrid poplar more efficiently. Parallel strand lumbers (PSLs) were manufactured from rotary peeled hybrid poplar I-214 veneers with phenol formaldehyde (PF) and urea formaldehyde (UF) adhesives. The effect of adhesive types on selected PSLs' physical and mechanical properties were investigated. Also the suitability of hybrid poplar I-214 was determined in PSLs' production. The physical and mechanical properties of PSLs' were affected by adhesive type. PSLs' with PF adhesives have better physical and mechanical properties as expected due to PF adhesives superior performance. PSLs' mechanical properties were higher than that of host solid woods'. Hybrid poplar I-214 was found to be suitable for the PSL production. The research is aimed to provide scientific data for PSLs' use in exterior and interior use for structural applications.

KEYWORDS: Hybrid poplar, I-214, parallel strand lumber, phenol formaldehyde, urea formaldehyde, structural applications.

INTRODUCTION

Hybrid poplar (*Populus*) species have been commercially grown on farmlands to provide a fast-growth raw material source (Banoun et al. 1984, Allig et al. 2000) for forest based industries. Hybrid poplar I-214 (*Populus* x *Euramericana Canadensis*) is one of the well known fast growing poplar clone in Turkey as well as in the world. Agricultural intercropping under hybrid poplar I-214 plantations is widely carried out usually by small farmers in the coastal and immediate coastal regions in Turkey (Diner and Kocer 2002). Annual commercial poplar wood production in Turkey is about 3.6 million cubic meters, half of which comes from hybrid poplar I-214 (Zoralioglu and Kocer 1996). It provides raw material for variety of uses in the forest products industry including pulp, paper, wood composites, packaging, pallets and moldings.

Hybrid poplar use for pulp and paper industry has declined and prompted interest in finding alternative value added market for this low density timber (Stanton et al. 2002). It is being considered to use in the area of structural composite lumbers (SCLs) manufacturing such as laminated veneer lumber (LVL), laminated strand lumber (LSL) and recently parallel strand lumber (PSL). Numerous investigations are being done to improve the utilization of poplar wood in engineered wood and wood composite panel products (Lowood 1997, Wu et al. 1998, Ozarska 1999, Wang and Ping 2005, Kurt and Mengeloglu 2002). With the introduction of SCLs and other engineered wood products, the utilization of poplar will increase (Kurt and Mengeloglu 2008).

SCLs can be defined as products manufactured by bonding together veneer sheets (for manufacturing LVL and PSL) or strands (for manufacturing LSL and oriented strand lumber (OSL) or other small wood elements (for manufacturing scrimber) with exterior structural adhesives to form lumber like structural products (Nelson 1997). Increasing demands for structural materials coupled with decreasing quality and quantity of raw materials are forcing the industry to introduce short rotation trees having unfavorable properties into the manufacturing processes (Bejo and Lang 2004). Using fast growing species for manufacturing SCLs is beneficial, it offers solution to the main problem of the wood products industry to develop products using forest resources efficiently since the availability and quality of timber are becoming worse.

Increasing demand for high quality structural lumber has accelerated the development of new strand based structural composite lumber (Wu et al. 1998). One of the important strand based SCL is PSL that have advantages over LVL since the wood utilization of PSL is 64 % that is higher than that of LVL's (52 %) and PSL permits the use of round up, fish tail and other pieces of less than full width veneer (Nelson 1997). Also, the process can use waste material from a plywood and LVL operation (Moody et al. 1999).

PSLs are manufactured by laminating rotary peeled veneer strands that are oriented in the same grain direction to form a material of thickness similar to sawn lumber with a waterproof adhesive (typically phenol resorcinol formaldehyde) (Nelson 1997). PSLs manufacturing is not the same as laminated strand lumber (LSL) manufacturing since in the LSL manufacturing, strands are used instead of veneer strands.

PSLs are commonly manufactured from Douglas fir, southern pine, western hemlock, yellow poplar (Nelson 1997). The use of Japanese cedar (Suzuki 2005) aspen, Dahurian larch, birch (Zhu 2001), rubber wood (Shukla et al. 1999), bamboo strips (Fan et al. 1995) were reported. Other species can be used including off-grade and fast growing species such as hybrid poplar. During the PSLs production, it is possible to eliminate, minimize and disperse veneer defects due to knots, shakes or drying. In addition, veneers can be positioned according to their grade, species and defects.

There are two important steps of PSLs production that determines the strength and quality of the final product. These are selecting wood/veneer and adhesive application. Selection of wood/

veneer step includes its species, quality, physical, mechanical properties and the availability to treatment and durability. Adhesive selection is another important factor in the PSLs production. It depends on the exposure conditions, end use, manufacturing conditions, technology, dimensions, treatment order, and design requirements of PSLs. For exterior exposure conditions, phenol formaldehyde (PF) adhesives and for interior exposure conditions urea formaldehyde (UF) adhesives can be used. PSL can be used for structural and non-structural purposes in residential, commercial, industrial, educational, bridges and other purposes.

Compare to LVL, the published research papers with regard to PSLs are very limited (Liu and Lee 2003). Very little research has been carried out on the utilization of different hybrid poplar clones for PSL manufacturing for structural applications. The objectives of this study are to manufacture PSLs from rotary peeled hybrid poplar I-214 veneers with PF and UF adhesives in the laboratory and to determine the effect adhesive type on selected PSLs' physical and mechanical properties. Their properties were compared to with those of solid hybrid poplar I-214 (*Populus* x *Euramericana Canadensis*) wood. The values of solid hybrid poplar I-214 wood values' are reported by Tunctaner et al. (2004) and Yildiz et al. (2005). Also, the study is aimed to contribute information on suitability of hybrid poplar in production of PSL. PF and UF adhesives usage for the production of PSLs can provide scientific data for PSLs' use in exterior and interior conditions respectively.

MATERIAL AND METHODS

The PSLs used in this study were manufactured using rotary peeled hybrid poplar I-214 (*Populus* x *Euramericana Canadensis*) wood veneers. Logs were only debarked prior to peeling, they were not steamed. The logs were rotary peeled into 600 mm long by 600 mm wide by 3 mm thickness veneers. For the production, strands were made by clipping veneers into average dimension of 600 mm long by 19 mm wide. The average moisture content of dried veneers varied between 6 - 8 % before manufacturing. The veneer strands were pre-selected for strength and appearance. They were without any stain, decay and fungi and they were also free of splits, knots and knot holes.

A commercial PF adhesive (47 ± 1 % solid) and UF adhesive (65 ± 1 % solid) were used. Their specification is given in Tab. 1 (Polisan Ltd 1999). The adhesive was spread using a glue spreading machine and the spreading rate was 400 $g.m^{-2}$. The gram weight pick up was calculated according to procedures described in ASTM D899.

Tab. 1: Specification of the phenol formaldehyde and urea formaldehyde adhesives

Specifications	PF	UF
pH at 20°C	10.5-13	8.5-9.5
Viscosity at 20°C (cps)	250-500	500-1000
Specific Gravity at 20°C	1.2	1.3
Solid Content (%)	47 ± 1 %	65 ± 1 %
Water Tolerance at 20°C	Unlimited	Limited
Hardener (%)	None	10 % NH_4Cl
Appearance	Red	Half transparent

To manufacture PSL, adhesives were spread to veneer strands (Fig. 1) and they were immediately assembled with the tight side facing out on each veneer. Billets were hot pressed with their grain directions parallel to each other for 1 min.mm^{-1} at a temperature of 110 °C (for UF) - 150 °C (for PF) and pressure of 1.7 MPa. Squeeze outs were observed for a glue line quality on both sides. After the pressing period, PSLs were sized to length, width and thickness (500 x 500 x 35 mm) using a circular saw. General views of manufactured PSLs are given in Fig. 2. PSLs were conditioned in an environmentally controlled room in relative humidity of 60 ± 5 % and temperature of 23 ± 2 °C until they reached the equilibrium moisture content of 12 %. For each type of adhesive 15 PSLs were manufactured yielding a total of 30 PSLs for selected physical and mechanical tests.

Oven dry specific gravities (30 (long) x 20 x 20 mm) and dimensional stability (thickness swelling and water absorption) (152 (long) x 152 x 25.4 mm) values of PSLs were determined in accordance with TS 2472 and ASTM D1037 respectively. Modulus of rupture (MOR) (perpendicular to grain) (300 (long) x 20 x 20 mm), modulus of elasticity (MOE) (perpendicular to grain), compression strength (CS) (parallel to grain) (60 (long) x 20 x 20 mm) and hardness (HA) (Janka, parallel to grain) (50 (long) x 50 x 30 mm) values were determined according to procedures described in TS 2474, TS 2478, TS 2595 and TS 2479 respectively. The specimens were tested for bending, compression strength and hardness using a Zwick Roell (Z010) testing machine.

Analysis of variance (ANOVA) is used to determine the effect of adhesive type on selected physical and mechanical properties of PSLs using SAS statistical package program (SAS Institute 2001). The resulting F value is compared to the tabular F value at the 95 % probability level. When there is a significant difference as a result of F tests, comparisons between means are made by Bonferroni (Duncan) t-test.

RESULTS AND DISCUSSION

The mean SG values of PSL with PF and UF adhesives were 0.64 and 0.62 respectively. The values of PSLs are given in Tab. 3 along with SG values of solid hybrid poplar I-214 wood. The specific gravities of PSLs are higher than that of solid hybrid poplar I-214 woods due to the effects of high pressure during manufacturing process. Also, the anatomical features of poplar might also contribute to that situation.

Thickness swelling (TS) and water absorption (WA) values are expressed as a percent for PSL specimens after a 2 plus 22 h (total 24 h) submersion are given in Tab. 2. The mean TS (24 h) values of PSL with PF and UF adhesives were 6.79 % and 15.11 % respectively. PSLs with PF adhesives show least TS and WA values after 2 plus 22 h submersion. F test was used to compare their variances at 0.05 significance level. The result of F test showed that there was a significant difference between TS and WA mean values ($p<.0001$) because of the adhesive type and thus their Bonferronni groupings are different. PSL with UF adhesives have higher TS and WA values. The low dimensional stability values of PSL with UF adhesives are due to their low sensitivity to moisture compare to PF adhesives. In addition, PF adhesives' resonant stability of the benzene ring and carbon-to-carbon bonds formed in polymerization play important roles (Marra 1992). The panel bonded with UF adhesives under exterior conditions was not as resistant as the panel bonded with PF adhesives (Pizzi 1993).

Strength properties (MOR, MOE, CS and HA) mean values including their standard deviations of PSLs are given in Tab. 3 along strength values of solid hybrid poplar I-214 woods. The mean MOR, MOE, CS and HA values of PSLs with PF adhesives are: 89.32, 7061.26, 52.52 and

50.89 N.mm^{-2} respectively. The mean MOR, MOE, CS and HA values of PSLs with UF adhesives are: 70.88, 5719.96, 44.89 and 42.16 N.mm^{-2} respectively.

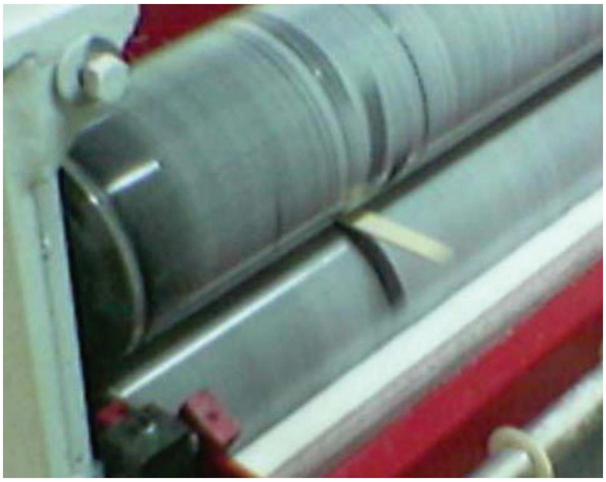

Fig. 1. Gluing strands in the gluing machine

Strength properties of PSLs with PF adhesives are much higher than those of PSLs with UF adhesives due to PF adhesives superior performance compare to UF adhesives. The main reason is attributed to PF adhesives' excess formaldehyde that facilitates a cross linking density results high tensile strength (Baldwin 1995). F test results (p<.0001) showed that mean strength values of PSLs' are affected by the adhesives type and thus their Bon groupings are different. The adhesive had a significant effect on the overall behavior of wood (Wu et al. 1998).

Fig. 2: A general views of manufactured PSLs

The strength properties of PSLs' are higher than those of their host solid hybrid poplar I-214 woods'. Most of the mechanical properties of wood are correlated with specific gravity (Bodig and Jayne 1982). Its increase results an increase in mechanical properties. Densifications play the most important role in PSLs increased specific gravities. The results are in agreement with Liu and Lees' (2003) study. In PSL productions, strength is enhanced by increasing the amount of densification instead of layering veneer strands by grade as in laminated veneer lumber production (Nelson 1997). Also, PSL reduces variations of the host solid wood and can be considered as better alternative to solid sawn lumber for structural applications (Liu and Lee 2003). Strength properties values of PSLs are comparable to that of commonly used softwoods (pine, fir, spruce).

Values of MOR and CS of poplar PSLs' produced in this study are comparable to the values of MOR (80.2 $N.mm^{-2}$ for PSL manufactured from southern pine and 87.5 $N.mm^{-2}$ for PSL manufactured from yellow poplar) and CS (54.2 Nmm^{-2} for PSL manufactured from southern pine and 48.6 $N.mm^{-2}$ for PSL manufactured from yellow poplar), but MOE (11790 $N.mm^{-2}$ for PSL manufactured from southern pine and 9721 $N.mm^{-2}$ for PSL manufactured from yellow poplar) values are lower than that of reported in the literature (Yihai and Lee 2003). The results show that the technology can be considered to use in manufacturing poplar PSL alternative to commonly used and manufactured southern pine and yellow poplar PSLs.

CONLUSIONS

Rotary peeled hybrid poplar I-214 veneers were used to manufacture Parallel strand lumber (PSL) with PF and UF adhesives. PSLs with PF adhesives gave higher values since PF is considered structural adhesive that is suitable for exterior conditions. Selected mechanical properties of PSLs were higher than that of host solid hybrid poplar I-214 woods'.

Hybrid poplar wood utilization in forest products industry is an important issue since timber resources for structural wood materials are getting scarce. Alternative use fast growing hybrid poplar wood will provide relatively inexpensive and sustainable source of material to the industry. The findings provide a unique opportunity to produce to replace structural wood use in some applications PSL in countries where poplar and other fast growing species are common. Utilization of hybrid poplar resources for PSL production may be one of the important solutions concerning raw material economy. To promote more usage of hybrid poplar in PSL productions, more information is needed regarding the durability of the material and also promotion, advertisement and market research. Further research is necessary to find the optimum manufacturing parameters. Several other clones of hybrid poplar trials are also underway.

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REFERENCES

1. Allig, R.J., Adams, D.M., Maccarl, B.A., Ince, P.J., 2000: Economic potential of short rotation woody crops on agricultural land for pulp fiber production in The United States. Forest Products Journal 50(5): 67-74.

2. ASTM D 899, 1994: Standard test method for applied weight per unit area of liquid adhesive.
3. ASTM D1037, 1999: Standard test methods for evaluating properties of wood-base fiber and particle panel materials.
4. Baldwin, R.F., 1995: Plywood and veneer based products: Manufacturing practices. Miller Freeman. San Francisco, 388 pp.
5. Banoun, F., Morgan, D., Viart, M., Zsuffa, L., 1984: The poplar. A multi-purpose tree for forestry development. Unasylva (FAO) 36(3): 23-33.
6. Bejo, L., Lang, E.M., 2004: Simulation based modeling of the elastic properties of structural composite lumber. Wood and Fiber Science 36(3): 395-410.
7. Bodig, J., Jayne, B.A., 1982: Mechanics of wood and wood composites. Van Nostrand Reinhold. New York, 711 pp.
8. Diner, A., Kocer, S., 2002: The economic impact of intercopping on I-214 poplar cultivation. In: IUFRO-Meeting: Management of fast growing plantations (ed. A. Diner et al.). Turkish Republic, Ministry of Environment and Forest, Poplar and Fast Growing Forest Trees Research Institute Izmit. Pp 33-42.
9. Fan, M.Z., Xu, R.X., Yang, A.H., 1995: Study on parallel strand lumber made of waste veneer/bamboo strips. Wood Industry (Beijing) 9(1): 10-13.
10. Kurt, R., Mengeloglu, F., 2002: An alternative utilization of poplar wood in the manufacture of oriented strand board (OSB). In: IUFRO-Meeting: Management of fast growing plantations (ed. A. Diner et al.). Turkish Republic, Ministry of Environment and Forest, Poplar and Fast Growing Forest Trees Research Institute Izmit. Pp 174-152.
11. Kurt, R., Mengeloglu, F., 2008: The effect of boric acid / borax treatment on selected mechanical and combustion properties of poplar laminated veneer lumber. Wood Research 53(2): 113-120.
12. Liu, Y., Lee, A.W.C., 2003: Selected properties of parallel strand lumber made from southern pine and yellow poplar. Holzforschung 57: 207-212.
13. Lowood, J., 1997: Oriented strand board and waferboard. In: Smulski S (ed) Engineered wood products: A guide for specifiers, designers, and users (ed. S. Smulski). PFS Research Foundation. Madison. Pp 123-145.
14. Marra, A.A., 1992: Technology of wood bonding, principles in practice.: Van Nostrand Reinhold. New York, 454 pp.
15. Moody, R.C., Hernandez, R., Liu, J.Y., 1999: Glued structural member. In: Wood handbook. Wood as an engineering material. Forest Products Laboratory, General Technical Report, FPL-GTR -113. U.S. Department of Agriculture, Forest service, Forest Products Laboratory. Madison. Chap. 11, 463 pp.
16. Nelson, S., 1997: Structural composite lumber. In: Engineered wood products: A guide for specifiers, designers, and users (ed. S. Smulski). Pp 174-152, PFS Research Foundation. Madison.
17. Ozarska, B., 1999: A review of the utilization of hardwoods for LVL. Wood Sci. and Technol. 33(4): 341-351.
18. Pizzi, A., 1993: Wood adhesives; chemistry and technology. Vol: 1. Marcel Dekker. New York, 364 pp.
19. Polisan Chemical Corporation, 1999: Application guide for the phenol formaldehyde and urea formaldehyde adhesives. Polisan Ltd, Kocaeli.
20. SAS Institute, 2001: SAS/Sat Release 8.2. Cary: SAS Institute, Cary.
21. Shukla, S.R., Rao, R.V., Sharma, S.N., 1999: Evaluation of parallel strand lumber (PSL) and

its comparison with laminated veneer lumber (LVL), rubber wood and teak. Holz als Roh- und Werkstoff 57(4): 267-270.
22. Stanton, B.J., Eaton, J., Johnson, D., Rice, B., Schuette, B., Moser, B., 2002: Hybrid poplar in the pacific northwest, the effects of market driven management. Journal of Forestry 100(4): 28-33.
23. Suzuki, S., 2005: Using cedar plantation for wood based composites in Japan. General Technical Report, FPL-GTR -163. U.S. Department of Agriculture, Forest service, Forest Products Laboratory. Madison. Pp 9-25.
24. TS 2472, 1976a: Wood - Determination of density for physical and mechanical tests.
25. TS 2474, 1976b: Wood - Determination of ultimate strength in static bending.
26. TS 2478, 1976c: Wood - Determination of modulus of elasticity in static bending.
27. TS 2595, 1977: Wood - Determination of ultimate stress in compression parallel to grain.
28. TS 2479, 1976d: Wood - Determination of static hardness.
29. Tunctaner, K., As, N., Özden, Ö., 2004: Investigation into growth performances, some technological wood properties and suitability to paper production of some poplar clones. Izmit: Turkish Republic, Ministry of Environment and Forest, Poplar and Fast Growing Forest Trees Research Institute Technical Bulletin No. 196, Izmit.
30. Wang, J.H.B., Ping, C.D., 2005: Hot pressing stress graded aspen veneer for laminated veneer lumber (LVL). Holzforschung 59(1): 10-17.
31. Wu, Z.H., Furuno, T., Zhang, B.Y, 1998: Properties of curved laminated lumber made from fast-growing species with radiofrequency heating for use in furniture. Journal of Wood Science 44(4): 275-281.
32. Yihai, L., Lee, W., 2003: Selected properties of parallel strand lumber made from southern pine and yellow poplar. Holzforschung 57(2): 207-212.
33. Yildiz, U.C., Yildiz, S., Gezer, D., 2005: Mechanical properties and decay resistance of wood-polymer composites prepared from fast growing species in Turkey. Bioresource Technology 96: 1003-1011.
34. Zhu, J.W., 2001: Comparison and analysis of the main technological factors of influencing mechanical properties of scrimber and PSL. Journal of Forestry Research 12(4): 266-268.
35. Zoralioglu, T., Kocer, S., 1996: Mechanization techniques for poplar development in Turkey. Biomass&Bioenerji 10(5/6): 261-265.

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