ISSN: 2687-6043
e-ISSN: 2687-6035
https://dergipark.org.tr/en/pub/wie

Volume 3, Issue 2
2021
pp. 31-36

Wood Industry and Engineering
International Scientific Journal

DETERMINATION OF THERMAL CONDUCTIVITY OF LAMINATED WOOD MATERIALS DEPENDING ON THE LAYER ORIENTATION

Özkan Cırrık[1]

Citation

Cırrık, Ö. Determination of Thermal Conductivity of Laminated Wood Materials Depending on The Layer Orientation. ***Wood Industry and Engineering****. 2021; 3(2): 31-36.*

Keywords
Laminated Wood Materials
Plywood
Laminated Veneer Lumber
Thermal Conductivity

Abstract

In this study, it was aimed to determine the thermal conductivity coefficient values of laminated wood materials produced with different layer orientation, according to wood species and adhesive type. For this purpose, 5-layers plywood, laminated veneer lumber (LVL), Kerto-Q-LVL and special type plywood (Q-plywood), which formed three rotary cut veneers in the inner layer parallel to each other, perpendicular to the outer layers, panels were produced. In the production of the panels, poplar (*Populus deltoides*), Scots pine (*Pinus sylvestris* L.) and spruce (*Picea orientalis* L.) were used as a wood species and was used urea formaldehyde (UF) and phenol formaldehyde (PF) as adhesive types. The thermal conductivity coefficient measurements of the panels were carried out according to the ASTM C 518 standard. As a results of the study, the highest thermal conductivity coefficient value was obtained from Q-LVL panels produced using UF adhesive from spruce veneers. The lowest thermal conductivity values were obtained from plywood produced using PF adhesive from spruce veneers.

Paper Type
Research Article

Article History
Received: 13/11/2021
Accepted: 26/11/2021

Corresponding Author
Özkan Cırrık
ozkan.cirrik@keas.com.tr

Phone: +90-534-5013667
Fax: +90-266-2811259

[1] Kastamonu Entegre Ağaç Sanayi ve Ticaret A.Ş., Balıkesir, Turkey

DETERMINATION OF THERMAL CONDUCTIVITY OF LAMINATED WOOD MATERIALS DEPENDING ON THE LAYER ORIENTATION

Özkan Cırrık
ozkan.cirrik@keas.com.tr
ORCID : 0000-0002-0119-7509

1. Introduction

Wood and wood products have an important place in human life and in the development process of culture since ancient times and today. Molecular, chemical and microscopic properties of wood have enabled it to be used for a wide variety of purposes. In addition to these properties, its fibrous structure has led to its high strength and flexibility in engineering uses. In addition, it has often been the reason for preference in terms of its isolation properties (Öztürk and Arıoğlu, 2006).

Laminated wood materials are obtained by bonding two or more layers and joining them in such a way that the fibre directions of the layers are parallel or perpendicular to each other. If the produced material is curved, the fibre directions of the layers must be applied in parallel. Laminated wood materials, different wood types, variable number of floors, different sizes, shapes, and coat thicknesses can be applied (Şenay, 1996). In the laminated wood material method, longer and wider wood materials can be produced from short and narrow-width wood materials. In addition, the quality properties of the wood product produced are better, since it allows the wood to be used by removing the defects of the material (knots, cracks, wormholes, irrigation, etc.). Due to the use of small-sized wood material, the waste rate in wood material decreases, which has an impact on the cost of the finished product (Perçin et al., 2009). The structure of the wood materials used in the production of laminated wood materials, surface roughness, pressing pressure, pressing time and the technical properties of the adhesive used are effective on the bonding and other mechanical strength properties of the materials (Keskin, 2003).

Thermal conductivity is the flow of thermal energy through a unit thickness of a material under a temperature gradient and expressed by the coefficient of thermal conductivity (Kollman and Cote, 1968). It is a very important parameter in determining heat transfer rate and is required for development of drying models in industrial operations such as adhesive cure rate (Kol et al., 2008). Also, it must be known when choosing the insulation materials to attenuate fluctuation in the outdoor environment which maintains an indoor temperature that is independent of outdoor temperature fluctuations. The materials used for insulation must have good warmth-keeping properties such as lower thermal diffusivity to provide sufficient protection from severe temperature changes (Kawasaki and Kawai, 2006). Wood materials possess a superior thermal conductivity property compared to other building materials which is due to its porous structure of them (Gu and Zink-Sharp, 2005; Kruger and Adriazola, 2010). They are one of the preferred materials in many applications such as construction industry, refrigerators, automobile industry, and in the manufacture of barrels, because of their low thermal conductivity and high resistance (Gu and Zink-Sharp, 2005). Thermal conductivity of wood materials has varied according to wood type, direction of wood fiber, resin type, and additive members used in the manufacture of wood composite panels (Kamke and Zylkowoski, 1989).

This study aimed to investigate the thermal conductivity coefficient values of laminated wood materials produced with different layer orientation, according to wood species and adhesive type. For this purpose, thermal conductivity tests were carried out by producing five-layer panels with 4 different layer orientations.

2. Materials and Methods

2.1. Material

The peeling logs used in this study were obtained from the operating directorates of the General Directorate of Forestry. As wood species, the species commonly used in the laminated wood material industry were selected. Coniferous wood species; Scots pine (*Pinus silvestris*) and Eastern Spruce (*Picea Orientalis*) were selected. In addition, Hybrid Poplar (*Populus deltoides* I-77/51) clone was used in the study as a hardwood wood species in logs.

The rotary cut veneer sheets with dimensions of 2 mm ×50 cm × 50 cm thickness were obtained from freshly cut logs. While the poplar veneers were manufactured from freshly cut logs, Scots pine and spruce logs were steamed for 12 h before veneer production. The horizontal opening between knife and nose bar was 85% of the veneer thickness, and the vertical opening was 0.5 mm in rotary cutting process.

The veneers were then dried to 6–8% moisture content with a veneer dryer. Two types of resins were used as adhesive, urea formaldehyde (UF) and phenol formaldehyde (PF) resins with 65% solid content. UF resin solutions used in the laminated wood materials manufacturing were composed of 100 parts UF resin, 30 parts wheat flour and 10 parts NH_4Cl (with 15% concentration) as hardener, by weight. PF was used directly for the laminated wood materials. The adhesive was applied at a rate of 160g per cubic meter to the single surfaces of veneers with a four-roller glue spreader. The bonded veneer sheets were formed in 5 layers using 4 different layer orientations. The panel drafts formed are given in Figure 1.

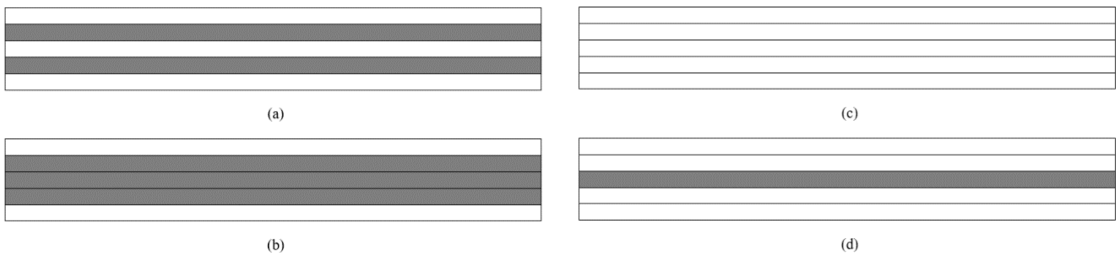

Figure 1: (a) 5-layer plywood, (b) 5-layer plywood with middle layers bonded in parallel (Q-Plywood), (c) 5-layer LVL, (d) 5-layer KERTO Q-LVL, the dark coloured layers were placed perpendicular to the fibres

Hot pressing time and temperature were applied as 10 minutes, 110°C for UF resin and 140°C for PF resin while press pressure was 12 kg/cm^2. Two replicate plywood panels were manufactured for each test group. Test samples were conditioned to achieve equilibrium moisture content at 20°C temperature and 65% relative humidity prior to testing.

The thermal conductivity of laminated wood materials was determined according to ASTM C 518 (2004). Two specimens with the dimensions of 300×300×2 mm was used for each group. The Lasercomp Fox-314 Heat Flow Meter shown in Figure 2 was used for the determination of thermal conductivity.

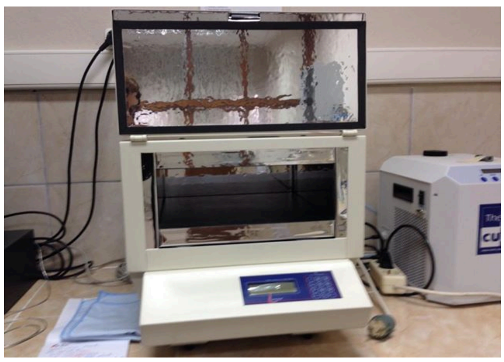

Figure 2: Lasercomp Fox-314 heat flow meter

3. Results and Discussion

The thermal conductivity coefficient values of the produced panels are given in Table 1 for each laminated wood material according to the wood species and adhesive type.

Table 1: Average values of thermal conductivity coefficient of the produced panels

Wood Species	Adhesive Type	Panel Type	Thermal Conductivity Coefficient (W/mK)
Scots pine	UF	Plywood	0.1017
		Q-Plywood	0.09594
		LVL	0.09611
		Q-LVL	0.09123
	PF	Plywood	0.08778
		Q-Plywood	0.09171
		LVL	0.1020
		Q-LVL	0.1034
Spruce	UF	Plywood	0.09388
		Q-Plywood	0.09621
		LVL	0.09249
		Q-LVL	0.1093
	PF	Plywood	0.07277
		Q-Plywood	0.09738
		LVL	0.09629
		Q-LVL	0.09419
Poplar	UF	Plywood	0.09135
		Q-Plywood	0.09777
		LVL	0.09817
		Q-LVL	0.09218
	PF	Plywood	0.09606
		Q-Plywood	0.09148
		LVL	0.08896
		Q-LVL	0.09371

As seen in Table 1, the highest thermal conductivity coefficient value was obtained from Q-LVL panels produced from spruce veneers using UF adhesive, while the lowest thermal conductivity values were obtained from plywood panels produced from spruce veneers using PF adhesive. The effects of layer orientation and adhesive type on thermal conductivity coefficient values differ according to wood species. Differences were observed between the thermal conductivity coefficient values of the panels in the same layer orientation produced with UF and PF adhesive.

The thermal conductivity coefficient values of the panels produced by using UF and PF adhesives within the scope of the study; depending on the layer orientation, the wood species obtained, and the type of adhesive used. The thermal conductivity coefficient changes of the produced panels are shown in Figure 3.

When the effect of the layer orientation on the thermal conductivity coefficient of the panels was examined, it was seen that the thermal conductivity coefficient values differed according to the adhesive type and wood species. Plywood for scots pine, Q-LVL for spruce; LVL for poplar gave the highest thermal conductivity values in UF adhesive. The lowest values were found in Q-LVL for Scots pine, in LVL for spruce, and in plywood sheets for poplar. Q-LVL for Scots pine, Q-Plywood for spruce, plywood for poplar gave the highest thermal conductivity values in PF adhesive. The lowest values were found in plywood for scots pine and spruce in LVL sheets for poplar. The differences between the thermal conductivity coefficient values of the groups are quite small. The ability to transmit heat in wood material varies according to the wood species and the direction of the fibres in the same wood, as well as directly related to the anatomical structure of the wood material (Berkel, 1970). In addition, it has been emphasized in many studies that the thermal conductivity value varies according to the tree species (Kol and Sefil, 2011; Rice and Shepard, 2004). In addition, density, moisture, amount of extractive material, fibre direction, structural irregularities such as knots, cracks and fibre angle, and temperature can be considered as effective the factors of the thermal conductivity of wood (Simpson and Tenwolde, 2007).

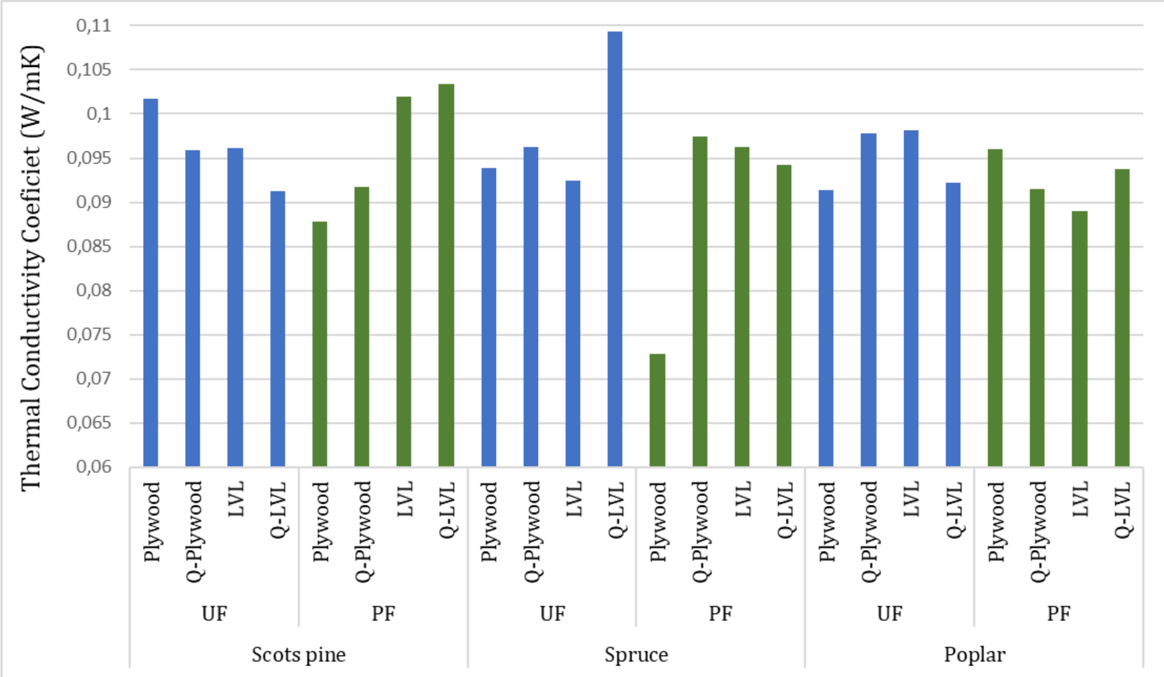

Figure 3: Thermal conductivity coefficient changes of laminated wood materials

When the effect of wood species used in production on the thermal conductivity coefficient of the panels is examined, (the highest thermal conductivity coefficient values were obtained in Scotch pine for plywood panels in UF adhesive, in Poplar for Q-Plywood and LVL, in spruce for Q-LVL. The lowest values were found in poplar for plywood; Scotch pine for Q-Plywood and Q-LVL, in spruce for LVL. The highest values in PF adhesive were obtained in poplar for plywood panels in spruce for Q-Plywood, in scots pine for LVL and Q-LVL. The lowest values were found in spruce for plywood; Q-Plywood in poplar for LVL, Q-LVL. It has been emphasized in many studies that the thermal conductivity coefficient value varies according to the wood species (Kol and Sefil, 2011; Rice and Shepard, 2004). Thermal conductivity in sheet products made of wood material; wood panels produced with various binders and fillers and additives added to them differ according to the type of binder and additives (Kamke and Zylkowoski, 1989). Demirkır (2012) stated that factors such as wood type, coating drying temperature, peeling temperature, type of glue used in production affect the thermal conductivity values of plywood.

When the effect of adhesive types used in production on the thermal conductivity coefficient of the panels was examined, the thermal conductivity coefficient values of the panels produced with UF adhesive were found to be higher than those of PF adhesive. The equilibrium moisture content of the panels produced with UF adhesive was found to be higher than that of PF adhesive. In the literature, it has been stated in the literature that thermal conductivity increases with the increase in humidity due to the high conductivity of water (Gu and Hunt, 2007; Kurt et al., 2008; Kol, 2009; Kol and Sefil, 2011). Kol et al. (2008), it was determined that the type of glue has a significant effect on the thermal conductivity values of laminated panels produced using UF and PF adhesives.

When the thermal conductivity coefficients of the produced experimental groups were compared with the thermal conductivity coefficients of some wood-based panels, results were consistent with the literature (Kawasaki and Kawai, 2006).

4. Conclusions

1. The highest thermal conductivity coefficient value was obtained from Q-LVL panels produced using UF adhesive from spruce veneers.

2. The lowest thermal conductivity values were obtained from plywood produced using PF adhesive from spruce veneers.

3. The effect of layer orientation and adhesive type on thermal conductivity coefficient values differ according to wood species. Differences were observed between the thermal conductivity coefficient values of the panels in the same layer orientation produced with UF and PF adhesives.

References

ASTM C 518. (2004). Methods of Measuring Thermal Conductivity, Absolute and Reference Method. ASTM International: West Conshohocken, USA.

Berkel, A. 1970. Ağaç Malzeme Teknolojisi, İstanbul Üniversitesi, Orman Fakültesi Yayınları, Yayın no: 147.

Demirkır, C., (2012). Using Possibilities of Pine Species in Turkey for Structural Plywood Manufacturing. PhD Thesis, Karadeniz Technical University, Institute of Science and Technology, Trabzon.

Gu, H. M. and Hunt, J. F. (2007). Two-dimensional finite element heat transfer model of softwood. Part III, Effect of moisture content on thermal conductivity. Wood Fiber Sci., 39, 159.

Gu, H.M. and Zink-Sharp, A. (2005). Geometric model for softwood transverse thermal conductivity. Part I. Wood and Fiber Sci 37(4): 699-711.

Kamke, A.F. and Zylkowoski, S.C. (1989). Effects of Wood –Based Panel Characteristics on Thermal Conductivity. Forest Products Journal., Volume 39 no:5 p:39-24

Kawasaki, T. and Kawai, S. (2006). Thermal Insulation Properties of Wood-Based Sandwich panel for use as structural insulated walls and floors. Japan Wood research Society, 52, 75-83.

Keskin, H. (2003). Some physical and mechanical properties of laminated oriental spruce (*Picea orientalis* Lipsky) wood. Journal of Süleyman Demirel University Faculty of Forestry, A (1): 139-151.

Kol, H. S. (2009). The Transverse Thermal Conductivity Coefficients of Some Hardwood Species Grown in Turkey, Forest Products Journal, 10, 59, 58-63.

Kol, H. S. and Sefil, Y. (2011). The thermal conductivity of Fir and Beech Wood Heat Treated at 170, 180, 190, 200 and 212°C, Journal of Applied Polymer Science, 121, 2473-2480.

Kol, H.S., Ozcifci, A. and Altun, S. (2008). Effect of some chemicals on thermal conductivity of laminated veneer lumbers manufactured with urea formaldehyde and phenol formaldehyde adhesives. Kastamonu University J of Forestry Faculty 8(2): 125-130.

Kollmann, F.F.P. and Cote, W.A. (1968). Principles of wood science and technology. Berlin: Springer-Verlag.

Kruger, E.L. and Adriazola, M.K.O. (2010). Thermal analysis of wood-based test cells. Constr Build Mater 24: 999–1007.

Kurt, Ş., Uysal, B. and Özcan, C. (2008). Effect of Adhesives on thermal conductivity of laminated veneer lumber. Journal of Applied Polymer Science, 110, 3, 1822.

Öztürk R.B., ve Arıoğlu N., (2006). Mechanical properties of laminated wood beams produced from Turkish *Pinus silvestris. ITU Journal, architecture, planning, design,*5(2), 25-36.

Perçin, O., Özbay, G., ve Ordu, M.., (2009). The Investigation of the Mechanical Properties of Wooden Materials Laminated with Various Glues. Dumlupınar University Journal of Science Institute, 19, 109-120.

Rice, R. W. and Shepard, R. (2004). The Thermal Conductivity of Plantation Grown White Pine (Pinus strobus) and Red Pine (*Pinus resinosa*) at two moisture content levels", Forest Products Journal, 54, 1, 92-94.

Şenay, A., (1996). Mechanical and Physical Properties of Laminated Oriental Beech (*Fagus orientalis* Lipsky), PhD Thesis, Istanbul University, Institute of Science and Technology, Istanbul.

Simpson, W. and Tenwolde, A. (2007). Chapter 3. Physical Properties and Moisture Relations of Wood. The Encyclopedia of Wood. U.S. Department of Agriculture Forest Service, Forest Products Laboratory, Madison, Wisconsin: Skyhorse Publishing.