

# **THERMAL CONDUCTIVITY VALUES OF SOME WOOD SPECIES USED IN PLYWOOD INDUSTRY**

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## **Abstract**

Thermal conductivity is one of the most important properties for construction materials. The aim of the study was to determine the thermal conductivity values of veneers from common wood species used in plywood industry. For this aim, Scots pine, maritime pine, black pine, poplar, beech, alder, spruce, birch, plane tree, tetra, okoume, ozigo were used as wood species in this study. Thermal conductivity values of the veneers were determined according to ASTM C518 by means of The Fox 314 instrument. It was determined from the study that there were differences among the thermal conductivity values of the veneers obtained from wood species in plywood industry. It was also concluded from the study that some manufacturing parameters such as veneer drying temperature affect the thermal conductivity values of veneers.

Keywords: Thermal Conductivity; Veneer; Drying Temperature.

## **Introduction**

Plywood, one of the most common wood based panels, has many usage areas varied from furniture (indoor) to construction (outdoor). Demirkir et al. (2013) stated that plywood one of the best sheathing materials in buildings for resisting earthquake loads, because it is able to tolerate the greatest amount of displacement before failing [1]. Wood has the advantages of relative tooling costs compared to those for competitive construction materials, a high strength to weight ratio, an excellent insulation and unique aesthetic properties [2]. Thermal insulation is one of the most desirable parameters for structural materials. Kawasaki and Kawai (2006) reported that materials need to be developed that have superior thermal insulation abilities to sustain an indoor temperature that is independent of outdoor temperature fluctuations [3]. Demirkir et al. (2013) also emphasized that wood composite materials are superior to other building materials in terms of thermal conductivity due to the porous structure of them [4]. Plywood panels have well-balanced thermal insulation and warmth keeping properties (steady and non-steady-states), which is important for insulation performance in that they maintained temperature and relax severe temperature changes in residences exposed to diurnal and seasonal temperature changes [3]. It was known that thermal conductivity of wood and wood composite materials such as plywood varied according to wood specie, direction of wood fiber, ratio of early and late wood, thickness of composite materials, density, moisture content, resin type and additives, temperature, and flow direction of heat [5, 6, 7]. It is possible to be an effect of different drying temperature applied on veneers on thermal conductivity of veneer sheets in manufacturing of wood composite materials such as plywood. Although drying temperatures between 90-160°C may be considered normal, increased temperatures are being used to reduce the overall drying time and increase capacity [8]. Although thermal conductivity values were determined for some wood species in former studies, there was no enough data for wood species used in plywood industry in Turkey. But it is critical to know that the thermal properties of wood and wood based materials used in construction to determine the proper using areas. Therefore, the aim of the study was to investigate the effect of wood species used for plywood production and drying temperature on thermal conductivity of the veneers.

## Materials and Method

Twelve wood species were used in this study, Scots pine (*Pinus slyvestris*), maritime pine (*Pinus pinaster*), black pine (*Pinus nigra*), poplar (*Populus deltoids*), beech (*Fagus orientalis*), alder (*Alnus glutinosa*), spruce (*Picea orientalis* L.), birch (*Betula pendula*), plane tree (*Platanus orientalis*), tetra, okoume, ozigo. The logs were steamed with 12 hours before the peeling process, and then veneer sheets with dimensions of 50 cm by 50 cm by 2 mm were clipped. The vertical opening was 0.5 mm and horizontal opening was 85% of the veneer thickness in the veneer manufacturing process. After rotary peeling, veneers were dried to 4-6 % moisture content at two different temperatures: 110°C and 160°C.

The Fox 314 instrument produced by Laser Comp (USA) was used to determine of thermal conductivity of veneer samples. It measures the steady-state heat transfer through flat materials according to ASTM Standard C518 [9]. Thermal conductivity ( $\lambda$ ) is a measure of a material's ability to transmit heat, and is expressed as heat flow in Watts per metre thicknesses of material for a temperature gradient of one degree Kelvin (K). It is expressed as W/mK and calculated by the following formula.

$$\lambda = \frac{Q \cdot e}{A \cdot z \cdot dt} \text{ (W/mK)} \quad (1)$$

Where,

$\lambda$ : Thermal conductivity

Q: Heat quantity

e: Thickness of material

dt: t2-t1 (Temperature difference)

A: Surface area

z: Time

A 30.5 cm square sample with a thickness of up to 10 cm thick is placed between two flat plates that are controlled to a specified constant temperature as shown in Figure 1.

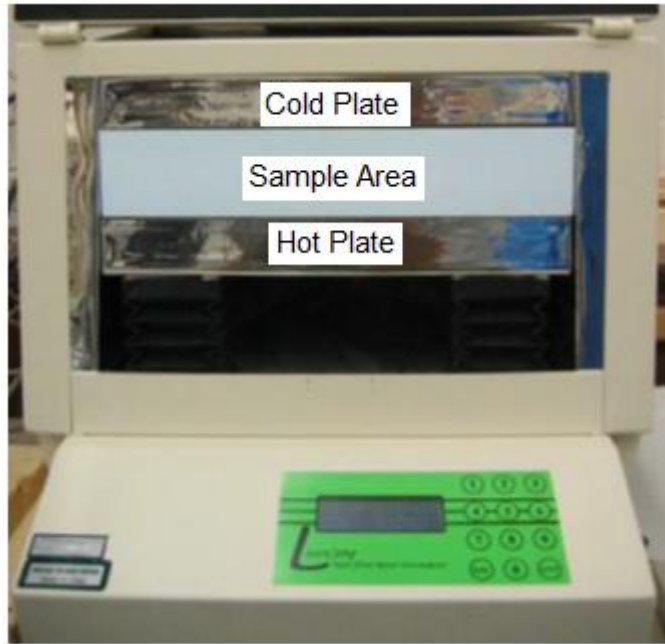


Figure 1. Schematic diagram of Fox 314 instrument

The temperature of upper flow meter (cold plate) was chosen as 20°C, while the one of lower meter was 40°C. Two veneer samples with 30 cm x 30 cm size were used for each test group to determine the thermal conductivity values.

### **Results and Discussion**

Average values of thermal conductivity of veneer sheets are given in Table 1.

Table 1. Thermal Conductivity Values

Wood Species	Drying Temperature (°C)	Thermal Conductivity ( $\lambda$ ) (W/mK)
Scotch Pine	110	0,0260
	160	0,0261
Maritime Pine	110	0,0282
	160	0,0267
Black Pine	110	0,0303
	160	0,0278
Spruce	110	0,0264
	160	0,0254
Beech	110	0,0239
	160	0,0246
Alder	110	0,0249
	160	0,0246
Poplar	110	0,0257
	160	0,0249
Birch	110	0,0181
	160	0,0182
Plane Tree	110	0.0246
	160	0.0246
Tetra	110	0,0279
	160	0,0319
Okoume	110	0.0266
	160	0.0245
Ozigo	110	0.0209
	160	0.0211

As can be seen in Table 1, thermal conductivity ( $\lambda$ ) values varied according to wood species. Although it is not possible to make a classify among the wood species according to thermal conductivity values of them, the results can be use in plywood industry to introduce the thermal properties of plywood panels manufactured from different wood species. It is also seen from Table 1, there is a difference among the thermal conductivity of veneer sheets according to drying temperature. The highest thermal conductivity value (0.0303 W/mK) was obtained from black pine veneers for 110°C. On the other hand, when the drying temperature got increased to 160°C, the highest value was determined on tetra veneers. Otherwise, the lowest thermal conductivity values were obtained from birch veneer sheets both of two drying temperatures. It could be concluded from the study that the thermal conductivity values of some wood species could be affected from the drying temperature, while the thermal conductivity of some species might not be affected. In former studies, it was stated that ability of thermal conductivity depended on wood species [10, 11], fiber direction on wood and anatomic properties of wood [12, 13, 14]. Therefore, it is thought that structural properties of wood species can cause the difference among the thermal conductivity values obtained from this study.

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### **References**

- [1] Demirkır, C., Çolakoğlu, G., Karacabeyli, E. The Effect of Some Manufacturing Factors on Technological Properties of Plywood from Northern Turkey and Suitability of the Panels for Use in Shear Walls. *ASCE Journal of Structural Engineering* 2013; 139(12): 1-6.
- [2] Ngohe-Ekam, P.S., Meukam, P., Menguy, G., Girard, P. Thermophysical characterization of tropical wood used as building materials: With Respect to the Basal Density. *Construction and Building Materials* 2006; 20: 929-938.

- [3] Kawasaki, T., Kawai, S. Thermal Insulation Properties of Wood-Based Sandwich panel for use as structural insulated walls and floors. *Journal of Wood Science and Technology* 2006; 52: 75-83.
- [4] Demirkır, C., Colak, S., Aydın, I. Some Technological Properties of Wood-Styrofoam Composite Panels. *Composites: Part B* 2013; 55: 513–517.
- [5] Bader, H., Niemz, P., Sonderegger, W. Untersuchungen Zum Einfluss Des Plattenaufbaus Auf Ausgewählte Eigenschaften Von Assivholzplatten. *Holz als Roh- und Werkstoff* 2007; 65(3): 173–181
- [6] Sonderegger, W., Niemz, P. Thermal Conductivity and Water Vapor Transmission Properties of Wood Based Materials. *European Journal of Wood and Wood Products* 2009; 67: 313-321.
- [7] Kol, H.S., Özçifçi, A., Altun, S. Effect of Some Chemicals on Thermal Conductivity of Laminated Veneer Lumbers Manufactured with Urea formaldehyde and Phenol formaldehyde Adhesives. *Kastamonu University Journal of Forestry Faculty* 2008; 8(2): 125-130.
- [8] Aydın, I. Surface Inactivation In Veneer Drying Process and Its Effects On Bonding Strength. *Journal of Artvin Forestry Faculty of Kafkas University* 2004; 1-2: 1-8.
- [9] ASTM C518. Standard test method for steady-state heat flux measurements and thermal transmission properties by means of the heat flow meter apparatus, *Annual Book of Standards*, 04.06, 153-164, American Society for Testing and Materials, Philadelphia, Pa; 2003.
- [10] Zylkowski, S. Introduction to wood as an engineering material, *APA Engineered wood handbook*. Thomas G. Williamson, PE, Editor, ISBN 0-07-136029-8, McGraw-Hill Publishing, 2002.
- [11] Rice, R.W., Shepard, R. The Thermal Conductivity of Plantation Grown White Pine (*Pinus strobus*) and Red Pine (*Pinus resinosa*) at two moisture content levels. *Forest Products Journal* 2004; 54 (1): 92-94.
- [12] EWPA. Engineered Wood Products Association of Australasia. *Structural Plywood & LVL Design Manual*. 2010.
- [13] Kol, H. S., Sefil, Y. The thermal conductivity of Fir and Beech Wood Heat Treated at 170, 180, 190, 200 and 212°C. *Journal of Applied Polymer Science* 2011; 121: 2473-2480.

[14] Simpson, W., Tenwolde, A. Chapter 3. Physical Properties and Moisture Relations of Wood. The Encyclopedia of Wood. U.S. Department of Agriculture Forest Service, ISBN-13: 978-1-60239-057-7; ISBN-10: 1-60239-057-6, Forest Products Laboratory, Skyhorse Publishing, Madison, Wisconsin, 2007.