The Effects of Humidity on Thermal Conductivity of Fir Wood

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Abstract
In this study it was aimed to describe the effects of different humidity on thermal conductivity of Uludag Fir (*Abies bornmülleriana* M.). The lowest thermal conductivity of 0.0910 Kcal/mh°C was obtained from oven-dry samples. The highest thermal conductivity of 0.1904 Kcal/mh°C was obtained in completely wet samples. Consequently, oven-dry wood samples could be used as insulation material.
Keywords: Thermal Conductivity, Uludağ Fir, Humidity

Introduction

Wood is globally one of the principal raw materials presently being used in construction, along with cement, steel, plastics, aluminum, etc. The growing world demand for affordable supplies of materials for building, furniture, packaging, paper, and consumer goods of all kinds ensures the future importance of wood-based industries.

Because of its natural origin, wood frequently exhibits an unusually wide degree of variability in physical and mechanical properties as a result of its genetic source, environmental factors (e.g. climate, soils, water supply, available nutrients, etc.), and also its complex internal multicomponent structure (anisotropy). These variations influence the suitability of wood, in other words wood quality, for a variety of purposes. Consequently, manufacturers and users of wood products are frequently confused about these wide variations of wood properties and they need to know the properties and potential of wood as a raw material for conversion to various products.

Some major developments in the past involving non-destructive evaluation (NDE) technologies have offered great opportunities for the characterization of wood material. NDE technologies currently used in lumber and veneer grading programs have resulted in engineered materials with consistent and well-defined performance characteristics. Through the development and use of NDE technologies, advances have been made in the grading of a variety of wood-based materials, and products used for both structural and non-structural applications. These technologies are an integral part of scanning systems used in the forest products industry to identify and locate defects in wood-based materials. Advances have also been made in the development of NDE technologies for use in the inspection of wood members in structures. In recent years, there has been an increased emphasis to develop NDE techniques for assessing the potential structural quality of green materials (Pellerin and Ross, 2002).

The methods employed to evaluate the quality of wood material are based on the assumptions that some simple physical properties can be used to give a reasonably good indication of the characteristics that determine such quality (Bucur, 2006). Most common NDE techniques utilize acoustic properties (propagation of stress wave or ultrasonic wave) and electrical properties (electrical resistance and dielectric properties) of wood for evaluation of its properties.

In recent years, although the thermal imaging method based on the thermal properties of medium has been used for defect detection in wood, there has been no study concerning the relationship between thermal properties and static elasticity and strength properties of wood. Hence, the basic idea of this study is that the thermal properties of wood can be used to evaluate its mechanical properties, especially thermal conductivity.

Materials and Methods

Wood

Fir wood species was chosen randomly from timber suppliers of Karabuk, Turkey. Forty clear (free from defects) timber pieces with a dimension of 20×60×400 mm were cut from timbers. Timber pieces were conditioned at different humidity (i.e., oven-dry, air-dry, fiber saturation point, completely wet) in required instruments such as stream boiler, oven, air-conditioned room until they reached their constant weights.

Thermal Conductivity Measurements

A quick thermal conductivity meter, based on the ASTM C 1113-99 hot-wire method, was used. In order to determine the coefficients of thermal conductivity (CTC) of wood, the hot wire of the device was placed on the radial plane of pieces in the parallel direction to the wood fibers as shown in Fig. 1. The measurements were taken from three different points on each timber piece. The QTM 500 device, which is a product of Kyoto Electronics Manufacturing in Japan, was used to measure the CTC. The measurement range is from 0.0116 to 6 W/m K. Measurement precision is F5% of reading value per reference plate. Reproducibility is F3% of reading value per reference plate. The measurement temperature is 100 to 1,000°C (external bath or electric furnace for temperature other than the room). Measuring time is a standard 100 to 120 s (Sengupta *et al*., 1992).

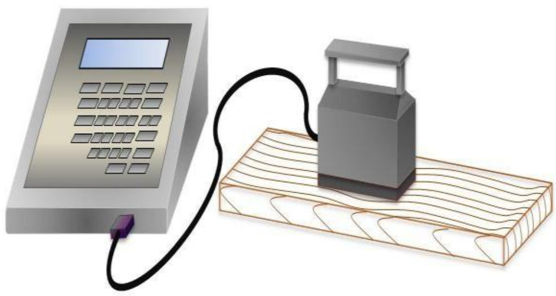

Fig. 1. Test setup of thermal conductivity measurements

Determination of Density and Mechanical Properties of Wood

For measuring air-dry density (12%) timber pieces were conditioned at 20±2 °C and 65±3% relative humidity until they reached their constant weights in an air-conditioned room. For measuring the oven-dry (0%) density timber pieces were conditioned at 103±2 °C relative humidity until they reached their constant weights in an oven. The density of the samples was determined according to ISO 3131 (1975).

Data Analyses

Data for each test were statistically analyzed by MS Excel and Statistical Package for the Social Sciences (SPSS). The analysis of variance (ANOVA) was used to test the significant difference between factors and levels. When the ANOVA indicated a significant difference among factors and levels, a comparison of means was done employing a Duncan test.

Results

The density of oven-dry samples was found as 0.36 g/cm^3, the density of air-dry samples was found as 0.42 g/cm^3, the density of the samples at fiber saturation point was found as 0.70 g/cm^3, the density of completely wet samples was found as 0.85 g/cm^3. All results related to the thermal conductivity of samples are shown in Table 1.

Table1. The average thermal conductivity values of oven-dry, air dry, fiber saturation point and maximum saturation point

The amount of humidity	Thermal Conductivity (Kcal/mh°C)
Oven dry	0.0910
Air dry	0.1152
Fiber saturation point	0.1717
Maximum saturation point	0.1904

The lowest thermal conductivity value of oven-dry samples was found as 0.1024 Kcal/mh°C. The lowest value was found as 0.0856 Kcal/mh°C and the average thermal conductivity value was found as 0.0910 Kcal/mh°C.

The highest thermal conductivity value of air-dry samples was found as 0.1237 Kcal/mh°C. The lowest value was found as 0.1070 Kcal/mh°C and the average thermal conductivity value was found as 0.1152 Kcal/mh°C.

The highest thermal conductivity value of the samples at the fiber saturation point was found as 0.2006 Kcal/mh °C. The lowest value was found as 0.1524 Kcal/mh°C and the average thermal conductivity value was found as 0.1717 Kcal/mh°C.

The highest thermal conductivity value of completely wet samples was found as 0.2086 Kcal/mh°C. The lowest value was found as 0.1778 Kcal/mh°C and the average thermal conductivity value was found as 0.1904 Kcal/mh°C.

Discussion and Conclusion

Thermal conductivity experiments show that oven-dry samples have the highest thermal conductivity value, while the completely wet samples have the lowest one. According to test results, oven-dry wood samples can be used in environments requiring insulation.

References

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