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Moisture Determination To Assess The Smoke in Commercial Wood

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Abstract:

Wood is one of the most common material used in the building interiors and exteriors. In the interiors, wood is a highly preferable material in different furniture, due to which it can be a strong reason behind building fires. It is also a good fuel that can easily contribute to the growth of a fire. Hence, their role in the spread of building fires needs to be study. An important property of wood is its moisture content. It is important to investigate the effect of moisture content, as it will lead to the generate the unnecessary smoke, which may create the delay in safe exit. There is a direct relation between the moisture in the wood and smoke release during the fire. Also, smoke can obstruct the exit or evacuation during a fire accident in commercial or public occopancy. Hence it is crucial to study the moisture content in different commercial wood. In this study different types of wood have been used, and the moisture contents studied.

Keywords: Moisture Content, Wood, Smoke, Maple, Particleboard, Plywood, Mahogany, and Pine.

I. INTRODUCTION

The impact of moisture content in wood-based fuels is mostly applicable to forest and wildlife fires than in structural fires, mainly because the wood used in buildings are dried to a large extent before use. The moisture content in untreated wood in forests and nature is considerably high. (Chomanee et al., 2009) studied the effects on smoke generation upon varying moisture content during the combustion of rubberwood. Rubberwood has a high moisture content, and the combustion produces thick smoke that spreads into work areas and impacts worker health and property. Since rubberwood is usually used as a fuel in rubber industries to manufacture ribbed sheets, rubberwood's burning and the health effects need to be clearly understood to protect the worker's health. The smoke concentration is high when rubberwood is burned and contains high volume of toxic substances like polycyclic aromatic hydrocarbons. (Verbesselt et al., 2002) studied the effect of moisture content on smoke production in a forest fire scenario. It stated that moisture content effectively delayed fire ignition. However, the vapor generated was present in the smoke and resulted in a higher optical density. Smoke generation and fire development are influenced not only by solid combustible materials such as wood but also by the characteristics of the fuel involved in combustion. (Varghese et al. 2022) conducted experimental investigations on pool fires involving diesel, n-propanol, and their blended fuels demonstrated that fuel properties significantly affect flame behaviour, heat release, temperature distribution, and combustion efficiency, all of which influence smoke production and fire hazards.

(Dietsch et al., 2015) highlighted the importance of determining wood moisture content. Wood, which retains moisture based on the relative humidity of the surrounding environment demonstrates positively-altered mechanical and physical properties when the moisture content is varied. It also results in a change in dimensions, either from swelling or shrinking due to moisture content variations. In these cases, the wood employed in a structural element, for instance, without providing for the moisture content, can weaken the structure or lead to failure because the physical properties are modified. (Dietsch et al., 2015) pointed out the need to analyze moisture content in all wood elements because all wood properties are, to some extent, influenced by the moisture content includes flammability. The moisture content is affecting the temperature around the fire. When the temperature reaches below 800 ºC, incomplete combustion with high moisture content is produced, which gives high concentrations of Carbon Monoxide (Nyström and Dahlquist, 2004).

According to (Briggs, 1993), smoke has been studied extensively due to its importance in the safe egress of building occupants in the event of a fire. Smoke obscures visibility, and hence smoke detectors and other active protection devices have to be designed based on the smoke generation rate during the fire. Though varying in scale, small scale test data can contribute significantly to the information required to design efficient detector and alarm systems.

(Briggs, 1993) reviewed the relevance of test data associated with fire test procedures in actual fire scenarios. The authors highlighted the importance of obtaining experimental data on nature and smoke generation during a fire. Since smoke plays the most significant role in inhibiting human movement during an escape from a building fire, smoke behavior has to be studied for good design of smoke control systems like detectors and alarms.

A related study was conducted by (Shi and Chew, 2012), who conducted fire experiments on six different types of wood, such as Beech, Pine, Oak, Maple, ash, and cherry, to determine moisture's impact content in wood on the auto-ignition. The experiment was conducted using a cone calorimeter. It was found that up to 11%, the moisture content of wood did not significantly influence the autoignition properties such as the ignition temperature or the mass-loss rate. However, the moisture content was found to influence the ignition time, which increased with increasing moisture content. The abstract of this paper did not explain the basis or purpose of conducting the research and the implications of having longer ignition time or high moisture content. It is deduced from the results that water's role leads to delay of ignition of wood when the fuel has high moisture content.

On the contrary, moisture content was known to influence flame temperature in a study by (Kreye et al., 2013). This study examined littered soil instead of wood in the context of forest fires. The moisture content and fuel load in these soils were the parameters studied to determine their influence on fire behavior. The authors constructed lab versions of the fuel-beds using the litter-soil samples and burned the fuel-beds to study burning characteristics like flame length and duration. Though wood was not directly used as fuel, it is considered present in the fuel bed since forest soil will include decayed wood remains. It was found that while the flame length and intensity increased with increasing fuel load, it decreased with increasing moisture content. Peak temperature was found to be unaffected by the moisture content. However, surface temperatures were found to be influenced by both parameters studied.

Fuel moisture content and relationship with smoke have been studied widely in forest fires and wildfires since moisture content during a fire is characteristic of wood-based fires. According to (Justin Ellenberger, 2013), the moisture content of a fuel is the percentage of moisture against the fuel's dry weight. This moisture content can add up to the smoke and increase its concentration, thereby producing thicker smoke. In the presence of moisture content either inherent to the fuel or in the atmosphere as humidity, water vapor contributes to a damp smoke condition. (Varghese et al. 2022) study stated that fire safety assessment requires a comprehensive understanding of both material properties and fire dynamics. Previous studies by employed experimental investigations and Fire Dynamics Simulator (FDS) modelling to analyse fire growth, heat transfer, smoke movement, and temperature distribution in fire scenarios. These studies demonstrated the importance of accurately characterising fuel behaviour for predicting smoke spread and occupant tenability. Similarly, the present study investigates the moisture content of commercial wood, as moisture significantly influences combustion behaviour and smoke generation, which are critical factors affecting safe evacuation during building fires

2. METHODOLOGY

2.1 Background

It is essential to determine the wood's moisture content to understand the burning characteristics. A moisture meter was used to measure the moisture content of the different samples of wood. The second series of wood samples were oven-dried so that the difference in combustion characteristics could be determined.

Oven drying was also recommended by (Laurenzi, 2018) as the best method to measure the moisture content of wood since it would enable slow and gradual drying of the wood that is more natural. Additionally, it offers a more accurate moisture content measurement based on the reduced weight of wood rather than non-destructive testing.

(Nyström and Dahlquist, 2004) studied the various methods used in industrial settings to determine the moisture content. In power plants and similar high safety industries, the identification of precise values for the fuel's physical and chemical properties is of utmost importance. It was found that Non-Ionizing Radiation (NIR) and Radio Frequency (RF) are the most common methods of measurement of wood moisture content in industries.

2.2 Moisture meter

Moisture meters are devices used to measure an object's moisture content without conducting extensive experiments to obtain the results. The moisture meter has been mainly use to help builders to select the right wood for flooring and carpentry buildings. The pin-type moisture meter are the commonly used moisture meter for this purpose. The pin-type moisture meter has two pins that act as two electrodes of opposite charge. A wood sample's moisture content is measured by inserting the pins into the sample and allowing current to flow between the electrodes. If the current flows freely, more of a conductor- water- is present in the sample. If the quantity of transmitted electric current is less, it shows high resistance offered by the wood sample due to less moisture. The moisture content is displayed as a percentage on the digital screen on the moisture meter.

3. EXPERIMENTAL SETUP

Figure 1: Moisture Meter

The moisture content measured using the device mentioned is based on the measurement of the dielectric constant. The dielectric constant has a direct relationship with moisture content and wood density. The dielectric constant increases with the temperature. However, it will decrease at higher temperatures (Fridh et al., 2018).

The moisture meter used in this project is the Quirrel Digital Wood Moisture Meter. Specifications of the device are as follow:

Table 1: Moisture Meter Specifications

Model Number	QL-MM001
Weight of device	118g
Power source	Battery-powered
Battery description	9V
Measurement range	0 – 99.9%
Accuracy	+/- 0.5%
Operating temperature	0 to 40^{0}C
Electrode details	Integrated, 10mm long

The procedure for measurement of moisture content using the Quirrel digital moisture meter is as follows. After removing the protective cap, switch on the power button, select the desired wood type by choosing the MODE option on the digital display, and insert the pins into the wood to a distance of 2 to 5 mm. Also, holding the device steadily until the reading is constant. The reading is recorded for analysis. A repetition is made after 15 minutes gap taking three readings for each wood type. In the end, the mean value of each reading is taken as the final value.

Selected different wood types are Maple, Particleboard, Plywood, Mahagony, and Pine, common in building furniture. The moisture content was measured using a handheld moisture meter.

4. RESULTS AND DISCUSSION

In this study, the wood species chosen include Maple, Particleboard, Mahogany, Plywood, and Pine. These are commonly found materials in residential furniture and can contribute as fuel to fire if a fire accident occurs. It was found that the moisture meter's moderate accuracy slightly underestimated the moisture content of the measured wood (up to 6%) (Fridh et al., 2018). Standard calibration features are used to improve measurement (Fridh et al., 2018). The measured values for the five types of wood used in this study are presented below:

Table 2. The moisture content of wood

No.	Wood type	Moisture content %
1	Maple	6.5
2	Particleboard	12
3	Plywood	8
4	Mahogany	14
5	Pine	18

Maple was found to have the least moisture content, followed by Plywood. Pine and Mahogany had the highest moisture content among the wood types. The combustion behavior was assessed by the ignition temperature and heat release rates determined in previous studies. The moisture content data was compared against the data for combustion properties. It was found that moisture content had some influence on delaying ignition temperature of the wood types. For instance, Plywood with low moisture content had a low ignition temperature.

Mahagony and Pine, on the other hand, has a high moisture content, which is reflected in the corresponding ignition temperature values. The ignition temperature is delayed when the moisture content is high because it is initially used to evaporate the moisture content. However, the moisture content was not found to significantly influence the heat release rate per unit area for any of the wood types. It is concluded that while moisture content has a significant effect on the ignition temperature of wood, other properties like density also play a role.

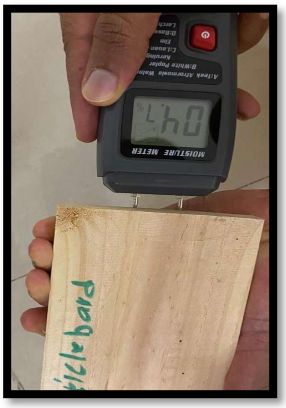
The table below represents some of the thermophysical properties of wood samples. Pine has the lowest density, which is corresponding to the lowest thermal conductivity and highest moisture content. Also, it can be concluded that less moisture content increases the thermal conductivity of wood. Besides, Pine has the highest moisture content of 18% compares with other types of wood.

Moisture content delays ignition temperature because the initial heat is used to evaporate the moisture. It was also found that the effects of moisture content on wood types' burning behavior were limited.

Maple

Plywood

Mahogany



Particleboard

Pine

Figure 2: Moisture content measurements

Table 3: Thermophysical properties of wood samples

Wood Type	Density (kg/m^3)	Thermal Conductivity (W/k.m)	Moisture content %
Maple (Ferrández-García et al., 2017)	750	0.349	6.5
Particleboard (Oyekunle et al., 2018)	6840	0.473	12
Plywood (Oyekunle et al., 2018)	5970	0.217	8
Mahogany (Shen et al., 2013)	560	0.134	14
Pine (Shen et al., 2013)	500	0.126	18

5. CONCLUSION

Wood-based fuels constitute a significant part of the fuel in building fire accidents. Regardless of posing a significant risk as a highly combustible fuel, wood is a common material used in furniture and wall elements due to the aesthetic quality, durability, and functionality. It is essential to study wood characteristics to ensure buildings' safety since the fire behavior is sensitive to the nature of wood. Not all wood types burn the same way, and properties like wood orientation and moisture content may contribute to the differences. The influence of wood moisture content on the burning characteristics of wood was determined. It was found that the moisture content contributes to delaying the ignition time and increasing the ignition temperature. Also, the thermal conductivity is inversely proportional to the moisture content. There is no consistent data found for ignition temperature for all wood types at the same heat flux. The accuracy of the results can be improved by measuring the ignition temperature at the same level of heat flux for all wood types. A further study will be focused on the cone calorimeter to determine the ignition temperature and heat flux for all these types of wood.

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