Improvement of moisture measurements for Egyptian wood samples at NIS -EGYPT

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Abstract:

The measurement of moisture content of wood is important in diverse areas of industry and research. Egypt is one of the important countries that manufacture and export wood furniture. Moisture content (MC) is one of the most important phenomena affecting the properties of wood. It has an influence on the performance of wood such as the mechanical properties and the dimensional change. Effective use of wood requires efficient and reliable methods of measuring wood moisture content. In this paper, the moisture content is estimated from the mass measurement of wet sample, dry sample and the mass of the container. A well-known method is the loss on drying method based on the weight loss of substance after a drying process. This method is the highest standard method in wood moisture measurements. The electronic meter will be used as the secondary standard for the determination of moisture in wood. This method is a very fast and easy method and its traceability to international system of units (SI) was established to give a hand for wood manufactures. The uncertainty of measurement for the 2 above mentioned methods was measured.

Keywords: Moisture, Eelectronic meter; Traceability, Uuncertainty

1. Introduction:

Wood is a hygroscopic material which is able to change its moisture according to the ambient humidity through an adsorption process. Moisture exchange between wood and surrounding environment depends of the relative humidity, the temperature of the environment and the current amount of water in the wood. The moisture remaining in the wood tends to come to equilibrium with the humidity of the surrounding air [1].
Changes in wood moisture content led to a virtual change in all physical and mechanical properties (e.g., strength and stiffness properties) [2].
When determining the moisture content (w_{mc}) using loss-on-drying methods (LOD) the result is obtained as a percentage of its wet mass (wet basis) or dry mass (dry basis):
Moisture content through loss-on-drying methods can be defined as a percentage of its wet mass "wet basis" or dry mass "dry basis :

$$w_{mc,wet} = \frac{m_w *}{m_m} \times 100 \text{ \% mc}$$

$$= \frac{m_w*}{m_w*+m_d} \times 100 \text{ \% mc}$$

$$= \frac{m_m-m_d}{m_w*+m_d} \times 100 \text{ \% mc} \quad (1)$$

$$w_{mc,dry} = \frac{m_w*}{m_d} \times 100 \text{ \% mc}$$

$$= \frac{m_m-m_d}{m_d} \times 100 \text{ \% mc} \quad (2)$$

Where:

m_w* = mass of water and other volatiles determined as the mass loss during drying of a material sample

m_m = mass of the material sample before drying

m_d = mass of the material sample after drying.

A calibrated balance must be used to get traceability.

This method is the most widely recognized for moisture determination due to its simplicity and fundamentality. However, the duration and the conditions of each part of the process (weighting, handling the sample, heating in an oven, cooling down) affect significantly the results. Because of the differences in water evaporation while heating, water adsorption while cooling and the chemical decomposition with different materials, a large number of standardised methods with different heating temperatures and durations for different materials have been set up in industry to obtain acceptable level of reproducibility.

2 Research Methodology:

In classic loss-on-drying technique, samples are weighed before and after oven drying according to a protocol of temperature, well time and end-point determination. The protocol usually depends on the material or application, and sometimes is documented in published standards [3]. The resultant mass fraction lost is reported as the moisture content. This value of 'moisture content' is not necessarily the same as 'water content', since other volatile substances can be involved during the drying process that contribute to a mass loss. A calibrated Wiseven drying oven model WON.105 and a calibrated analytical balance (0.1g resolution) are used in order to make loss-on-drying measurements with traceability to NIS mass standards.

An oven was used to attain and holds temperature at 103 ±2 °C for several hours. It has an adjustable hole which provides a way for moisture to get out and fresh air to get in. It is also provided with thermometer to read its correct temperature without opening the oven. It has a circulating fan to be sure of the homogeneity of its space. The oven and the thermometer were calibrated at our lab (thermometry lab) according to ITS-90. A balance was used for weighing the samples. Its capacity is 5Kg and weight to 0.1 gram.

It was calibrated at NIS mass lab. Plastic gloves which were cleaned using cotton and alcohol are also used to prevent contamination of the samples. After heating, the samples were kept at dissector containing calcium chloride until it reached the room temperature for weighing.

2.1.Samples:

Samples of different wood species of dimensions (120 x 120 x 25) mm shown in Figure 1were used. The samples were placed in special chambers with saturated salt solutions with adjusted conditions as (CH_3 cook for 22.9% rh, MgCl for 43 %rh and K_2CO_3 for 84 %rh, respectively). The salts purity must be at least 98%.

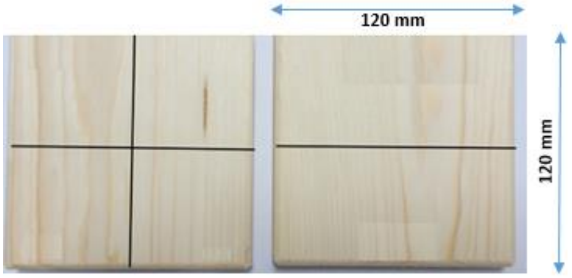

Figure 1. Image of wood sample

2.2. Humidification of samples:

Chambers were constructed from low thermal conductivity material with dimensions 50 cm x 50cm x 30 cm to insure reliable equilibrium moisture content (EMC) values for wood samples. These chambers are used to insure isolation of the system from the temperature and humidity of the environment. Calibrated thermo hygrometer model was used to measure the humidity and temperature of the chambers. A small hole was made in the center of the upper side of the chambers. A fan was fixed in the center of the middle shelf to circulate the air to obtain homogenous relative humidity. The humidity inside the chambers was changed using three different salt solutions. The stability of the chambers was studied before using to be sure of its homogeneity and stability.

The samples were maintained for at least 6 weeks to ensure that the samples have stability moisture content. A schematic representation of one of the chambers is shown in Figure 2.

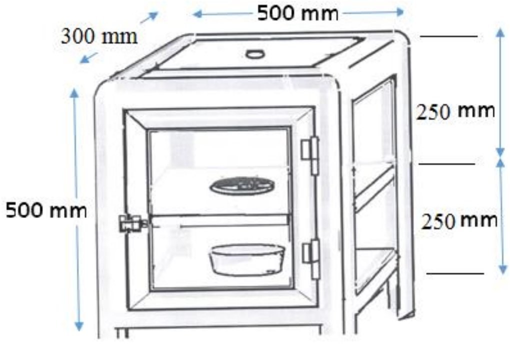

Figure 2. Schematic representation of one of the chambers

2.3. Method of drying sample:

The standard procedure [3] to dry wood was applied in this paper. A sample is weighed and then dried at a temperature of (103 ± 2) °C till reaches a constant mass (the criterion of the end point is a mass change smaller than 0.5 % of the sample mass between two successive weightings carried out at 6 hours interval). There are many other faster and more practical indirect techniques available for measuring moisture in solids in laboratories and on site such as electrical conductance and capacitance…etc [4-6]. Those methods required high material specification and frequent calibration with representative material samples to obtain the accuracy level needed in the measurements.

2.4. Moisture meter:

Moisture meters are the type of instruments that able to measure the trace amounts of moisture in solids, gases and hydrocarbon liquids. In this paper, DELMHORST Pin-type meter model total check was used to measure the moisture content of wood samples considered as indirect method. Pin-type meter works on the principle of electrical resistance. With the pins inserted into the material, a small electrical current is passed between them. The amount of resistance correlates to the amount of moisture in the material. Because moisture is a good conductor, higher moisture levels result in lower resistance values. In this way the moisture level can be quantified. Pin-type meters are an invasive way to measure moisture. They consist of a pair of pins attached to the meter which are pushed or driven into the sample being tested as shown in Figure 3. The meters must be calibrated by a direct method (loss on dry method).

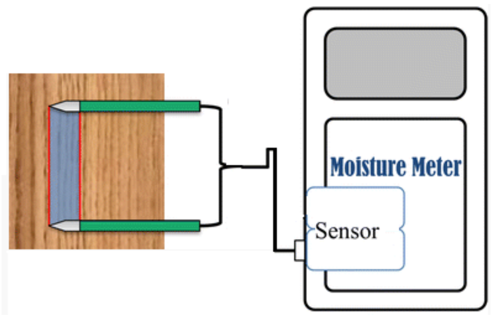

Figure 3. Schematic diagram of area measured by resistance moisture meter

3. Theory and Calculation

Moisture content determination:

Moisture content affects many physical and mechanical properties of wood. In this paper, moisture content (MC) is expressed in percent on dry basis, i.e:

$$MC = \frac{m_{wet} - m_{dry}}{m_{dry}} \times 100\ \% \qquad (3)$$

Where:

m_{wet}: *is* the initial mass of the sample
m_{dry}: is the mass of the dried sample to a constant mass.
The measurements of wood samples of box (1) potassium acetate (22.9% rh) using loss-on-drying (LoD) method shown in Table 1 as an example.[7]

Table 1. the measurements of wood samples of box (1) contain potassium acetate (22.9% rh) using loss-on-drying (LoD) method

Wood samples at 43% rh	Sample weight before drying g	Sample weight after drying g	*Moisture content* %
Oak	**363.0**	**338.3**	**7.30**
Beech	**377.0**	**285.8**	**7.27**
Beech pine	**199.3**	**184.6**	**7.96**

The loss is drying method is the most direct and accurate method of determining moisture content in most cases, as it involves a direct measurement of the mass of wood material and the mass of the water evaporated from it. Oven-drying usually takes at least 18 to 24 hours. This is one of its disadvantages, particularly if an approximate result is required quickly.
In this paper, Pin-type meter was used to measure the moisture content of wood samples considered as indirect method. Measurements were made at least 1cm from the lumber ends and 1 cm from knots and lumber sides as shown in "Figure 4". These zones respond faster to humidity changes and often bias the measurements. At least three measurements per board are required to get a reliable average measurement for the board. Drive the pins into the wood so that an imaginary line between the pins is parallel to the direction of the grain. The pins were driven to a depth of 1/4 of the thickness of the piece of wood being measured. This will yield the best overall average for the piece.

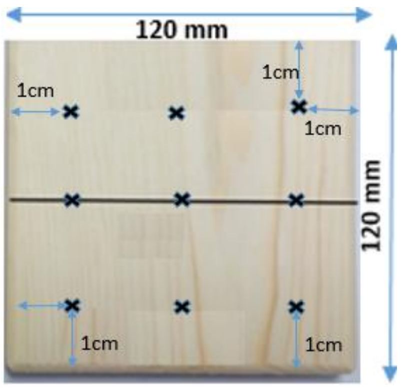

Figure 4. Illustration of measurement zones

The collective data for the different wood samples at different humidity environment by loss on drying (LOD) method and pin meter shown in Table 2.

Table 2. The different wood samples at different humidity environment by LOD method and pin meter

Boxes	Box (1) contains potassium acetate 22.9 %rh		Box (2) contains magnesium chloride 43 %rh		Box (3) contains potassium carbonate 84 %rh	
Moisture / wood sample	Moisture content by LOD method ±0.5%	Moisture content by Pin meter ±1%	Moisture content by LOD method ±0.5%	Moisture content by Pin meter ±1%	Moisture content by LOD method ±0.5%	Moisture content by Pin meter ±1%
Oak	7.3	7.2	9.4	9.3	12.5	12.4
Beech	6.9	6.8	9.3	9.1	12.9	12.8
Beech pine	7.9	7.6	10.5	10.1	13.1	13.9

The expanded uncertainty of measurements is described by an uncertainty budget. Table 3 shows the calculated uncertainty budget for the LOD method with an expanded uncertainty of ±0.5 %. The uncertainty budget comprises a composite of the uncertainties of each element in the method (the expanded uncertainty is equal to twice the standard combined uncertainty) [8-10].

Uncertainty evaluation of the LOD techniques took into account factors including balance calibration, drift, resolution and repeatability as shown in Table 3.

In this study, the uncertainties in the wood moisture content measured by the two methods; loss on dry method (st) and the electronic meter were evaluated and the data were referred to the SI units. The uncertainty of the loss on drying method was ±0.5 %. The uncertainty of the electronic meters was found to be (± 1 %). It is clear that its values are a bit bigger because it includes the drift of the meter, its resolution and type (A) uncertainty beside the uncertainty of the st method (± 0.5%).

Although the uncertainty of the electric meters is high but it is widely used according to it's easier in use, nondestructive and gives fast results.

Table 3. The uncertainty budget of loss on dry method

Description	Estimate	Unit	Probability distribution	Sensitivity coefficient		Uncertainty Contribution	
Repeatability	0.25756	%	Normal	1	%w/%	0.25756	%
Wet under vacuum	0.367795	gm	Rectangular	0.2	%w/gm	0.008481	%
Balance (certificate)	0.06	gm	Normal	2	%w/gm	0.012	%
Drift of Balance	0	gm	Rectangular	0.2	%w/gm	0	%
Oven (certificate)	1.5	ºC	Normal	0.128	%w/ºC	0.001419	%
Drift of oven	0	ºC	Rectangular	0.0128	%w/ºC	0	%
thermometer uncertainty	0.05	ºC	Normal	0.0128	%w/ºC	4.1E-06	%
Drift of thermometer	0	ºC	Rectangular	0.0128	%w/ºC	0	%
Contamination	0	--	Rectangular	0	%w	0	%
Transfer	0	--	Rectangular	0	%w	0	%
Combined uncertainty						**0.257983**	%
Expanded uncertainty (k = 2)						**±0.5**	%

4. Conclusion:

In this study, drying at (103±2) °C to a constant mass was appropriate to determine the moisture content for wood samples by the loss on dry method compared with the electronic meter. The correct moisture content is important for product quality and the loss on dry test is an important quality control tool. The uncertainties in the wood moisture content measured by the loss on dry method (st) was evaluated by ±0.5 %. The uncertainties of the electronic meter were found to be ± 1%. It is clear that its values are a bit bigger because it includes the drift of the meter, its resolution and type

(A)uncertainty beside the uncertainty of the st. method (± 0.5%). It is clear that the dominating component affecting the uncertainty is the resolution, repeatability and the drift. For meters have low resolution, they may be mainly affected by the drift of the instrument and temperature effect.
Although the uncertainty of the electric meter is high but it is widely used according to its easier in use nondestructive, gives fast results and some meters has long pins which enables the measurements in a deep especially during export and import of wood.

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