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Effect of Handling, Packing and Transportation on the Moisture of Timber Wood

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Abstract In order to improve the efficiency of moisture meters calibrations, we studied the effect of ambient humidity, sample handling, packing and transportation on the timber wood (spruce) moisture determination. It was proved by experiments that dry timber samples ($12 \times 12 \times 2.5$ cm) reach equilibrium within 30–40 days even when moisturizing them at a high relative air humidity (80 %). On the other hand, the major mass loss of moist samples placed at normal laboratory conditions was found to occur during the first few days while the first 5 days are critical. The effects of sample handling, packing and transportation were studied by means of interlaboratory comparison between CMI, CETIAT, INRIM, NIS and KRISS. The obtained results show that samples with moisture content less than 7 % tend to absorb small amount of water, whereas samples with moisture content larger than 15 % tend to desorb small amount of water during the handling and transporting even when using vacuum packing and short handling times.

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1 Introduction

In most cases, sampling is an essential part of determination of moisture in solids. Furthermore, moisture measurements involve usually several steps where sample is handled by an operator. Whenever a sample is exposed to ambient air, temperature changes or mechanical stresses, water mass transfer is generated within the sample and with ambient. These need to be considered in particular when handling timber wood samples.

Wood is a hygroscopic material which is able to change its moisture according to the ambient humidity through an adsorption–desorption process. Water exchange between wood and surrounding environment depends of the relative humidity and temperature of the environment and the current amount of water in the wood. The moisture potential of water stored in the wood tends to come to equilibrium with the moisture potential of the surrounding air [1]. The amount of moisture held by wood depends even on the direction from which the equilibrium is approached. The sorption hysteresis of wood, which can be attributed to irreversible uncoupling (during adsorption) and recoupling (relatively delayed stages in the desorption process) of hydroxyl groups in the cellulose structure, has been known for many years [2–5]. In other words, the strength of water molecules bonds bound directly to sites in the cellulose chain is larger during the desorption process than during the adsorption process. When wood is neither gaining nor loosing moisture, we can say that the equilibrium moisture content (EMC) was reached. The common values of EMC are (6–8) % for 25 °C and (30–40) %rh, (8–10) % for 25 °C and (40–50) %rh and (16–20) % for 25 °C and (80–90) %rh for spruce [6].

Changes in wood moisture content lead to changes in virtually all physical and mechanical properties (e.g., strength and stiffness properties) of wood [7]. Proper drying, handling and transportation will minimize moisture content changes. We studied the effect of ambient conditions (humidity and temperature), handling during sample preparation and transportation on the moisture content of different sizes of timber spruce. The goal is to establish the procedure to minimize all ambient effects on moisture content.

2 Material and Methods

2.1 Samples

Samples of different wood species of given dimensions (120 × 120 × 25) mm were obtained from local joiner's shop. Two different methods of wood moistening were used. In the first one, samples were placed in a desiccator with saturated salt solutions (according to OIML R 92 and [8]). This method, however, is time-consuming (6 weeks). Therefore, another system with three climatic cells and saturators (Fig. 1) was developed at the Czech Metrology Institute (CMI) to speed up wood moistening process. The operation of this system is based on the continuous flow of humidity controlled air through the cells. In this device, dry air passes through the saturators

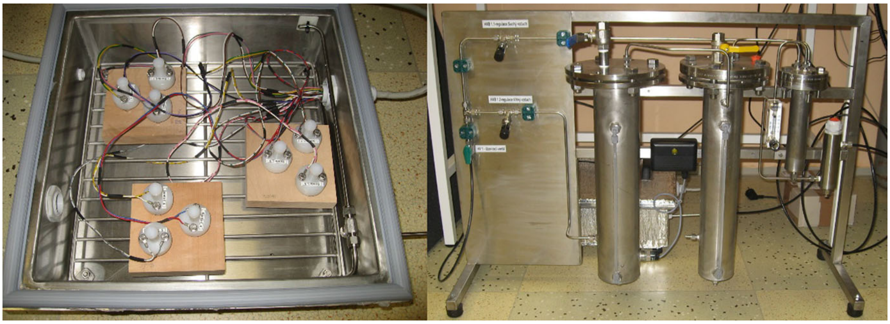

Fig. 1 System of climatic cell with nine probes together with saturator

and enters the three measuring cells. It enables to set different levels of humidity in each cell and to humidify up to three desired humidity levels in one device. Another advantage is that we are able to monitor sample conditions online without disruption of cell conditions (e.g., by opening them) in comparison with desiccators containing saturated salt solutions. This is realized using several probes measuring the resistivity of the samples [9]. The moistening process is carried out at three relative humidity levels: (25–30) %rh, (60–65) %rh and (85–90) %rh for 25 days. The moisture content of all samples was determined using a gravimetric method according to European Standard EN 13183-1:2002.

2.2 Effect of Handling and Transportation

Effect of handling and transportation was studied using samples of spruce. All samples were dried to a constant mass according to ISO 13061-1. Half of each dried sample was weighed and vacuum-packed into a plastic bag, and the other half was moisturized in the climatic cells. Moisturized samples were weighed and immediately vacuumed into a plastic bag. Samples for Centre Techniquie des Industries Aérauliques et Thermiques (CETIAT) and Instituto Nazionale di Ricerca Metrologica (INRIM) were cut into four pieces (60 mm × 60 mm × 25 mm), weighed and separately vacuum-packed into plastic bags. One piece of each prepared sample was sent to CETIAT, one was sent to INRIM and the other two stayed vacuum-packed in CMI (Fig. 2a). Samples for National Institute of Standards (NIS) and Korea Research Institute of Standards and Science (KRISS) were cut in half (120 mm × 60 mm × 25 mm), weighed and separately vacuum-packed into plastic bags. One piece of each prepared sample was sent to NIS or KRISS while the other one stayed vacuum-packed in CMI (Fig. 2b). Postal company with express delivery (delivery made within 3 days) was chosen for transporting samples to the participants. The samples which stayed in CMI were stored in laboratory conditions for 1 week. All samples were unpacked, weighed and dried to constant mass after this time.

2.3 Humidification of Samples

In this work, the absorption of water vapor was studied at CMI using the system of three climatic cells adjusted the conditions of 34 %rh, 43 %rh and 85 %rh, respectively.

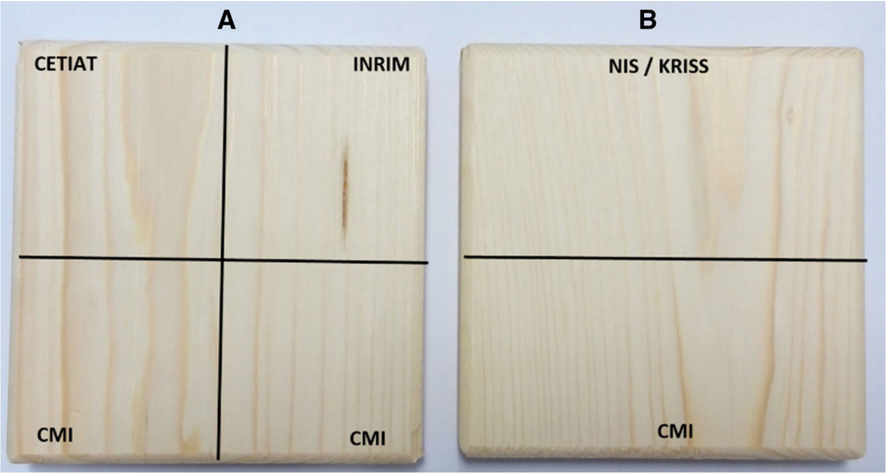

Fig. 2 Illustration of sample dividing between participants

The moisture gain in the samples was monitored using three resistive probes for each sample. Also the other participants used humidity controlled chambers or desiccators with saturated salt solutions (MgCl for 34 %rh, K_2CO_3 for 43 %rh and KCl for 85 %rh [8]).

2.4 Moisture Content Determination

The standard procedure to dry timber wood was applied in this work. According to it, a sample is weighed and then dried at a temperature of (103 ± 2) °C to a constant mass (the criterion for the end point is a mass change smaller than 0.5 % of the sample mass between two successive weightings carried out at 6 hour interval). Dryings were carried out in ovens at CMI, KRISS, NIS and CETIAT. INRIM used an infrared moisture analyzer (Sartorius MA150).

In this paper, moisture content (MC) is expressed in percent on dry basis, i.e,

$$\mathrm{MC} = \frac{m_{\mathrm{wet}} - m_{\mathrm{dry}}}{m_{\mathrm{dry}}} 100\,\%\mathrm{mc},$$

where m_{wet} is the initial mass of the sample and m_{dry} is the mass of the sample dried to a constant mass.

3 Results and Discussion

3.1 Effect of Ambient Conditions

Samples of dried timber spruce of dimensions (12 × 12 × 2.5) cm were placed into the climatic cells at (85–95) %rh, and the conductivity of each peace was monitored. Another samples were placed into the desiccator with saturated salt solution of K_2SO_4

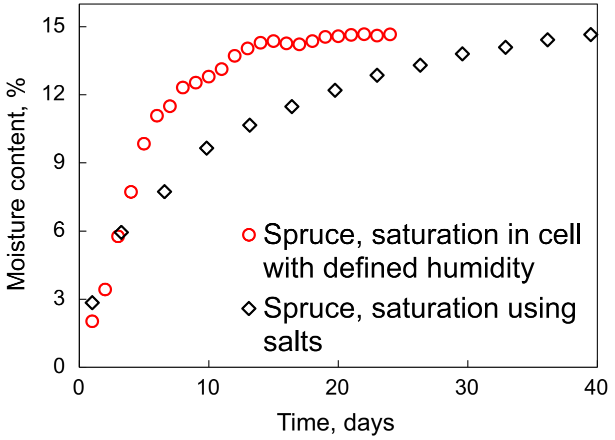

Fig. 3 Moisture gain of spruce during humidification at 85 %rh to 95 %rh and (23 ± 2) °C

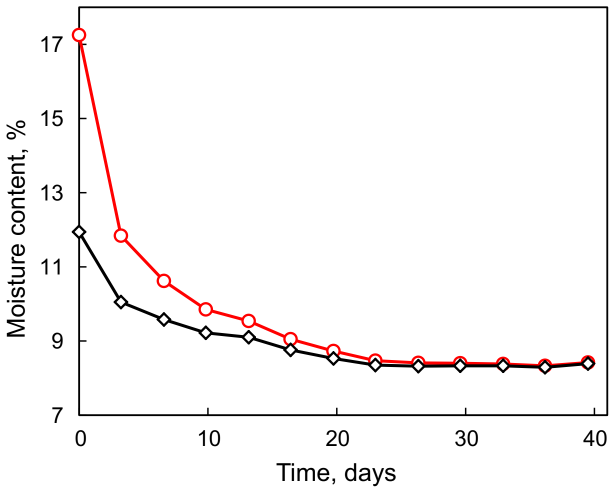

Fig. 4 Loss of moisture in wood sample (spruce) kept in the laboratory at 20 °C and 45 %rh. Stable moisture was achieved after approx. 26 days

(97 %rh). Comparison of these two methods is shown in Fig. 3. The results show that all samples reached equilibrium after 20 days in the climatic cells and after 40 days in the desiccator. Higher air humidity or longer saturation causes development of fungi on the surface of samples.

Moisture loss of wet samples at laboratory conditions was demonstrated with another experiment using two spruce samples (Fig. 4). The loss is faster during the first few days, and the first 5 days are critical from the uncertainty point of view. We can see that both samples reach the same moisture eventually. The moisture content at equilibrium corresponds to the sorption isotherm values published in [8].

It is concluded from the results shown in Figs. 3 and 4 that the moisture content of wood samples significantly changes during the first 5 days when exposing dry or

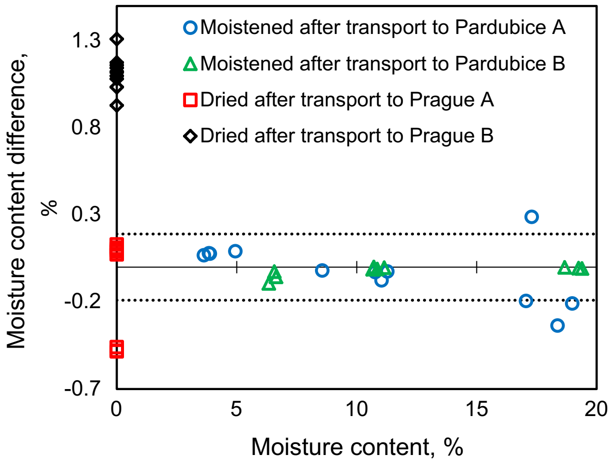

Fig. 5 Influence of handling and transportation on sample moisture for dried and moistened spruce samples (12 × 12 × 2.5) cm

wet samples to normal laboratory ambient air. Therefore, it is essential to measure the moisture of sample as soon as we unpack it.

3.2 Effect of Handling, Packing and Transportation

Further information about the effect of handling, packing and transporting samples was obtained in the comparison between CMI, KRISS, NIS, CETIAT and INRIM. The first step in this comparison was to humidify samples. This was done using the system of three climatic cells and saturators at CMI in Prague. For the purpose, all samples (12 pieces marked A and 12 pieces marked B) dried to constant mass at CMI in Pardubice (approx. 130 km from Prague) were vacuum-packed and transported to Prague. The first 12 pieces (A) were placed into three cells (4 pieces to one cell), each at different air humidities, for 6 weeks. After the humidification, the samples were weighed, vacuum-packed and transported back to Pardubice. The same process was applied to the rest of the 12 pieces (B). Figure 5 shows the difference between the moisture contents in dried samples determined in Pardubice and Prague. The results indicate that dried samples are able to adsorb small amount of moisture even during careful sample handling and transportation with short exposition to ambient air and well-sealed sample bags. The amount is even larger when samples stayed packed in the laboratory for 6 week before the measurement (dried after transport to Prague B). Adsorption process after moisturizing in the climatic cells decreases; thus, the difference in moisture content in moisturized samples before and after transport is much smaller. Only in higher value of moisture we can observe slight increase in moisture content difference due to beginning of desorption process of wood.

Next step was to cut all A samples to four pieces and all B samples to two pieces (specific splitting of samples is shown in Fig. 2). This was done using a circular saw. All

Table 1 Expanded uncertainty of moisture determined by each participant ($k = 2$)

Participant	CMI	KRISS	NIS	INRIM	CETIAT
Expanded uncertainty, % of moisture content	0.19	0.11	0.52	0.11	0.05

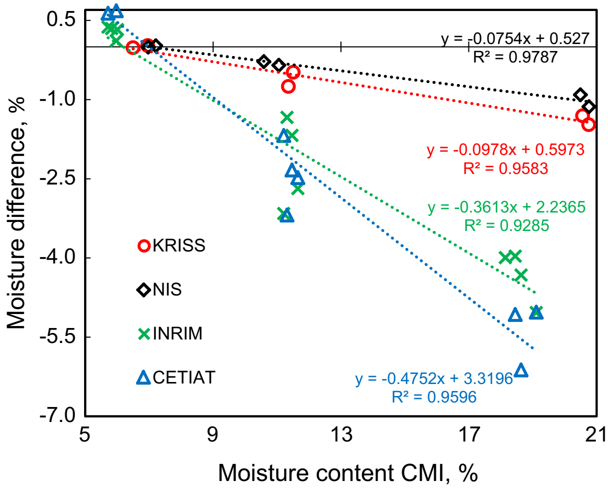

Fig. 6 Moisture difference between CMI and other participants determined with samples sent by CMI to the other participants

cut samples were cleaned from splinters and sawdust, marked with numbers, weighed and immediately vacuum-packed into a plastic bags separately.

Meanwhile, dried samples were prepared from already cut pieces. All pieces were marked with numbers and dried to a constant mass. Samples were weighed after 4 h in desiccator, immediately vacuum-packed into a plastic bags separately and sent to each participant together with moistened samples.

All participants check all samples up (mildew, vacuum) and weighed them according to the protocol 24 h after delivery. Drying of moistened samples or moistening of dried samples followed. All dried samples were sent back to CMI after weighting and vacuum packing. Saturated salt solutions were used by all participants to humidify the samples. After weighing all samples, half of them representing evenly all moisture values was sent back to CMI while the other half was dried to a constant mass by the participants. Table 1 shows the expanded uncertainty determined by each participant for their measurements.

Figure 6 shows clear trends in the differences between the results obtained by CMI and the other participants. It is obvious that the effect of desorption during sample handling and transportation is larger with larger moisture content. The effect of the sample size (Italy and France × Korea and Egypt) can also be observed: The desorption effect is larger with smaller samples (INRIM and CETIAT). When studying the results obtained before and after sending samples back to CMI (Fig. 7), we can see the same trends there confirming the effects of sample handling and transportation.

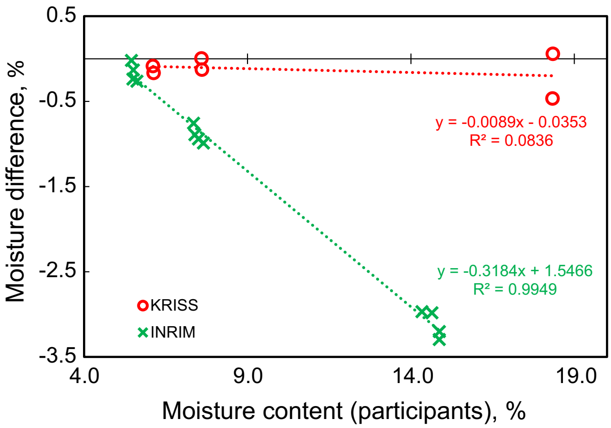

Fig. 7 Moisture difference between CMI and other participants determined with samples sent by the participants to CMI

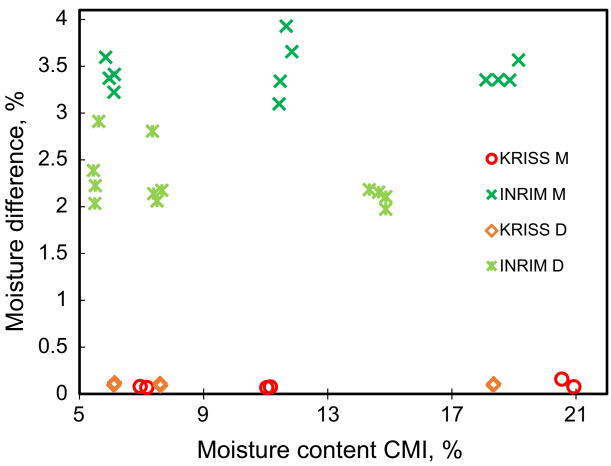

Fig. 8 Increase in moisture content of dried samples transported between participants and coordinator

Figure 8 summarizes the data of two participants where 'M' and 'D' refer to moisturized samples and dried samples, respectively, sent by CMI to KRISS and INRIM. They dried the M samples and sent back to CMI. These results indicate that there is some adsorption process during handling and transportation of dried wood sample. Furthermore, the adsorption effect is larger with smaller sample size.

It is concluded that even with vacuum packing and careful sample handling adsorption and desorption of moisture can be very significant source of error in reference wood moisture measurements.

4 Conclusion and Discussion

The effects of handling, packing and transporting samples were studied in this work by means of an interlaboratory comparison between five laboratories. The results show that these effects have a significant influence on the moisture of samples even with well-defined and controlled procedures of packing and handling. Smaller samples were found more sensitive to errors due to adsorption/desorption process. In particular, when operating with very dry or moist wood samples, special attention must be paid to monitoring the mass change of the samples during each step of reference moisture measurement process (including transportation). All these effects have to be counted into an uncertainty budget of wood moisture determination.

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