NORDTEST PROJECT ON MOISTURE BUFFER VALUE OF MATERIALS

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ABSTRACT

Building materials and furnishing used in contact with indoor air have some effect to moderate the variations of indoor humidity in occupied buildings. Very low humidity can be alleviated in winter, as well as can high indoor humidity in summer and during high occupancy loads. Thus, materials can possibly be used as a passive means of establishing indoor climatic conditions, which are comfortable for human occupancy.

But so far there has been a lack of a standardized figure to characterize the moisture buffering ability of materials. It has been the objective of a Nordic project, which is currently being completed, to develop a definition, and to declare it in the form of a NORDTEST method. Apart from the definition of the term Moisture Buffer Value, the project also declares a test protocol which expresses how materials should be tested. Finally as a part of the project, some Round Robin Tests have been carried out on various typical building materials.

The paper gives an account on the definition of the Moisture Buffer Value, it outlines the content of the test protocol, and it gives some examples of results from the Round Robin Tests.

KEYWORDS

Moisture, materials, transport properties, indoor air, buffer capacity, Round Robin Test.

INTRODUCTION

Indoor humidity is an important parameter to determine the occupants' perception of indoor air quality (Fang et al. 2000), and is also an important parameter as a cause of processes which are harmful to the health of occupants (Bornehag et al., 2003). Materials that absorb moisture and release it in other periods can be used positively to reduce peaks of humidity levels in indoor climates. Some investigations indicate that the use of hygroscopic materials can improve the indoor climate and comfort of occupants because of the way the materials moderate the indoor humidity variations (Simonson et al., 2001).

For these reasons, and because of the role played by indoor moisture conditions on the durability of the envelope of buildings, there is significant interest in characterizing both the moisture transmitting and buffering properties of absorbent, porous building materials.

At present there is no consensus on how to describe the moisture buffer property of building materials. Therefore, there is a need for a robust definition of a term for the moisture buffer

effect of materials, which is technically sound, yet comprehensible and indisputable for the industry and users that will apply it: i.e. a number that is able to indicate the rate and amount of moisture flowing between a material and its surrounding climate in a dynamic situation.

Also, a test method to determine the moisture buffer performance according to the definition needs to be defined. A Round Robin Test should be executed in order to ensure that testing laboratories are able to handle the test method, and to establish the first reference measurements on a limited number of representative materials. The purpose of the NORDTEST project described in this paper is to fulfil these needs, and that was also the conclusion at a workshop that was arranged prior to starting the NORDTEST project (Rode, 2003). We propose to call this desired property the *Moisture Buffer Value*.

Partners in the NORDTEST project are the Technical University of Denmark (DTU) (as project leader); Technical Research Centre of Finland (VTT); Byggforsk, Norway (NBI); and Lund Institute of Technology, Sweden (LTH). In addition the project is followed by an international reference group with participants from six other research institutions.

DEFINITION OF MOISTURE BUFFER VALUE

The Moisture Buffer Value (MBV) indicates the amount of moisture uptake or release by a material when it is exposed to repeated daily variations in relative humidity between two given levels. When the moisture uptake or release from beginning to end of the exposure to a new relative humidity is reported per open surface area and per % RH variation, the result is the MBV. The unit for MBV is $kg/(m^2 \cdot \% \text{ RH})$. The concept of moisture buffer value can easily be appreciated and understood from an experimental standpoint, and likewise, it is relatively straightforward to measure. Theoretically, the MBV can be associated with the effusivity for moisture exchange, a definition parallel to thermal effusivity (Hagentoft, 2001).

The value is a direct measure of the amount of moisture transported to and from a material when the exposure is given. The value is mainly, but not only a property of the material. Also the mass transfer coefficient at the boundary layer plays a role, and thus, the moisture buffer value becomes a true material property only in the limit of the convective mass transfer coefficient tending to infinity. For many materials the internal resistance to moisture transport is considerably larger than the convective surface resistance.

TEST PROTOCOL

The NORDTEST project defines a test protocol for experimental determination of the moisture buffer value. The principle is based on climatic chamber tests, where a specimen is subjected to environmental changes that come as a square wave in diurnal cycles.

The test protocol proposes to use climatic exposures which vary in 8 h + 16 h cycles: 8 hours of high humidity followed intermittently by 16 hours of low humidity. The reason for the asymmetry in this time scheme is twofold: (1) It replicates the daily cycle seen in many rooms, e.g. offices or bedrooms, where the load comes in approximately 8 hours, and (2) for practical reasons during testing if the climatic chamber conditions are changed manually, it is a scheme which is easier to keep than a 12 h + 12 h shift.

TABLE 1. Materials tested in the Round Robin, and indication of institutions performing the tests.

Material/Product	DTU	VTT	LTH	NBI
Spruce Plywood (pre-test)	x	XX	x	x
Spruce boards from *Woodfocus*, FIN	x	XX		x
Concrete from *Betonelementforeningen*, DK	XX		x	x
Gypsum from *Gyproc*, S		x	XX	x
Laminated Wood from *Annebergs Limtræ*, DK	XX	x		x
Light weight aggregate concrete from *maxit*, DK	XX		x	x
Cellular concrete from *H+H Celcon*, DK	XX	x	x	
Brick from *Kalk- og Teglværksforeningen*, DK	XX	x	x	
Birch wood panels from *Tresenteret*, N		x	x	XX

XX - country responsible for supplying the material

The low humidity is proposed to be 33% RH, while the high should be 75% RH. However, the NORDTEST project also proposes the following alternatives: 33/54%, 54/75%, and 75/93%. These humidity levels are chosen because they can be maintained by saturated salt solutions, but some other conditioning system may also be used. The choice of RH-level may have some impact on the results as the sorption and permeability properties depend on humidity. Therefore, testing should be done in a range which reflects a relevant level for the application of the material. During the tests, it is important that the equipment is able to make rapid RH-changes. Testing should always be carried out at 23°C as a reference.

Specimens will normally be sealed on all but one or two surfaces so the minimum exposed surface area should be 0.01 m^2. The thickness of the specimen should be at least the moisture penetration depth for daily humidity variations, or 10 mm, whichever is larger. At least three specimens should be used for testing.

Using an accurate scale, the specimens should be weighed continuously or intermittently during the test. At least five weight measurements should be carried out during the 8 hour high humidity part of the last cycle. A minimum of three cycles have to be carried out, and the weight amplitude must not vary by more than 5% from day to day. This is defined as the three stable cycles (see Figure 2 for an example of a measurement sequence). The stable cycles are also characterized by the fact that the daily amounts of moisture uptake and release are approaching each other as shown in Figure 3. The mass change should be plotted and normalized as mass change ($m_{8\ hours}$-m_0) per m^2 and per ΔRH to give the MBV (see Figure 3).

ROUND ROBIN TEST AND INITIAL RESULTS

A Round Robin Test is carried out within the NORDTEST project to try the testing paradigm and to obtain some initial results for typical building materials. In addition, and to guide the formulation of the test protocol, a preliminary test was carried out on some spruce plywood boards that were distributed to all project partners. The materials tested and the institutions doing the tests are listed in Table 1. Each material is tested by three partners.

The institutions do not have quite the same experimental equipment available and some of the operational routines were also dissimilar, although in accordance with the common test protocol. E.g., some institutes made manual weighing of the specimen, while it for others took place by automated logging of a scale. Thus, it has been part of the Round Robin Test to see if it were possible to obtain similar and agreeable results by all institutes.
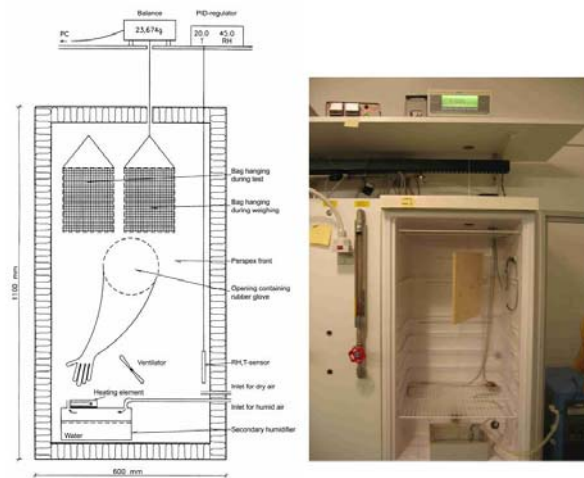
Figure 1: Drawing and picture of one of the climatic chambers used at DTU.

Figure 1 shows a drawing and photograph of one of the climatic chambers used at DTU. The humidity control of the chamber works by supplying it with either humid or dry air in an intermittent mode, such that the desired humidity in the chamber is achieved.

Figure 2 shows the measured weight change response of one of the specimens when it was subjected to cycles that varied the ambient humidity between 33% and 75 % RH for 16 and 8 hrs respectively. The choice of stable cycles and the moisture uptake is marked in the figure.

Figure 3 shows for three different specimens of the same type of material how the moisture uptake and moisture release varied from cycle to cycle until the three stable cycles were attained. Thus the results of measurements of one type of material give the following background for statistical analysis: Three specimens with results from three cycles of both moisture uptake and release - altogether 3x3x2 = 18 bids for the MBV result. The results should be represented at least with their mean value and standard deviation together with information about the number of tested specimens and stable cycles (if different from 3x3).

Figure 4 shows the MBV for the materials tested by the participating institutions until the day of completing this paper. The materials are labelled M1, M2, ..., M8, and the bar diagrams indicate for each material and testing laboratory the average of the MBV-value and its standard deviation. More results need to be obtained before statements can be issued about how agreeable the results are, and it is also too early to give statements about how well the different materials perform as moisture buffers. However, it seems that the order of magnitude for the tested materials is around 1 g/(m^2·%RH), and there may be approximately a factor 3 of a difference between the materials with the highest and lowest MBV among those tested.

PRACTICAL APPLICATION OF THE MOISTURE BUFFER VALUE

The Moisture Buffer Value is primarily meant as a number that can be used to appraise a material's ability to absorb and release moisture from an adjacent space. For practical application it can also be useful as a number for estimation of the moisture balance of rooms, as indicated by the following example.
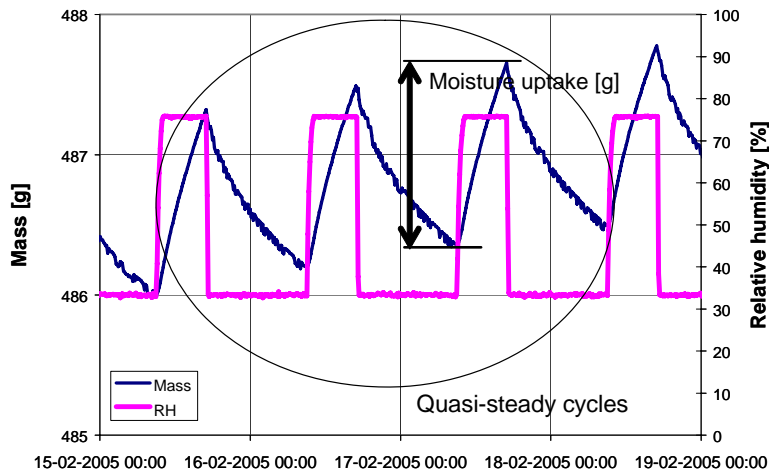
Figure 2: Moisture uptake and release cycles for M6. Exposure between 33 and 75% RH.
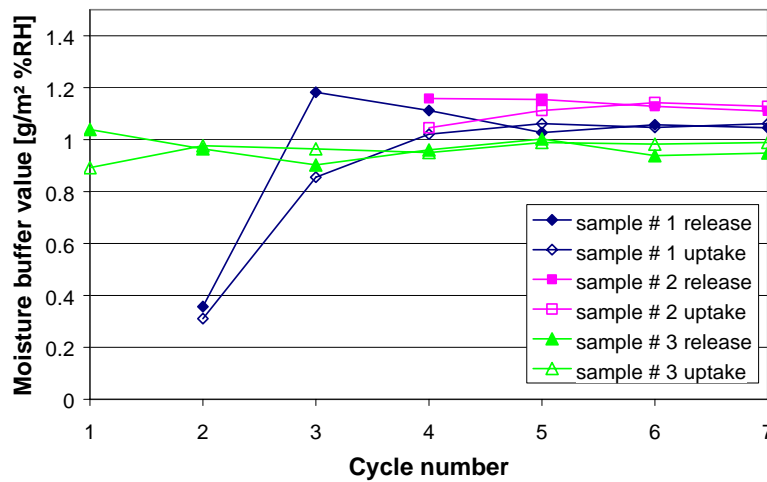

Figure 3: MBV of material M1 as a function of cycle number and uptake versus release. The last 3 cycles are the stable cycles (=quasi-steady)
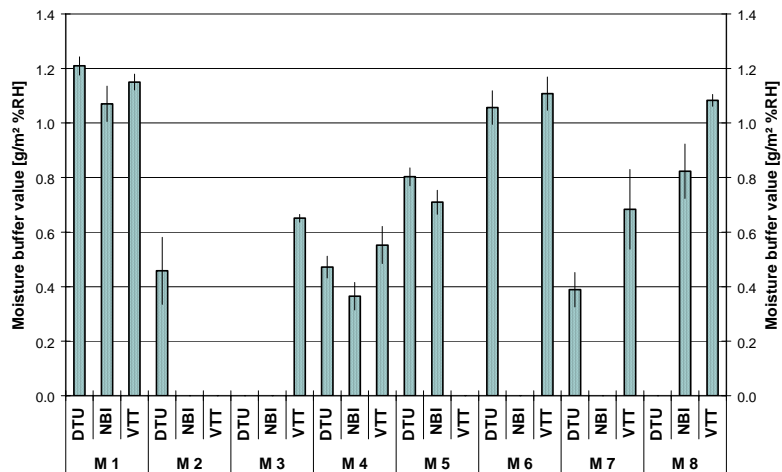

Figure 4: Moisture Buffer Values found by different institutions for the different materials. Each bar indicates the average of three specimens over three stable cycles. The thin vertical line-bars indicate standard deviations.

Example

An unventilated room has dimensions 4 x 5 x 2.5 m = 50 m^3, and temperature 23°C. In the room is released G = 100 g of moisture per hour. The room is clad with A = 45 m^2 of material with MBV = 1.2 g/(m^2·ΔRH). By how much will the indoor humidity increase in 8 hours?

First, the wall cladding is neglected. The saturation water vapour concentration at 23°C is 20.6 g/m^3. Thus, the air itself has a moisture buffer value of 0.206 g/(m^3·%RH), so in 8 hours ΔRH will be $\dfrac{8\,h \cdot 100\,g\,/\,h}{50\,m^3 \cdot 0.206\,g\,/(m^3 \cdot \% RH)} = 78\,\% \,RH$ (or condensation may occur before then).

Next, if the room cladding is considered, but the buffer capacity of the air is neglected, the RH increase can be calculated by assuming that all the released moisture will be absorbed by the wall cladding material. The increase in indoor relative humidity will be:

$$\Delta RH = \frac{G \cdot \Delta t}{\text{MBV} \cdot A} = \frac{100\,g/h \cdot 8\,h}{1.2\,g/(m^2 \cdot \% RH) \cdot 45\,m^2} = 15\,\% \,RH$$

Finally, if as in reality, the room experiences an air change with other environments, its humidity would be governed also by the air change rate and vapour content of the ventilation air, and this could well be more important than the buffer capacity of the air and materials.

CONCLUSION

The described work declares a uniform definition of a term such as *Moisture Buffer Value* as well as an experimental protocol for its determination. *Moisture Buffer Value* can be used to appraise the ability of materials used in buildings to moderate indoor humidity variations. The term should replace an inconsistent variety of other numbers used till now to appraise this quality of building materials. A Round Robin Test is carried out in which the moisture buffer value has been determined for some examples of common building materials. The results of the described project will be published in the form of a NORDTEST method.

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