CLIMA 2016 - proceedings of the 12th REHVA World Congress

volume 7

Heiselberg, Per Kvols

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Heiselberg, P. K. (Ed.) (2016). *CLIMA 2016 - proceedings of the 12th REHVA World Congress: volume 7*. Department of Civil Engineering, Aalborg University.

The sample size effect to obtain the moisture buffer value

I. Gomez-Arriaran[#1], I. Sellens-Fernandez[1], M.Odriozola-Maritorena[1], E. Pérez-Iribarren[1], Z. Azkorra-Larrinaga[1]

[1]*ENEDI Research Group – Department of Thermal Engineering, Polytechnic University*
College of Donostia – San Sebastián. University of the Basque Country
Plaza Europa 1, 20018 – Donostia – San Sebastián – Spain

#gomez.arriaran@ehu.eus

Abstract

Achieving a satisfactory indoor air quality in buildings requires control of the relative humidity of indoor environments. Maintaining proper moisture conditions inside buildings is determined by the hygroscopic balance in interior spaces. In that balance, the ability of materials that form the inside surface of the building envelope, to buffer fluctuations in indoor relative humidity is a capacity that can play a key role. This ability is measured by the Moisture Buffer Value (MBV) of the material used as inside coating.

Two variables that have great influence when assessing MBV of a material are the mass transfer resistance value of the vapor film surface layer and the sample width. The last has to be, as minimum, equal to the moisture penetration depth of the material. Besides, it is not so clearly defined the influence of the exposed surface of the samples during testing.

In this work the influence of the size of the testing sample is studied and its impact on the MBV results is evaluated. The MVB is determined according to the Nordtest protocol. Samples of different size are evaluated by dynamic tests in a climatic chamber.

The testing material is lightweight ceramic clay, widely used in buildings energetically efficient for its high thermal performance and hygroscopic character.

It is concluded that the size of the specimens is critical not only in the accuracy of results, but in the interpretation of the hygroscopic behavior thereof.

Keywords - Moisture Buffer Value; building materials; sample size

1. Introduction

The capacity to buffering oscillations of ambient relative humidity can be used as a passive system. This fact can help to satisfy the requirements of European Directives of Energy Efficiency [1] to reduce both the energy consumption and the greenhouse gas emissions associated to HVAC systems. This can be critical in environments intended for use as archives and museums, in order to adequately maintain the storage conditions of materials, objects and documents sensitive to cyclical changes in relative humidity.

The Moisture Buffer Value is a material property based on porous materials capacity to uptake and release ambient moisture. The hygroscopic balance has a significant effect on occupant comfort, indoor air quality, occupant health, building durability and energy consumption. Therefore, the study and development of hygroscopic materials in buildings is important.

There are different protocols and standard test methods to obtain the moisture adsorption and desorption content in response to humidity variation. The Japanese Industrial Standard A 1470-1 (JIS) [2], the ISO 24353 [3] and the Nordtest protocol [4] are the most well-known. A comparison of the methods was analyzed in [5].

There are some variables that have impact when assessing the MBV of a material as the mass transfer resistance value of the vapor film surface layer and the sample width. The last has to be as minimum equal to the moisture penetration depth of the material according to [4]. The influence of the film layer resistance was studied in [6]. But, the influence of the exposed area it is not so clearly defined.

In this work, the influence of the size of the exposed area of samples used to determine the practical value of the MBV is studied.

2. Teorethical detrmination of Moisture Buffer Value

The theoretical or ideal Moisture Buffer Value (kg/m²·%RH) is given by (1), according to Nordtest protocol [4].

$$\mathrm{MBV_{ideal}} \approx \frac{\mathrm{G(t_p)}}{\Delta\,\mathrm{RH}} \approx 0.00568 \cdot \mathrm{p_{sat}} \cdot \mathrm{b_m} \cdot \sqrt{\mathrm{t_p}} \qquad (1)$$

being b_m (kg/m²·Pa·s½) the material's moisture effusivity, p_{sat} (Pa) the saturation pressure and t_p (s) the period of time.

For cyclic relative humidity changes the accumulated moisture content change $G(t_p)$ in the sample is measured and normalized with the change of relative humidity, ΔRH, in order to obtain the ideal Moisture buffer Value. The moisture uptake within 8 hours corresponds to the moisture release during 16 hours, to complete cycles of 24 hours.

To calculate the moisture effusivity, the hygroscopic characterization of the material is required. The sorption isotherm, w (ø) (kg/m³), and the vapour permeability, δ_p (kg/m·s·Pa), have to be experimentally determinated to calculate the material's diffusivity, D_w (m²/s), by (2) and then, the material's effusivity, b_m (kg/m²·Pa·s½), by (3).

$$D_w = \delta_p \frac{p_{sat}}{\partial w / \partial \emptyset} \tag{2}$$

$$b_m = \frac{\delta_p}{\sqrt{D_w}} \tag{3}$$

Water permeability is obtained through the water vapor diffusion test, according to the UNE-EN ISO 12572 [7], American ASTM-E96 [8] or German standard DIN 52 615 1973 [9]. Vapor permeability measurements at different relative humidities were performed and the fitting was obtained according to the following model proposed by [10]:

$$\mu = \frac{1}{a + b \cdot e^{c\emptyset}} \tag{4}$$

where a, b and c are the parameters of fit (see table 1).

Table 1: Parameters of fit for the vapor diffusion resistance factor.

a	0
b	0,0025
c	2,8823

For the determination of moisture diffusivity D_w, it is also necessary to obtain the moisture capacity, that is, the slope of the sorption isotherm, obtained through a hygroscopic sorption test.

The determination of the sorption isotherm was done according to the UNE-EN ISO 12571 [7] through a hygroscopic sorption test. Hygroscopic sorption curve can be adjusted by various existing models [11]. In this case the adjustment model with a better fit is the proposed by [12]:

$$w = A \cdot \left[\frac{1}{1-\emptyset} - 1\right]^{B} \tag{5}$$

where w (kg/m^3) is the moisture content, $\emptyset$ (-) the relative humidity, and A and B, are the parameters of fit.

Table 2: Parameters of fit for the sorption isotherm.

A	9,3974
B	0,3835

The results of the moisture characterization and the calculated ideal MBV are shown in table 3.

Table 3: Hygroscopic properties at 54% RH

μ	84,6726	(-)
δ_v	2,3040E-12	(kg/m·s·Pa)
D_w	4,1935E-10	(m^2/s)
b_m	1,1300E-07	(kg/(m^2·Pa $s^{\wedge 1/2}$))
MBV_{ideal}	0,3045	(g/m^2%RH)

3. Practical determination of Moisture Buffer Value

The practical Moisture Buffer Value can also be determined for materials that are thinner than the penetration depth. The practical and the ideal MBV have to be similar only if the material is homogeneous and its thickness is at least the same than moisture penetration depth of the material. If these conditions are not fulfilled, the direct comparison with a theoretical buffer value is no possible.

Tests were carried out according to Nordtest protocol [4] to determine the practical MBV. The samples were exposed to repeated step changes on relative humidity between 75% RH during 8 hours and 33% RH during 16 hours. The temperature was kept constant at 23ºC. A climatic chamber was used to obtain the relative humidity and temperature conditions.

Fig. 1 Climatic chamber and data caption and register.

The samples were sealed with aluminum tape on five out of six sides. The samples weight changed according to the periodic relative humidity changes. The changes of weight were normalized per exposed surface and RH change, in order to obtain the MBV (kg/m²·%RH) of the material.

Fig. 2 Sealed back side of a sample.

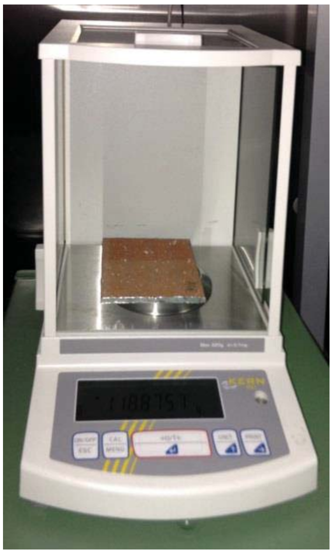

Fig. 3 Electronic precision balance during testing

One of the variables established by [4] is the open surface area of the unsealed surface of the sample. The Nordtest protocol sets the sample minimum exposed area in 0,01 m². In this research two samples sizes were used. In order to analyze the influence of the sample dimensions, some samples, coded “AXX”, were according to the Nordtest protocol with 0,012 m² of exposed area and the others, coded “SDXX”, with 0,003 m² of exposed area were smaller than the required by the protocol. Table 4 shows the dimensions of all tested samples.

Table 4. Dimensions of samples

	With	Length	Thickness	Area
	(mm)	(mm)	(mm)	(m²)
SD 32	3,41E+01	9,35E+01	4,18E+00	3,192E-03
A01	1,02E+02	1,10E+02	5,41E+00	1,12E-02
A02	1,11E+02	1,11E+02	5,44E+00	1,23E-02
A03	1,12E+02	1,11E+02	6,44E+00	1,24E-02
A04	1,10E+02	1,10E+02	5,76E+00	1,20E-02
A05	1,10E+02	1,10E+02	5,49E+00	1,21E-02
A06	9,70E+01	1,11E+02	6,04E+00	1,08E-02

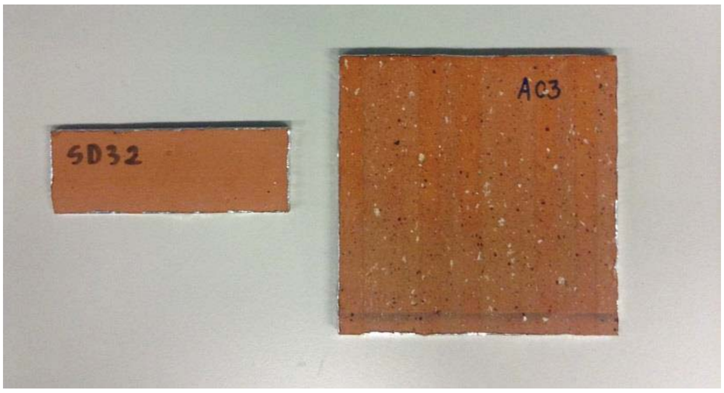

Fig. 4 Two types of tested samples

4. Results and Discussion

Tests with different sample of different dimensions provided very different results. For the “SDXX” (small samples) the weight increased when the relative humidity decreased, and the weight decreased when the relative humidity increased (see fig. 5). The result was exactly the opposite than should be expected according to moisture transfer principles.

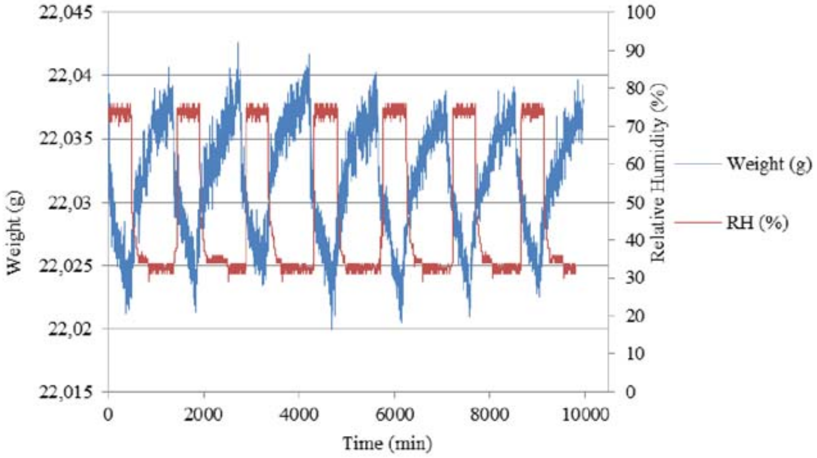

Fig. 5 Weight and relative humidity in function of the time (7 cycles) for sample SD32.

The results for “AXX” samples (with dimensions according to the Nordtest protocol) are shown in fig. 6. In this case, the weight decreased when the relative humidity decreased, and increased when the relative humidity increased, as expected.

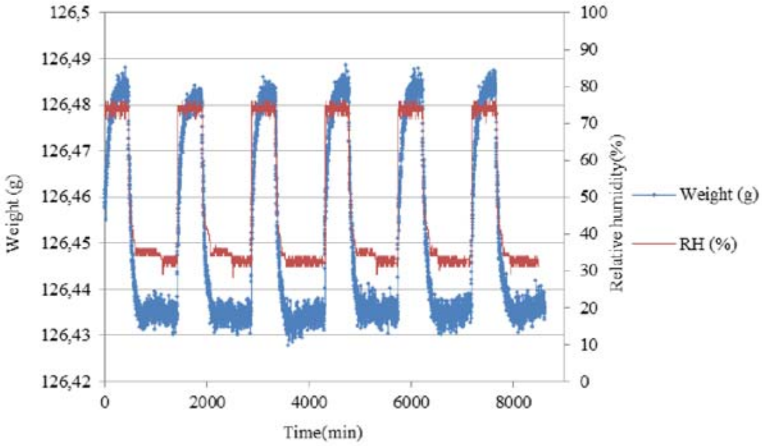

Fig. 6 Weight and relative humidity in function of the time (5 cycles) for sample A04.

5. Conclusions

The most important conclusion is about the importance of the required minimum size for the testing sample when measuring the MBV. It is important not only for the accuracy of the test results but also for the correct reproduction of the physical phenomenon involved.

Not using samples with the minimum required area means less hygroscopic inertia but also a lower coefficient of mass transfer resulting in a combined effect of both parameters that may be inconsistent with the phenomenon to be reproduced.

Consequently, it is critical selecting a correct sample size when measuring the Moisture Buffer Value, in order to reproduce the buffering phenomenon that occurs in buildings indoor environment.

Future works have to be done in order to obtain the sample size for which the buffering phenomenon is inverted, and extend the scope of the research to other building materials.

According to obtained results, it is necessary to investigate the possible different behavior that the moisture buffering of a room can have depending on whether the walls are covered by a continuous surface or by tails of material.

References

[1] European Union. Directive 2010/31/EU of the European Parliament and of the Council of 19 may 2010, on Energy Performance of Buildings (Recast). Official Journal of the European Union L 153, (2010). 13-35.

[2] Japanese Standards Association. "Test method of adsorption/desorption efficiency for building materials to regulate an indoor humidity–Part 1: Response method of humidity." JIS A 2002 (2002): 1470e1.

[3] ISO 24353. Hygrothermal Performance of Building Materials and Products - Determination of Moisture adsorption/desorption Properties in Response to Humidity Variation (2008).

[4] C. Rode, et al. Moisture buffering of building materials. Technical University of Denmark, Department of Civil Engineering (2005).

[5] Roels, Staf, and Hans Janssen. "A comparison of the Nordtest and Japanese test methods for the moisture buffering performance of building materials."Journal of Building Physics 30.2 (2006): 137-161.

[6] Gómez, I., et al. "Moisture buffering performance of a new pozolanic ceramic material: Influence of the film layer resistance." Energy and Buildings 43.4 (2011): 873-878.

[7] UNE-EN ISO 12572. 2001. Hygrothermal performance of building materials ans products. Determination of wáter vapour transmission properties (2001).

[8] ASTM. Standard test method for water vapor transmission of materials. E96-90. In Annual Book of American Standard Testing Methods, ASTM: Philadelphia, PA (1990).

[9] German Standard, D. I. N. 52615. Testing of Thermal Insulation, Determination of Water Vapor Permeability of Building and Insulating Materials (in German) (1973).

[10] Kerestecioglu, A., M. Swami, and A. Kamel. "Theoretical and computational investigation of simultaneous heat and moisture transfer in buildings: effective penetration depth theory." Ashrae Transactions 96.1 (1990): 447-454.

[11] Gómez, I., J. M. Sala, and J. A. Millán. "Moisture Storage Properties of Multi-Slotted Light-weight Ceramic Blocks: Comparison Between Two Manufacturers." Journal of Building Physics 31.3 (2008): 225-242.

[12] Burch, Douglas M., and Joseph Chi. MOIST: A PC Program for Predicting Heat and Moisture Transfer in Building Envelopes: Release 3.0. US Department of Commerce, National Institute of Standards and Technology, (1997).