HYGROSCOPIC INERTIA INFLUENCE ON INDOOR ENVIRONMENTS: MOISTURE BUFFERING

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ABSTRACT

In recent years great advances have been made, both in terms of regulation and technology, regarding the thermal behavior of buildings.

However, a sustainable building, in addition to being energy efficient, must also ensure adequate hygroscopic performance, so as to guarantee adequate indoor air quality and comfort.

As well as thermal inertia plays a very important role in the energy demand of buildings, the hygroscopic inertia of their enclosures is a regulating element in the hygroscopic balance of their interior environments, which, when properly used, can regulate the abrupt oscillations of relative humidity inside.

In particular, the inner layer of the enclosures of a building interacts with the interior environment adsorbing and desorbing moisture as a function of the relative humidity of the indoor air, and therefore, that damping capacity constitutes an important term on the moisture balance of the spaces.

In this paper the influence of the moisture buffering capacity of different materials on inside relative humidity is studied for different climates, ventilation rates and vapor production schemes by numerical simulation.

Using these measurements for the resolution of the mass balance in dynamic regime including the MBV of the inside layer of the walls, the evolution of indoor relative humidity in buildings for different ventilation rates, European climates and internal latent loads have been simulated.

The results demonstrate the importance that the MBV can have in the achievement of comfortable and healthy indoor environments, without risk of mould germination.

INTRODUCTION

Analogous to thermal capacity, thermal diffusivity and thermal effusivity, the hygroscopic capacity, hygroscopic diffusivity and hygroscopic effusivity of the inner layer allow determining its hygroscopic inertia. In fact not all the thickness of the inner layer interacts with the interior environment, but it is a certain thickness of inner layer that actually interacts with the interior environment. This thickness is known as the moisture penetration depth.

The way to quantify the environmental moisture damping capacity of a material is known as Moisture Buffer Value (MBV). In order to measure it, dynamic tests have been carried out according to [1] in a climatic chamber in which the amount of moisture absorbed and desorbed by a material when it is subjected to cyclical changes of ambient relative humidity is measured.

NOMENCLATURE

RH	[%]	Relative humidity
V	[m^3]	Volume
R_v	[J/kgK]	Constant of water vapor
P_{vi}	[Pa]	Indoor water vapour partial pressure
P_{ve}	[Pa]	Outdoor water vapour partial pressure
G_v	[g/s]	Indoor vapour production
T_i	[K]	Inside temperature
t	[s]	Time
A_{sj}	[m^2]	Inner wall surface area
g_{mbj}	[g/sm^2]	Moisture buffering capacity

EXPERIMENTAL DETERMINATION OF MBV

The MBV was calculated from dynamic tests according to the NORDTEST protocol, in which the samples are exposed alternative to step cyclic changes on ambient relative humidity, according to a time scheme. There are other standards [2] to measure the moisture buffering capacity of building materials, but they do differ mainly on the time scheme during the test. Basically, during the test, the sample absorbs and releases moisture from/to the environment inside the climatic chamber and once the stationary regime is reached on the moisture content change evolution of the sample, the amplitude of the weight change normalized by the relative humidity difference and the exposed area gives the value of the MBV. The time scheme used was 8 h at 75% RH and 16 h at 33% RH, resulting in an average relative humidity of 54%

Two materials were tested:

- EPS (expanded polystyrene)
- Pine board

The first as representative of a low MBV material and the second one representing a material of with good MBV.

Table 1 shows the obtained MBV values for each material and figure 1 represents the moisture content evolution on one EPS sample during the dynamic test.

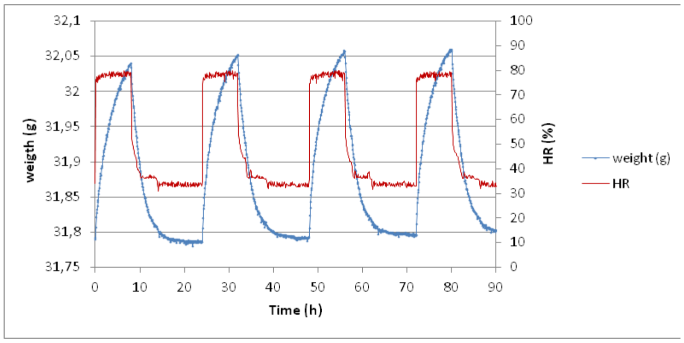

Figure 1 Moisture content evolution during MBV dynamic test

Table 2 Calculated MBV from measured data during dynamic test

Material	HR (%)	MBV $g/(m^2 \cdot \%RH)$
EPS	0,54	0,3
Pine board	0,54	1,3

Figure 2 Climatic chamber used for MBV tests

NUMERICAL SIMULATION

Using the experimentally obtained MBV for both materials, the mass conservation equation (1) was solved to predict the relative humidity evolution inside a room which inside finishing materials were the tested materials, pine board and EPS:

$$\frac{V}{R_v T_i}\frac{\partial P_{vi}}{\partial t} = \frac{nV}{3600 R_v T_i}\left(P_{ve} - P_{vi}\right) + \dot{G}_v - \sum_{j=1}^{k} A_{sj} \cdot g_{mbj} \qquad (1)$$

where g_{mbj} represents the moisture buffering capacity per time and exposed surface j, from a total of k surfaces, according to [3].

The simulated room was 33 m^3 volume and 27 m^2 walls surface, with a transmittance value of U = 0.6 W/m^2K. Simulation was made for 2 different cities (Barcelona and Bilbao), for two different ventilation rates (0.3 and 0.65 h^{-1}) and for two different vapor production rates (55 g/h and 70 g/h, for a occupation scheme of 4 hours (from 17:00 to 21:00 h) in order to analyze the influence of using a high or low MBV material under operation conditions according to common European normative values as well as values out of normative.

The time step used for each calculation was 1 hour and the initial conditions were settled at 40% of initial RH and the inside temperature profile was according to the UNE EN ISO 15026 [4].

RESULTS

Due to extension reason, there will only be showed some of the results for Barcelona and Bilbao simulations. Figures 3 to 8 represent the indoor relative humidity evolution during January and July for EPS and pine board (red color) compared to a non moisture buffering capacity material (MBV= 0).

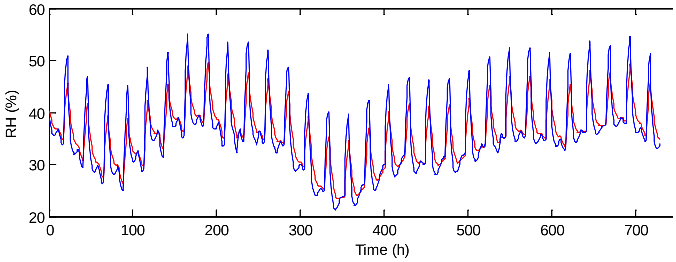

Figure 3 Interior RH(%) for Barcelona, n = 0.65 h^{-1}, G$_v$ = 55 g/h, January. No MBV material (blue) and MBV = 0,3

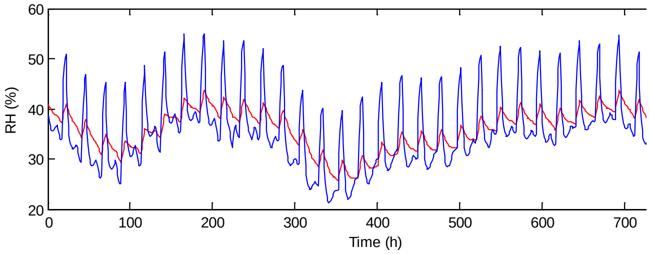

Figure 4 Interior RH(%) for Barcelona, n = 0.65 h^{-1}, G$_v$ = 55 g/h, January. No MBV material (blue) and MBV = 1,3

From figures 3 and 4 it can be observed that a reduction of 5 % on RH is obtained with a 0.3 MBV material but it can rise to a reduction of 10% when using a 1.3 MBV material as inner finishing material. This can became critical when due a non correct operation conditions, the ventilation rate or the moisture production are out of normative usual values, for instance, with a ventilation rate of 0.3 and vapour production of 70 g/h (see figures 5 and 6).

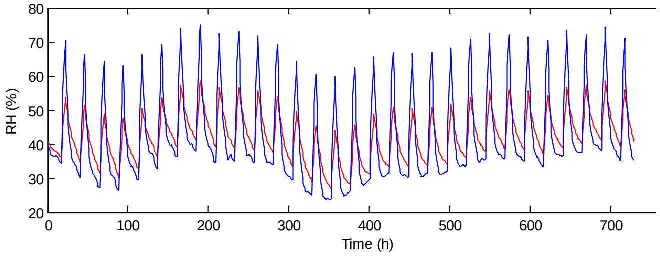

Figure 5 Interior RH(%) for Barcelona, n = 0.3 h^{-1}, G$_v$ = 70 g/h, January. No MBV material (blue) and MBV = 0.3

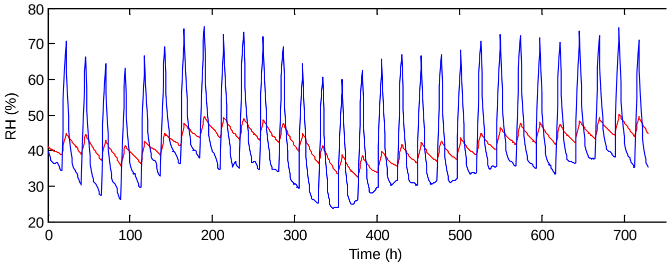

Figure 6 Interior RH(%) for Barcelona, n = 0.3 h^{-1}, G$_v$ = 70 g/h, January. No MBV material (blue) and MBV = 1.3

As representative of months with higher relative humidity mean values, simulation results for July are represented in figures 7 and 8.

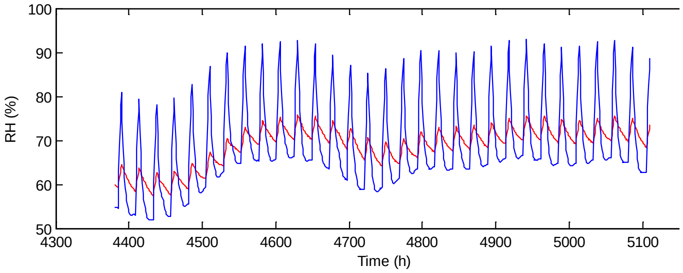

Figure 7 Interior RH(%) for Barcelona, n = 0.3 h^{-1}, G$_v$ = 70 g/h, July. No MBV material (blue) and MBV = 1.3 material (red)

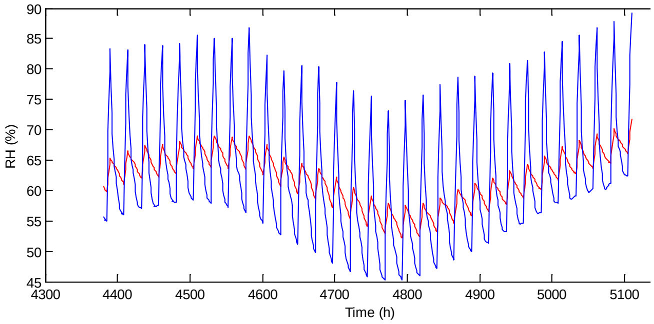

Figure 8 Interior RH(%) for Bilbao, n = 0.3 h^{-1}, G$_v$ = 70 g/h, July. No MBV material (blue) and MBV = 1.3 material (red)

For each case, the risk of mould germination was evaluated. With that purpose, each inner surface temperature and RH conditions during the simulation was represented within the LIM isopleths. In figures 9 and 10 the risk of surface condensation is evaluated for Barcelona and Bilbao climate in July:

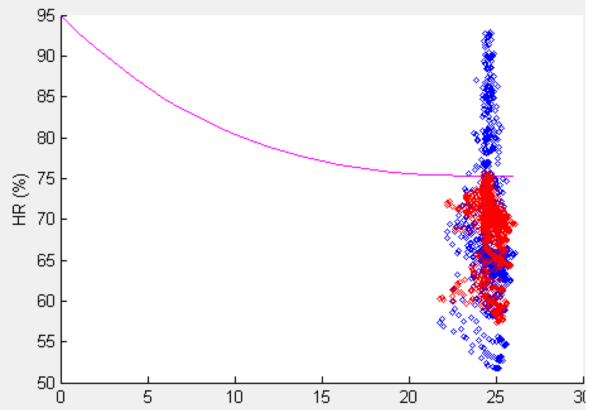

Figure 9 Surface condensation risk evaluation. Interior RH(%) for Barcelona, n = 0.3, G_v = 70 g/h, July. No MBV material (blue) and MBV = 1.3 (red)

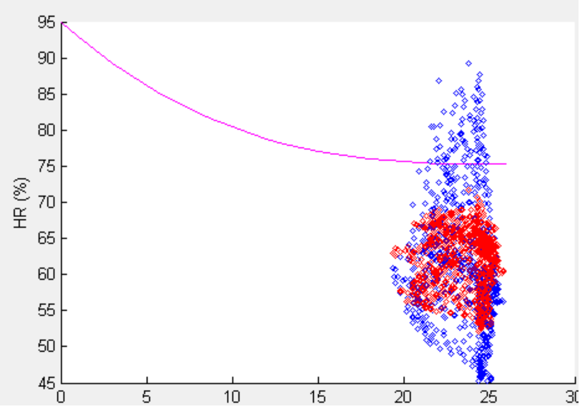

Figure 10 Surface condensation risk evaluation. Interior RH(%) for Bilbao, n = 0.3, G_v = 70 g/h, July. No MBV material (blue) and MBV = 1.3 (red)

CONCLUSION

It was found that for cases where the vapour production rate and the ventilation rate are not according to normative usual values, the inner finishing materials of the walls can avoid possible condensation as well as buffer the high relative humidity increases, especially in humid and cold climates.

Numerical results indicate that the moisture buffering capacity of building materials can play a key role on indoor air quality and comfort conditions. It is also expected that the buffering effect on relative moisture can lead to reduce energy consume in buildings and be used as a passive solution for conditioning indoor air, especially in buildings as museums and documentary archives, where accurate and stable hygroscopic conditions are required.

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