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Study of moisture in buildings for hot humid climates

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Abstract

Humidity in buildings generates many disorders or disadvantages. A dry-bulb temperature of the air relatively low, strong moisture and wall surface temperatures very low characterize the interior conditions of the highland dwellings in Reunion Island, during the southern winter. This causes many disorders related to phenomena of condensation on walls: deterioration of the envelope, odor of mould. It is thus, significant to precisely know the evolution of the moisture in a building to avoid any disorder on the frame. In this study we will expose a series of experiments carried out on real residences in order to highlight main parameters of the problem. On the basis of these results, numerical simulations were used to extrapolate the behavior of this building on unusual climatic sequences, holding account various improvements of its constitution. A curative study and a preventive study were carried out on two different types of residences. The aim is to propose solutions to prevent deteriorations of the coatings due to the surface condensation.

Keywords: Humidity; Condensation; Expérimentations; Numerical simulations; Humid climate

1. Introduction

In moderate climate, hydrous transfers in buildings are relatively well controlled as they are generally in a well-defined direction. Indeed, interior climatic conditions are controlled by air-conditioning systems, which ensure a constant temperature. In certain cases, humidity is also controlled precisely In wet tropical climate a majority of residences is not air-conditioned and the interior temperature and humidity are free floating. Moreover, in the highlands of Reunion Island, the dry-bulb temperature of the air decreases appreciably with altitude to go down below the usual values of comfort. Low dry-bulb temperature of air, strong moisture and wall surface temperatures very low characterize the interior conditions of the highland dwellings, during the southern winter. Taking into account the external conditions the transferred moisture quantities are significant. It follows of many disorders related to phenomena of condensation on wall. The buildings' owners confronted with these problems have significant maintenance and restoration costs, and must work out preventive and curative solutions. They then initiated this study and the carried out reflection takes into account the economic constraints they are confronted with. This paper proposes to present the methodology used and the results obtained. After a reviewing concerning moisture in buildings, we will present the study undertaken in order to cure the problems on existing dwellings. This first study is composed of a series of measurements carried out to examine buildings having undergone degradations with an aim of identifying the causes of the damages. We will then present the tools used for simulations and the results, which validate some improvements concerning the thermal design of the envelope and the associated systems, in order to cure the problems. In the third part, we will present the study carried out for a building project with a timber structure and therefore with preventive purposes.

2. Outline relating to humidity in buildings

Humidity in dwellings has consequences not only on the comfort and health of occupants but also on perenniality of the coatings and the frame. Condensation of water contained in air occurs when the relative humidity reached a limiting value known as saturation. Condensation can appear in the form of droplets in suspension in air (fog) or on a cold material support. The presence of fog in a dwelling

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Nomenclature

φ	mass flow rate (kg/m^2 s)
$\dot{m}$	mass flow (kg/s)
π	permeability (kg/m Pa s)
H	relative humidity (%)
P	pressure (Pa)
x	distance (m)
T	temperature (k)
w	humidity ratio (kg/kg$_{\text{dryair}}$)
h	exchange coefficient (W/Km^2)

Subscripts

v	vapour
air	air in the zone
ae	outside air
as	dry air
surf	surface
sat	saturation
c	convection
i	subscript of the zones

is rare. It is generally confined in specific parts and over short periods related to the occupant activity. Natural or mechanical ventilations are intended to fight efficiently against these internal contributions. Condensation on a material support occurs when the temperature of this one is lower than the air dew point temperature of the zone. This case worries the designers by the degradations involved on the support. The caused disorders are generally deteriorations of the interior coatings (yellowish, black spots and then separation of paintings). Phenomena of corrosion of the metal structure can appear in the event of cracks in the coating. The hydrous transfers depend on the following phenomena:

- Diffusion of water vapor through the envelope of the room;
- Surface condensation of the water vapor;
- Absorption and water vapor desorption by hygroscopic materials of the room;
- Airflow transfers with the outside or the other zones of the building;
- Diffusion of vapor in the air;
- Production of vapor dependent on occupants and their activities;
- Injection or withdrawal of moisture by HVAC system.

2.1. The water vapor diffusion through a wall

This depends on the difference of partial pressure of vapor on both sides of the wall and the permeability of material following the law

$$\varphi_{v_{\text{dif}}} = -\pi \frac{dP_v}{dx} \tag{1}$$

This equation imposes a good knowledge of the material properties constitutive of the wall and applies badly to heterogeneous or strongly hygroscopic materials. Several methods of wall design are based on this equation: Dew-point method, Glaser diagram. Their objective is to evaluate the possibility of condensation of the water vapor during its migration through the wall. These methods are intended for the study of the wall in steady state conditions. In moderate climates, as the building are more often heated, the migration of vapor is from outside to inside. In tropical climate, most of the time, outside and inside conditions vary without any control and consequently, the direction of the vapor flow is not so well defined as the experiment will show it. Moreover, the steady state methods do not consider the cycles of condensation/evaporation. It is then difficult to evaluate generated damages, knowing that a small quantity of condensation remains tolerable. In the simulation codes, the term of water vapor diffusion through the envelope is often neglected in the hydrous balance of a zone. Its influence is indeed weak comparison with the quantities exchanged through openings or by ventilation.

2.2. Surface condensation

It happens when the temperature of a wall is lower than the dew point temperature, we have

$$\dot{m}_{v_{\text{cond}}} = S\varphi_{\text{cond}} \tag{2}$$

The rate of vapor condensation depends on the difference in partial pressure of vapor between the air of the room and the air on the surface of the wall and can be expressed by [1]

$$\varphi_{\text{cond}} = \varpi(P_{v_{\text{air}}} - P_{v_{\text{surf}}}) = \varpi(P_{v_{\text{air}}} - P_{v_{\text{surf,sat}}}),$$
$$\varpi = 7.4 \times 10^{-9} h_c \tag{3}$$

where, for walls

$$h_c = 1.079\,\Delta T^{0.33} \text{ and for tilted roofs,} \quad h_c = 1.135\,\Delta T^{0.33} \tag{4}$$

with [2]

$$P_{v_{\text{air}}} = \frac{H}{100} P_{v_{\text{air,sat}}}$$
$$P_{v_{\text{air,sat}}} = 140974 \times 10^5 \exp\left(\frac{-3928.5}{T_{\text{air}} + 231.667}\right) \tag{5}$$

$$P_{v_{\text{sat,surf}}} = f(T_{\text{surf}}) = 140974 \times 10^5 \exp\left(\frac{-3928.5}{T_{\text{surf}} + 231.667}\right) \tag{6}$$

2.3. The hygroscopic behavior of materials

The hygroscopic behavior of materials is not always taken into account in building thermal simulations. However, it constitutes in certain case a significant element of moisture