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Published in:
Healthy Building 2009

Publication date:
2009

Document Version
Også kaldet Forlagets PDF

Humidity in air during and after humidifying incidents in three different houses

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SUMMARY
In three different occupied houses water boilers were set up to release approximately 1 kg of steam during approximately 0.5 hours. Before, during and 40 hours after this incident moisture content in indoor air and outdoor air was measured as well as temperatures, air change rate, air volume in the house and areas of main inner surface structures. The ability of the houses to absorb water in their structures after these experimentally created humidifying incidents was assessed based on mathematical models. Moisture absorption was most significant in the old masonry house during the first four hours after the steam was added. After this period the modern masonry house, with the slowly reacting concrete, had the highest absorption. At all times the least absorption was seen in the wooden house.

KEYWORDS
Moisture, ventilation, absorption, building materials.

INTRODUCTION
Humid buildings are widely acknowledged as a serious health risk for the occupants. A balance between moisture sources and moisture removal, primarily due to ventilation with outdoor air, is vital to avoid infestation with mould, house dust mites and other moisture related problems. Diffusion of water through the building envelope is normally not significant for the moisture balance of the indoor air, but different building materials may have significant impact on water absorption speed and capacity. These differences may impact the robustness of an indoor climate to sudden changes in moisture loads. Many everyday activities such as cooking, bathing and clothes drying are also moisture load incidents that challenge the robustness of the house to moisture problems.

The purpose of this study is to compare the time dependency of moisture concentrations in the indoor air of three different single family houses before, during, and after the evaporation by boiling of approximately 1 kg of water. The steam generation caused by this action simulates a major moisturizing incident.

METHODS

The first house was an older house with a brick masonry frame. The second house was a modern house with concrete slabs on the inside and masonry on the outside. The third had a wooden frame and gypsum plates as inner walls. The two modern houses had acrylic paint on inner walls and the older house had only lime and sand mortar and no further surface coating. Air change, inside and outside air humidity, and inside and outside temperature were measured every minute for a period of 40 hours after the moisturizing incidents in the three houses occurred. The data was used as a basis for the development of a mathematical model for absolute humidity in the indoor air.

Table 1 shows construction data and Table 2 shows moisture loads and temperatures during measurement periods in the three houses.

Table 1 Construction data and air change rate for the three houses

	All masonry house	**Wooden house**	**Masonry and concrete house**
Inner walls	Colorized lime mortar on masonry	Painted gypsum over plastic moisture barrier	Painted lightweight concrete
Outer walls	Colorized lime mortar on masonry	Painted planks of wood	Masonry
Building footprint m^2	137	106	142
Measurement zone floor area m^2	33.4	39.1	59.2
Room height m	2.34	2.75 (2.27-3.23)	2.40
Measurement volume m^3	78.2	107.5	142.1
Air change rate h^{-1}	0.42	0.25	0.48
Wall surface area m^2	48.4	45.2	95.5

Table 2 Moisture load and temperatures inside and outside

	All masonry house	**Wooden house**	**Masonry and concrete house**
Moisture persons, kg/day	0.67	1.67	1.67
Other moisture, kg/day	1.33	1.33	1.33
Avg. moisture load, g/h	85	125	125
Vaporized water, kg	1.368	1.023	1.602
Outside temperature, $^{\circ}$C	4.1	-2.1	11.6
Indoor temperature, $^{\circ}$C	21.8	21.2	22.3
Moisture outside air, g/m3	4.39	3.03	9.35

Based on the indoor moisture production (G [g/h]), air change rates (n [h^{-1}]), room volume (V [m^3]), moisture content of ambient air (v_e [g/m^3]), the following differential equation may be set up for the moisture content of the indoor air (v_i [g/m^3]) assuming that there is no moisture transport through the building envelope.

$$(1) \quad \frac{dv_i}{dt} = n(v_e - v_i) + \frac{G}{V}$$

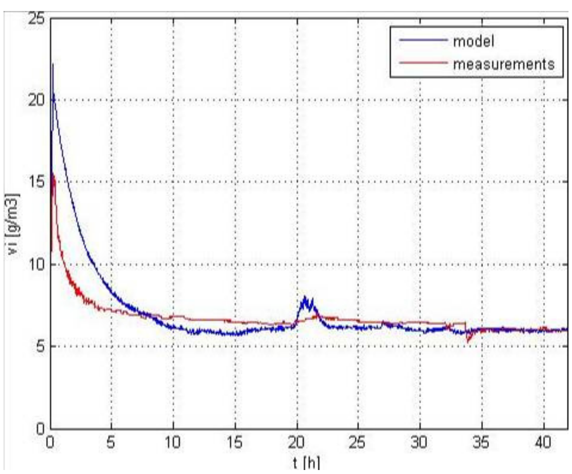
The differential equation may be solved by Laplace transformation giving the folowing mathematical model for the moisture content of the indoor air after humidifying:

$$(2) \quad v_i(t) = v_e(t) + (v_i(t_1) - v_e(t)) \cdot e^{-nt} + \frac{G}{Vn}(1 - e^{-nt})$$

t og t_1 is the time and the time when moisturizing ended [h].

RESULTS

A



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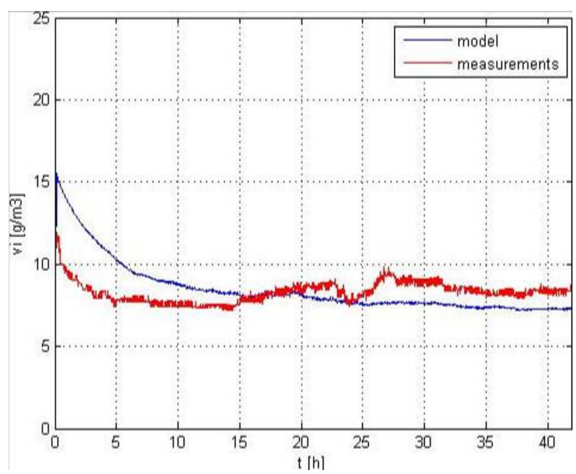

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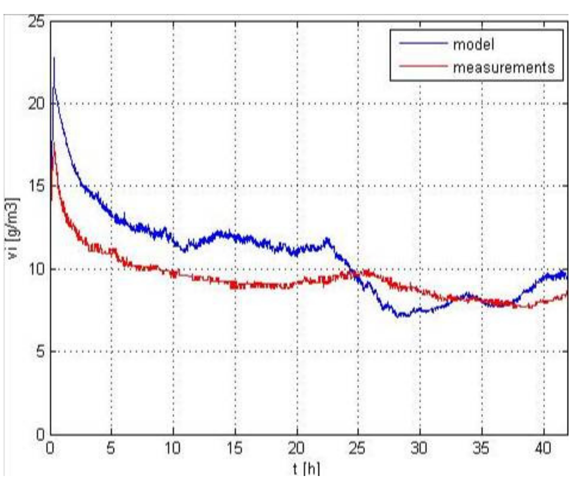

Figure 1 shows the moisture content of the indoor air (v_i) as a function of time (t) in first the all masonry house then the wooden house and finally the masonry and concrete house.

DISCUSSION

The intercept between the curves for model and measurements shows the time when most water absorption occurs in materials after the moisturizing incident. The absorbed amount of water may be calculated based on measured moisture concentration times air change times air volume. Table 1 shows information about absorbed water.

Table 1 The time when materials change from absorbing to desorbing water as well as estimates of the absorbed amount of water before this change. To increase comparability the estimated absorbed amounts 4 and 8 hours after the onset of moisturizing is also shown

	All masonry house	**Wooden house**	**Masonry and concrete house**
Time before desorption (h)	8,1	15,4	24,7
Absorbed water after 4 hours (kg)	0,6	0,4	1,0
Absorbed water after 8 hours (kg)	0,7	0,6	1,7
Maximum absorbed water (kg)	0,7	0,8	4,0

CONCLUSIONS

Application of the model showed significant differences in the moisture absorption properties of the three houses. Moisture absorption was most significant in the old masonry house during the first four hours after the steam was added. After this period the modern masonry house with the slowly reacting concrete had the highest absorption. At all times the least absorption was seen in the wood house.

ACKNOWLEDGEMENT

This study was supported financially by the Mortar- and Brickmakers Association in Denmark.