THE EFFECT OF THE INNER SURFACE MATERIAL ON THE INDOOR RELATIVE HUMIDITY

Oľga Koronthályová

Institute of Construction and Architecture, Slovak Academy of Sciences
Dúbravská cesta 9, 842 20 Bratislava, Slovakia

Abstract

The indoor air relative humidity is an important parameter influencing the human comfort and hygrothermal performance of a building. From the comfort aspect not only time averaged relative humidity but also its actual courses are important. With the aim to evaluate the effect of interior surface materials with different hygroscopicity on the resulting daily courses of indoor relative humidity the non-steady numerical calculations of the indoor relative humidity, considering time variable outdoor climatic conditions, indoor moisture production and ventilation rate were done.

1. Introduction

The value of indoor relative humidity is a result of the simultaneous effect of the following factors: outdoor climatic conditions, ventilation rate, indoor moisture production, indoor air temperature and the release or uptake of moisture by interior surface materials. The numerical model used in this study enables to evaluate the effect of the particular factors on indoor relative humidity. The presented calculations were focused on the effect of the interior surface material hygroscopic properties on the courses of the indoor relative humidity in the cases of constant or time variable ventilation rates.

2. Numerical model

On the assumption of the well-mixed air in the room the mass balance equation for indoor water vapour may be written as follows (ref (1)).

$$\frac{\partial p_i}{\partial t} = \frac{462 \cdot T_i \cdot \left\{G_p + \sum G_{sk} - \sum\left[\beta_j \cdot A_j \cdot (p_i - p_{sat,sj})\right]\right\}}{V} + n \cdot (p_e - p_i) \qquad (1)$$

where p_i is the indoor vapour pressure [Pa], p_e is the outdoor vapour pressure [Pa], t is time [s], T_i is the indoor air temperature [K], G_p is the indoor vapour production [kg.s^{-1}], ΣG_{sk} is the sum of the moisture flows from or into the room construction surfaces, V is volume of the room [m^3], β_j is the diffusion surface film coefficient [s.m^{-1}], A_j is the area of the surface where condensation or drying takes place [m^2], $p_{sat.sj}$ is the saturation vapour pressure on that surface [Pa], n is the ventilation rate [s^{-1}].

According to the equation (1), the indoor vapour pressure after small time increment Δt can be written as:

$$p_i(t+\Delta t) = p_i(t) + \frac{\Delta t \cdot 462.5 \cdot T_i(t) \cdot \left\{G_p + \sum G_{sk} - \sum\left[\beta_j \cdot A_j \cdot (p_i(t) - p_{sat,sj}(t))\right]\right\}}{V} +$$

$$+ \Delta t \cdot n \cdot (p_e(t) - p_i(t)) \qquad (2)$$

The presented numerical model for calculation of the indoor air relative humidity consists in the solution of the equation (2) coupled with 1-D numerical simulation the heat and moisture transport through the room constructions. On the base of that simulation the moisture flow from or into the hygroscopic surface of the room is calculated for each time step:

$$G_{sk} = \beta_k \cdot (p_{sk} - p_i) \cdot A_k \qquad (3)$$

where p_{sk} is the vapour pressure on the wall surface [Pa], A_k is area of the surface [m^2].

The numerical simulation of the heat and moisture transport through the room constructions was done using the program NEV 3, based on numerical solution of two coupled partial differential equations for heat and moisture balance. The more detailed description of the model used in program NEV 3 is in ref.(2)

The used numerical model for the calculation of the indoor air relative humidity was verified by comparing the calculated courses of the indoor relative humidity with the measured results. The experimental data were taken from ref. (1). The experiment was done for two rooms with volume 40 m^3 and total wall area 50 m^2. The walls and ceiling of the first room were covered with aluminium plates, the walls and ceiling of the second room were finished by gypsum board with textured paper. The plastic flooring was used in both of the rooms. The considered water vapour production was 0.2 kg per hour during the first 3.5 hours and the ventilation rate was time variable. The courses of the vapour production and ventilation rate are shown in Fig. (1). The material properties used in calculation were taken from ref. (3) The time step Δt = 300 s was used in numerical calculation. The comparison between the measured indoor relative humidity courses and the courses calculated by the numerical model is in Fig. (2). The calculated data coincide sufficiently with the measured ones.

3. Results of the numerical simulation

With the aim to evaluate the effect of the interior surface material hygroscopic properties on the indoor relative humidity the numerical calculations of its daily course for three rooms with different wall surface materials and for two different ventilation strategies were done. The volume of the each of the rooms was 81 m^3, the area of the possible hygroscopic surfaces was 55 m^2. In the first room the cellular concrete walls were finished with 15 mm of gypsum plaster (vapour resistance factor μ = 8), in the second room the concrete walls were covered with 0.3 mm thick vinyl wall paper (vapour diffusion thickness μd = 2.1m) and in the third room the concrete walls were

finished with 12 mm gypsum board (μ = 11) covered with 0.3 mm paper wall paper (vapour diffusion thickness μd = 0.027 m).
The considered daily course of vapour production is shown in Fig. (3). Two different ventilation strategies were considered :
- the constant ventilation rate
- basic air change rate with the additional ventilation by the window opening during the water vapour production periods (Fig. (3)).
The daily mean ventilation rate was the same in both of the cases: $n = 0.4\ h^{-1}$.
The considered indoor air temperature was constant $t_i = 20°C$. The daily courses of the outdoor temperature and relative humidities were used correspond to January in Bratislava with the daily mean temperature -1.3°C and the daily mean relative humidity 78 % (Ref. (4)). The solar radiation was not taken into the account. The calculations were done for one week period with the time step Δt = 300 s.

The calculated daily courses of indoor relative humidity for the all considered cases are shown in Fig. (4). As can be seen from the figure the ventilation strategy was very important as for the daily course of the indoor relative humidity as for its mean value. The hygroscopicity of the interior surface material decreased significantly the amplitude of the indoor relative humidity variation. The effect of the interior surface material hygroscopic properties was more significant in the cases when the constant ventilation rate was considered. The 'active thickness' that means the thickness of the surface material moisture content of which was changing daily as a result of the release or uptake the moisture into or from the indoor air was about 10 mm as in the case of gypsum plaster as in the case of gypsum board with paper wall paper.

4. Conclusions

The numerical model enabling the evaluation of the effect of the particular factors on the indoor relative humidity was presented.

The examples of calculation confirmed that as mean value of the ventilation rate as the ventilation strategy are important for the actual course of indoor relative humidity. The presented calculations confirmed the importance of the interior surface hygroscopicity on the daily course of the indoor relative humidity. It is more signifficant in the cases with constant ventilation rate.

A lot of further calculations for various ventilation and moisture production strategies, geometry of the room and longer time periods are necessary for more general conclusions regarding the global effect of the particular factors influencing the actual relative humidity courses.

Acknowledgment
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5. References

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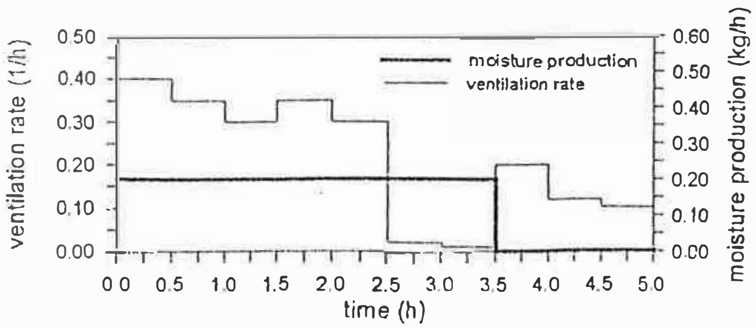

Fig. 1 The courses of the vapour production and the ventilation rate used in comparison between the measured and calculated data

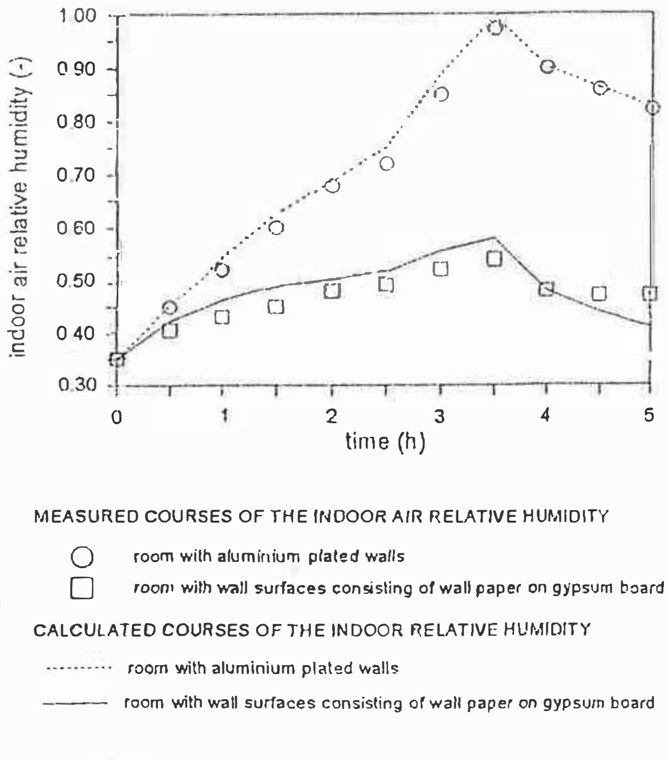

Fig. 2 The comparison between the measured indoor relative humidity courses and the courses calculated by the developed numerical model

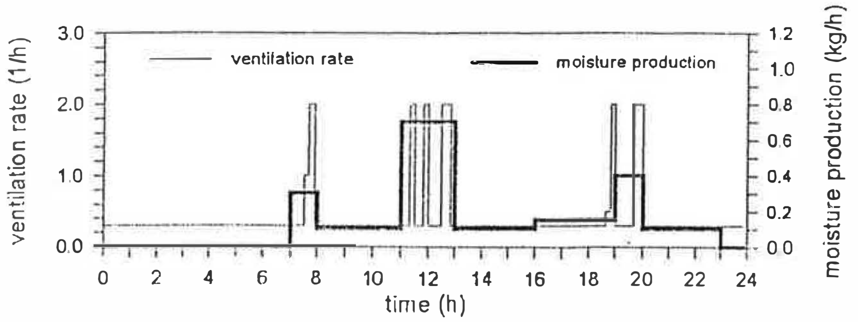

Fig. 3 Daily courses of the vapour production and the ventilation rate used in calculation

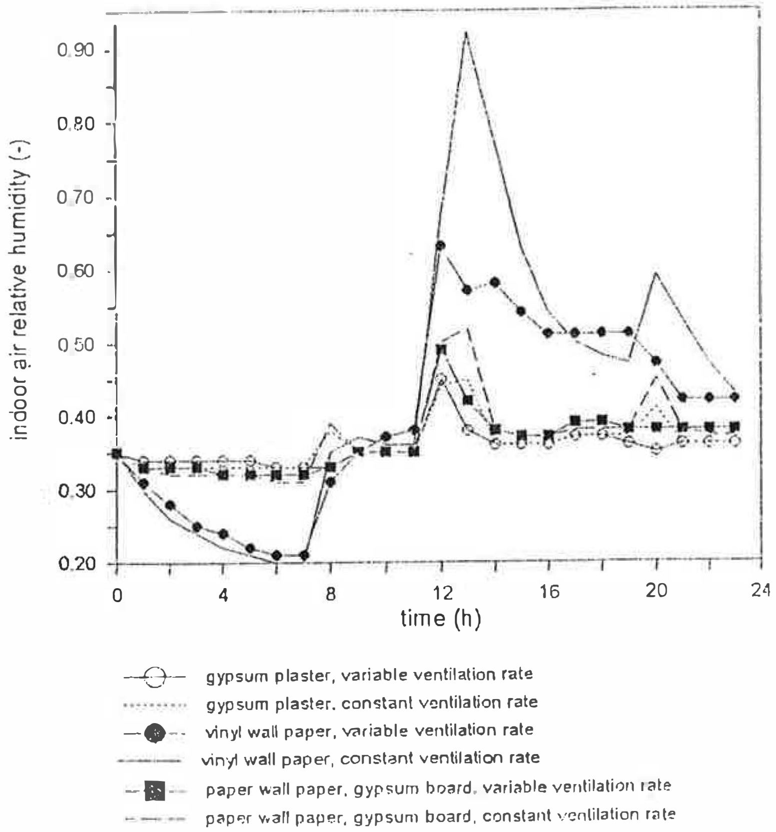

Fig. 4 Calculated courses of the indoor realtive humidity for different wall surface materials and ways of ventilation