Moisture Buffer Performance of a Fully Furnished Room

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ABSTRACT

The moisture buffer capacity of hygroscopic materials can be used to moderate the relative humidity of indoor air as well as moisture content variations in building materials and furnishing. Since moisture plays a significant role in the development of many processes that affect the quality of the indoor air, such as growth of house dust mites, emissions from materials, and mold growth, it is anticipated that the moisture buffer effect can help to ensure healthier indoor environments.

Building materials, as well as furniture and other furnishing materials exposed to indoor air, will contribute to the moisture buffer capacity of rooms. Few studies have been made on the impact of furnishing materials in comparison with traditional building materials. This paper will present such a study conducted in a full-scale climatic test cell.

A series of experiments have been carried out in the test cell to show the moisture buffer performance of various furnishing objects. The objects will be exposed to cyclic humidity variations as in an inhabited indoor environment, and the response of the indoor humidity will be followed over time. It will be a step-by-step investigation starting with an empty room and going toward a fully furnished room. Comparisons are made with previous studies covering traditional building materials and calculations.

The study shows that the furnishings have to be included in the understanding of the moisture buffering performance of a room and that more material data in this area is needed.

INTRODUCTION

We spend most of our lives indoors and the primary purpose of designing buildings is to ensure good indoor environments for the occupants. This is obtained by interactions between the outdoor conditions, the building envelope, and the occupants. The thermal conditions are already recognized as being important, but moisture is still not considered to be an essential part of building design. In a hygrothermal approach, moisture buffer performance will play an important role. The interactions mean that the surface materials, which are capable of functioning as moisture buffers, are in contact with the indoor air. This study was initiated to increase the knowledge about the interaction between the indoor air and the moisture buffering surface materials. One reason for a growing interest in this topic is a widespread concern for indoor air quality, which to some extent is determined by the level and fluctuations of the humidity of the indoor air (Bornehag et al. 2001). The progress within hygrothermal and energy modeling is another reason for the growing interest in the moisture buffering issue. A literature survey conducted by Harderup (1998) has shown that in order to develop hygrothermal calculation models further, there is a need for a better understanding of the moisture buffer performance of a room, including furniture and furnishings, and more data are also needed concerning moisture properties of the surface materials used in the indoor environment.

Surface materials exposed to variations in the surrounding climate will absorb moisture when the relative humidity (RH) increases and desorb moisture when the RH decreases. This process is referred to as moisture buffering and is to a large extent due to the material composition and structure and to the surface treatment of the material. The moisture buffer capacity of the surface materials in the indoor environment

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will help to minimize the daily variations of RH in the air, which result from the activities of the occupants and the operation of HVAC systems. Both the surfaces of the inside of the building envelope, such as ceilings, floors, and walls, as well as the furniture and other furnishings, have an impact on the moisture conditions in the room. For example, Plathner and Woloszyn (2002) have shown that the correlation between simulated and measured moisture conditions of the indoor air is much better if the sorption of interior surface materials is taken into account.

One benefit of avoiding peaks of high RH is to decrease the risk of condensation on cold surfaces and thereby prevent biological growth. If the RH variations are held within 30% and 60% RH, the growth of allergenic or pathologic organisms can be minimized (ASHRAE 2001). Another advantage is that air with a lower relative humidity will be perceived as being fresher (Toftum and Fanger 1999) due to the increased cooling of the mucous membrane and thereby the increased well-being of inhabitants in the indoor environment. Moist air can also increase the pollutant emissions from materials in contact with indoor air, such as, for example, paints (Fang et al. 1999). These emissions should be avoided in order to keep a good air quality in the indoor environment since work efficiency decreases with rise in air pollution.

The moisture buffer performance is influenced by several material properties—e.g., moisture capacity, water vapor permeability, and the period time of the variations—and today there is no single parameter used to express the moisture buffer performance. A NORDTEST project to deal with this question has been initiated (Rode 2003) and work will be continued to define the moisture buffer performance and to develop standardized measuring methods.

Also, the ventilation and the microclimate influence the moisture buffering performance of the room. The impact of the ventilation depends on the ventilation rate and the vapor content of the indoor and outdoor air. If the ventilation rate is very high, it will control the RH of indoor air to a very high degree. If, on the other hand, the ventilation rate is low, the impact of moisture buffering in surface materials is larger (Christoffersen 1996). The ventilation rate will govern the mean level of RH in the indoor air, and the moisture buffer performance will affect the amplitude of the RH variations. It should be noted that moisture buffering in materials could never replace ventilation, since ventilation also removes heat and sensory and chemical pollution and provides clean air.

To understand the hygrothermal behavior of real rooms is a huge task, which requires a lot of field data and experience about how it can be modeled. Furthermore, the moisture buffer performance is of relevance in many countries worldwide and is much influenced by local climates, the building traditions, and how buildings are used and conditioned in different countries.

Previous research has also been concerned with the moisture buffer performance. In earlier studies the moisture buffer capacity of several materials has been investigated on a small scale (Padfield 1998; Mitamura et al. 2001; Svennberg and Harderup 2002; Peuhkuri 2003; Ojanen and Salonvaara 2003). In Finland, the moisture buffer capacity of a bedroom was studied in an ecological building without vapor retarder (Simonson 2000; Simonson et al. 2001). In the first investigation it was found that the highest peak humidity in the bedroom could be reduced by up to 20% RH, and the humidity during the winter months could be increased by up to 10% RH. The second investigation concerned the same room exposed to weather data from four different cities, and buffer materials were found to have most impact in a moderate climate such as Scandinavia, and, furthermore, the buffer effect of hygroscopic thermal insulation was strongly reduced when it was not directly exposed. In a comparison between calculations and measurements in a test house, Plathner and Woloszyn (2002) showed that taking into account the impact of the moisture buffering of the surface materials gave a better correlation between measurements and calculations.

The topic of moisture buffer performance has become a part of a newly started international research project, "Whole Building Heat, Air and Moisture Response," which is Annex 41 of the International Energy Agency's (IEA) Energy Conservation in Buildings and Community Systems Programme (Hens 2003). As an IEA activity, it also has the scope to illustrate how a better understanding of the overall hygrothermal behavior of buildings can lead to better energy performance, e.g., by inventing optimized strategies for ventilating, heating, and cooling that take the overall hygrothermal reality of buildings into account.

Most previous research have been conducted on unfurnished rooms, even if the furniture and furnishings of a room to a high extent cover the traditional building materials (Harderup 1998). The scope of this investigation has been to conduct a full-scale experiment with a fully furnished room under well-controlled conditions.

MATERIALS IN THE INDOOR ENVIRONMENT

Materials used in the indoor environment are a heterogeneous group of materials, from heavyweight concrete used in the building construction to lightweight textiles found in furniture and furnishings.

To ensure durability, facilitate cleaning, and/or for esthetical reasons, the materials of the indoor environment are often surface coated. The surface coatings are often based on polymers, e.g., latex paint, wax, and plastic films. In the indoor environment, surface coatings vary from sparse oil treatments to thick and almost impermeable enamel paints. The moisture resistance of a surface coating is dependent on the material used and the application. If there is a "heavy" surface coating on the top surface of furniture, e.g., a wooden table, usually the bottom will be untreated. The furnishing and furniture also hide the building materials of the building envelope. Therefore, an estimation of the accessibility of indoor air to the potential moisture buffer areas has to be included in an estimate of the moisture buffer performance.

In a preliminary study, Berggren and Skoog (2003) made an inventory of the surface materials present in a dwelling and an office. The comparison between the two buildings showed that in the office, a larger part of the surface materials had a surface coating, and in the dwelling, more untreated wood and textile materials were present (see Figure 1).

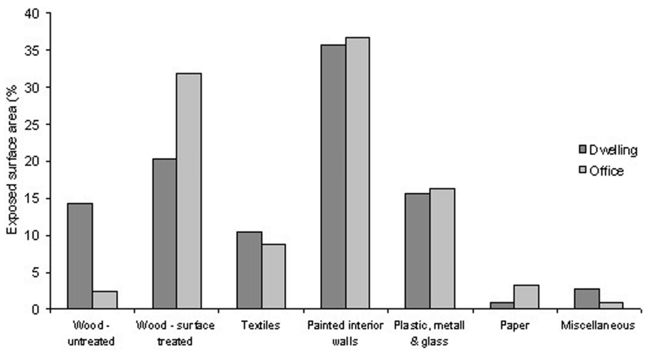

Figure 1 *Surface materials—a comparison between a dwelling and an office.*

In this study we have concentrated on furniture and furnishings. The materials present in the experiment, as listed in Table 1, were wood with different surface coatings, plastic, textiles, and paper.

TEST CELL AND EQUIPMENT

The experiments were performed in an airtight and moisture-tight test room. The test facility consists of a highly insulated steel box standing on pillars with an indoor floor area of 13.8 m^2 (149 ft^2) and room height of 2.75 m^2 (9 ft), giving a volume of 38.0 m^3 (1340 ft^3). The test cell consists of two rooms, a test room and a service room. The walls are insulated with 0.40 to 0.50 m (16 to 20 in.) of polystyrene and mineral wool and are covered with steel sheets on both the inside and the outside. An exception to this is the south wall, which is exchangeable. During the later experiments the south wall consisted of (from the outside) a wooden cladding, 0.30 m (12 in.) of mineral wool, 0.11 m (4.3 in.) of brick wall, and a polyethylene foil on the inside to provide a vapor-tight and non-absorbing interior surface. A picture and a diagram of the test cells are shown in Figures 2 and 3.

Table 1. Materials Present in the Experiment

Furnishing	Material	Surface Area m²	Thickness m	Volume m³	Weight kg
Writing desk	Melamine on all surfaces, except wood fiberboard on underside	2.56	0.034	0.041	10.24
Table legs	Wood	0.46		0.007	3.50
Room divider	Two thin sheets of wood fiberboard with 30 12 mm holes and an air cavity in between	1.04	0.038	0.018	4.12
Low plate on wheels	Wood fiberboard with melamine coating	0.42	0.022	0.004	2.64
Bookcase with 1 shelf	Wood with varnish	2.83	0.020	0.026	16.46
Book/accessory case on wheels	Wood with varnish	3.72	0.020	0.034	22.26
Office chair on wheels	Wool, foam plastic, plastic back, metal frame	0.30	0.050	0.015	7.50
Chair seat (for penetration measurements)	Wool, foam plastic, plastic back	0.19	0.050	0.010	
Carpet	Nylon on synthetic rubber backing	4.89	0.003	0.012	2.84
Curtain	Cotton	15.15	0.000	0.003	1.53
Books				0.046	37.20
Paper on desk and in waste basket					
Total		31.56		0.216	108.29

Figure 2 *Photo of the test cells.*

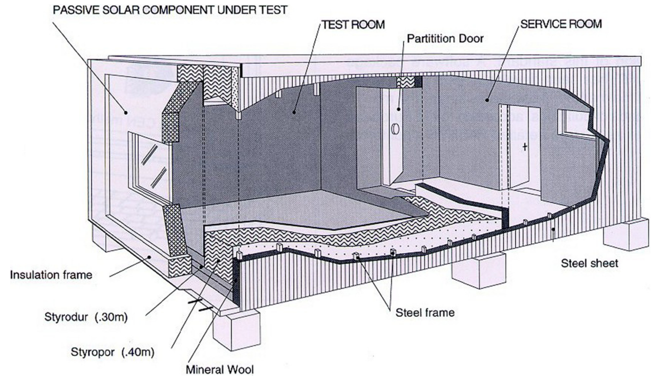

Figure 3 *Diagram of the test cells.*

The test room has an air distribution system connected to the cell's heating and cooling coils. A service room containing the cooling and control systems is placed at the northern end of the test cell. The cell is instrumented with sensors for measuring both the outdoor climate and the indoor conditions (air temperatures, surface temperatures, heating, power used by the cooling system and fans, heat fluxes, air infiltration rate, relative humidity, and air velocity). The indoor relative humidity is measured with capacitive moisture sensors with an accuracy of about ±2% RH. The data acquisition system is located in an adjacent building, from which the test cell can be controlled.

To measure the moisture buffering effect of the materials in this experiment, the room was subjected to controlled moisture variations. The idea was to mimic the exposure of moisture variations to interior surface materials in a common indoor climate, but in a controlled way. The moisture production was controlled, and the resulting RH variation within the test cell was registered.

The indoor humidification, which represents the moisture production of an inhabited room, was provided by evaporation of moisture from a reservoir of water heated by an electric coil. Humidity was withdrawn from the air by a dehumidifier draining into the same reservoir. The drying represents the removal of humidity from the room that would normally take place by ventilation.

The water reservoir was suspended in a load cell, and the rates of humidification and drying were controlled according to a predefined schedule. Padfield (1998) has used the principle in a small (0.5 m^3, 18 ft^3) test chamber in a laboratory. A schematic diagram of the apparatus is shown in Figure 4.

Another similar load cell, as for the water reservoir, was suspended in a rack from which a material specimen could be weighed continuously during the tests. The range and accuracy of the load cells was 10 kg±3 g (22±0.007 lb).

Two small fans were placed on the floor at both ends of the test cell to ensure a well-mixed airflow. The control system was set to save registered average data for a ten-minute period of measurements with sampling every thirty seconds.

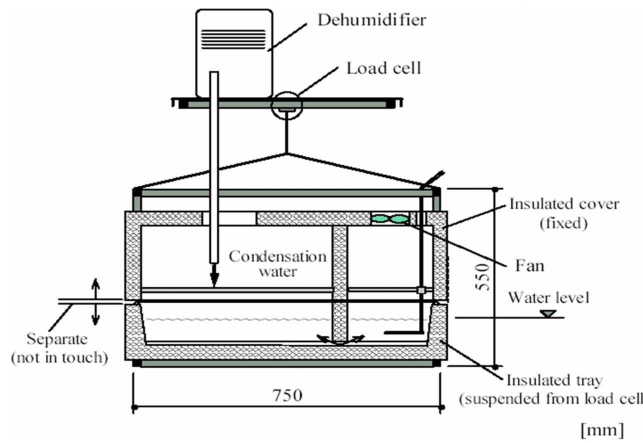

Figure 4 *A schematic diagram of the climatic control system of the test chamber.*

The air change rate of the test cell has been measured with tracer gas using the decay method and found to be about 0.20 h^{-1} at 50 Pa (0.015 in. Hg) pressure difference. Without pressurization the air change rate was about 0.007 h^{-1} (Mitamura et al. 2001).

MEASUREMENTS

This paper explains two sets of measurements in the test cell. The main experimental set presented for the purpose of this paper deals with the effect of furniture and other furnishing in a room to buffer the indoor humidity variations. For comparison, this is followed by a short presentation of a former study in the same equipment, where the moisture buffer effect of different interior wall systems was investigated.

Fully Furnished Room

In this investigation the relative humidity variation in an office was investigated. During the experiments the daily variation in the test cell was humidification and dehumidification moisture load of 33 g water per hour (1.2 oz per hour) and an isothermal temperature of 20.0±0.5°C (68±1°F).

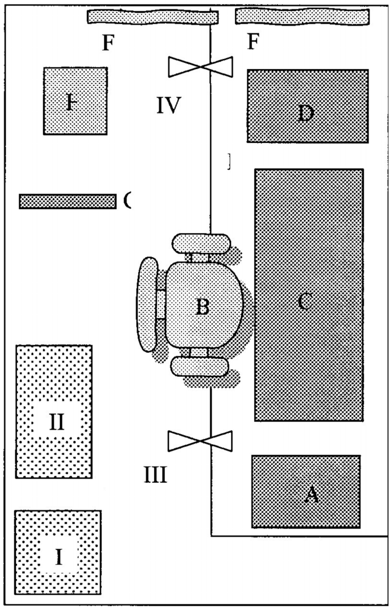

Figure 5 A schematic diagram of the test cell.

Figure 6 Placement in the fully furnished test cell.

The experiment concerned nine different cases. Cases 1 and 9 were both performed for the empty test cell as reference tests. Case 2 comprises the basic furniture of an office, with a desk, a room divider, an office chair and chair seat, a computer shelf, and a rolling shelf. In case 3 books were added in the shelves. A carpet was applied in case 4. Case 5 was a real office situation with papers in the wastebasket and spread over the table. Finally, a curtain was added to the test cell in case 6. The placement in the fully furnished test cell is shown in Figures 5 and 6.

The following cases were a gradual emptying of the test cell. In case 7 the curtain, the paper on the table, and the carpet were removed. In case 8 the books was removed, and in case 9 the test cell were empty except for the chair seat used for the penetration measurements.

Penetration Measurements

A chair seat was used for moisture penetration measurements. The chair seat was from an industrially manufactured chair and consisted of a 5 mm (0.2 in.) plastic board, 31 mm (1.2 in.) foam plastic, and a wool fabric as a cover. The plastic board was covered underneath with a nonwoven synthetic fabric.

Four combined temperature and relative humidity sensors were applied. The first sensor was placed between the plastic board and the foam plastic in the center of the seat. The second sensor was placed halfway down in the foam plastic and the third sensor on top of the foam plastic but under the wool fabric. The fourth and last sensor was placed on top of the wool fabric. The sensors were somewhat displaced so that interference from the other sensors was minimized.

The chair seat was suspended in the specimen load cell in the test room.

Interior Walls

A previous experiment (Hedegaard 2002) studied the moisture buffer capacity of an interior wall. In the setup the daily moisture load was set to evaporation at a constant rate of 25g/h (0.88 oz/h) for half a day followed by a similar period with condensation at the same rate. The experiments were performed under isothermal conditions of 21.0±0.5°C (70±1°F).

The inner wall consisted of a steel frame with insulation inside. The thickness of this basic part of the wall layer was 70 mm (2.8 in.). In cases 2 and 3 measurements were made with mineral wool as insulation or, alternatively, with loose fill cellulose insulation (65 kg/m^3, 4.0 lb/ft^3). A metal wire netting was added in order to keep the cellulose insulation in place. The following cases were only made with cellulose insulation. In case 4 untreated plasterboards were added on each side of the construction. The thickness of the plasterboard was 13 mm. In case 5 painted plasterboards replaced the untreated plasterboards. The painting consisted of two coats of latex wall paint. Finally, in case 6, a vapor retarder was added between the insulation and the painted plasterboards, although this is not normal to have in an interior wall. During all the experiments, moisture transport though the edges of the test walls was prevented by use of moisture proof tape. The exposed surface areas for each case are given in Table 3.

Table 2. Types of Furniture/Furnishing Exposed

Case	Furniture - Table - Chair - Room divider - Shelf 1 - Shelf 2	Books	Carpet	Paper on Table	Curtain
1 (empty)					
2	*				
3	*	*			
4	*	*	*		
5	*	*	*	*	
6 (fully furnished)	*	*	*	*	*

Table 3. Exposed Surface Areas

Case	Material	Exposed Surface Area, m^2
1	Empty test cell	0.0
2	Mineral wool in steel frame	15.38 (166 ft^2)
3	Cellulose insulation in steel frame	15.38 (166 ft^2)
4	Cellulose insulation in steel frame under untreated plasterboards	20.15 (217 ft^2)
5	Cellulose insulation in steel frame under painted plasterboards	20.24 (218 ft^2)
6	Cellulose insulation in steel frame under vapor retarder and painted plasterboards	20.24 (218 ft^2)

CALCULATIONS

The indoor humidity has also been modeled with a whole-building hygrothermal simulation tool (Rode and Grau 2003; Rode et al. 2001). The tool is capable of making transient prediction of the heat and moisture condition of materials in the building envelope and in indoor furnishings and simultaneous prediction of the humidity condition of the indoor air. Significant in this modeling is to see how the hygroscopic materials are able to moderate the variations of the indoor humidity. The scope of the modeling was to see if it could be possible to predict the effect of various items in indoor furnishing to act as moisture buffers and possibly to use the experimental results just presented to benchmark the model.

The calculation tool uses a finite control volume method and models the hygroscopic absorption of moisture in materials according to their sorption curve. In doing so, it also models the hysteresis that characterizes the difference between the sorption curves for absorption and desorption, and it models the so-called scanning curves that are followed in the transition between absorption and desorption. Moisture transport within the materials is modeled as vapor diffusion according to Fick's law. The heat and vapor transport coefficients at the surfaces of materials in the room are modeled with constant surface resistances: 0.13 m^2K/W (0.74 $ft^2 \cdot h \cdot °F/Btu$) for heat transfer and 5.1·107 $Pa \cdot m^2 \cdot s/kg$ (corresponding to a permeability of 340 perm) for vapor transfer.

To model the materials in indoor furnishings, e.g., an office chair or the books on a shelf, it is necessary to approximate these elements with planar construction surfaces, just like inner walls. Thus, it must be realized that even the relatively simple test chamber and furnishings that were analyzed in these tests can only be simulated using some rough approximations about how the materials should be represented in the model. It is not possible with the calculation model used to represent the real microclimatic conditions near the surfaces of the objects in the room. However, to get some indication of the influence of the boundary conditions in the interface between furnishing and indoor air, a simulation was also carried out for the fully furnished room when the surface resistance for vapor transfer was doubled to the value 1.02·108 $Pa \cdot m^2 \cdot s/kg$. This had the effect of increasing the amplitude of the daily indoor RH variation from about 21.6% RH to 22.8% RH, i.e., a relative increase in the order of 5%. This must be seen only as an indicative number since it depends on the choice of materials and their aerial configuration in the room. More research is needed into the importance of the surface mass transfer coefficient and the microclimatic conditions around indoor furnishings is needed.

Some simulation models were set up to predict the indoor humidity variation in different cases, from the empty test cell to the test cell fully furnished as an office with a desk with working papers, upholstered office chair, book cases with books on the shelves, a carpet, and curtains. The modeled setting was the same as in the experiments described previously. The room was the well-insulated steel box, which is practically inert to moisture flow through its walls and is very airtight. A humidification of the room of 33 g/h (1.2 oz/day) was simulated for 12 hours followed by a dehumidification of the same magnitude for the other 12 hours per day. The indoor air temperature was modeled so it was constant at 20°C (68°F). The materials of the furniture were entered into the simulation model as multi-layered structures of homogenous material layers—sometimes down to a control volume thickness of around 0.1 mm (4 mil). The numerical grid was expanding, so the surface control volumes were thinner than control volumes deeper in the material. The calculations were carried out for one-week periods, where each day was calculated under identical assumptions. All materials started at a moisture content corresponding to a given initial relative humidity. This value was chosen to match as closely as possible the same conditions as in the experiments.

RESULTS

Comparison: Empty Room—Fully Furnished

The difference in the moisture buffer performance between the fully furnished test room and the empty test room can be seen in Figures 7 and 8. The two cases have approximately the same average RH (55% resp. 57% RH) but the fully furnished room has a smaller amplitude. A smaller amplitude indicates a larger moisture buffer capacity in the surface materials if the ambient conditions are similar in the cases compared, as in these experiments. For a one-day variation, the fully furnished room has a highest peak of humidity 10% RH lower than it was for the empty room, and the daily minimum value is 5% RH higher than for the empty room. Overall, this gives a less varying indoor climate. Comparing all the different cases (see Table 2 and Figure 8) it can be noted that the cases where lightweight organic materials, such as papers and textiles, are exposed have the lowest variation in RH for these weekly sequences of daily variations.

Penetration Measurements

The result of the measurement of moisture penetration into the chair seat that was used as a weighed specimen indicates that moisture penetration into the seat progresses almost instantaneously. Although there is a small time-delay for the moisture variation, it depends on the distance from the top surface. This is easiest to see when the change in RH is plotted as a function of time and at the lowest value for the moisture variation (see Figure 9). The upper half of the chair seat has a larger moisture variation.

It can also be noted that the effect of the disturbances, mainly from the control system of the humidification/dehumidification system, decreases with the distance from the top, as expected. In the bottom half of the chair seat, the sensors register almost no disturbances in comparison to the sensors on top of and just underneath the wool fabric.

Comparison Measurements and Calculations

Figure 7 shows the measured variation of indoor relative humidity for one typical day for the room without materials, as well as for the fully furnished room. For the empty room, the relative humidity varies between approximately 35% and 80% RH, while for the fully furnished room it varies between 40% and 70% RH. For the empty room, this corresponds to a variation in humidity ratio of the air between 5.1 g/kg and 11.7 g/kg (at 20°C, 68°F) and between 5.8 and 10.2 g/kg for the fully furnished room. The theoretical variation in indoor humidity ratio should be ±8.7 g/kg for the empty room when the as-planned 33 g/h (1.2 oz/day) of moisture are added to and withdrawn from the 38 m^3 (1340 ft^3) test cell in 12-hour periods. These results illustrate some deficits of the experimental configuration: The dehumidifier used to withdraw humidity from the air had some difficulty in desiccating the air significantly below 40% RH, so not all the planned humidity variation could be realized. Further, it may be possible that there was some hygroscopic absorption of moisture in the paint, polyethylene sheets, dust, and electrical wires in the otherwise empty room.

The same figure shows the results of the calculation of indoor humidity. The simulation result for the empty room shows a variation between 26% and 88% RH, while it varies between 45% and 66% RH for the fully furnished room.

Interior Walls

The results of indoor RH variation with inner walls as moisture buffers are shown for representative one-day periods in Figure 10. The experiments show that cellulose insulation has a very good buffering effect. In a small office with a 15 m^2 (166 ft^2) buffer wall of cellulose insulation the variation range of relative humidity can be reduced to half the variation in a similar room with non-absorbing materials. On the other hand, the moisture buffer capacity for mineral wool has been found to be very small. It was also found that if plasterboards cover the insulation in an interior wall, the moisture buffer capacity of the insulation is insignificant.

For the three cases with plasterboards it is hard to differentiate between the moisture buffer capacities. The curves for the two painted plasterboards are very similar. This seems reasonable since the penetration depth for the untreated plasterboard was less than the 13 mm (0.5 in.) thickness of the plasterboards so the test results were expected to be identical. The resulting error was 10% and thereby it seems fair that the two test series are alike. However, this also means that it is impossible to distinguish between the test with the untreated plasterboard and the tests with the painted plasterboards. The plasterboards have a moisture buffer effect somewhere between that of mineral wool and that of cellulose insulation.

DISCUSSION

The moisture buffer capacity of the surface materials of the indoor environment can be used to minimize the daily peak variations of relative humidity in the air and thereby avoid periods with both very high and very low relative humidity. As

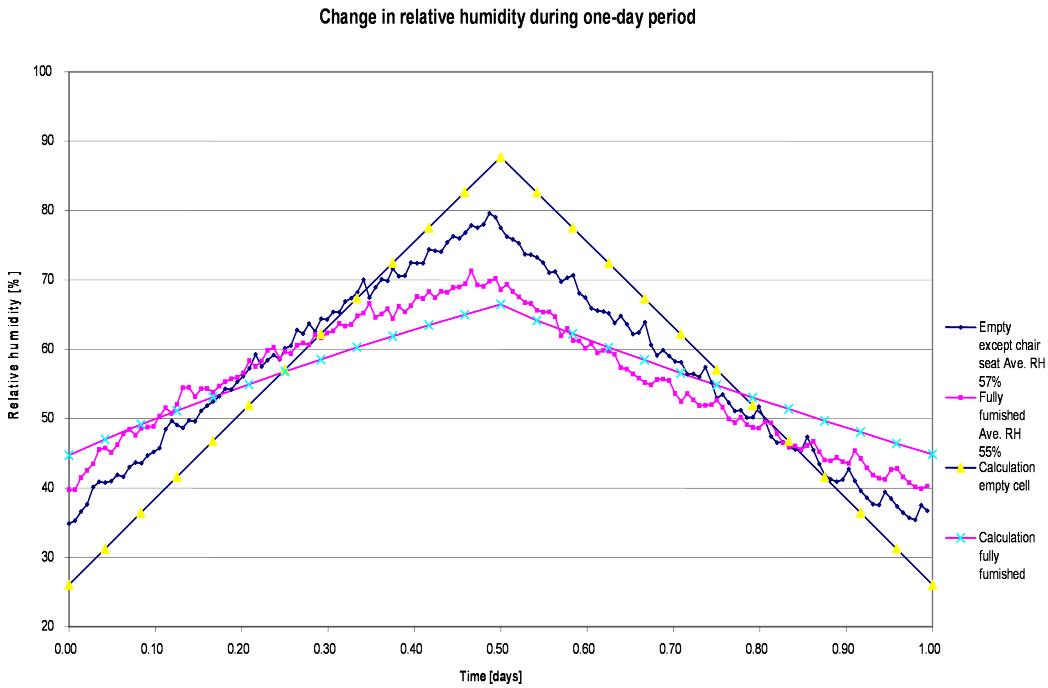

Figure 7 *Difference in the moisture buffer performance between the fully furnished test room and the empty test room.*

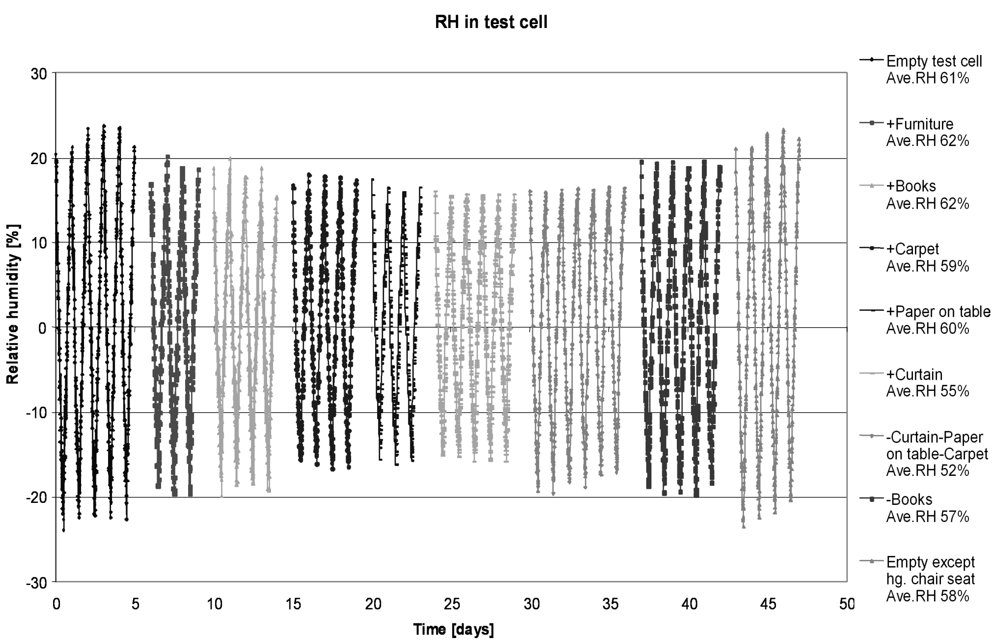

Figure 8 *The variation in RH for the nine different cases for the furnished room experiments.*

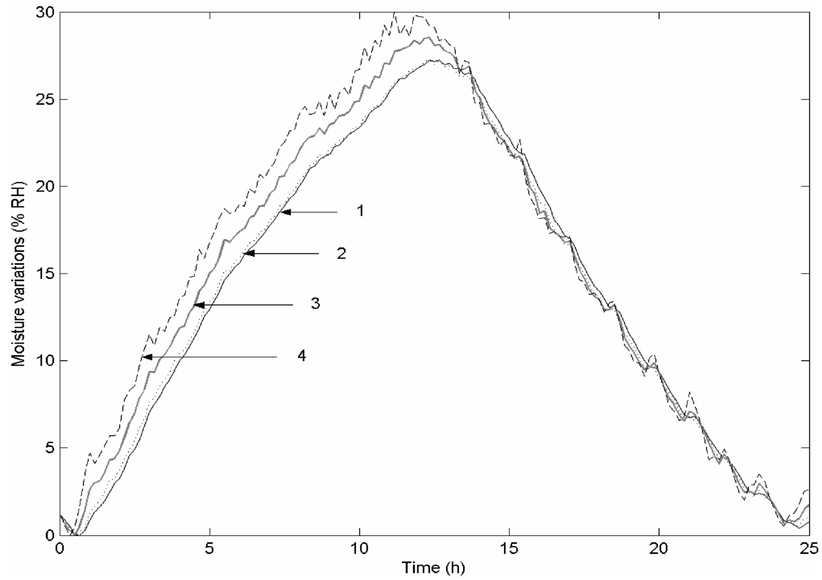

Figure 9 *The moisture variation in the chair seat.*

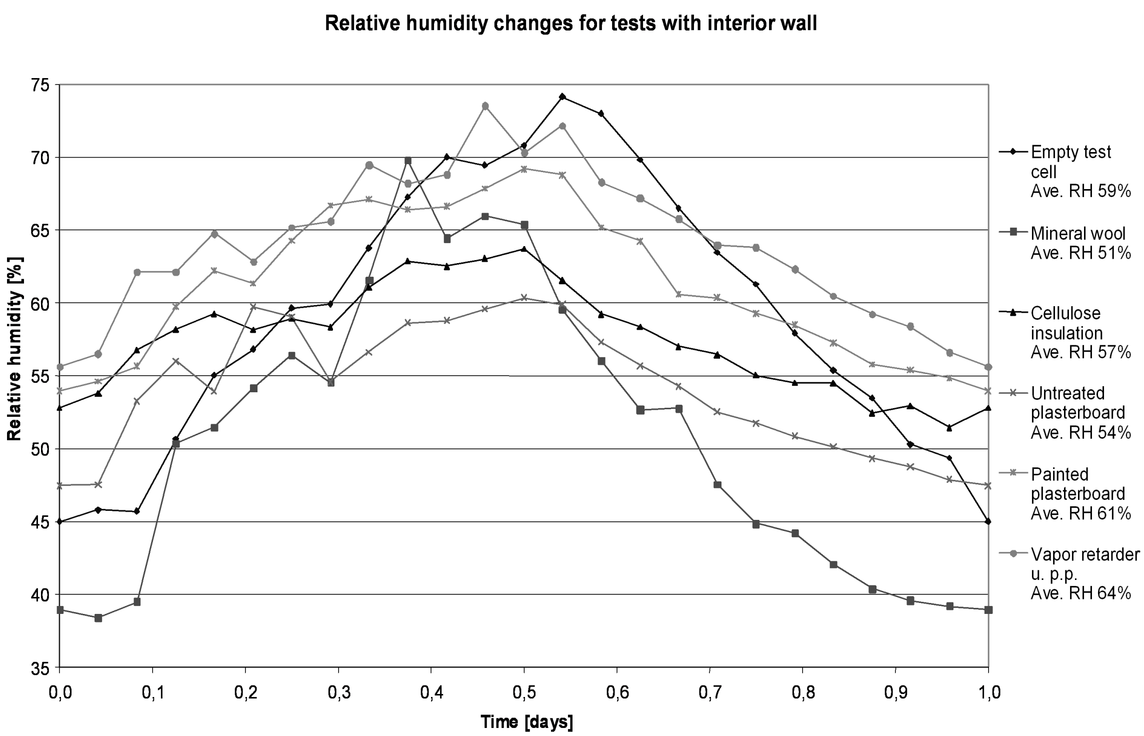

Figure 10 *The results of indoor RH variation with inner walls as moisture buffers are shown for representative one-day periods.*

mentioned in the introduction, there are many advantages. Reducing the highest appearing RH in the indoor air reduces the risk of condensation on cold surfaces and the number of emissions from surface treatments and causes the air to be perceived as fresher. The reduction of the high peak values is advantageous for both the constructions and the indoor air, since fungal growth and consequent deterioration and spread of spores are less likely to appear.

To play an active role in minimizing the daily peak variations, the materials in the indoor environment need to be relatively open and have a moisture buffer capacity together with a sufficient exposed area. In this experiment it has been shown that a fully furnished room has a better moisture buffer performance than a sparsely furnished room. Highly permeable and lightweight materials, such as papers and textiles, play an important role in moderating the hourly or daily variations, since to a high degree they cover other materials, such as surface-treated wooden book shelves or painted interior walls. There is a need for moisture properties for surface materials, both traditional building materials and materials for furnishing, and special interest should be paid to surface treatments such as lacquers and paint. The results from the experiment with the interior walls indicate that a further investigation in the field of paint coverings should be carried out. A larger survey of the materials present in the indoor environment is another topic for further research, which can be used to describe the indoor environment in a more precise way.

To model the indoor humidity of rooms while taking into account the moisture absorption in surfaces of the objects in the room requires detailed knowledge about the surface area, texture and topology of the surfaces, as well as knowledge about the material properties and the local surface coefficients for convective moisture flow at the different loci where humidity exchange takes place. Regarding these properties for real rooms with all their gadgets or even a simplified setup like the test cell investigated in this work, it is obvious that it will become an immense, or even impossible, task to achieve high precision in the provision of these data. The work illustrated in this paper has shown that it is possible to some extent to model the conditions in a room under simplified and idealized assumptions. By comparison of test cell and field test data, it should be possible to obtain good guidelines on how the complex layout of a room can be modeled in a way that merges all objects into a limited number of idealized surfaces. In addition, it should be possible by studying the microclimates in some characteristic material/air interfaces and analyzing these (e.g., with CFD calculation) to get a better understanding of the local mechanisms for heat and moisture exchange in such loci.

A large source of uncertainty in the experiments and calculations presented here is the surface moisture transfer coefficient, which to a high extent is governed by the microclimate at each location. We lack knowledge about the true microclimate and this has to be more carefully studied, as mentioned above. Also, the effective exposed surface areas introduce uncertainties into the experiments and calculations, and a methodology to determine the effective exposed surface area has to be carefully thought through.

The comparison between calculations and measurements as shown in the "Results" section and in Figure 7 illustrates some deficits of the experimental configuration. The dehumidifier used to withdraw humidity from the air had some difficulty in desiccating the air significantly below 40% RH, so not all the planned humidity variation could be realized. The possibility of some hygroscopic absorption of moisture in the paint, polyethylene sheets, dust, and electrical wires in the otherwise empty room poses another potential source of error.

The usefulness of this type of controlled full-scale measurement should still be considered very high, since it provides an important step between calculations and laboratory measurements on one hand and field measurements in real environments on the other hand. Especially this type of test cell with an exchangeable wall (see Figure 3) provides an advantage when future experiments can be done more realistically by conducting non-isothermal tests with a naturally varying indoor climate due to solar gain.

In the IEA Annex 41 project (described in the introduction) there will be activities that seek to gather as much field and test case information as possible from the different participating countries such that a broad knowledge base will be obtained. It is also anticipated that common exercises will be carried out where the modeling capabilities will be benchmarked and further developed. It appears obvious that the effect of furniture and other indoor materials to moderate the indoor humidity will be a part of this international study.

Altogether, it should be possible to establish a better empirical and analytical understanding of how a real room with all its furnishings performs to buffer the indoor humidity. The work presented in this paper may be seen as an early step on the path to improving this understanding.

CONCLUSION

The full-scale measurements of a fully furnished room have shown that moisture buffering needs to be more carefully studied since it has a notable impact on the moisture conditions in rooms. Calculation tools need to be modified to be able to handle, not only traditional building materials, but also furniture and other furnishing materials. There is also a lack of data for the moisture properties of the surface materials in the indoor environment. Also, a description of different surface materials present in normal indoor environments is needed. Alongside the task to find better descriptions of the materials, a better understanding and greater knowledge of the microclimate indoors is necessary.

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