Use of moisture buffering tiles for indoor climate stability under different climatic requirements

Florian Antretter[1,*], Christoph Mitterer[1], Seong-Moon Jung[2] and Andreas Holm[1]

[1]Fraunhofer Institut für Bauphysik, Germany
[2]LG Hausys, Korea

[*]*Corresponding email: florian.antretter@ibp.fraunhofer.de*

ABSTRACT
Indoor humidity is an important factor for human health, well-being or damage like mold growth. Excessive indoor humidity conditions may be caused by non-adequate ventilation or temporarily due to change of temperature in rooms. The moisture buffering effect of linings and the resulting impact to air humidity are topics of this study.

Special developed unsealed ceramic tiles and their capability to dampen the fluctuation in air humidity have been investigated, including the determination of relevant hygric material properties. A series of experiments in chambers were designed and executed to show summer and winter situations with temperature changes or different moisture sources. The resulting relative humidity in the chamber was monitored in the baseline experiment with no moisture buffer capacity as well as in the experiment with the installed new developed moisture buffering tiles. The experiment was validated and extrapolated to real room conditions, using a transient hygrothermal whole building simulation tool.

The results show a reduction of relative humidity fluctuation, which attest the humidity-buffering effect of the material. The validation of the hygrothermal simulation with the experiment was successful. A hygrothermal whole building simulation demonstrates the damping of air humidity fluctuations for buildings under real usage conditions and in diverse climate regions. It is shown that thermal comfort conditions can be improved along with lower energy requirements for de-/humidification by using humidity buffering linings. A correct assessment can only be conducted with hygrothermal whole building simulation tools.

KEYWORDS
hygrothermal simulation, moisture-buffering, climate stability

INTRODUCTION

Indoor humidity in residential buildings is a recurrent topic of building physics, since it is an important factor for the human health and the well-being. Even in buildings with high-quality insulation excessive indoor humidity conditions may occur because the occupants produce too much moisture which is not compensated by adequate ventilation. In addition the change of temperature in rooms can result in temporary high air humidity.

Beside furniture, indoor lining materials have the potential of a humidity-buffering effect. Appropriate materials absorb water vapor, if indoor relative humidity increases and they release it, if indoor relative humidity decreases. The result is the damping of fluctuations in air humidity.

This so called moisture buffering effect was studied within the ECBCS ANNEX 41 (Holm et al, 2008). The advantages mentioned are more stable climate conditions which result in a higher comfort level. Furthermore the energy use for humidification and dehumidification is expected to decrease, as short time humidity extremes are buffered in the enclosing surfaces and action from the mechanical system is not required.

HYGROSCOPIC INTERIOR TILES

The new developed material is a ceramic interior tile which is optimized with its pore structure to show a good performance in terms of moisture buffering. This requires that the tiles are not sealed. The ceramic interior tiles were tested for their hygrothermal material properties at the certified laboratory of Fraunhofer IBP in Holzkirchen, with common and standardized test methods. The results of the material property tests are shown in Table1 and Figure 1.

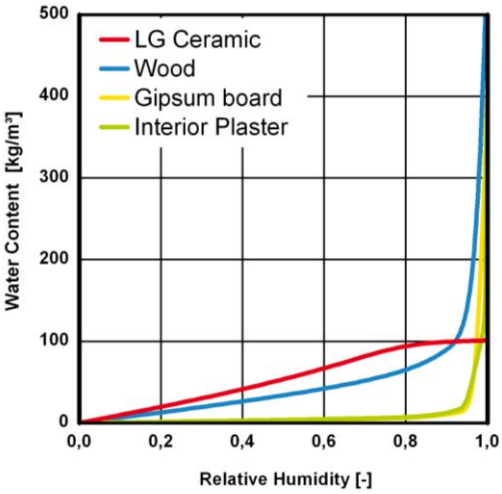

Figure 1. Comparison of moisture storage functions for different materials and picture of the ceramic interior tile

Table 1. Material properties of ceramic interior tiles

	LG Ceramic
Bulk density [kg/m³]	1335
Porosity [m³/m³]	0.51
Specific heat capacity dry [J/kgK]	850
Thermal conductivity [W/mK]	1.6
Water vapour diffusion factor [-]	9.8

CLIMATE CHAMBER MOISTURE BUFFERING TEST

A VCE 1000 test chamber was used for the experiments. This chamber allows conditioning the interior space from 20 °C to 130 °C with an accuracy of ± 0.1 °C and a temperature change rate of 0.3 K/min. The relative humidity can be controlled by the dew point temperature in a range between 5 °C and 60 °C supplied by an air change rate from 0 1/h to 1 1/h. The useful chamber volume is 0.916 m³ resulting from dimensions 0.75 m width to 0.75 m height to 1.63 m depth.

The material was stored inside the test chamber to allow air flow between the tiles with temperature and relative humidity sensors in 0.25 m and 1.00 m depth from the front opening in 0.25 m and 0.5 m height. The temperature was measured with in-house calibrated ThermoSensor PT100 sensors with an accuracy of ± 0.1 °C and the relative humidity with Rotronic SC05 sensors with an accuracy of ± 2 % RH.

The boundary conditions for the test are shown in Figure 2. For the summer case a constant absolute humidity inside the zone is assumed. The temperature for this case changes over the day between 20 and 35 °C. The first ten hours of the day the temperature is kept at constant 20 °C. Two hours linear temperature increase result in 35 °C which are maintained for the next ten hours, followed by a linear decrease back to 20 °C. This is alike an experiment in an airtight chamber described by Maeda and Ishida (2008). They found excellent humidity-controlling properties for hydrothermally solidified materials.

A constant temperature at 23 °C defines the winter case. Moisture production inside the chamber is reproduced by a certain scheme of dew point temperature and air change rates. Both cases are initialized with the shown initialization conditions to reach consistent initial conditions for all test cases.

The first test case was the summer case with changing temperature conditions. In advance the chamber was initialized to 20 °C air temperature and 18 °C dew point temperature. As this dew point temperature inside the chamber can not be reached within a reasonable period of time (especially with installed moisture buffering tiles, which leads to a slowly asymptotic convergence up to the desired chamber RH), the initialization process was stopped at 75 % RH inside the test chambers and the summer test case was started.

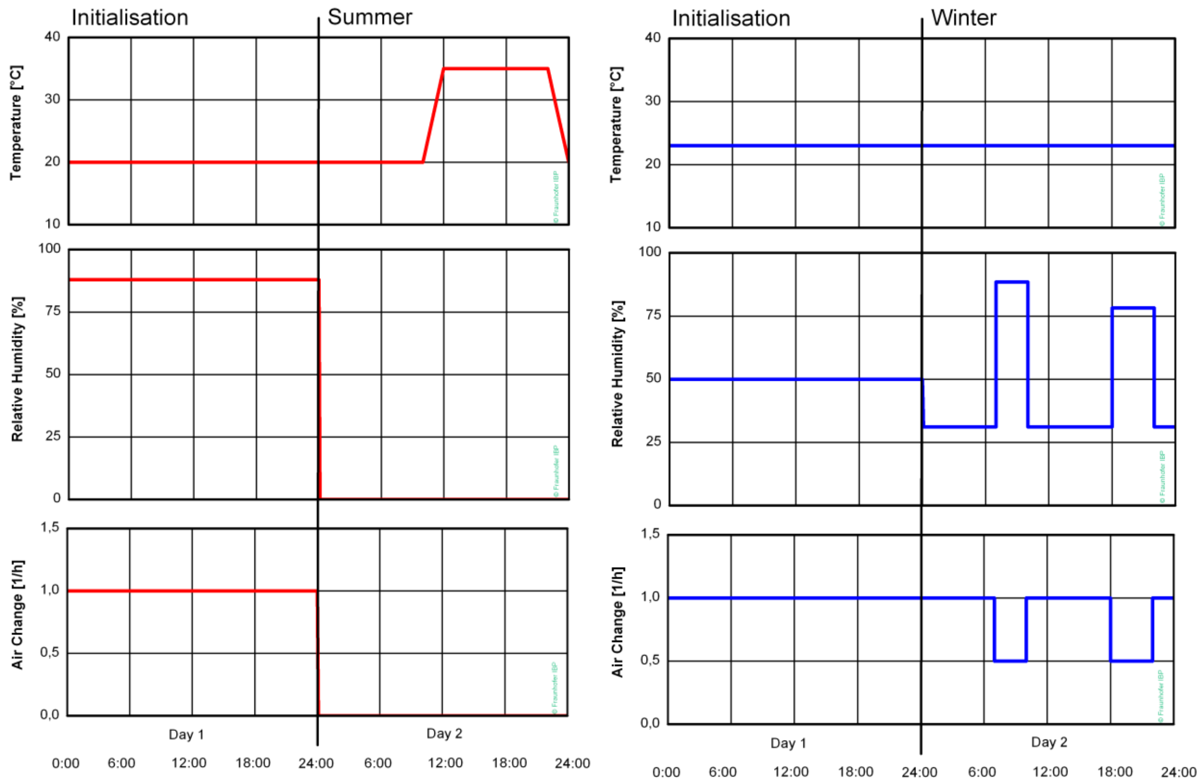

Figure 2. Boundary conditions for the summer and winter test case.

Realistic humidity production cycles inside the zone are assumed for the winter case. This means a basic level of moisture production all over the day caused by humans, animals, plants and so on. Two cycles, one with high moisture production reflects first the morning time with showering people, or people preparing their food for the day. The second one reflects the time in the afternoon, when people arrive back home from work, preparing food or taking a bath. The first cycle is assumed to be 3 hours, starting from 7 a.m. to 10 a.m., the second 4 hours, from 4 p.m. to 8 p.m. The total moisture production as integral over the moisture production rate over the day is downscaled from 12 kg/d for a regular four person family in an according living space.

The results of the experiment are shown in Figure 3 for one day of the experiment. Temperature and relative humidity inside the test chambers on one representative measurement point are compared in the graphs for the summer and winter test case with both, empty test chambers and test chambers with moisture buffering tiles installed.

The winter test, with moisture production rates inside the zone and constant temperature show a very significant reduction of daily relative humidity fluctuations. The first moisture production cycle with highest moisture production rates results in a higher peak than the second moisture production cycle in the afternoon, which lasts for one hour longer than the first moisture production cycle.

In the summer case, the empty chamber shows with increasing temperature a decreasing relative humidity, just as one would expect. With moisture buffering tiles installed, the decrease in relative humidity is much lower. The peaks in the beginning and at the end of every test cycle are caused by the control of the chamber.

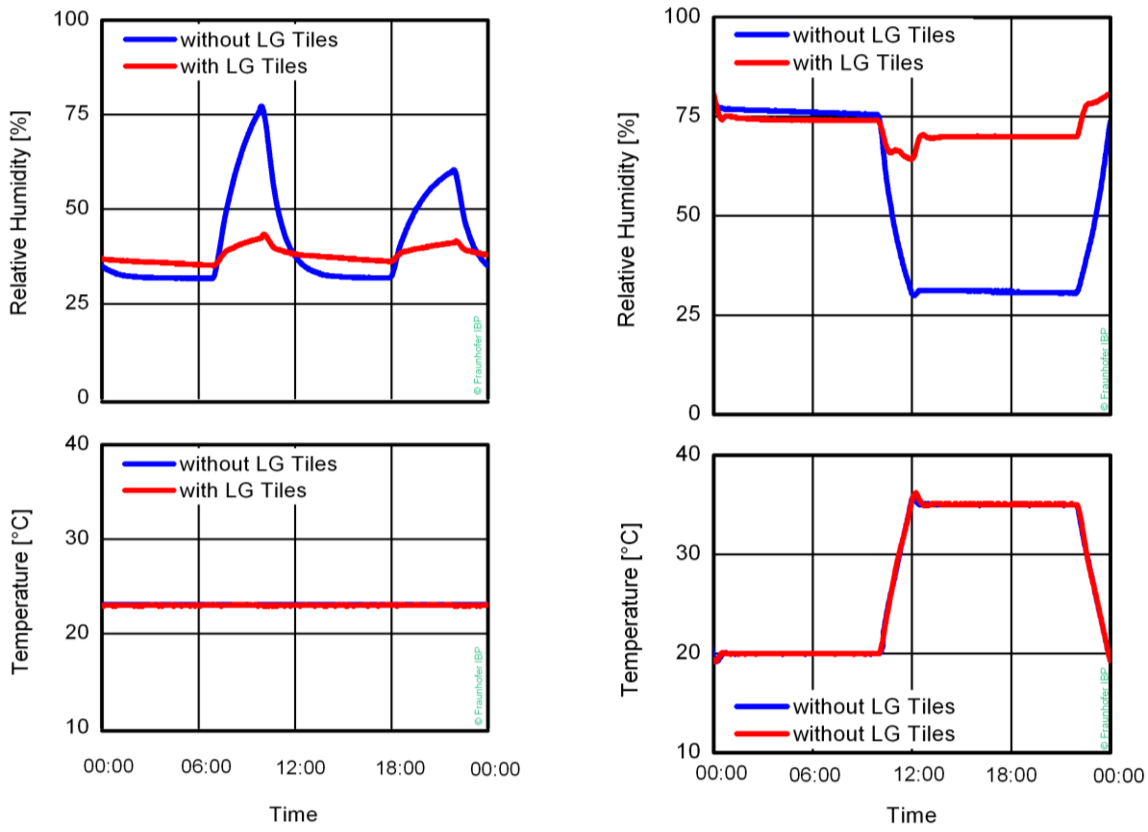

Figure 3. Comparison of test results for summer and winter case.

The maximum daily range of RH without tiles is around 45 %. With moisture buffering tiles installed on the surfaces, the daily delta in RH decreases to 11 % RH in the summer case and 7 % RH in the winter case.

The measurement results show a significant effect of the moisture buffering tiles on the relative humidity inside the room. The tiles are able to buffer moisture in times with high relative humidity and release the moisture again in times of low relative humidity. This results in a damped relative humidity inside the room. The resulting more stable climate provides longer periods with good comfort conditions and reduces the risk of mould growth. Similar results were found by using other types of moisture buffering materials like wood based materials (Künzel et al., 2006). The performance in terms of moisture buffer capacity is even higher for the tiles presented within this paper.

VALIDATION OF SIMULATION MODEL

The newest version (2.0.0.4) of WUFIplus, a hygrothermal whole building simulation tool, is used for simulation. The software calculates the coupled heat and mass transfer for every enclosing assembly and couples heat and moisture fluxes from the inner surfaces with the zone temperature and relative humidity. The simulation model has to be validated by simulation of the experiments in the chamber. The used air chamber is not 100% airtight, therefore an air change rate of 0.003 ACH is used for simulation.

A 3D-model of the chamber is built in WUFIPlus with all parameters recorded in the experimental setup used as input conditions. “External” temperature and relative humidity conditions as well as ventilation rates are used from the chambers target value logging. The simulation runs with a two minute time step, to accurately model all changes in temperature and relative humidity. Outputs of the simulation are resulting temperature and relative humidity inside the chamber which are used as validation values.

The validation of the software model WUFIplus is performed in two steps. In a first step the results of the measurements of the empty chambers in summer and winter test case are compared. This validates the zone model, as moisture transport in the building enclosure is not existent.

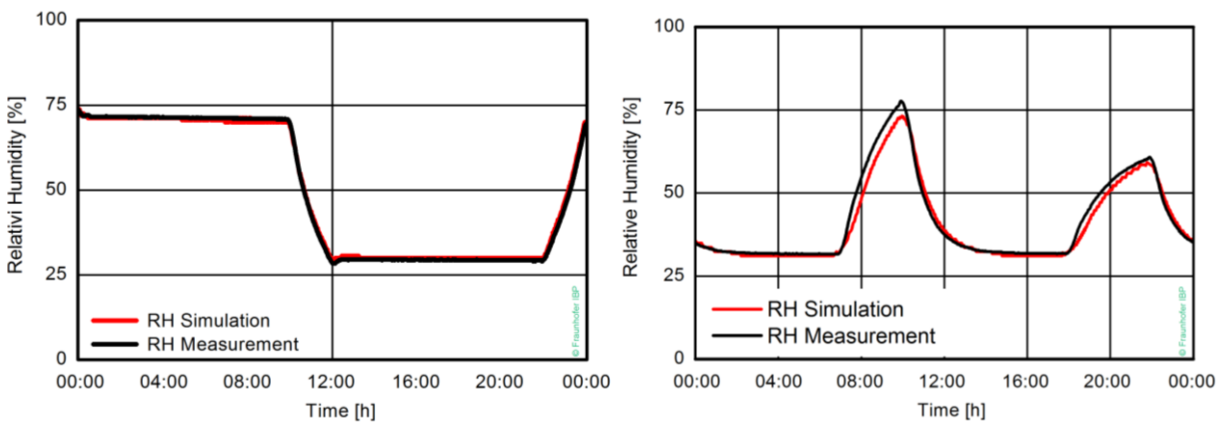

Figure 4. Validation simulation results for empty test chamber.

Figure 4 compares the simulation results with measurements of the relative humidity. In both cases, summer and winter, a very good agreement between validation simulation and validation measurement is found. In the winter case, the peak in relative humidity during the first moisture production cycle is slightly higher for the measurement.

Validation measurement and validation simulation also show a very good agreement for the winter case with moisture buffering tiles installed as shown in Figure 5. In the summer case the starting level is not the same, resulting from differences during the initialization process between simulation and measurement. Still the fluctuations in measurement and simulation are found to be very close, but slightly higher for the simulation case.

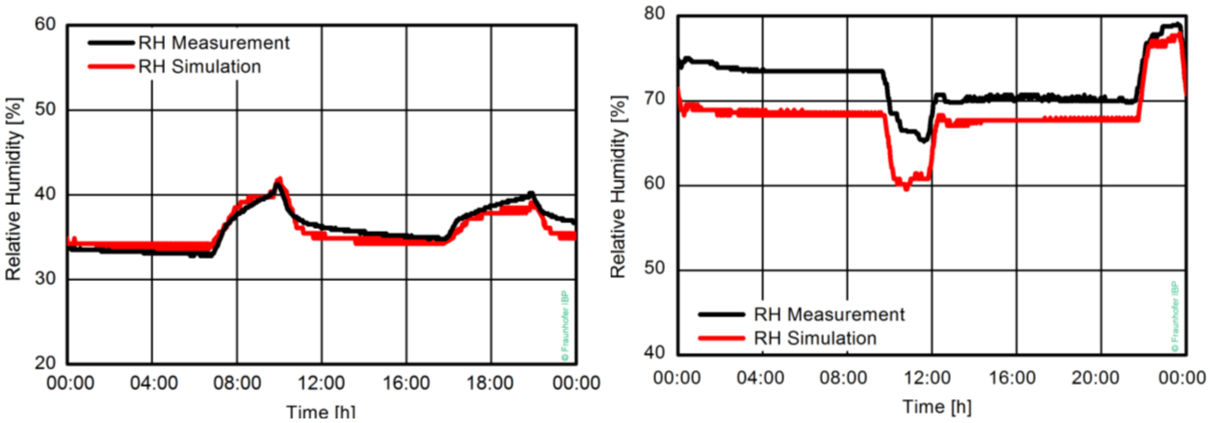

Figure 5. Validation simulation results for test chamber with moisture buffering tiles installed.

Modeling the experiment with the hygrothermal whole building simulation allows validating the tool WUFIplus. Very good validation results can be achieved by accurately applying all necessary boundary conditions in the model. WUFIplus uses fixed heat transfer resistances on the inner surface and linear dependent moisture transfer resistances. In the summer case, with changing air change rates and very small zone volume, this leads to inaccuracies as in reality the heat and moisture transfer resistance depends on the air velocity on the surface. This is partially solved by using different fixed resistances in different simulations and combining them together. Still, zero air velocity is not allowed within WUFIplus. The real velocity for the summer case, with airtight chamber and very constant interior temperature, is very low. This results in the small differences for the summer case validation simulation. An assessment of the performance of moisture buffering materials is therefore possible.

REAL ROOM APPLICATION

After a successful validation, analysis and up-scaling to real room scenarios can be performed with the simulation software. This allows energy demand computation, enables the assessment of thermal comfort conditions inside the balanced zone combined with the assessment of heat and mass transfer in the building assemblies.

Detailed assessments are undertaken by performing simulations in eight different climatic zones in the USA. The same model of a room – one equipped with moisture buffering tiles on one wall and the ceiling, the other equipped with painted gypsum boards on the inside – is simulated with climate conditions from Anchorage, Atlanta, Baltimore, Chicago, Fargo, Miami, Minneapolis and Phoenix according to ASHRAE zone specification (ASHRAE 90.1, 2007). The modelled room contains one zone with a volume of 229.8 m^3 and a floor area of 96.7 m^2. 5.4 m^2 North facing and 9.0 m^2 South facing windows are installed. A constant ventilation rate of 0.5 ACH with a total daily moisture production of 7.5 kg produced in a daily cycle to reproduce residential usage was assumed. Assessed are the hours with relative humidity in the range between 35 % and 75 %. Furthermore, the annual humdification/dehumidification load to maintain the above mentioned criteria are computed.

The effectiveness of the moisture buffering tiles depends on the external climate and on the use of the room, as well as on the used HVAC. Figure 7 shows, that an effect can be found in every of the eight climate zones. For every climate zone an improvement, i.e. a longer period of time with relative humidity above 35 % and below 75 %, is found.

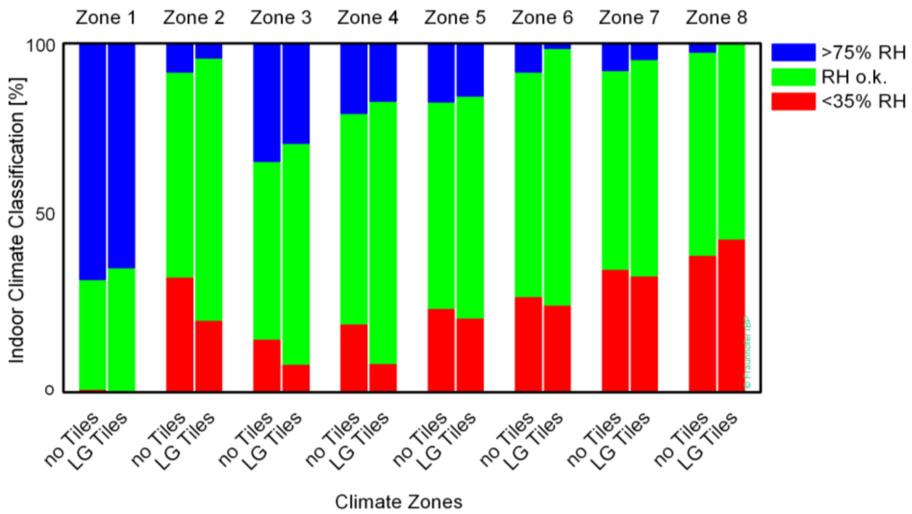

Figure 7. Indoor climate classification for eight climate zones in the US as comparison between model-room with and without tiles.

The same is found for humidification and dehumidification load. The load can be decreased in every climate zone by using moisture buffering materials as inner lining. Figure 8 compares the necessary loads to keep the relative humidity between 35 % and 75 %.

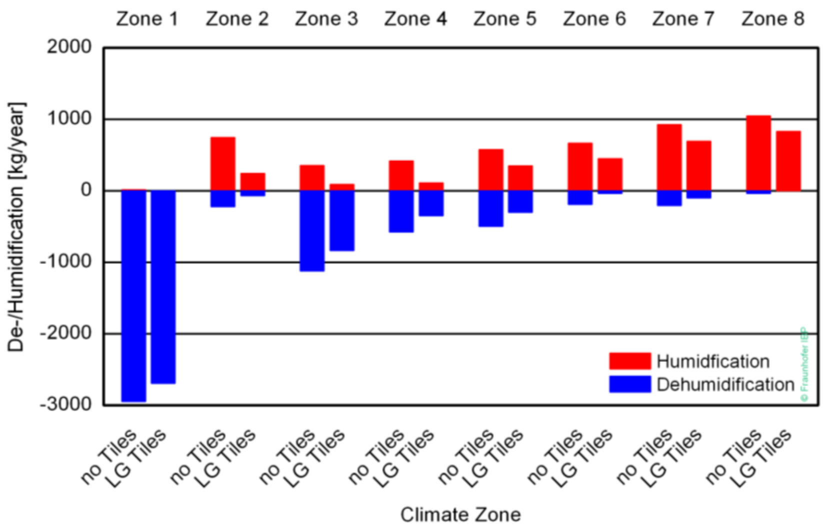

Figure 8. Humidification/Dehumidification for eight climate zones in the US as comparison between buildings with and without tiles.

CONCLUSIONS

A successful experiment was conducted. It showed the influence of specially designed ceramic interior tiles on the moisture performance of rooms. The tiles proofed to have a high effect on the dynamic changes of the interior humidity conditions.

The validation simulations showed that it is possible to use hygrothermal whole building simulation tools like WUFIplus for the assessment of the effect of moisture buffering materials in buildings. This allowed the up-scaling of the experiments to real room scenarios via simulation. As energy use for heating/cooling and de-/humidification is significantly influenced in rooms with moisture buffering surfaces, the use of modeling tools capable of modeling the hygrothermal interaction between room and surrounding surfaces must be highly recommended.

Using moisture buffering materials as inner surface materials allows maintaining a more stable climate without active measures. This reduces on one hand the risk of mould growth; on the other hand a higher comfort level can be achieved. Energy use for humdification and dehumidification can be reduced significantly in every climate zone by using moisture buffering material.

It is to be assessed, how much area of moisture buffering material needs to be installed for different building types and usages applied in different climate zones. This will allow an optimization of building energy use and comfort conditions under an economical point of view.

REFERENCES

ASHRAE. 2007. ASHRAE Standard 90.1-2007, Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Holm A. 2008. ANNEX 41 Whole Building Heat, Air and Moisture Response (MOIST-EN), Volume 4: Applications: Indoor Environment, Energy, Durability. Final Report.

Künzel, H. et. al. 2006. Feuchtepufferwirkung von Innenraumbekleidungen aus Holz und Holzwerkstoffen. Fraunhofer IRB Verlage: Bauforschung für die Praxis, Band 75.

Maeda, H. and Ishida, E. 2009. Water vapor adsorption and desorption of mesoporous materials derived from metakaolinite by hydrothermal treatment. Ceramics International 35 (2009), 987-990.