

Effect of moisture on the sound insulation of building components



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Summary

Water is an essential part in the production and application of building materials. Several years may pass until construction moisture dries out and the building components achieve moisture equilibrium. This paper investigates the influence of water contents in walls on the sound insulation properties. Therefore, monolithic walls made of different materials with variable moisture levels were systematically measured. The results clearly showed: The higher the moisture content, the higher the sound insulation. However, the effect of moisture on sound insulation cannot be explained by the increase of mass due to the additional water content alone. Thus further acoustic parameters like the loss factor or the module of elasticity were determined in dependence of moisture. Furthermore the change in water content of several walls was calculated by transient hygrothermal simulation for a period of several years. By coupling the calculation results with the acoustic measurement data the seasonal variation of the sound reduction index of walls could be determined.

Keywords: Moisture content; monolithic walls; sound insulation; acoustic comfort, sustainability

1. Introduction

An environment, which is continuously more densely populated, will inevitably entail higher noise loads for every person in urban centers. Since noise has a negative impact on human health, there is a steadily growing desire for silence. Residential buildings are playing a significant role in this context: What residents increasingly expect here is a zone of quietness, where they can relax from the stresses and strains of the noise of everyday life without any hermetical isolation. This requires building components with adequate sound insulation. It is not sufficient to consider only the influence of exterior noise but also the protection against sound transmission from adjacent rooms. This requires a permanently adequate sound insulation of partitions and floors in buildings. The sound insulation of this kind of building components is an essential factor for the acoustical comfort in interiors also in non-residential buildings. Thus, they make a significant contribution to the socio-cultural and functional quality in the field of sustainable buildings. A permanently positive influence is achieved in this way to preserve health and thus the performance of adults as well as children. Moreover, these factors effectively contribute to preserve the value of a building.

A sufficient sound insulation level can only be achieved by adequate building components and highest possible accuracy in construction. Since considerable quantities of water are necessary for the construction of buildings and for manufacturing building components and building materials, the following questions consequently occur:

What effect does water have on the acoustic properties, which is trapped in the building materials and absorbed during manufacturing and processing?

Is the increase of mass of the building component due to water actually so serious that there could be an impact on sound insulation?

Is the mass increase due to water actually the decisive factor to influence sound insulation?

What about a permanent sound insulation of walls? Is the sound reduction index, once determined in the laboratory or in-situ, an invariable parameter?

Must users of buildings be prepared for a lower sound insulation level after the building is dried out?

Does the seasonal cycle probably produce varying quantities of moisture in building materials resulting in variable sound insulation coefficients of the respective building components?

Literature research within the context of this paper, however, showed that only a few publications deal with the topic of the acoustic properties of humid building components [1] [2] [3] [4]. Statements made there do not deliver any homogeneous view. The state-of-the-art research that could be found out within the context of this paper clearly shows that the real effects of water trapped in the building material porous structure on the sound insulation properties of building components has not been yet sufficiently investigated.

Thus, this paper was aimed at determining the influence of varying moisture contents on the airborne sound insulation of building components systematically. Since the quality of airborne sound insulation results from the interaction of the previously mentioned influencing parameters, it was necessary to investigate the overall impact of moisture on sound insulation as well as on the various influencing parameters. Therefore, a measurement program was established for systematic investigations.

2. Experimental and numerical investigations

2.1 Experimental set-up

Removable single-shell walls were installed in various building blocks (Figure 1). The individual building blocks of lime sand, lightweight and aerated concrete were stored in water until free saturation before the walls were constructed.

After weighing, each wall unit with the dimensions of approx. two square meters was installed in the building acoustical test facility and the acoustical measurement program was conducted. For this purpose, the airborne sound reduction index and the structure-borne reverberation time were measured, and the pulse time delay was measured after demounting. Afterwards the respective wall was removed and placed for drying. The walls were weighed almost every day until the next measuring period started to document the stepwise reduction of the moisture content.

This measurement cycle was repeated up to six times for each wall until the dry state of the building material was achieved. Afterwards, the weighted sound reduction index was determined from the frequency-dependent sound insulation curve for each moisture level of each test specimen. In addition, the total loss factor of the test walls was determined from the measured structure-borne reverberation time, and the longitudinal wave velocity from the pulse time delay, which were of significant importance for the calculation of further influencing factors.

Test walls

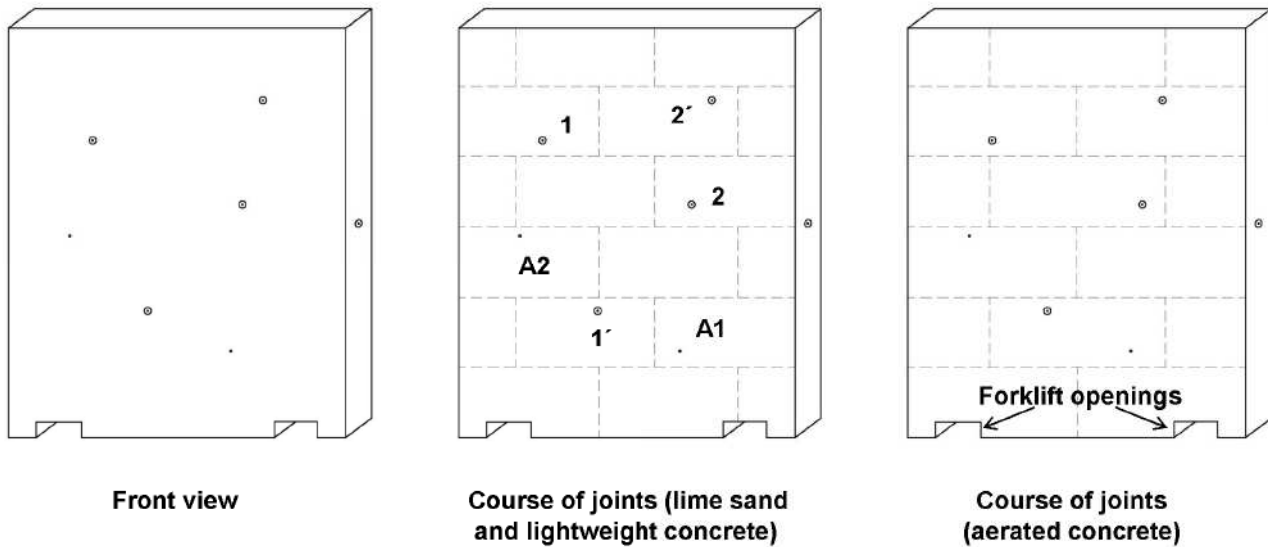


Fig. 1: Drawing to scale of 120 cm wide, 145 cm high and 11.5 cm thick test walls. Besides specifications of the course of joints of lime sand, lightweight and aerated concrete masonry units there are also positions for structure-borne sensors with the numbers 1, 1', 2 and 2' as well as the Shaker excitation positions A1 and A2. The statistic distribution of the points did not provide for a direct positioning on/in the joint of the brick.

2.2 Influencing parameters

Airborne sound insulation of building components is influenced by a variety of factors, whereby frequency and mass per unit area as well as bending stiffness, loss factor and coincidence effect are among the fundamental parameters [5] [6] [7].

The significance of the individual influencing parameters on the sound insulation curve was analyzed by calculation by means of an approximation method. The measurement results of the three influencing factors mass, loss factor and coincidence for the saturated initial variation were successively replaced for each wall by the measurement results of the dry state of the building material, and the impact on the weighted sound reduction index was determined in each case.

2.3 Hygrothermal simulation

To analyze the building physical interaction of moisture and sound insulation the temporal modification of moisture and thus mass of a partition and an exterior walls made of aerated concrete was measured by means of hygrothermal simulation.

Figure 2 represents the investigated building. The ground floor of the building section is 5 x 9 m. The wall height of the building is 2.80 m. The surface area of the interior partition made of 24 cm thick aerated concrete is 14 m².

The climate boundary conditions are based on the data records for Holzkirchen, and the developed indoor climate was calculated by means of WUFI plus [8]. Investigations were based on the assumption of heating in winter, two adults with a moisture emission of 246 g/h, and an average air change of 0.95 h⁻¹.

The calculation results were converted into the respective volume-related moisture content and coupled with the moisture-dependent sound reduction index measured before.

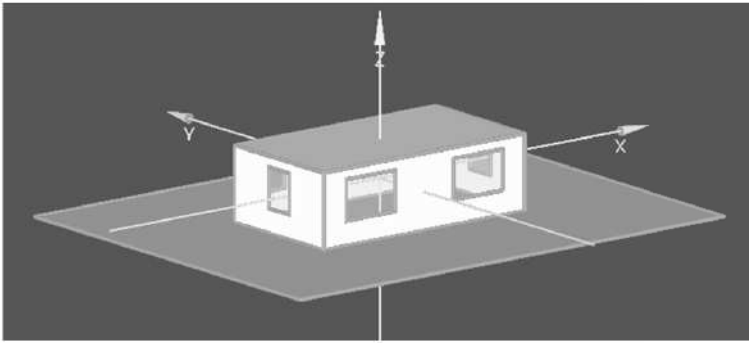


Fig. 2: Representation of a building section, where a transient hygrothermal simulation by means of WUFI plus [8] was carried out.

3. Results

3.1 Sound insulation

3.1.1 Sound reduction index

The moisture trapped in the pore volume of the building material definitely modifies the airborne sound reduction index of the respective building component (Figure 3).

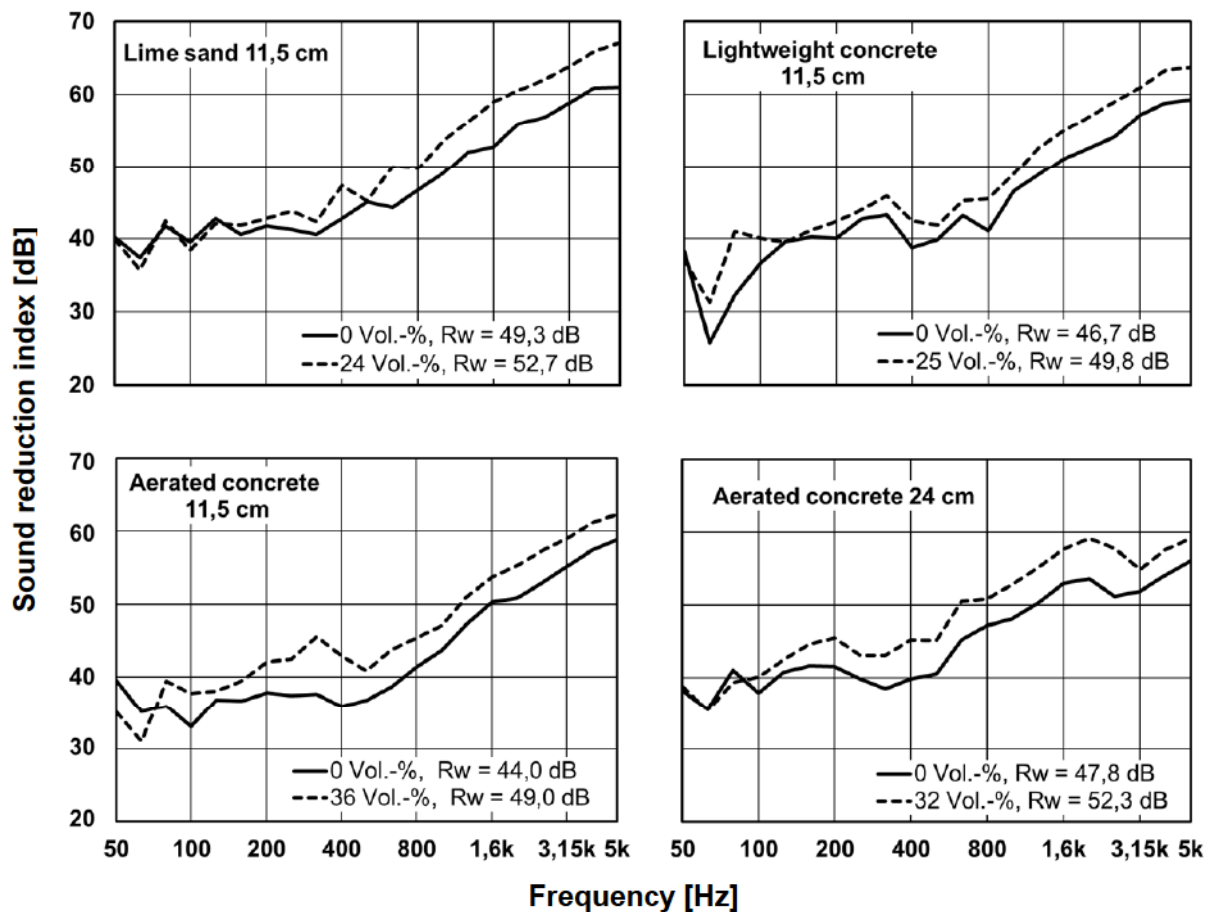


Fig. 3: Development of the frequency-dependent airborne sound reduction index for all four wall structures in a survey. The curve of the water-saturated and the dry state is represented for each wall.

It could be demonstrated without any exception: The higher the moisture content, the higher the airborne sound insulation (Figure 4).

In the process, according to the respective building material higher values of up to five decibel were measured comparing the water-saturated and dry state of a wall as concerns the weighted sound reduction index.

Change in Sound reduction index

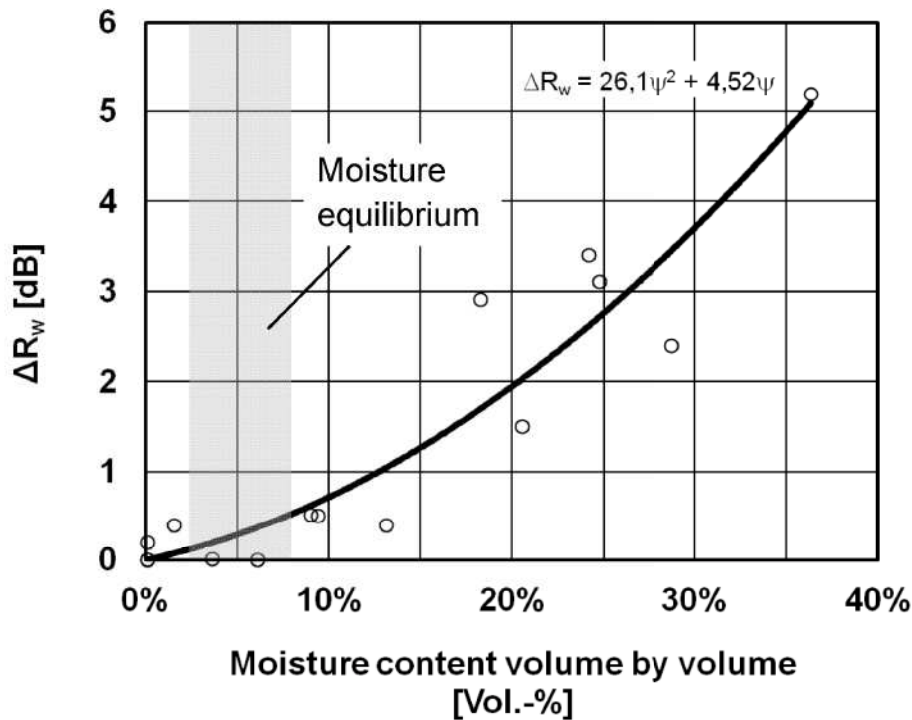


Fig. 4: Representation of the modification of the weighted sound reduction index in dependence of the volume-related moisture content, whereby modification is related to the dry state of the wall. The determined approximation equation for interaction can be found in the upper part of the diagram (ψ means moisture content volume by volume).

3.1.2 Loss factor

The trapped moisture contents cause a clear modification of the loss factor primarily for lightweight concrete and lime sand masonry units. The trapped water causes an increase of the frequency attenuation in the building material.

3.1.3 Modulus of elasticity

The modulus of elasticity shows slightly decreasing values for the lightweight concrete and lime sand masonry units in comparing the water-saturated and the dry state of the wall. The modulus of elasticity, however, was almost constant for all moisture contents in case of the aerated concrete.

3.1.4 Coincidence

In case of the aerated concrete the coincidence cut-off frequency is continuously shifted to lower frequencies with decreasing moisture. In case of the lightweight concrete and lime sand masonry units, however, the influence of the moisture content on the coincidence cut-off frequency is almost negligible.

3.2 Influencing parameters

The modification of the airborne sound insulation does not only occur due to the mass increase caused by water, but also the loss factor has an essential impact on the airborne sound insulation. Due to the different structure of the material matrix of the individual building materials the impact of the various influencing parameters varies. The maximum moisture-related modification of the weighted sound reduction index in case of the aerated concrete amounts to approx. three quarters due to moisture-conditioned mass increase. In case of the lime sand masonry units this value amounts approx. to only one quarter. The increase of the sound reduction index by trapped water is essentially caused by an increase of the loss factor (Figure 5).

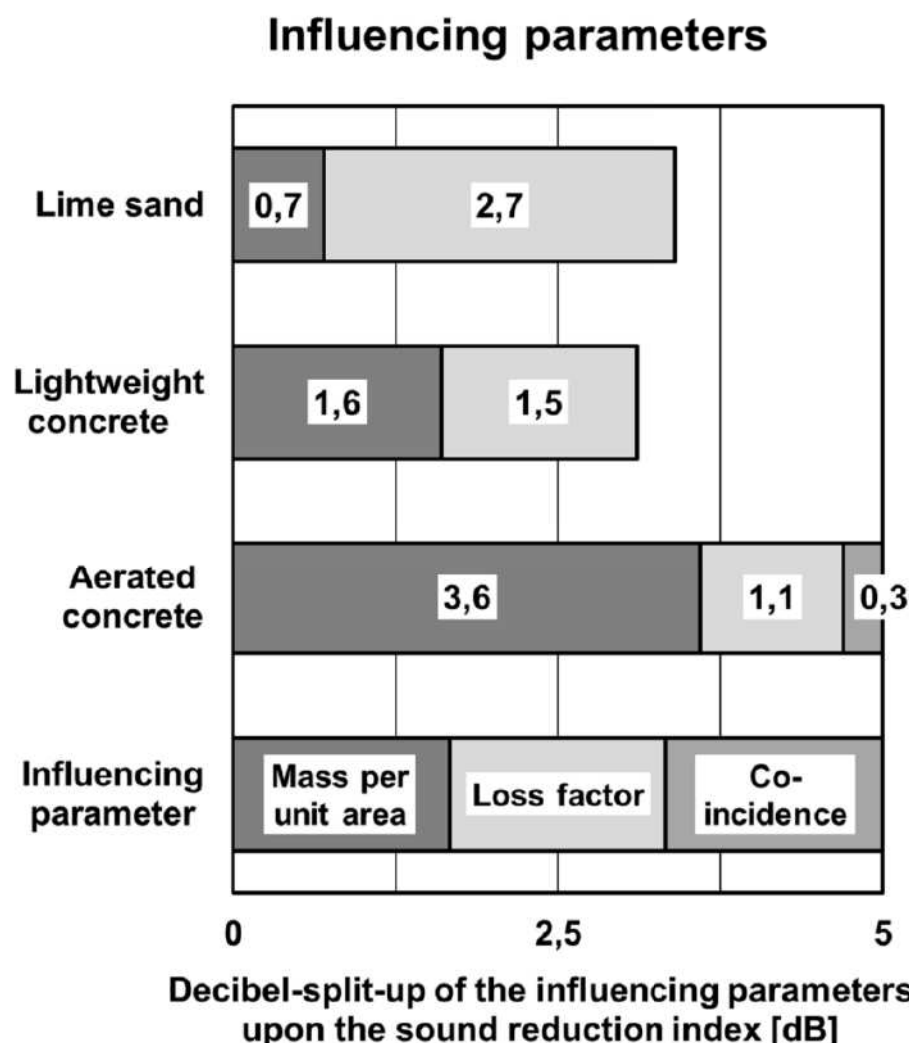


Fig. 5: Result of the analysis of influencing factors. The greatest modification of water-saturated and dry state shows the aerated concrete wall with a total modification of the weighted sound reduction index of 5.0 dB. The greatest share is the influence of mass with 3.6 dB (71%). Moisture has an impact of additional 1.1 dB above the loss factor, and the influence of coincidence is 0.3 dB. The overall modification for lightweight concrete is 3.1 dB, and for lime sand masonry units 3.4 dB, whereby the loss factor here has an influence of 78% upon the sound reduction index of the lime sand masonry unit.

3.3 Moisture content

Partitions as well as exterior walls modify the mass by varying water contents according to the periodical seasonal cycles during the year resulting in the modification of the sound insulation properties. These seasonal changes, however, were not sufficient in the indi-

vidual cases to generate any acoustically perceptible modification of the sound reduction index (Figure 6).

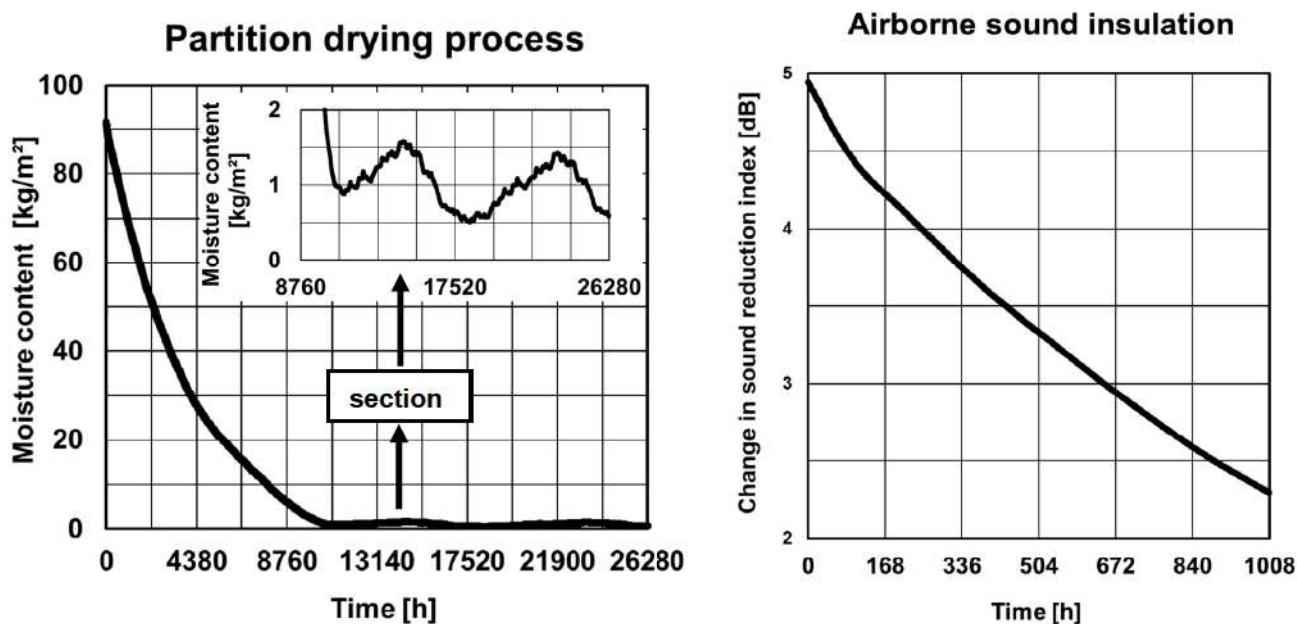


Fig. 6, left: Representation of the simulated drying process of a 24 cm thick partition made of aerated concrete over a period of three years. The partition is installed in the building section as shown in Figure 2. The calculation result shows that dehumidification is executed relatively fast for several reasons: a user profile with only 2 persons and only average activity, a relatively high average air change rate, which is not reduced in winter, no controlled sun protection system. Consequently, temperatures of over 30°C occur in the interiors and in the partitions. Seasonal cycle fluctuations of the moisture contents of the partitions can be clearly verified in the second and third year (section), but seem to be negligible with regard to the initially high overall moisture content. Right: detail of the modification of the sound reduction index of Figure 65 for the period of approx. the first thousand hours. In these six weeks, the influence of the trapped water is obviously higher with values of more than 2 dB above the sound insulation values of the dry wall. This condition must be taken into consideration in sound insulation testing of newly constructed building components made of aerated concrete. These building components show a deviation due to water of approx. 4 dB in the weighted sound reduction index even after a period of 336 hours or two weeks of dehumidification.

4. Discussion and conclusion

The measurement results of this paper offer a great variety of incentives and approaches to continue investigations so far in the field of acoustics and hygrothermics. The following items shall give a first survey:

Concerning the drying out of the moisture in building components dehumidification periods occurred, which cannot be observed in the general testing processes in building acoustical test laboratories. Definitely higher sound reduction indexes in comparison to moisture equilibrium occur still after a period of twelve weeks of dehumidification time (whereas four weeks are the usual period in most test laboratories).

Therefore a critical verification of the periods of drying out of newly manufactured building components to be tested in the laboratory or by in-situ measurements in new buildings is needed. According to the measurement results a period of dehumidification of two to six weeks is definitely too short for the investigation of walls. The values of the measured sound reduction indexes are too favorable with nearly three decibel. The determination and definition of the moisture content alone, as is usual nowadays, is not adequate. An

appropriate moisture reduction of the measured values could contribute to a more realistic assessment of sound insulation, and to achieve more security in designing buildings.

This kind of moisture reduction could also provide that on the basis of an adequate application building components can permanently maintain the desired and required sound insulation function even after dehumidification. This is not only an improvement of the durability of the acoustical comfort of a building but also of the preservation of the value. Therefore, these factors are significant to assess the sustainability of a building.

The application of massive building components with high initial moisture in present new buildings runs the risk that users get accustomed to the initially good sound insulation level after moving into the apartment or office. Due to the dehumidification of the building material, however, they must get acquainted with a lower level. In case of acoustically scarcely measured building components dehumidification can cause a growing reduction of sound insulation so that the requirements of sound insulation are no longer observed. In this context, it would be helpful to have a better understanding of the psychological impacts on the user behavior for determining future sound insulation standards.

Additional systematic calculations of further constructions to determine the dehumidification period and seasonal cycle fluctuations for further materials as well as modified climate boundary conditions and varying user profile attitudes should be done.

The focus of investigations was single-shell building components in this paper. Further investigations of other materials and constructions are necessary, and a database with acoustic-hygric data for relevant building simulation methods should be established. This should provide for a better prognosis of the future acoustic comfort for different user profiles and climate zones.

5. Acknowledgements

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