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Experimental characterisation of absorbing materials made from renewables

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ABSTRACT

The amount of ecological implications caused by the whole building process is gaining more and more attention. One measure to reduce ecological implications may be the use of building material made from renewables. To investigate this possibility, a joint research project is under way in Germany, which is focused on insulating material made from renewables. Besides fire protection, heat insulation, moisture proofing, emissions and sustainability assessment, also sound insulation is investigated. PTB contributes to this project by experimentally characterising insulating materials made from renewables. For this, existing measurement methods have been reviewed and adapted to the special needs of the project. The contribution is focused on the measurement of airflow resistivity by the alternating flow method and measurements in a transmission tube. Special attention is given to the influence of the material orientation and to the uncertainty of the measurement results.

Keywords: absorbing material, renewable resources

1. INTRODUCTION

A joint research project is under way in Germany to increase the applicability of insulating material made from renewable resources in buildings. The project is funded via FNR (Fachagentur Nachwachsende Rohstoffe e.V.), the central coordinating institution for research, development and demonstration projects in the field of renewable resources. The project is a cooperation of 12 research institutions and a number of manufacturers of insulating materials and manufacturer associations. The acoustic part of the project is coordinated by Rosenheim Technical University of Applied Sciences. In the context of this project, PTB is responsible for the material characterisation which is done by improving existing measurement methods or developing new measurement methods.

The acoustic part of the project is focused on two major applications for acoustic insulating material in buildings. The first is the use as an underlay under floating floors. For this, the dynamic stiffness is the main quantity to be considered. Its measurement is standardised in ISO 9052-1 (1), and a contribution on the project work in this field can be found in (2).

The second major application considered is the filling of hollow building elements to increase the sound insulation. In Germany, a material can be applied for this purpose if its airflow resistivity is in a certain range. Therefore, the measurement of airflow resistivity is a major issue in the mentioned project which is discussed in clause 2 of this contribution.

Nevertheless, it is questionable whether the global values for dynamic stiffness and airflow resistivity enable a sufficient characterisation of acoustic insulating material. Therefore, several insulating materials were used for measurements of sound insulation and impact noise in test facilities at Rosenheim Technical University of Applied Sciences. In parallel, the acoustic performance of the tested objects is calculated by detailed modelling. A contribution on this aspect is (3). The input parameters for the modelling are also provided by PTB. The corresponding measurements are performed in transmission tubes and this work is described in clause 3 of this contribution.

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2. MEASUREMENT OF AIRFLOW RESISTIVITY

2.1 Experimental setup

There are two different standardised methods for the measurement of airflow resistivity. The first is the static flow method (3) and the second the alternating flow method (4). Whereas the standard for the first method has been updated recently, the standardisation process is still ongoing for the alternating flow method.

Due to the long experience with the alternating flow method, PTB designed a new measurement device for its application (figure 1 and ref. (5)). It consists of an air cavity with a volume of about 1.5 l with a quadratic cross section which is compressed and decompressed by a piston of 20 mm diameter. The piston is excited by an electric gear motor driven by an external power supply. Thereby, piston frequencies between 0.5 Hz and 6.3 Hz can be reached. The piston stroke length can be chosen as 1.4 mm; 2.3 mm; 3.6 mm; 5.8 mm, 9.0 mm and 14.5 mm. The air cavity is terminated either by an airtight acrylic plate or by a measurement cell in which the test specimen is mounted. Different cells have been manufactured. The one shown in the left picture of figure 1 consists of acrylic glass with the inner dimension of 0.2 m X 0.2 m X 0.2 m. The dimension is chosen that the same specimen as for the measurement of dynamic stiffness according to (6) can be used. Furthermore this test cell enables measurements at different flow directions by rotating the test specimen in the cell.

The measurement cell shown in the right picture of figure 1 consists of a cylinder made of acrylic glass. It has a diameter of about 70 mm and is mounted in a solid acrylic block also shown on the picture. The lower end of the cylinder can be covered by a supporting mesh so that an unbound filling can be used as a specimen.

Initially, the sound pressure inside the cavity was measured by a 1" microphone (shown in figure 1). In the meantime, this microphone has been replaced by a special low-frequency 1/2" microphone. The sound pressure level is measured by a one-third octave band analyser. The measurement signal is simultaneously analysed by an FFT to determine the frequency very accurately.

The standard uncertainty of the measurement of the airflow resistance was estimated to be 7 % (ref. (5)). For the airflow resistivity, a standard uncertainty of 9 % was yielded. These values do not cover the influence of specimen mounting and material inhomogeneities.

Figure 1 – Left hand: Measurement device with a cubic measurement cell made of acrylic glass, Right hand: measurement cell made of solid acrylic glass with a cylindrical specimen holder for the measurement of unbound fillings

2.2 Measurement results

An example for directly measured sound pressure levels is shown in the left graph of Figure 2. For these measurements, the measurement cell is terminated either by the airtight acrylic plate or by the specimen holder shown on the right side of figure 1. Different heights of straw fillings have been realised. It was ensured that the density of the filling was identical for all measurements.

The airflow resistance was then calculated from the sound pressure levels. The airflow resistance of the supporting mesh is very small (right graph of figure 2). Doubling the height of the straw filling doubles the airflow resistance, as expected. At very low frequencies, the results show a larger scatter. This is probably caused by instabilities in the rotational speed of the piston during the measurement interval of 160 s. Otherwise, the measured airflow resistivity does not depend on frequency. This indicates that the airflow resistivity does not depend on the flow velocity since piston frequency also changes flow velocity. The nominal airflow velocity of 0.5 mm/s as required by (4) corresponds to a frequency of about 2 Hz for the used piston stroke length of 9 mm.

When the airflow resistivity is finally calculated, all results fall in a reasonably narrow range (figure 3, left graph). Even the results at the low frequencies are not discrepant in view of an estimated expanded uncertainty of 18 %.

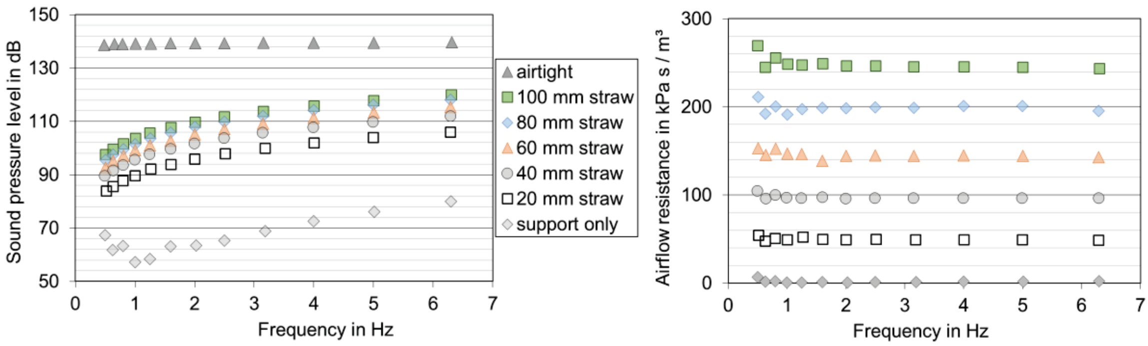

Figure 2 –Left hand: Sound pressure level in the cavity for the measurement of the airtight termination, straw fillings of different heights and the supporting mesh only, right hand: airflow resistance of straw fillings of different heights

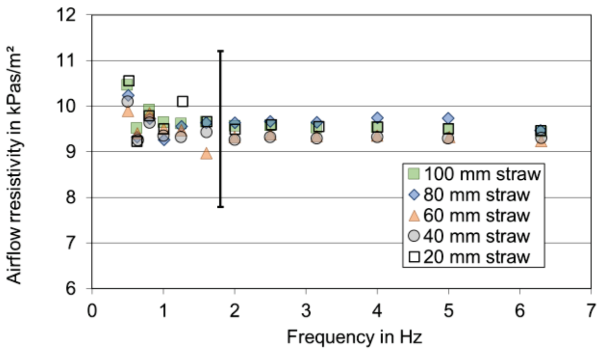

Figure 3 – Airflow resistivity of straw fillings of different heights and expanded uncertainty

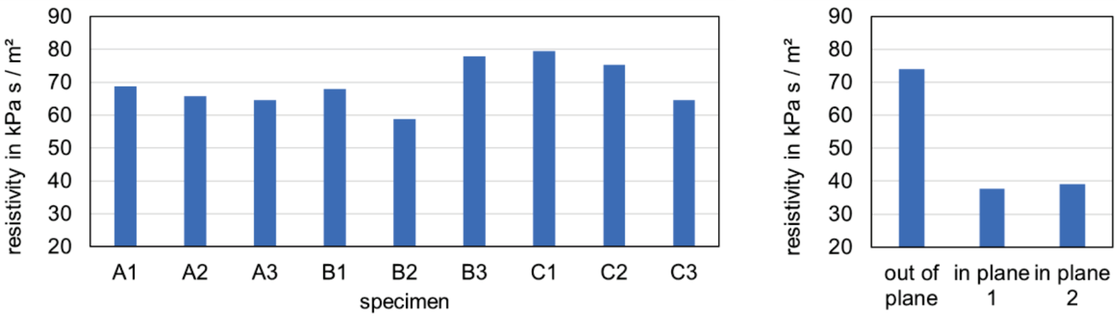

Figure 4 – Left hand: Airflow resistivity of 9 different specimens from the same material, right hand: airflow resistivity of a cubic specimen made from a pile of specimens A1 – C1 measured in three different directions

Another interesting question is how much scatter is observed for different specimens made from the same material. A typical example is shown in the left graph of Figure 4 where altogether 9 different specimens were manufactured from different plates of a material with a thickness of 30 mm. In this case, the relative standard deviation of the measured airflow resistivity is about 10 %. When one cubic test specimen is assembled from the 7 specimens A1 – C1, the measured airflow resistivity is about the mean value from these 7 specimens (right graph in figure 4 – out of plane). By rotating this cubic shaped test specimen into the other directions, the airflow resistivities for both in plane directions was also measured. It is in this case about half the resistivity of the usual direction.

3. MATERIAL CHARACTERISATION IN TRANSMISSION TUBES

3.1 Experimental setup

The measurements are performed in transmission tubes according to ASTM E 2611-09 (8). To cover the frequency range between 50 Hz and 7.5 kHz, two tubes were constructed (Figure 5). Both tubes are modular systems consisting of three parts. The medium part can hold the test specimen. Different terminations (reflecting, absorbing) can be fitted into the end of the tube.

The small tube has a length of 43 cm and covers the frequency range between 400 Hz and 7.5 kHz. Measurements are performed by 1/4" microphones. The large tube has a length of 132 cm and is applicable in the frequency range between 50 Hz and 1.5 kHz. Here, measurements are performed with 1/2" microphones.

Several test measurements have been performed with these two tubes (9). Among other tests, the complex impedance and wave number of an air cavity of known depth was measured and compared to the known theoretical values.

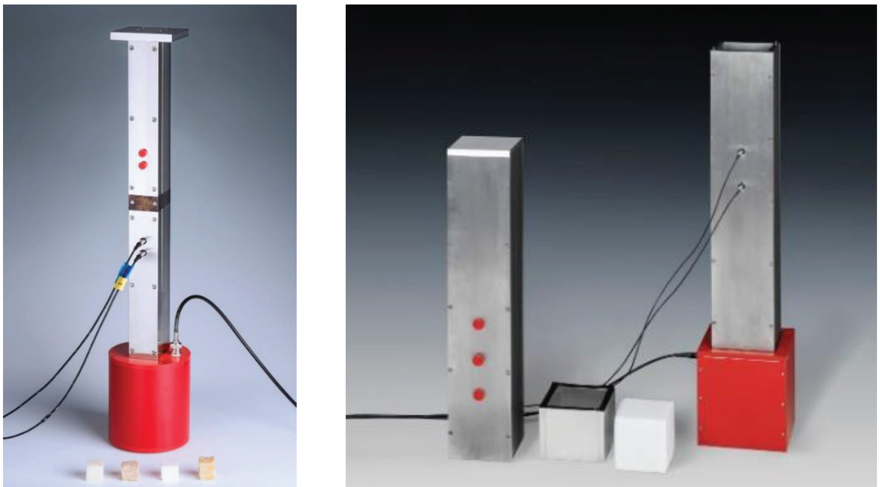

Figure 5 – Left hand: small transmission tube with cubical-shaped test specimen with an edge length of 20 mm, right hand: large transmission tube with cubical-shaped test specimen with an edge length of 100 mm

3.2 Measurements with different specimen orientation

From the beginning, it was planned to perform measurements with different specimen orientation. This seemed to be necessary due to the structure of the tested specimens. Very often, specimens consist of fibers which are somehow processed into plates or mats. Therefore, different material properties are expected in different directions.

This was tested by measuring a visually homogeneous foam block and turning it into three different directions. The transmission loss (Figure 6) turned out to be identical for all three orientations. This was also the case for the other quantities like wave number or impedance which can be derived from the measurements. For a polyester fleece, the results show a clear influence of the orientation (Figure 7) which is due to the fiber orientation.

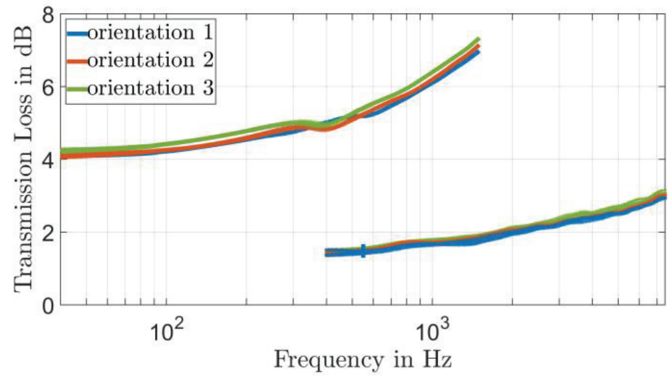

Figure 6 – Transmission loss of a cubicle-shaped foam block with an edge length of 100 mm (upper curves) and an edge length of 20 mm (lower curves) measured with three different orientations

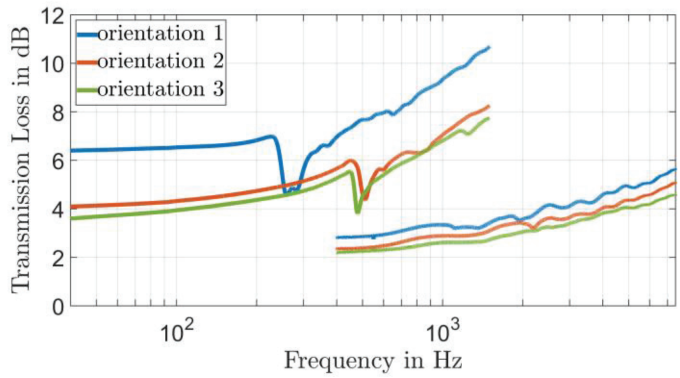

Figure 7 – Transmission loss of a cubicle-shaped block of fibrous material with an edge length of 100 mm (upper curves) and an edge length of 20 mm (lower curves) measured with three different orientations

3.3 Measurements with unbound fillings

Insulating material based on renewable resources is often applied as an unbound filling. The measurement of such material in the transmission tube was enabled by supporting the test material with a fine gauze. The influence of the gauze was checked by measuring its properties without any additional insulating material. Then, insulating material was added and the measurement was repeated. It turned out that the gauze did not contribute significantly to the results of the overall assembly. Then, straw fillings (similar to Figure 1, right graph) with thicknesses of 20 mm were measured in both tubes whereas a filling of 100 mm thickness was measured only in the large tube.

From the measured transfer functions, the complex impedance was calculated (Figure 8). The real part turned out to be nearly identical for the fillings with the different thicknesses. In the frequency range between 400 Hz and 1.5 kHz, results from both tubes are available. There, the real part of the impedance shows an excellent agreement between all three results. The imaginary part of the impedance is much smaller than the real part. It is probably influenced by the remaining damping of the empty tubes.

The results for the wave number show a similar result (Figure 9). The real part and the imaginary part are in excellent agreement. The exception is the imaginary part measured in the small tube below 1.5 kHz. These results are deteriorated by the empty tube damping which is significantly larger in the small tube than in the large one. So, for the overlapping frequency range, results from the large tube are preferably used.

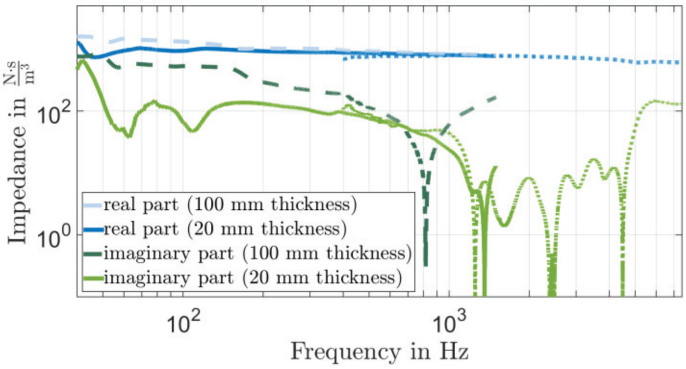

Figure 8 – Impedance of straw fillings of different thickness, dotted lines: measurements in the small tubes, dashed and solid lines: measurement in the large tube

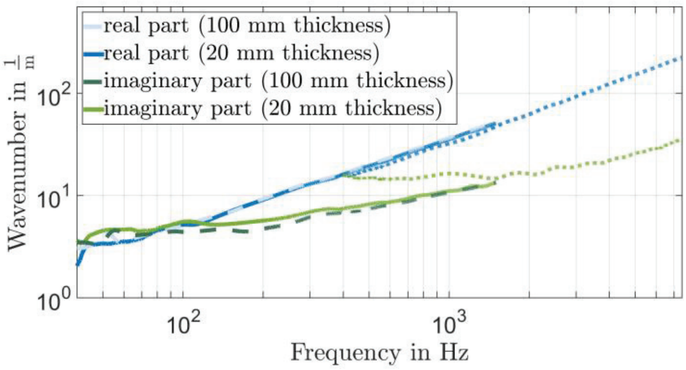

Figure 9 – Wave number of straw fillings of different thickness, dotted lines: measurements in the small tube, dashed and solid lines: measurement in the large tube

3.4 Suppression of the first structural mode of the specimen

For specimens in plates, the first structural mode may deteriorate the measurement results. This is observed in figure 6, where the transmission loss is reduced in a certain frequency range. For a plate material with a thickness of about 15 mm, the transmission loss was measured with different numbers formed to a stack. The result clearly shows the influence of the first structural mode which in this case increases with frequency with a growing number of specimens (Figure 10). When a single plate is mounted very loosely the effect is still observed but it becomes smaller. Nevertheless, loose fitting also decreases the transmission loss at all other frequencies probably due to the fact that the loose mounting does not sufficiently suppress a movement of the test specimen. This means, that a loose mounting is not appropriate for the measurement. Measurements with other orientations were also performed with the 7 plate stack. For this particular material, the modal effect is not observed for the other two orientations. This is different to the results in figure 6 where the modal resonance is observed for all orientations.

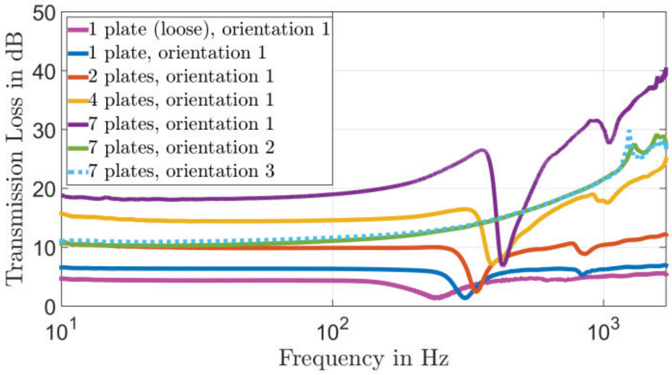

Figure 10 – Transmission loss of a fibrous plate material with a thickness of about 15 mm, different numbers of plates formed to a stack, the largest stack (made of 7 plates) measured in three orientations, one plate measured with normal fitting and with lose fitting

This observation lead to the idea to design a special specimen holder (Figure 11). It is made of a plastic material and subdivides the cross sectional area of the large tube into a 4 X 4 matrix. Small material samples are manufactured and fitted into the specimen holder (Figure 11). The orientation can easily be switched when cubicle-shaped test specimens are chosen.

Measurement results for the transmission loss of the material used for Figure 10 are shown in Figure 12. The transmission loss obtained with the specimen holder is very close to the result of the full size specimen. Only in the region of the structural mode, the sudden drop of the transmission loss is not observed. Figure 12 also contains the transmission loss of the specimen holder without a specimen. It is close to 0 dB which means that the influence of the specimen holder can be neglected.

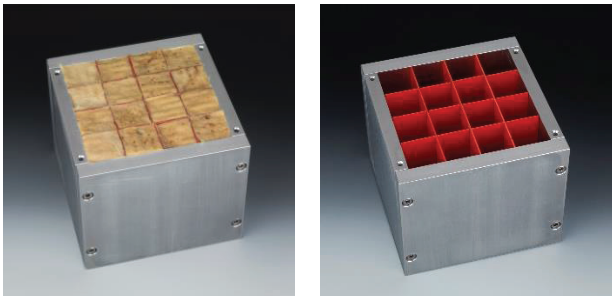

Figure 11 – specimen holder with and without a fitted specimen

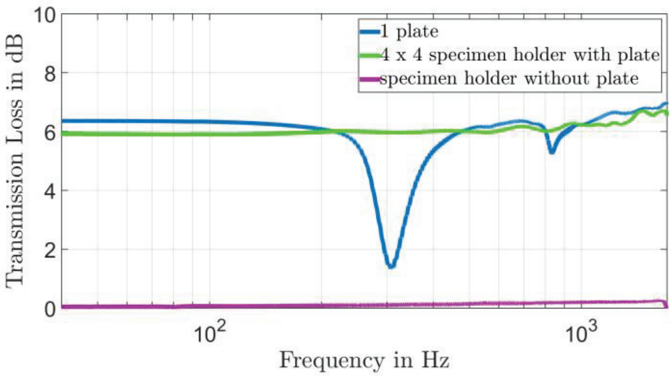

Figure 12 – Measured transmission loss for the 4 X 4 specimen holder only, for the specimen fitted into the specimen holder and for the full size specimen

4. CONCLUSIONS

The measurement of acoustic material properties is an important issue to ensure an adequate application of insulating material in buildings. Within a research project, new devices for the measurement of airflow resistivity and transmission quantities were developed, installed and tested. To ensure an applicability to test specimens made from renewable resources, special attention was paid to the measurement of unbound fillings and to measurements with different specimen orientation. The measurement devices are now used to produce the input data required for the detailed modelling of sound transmission.

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REFERENCES

1. ISO 9052-1:1989 Acoustics -- Determination of dynamic stiffness -- Part 1: Materials used under floating floors in dwellings
2. Bietz, H.; Schmelzer, M.; Brezas, S.; Wittstock, V.: Investigations regarding the Influence of Static Load and Airflow Resistance on the Measurement of Dynamic Stiffness. Proc. ICA 219, Aachen, Germany
3. Mecking, S..: Prediction models for the sound insulation of building elements including renewable insulation materials. Proc. ICA 219, Aachen, Germany
4. ISO 9053-1:2018 Acoustics -- Determination of airflow resistance -- Part 1: Static airflow method
5. ISO/WD 9053-2 Acoustics -- Determination of airflow resistance -- Part 2: Alternating airflow method
6. Wittstock, V.; Schmelzer, M.: Measurement of airflow resistance by the alternating flow method. Proc. Euronoise 2018, 11th European Congress and Exposition on Noise Control Engineering, Heraklion, Crete, 28. May - 31. May, 2018, Greece
7. 7. F. Pompoli et al: How reproducible is the acoustical characterization of porous media? The Journal of the Acoustical Society of America 141, 945 (2017); doi: 10.1121/1.4976087
8. ASTM E 2611-09: Standard Test Method for Measurement of Normal Incidence Sound Transmission of Acoustical Materials Based on the Transfer Matrix Method
9. Sgrieß, D.; Wittstock, V.: Messung von richtungsabhängigen Materialkennwerten in Transmissionsrohren. DAGA 2019, Rostock, 18.-21. März 2019