Development of Sound Absorbers from Renewable Raw Materials: Challenges and first Steps

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Introduction

The analysis of the world-wide CO_2-Emissions show, that 40 % of the emissions are due to the building sector [1]. About 70 % of the mining of raw materials in Germany are used for buildings. 50 % of the total waste in Germany is related to building activities [2].

On the other hand, the goal for net zero CO_2-Emissions in the EU is given for the year 2050 in the European Green Deal. In Germany, this goal is defined for 2045 [3] and has been implemented in the German constitution just last week.

For the lifespan of buildings, we can state for non-residential buildings a time of approximately 30 to 50 years, for residential buildings it is between 50 to 80 years.

The average lifespan of German residents, not much different to all Europeans, is approximately 80 years.

The conclusions of the above statements are that the reduction of the CO_2-emissions need to be tackled for all activities and products, especially in the building sector. The use of „new“ materials from mining etc. needs to be drastically reduced, the re-use of material in a circular economy and the use of renewables has to be established in the whole building sector. Therefore, the change to (much more) sustainable products is overdue and this also is true for room acoustic applications and materials. Sustainable sound absorbers need to be developed, and this goal has to be tackled as soon as possible.

Challenges

Sustainable sound absorbers with good absorbing properties need to be developed, but further properties of such materials need to be considered as well:

- Stability and workability of the material
- Good surface properties like optical appearance, colour, possibility for reuse and recycling and others
- Low CO_2 emissions in production and handling
- Good sustainability
- Possibility for re-use or recycling
- Fire resistance
- Low price.

These are the main requirements, but others may also play an important role in the development process, we might not now today. Nevertheless, the above stated future demands are urgent and we need to work in this direction.

First steps

First steps have been taken to develop a new porous sound absorbing plate material. This material should be made from renewables, as a lot of biological material is available and it could be waste from other processes, like fibres from the wood industry, or from the clothing industry. This material needs to be held together by an appropriate binder, if not inherent binding substances or physical connections between the material surface can lead to a stable open porous plate like material. In the best case, the binder increases the fire resistivity of the material. The binding process should be energy efficient, which means that high temperatures and drying of the material should be avoided or at least, reduced. When using a binder, it should be produced in a sustainable way and with low energy consumption.

Testing equipment

For testing the material properties, many different testing facilities are available at the Fraunhofer IBP, of which the following are available for acoustic material research

- Measurement of the flow resistivity
- Measurement of the porosity in a self-build air-pycnometer, shown in Figure 1

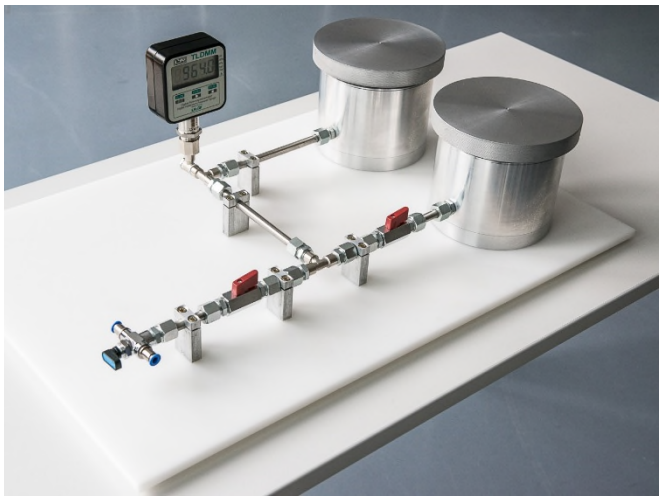

Figure 1: Air-pycnometer to measure the open porosity. Source: IBP.

- Measurement of the impedance and absorption coefficients for normal incidence in different impedance tubes
- Measurement of the absorption coefficient under random incidence in a reverberation chamber with 392 m³ volume
- Computer tomography and x-ray analysis
- material testing equipment for mechanical stability

Parametric modelling of pore geometries

From computer tomography of material probes, a modelling of the acoustical parameters of absorption models like Johnson-Champoux-Allard (JCA) and others is possible, by applying appropriate software tools like Comsol or others.

First materials tested

In first small projects, different materials from renewables have been tested, for example Typha plate material (*Typhaceae*, cattail). This material was developed by Fraunhofer IBP with the goal to produce a building plate [4]. Two of the tested Probes are shown in Figure 2. The plates are formed by using parts of the typha stem, which includes hard outer shell material as well as inner sponge-like tissue, which provides good thermal insulation properties. The Plates are bound by magnesite. Measurements of the flow resistivity of unit length and the sound absorption coefficient of five different probes are shown in figure 3. The results of the measurements show a wide range of flow resistivity of unit length, in two cases much too high values, and different sound absorption characteristics. Some of the probes show high values of sound absorption coefficient in the mid frequencies, but quite low values at higher frequencies. Two other probes show higher sound absorption at low frequencies, indicating their high flow resistivity, compared to classic porous absorbers. Looking at the probes, we can see that the structures of the typha material are quite course and have a structural scale which is much bigger than other porous absorbers, and we can assume too much binder within the probes, leading to the high flow resistivity.

Figure 2: Probes of typha plate material from Fraunhofer IBP. Source: IBP.

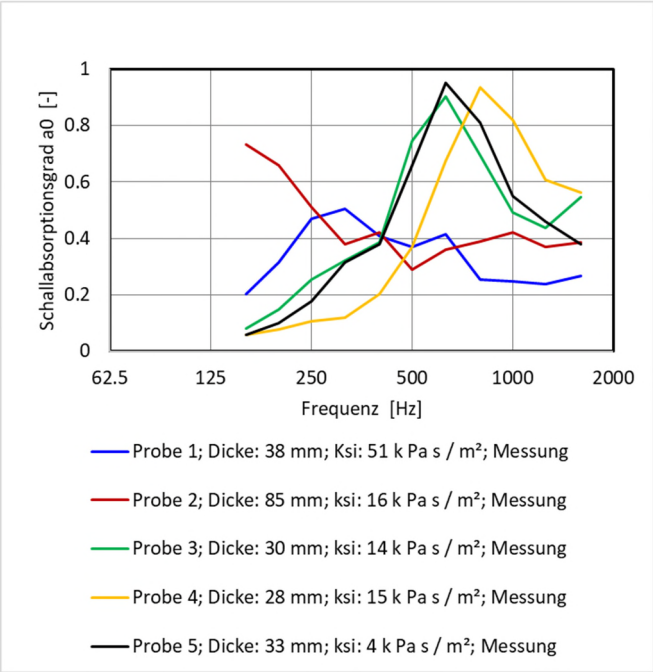

Figure 3: Sound absorption coefficient of typha plate material at 0° incidence from a 100 mm round impedance tube.

Therefore, the analysis shows, that this material has no acoustical optimized structural properties. Source: IBP

Among other material probes we tested miriti wood (*Mauritia flexuosa*), a material from brasil which is verry lightweight (with lower density then balsa wood), but having a very high stiffness in the direction of growth. In directions perpendicular, it is relatively soft. Miriti wood contains sponge-like tissue, quite similar than typha. For the first testing, only a probe with 9 mm thickness was available. The probe is shown in figure 4.

Figure 4: Miriti wood probe, cut perpendicular to the fibre direction, with thickness of 9 mm. Source: IBP

The measurement of the sound absorption coefficient of the miriti wood probe with 0 mm, 50 and 100 mm air gap behind it is shown in figure 5.

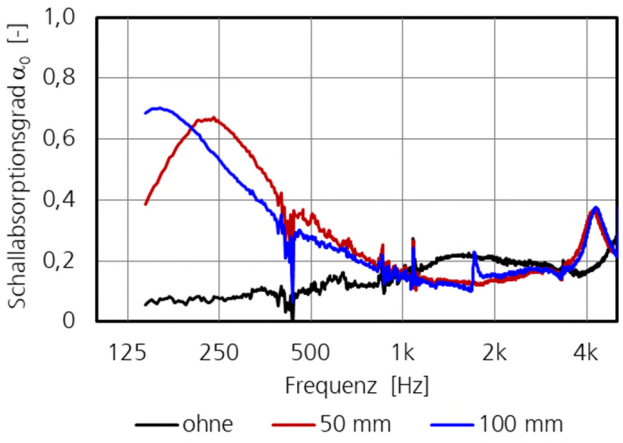

Figure 5: Sound absorption coefficient at 0° incidence of miriti wood, measurement perpendicular to the fibre, from a 100 mm round impedance tube. Source: IBP

The results of the miriti wood probe shows low absorption up to approximately 0,2 for the probe with no air gap, but with 50 and 100 mm air gap, the absorption reaches values of about 0,7 at low frequencies at approximately 160 and 250 Hz, depending on the air gap. This shows, that the miriti wood probe is air-permeable and that damping in the material is apparent. It seems that the miriti wood has cylindrical pores that are partly open, and therefore, low frequency sound absorption is quite high. If the specimen is thinner, the high frequency transparency will be higher. It can be used for micro-perforated surfaces of natural material. For a first approach, miriti wood could be a good starting point for development of a lightweight sound absorber from renewables, as it offers an open pore structure.

Conclusions and further steps

The improvement of the sustainability of building materials is a major factor for the future building industry. This is also the case for sound absorbers, as there are not many sound absorbers with good sustainability, for example low GWP and CO_2 emissions. Besides production of the material, re-use and recycling possibilities needs to be considered, as well as disposal or composting after the use of the material. From the standpoint of available material, biological material could be a possible approach, in the best-case material, which is regionally available and not used for other purposes. Additionally to acoustical and physical properties, fire safety is a major topic and requirements for fire safety can interfere with the above stated requirements. Nevertheless, there are possibilities for development of sound absorbers, that can improve the sustainability aspects a lot, without compromising the other requirements.

To develop such material, first project applications have been launched and other applications are planned. For such development projects, we are seeking partners in different fields, from material providers, material science, fire safety, production techniques, to companies for building prototypes and product development and others.

Literature

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