inter.noise 2014
MELBOURNE AUSTRALIA
16-19 NOVEMBER

Reducing noise pollution by increasing sound absorption of carpets

Musa AKDERE[1]; Anke HANNIG[2]; Tanja KLIETZING[3]; Gunnar SEIDE[4]; Thomas GRIES[5]

[1-5] Institut für Textiltechnik der RWTH Aachen, Germany

ABSTRACT

Noise is an often underestimated health risk in our life. Most office workplaces have a general unhealthy and annoying soundscape. Architects intend to minimalize this noise pollution by certain structural measures. One space-saving possibility to do this lies in the field of highly sound absorbing carpets which are predestinated due to their large surfaces. To be able to evaluate and distinguish the sound absorbing quality an evaluation criterion is necessary. In European countries this is usually the weighted sound absorption coefficient α_w (according to the European/International standard EN ISO 11654). The influence of the carpets design parameters on this single-number rating is analyzed and statistically evaluated. Based on these result a prediction of the coefficient is pursued.

Keywords: Room Acoustics, Noise, Absorption, textile floor covering

1. INTRODUCTION

Noise pollution is an ever mounting problem of modern times. Even though we often do not notice it, we expose ourselves almost daily to a noise level which is unhealthy for us. But not only building yards, aircraft noise and other technical sounds endanger our hearing. Human conversation too can reach an alarming sound volume. In for example open-plan offices or classrooms we spend hours and hours risking our health and often not even realizing how loud it is. Nevertheless the danger to both our physical and mental health is real.

In order to minimalize this danger it is necessary to reduce the volume level. This can be done by altering the room's sound-absorption-abilities through structural measures as for example suspended ceilings. Taking in much space, these ceilings are frowned upon by architects who desire a less conspicuous construction measure. This could be the use of highly sound absorbing carpets whose development is the content of this paper.

2. BASIC INFORMATION ON ACOUSTIC

2.1 Characteristics of Sound

Sound is a mechanical wave resulting from tiny molecule movements of the medium the wave is moving through. This causes slight variations in pressure which the human ear can detect. The louder the sound event the heavier are these pressure variations and therefore the higher the wave's amplitude. The frequency on the other hand is influenced by the tone pitch: the higher the tone, the higher the frequency.

Sound emitted by a source usually propagates into all directions of space. If the wave hits an object or a wall it is partly absorbed and partly reflected back into the room. The ratio of absorption and reflection is dependent on the object's character and the angle of incidence between wave and the object's surface.

2.2 Standardized Measurement

Humans are able to perceive frequencies from 20Hz to 20000Hz (1). The sound pressure level needed to cause a perception is no constant but frequency-dependent and increases with very low or

1 Musa.Akdere@ita.rwth-aachen.de
2 Anke.Hannig@ita.rwth-aachen.de
3 Tanja.Klietzing@ita.rwth-aachen.de
4 Gunnar.Seide@ita.rwth-aachen.de
5 Thomas.Gries@ita.rwth-aachen.de

very high frequencies. The human ear is particularly sensitive for frequencies between 200Hz and 10000 Hz, which approximately corresponds to the range of human speech (2). On the one hand this is useful if we are speaking to someone so we would easily understand them but on the other hand noise disturbances in these frequencies are exceptionally bothersome.

International standardized methods for measuring sound absorption have been set to the range between 100Hz and 5000Hz. This is the region in which most every-day-sounds lie.

Many parameters describing room acoustics are frequency-dependent. So for detecting these parameters it is necessary to identify the influence of frequency by running several tests with different frequencies.

In order to ensure the comparability of the results the range of 100 to 5000Hz is subdivided in standardized steps. These can be six octave bands or 18 one-third octave bands depending on how precisely the parameter is to be researched (3).

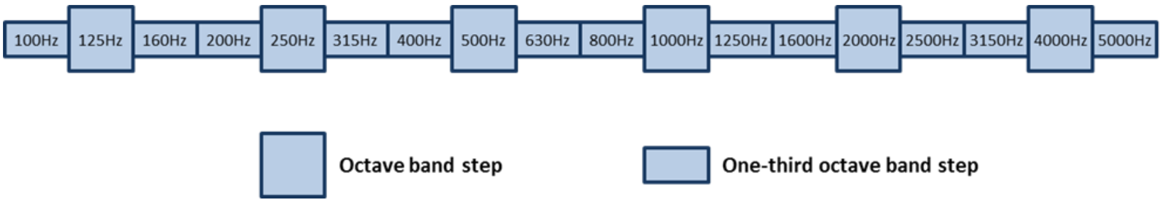


Figure 1 – Octave Band

2.3 The weighted Sound Absorption Coefficient α_w

The weighted sound absorption coefficient α_w is an important European criterion for diagnosing an object's sound absorption abilities. It is independent on frequencies and thereby the most commonly used quantity for judging the absorption ability of textile covering.

α_w is gained through the frequency-dependent absorption coefficients $\alpha_s(f)$. Thereto α_s is plotted against the frequencies (in octave or one-third octave steps) and compared to a reference curve whose form is defined in the European/International standard DIN EN ISO 11654.

As α_s is to be located at most 0.1 beneath the reference curve, the latter is shifted until this requirement is fulfilled. Upward deviations of α_s are not taken into account.

The weighted sound absorption coefficient α_w is then defined as the value of the reference curve at 500Hz (4).

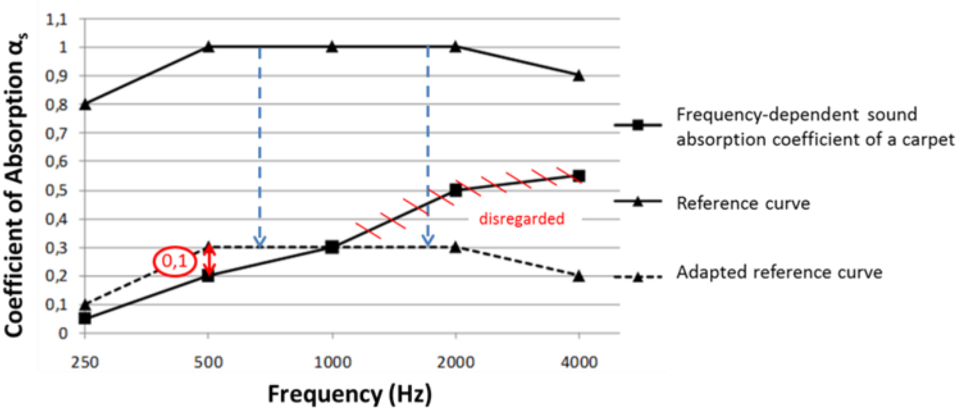
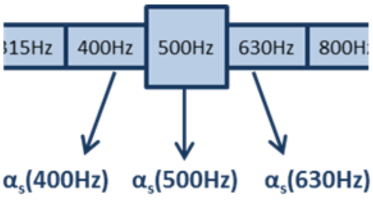


Figure 2 – Definition of the weighted sound absorption coefficient α_w

As can be seen in the diagram above the important frequencies are 250, 500 … 4000Hz (octave band). The belonging α-values are marked in the diagram and linked through straights. They are called α_p-values and calculated through averaging the three surrounding α_s-values which arise by measuring the absorption abilities in one-third octave band steps. Thereby the measured one-third octave band values are converted into averaged octave band values as may be seen in the example below:



$$\alpha_p(500Hz) = \frac{\alpha_s(400Hz)+\alpha_s(500Hz)+\alpha_s(630Hz)}{3}$$

Figure 3 – Calculation of α_p-values

2.4 Reverberation Chamber

The α_s-values can be quantified using the reverberation chamber. This is a room designed to create a diffuse sound field. It is constructed in such way that the sound reflects on all the walls at a very high percentage and is distributed evenly throughout the room. Thereby a long reverberation time is achieved. The room's walls are made of a very even and hard concrete so that they absorb nearly no sound and in order to avoid any resonance are positioned nonparallel.

These construction measures arrange for a constant non-directional sound pressure. The room is calibrated through reverberation-time-measurements in which a sound-pressure-difference is to be gained. This difference occurs between the given sound pressure of the source of sound and a sound pressure measured within the reverberation chamber. It is frequency-dependent and can be altered by stocking the room with differently sound-absorbing objects. The more sound is absorbed, the higher the difference. Thereby different samples can be tested on their absorption characteristics under equal conditions (5).

3. CARPET STRUCTURE

Carpets are textile floor coverings composed of different layers. The exact structure is dependent on the manufacturing process. Carpets can be woven, needle felt, knotted or tufted. The carpets examined in this project are tufted ones.

A carpet usually consists of an upper layer called pile which is attached to a backing. Piles are either made from wool or artificial fibers such as polypropylene, polyester or nylon (6).

The tufted carpets have their pile injected into a primary backing material. The latter is then bonded to a secondary backing which is usually made of a woven hessian weave or an artificial alternative to provide the required stability.

4. REALIZATION OF THE PROJECT

4.1 Sample Preparation and Examination

The main gain is to increase α_w. In order to achieve this goal it is necessary to determine the frequency-dependent coefficients α_s and to investigate their dependency on the construction parameters of the carpet.

So samplings differing in their pile weight, their surface texture or their backing weight were produced. These samplings then were tested for acoustic aspects. A typical curve progression is demonstrated in figure 4. One can easily recognize the in general steady increase of the curve on the one hand and on the other hand a typical local maximum at approximately 500Hz. This progression is roughly the same for all tested samplings showing more or less great deviations.

On the basis of this curve progression the conclusion can be drawn, that sound absorption of carpet is composed of two different mechanisms: the porous absorption and the resonance absorption.

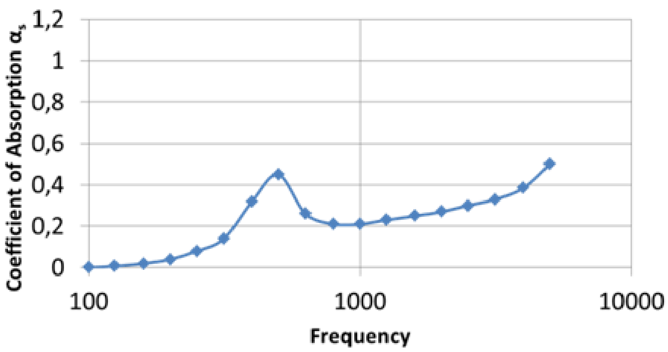


Figure 4 – Sample 14-06-0022

4.2 Different Absorption-Mechanisms

4.2.1 Porous Absorber

The porous absorber is particularly effective to absorb high frequencies. The higher the frequency is, the better is the absorption. The air, set into vibration through the sound, meets a porous surface and enters its pores. Through friction on the pore walls oscillation energy is transformed into heat and thereby absorbed by the wall.

Regarding carpets, the porous absorber corresponds to the pile because the filaments in the pile are set into movement and thus dissipate sound energy.

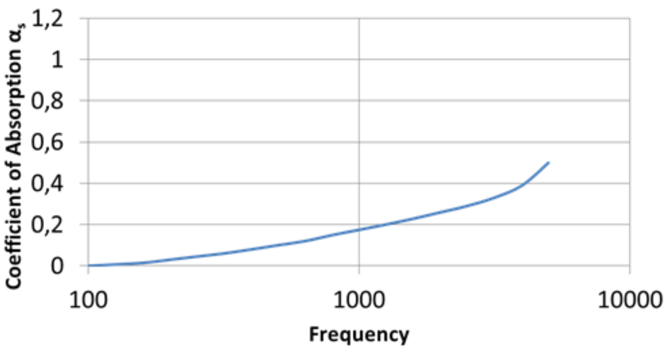


Figure 5 – Porous Absorption

4.2.2 Resonance Absorber

The resonance absorber on the other hand, which is embodied by the carpet's backing, absorbs low-frequency vibration by converting oscillation energy in kinetic energy. The sound hits a wall and sets it in motion. It starts to vibrate with a certain resonance frequency dependent on its construction and thereby absorbs this frequency. So in contrast to the porous absorber which becomes more effective with increasing frequency, the resonance absorber has a certain absorption-maximum depending on its structure.

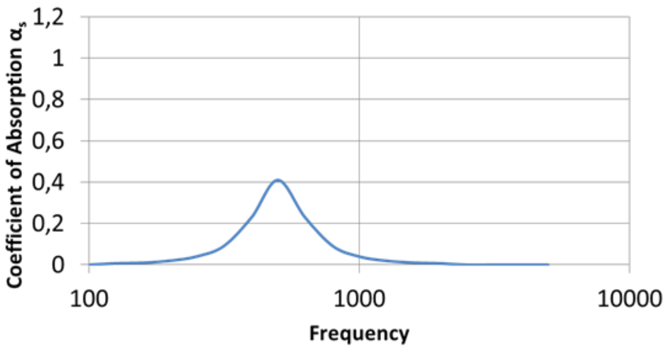


Figure 6 – Resonance Absorption

4.3 Evaluation of Graphs

As can be seen in figure 4 the absorption of high frequencies is already sufficiently good due to the porous absorber. The absorption in low frequency range (250Hz) though holds a certain deficit, which owing to the standardized form of the reference curve, leads to poor αw-values.

5. CONCLUSION

5.1 Insufficiency of DIN-Standard

The analysis of the sampling's absorption properties leads to persistent low values for α_w even though the α_s-curves feature great variations in the high-frequency-field. This is brought about through the calculation of α_w in which only the downward deviations of α_s are taken into account whereas the good absorption in high frequencies is disregarded.

Regarding the case of sound-absorbing carpets the main problem leading to low α_w-values is the insufficient absorption of low frequencies. For this reason the aim is to shift the resonance absorber's absorption-maximum to lower frequencies. Therefor tests were made to detect the factors of influence on the position of the maximum. It became apparent that the maximum absorption is to a decisive extent dependent on the stiffness of the textile backing. This phenomenon can also be explained by considering the resonance absorber as a mass-spring-system as can be seen in figure 7. It becomes clear that the most important factors are the mass of the pile m' and the spring stiffness which is identical to the textile backing's stiffness s'.

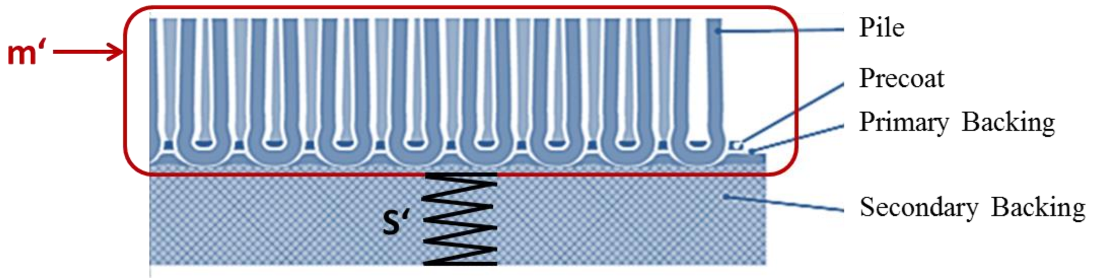


Figure 7 – Mass-Spring-System

5.2 Mathematical Modell

The correlation between the maximum-absorption-frequency and the textile backing's stiffness can by approximation be described through the formula:

$$f \sim k * \sqrt{\frac{s'}{m'}} \tag{1}$$

f = frequency of absorption-maximum

s' = dynamic stiffness of the textile backing

m' = area related mass

k = constant of proportionality

With:

$$s' = \frac{E_{dyn}}{d} \tag{2}$$

E_{dyn} = modulus of elasticity

d = diameter of the interlayer

6. PROSPECT

For further investigation on this relation six samplings will be produced, differing in terms of the carpet's backing-stiffness s' and the pile-mass m'. Based on the results of these tests a method will be drawn out, to adjust the position of the maximum by means of construction parameters. Thereby it would be possible to improve the sound absorption of low frequencies and simultaneously achieve higher α_w-values.

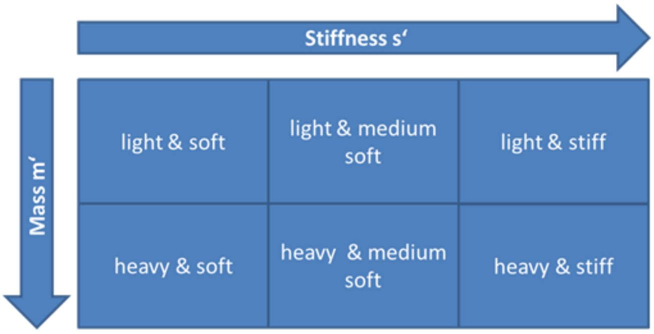


Figure 7 – Sample Matrix

REFERENCES

1. Cutnell, John D. and Kenneth W. Johnson. Physics. 4th ed. New York: Wiley, 1998: 466.
2. Hearing at low and infrasonic frequencies, H Moller, CS Pedersen, Department of Acoustics, Aalborg University, Denmark
3. Office Acoustics, Information-Brochure by buero-forum
4. European/International standard DIN EN ISO 11654
5. European/International standard DIN EN ISO 354:2003
6. The Complete Carpet Buying Guide. Portland Oregon: AJ Books 2006.