

Application of micro-perforated stretched ceilings

Christian Nocke, Catja Hilge

Akustikbüro Oldenburg, Alte Raad 20a, D-26127 Oldenburg, Germany, www.akustikbuero-oldenburg.de

Introduction

Stretched ceilings have been introduced around thirty years ago [1]. The stretched membrane ceiling consists of a special PVC foil, which is mounted in-situ by clamping it to a frame construction. The foil is heated before mounting, and the membrane acquires its final tension after cooling. Nearly any shape might be built by this technique. Over the last 30 years this kind of ceiling and wall covering has become a popular product with regard to modern architecture and design. However, so far only optical and other aspects of the product were generally of interest. After first experiences with a micro-perforated polycarbonate foil [14], micro-perforation of the foil used for the stretched ceiling was seen as an innovative feature. This new acoustic property now opens another range of applications for stretched ceilings. In November 1999, the first micro-perforation of a stretched ceiling has been introduced and successfully been applied for room acoustic purposes.

One of the first publications by D.-Y. Maa [2] on the theory and design of micro-perforated panel absorbers (MPA) has been published in 1975. Further developments of the theory and applications are presented in various other papers [3] to [8]. The potential of MPA is shown in a recent publication [9] together with some possible applications. The calculation and measurement of MPA in random incidence of diffuse sound fields has been investigated in two publications [10, 11] in the year 2000. Other aspects and further investigations on micro-perforated structures are still under development and described elsewhere [12, 13, 17].

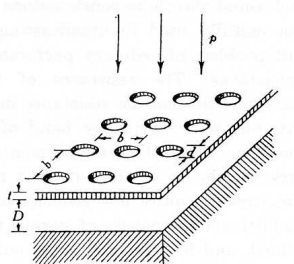


Figure 1: Sketch of principal set-up of a micro-perforated sound absorber, from [2].

Theoretical background

The theory of the micro-perforated panel absorber as initially presented in [2] is based on the classical treatment of sound propagation in short tubes. The derivation by Maa [2] first delivers an approximation for the specific acoustic impedance Z_{MPP} for a micro-perforated panel of thickness t with holes of diameter d spaced at a dis-

tance b apart in front of an air cavity with a depth D , see Figure 1 for principal set-up.

From the angle-dependent impedance Z_{MPP} the sound absorption coefficient for normal and random incidence of sound on the micro-perforated sound absorber can be easily calculated using well-known principles [2, 3, 17].

Results from laboratory

From other publications [10, 11, 14] it is known that theoretical predictions of the sound absorption coefficient of micro-perforated panel absorbers agree well with corresponding measurements.

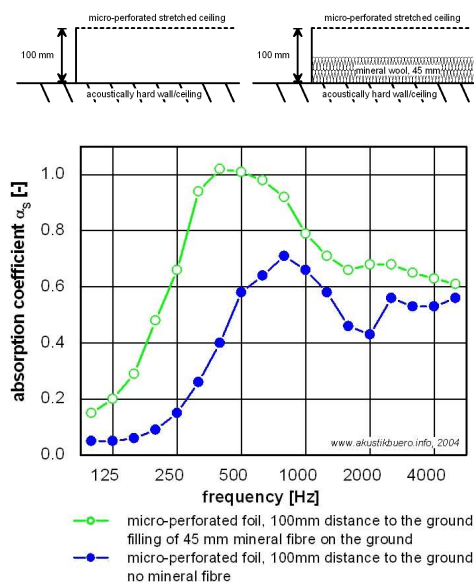


Figure 2: Sound absorption coefficient (from reverberation chamber) of the micro-perforated foil with 100 mm distance to the wall with and without partly filling of 45 mm mineral fibre, placed directly onto the ground.

Results from reverberation chamber measurements of various assemblies using micro-perforated stretched ceilings are now available [1]. All measurements presented have been carried out according to the procedure described in DIN EN 20354 (ISO 354)[15] and rated according to [16]. The foils have been stretched within an aluminium frame that is also used for the installation in rooms [1]. In general, increasing the depth of the air cavity between foil and backing wall shifts the sound absorption maximum towards lower frequencies. To broaden the absorption range of a micro-perforated sound absorber two or more micro-perforated panels may be combined [2, 8, 10, 14]. Another possibility to broaden the sound absorption curve is to add porous material into the air cavity between the stretched foil and the backing

wall. Figure 2 shows the set-up for a micro-perforated stretched ceiling with and without porous material in the air cavity between foil and backing wall. The introduction of the porous material shifts the sound absorption curve by one octave towards lower frequencies and increases the values of the maximum.

Application: Church S. Agnese - Modena (Italy)

The congregation of the church Santa Agnese in Modena (Italy) complained about too much reverberation during services and music performances in their church. The church was built in the 1970s. The floor is made of marble, the walls and the ceilings consist of concrete. There are large painted windows on both sides of the church. The measurement of the reverberation time in the church showed values above 7 seconds for frequencies below 1000 Hz, see Figure 3.

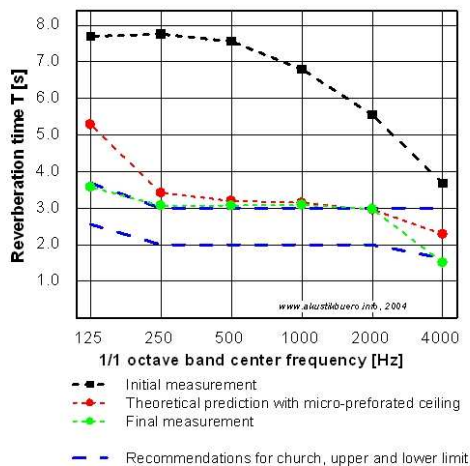


Figure 3: Measured reverberation time before and after reconstruction of church S. Agnese, Modena.

The shaping and design of the new stretched ceiling in the church were suggested by the architect, the acoustic requirements of the ceiling set by the authors.

The acoustic design concentrated on the decrease and smoothing of the reverberation curve. Two different set-ups of micro-perforated stretched ceilings have been applied to deliver the sound absorption required. Fig. 4 shows the positioning and set-up of the stretched ceiling in the church. Fig. 3 also gives a comparison of the reverberation time between the theoretical prediction and the proofing measurement after the reconstruction. The agreement between prediction and proofing measurements is very high, especially in the mid-frequency range. At 125 Hz and 4000 Hz the reverberation time even is lower than expected.

Acknowledgement

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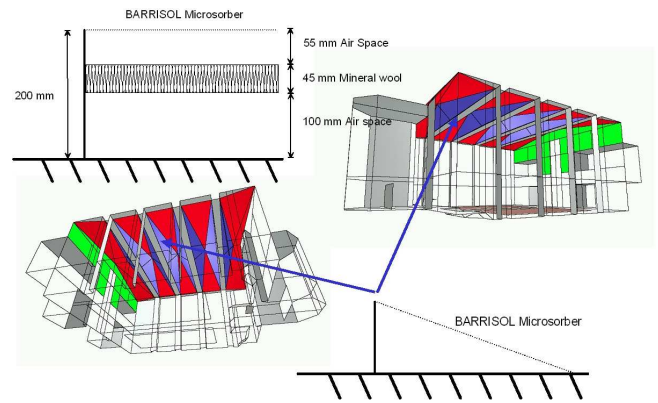


Figure 4: Two set-ups of micro-perforated stretched ceilings for Church S. Agnese. The blue areas are single micro-perforated ceiling whereas the red areas have some porous material in the air cavity behind the micro-perforated sheet.

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