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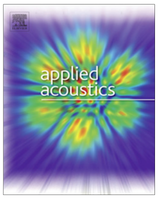

Improved sound absorption performance of three-dimensional MPP space sound absorbers by filling with porous materials

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ABSTRACT

Because microperforated panels (MPPs), which can be made from various materials, provide wide-band sound absorption, they are recognized as one of the next-generation absorption materials. Although MPPs are typically placed in front of rigid walls, MPP space sound absorbers without a backing structure, including three-dimensional cylindrical MPP space absorbers (CMSAs) and rectangular MPP space absorbers (RMSAs), are proposed to extend their design flexibility and easy-to-use properties. On the other hand, improving the absorption performance by filling the back cavity of typical MPP absorbers with porous materials has been shown theoretically, and three-dimensional MPP space absorbers should display similar improvements. Herein the effects of porous materials inserted into the cavities of CMSAs and RMSAs are experimentally investigated and a numerical prediction method using the two-dimensional boundary element method is proposed. Consequently, CMSAs and RMSAs with improved absorption performances are illustrated based on the experimental results, and the applicability of the proposed prediction method as a design tool is confirmed by comparing the experimental and numerical results.

1. Introduction

Microperforated panels (MPPs) are one of the most promising alternatives for next-generation sound absorbers [1–4]. Typically MPPs are used in conjunction with an air cavity backed by a rigid wall. This setup limits the use of MPPs because MPPs must be professionally installed below ceilings or in front of walls as interior materials.

To offer easy-to-use sound absorption devices using MPPs, the authors have been researching MPP space sound absorbers. First, the sound absorption characteristics of the proposed double-leaf MPP space sound absorber (DLMPP) [5,6] were examined theoretically and experimentally. However, a DLMPP is a panel-like object with limitations as it is basically set on a floor or hung from a ceiling. If a space sound absorber made of MPPs can be placed more freely, its applications would be diversified. Next, three-dimensional MPP space sound absorbers [CMSA (cylindrical shaped) and RMSA (rectangular shaped)] were proposed [7–9]. CMSA and RMSA can offer reasonable absorptivities over a rather wider frequency range. Because the sound absorptivity is not very high, herein filling the cavities of CMSA and RMSA with porous materials is investigated.

Porous material in the cavity of typical MPP absorbers has been previously shown to increase the peak and broaden the absorption frequency range [10,11]. Thus, a similar effect is expected for three-dimensional MPP space sound absorbers. Herein experimental studies on the absorption characteristics of CMSAs and RMSAs filled with porous materials (hereafter referred to as CMSA/RMSA with porous material) are carried out, and a prediction method as a design tool is proposed using the two-dimensional boundary element method.

2. Experiment

2.1. Setup

Because a detailed description of the manufacturing process for CMSA and RMSA specimens is reported elsewhere [7,9], only the important parameters of the specimens are given here. CMSA specimens with 1- and 2-m perimeters (318 and 637 mm diameters, respectively) were made of 1-mm-thick polycarbonate MPP. The hole diameter, perforation ratio, and surface density were 0.5 mm, 0.785%, and 1.2 kg/m^2, respectively. RMSA specimens with

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1- and 2-m perimeters (squares with 250- and 500-mm sides, respectively) were made of a similar polycarbonate MPP with the same parameters as above except the thickness and surface density were 0.5 mm and 0.6 kg/m^2, respectively. The MPPs were fixed with slim wooden frames. The height of all specimens was 1 m. As the porous material, a 50-mm-thick panels of fiberglass of 32 kg/m^3 were stacked in the cavity. Consequently, the CMSA and RMSA cavities were filled with porous materials. The CMSA/RMSA with porous material described above were placed on the rigid floor of a reverberation chamber (513 m^3 volume and 382 m^2 surface area).

The measurements were performed according to JIS A 1409 [ISO 354 (Ref. [12]) compatible]. In all cases, six specimens were used, and the measurements were carried out with and without a cover (12-mm-thick plywood) on the open top-end. The absorption coefficients were estimated from the measured absorption power divided by the total surface area of the MPPs while ignoring the area of the top-ends. Fig. 1 shows a picture of the experimental setup.

2.2. Results

Figs. 2 (1-m perimeter) and 3 (2-m perimeter) compare the measured results for CMSA with porous material to those without a porous material inside [7]. In addition, the cases with and without a cover on the open top-end are shown. The absorptivity greatly increases due to the effect of a porous material inside. The effect is especially significant around the peak frequency, but gradually becomes smaller as the frequency increases. In the 2-m perimeter case, the absorption peak becomes higher upon inserting a porous material. It is inferred that the absorption peak is due to the resonance inside the cavity because the peak frequency is lower than that of the 1-m perimeter case and the bandwidth of absorption is extended by the decrease of the acoustical stiffness of the cavity due to its bigger volume. The maximum absorption coefficient exceeds 1.0 due to the area effect [13], demonstrating that CMSA with porous material is far more efficient as a sound absorber. The impact of the cover on the top-end is observed around and above the peak frequencies; the absorption coefficients of CMSAs without covers are larger than those with covers. This is because the top-end area relative to the entire surface area in the 2-m perimeter case is larger than that in a 1-m perimeter case, where the surface of the porous material itself is exposed to air without covers. Hence, the effect of a cover can be ignored when the perimeter is sufficiently small.

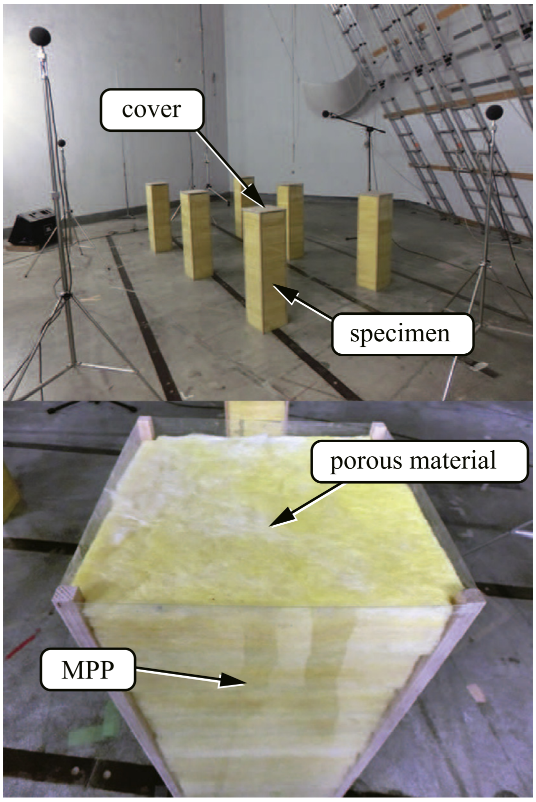

Fig. 1. Example of the experimental set-up for 1-m perimeter RMSAs filled with a porous material in the reverberation chamber. The arrangement of RMSAs with covers and the close-up of an RMSA without a cover are shown in upper and lower pictures, respectively.

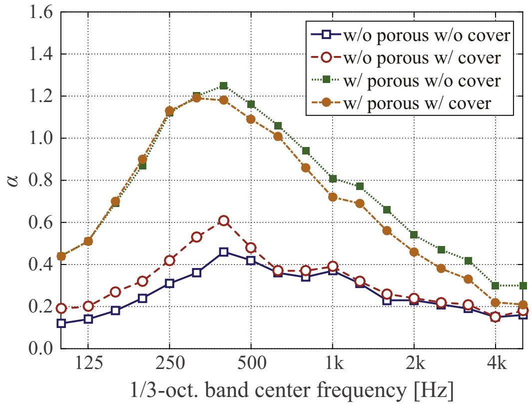

Fig. 2. Comparison of the experimental results for 1-m perimeter CMSA with and without a porous material.

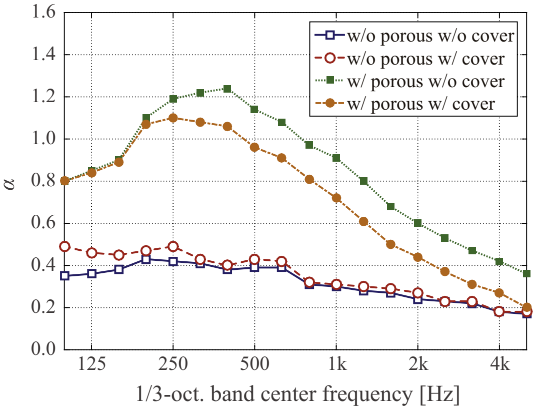

Fig. 3. Comparison of the experimental results for 2-m perimeter CMSA with and without a porous material.

Figs. 4 (1-m perimeter) and 5 (2-m perimeter) compare the results for RMSA with porous material to those without porous material inside [9]. Additionally, the cases with and without a cover on the open top-end are compared. The same tendencies as CMSA with porous material cases are observed. The effect of the porous material inside is significant, and the influence of the cover, which is stronger in the 2-m perimeter case, is observed around and above the peak frequencies.

3. Prediction

3.1. Formulation

3.1.1. Model

A three-dimensional calculation model should be considered when dealing with CMSAs and RMSAs. However, the total dissi-