IMPLEMENTATION EXPERIMENT OF A HONEYCOMB-BACKED MPP SOUND ABSORBING PANEL IN A MEETING ROOM

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In order to improve the acoustics of an existing meeting room of which the reverberation time is too long for speech communication, we implemented the honeycomb-backed MPP panels in that room to control the reverberation time with minimum amount of sound absorbers. MPP is not allowed to be used for an interior wall due to the regulation in Japan, we propose a panel of honeycomb-backed MPP which is not for an interior finishing but an additional panel hang on the walls and ceilings, in the way not to violate the interior regulation. The absorption characteristics of MPP panels were designed using FEM simulation and its absorption coefficient were measured in an echoic chamber. Additionally, the effect of installed MPP panels was checked by acoustic parameter measurement. As the results, we observed that the reverberation time was reduced half, the equivalent absorption area increases double, the EDT values were also reduced, $C_{50, \text{mid}}$ increases more than 5 dB and STI value turns one rank up.

Keywords: Honeycomb-backed MPP, Meeting room, Reverberation time, $C_{80}$, STI

1. Introduction

1.1 Background

A microperforated panel (MPP) is nowadays recognised as one of the most promising alternatives of next-generation sound absorbing material. Recently many commercial products using MPPs are produced and used in many countries especially European countries. As is known an MPP was first proposed and its theoretical basis was studies by Maa [1-4]: it is usually made out of a thin panel (less than 1mm thick) with submillimeter perforations with perforation ratio less than 1 %. An MPP is usually used as an interior surface with a rigid-back wall and an air-cavity in-between to produce Helmholtz resonators with each perforation and the air-back cavity.
In many cases MPPs are thin and do not have enough strength to be used for an interior wall, it is difficult to use them as an interior wall: therefore they are often used for a ceiling with lighting system etc. Besides, in Japan MPPs are not allowed to be used for an interior wall of a building due to the interior regulation by fire code. Considering this situation Sakagami and Yairi and the collaborators have proposed various type of space absorbers using MPPs [5-7]. In the same time, they proposed a honeycomb-backed MPP sound absorber, and made theoretical and experimental studies [8, 9]. In the same study the honeycomb is proven not only to strengthen the MPP enough for interior wall but also to improve its sound absorption performances. The effect of the honeycomb or partition which subdivides the air-back cavity has been known for long time and applied mainly for porous materials [10]: that structure makes the sound in the cavity to propagate normally which contributes to establish the similar condition as local reaction. Besides, as it subdivides the cavity not to mix up the sound field in it, so that the resonance characteristics are inferred to be enhanced. Using the honeycomb for backing structure, it is possible to produce a sound absorbing panel with MPP, honeycomb and a back plate, which has enough strength and used as not an interior wall but a panel which is additional furniture-like panel attached from a ceiling or on a wall. This can be one of the most practical methods to apply an MPP to rooms without conflicting the regulation.

1.2 Outline of the implementation experiment

In this paper, the detailed description and results of the implementation experiment of the honeycomb-backed MPP absorbing panels for an existing meeting room to improve its acoustics will be reported. In order to improve the acoustics of an existing meeting room of which the reverberation time is too long for speech communication, we implemented the honeycomb-backed MPP panels in that room to shorten the reverberation time. As mentioned above MPP is not allowed to be used for an interior wall due to the regulation, we propose a panel of honeycomb-backed MPP which is not for an interior finishing but an additional panel hang on the walls and ceilings, in the way not to violate the interior regulation. In this implementation project, first the acoustical characteristics of the meeting room was measured, and both the team at Kobe University and Nihon University discussed the method of its improvement with theoretical consideration including numerical simulations. As the conclusion of the discussion, from the design considerations, we decided to employ MPPs. Then, from the results the preliminary studies by numerical simulations we determined the detailed specifications of the panels. The panels were produced by JSP Corp., and Hazama Ando Co. made the experimental confirmation of the panels’ acoustic performance and the actual installation in the room.

2. The meeting room for the experiment and the specification formulation of the absorbers

First, the meeting room where the implementation experiment of honeycomb-backed MPP absorbing panels was carried out is described. Figure 1 shows the interior view of the meeting room. The room is of rectangular shape (3.55 m wide, 8.55 m depth and 3.00 m high) and its walls are hardly furnished with sound absorbing treatment. Its frequency characteristics of the reverberation time measured according to ISO 3382-1 are shown in Figure 2. The reverberation time values from 250 Hz to 2 kHz are over 2.0 seconds, especially the values of 500 Hz and 1 kHz are over 2.5 seconds. The reverberation time is very long at frequencies important for speech communications, which needs some treatment to improve acoustically. The somewhat shorter reverberation times at lower frequencies are supposed to be due to the sound transmission through the windows and doors. Therefore, in this experiment the frequency region important for speech communication where the reverberation time is long is determined for the target of sound absorption treatment. Also, from the design considerations, it is determined to explore the possibility to realise this treatment with minimum furnishing of sound absorbing panels.

Therefore, we determined to control the reverberation time at mid-frequencies (500 and 1k Hz) with two honeycomb-backed MPP absorbers with different peak frequencies tuned to 500 and 1k Hz.
As it is not desirable to attach these panels at places where people using the room can reach, these absorbers are planned to be placed around the corner of ceilings and walls. This is important because it is desirable to avoid unevenness of the room surfaces for both design and safety considerations, even though honeycomb-backed MPP absorber panels have enough strength.

Next, we made a basic consideration for determine the parameters of the absorber with electro-acoustical equivalent circuit theory. Supposing to use a plastic panel of 1 mm thick, through the numerical calculation the parameters are fixed at: hole diameter 0.5 mm, perforation ratio 0.75 %, and cavity depth 10 mm (for 1 kHz) and 50 mm (for 500 Hz). Also, it is confirmed that, due to the effect of the honeycomb, the dependence of the angle of incidence is smaller than conventional MPP absorbers (without honeycomb), thus it is the most preferable to obtain the best absorption performance with smaller absorbers. Therefore, in the next stage, by using FEM simulation, the effect of these absorbers is numerically discussed in more details.

3. Numerical simulation by Finite Element Method

In order to determine specification formulations of the sound absorbing panels with honeycomb-backed MPPs, wave acoustic simulation of the meeting room was carried out by Finite Element Method [11]. This is important step in this project because the area to install the absorbers are limited to the corner of the walls and ceilings, and the room is rather small space in which modal characteristics will be of large effect that should be considered to discuss the effective implementation of the absorbers. In the simulations, the room was modelled as a simple rectangular shape without doors, windows and other structural elements, and absorbing panels (two types for mid and high frequencies) are supposed to be attached on the corner of the ceilings and walls only. The sound absorption characteristics of the honeycomb-backed absorbing panels calculated by electro-acoustical equivalent circuit theory, two types for mid (500 Hz) and high (1k Hz) frequencies with the parameters determined by the preliminary studies above, are shown in Fig. 3. In the simulations, the size of the absorbers, the places to be attached and the combinations of the two types of absorbers were mainly discussed through the numerical results.

Considering the limitations in the actual room, in conclusion the instalment of the absorbers shown in Fig. 4 is found to be the best among the various other instalments. By installing the absorbers this way, the FEM simulation gives the prediction of the decrease in average sound pressure level by
4.6dB at 500 Hz, and 3.7dB at 1k Hz. Regarding the decay curve of the reverberation in the room, as shown in Fig. 5, simulated results show that the reverberation time becomes shorter, especially 40% decrease in the early decay time (EDT) is resulted.

From the above discussion through the numerical results by FEM simulation, we determined the specification formulation of the honeycomb-backed MPP sound absorbing panels finally as: MPP panel thickness 1 mm, hole diameter 0.5 mm, perforation ratio 0.77 % (hole separation 5 mm), and the cavity depths are 50 mm for 500 Hz and 10 mm for 1 kHz. They are installed as shown in Fig. 4 (in the longitudinal direction on the walls and ceilings, as possible as the other consideration allows.) The materials for each element of the panels are discussed later in the test-production stage.

Figure 3: The calculation results of sound absorption characteristics of the honeycomb-backed MPP panels. Both panels are assumed as a 1 mm thick board, 0.5 mm diameter holes and 0.75 % perforation ratio for calculation.

Figure 4: Absorption materials arrangement. Absorption panel (A) has 50 mm depth air layer and (B) has 10 mm depth air layer. This rectangular room is consisted with 3.00 m height, 3.55 m width and 8.55 m depth.

Fig.5: Reverberation decay curves calculated from FEM simulation results (500 Hz octave band). The result of with none-absorption panels is drawn with a black line and that of with absorption panels is drawn with blue line.

4. Production of the honeycomb-backed MPP sound absorbing panels and the measurements of its absorption coefficients

The production of the honeycomb-backed MPP sound absorbing panels used for the present implementation experiment was carried out at JSP Corp. The finalised specifications of the absorbers are presented in Table 1. Figure 6 shows the panel produced. The panels were assembled as a box-like shape of 500 x 600 mm, with an MPP on the face and a blind (without an opening or perforation) panel on the back and sides. Inside is a honeycomb of 50 mm square. All panels are made of plastic. These panels are installed on the walls and ceiling of the meeting room with metal fittings.
Before the instalment, the panels were tested to measure the absorption coefficients in the reverberation chamber at Hazama Ando Ltd. (V = 212m³, Floor area = 46m²). The measurements were carried out according to JIS A 1409 (ISO 332 compatible). In the measurements, the area of the specimen was 9m² and the following cases were examined: (i) 50 mm thick panels only, (ii) 10 mm thick panels only. The results are shown in Fig. 7, in comparison with a fiberglass board (32kg/m³) 25 mm thick as a reference.

From the results in the cases (i) and (ii), the produced absorbers show the absorption peak at the frequencies as theoretically predicted in the design stage. The absorption characteristics are also as expected from the theoretical prediction. Therefore, we considered that they will obtain the good results in the site as expected by preliminary studies.

5. Implementation and the measured results after it

After the above mentioned circumspect preparation, the actual installation of the honeycomb-backed MPP panel sound absorbers were planned as presented in Fig. 8 and carried out. The photographs of the absorbers installed in the meeting room are presented in Fig. 9. As the result of the careful colour matching, the difference in colours of the wall, ceiling and the absorbers are hardly noticeable, therefore, the absorbers are not distinguishable.
Figure 7: The measured absorption coefficient of produced Honeycomb-backed MPP panels. For comparison, the measurement value of glass wool 32 kg/m$^3$ density 25 mm thick are also plotted.

Figure 8: Install plan of Honeycombed-backed MPP panels. Left: Installing position on the ceiling board. Right: Installing position on both long side walls. Shown in each figure (1) and (4) are 50 mm thickness panels, (2), (3) and (5) are 10 mm thickness panels. Just one panel was not able to install for interfering in a service duct.

Figure 9: Installation and arrangement of honeycomb-backed MPP panels.

5.1 Reverberation time measurement and its result

The reverberation time measurement after the implementation of the absorption panels are also conducted with the same condition as the previous measurement before it.

The measurement result shown in Figure 10 is plotted with that of before the installation. Additionally, the equivalent absorption area calculated from the measurement results of reverberation time are shown in Figure 11.

At first focusing on Figure 10, the reverberation time from 200 Hz to 3 kHz is reduced so much. Especially, the value of from 500 Hz to 1 kHz are reduced about half. This effect can also be seen that the value of equivalent area increases double shown in Figure 11. Only the small area instalment at edge line of ceiling and walls against all of surface area, we were able to get the double equivalent absorption area using honeycomb-backed MPP panels.

5.2 The results of EDT and $C_{50}$

The EDT (Early Dacey Time) and $C_{50}$ values are also calculated from the impulse responses obtained by reverberation time measurement. The calculation results of EDT and $C_{50}$ are shown in Figure 12 and 13 respectively. Focusing on Figure 12, the EDT values at from 250 Hz to 2 kHz are significantly reduced, especially reducing at 500 Hz and 1 kHz are huge. From these results, we can expect that
the reverberant is also significantly reduced. Secondly, shown in Figure 13, the $C_{50}$ values at 500 Hz and 1 kHz increase so much. Therefore, the $C_{50,mid}$ (average of the $C_{50}$ values of 500 Hz and 1 kHz and five receiving points) values at after installation and before are calculated respectively. As results, the improvement more than 5 dB (–4.1 dB before installation and 1.5 dB after it) can be seen by the effect of MPP panels installation. This result supports that the clarity at mid frequency in each position in this meeting room could be improved.

![Figure 10](image1.png)  
**Figure 10:** Reverberation time of the meeting room with or without honeycomb-backed MPP panels. (with no furniture).

![Figure 11](image2.png)  
**Figure 11:** Equivalent sound absorption area of the meeting room with and without honeycomb-backed MPP panels. (with no furniture).

![Figure 12](image3.png)  
**Figure 12:** EDT (Early Dacey Time) of the meeting room with and without honeycomb-backed MPP panels. (with no furniture).

![Figure 13](image4.png)  
**Figure 13:** $C_{50}$ in the meeting room with and without honeycomb-backed MPP panels. (with no furniture).

### 5.3 STI measurement and results

We also conducted impulse response measurement with actual meeting style conditions for calculating STI values [12]. The two conditions of a loudspeaker and receiving points were arranged. A loudspeaker simulated the directivity of actual people speaking is used. The STI values in each condition are shown in Figure 14 respectively. The upper values are after installation and the lower ones are before it. The values after installation increase more 0.1 than those of before it. The average values after installation and before, STI is 0.67 and 0.55 respectively. This variant bring rank up from “Fair” to “Good”. This result shows us that the speech environment of this meeting room could be improved significantly.
6. Conclusion

In this experiment, the effect of honeycomb-backed MPP panels design and implementation on small area for improving poor and long reverberant acoustic condition were examined in a small meeting room. These MPP panels are able to remove easily like furniture because of avoiding to be against the fire regulation in Japan. The absorption characteristics were designed using classical theory, FEM simulation and the measurement of absorption coefficient in a reverberant chamber. Additionally, the effect of MPP panels installation was checked by acoustic parameter measurement in before installation and after it. As results, we can see that the reverberation time was reduced half (in other words, the value of equivalent absorption area increases double). The EDT values was also reduced, $C_{50,mid}$ increases more than 5 dB and STI value turns one rank up. This trial was also able to suggest that aiming acoustic effects could be obtained without drastic visual changing. MPP panel has large possibility for surface design. This trial can suggest that the MPP panels will becomes one of the most popular absorption techniques.

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