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Notification of acceptance	**28 FEBRUARY 2013**
Submission of final camera-ready papers	**15 APRIL 2013**

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ICAME2013

#179 (1569723419): *Study on the Use of Micro-Perforated Panel to Improve Acoustic Performance in Mosque*

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Property	Change Add	Value
Conference and *track*		**International Conference on Advances in Mechanical Engineering 2013** - *Related Topics*

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Property	Change Add	Value
Title		*Study on the Use of Micro-Perforated Panel to Improve Acoustic Performance in Mosque*
Abstract		Most activities in mosque such as Friday prayer and the sermon by an Imam require clarity of speech. Unfortunately, this 'speech intelligibility' performance is often poor due to initial design of a mosque. This paper presents assessment of the indoor acoustics of a mosque. Acoustical properties such as reverberation time, clarity and early decay time are obtained from simulation data using CATT indoor acoustic software. The study started with an empty mosque with no acoustic treatment. Acoustic 'green' absorbers using micro-perforated panel (MPP) are then introduced to improve the acoustic performance. The application of MPP is still rare for mosque and is expected to replace the typical porous absorber. The effect of the panel size, location and frequency range of sound absorption are simulated and the results are discussed.
Keywords	Only the chairs (icame2013-chairs@edas.info) can edit	speech intelligibility; reverberation time; micro-perforated panel; acoustics
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Reviews

1 Review form for ICAME2013

Review 1 (Reviewer A)

Reviewer 1

Originality	Contribution	Significance to the Conference Topics	Presentation Style	Quality of Language
Satisfactory (3)	Good (4)	Good (4)	Good (4)	Satisfactory (3)

Contribution (Briefly, the contribution of the paper appears to the following)

The manuscript under review pertains to the assessment of simulated indoor acoustics of 'a' mosque. The effect of a micro-perforated panel (MPP) mounted on the surface of existing walls, roof and pillars with a certain air-gap on the reverberation time is studied. Optimization of the air-gap distance (denoted as D) and MPP mounting configuration are made and discussed in the article.

Improvement (Suggestions for Improving the paper)

1. Please enlist the specification of the sound source.

2. Please recheck the article for improvements related to language and format. This is minor but worth considering.

Best Paper Award (Recomended for Best paper Award Candidates? (Yes/No/Not Sure))

No.

Study on the Use of Micro-Perforated Panel to Improve Acoustic Performance in Mosque

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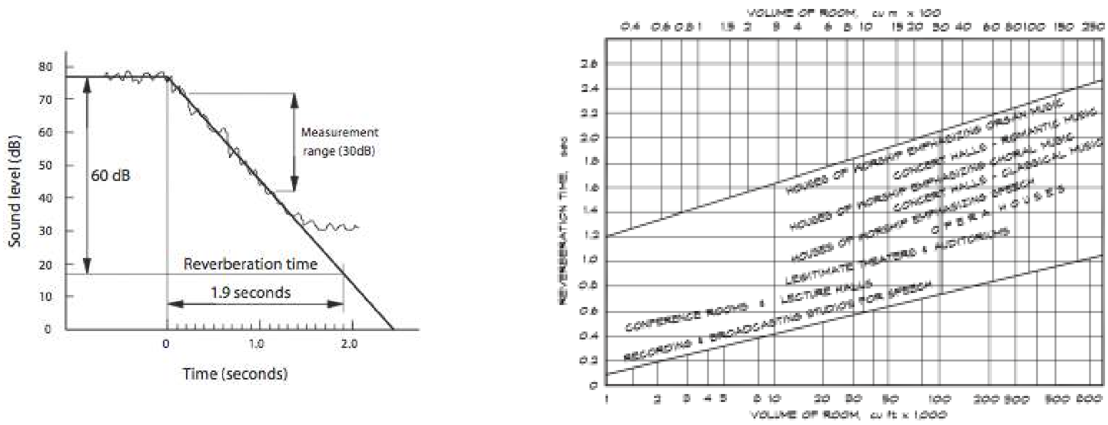
Keyword: speech intelligibility, reverberation time, micro-perforated panel, acoustics.
Abstract. Most activities in mosque such as Friday prayer and the sermon by an Imam require clarity of speech. Unfortunately, this 'speech intelligibility' performance is often poor due toinitial design of a mosque. This paper presents assessment of the indoor acoustics of a mosque. Acoustical properties such as reverberation time, clarity and early decay time are obtained from simulation data using CATT indoor acoustic software. The studystarted with anempty mosque with no acoustic treatment. Acoustic 'green' absorbers using micro-perforated panel (MPP) are then introduced to improve the acoustic performance. The application of MPP is still rare for mosque and is expected to replace the typical porous absorber. The effect of the panel size, location and frequency range of sound absorption are simulated and the results are discussed.

Introduction

Acoustics in Mosque. Mosque is a very important architecture in Islam which servesas a multifunction public space where Muslims perform various activities including praying, preaching and Quran recitations. All of these functions require good speech intelligibility.However, many mosques are built without the attention of its acoustical properties. Acoustics in mosque usually come after the final construction stage. According to Setiyowati [1], many mosques have reverberation problem and bad sound pressure distribution. Parallel walls and dome, for example, consecutively create standing waves and focusing sound in acoustic of mosque.The proportion of the wall in terms of aspect ratio of length and width also affects the sound distribution. Longer wall facing Qibla tend to achieve optimum speech intelligibility [2]. Abdou investigates the effect of wall arrangement on the acoustics [3]. It is found that square walls deliver uniform spatial distribution which is sufficient to provide good speech intelligibility during daily prayer and 'Friday' speech. Amplified sound resulting from improper loudspeaker distribution is shown by Soegijanto to lower the performance of speech intelligibility [4].

Reverberation time. Common controlled acoustical parameter to determine the clarity of speech or quality of sound in room is reverberation time (RT). It is defined as the time required for the sound energy to decay 60 dB after a sound source is turned off. Other parameters also exist which are equivalent to the RT such as early decay time, clarity and lateral fraction; each provides its own quality of representation with the subjective of listeners to the perceived sound.

The reverberation time required for good room acoustics depends on the function of the room. Figure 1 shows the recommended occupied RT according the room function and volume [5]. The mosque can be categorized in to 'house of worship emphasizing speech'. For example with room having volume of 500,000 ft^3, the RT required is 1.6 s. For good speech intelligibility, RT at frequency 500 Hz and 1 kHz should be ensured to be around the recomended value [6]. It can also be seen that for music performance, higher RT is allowed.



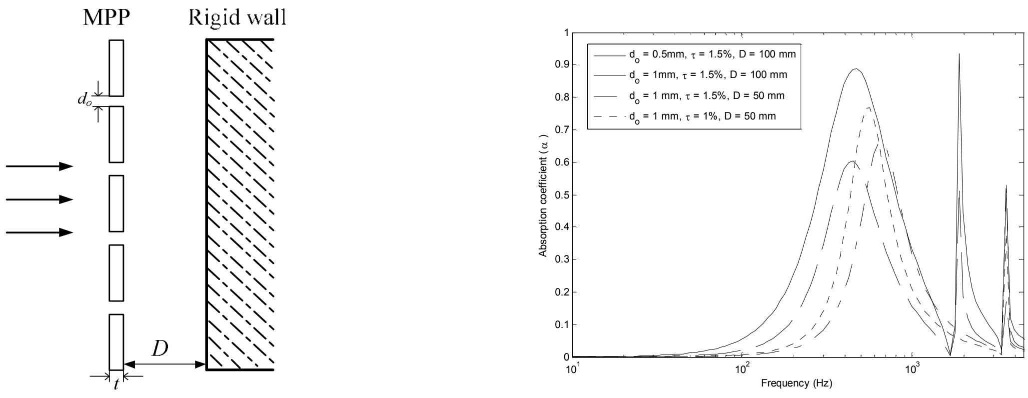
(a) (b)

Figure 1:(a). Reverberation time [6] and (b) recommended reverberation time according to room volume and functions [5].

The RT can be shorten by reducing the reflections from the surface. For this purposes, sound absorbing materials are required. This paper discusses the possibility of using micro-perforated panel which according to author's knowledge is rarely found applied in mosque as sound absorber.

Micro-perforated panel. Micro-perforated panel (MPP) is well known as an alternative green sound absorbing material replacing the synthetic porous absorber. Its theory and design were pioneered by Dah You Maa in 1975 [7].The MPP can be made from any solid material such as plastic, metal, plywood introduced with holes having diameter of less than 1 mm and perforation ratios between 0.5 – 1 %.Because it is constructed from panels, MPP is thus non-abrasive, easy to clean and has good durability compared to classical porous absorber. It also provides optically attractive surface adding the artistic value in room interior.

Fig.2 (a) shows the arrangement of the MPP as sound absorber which is located in front of a rigid wall with an air gap. The system resembles a Helmholtz resonator mechanism where maximum sound absorption can be obtained at resonance. The general trend of the absorption is thus quite narrow in terms of the frequency band and is mainly at low frequencies. Fig. 2(b) presents the analytical simulation of absorption coefficient of MPP for different hole diameters, perforation ratios and air gap. It can be seen that the peak amplitude and the peak frequency can be controlled by adjusting the hole diameter *cc*, perforation ratio τ and the air gap *D*.



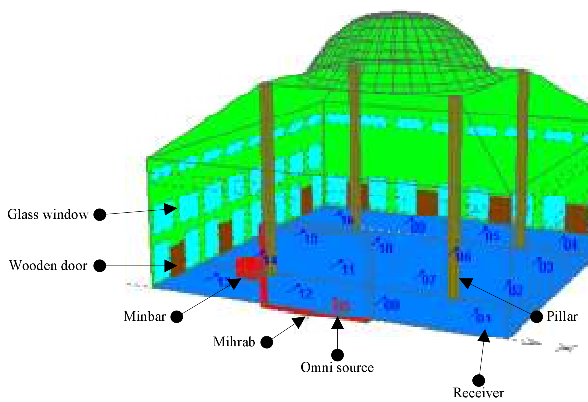
(a) (b)

Figure 2: (a) Schematic diagram of MPP in front of a rigid wall and (b) its absorption coefficients.

Simulation model and results

Room without MPP.A typical model of a mosque is first developed using CATT room acoustic software as seen in Fig. 3(a). The main prayer room has rectangular shape joined with lining walls and roof with dome shape supported by four pillars. The total volume of the room is roughly 18,000 m^3. The walls are made from concrete and the side and back walls have glass windows and doors made from woods. The whole floor is covered with thick carpets.

In the simulation, the sound source is placed in front of the mihrab to simulate the speech coming from this area. The sound source used in the experiment was GDB-S 01dB Metravib noise generator. The main prayer hall is divided into 16 symmetric areas, each with a receiver location where the acoustic parameters to be determined from the simulation.This is set to be 0.5 m height from the floor to represent the distance of the floor to the listener's ear when sitting. Fig. 3(b) shows the reverberation time (RT) obtained from the simulation where at low frequencies below 500 Hz, the RT can reach up to 6.5 seconds indicating poor acoustic performance. This is suspected due to the room acoustic mode. According to Fig. 1(b), for the corresponding volume of 18,000 m^3, the RT should around 2 seconds.



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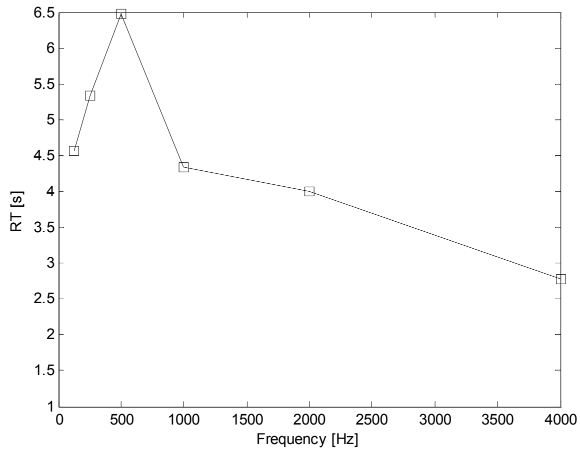
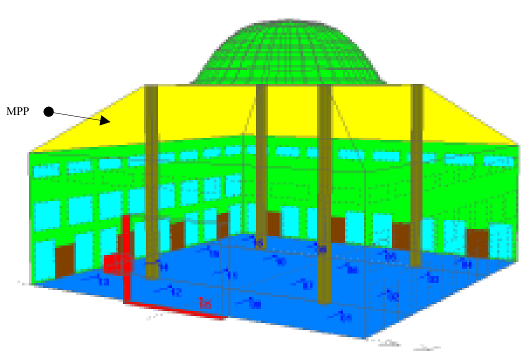


(b)

Figure 3:(a) CATT model of an empty mosque and (b) the simulated reverberation time.

Room with MPP. As the RT for speech intelligibility is critical between 500 Hz and 1 kHz [6], the simulation is conducted to only control the RT at these two frequencies. Figure 4(a) shows the CATT model of the mosque with MPP assumed to cover the whole lining roof. The MPP parameters chosen are $d_0 = 0.4\text{mm}$, $\tau = 1\%$ and $D = 10\text{mm}$ producing absorption coefficient of 0.99 at 500 Hz and 0.43 at 1 kHz. By increasing the air gap the maximum absorption shifts to 1 kHz to be 0.99 and 0.29 at 500 Hz.



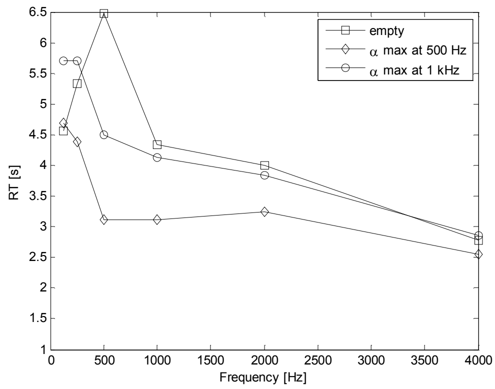
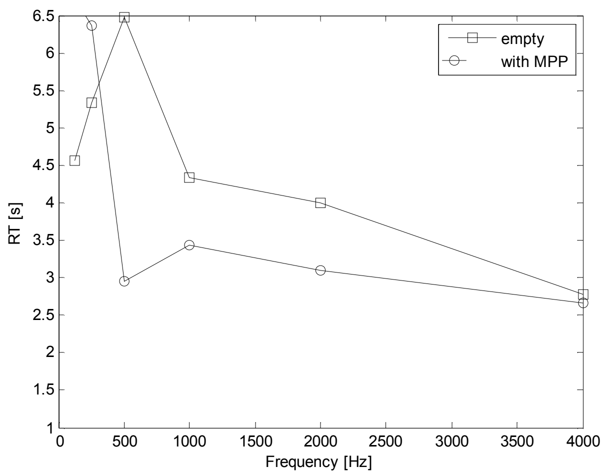


Figure 4: (a) CATT model with MPP installed on the roof and (b) the simulated reverberation time.

The results show that designing maximum absorption coefficient of MPP at 500 Hz is effective to bring down the RT for other frequencies. RT at 500 Hz can be reduced significantly from 6.5 s to 3 s and from 4.5 s to 3 s at 500 Hz. Meanwhile for MPP with maximum absorption at 1 kHz, almost no effect for RT at 1 kHz. This can be understood since the frequency band of absorption of MPP is broader when the resonance is at lower frequencies and narrower at higher frequencies.

The next simulation is therefore conducted for MPP with resonant frequency at 500 Hz. Fig. 5(a) shows full installation of MPP on the whole surface of the lining roofs, front and back walls. The RT can be seen to have almost negligible effect compared to the results in Fig. 4(b), i.e. without treatment of the front and back walls. However, adding MPP on the pillars can be seen to reduce the RT at 500 Hz and 1 kHz close to 2 s. MPP on the pillar enhances the absorption for the direct sound from the mihrab and also reflected sound from the walls and roofs before arriving to the listeners.



(a) (b)

Figure 5:(a) Simulated reverberation time with MPP assumed installed on the whole surface of the roof, on the front and back walls and (b) with MPP at the surface of the pillars.

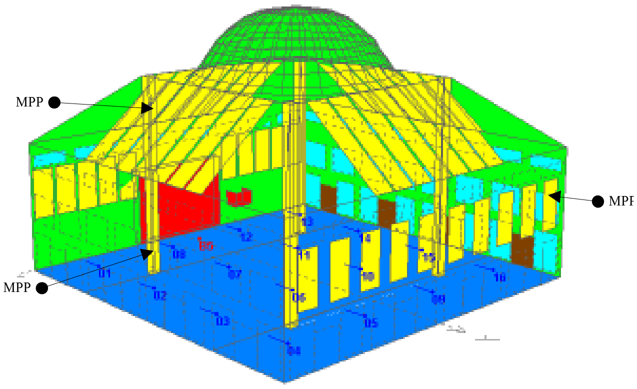
However, installing the whole surfaces with MPP is not practical and not efficient. Compromised situation must be taken into account between the required surface of absorber and the resulting RT.

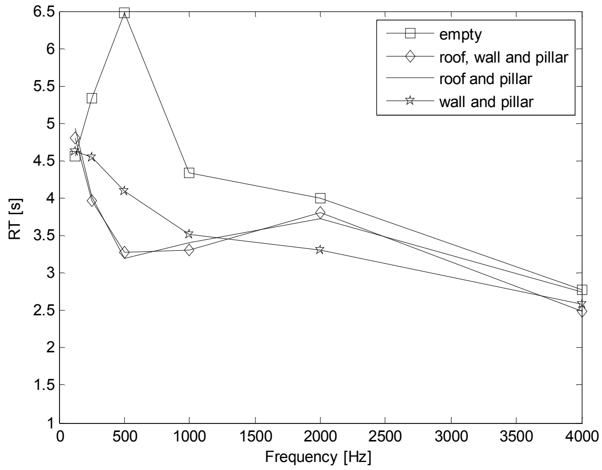
Optimisation. Fig. 6 shows strip panels of MPP having width of 2 m installed on the roof, back and front walls as well as the pillars as shown in Fig. 6(a). Combination of the presence of the MPP on the roofs and the walls while retaining it on the pillars is simulated. The results in Fig. 6(b) show the installation of MPP on roofs, walls and pillars has similar RT to the MPP installed on the roofs and pillars (without MPP on the front and back walls).

This arrangement increases RT around 3 s which is greater than the recommended value. For engineering purposes, this could be accepted. Moreover, the mosque cannot be treated totally as, for examples, classroom and listening room. More 1 second reverberation time increases the 'bass' sound which is important to create a 'warmth' sound environment inside the mosque. This will create the perception of 'grandeur' in the house of God when the Quran is recited. However subjective assessment for this hypothesis is required to provide a valid conclusion.

Summary

Based on the room acoustic simulation in mosque with the installation of MPP, it has been shown that this can control reverberation time at low frequencies. Effective addition of MPP particularly at the surface receiving large number of impinging sound is found to be capable to reduce the reverberation time, although the frequency band of absorption for the MPP is quite narrow. It has been presented here that it is possible to apply MPP in the mosque as sound absorbers. The presence of MPP will also enhance the aesthetic value inside the mosque.





(a) (b)

Figure 6: (a) CATT model of strips of MPP installed in a mosque and (b) simulated reverberation time.

Acknowledgement

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