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The Importance of Acoustic Design in the Mosques towards the Worshipers' Comfort

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Abstract

A good acoustic design will provide a better and comfortable environment in the mosque in term of sound audibility and speech intelligibility. Unfortunately, architects nowadays often focus more on designing a building based on its looks or form, and the main function of space most often neglected. The research has taken place at Masjid Al-Hussain Kuala Perlis. The research approach includes interviews and observations guided by the theory of affordance employed. Although the acoustic design was not that perfect, the acoustic design is still acceptable. There is a correlation between the acoustic designs of the mosque and the worshipers' comfort.

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Keywords: Acoustic design; sound audibility; speech intelligibility; worshipers' comfort

1. Introduction

Architectural acoustics is the art of achieving a good sound within a building. Based on Wikipedia the first application of modern scientific methods to architectural acoustics was carried out by Wallace Sabine in the Fogg

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Museum lecture room. He then applied his new found knowledge to the design of Symphony Hall in Boston. Architectural acoustics is about achieving a good quality of speech in a theatre, improvise quality of music in a concert hall or recording studio, or suppressing noise to make offices and homes more comfortable and peaceful places to work and live.

Nowadays, architects have often focused on the design a beautiful mosque. Acoustic design is an important characteristic of a mosque. A high level of quality of sound is needed for all worship activities. Poor acoustic design in a mosque will disturb the concentration of the worshipers. According to Khabiri et al. (2013), to ensure good listening conditions, acoustical needs must be considered in the design phase. High-quality sound also is vital, especially for pure tones that must be both wide and effective.

1.1. Statement of the problem

Architects now days often concentrate more on designing a building based on its looks or the forms and the main function of space have been put aside. In designing a mosque, a good acoustic design is needed for the worshipers. While giving talks or lectures in a mosque, some of the worshipers unable to hear clearly, and the message cannot deliver to them efficiently.

A poor acoustic design in a mosque will also cause the worshipers unable to hear clearly the voice of the “Imam” during the "Jemaah" prayer. Therefore, the acoustic design must be considered at the early stage of designing a mosque such as the choice of materials used, the construction and the geometrical form of the mosque itself.

1.2. Purpose of the study

The purpose of the study is to identify the importance of acoustic design in the mosque towards the comfort of the worshipers. From the investigation, it is expected to raise awareness among the people especially the designers about the importance of acoustic design in a mosque in ensuring the comfort of the worshipers. This investigation was done firstly through exploring the knowledge on the implication of poor and good acoustic design towards the comfort of the worshipers. Consequently, observing and understanding the importance of acoustic design for the worshipers in achieving comfort.

1.3. Aim and objectives of research

The aim of this study is to identify the importance of acoustic design in the Masjid Al-Hussain at Kuala Perlis, Perlis towards the comfort of the worshipers. The main question of the research: Is it necessary to have an acoustic design in the mosque to ensure the comfort of the worshipers? Thus by going through observations and interviews, it is to clarify how comfortable the worshipers when they are in the mosque.

Therefore, it is expected by the end of this study; researcher has come to the conclusion on the importance of acoustic design in the mosque towards the comfort of the worshipers. The objectives are:

- To create awareness of the importance of acoustic design in designing a mosque among architects for the comfort of the worshipers.
- To identify the application of good acoustic design in the mosque for worshipers.
- To observe and analyse the worshiper’s behaviour in the mosque.

2. Literature review

2.1. Introduction of building acoustic

Building acoustic is considered to be one of the most important aspects of building design that prioritises speeches and music, primarily buildings such as concert halls and places of worship such as mosques. As studied by Lidia Álvarez-Morales, building acoustic is typically defined from which the positions of the source and positions of listeners in the various zones is analysed by processing acoustic parameters related to reverberation, sound strength, clarity, early lateral reflections, and the speech intelligibility. Meanwhile, as researched by Ismail (2013), rooms for

musical performance shows a growing understanding of the more important acoustical characteristics of the concert (such as bass effect) and are well defined although the need to improve tools for applying this knowledge to the design of these spaces is still in progress. On the other hand, rooms for speech are not as well defined because of special groups of listener such as the very young or old, hearing impaired listeners, and those listening in a second language. From here, it can be seen that building acoustic is divided into two categories, speech and music.

2.1.1. Speech

The study by Ismail (2013) speech intelligibility is affected by an excessive reverberation time, (T60). It has been defined as the 60dB decay time of sound level in the auditorium, after cutting off the sound energy. Sabine's formula is usually used to calculated (T60) from the empirical relation: (T60) = 0.16V/A in seconds, where V is the volume (m3) of the auditorium, and A is the total absorption (m2). Early decay time (EDT) is defined as the decay time from 0dB to -10dB. It is used as a quick indication of the amount of reflections, diffusion, or clarity of sound waves in the auditorium. He also stated that, an advanced technique, introduced by Schroeder, uses the squared reverse-integrated impulse response of an auditorium (which is equivalent to the ensemble average of an infinite number of squared reverberation decays). In conclusion, this technique is useful for quick calculation of the EDT, and can be used for in-situ applications.

2.1.2. Music

In musical acoustics, the room should be able to enhance the quality of the musical reverberation, whereas studied by Bradley (2009) the room should strongly reproduce bass sounds for most types of musical performances.

He also found that the classical approach to providing the adequate strength of the bass sound assumes that the degree of bass is related to low-frequency reverberation times. Moreover, the rooms for musical performances should have increased low-frequency reverberation times, where the further study shows that typically the 125 Hz reverberation time is required to be 1.5 times the mid-frequency value. It sometimes leads to quite extreme efforts to reduce low-frequency absorption in halls.

2.2. Importance of acoustic design within mosques

Every mosque requires acoustic design. Mosques are a multi-function public hall with many worshipping activities that have different acoustical requirements (Khabiri et al., 2013). In a study by Zühre Sü Gül and Mehmet Çalıskan (2013), they found that having a high quality of sound is an important feature in main prayer hall design, and it is a fundamental element in mosques and various places of worship. Acoustical design of mosques is considered critical considering speech and music related activity patterns held in such religious spaces.

Although that is true, studies by Ismail (2013), stressed that the importance of speech intelligibility became more important in contemporary mosque design, that the integration of other activities such as the Holy Quran recitation, speeches, and lectures in the prayer halls is a norm. It means that acoustical design is crucial within mosques to ensure that the quality of sound, whether in term of speech or music, is maintained to ensure religious activities can proceed more smoothly.

2.3. Effect of reverberation time on mosque

In a study by Zühre Sü Gül and Mehmet Çalıskan (2013), they found that reverberation time, in scientific term is defined as the time required for the average sound energy density to decay by 60 dB from an equilibrium level after the sound source has stopped. Since 1900, Sabine has studied the phenomenon, and RT has been used as the main technique for discovering the acoustic characteristics of room's environment and, in the case of the holy mosque, clues on intelligibility and sound aesthetics. In Doğramacızade Ali Paşa Mosque acoustical simulations of T30 over frequency range are assumed as a global average of the interior volume and presented for each receiver location in the form of distribution maps.

As studied by Zühre Sü Gül and Mehmet Çalıskan (2013) found that the result of global estimates indicate that perforated wood application on inverse triangular pendentive surfaces is effective both for occupied and unoccupied

conditions of the mosque, particularly in the improvement of lower to mid frequency range. They also found that being the selected alternative design solution all other simulation results are presented only for perforated wood application on pendentive surfaces. Average mid frequency T30 for an unoccupied mosque with acoustical treatment on pendentive surfaces is 1.94 s, and average low-frequency T30 is 2.07 s. As studied by Mazloomi (2010) the unique of this type of pendentive surfaces construction is that it creates massive multivolume space to the mosque's interior. With treatment, average mid frequency T30 for the occupied mosque is 1.34 s, and average low-frequency T30 is 1.86 s. Warmth expressed regarding bass ratio (BR) should be greater than 1.20 for music performances. Lastly, they found that although speech is the main activity in a mosque, the low frequency and spiritual context of the male imam's voice proved rather different than the ordinary speech, making it advisable to have a BR that is closer to optimal for music. In the case of Doğramacızade Ali Paşa Mosque, Zühre Sü Gül and Mehmet Çalıskan (2013) found that BR is 1.06 for the unoccupied mosque and 1.38 for the occupied mosque. Worshiper's corporeal presence attribute to further absorption in mid to high-end frequency range of the occupied mosque space, creating the warm acoustical environment.

2.4. Integration of acoustic design

Table 1. Room acoustic parameters and allowable limits (occupied spaces)

Parameter	Recommended range (for given volume)	Just noticeable difference
T30 (for 500–1000 Hz)	1.15 s (for speech only) to 1.96 s (for religious music)	About 0.1 s
C80 (for 500–1000 Hz)	0–9 dB (for speech + music) –2 dB to 2 dB (for music)	1 dB
STI	Greater than 0.60	0.05
SPL-A	Minimum variations in SPL < 10 dB	2 dB

Source: Zühre Sü Gül, & Mehmet Çalıskan (2013)

2.5. Spaces

As studied by Ismail (2013), the selection criteria were set to maintain various cross relationship geometrical parameters with increasing mosque size. The relationship of the mosque plot area and volume is shown in Figure 1. Evidently, the linear relationship demonstrated by the graph proves that the selected mosques maintain a sheer volume and plot area relationship. The volume increases with increasing plinth area. This linear relationship will ensure a linear increase in RT with the increase in volume. Any deviation is due to the effect of the geometrical disposition of each mosque and the design aspects if the finishing materials are of similar absorption characteristics.

He also studied about the linear increase in volume with increasing surface area is represented Figure 2. The relative data are represented regarding its relationship to the plinth area of the mosque prayer hall. The strong relationship between the effective surface areas and the surface area of the plan is shown by the solid circle lines. However, the resultant volume from the integration of these surface areas resulted in a relative increase in the effective volume to plan the surface area ratio for some geometry. This result is most probably due to the presence of the dominant hemispherical domes in the main prayer and daily prayer halls of the mosque.

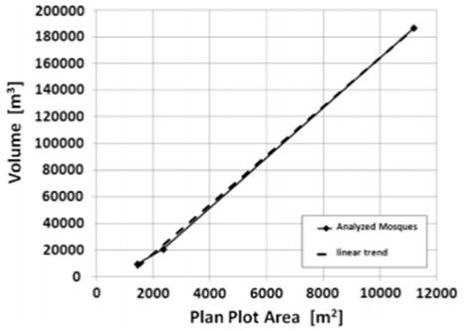

Fig.1.Volume plinth area relationship
Source: (Ismail, 2013)

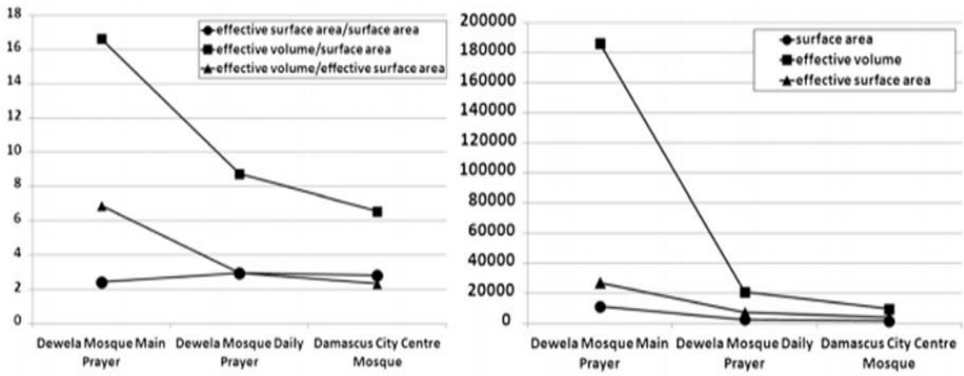

Fig.2. Prayer halls geometrical parameters relationship
Source: (Ismail, 2013)

2.6. Shape

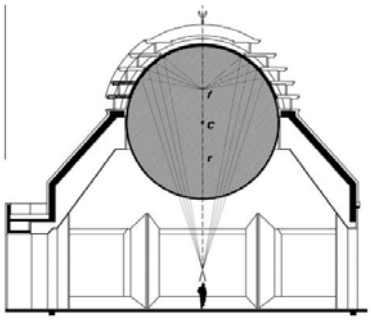

Fig.3. Shaded area effective acoustical dome area of Doğramacızade Ali Paşa Mosque (c: center, r: radius, f: sample focal point).
Source : b. Zühre Sü Gül a, ⇑, Mehmet Çalıs kan c (2013)

Speech intelligibility is the primary acoustical concern and necessitates suitable designation of volume, the geometry of the main space and appropriate use of acoustically absorptive and diffusive materials as finish surfaces (Zühre Sü Gül & Mehmet Çalıskan, 2013). He stated that acoustical design should be integrated into the architecture in the very early stages of concept design of a mosque. During schematic design, major geometric forms are generated and a material selected to solve aesthetic and acoustical concerns. As previously mentioned, the dome is the symbolic shelter element of traditional mosque model. He studied the case of Doğramacızade Ali Paşa Mosque,

in which the architect specified a modest-sized stained glass dome to embrace architectural aesthetics and minimize probable acoustical defects. The ratio of the effective surface area to the effective volume for the three prayer halls is plotted in Figure 4. The effect of the large hemispherical domes in reducing the surface area is represented by the solid square plots. The upper curves in Table 4 clearly show the low surface area/volume (SA/V) ratio of the sphere compared with the other geometrical shapes.

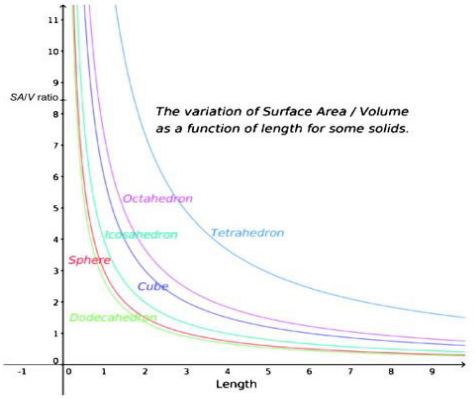

Fig.4. The variation of Surface Area/Volume as a function of length for some solids
Source (Ismail, 2013)

2.7. Material

Ismail (2013) found that most contemporary mosques have sound-reflecting materials on most of its internal surfaces, except at the floor level and on horizontal surfaces that are usually carpet finished. Doors made of wood and large openings are probably of single glazing. The positioning of the central chiller units or stand-alone split units inside designated spaces or on rooftops amplifies the background noise levels inside prayer areas and affects the acoustic spatial tranquility of space.

Table 2. Sound absorption and scattering coefficients of materials

Sound absorption and scattering coefficients of materials.

Material	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	Scattering factor
Sand blasted travertine	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.15
Solid timber door	0.14	0.14	0.10	0.06	0.08	0.10	0.10	0.10	0.25
Double glazing	0.10	0.10	0.07	0.05	0.03	0.02	0.02	0.02	0.10
Single pane of glass	0.08	0.08	0.04	0.03	0.03	0.02	0.02	0.02	0.10
Ceramic tiles	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.15
2 × 13 mm gyps. board on frame, mineral wool backing in 50 mm cavity	0.15	0.15	0.10	0.06	0.04	0.04	0.05	0.05	0.10
12 mm wood on studs	0.28	0.28	0.22	0.17	0.09	0.10	0.11	0.11	0.10
Peforated MDF panel-TopAkustik 5/3T, thickness (1.6 cm) with mineral wool backing in 200 mm cavity (130 m^2 in total) or its equivalent	0.20	0.30	0.80	0.95	1.00	0.80	0.60	0.60	0.10

Source: Zühre Sü Gül & Mehmet Çalıskan (2013)

2.8. Role of acoustic design towards the comfort of the worshipper

As studied by Berardo Naticchia (2007), buildings are often inserted in highly inhabited urban areas, near infrastructures and plants radiating high noise levels, the strategic importance of this task is increasing, together with the importance of acoustic comfort inside buildings. They state that acoustic comfort is defined by reducing the noise to an acceptable level.

3. Research methodology

In this research, the method that will be used is a qualitative method. The qualitative method investigates the why and how in this topic, based on analysis of information such as interviews and group discussions, observation and reflection field notes, various texts, pictures, and other materials. According to McNamara (1999), who also mentioned that interviews are particularly useful for getting the story behind a participant's experiences. The interviewer can pursue in-depth information around a topic. Interviews may be useful as a follow-up to certain respondents to questionnaires.

This chapter is divided into two main parts; the first part explained the strategy was chosen and the second part is about the methodologies chosen. The first part explains the surveys, which also included on the scope of study upon mosque with acoustic designs and the choice of Masjid Al-Hussain as the mosque chosen in Perlis. While, on the other hand, the second part is divided into two phases – preliminary study and special study that also included methods for the data collection.

3.1. Case study, Masjid Al-Hussain

The sample mosque was Masjid Al-Hussain situated in Kuala Perlis, Perlis. The study was carried out on various age groups of worshipers that are at the mosque with an age range of six to seventy years old. The mosque was a rectangular plan connected with a 50-metre bridge. The Mihrab's plan ends with semi-circular and formed in concaved. The main prayer hall has only one door with eight side windows and another window on the qibla wall. The unpainted walls of the mosque adorned with corals, quartz, granite, marble and pebbles with four (4) free standing columns. The dome made from two layers of aluminium, with a layer of polyvinylidene difluoride (PVDF) protecting its surface.

3.2. Instruments

This study was carried out through interviews, observations and behaviour mapping. Furthermore, the researcher used the participatory technique in conducting this research on worshiper behaviour. According to (Seamon, 2000) as cited by (Azlina & Zulkiflee, 2012), this approach discovers and defines the situation or experiences of people with the environment. Therefore, this approach was done to know how the importance of acoustic design in the mosques towards the comfort of the worshippers. The study was through observations of worshipers during the Jemaah prayer and motivation lectures. The worshipers were also interviewed through several questions to facilitate a more precise answer. Their feedbacks are analyzed comparatively to determine whether or not, the acoustic design is importance toward the comfort of the worshipers in the mosque.

3.3. Observation

The first instrument of analysis is through observation. A systematic observation was made to observe the worshipers behaviour whether they are comfortable or not when they in the mosque during the Jemaah prayer or lectures. The researcher started the observation during Maghrib prayer. The observation was carried out during Maghrib prayer that is at 7.30 p.m. and during lectures after the prayer. The observation also was made to observe the preferable space chosen when they want to do the worship activities or sit when to hear the lectures in the mosque.

3.4. Interviews

The second instrument of the study is through interviews. The interviews were carried out by the researcher with the selected worshipers from the mosque.

The interview questions are:

- Are you aware the importance of acoustic design in a mosque toward the comfort of the worshipers?

- Is the sound waves from the sea disturb the worship activities?
- Is there any seating preference during motivation lectures? Why?
- Will good acoustic design bring positive effect toward the comfort of the worshipers? Why?
- Should acoustic design approach be applied on every mosque?

3.5. Procedure

Data collection was carried out during the Maghrib's prayer and Maghrib's lectures. The reason for choosing Maghrib time to conduct the research is because the number of worshipers is more compares to the other times. Noise from the surrounding is also higher during that time. Therefore, the effective acoustic design of the mosque can be analyzed accordingly. The observations were from 6.45 pm, about 30 minutes before Maghrib, during the prayer till the following motivation lecture ended. Interviews were carried out immediately before the worshipers dispersed. For references and record purposes a camera used to capture images of the interiors and the surrounding.

4. Data analysis and finding

4.1. The case study

The case study of the research is a mosque located at Kuala Perlis, Perlis. The mosque has a 50-meter bridge connected to the main prayer hall above the water as seen in Figure 5. There are a few "waqaf" along the waterfront for the convenience of the guests while waiting for the prayer time. The landscape pattern of the mosque showed a combination of open spaces, water element and, of course, the indoor space.

a) (b)

Fig.5. 50 meter bridge connects to the main prayer hall

4.2. Acoustic design

The plan of the mosque is rectangular in shape. The Mihrab's plan ends with semi-circular and formed in concaved as represented in Figure 6. As studied by Ismail (2013), the circular shape and quarter spherical top of the Mihrab was geometrically developed to improve the reflected sound component towards the worshipper's direction. The main prayer hall has only one door with eight side windows and another one window on the qibla wall. The door was always closed to prevent the unwanted sound from the outside. The walls of the mosque are unpainted but adorned with corals, quartz, granite, marble and pebbles as seen in Figure 7 with four free-standing columns. It has been observed that this kind of material of the wall helps to block the noise from the outside that are the wave of the sea and the vehicles noise from the main road. Besides that, the vegetation around the mosque also helps prevent and trap the noise go through into the mosque. Based on the research have been done, the dome is made from two layers of aluminium, with a layer of polyvinylidene difluoride (PVDF) protecting its surface. The floor of the main prayer hall also fully covered with carpets in Figure 8.

Fig. 6. Mihrab

Fig. 7. Unpainted walls of the mosque adorned with coral qua7rtz, granite, marble and pebbles

Fig. 8. Carpeted Main Prayer Hall

Fig. 9. The Main Prayer from outside (above water)

Fig. 10.The above the Main Prayer Hall

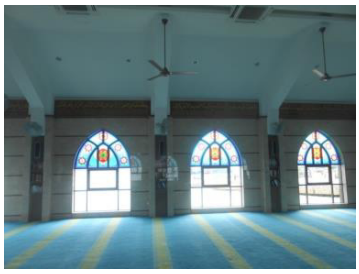

Fig. 11.The placement of Air-Cond Diffuser

4.3. Comfort of worshipers

It has been observed that when the researcher enters the main prayer hall the noised from outside such as the wave of the sea, people voices, the noised from the boats at the sea and the vehicles from the main road was not heard. The presence of air-conditioner unit helps to reduce the usage of fans. Therefore, the noise from the fans can be avoided. The worshipers in the mosque can devote in doing their worship activities with the absent of noise from the outside. During Maghrib prayer, it has been observed that the voice of Imam when reciting the Holy Quran was clearly heard. Meanwhile, when the lectures begin after the Maghrib prayer, it was found that the worshipers have their seating preferences depending on the age group. It is because the lectures can be heard clearly although the worshipers did not sit in front as long they are in the prayer hall.

5. Conclusion and recommendation

5.1. Conclusion

Based on the researched, it can be concluded that this paper has focused on the importance of acoustic design in mosque towards the comfort of the worshippers. Based on the observation and interview, it can be seen that the mosque applied the acoustic design. Although the acoustic design was not that perfect, the acoustic design is still acceptable. Through observation and interview, it can be concluded that the Al-Hussain Mosque applied good acoustic design through carpet flooring, walls adorned with corals, quartz, granite, marble and pebbles, and the mihrab is of semi-circular shape.

However, in Malaysia setting especially in the village, most of the mosques do not take this issue as a vital thing to be addressed. Some of the mosque designers or architects just give the priority on the aesthetics or the form and some of the mosques merely focused to provide as much space as possible to cater for more worshipers.

Besides that, this research indicates that there is a correlation between the acoustic designs of the mosque and the comfort of the worshipers. The worshipers do need a comfortable space for them to carry out the worship activities such as Jemaah prayer, to listen to speeches or lectures, to recite the Holy Quran and many more. In conclusion, the condition for the best acoustic comfort for the worshipers is where the unwanted or annoying sound level and noise is at its lowest.

5.2. Recommendation

Several recommendations are proposed for future research:

- To use a better equipment for the calculation of acoustic comfort in the mosque.
- The research must be conducted at least more than one mosque to make a comparison between the mosques and get a better result.
- The research period must be long enough for a researcher to study and analyze the results properly.

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