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Influence of Proportion towards Speech Intelligibility in Mosque's Praying Hall

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Abstract

This research is to measure the speech intelligibility on few samples of praying halls of different configurations and the influence of design, size and proportion on the overall acoustics performance. The speech intelligibility levels were measured using 01 dB Dual Channel Real Time Frequency Analyser Type Symphonie, and analysed using acoustics software to give the RASTI values. The RT of the sound source was determined using dBBati32. Results of the study confirmed that the proportion of the praying halls does influence the level of speech intelligibility, and very much related to the RT of the space.

Keywords: RASTI (Rapid Speech Transmission Index); RT (Reverberation Time); Sound Audibility; Speech Intelligibility

1. Introduction

Khaiyat (1996) in his study on the general overview of a mosque defined that mosque is a multi-function public space where worshipers performing various activities.

With regards to the mosque's functions, the most important criteria upon which its architectural design should be based on is its acoustical requirements. Some of the basic aural requirements that lead to the optimum acoustical environments are as followed:

- Sound audibility; where all members of the audience could hear an acceptable degree of loudness with some degree of consistency.

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- Speech intelligibility; where all speech sounds should be comprehensible irrespective of the position of the listener.
- Full perception of emphasis laid on some consonants and vowels when reciting Quranic verses.
- Naturalness of the speaker's voice; where the listeners able to determine the location of the sound source and thus, maintaining a feeling of pragmatism and naturalness.

Thus, it must have good acoustical characteristics especially in intelligibility, so that people in the mosque can hear clearly what the speaker has said, the acoustic quality of sound in a mosque can affect the way that people judge sound level.

1.1. Aim

The aim of this paper is to study the influence of a mosque prayer hall's proportion on the speech intelligibility.

1.2. Objectives

There are several objectives of this study:

- To study the design of the prayer hall of sample mosques in Kuala Lumpur.
- To measure the speech intelligibility of particular prayer halls.
- To carry out a comparative study of samples to determine the effect of shape and proportion on the speech intelligibility.

2. Literature Review

2.1. Mosque design

According to Sergeld (1996), mosques possess basic universal design features as spaces for worship. In general, mosques may have a square or rectangular walled enclosure, with a roofed prayer-hall. The prayer hall has relatively high ceilings, where vaults and domes are more frequently used than low ceilings. The long side of the rectangle called the "qibla" wall is always oriented towards the holy mosque in Mecca. Variation in architectural form, constructional systems, and materials used were influenced by regional, cultural and climate.

Zerhan (1999) listed three distinct acoustical requirements for mosques:

- To hear the "namaz" (prayer) orders of the Imam.
- To understand the sermon of the preacher.
- To listen or to join to the recital of the musical versions of the Holy Quran

The final shape of the mosque is determined by the designer or architect, influenced by the Islamic values, teachings and the way the prayer is performed, either individually or in a group, as religiously prescribed.

2.2. Speech Intelligibility

Speech intelligibility is defined as a percentage of speech or words heard correctly by the listeners. It is a vital element of human communication. Without outstanding speech intelligibility, communication is hampered. Good intelligibility is influenced by reverberation time (RT), background noise and distance of the listener from the speaker. Of the three elements, RT and background noise are influenced by the

architecture of the room; therefore, they should be given greater attention at the design stage. However, the quality of speech is also dependent on vocal strength or power, dialect and clarity of the spoken words. In mosques, speech intelligibility is a major concern in a mosque acoustical design. According to Hamadah and Hamouda (1997), the intelligibility of speech in a mosque is essential to the performing of prayers, and other related activities. Noxon (2002) highlighted that in the draft version of the new ISO 9921 standard on the "Assessment of Speech Communication" defined speech intelligibility as "a measure of effectiveness of understanding speech". The measurement is usually expressed as a percentage of a message that is understood correctly. Speech intelligibility does not imply speech quality. Speech intelligibility is related to the amount of speech items that are recognized correctly, while speech quality is related to the quality of a reproduce speech signal with respect to the amount of audible distortions. Thus, a message that lacks quality may still be intelligible.

2.3. Reverberation Time

Reverberation is the perseverance of sound in an enclosed space when the original excitation of sound has ceased. It consists of a series of very closely spaced reflections, or echoes, whose strength decreases over time due to boundary absorption and air losses. Mullan (1983) defined reverberation as the continuing presence of and audible sound after the source of the sound have been stopped. Technically, "reverberation time" referred to as the time taken for the sound to reduce by 60 decibels (dB). Typical reverberation times vary from a fraction of a second in small rooms to five seconds and more at very large enclosures like a prayer hall in a mosque. Different types of rooms and activities require different reverberation times for acceptable acoustical quality.

In general, the best reverberation times are less than 1 second for speech and longer than 1 second for music. Short reverberation times are necessary for clarity of speech; otherwise, the continuing presence of reverberant sound will mask the following sound and cause the speech to be blurred. Longer reverberation times are considered to enhance the quality of music, which will sound "dry" or "dead" if the reverberation time is too short. Larger rooms are judged to require longer reverberation times, as is also the case with lower frequencies of sound.

According to Berg and Stork (1995), the best RT for a speech should be less than 1 second at frequency band of 500Hz and below. The reverberation time of a room must be suitable to the function and volume of the room. Fig. 1 gives the optimum values for these, and they should apply for sound frequency from 125Hz to 4,000Hz. In this research, the reverberation time curve used is of the "Protestant Church" which is being closer to a typical mosque's activities and set-up.

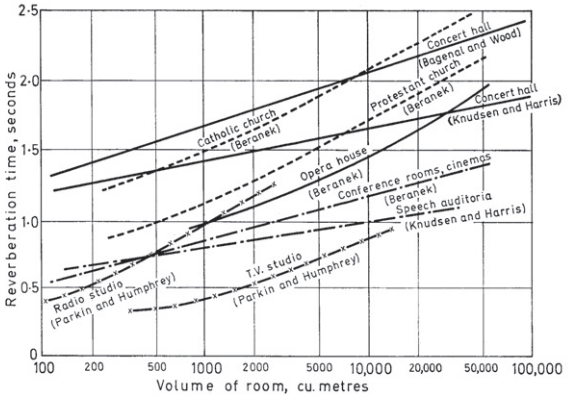

Fig.1. Variation of optimum reverberation time with volume *Sources: Harris,C. M. Handbook of Noise Control, McGraw Hill,1997*

2.4. Rapid Speech Transmission Index (RASTI)

With reference to www.bruel-ac.com/eng/rasti.html, the RASTI-method is an objective method for rating the transmission quality of speech with respect to intelligibility. The method is intended for rating speech transmission in auditorium, halls and room with or without the sound system. It is economical, and time saving for each station can be evaluated either in eight, sixteen or thirty two seconds.

Rapid speech transmission index (RASTI) is a simplified version of speech transmission index (STI). A modulated test signal is fed to a loudspeaker at the talker's location. The receiver's microphone is positioned at the receiver location. The system gives an accurate read out of the measured RASTI value at the receiver position. RASTI can also take account of the effects of reverberation, as well as background noise. It tests in only two frequency band with the assumption that the response of the sound system is more than 100Hz to 8 kHz or higher with a flat frequency response. Poor designed systems often tend to show a too optimistic measurement. The measured values were represented by the properly flat systems with the frequency spectrum. RASTI is an index, which varies between 0 and 1, and used as a measurement rating of the speech intelligibility. Fig. 2 below converts RASTI values to more qualitative interpretation description of the speech transmission quality.

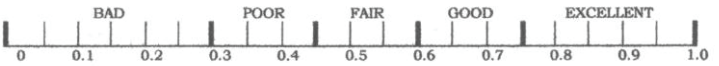

Fig. 2. Qualitative interpretation of RASTI. *Sources: Bruel & Kjaer, Acoustic Noise Measurements, 1988*

3. Methodology

Six samples of mosques around Kuala Lumpur were selected of various shape, sizes and proportion. For acceptable comparative purposes, the material used in each respective mosque is about the same, i.e. the floor is carpeted, the wall is of brick and plastered, and the ceiling is of asbestos or cement rendered. Field measurement using acoustical instrument was used to measure acoustical room criteria, and acoustical software was used to analyze the data and give the value of RASTI (rapid speech transmission index). The intelligibility level will be determined using Rapid Speech Transmission Index (RASTI). The measurement is done inside the mosque when the mosque is empty. The notebook computer and the sound amplifier were located at a suitable place which provides reasonable distance from the sound source. The sound source was placed in the "mihrab" area situated at the front of the main prayer hall, and the microphone was placed at the points marked along the role of the jemaah *saf* (aisle) to forming a grid. The microphone is mounted on the tripod at the height of about 1m from the floor and placed at 1m away from any reflective surface.

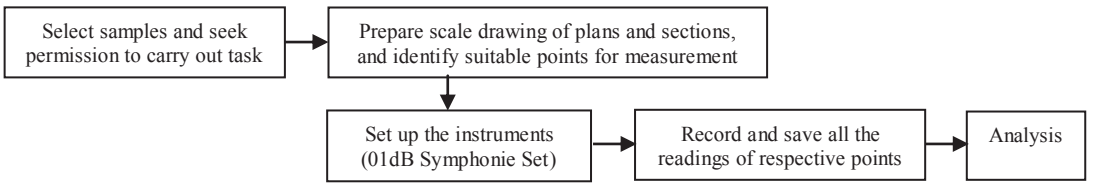

Fig. 3. The flow diagram of the research procedure

4. Results and Discussions

Table 1. The average RASTI and RT for the six case studies.

Prayer hall	Volume (m^3)	RASTI	RT	Design RT
Masjid Jamek Sungai Besi	539	0.67 (GOOD)	1.30	1.00
Masjid Jamek Selayang Lama	710	0.65 (GOOD)	1.20	1.10
Masjid Jamek Jalan Haji Salleh	809	0.71 (GOOD)	0.98	1.10
Masjid Jamek Tengku Abdul Aziz Shah	1,687	0.69 (GOOD)	1.44	1.25
Masjid Jamek Sungai Mulia	4,219	0.57 (FAIR)	2.41	1.40
Masjid Jamek Bandar Manjalara	12,200	0.48 (FAIR)	3.32	1.70

4.1. Masjid Jamek Sungai Besi

The floor dimension is 14m x 11m. The average RASTI value for this prayer hall is 0.67, which is 'Good' under the qualitative interpretation of RASTI, while the average RT is 1.30 seconds. With the volume of this prayer hall at 539m^3, the design RT should be at 1.00 second. As the RT of this prayer hall is higher than the design RT by 0.3 second, it is not an acceptable condition for speech intelligibility. The actual RT is more than 1 second, which means that the even though listeners can still hear what the speaker is saying, the quality of the speech is a bit blurred.

4.2. Masjid Jamek Selayang Lama

The floor dimension is 14m x 14.5m. The average RASTI value for this prayer hall is 0.65, which is 'Good' under the qualitative interpretation of RASTI, while the average RT is 1.20 seconds. With the volume of this prayer hall at 710m^3, the design RT should be at 1.1 seconds. As the RT of this prayer hall is higher than the design RT by 0.1 second, it is not an acceptable condition for speech intelligibility. The actual RT is more than 1 second, which means that the even though listeners can still hear what the speaker is saying, the quality of the speech is slightly blurred.

4.3. Masjid Jamek Jalan Haji Salleh

The floor dimension is 13.4m x 12.3m. The average RASTI value for this prayer hall is 0.71, which is 'Good' under the qualitative interpretation of RASTI, while the average RT is 0.98 seconds. With the volume of this prayer hall at 809m^3, the design RT should be at 1.1 seconds. The RT of this prayer hall is lower than the design RT by 0.12 seconds, which is good that listeners can hear what the speaker is saying.

4.4. Masjid Jamek Tengku Abdul Aziz Shah

The floor dimension is 15.4m x 27m. The average RASTI value for this prayer hall is 0.69, which is 'Good' under the qualitative interpretation of RASTI, while the average RT is 1.44 seconds. With the volume of this prayer hall at 1,687m^3, the design RT should be at 1.25 seconds. As the RT of this prayer hall is higher than the design RT by 0.19 seconds, it is not an acceptable condition for speech

intelligibility. The actual RT is more than 1 second, which means that the even though listeners can still hear what the speaker is saying, the quality of the speech is blurred.

4.5. Masjid Jamek Sungai Mulia

The floor dimension is 21m x 24.6m. The average RASTI value for this prayer hall is 0.57, which is 'Fair' under the qualitative interpretation of RASTI, while the average RT is 2.41 seconds. With the volume of this prayer hall at 4,219m3, the design RT should be at 1.4 seconds. As the RT of this prayer hall is higher than the design RT by 1.01 seconds, it is not an acceptable condition for speech intelligibility. The actual RT is more than 1 second, which means that the even though listeners can still hear what the speaker is saying, the quality of the speech is rather blurred.

4.6. Masjid Jamek Bandar Manjalara

The floor dimension is 40m x 40m. The average RASTI value for this prayer hall is 0.48, which is 'Fair' under the qualitative interpretation of RASTI, while the average RT is 3.32 seconds. With the volume of this prayer hall at 12,200m^3, the design RT should be at 1.7 seconds. As the RT of this prayer hall is higher than the design RT by 1.62 seconds, it is not an acceptable condition for speech intelligibility. The actual RT is more than 1 second, which means that the even though listeners can still hear what the speaker is saying, the quality of the speech is extremely blurred.

5. Conclusion and Future Studies

The mosque with the best speech intelligibility is Masjid Jamek Jalan Haji Salleh which has the highest RASTI rating of 0.71. The prayer hall is small and simple, and this gives excellent speech intelligibility while the interior of the prayer hall uses non reflective material that absorbs the sound. For Masjid Jamek Tengku Abdul Aziz Shah, Masjid Jamek Sungai Besi and Masjid Jamek Selayang Lama, the speech intelligibility are good in the prayer halls with RASTI rating of 0.69, 0.67 and 0.65 respectively, however, the RT measured were not so acceptable, i.e., between 1.20 to 1.44. The best RT should be less than 1 second in the frequency of 1 KHz and below.

In the case of Masjid Jamek Sungai Mulia and Masjid Jamek Bandar Manjalara, the speech intelligibility is fair, with RASTI rating of 0.57 and 0.48 respectively. The RT is high in the range of 2.41 and 3.32 seconds at the 1 KHz frequency. For both examples, the prayer halls are not good for speech intelligibility; the speech heard is blurred and likely to be misunderstood.

On the proportion aspect, we can see that the bigger the volume the bigger the RT, even though the material used is almost the same. However, for RASTI rating there is a slight variation depending on the shape and proportion (length, width and height). Too big the volume of the prayer hall will have a small RASTI rating, hence, poor speech intelligibility, as can be seen at Masjid Sungai Mulia and Masjid Jamek Bandar Manjalara, where both of the prayer halls having enormous dome. Therefore, these lofty prayer halls require acoustic treatment if speech intelligibility are to improve.

However, this does not stop us to build large prayer halls, but to control the proportion. If we look at the sizes of the Masjid Jamek Sungai Besi, Masjid Jamek Selayang Lama and Masjid Jamek Jalan Haji Salleh, even though the floor areas almost the same, but due to variation in the plan aspect ratio (length: width), they have different RASTI rating. On this note, we can conclude that rectangular prayer hall (longer side facing the Qibla) is the best proportion to achieve optimum speech intelligibility. Therefore, proportion do influence the speech intelligibility in a mosque's prayer hall, however, to have optimum

prayer hall design many other parameters need to be considered, besides acoustics, visual and thermal comfort also need to be addressed.

Based on the conclusions, there are several recommendations for future studies of the following areas;

- To do a detail comparative analysis between speech intelligibility and the daylighting through dome design.
- To do a comparative analysis between speech intelligibility and RT with multiple sound sources.
- To do a cost analysis in achieving optimum speech intelligibility in the prayer hall design.
- To study the effect of noise from mechanical ventilation system towards speech intelligibility.

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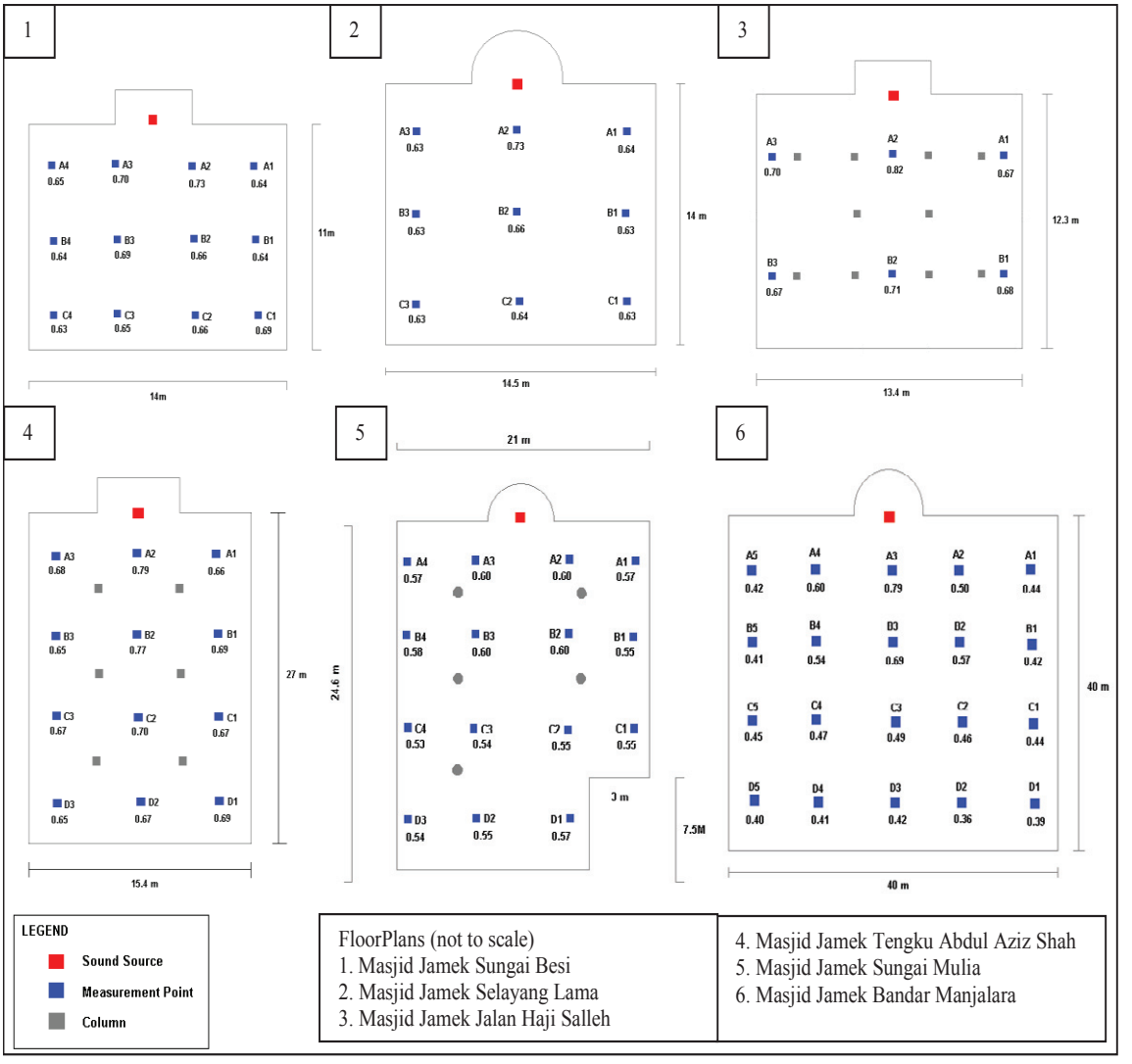
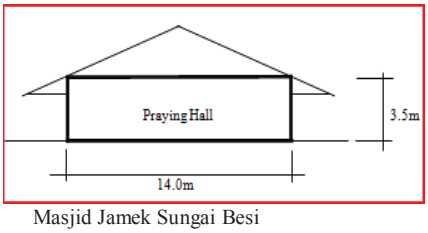
Appendix A.

Prayer Hall floor plans of respective mosque showing the measurement points (not to scale)

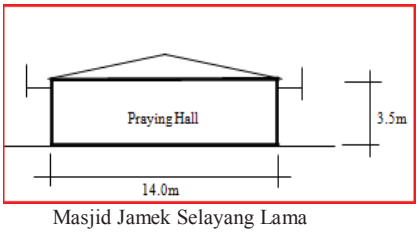


Appendix B.

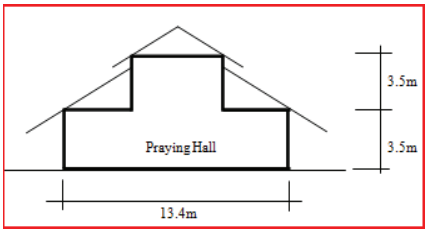
Cross section through Praying Hall of respective mosque (not to scale)



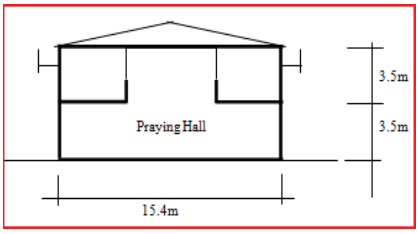
Masjid Jamek Sungai Besi



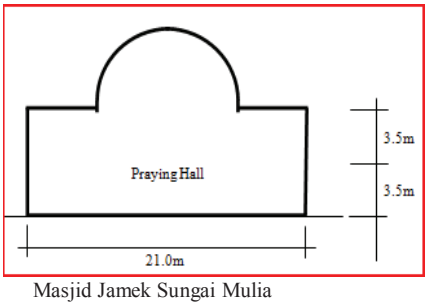
Masjid Jamek Selayang Lama



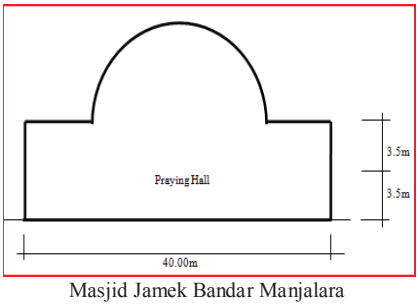
Masjid Jamek Jalan Haji Salleh



Masjid Jamek Tengku Abdul Aziz Shah



Masjid Jamek Sungai Mulia



Masjid Jamek Bandar Manjalara