SUPERVISOR DECLARATION

"I admit to have read this report and it has followed the scope and quality in Partial Fulfillment of Requirement for the Degree of Bachelor of Mechanical Engineering (Structure and Material)

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Date: JUNE 2013

ACUSTIC OF MOSQUE: THE EFFECT OF ROOF SHAPE ON IT'S ACOUSTIC PERFORMANCE

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ADMISSION

I admit that this report is the result of my own work except for the summary and each passages which I have mentioned the source.

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ABSTRACT

Speech intelligibility has been found to be a major concern in mosques due to lack of acoustical concern of their design stage. Speech intelligibility is a major concern in mosque acoustical design. The design of roof can be one of the contributors to a poor speech intelligibility inside a mosque. This study investigates the acoustical performance of different roof shapes of commonly built forms of mosque utilizing room-acoustics computer models. Simulation of three different roof shapes namely dome, pyramidal and flat shapes are conducted using the CATT indoor acoustic software to obtain acoustic parameters such as Reverberation Time (RT-30), Early Decay Time (EDT), Clarity (C-80), Lateral Fraction (LF), Definition (D-50) and Speech Transmission Index (STI). The purpose of this project is to identify the effect of the roof shapes on its acoustical performance, particularly on the spatial distribution patterns of speech intelligibility in the absence of sound reinforcement system. Speech intelligibility contours were quantified and compared to characterize acoustics merits, dissimilarities and overall acoustics performance. The gaining of the knowledge of the acoustical performance of mosque give positive and good reflection of the results. Therefore, it is confirmed that with the large volume of mosque and the different type of ceilings, acoustical performance can be improved with the help of acoustic materials and resonators which it can help in performing well in reducing the reflected sound energy especially for the late energy reflections.

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INTRODUCTION

1.1 BACKGROUND

Nowdays, the architectural design of buildings always becoming a barrier to clear communication between building occupants. Ambient noise level in some facilities or buildings type are trending up and the architectural design of the building is the main reason that cause the poor clarity of speech between occupants. For many public spaces such as the places of worship are design to enable the users to hear the space and the level of activity and excitement within it.

Mosque is the important building for muslim society, because it's a place for them to do many islamic activities [1]. Most of the activities need the clarity of sound, like jamaah daily prayers and Friday speech [1]. Those can be done well if only the most have a good quality of acoustics. On the first scrutiny that have been done before, a lot of mosque nowdays has less attention in the acoustical problem. Many of them have reverberation problem and bad sound distribution. This may cause the different clarity level of imam's voice to people who sits in the different area of the mosque. This problem could happen whether in a big mosque with reinforcement system or in a small mosque without one.

In this research, the study of architectural design of mosque will be the main part of the project to clarify the important of the design to its acoustic performance in the way to contribute good acoustical performance. The roof design is likely to be the main part of the design that will be discussed in this research This is because the shape of the roof shape is the major problem that always give to poor acoustical performance inside mosque.

Other than that, most of the mosques in Malaysia are using reinforcement system. Although it's a small mosques or huge, it's still depending on the reinforcement system [2]. It means that the sound distribution in those mosques is not good enough. Thus, some special strategies are needed in designing a good mosque with a good acoustic quality without reinforcement system. This study will give the result of good acoustical performance in the way to give best decision for the architects to choose their design before constructing the worship buildings.

1.2 PROBLEM STATEMENT

The architectural design of roof mostly contribute to a poor acoustical design. This oftenly generate poor speech intelligibility inside mosque and the roof design is the major problem that will affect the sound distribution inside mosque. Poor acoustic of sound inside mosque will always contribute to poor clarity of speech inside mosque. In this research, the main concept of the roof design that have tendency to influence the reflection of the sound rays and also give the result of the sound behavior due to the absortive and reflective material inside mosque.

1.3 OBJECTIVES

To assess and to discuss the effect of different roof shapes on the acoustical performance using CATT software.

1.4 SCOPE

This final year project only focused on the experimental of acoustic performance using CATT software, which only to model the shape of roof and hall and to assess acoustic parameter inside mosque. Measurement were taken to design the model and from the design it can show the best architectural design of roof which obey the important of acoustical performance. The project also intends to find the result of the clarity of speech through different designs of roof shape. In using CATT software, parameter of the three selected roof design will be conducted. The audience area mapping will be designed for each roof shape.

The audience area mapping will be included the audience and floor surface, walls and ceiling, entrance wall and door, the stage, source and receiver locations, and lastly side wall relfectors. The diamension of the design will proposely follow the actual size of the basic mosque and the size of the design of the mosque will be the same in the way to give fair result for all the designs that have been made. The design will be made by pointing every corners of the design through x, y, and z axis. The material characteristic will be included in every part of the design.

This audience area mapping however will give colour mapping of parameters and direct sound over selected audince planes based on ray-tracing. Other than that, after completed conducting the audience area mapping for each roof shape using CATT software, early part detailed ISM will be selected to be used for prediction module to calculate image source for the early part of the echogram. This calculation type is to be used for qualitativeearly specular reflection path analysis. Finally, full detailed calculation will be conducted to perform prediction module.

A mosque needs a good sound distribution, that is why the selection of the right dome shape has to be done. The size, shape and the height of the dome shape has to be well-selected. The selection of the size, shape and the height of the dome can contribute to the excessive or lack of sound reflection that can cause reverberation or echos. This project need in obtaining of six acoustic parameters such as reverberation time (RT-30), Early Decay Time (EDT), Clarity (C-50), Lateral Fraction (LF), Definition (D-50) and Speech Transmission Index (STI). These modification were used to determined some strategies to create a better acoustic quality of the mosque in this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Sound

Every day we are exposed to sound either it is not required, necessary, or beneficial, twenty-four hours a day, seven days a week. In a physical way, there was no different between sound and noise.

Sound is a sensory perception by human [3] which it is can be define as a pressure variation that travels through air (wave) and can be detected by the human ear [2]. Sound wave that travels through air is the resulting of the physical disturbance of air moleculessuch when tapping a tuning fork and the waves will combine to reach the listener direct or indirectly [4].

In a general way, the sound wave is any disturbance that transmitted in an elastic medium consisting of gas, liquid, or solid [5]. Although sound travels and can be heard but not all the sound are audible. Limits of audibility are only from 20 Hz to 20 kHz [6]. Sound below 20 Hz is infrasonic sound and sound greater than 20 kHz is an ultrasonic sound.

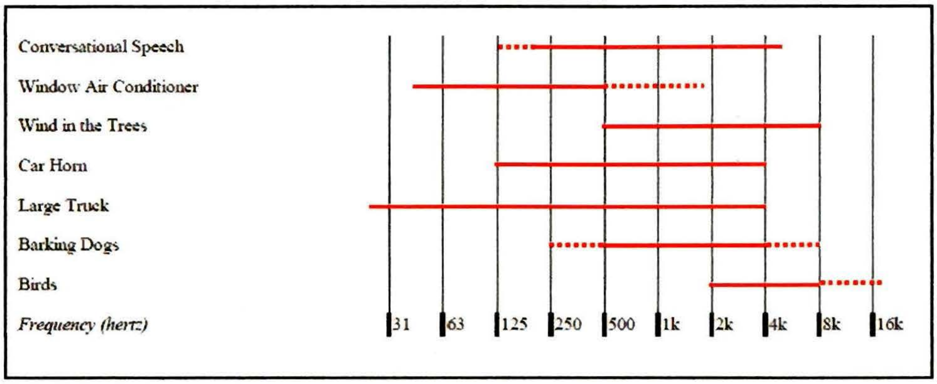

Figure 1 : Frequency range of typical sound source [2]

Decibel (dB) is the most common unit of sound measurement is the decibel, and is abbreviated as dB [6]. The threshold of hearing is considered to be 0 dB, and the range of sounds in normal human experience is 0 to 140 dB.

2.1.2 Sound Absorbtion

Every material has its own ability to absorb sound energy. Material that has low absorption ability tends to reflect most of the acoustical energy and vice versa. Sound absorption is a capability of a material to convert sound energy into other energy.

This energy is usually converted to heat energy [9]. The property of a material absorbing ability is called sound absorption coefficient at a particular frequency range.

Absorption material in building usually used Noise Reduction Coefficient (NRC) with the average sound absorption coefficient range of 250 Hz to 2 kHz with NRC of 1.0 as perfectly absorptive and NRC of 0.0 as perfectly reflective for its scale [4].

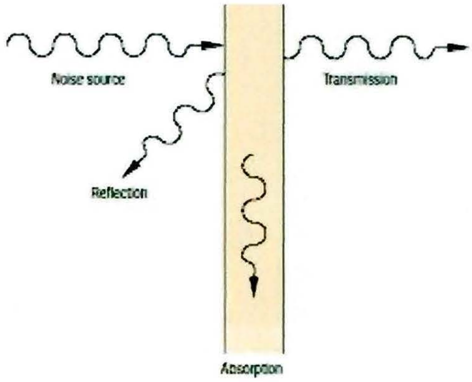

Figure 2 : The ray path of the reflection and absorbtion of sound [4]

2.2 Mosque Design

According to previous research by Sergeld in 1996, mosques aalways give basic design features as spaces for worship. In general, mosques may have a square or rectangular walled, with a roofed prayer-hall. The prayer hall has relatively high ceilings, where vaults and domes are more frequently used than low ceilings [8]. The long side of the rectangle called the "qibla" wall is always pointed towards the holy mosque in Mecca. Variation in architectural form, constructional systems, and materials used were influenced by regional, cultural and climate in certain countries. According to Zerhan from his research in 1996 listed three distinct acoustical requirements for mosques [9] :

- To hear the prayers 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.

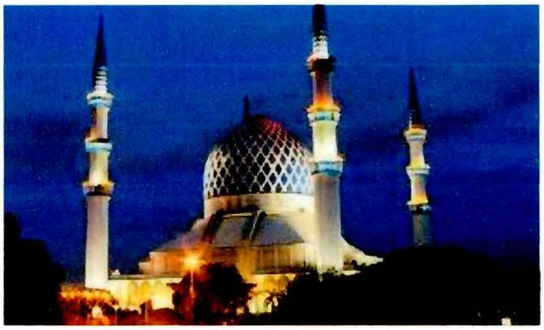

Figure 3 : Typical design of mosque in Malaysia

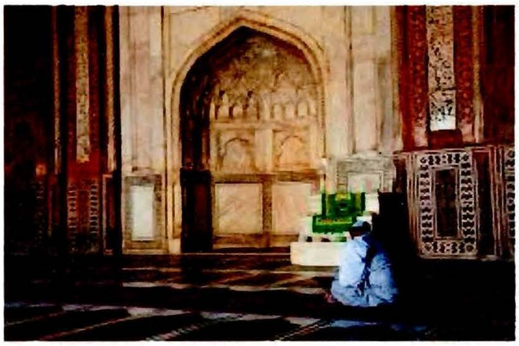

Figure 4: Place of imam to recite prayers order inside mosque.

2.3 Reverberation Time

When a sound is triggered or generated in a room, many things will happen in the blink of eye. The reflecting boundaries of the room will result repeated reflections which determine the rapid establishment of more or less uniform sound field. And this field then decays as the sound energy is absorbed by the bounding materials. The reflecting surface with its absorptive ability will determine the rate of the sound energy decays. And time taken for the sound intensity to decays for 60 dB (decibel) is called the "Reverberation Time" [10,11,12].

The Reverberation Time is an important part as a quantity for characterizing the acoustic properties of a room. When building a room, the first step in architectural acoustic design is to identify the good values of the reverberation time depends on the function of the room. Furthermore, we can specify the materials that to be used in the construction which will achieve the desired value of the Reverberation Time.

For an example, a classroom should have the reverberation time in the range of 0.4 to 0.6 seconds. But in reality, many did not manage to achieve the suitable reverberation time and having reverberation time of 1 second and more. In such reality cases, teachers have to compete against the lingering reflection of his or her own voice to get the student's attention. The result is a chaotic jumble of sound [10].

In 1922, a pioneer in the study of room acoustics, Wallace Sabine came up with the formula which is defined as equation (1) below,

$$RT = 0.16m^{-1}\frac{V}{S\alpha} \quad (1)$$

The equation (1) above show that the RT is the reverberation time, V is for the room volume in m^3, S will be the total surface area in m^2, and lastly the symbol α is the average of the absorption coefficient of room surfaces.

The formula is based on the volume of space and the total amount of absorbtion within a space. The total amount of absorbtion within a space is refered as " Sabins" where the product of $S\alpha$ is the total absorption in sabins.

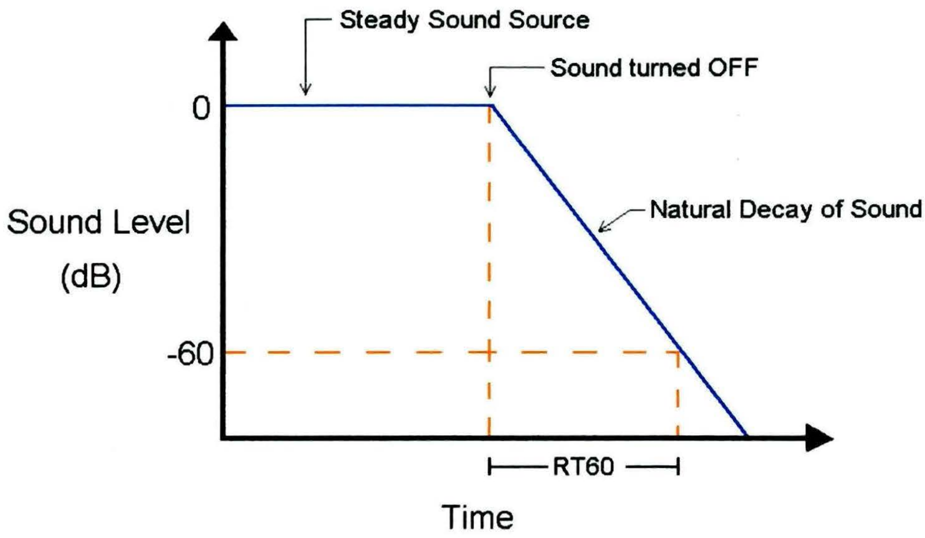

Figure 5: The diagram of RT60 where T is defined as the duration required for the space-averaged sound energy density in an enclosure to decrease by 60 dB after the source emission has stopped [11].

Things that will be effect reverberation are size of space and the amount of reflective or absorbtive surface within space [10]. A space with high absorbtive surface will absorb the sound and stop it from refecting back into the space [11]. This world yield a space with a short reverberation time. Reflective surfaces will reflect sound and increase the reverberation time within space. Therefore, a large space will need more absorbtion instead of reflection in the way to achieve the same reverberation time as a smaller space.

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 give "dead" environment 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 on their research in 1995, the best RT for a speech should be less than 1 second at frequency band of 500Hz and below [13] .

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 [13].

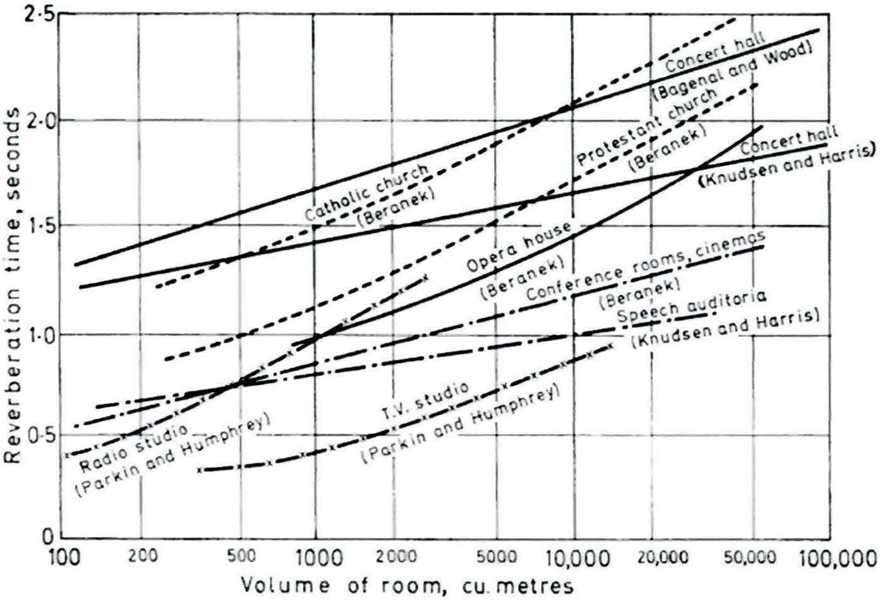

Figure 6: The variation of optimum reverberation time with volume [19]

2.4 Speech Intelligibility

Speech intelligibility is defined as a percentage of speech or words heard correctly by the listeners. It isa vital element of human communication. Without outstanding speech intelligibility, communication is hampered. Good intelligibility is influenced by reverberation time (RT), background noise and distance ofthe listener from the speaker. From 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 on their research in 1997 , the intelligibility of speech in a mosque is essential to the performing of prayers, and other related activities [14] . From Noxon in his research in 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" [15]. 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.

Speech intelligibility in the mosques is a crucial aspect in order for the congregation to perform congregational prayerand to hear Friday's speech, tazkirah (short reminder) and lecture given. When performing daily prayer in congregation, the congregations must hear clearly recitation done by the Imam (leader) before following the actions, and movements. Regularly, tazkirah or lecture will be held after the congregational prayer. During Friday prayer, the Imam stands up to deliver Friday's speech before lead the prayer. Hence, acoustic quality and speech intelligibility is a vital aspect in the construction of mosques.

2.5 Rapid Speech Transmission Index (RASTI)

RASTI method is an objective method for rating the transmission quality of speech with respect to intelligibility [16]. The method is intended for rating speech transmission in auditorium, halls and room with or without the`sound reinforcement 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 [16].

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.

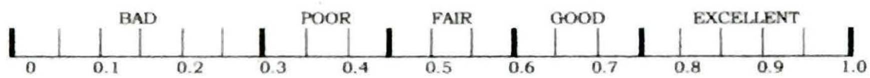

Figure 7 : Qualitative interpretation of RASTI [16]

2.6 Early Decay Time (EDT)

EDT is the initial rate of decay of reverberant sound appears to be more important than the total reverberation time. Early Decay Time (EDT) could be defined as 6 times the time interval from 0dB to -10dB on the decay curve. A rapid initial decay is interpreted by the human ear as meaning that the reverberation time is short.

The intergration of the early decay time can be defined as the equation (2) below:

$$E(t) = \int_t^\infty p^2(\tau)d\tau \quad (2)$$

The equation (2) above show the Schroder integration for the Early Decay Time rate of sound decay over the first 10 dB, expressed in the same way as a reverberation time. EDT is relates to perceived reverberance. In a diffuse field it