Acoustical analysis and improvement - A case study of Asgar Ali Chowdhury Jame Moshjid, Halishahar, Chittagong

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Abstract— This paper investigates the acoustical characteristics of Asgar Ali Chowdhury Jame Moshjid which is situated at Halishahar, Chittagong. The acoustical characteristics of the mosque were analyzed by percentage of syllable articulation (PSA) test including reverberation time (RT). The results show the existing situation of acoustical requirements in terms of sound intelligibility and reverberation time. This Paper will draw a recommendation to solve the founded acoustical problem from the investigation.

Index Terms— Acoustic, Intelligibility, Mosque, Materials, PSA test, Reverberation time (RT), Speech

1 Introduction

Mosques are multi-function public spaces where various worship activities are performed through various modes of use. Sounds in a mosque might be classified in major two categories -recitation and speech. Recitation from the Holy Koran is conducted during prayers and as citation during theological speech [1]. Unfortunately, most of Bangladeshi mosques' typological form were given very little attention about their acoustical problem. So poor intelligibility and high RT are some common scenarios in Bangladeshi mosques. The term intelligibility refers to a qualitative term that describes the ability of an acoustic environment to transmit speech intelligibly [2] and it is expressed in the percentage of correctly received phrases [3]. Some strategies can be practiced on mosque's interior surfaces such as ceiling, walls, and floor to deduce the optimum RT that fulfills the requirements of both recitation and speech intelligibility.

2 Methodology

-Field survey through the android app 'Noise Meter' instead of Sound Level meter
-PSA test
-Preparing a basic plan and section
-Calculating RT
-Comparing the present RT and Optimum RT
-Formulation of recommendation.

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3 Literature Survey

The mosque as an important building type of Muslim architecture has evolved to meet Islamic needs. A variety of different worship activities happen within these multifunctional public spaces; these different uses have different acoustical requirements. As in many other religions, worshippers sometimes need solitude while at other times they want to feel in absolute unity with the others present [4]. Acoustics are one of the basic means of creating different effects [5]. Although mosques are uniquely important buildings in every Muslim community, their acoustical quality has not received adequate attention especially in recent examples.

The importance of mosque acoustics has long been realized. The importance of mosque acoustics in terms of clarity of speech is very essential. Besides the cleanliness, spaciousness, serenity in mosques that are required by the congregation to perform prayers and other religious rituals, Friday sermon and lectures are important speech activities in mosques. Through these activities, the congregation will be hearing messages of reminder of their religious and social duties.

Speech intelligibility in the mosques is a crucial aspect in order for the congregation to perform congregational prayer and to hear Friday's sermon, 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 sermon before lead the prayer.

According to Everest and Pohlman 2009, speech intelligibility in a room is often estimated using subject-based measures that are by using live experimentation. A talker reads from a list of words and phrases, and listeners in the room writing down what they hear. The list includes examples of important speech sounds. Between 200 and 1.000 words are used per test. The higher the percentage of correctly understood words and phrases, the higher the speech intelligibility. In some cases,

listening difficulty is measured. When level of speech is the same as the noise level, intelligibility can be high, but listeners can still have difficulty in understanding what is being said, and considerable attention is required. When the speech level is raised by 5 or 10 dB over the noise, intelligibility is not greatly improved, but listeners report much less difficulty in hearing.

Percentage of Syllable Articulation (PSA): The percentage of meaningless syllables correctly written by listeners is called Percentage of Syllable Articulation. The minimum admissible PSA should be 75% for a satisfactory Speech Intelligibility [6].

Reverberation Time (RT): The reverberation time of a room is defined as the time required for the sound pressure level in a room to decrease by 60 dB after the sound is stopped, and is calculated by the formula, RT= 0.16V/A+xV [6]

Where :
RT= Reverberation time in second
V= Room Volume in cubic feet
A=Total room absorption in m^2 sabin
x= Air absorbent coefficient

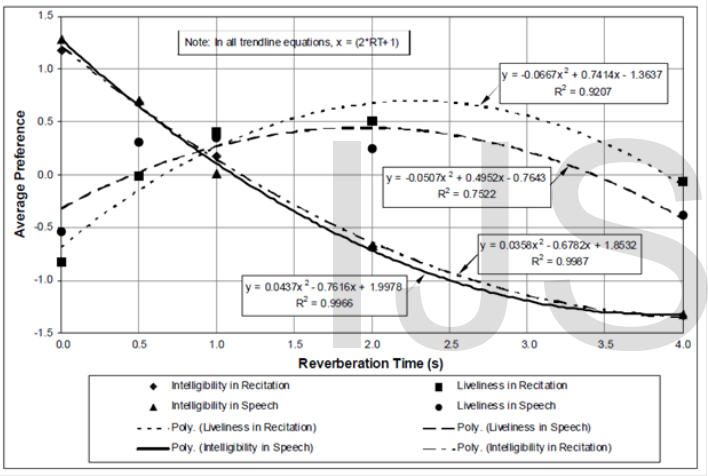

Fig1. Shows the average preference for varying Reverberation Time [1]

The two types of sounds in a mosque, recitation and speech, are unique in terms of their inherent nature and preferences to the respondents. The average preference for intelligibility in recitation and intelligibility in speech decreases with the increase of corresponding RT. Average preferences for liveliness in recitation and liveliness in speech initially rise with the increase of RT until it reaches at about RT of 2.0 to 2.5 s, but starts falling off beyond that, which happens earlier for speech than for recitation. Since in general terms, RT adds reverberance or liveliness; it might be generally assumed that more the RT more the liveliness. This assumption is proved erroneous basing on the derived data and also on the explashow extreme diversity in nature of preferences.

Considering preferences of all aspects the optimum RT is proposed as 0.9 s for an overall balanced acoustical performance for both recitation and speech for a mosque in Bangladesh [1].

4 Information of The Mosque

Asgar Ali Chowdhury Jame Moshjid is an example of contemporary mosque. It is constructed at 2015. It is located at the back of old Asgar Ali Chowdhury Jame Moshjid which was built over 200 years ago. The old mosque is now conserved as a heritage building. The newly build mosque is surrounded by agricultural land and beautiful nature. There is a 'Shaan' space in front of it along with a small water body to the South. The old mosque is adjacent to the 'Shaan' space. In front of the old mosque there is a 12 feet wide road and a big pond beside the road. A primary school is located at the North-West corner of the mosque. There is no mentionable noise source in this area rather it's a quiet and calm place blended with nature.

Fig2. The site and surroundings from google map.

Fig3. Exterior perspective

5 Geometry and Materials

The composition of materials in this mosque is some reflective and absorbing materials which are rough concrete wall, huge wooden doors, some glass works at the top corners. Ceiling is composed with rough concrete and glass. All area

of the floor is covered by mosaic floor finishing. A square plan mosque with a cubic form is very significant. The semi outdoor space is surrounded by massive steel Jali (net). The main prayer hall is consists of a square plan of 38′-0′′ X 38′-0″ and height of 38′-0″. The main prayer hall of this mosque has an estimated volume of 54,872 cubic feet and a floor area of 1444 square feet. No extra acoustical design is noticeable in this mosque.

Fig4. Interior perspective shows the west facade details

Fig5. Interior perspective shows the north-east corner details

6 Field Survey and Analysis

6.1 Ambient Noise

The ambient noise is measured with the help of android app namely 'Noise Meter'. Noise has been measured from four corners and the center of the prayer hall. The average ambient noise is measured 40.3 dB when the fans are switched off and 65.23 dB when those are switched off.

6.2 PSA Test

A group of volunteers participated in the test. The age range of volunteers is 20 to 23 and they all have good capability of hearing the sound. 15 volunteers have been set equally in the front, middle and back row in the prayer hall. The syllables have been pronounced from the 'Mihrab' through a microphone where the *Imam* (prayer leader) usually performs. There were two speakers on the West wall. Two different sets of syllables script each containing 36 meaningless words has been pronounced keeping the fans switched off and on respectively. The volunteers have written those words on the provided blank scripts as they have heard those for the first time. The average outcomes of PSA test are quite interesting which are given below:

Keeping the fans off:

a) Front row - 39%
b) Middle row - 35%
c) Back row - 13%

Keeping the fans on:

a) Front row - 52%
b) Middle row - 49%
c) Back row - 20%

The PSA is even better when the fans are switched on. However the result shows that in both cases the speech intelligibility of this mosque is below satisfactory level and the listeners of back row actually do not understand any unknown words. Again the test has been done with the meaningful sentences (Hadith from 'Sohih Bokhari Sharif') contains Bengali and Arabic words. Almost every participant understood the Hadith at a satisfactory level except the Arabic words.

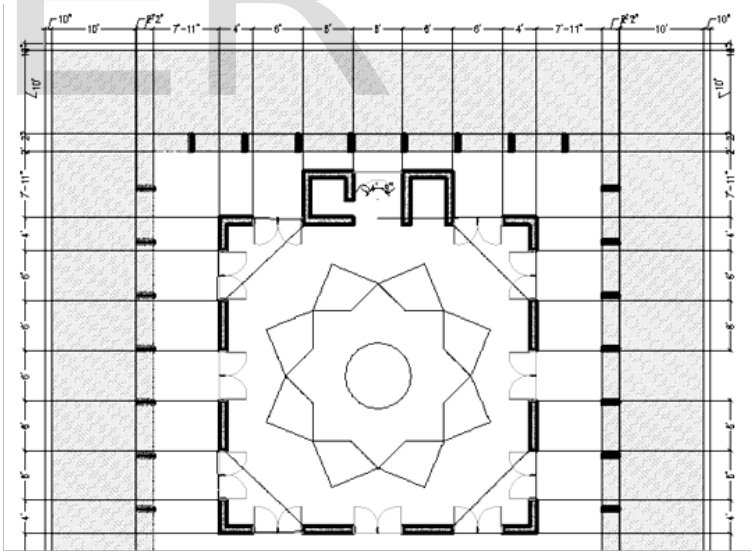

Fig6. The main prayer hall plan with detail dimensions

6.3 Calculation of the RT

RT=0. 05V/ A+xV (for English units) [7]
Where:
RT= Reverberation time in second
V= Room Volume in cubic feet
A=Total room absorption in sabin
x= Air absorbent coefficient in thousand ft-cube

Content	Materials	Area (sft)			Co-efficient at 500 hz	Absorbent
South wall	Concrete wall	1165			0.03	34.95
	Wooden door	165			0.14	23.1
North wall	Concrete wall	1165			0.03	34.95
	Wooden door	165			0.14	23.1
West wall	Mihrab glass wall	55			0.04	2.2
	Concrete wall	1165			0.03	34.95
	Wooden door	110			0.14	15.4
East wall	Concrete wall	1165			0.03	34.95
	Wooden door	165			0.14	23.1
Floor	Mosaic	1444			0.01	14.44
Ceiling	Glass	580			0.02	11.6
	Concrete	865			0.03	25.95
Four corners	Glass	528			0.02	10.56
	Wooden frame	92			0.14	12.88
Congregation	people	200		Considering 50%	.42	42
				Total		344.13

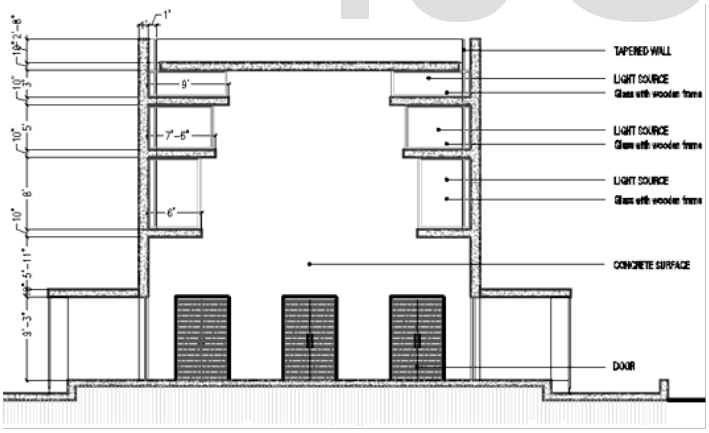

Fig7. Section shows the details of North, South and East facade of main prayer hall.

So, RT= 0.05 X 54,872 / 344.13
=7.97 s

This is calculated when the door is closed. But when the door is open the room absorption is increased to 769.83 sabin.

Then RT =.05x54872/769.83
=3.56 s

Here the calculation shows RT is excessive where allowable reverberation time is .9 s in Bangladeshi Mosque [1].

6.4 Getting Optimum Reverberation time

From the previous research it is depicted that for Reverberation time should be .9 s. To getting this following data is measured

The total room absorption A should be
=.05 V/0.9 =.05 X 54,872 / 0.9
= 3048.45sabin

Existing absorption (considering door is open)
= 769.83
So the required sabin is = 3048.45 -769.83
= 2278.61

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7 RECOMMENDATIONS

7.1 Absorption by Walls

If the present aesthetic value of the prayer is ignored then some absorptive materials with good NRC (Noise Reduction Coefficient) value can be installed on the walls. Acoustic building materials are generally rated by their noise reduction coefficient (NRC). A material is usually considered to be a sound absorber if it has an NRC value greater than 0.35.When absorptive materials are placed over a surface, one must take into account the loss of absorption provided by the original surface. The net increase in absorption over an area is the absorption coefficient of the new material minus the coefficient of the original material [2].It is important to remember that the NRC is an average value, and also only accounts for absorption at middle frequencies. NRC is therefore most useful for speech applications [2]. Introducing as much sound-absorptive treatment as convenient in the mosque has the following advantages:

1. The mosque will be quieter (except for persons located in the direct sound field)
2. The overall sound level will be reduced.
3. The treatment will tend to localize noises in the area of their origin.
4. The RT will be reduced. This is particularly beneficial in speech and recitation.

7.2 Imputing Sound Reinforcement Systems (SRS)

If the present aesthetic value is considered then it is recommended to impute sound reinforcement systems (SRS). There is a microphone and two speakers at the mosque which are not sufficient in terms of intelligibility. According to Canvanaugh 'Good sound is central to the function'. Good amplified sound system can solve the existing problem of high RT and poor speech intelligibility.

Well-designed sound reinforcement system provides:

1. Appropriate loudness for the program without distortion
2. Uniform coverage both spatially and over the frequency range
3. Illusion that sound is originating from the original source should be preserved
4. Must not cause to acoustical defects such as echo
5. Should be sensitive to the architecture [7].

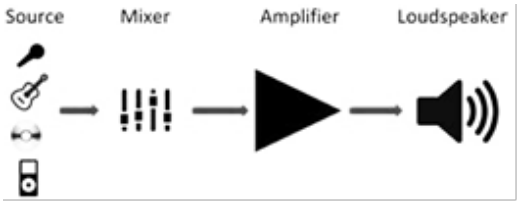

Fig8. Shows how SRS works.

8 CONCLUSION

The finding problems of this study especially portray the poor sound intelligibility for the high RT. Though Bengali words can be understood by the careful listeners in the existing acoustic condition but it can be a serious problem in case of Koran recitation and other Islamic programs where native language might not be used. Besides, only a few Bangladeshi people understand Arabic, the language of the Holy Koran. Thus, the demand for intelligibility is much less in recitation. On the other hand, we are interested almost exclusively in the intelligibility of speech [8]. It's expected that the perfect design solution for the optimum PSA and thus intelligibility can be achieved if the recommended steps are followed.

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