MIHRAB DESIGN AND ITS BASIC ACOUSTICAL CHARACTERISTICS OF TRADITIONAL VERNACULAR MOSQUES IN MALAYSIA

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Abstract
Mosque design, globally, has evolved considerably from being very simple design and functional, to more sophisticated forms and layout and recently being very monumental. Its function; however, remain the same, not only as a place for prostrations, but more so as a community centre and a symbol of Islam. Basic elements and spaces such as prayer hall, ablution, minaret, minbar and mihrab; for example, are common features in any mosque. Mihrab, a component of Qibla wall marks the Qibla direction. Functionally, it positions the Imam who recites during congregations. It form and design helps the Imam to have khusyu' in prayer. Mihrab should also function acoustically. This research was carried out with the objectives to review the level of acoustic performance in selected mosques and to evaluate the design and acoustic performance of the mihrabs. Initial survey of 37 traditional mosques in Malaysia, built between 1728-1830, has concluded that the mosques are either square or rectangular in plan with clear Mihrab visibility from the main entrance. Mihrab's form vary from having circular niche with flat ceiling to rectangular shaped with slanting ceiling and semi-circular concaved niched forms. To evaluate the acoustical characteristics of the selected mosques the PC-based acoustic measuring system and analyser was utilized. The PC-based measuring system (dBBati32) was integrated with sound level meter (01dB Solo Metravib) as analyser. Data collected from five case study reveals initial findings that the operating facilities in the mosques resulting higher rating NC-49 which is reducing the performance of speech intelligibility. The investigations on the mosque's mihrab offer good characteristics to confirm the tendency of fair acoustical performance with a maximum difference of 4.0dB.

Key words: Acoustic, Mihrab, Mosques.

Introduction

Study within the boundaries of mosque art and architecture has turned to be an eminent subject among scholars. Valuable information was captured and used for the enhancement and evolvement of Muslim religious buildings. After the demise of Prophet Muhammad ﷺ, the administration of the Muslims and Islam in general, including the administration of mosque buildings were taken over by his four companions and then by a number of Islamic dynasties such as the Ummayad, Abbasid, Fatimids, Safavids, Ottoman and many more. Even though the leadership of Islam and the architecture of mosques changed over time, the basic components inside the *zulla* (main prayer hall) remained the same with a few components being added following the needs of the believers during the period of that particular mosque was built.

In his study on early Muslim architecture after the Prophet's mosque, Kuban (1974), lists eight important components in mosques namely the *Haram*, *Qibla* wall, Courtyard, *Riwaq* (arcades), *Mihrab*, *Mimbar*, *Minaret* and *Maqsura*. Twenty years later, Frishman (1994) who derived the list from his research on mosques throughout the Muslim world including South East Asia added *Dikka* (a tribune for the leaders), *Kursi* (Al-Quran holder), and *Maida* (for ablution). While agreeing to the existing components, Ashraf (2006) researched and added other elements to the mosques such as such as *Qubbah* (dome), *Aisled* (sanctuary), *Iwan* and Cresting or Crenellations . The study of components is crucial to determine the overall mosque designs as stated by Hasan-uddin, (1994; 247-248) who believes that mosque design in different time and regions, evolves in creating new expressions in various terms and identity.

No studies have been carried out to evaluate the performance of Mihrab acoustically except studies on acoustical characteristic of mosques in general. Ahmad (1990) presented evaluation of speech intelligibility in mosques in Amman, Jordan and concluded the acoustical characteristics of mosques had been neglected. In Saudi Arabia, 21 extensive field measurements of mosques were carried out in order to characterize their acoustical quality and to identify the impact of active environment control systems (Abdou, 2003) However, limited numbers of studies have been conducted in Malaysia. Dimon *et al* (2007) highlighted the compilation of contemporary issues of mosques acoustics including optimization of the reverberation time and acceptable Speech Transmission Index (STI). However, none of the studies had reported the visibility of mihrab as one important function or element into architectural acoustics performance.

The first Mihrab was *Mihrab Mujawwaf* which formed in semi-circular and concaved. According to El Gohary (1986), a good curved niche as a Mihrab gives the feeling of being concealed and protected. Those feelings are most conducive to total attention (*khusyu*') towards the prayer ; and achieving *khusyu*' in prayer is very much recommended in Islam. Mihrab provides a special place deserved by the *imam* in leading the congregation prayers. Semi circular concave Mihrab was first designed and built during the Caliphate of al Walid and governorship of Umar bin Abdul Aziz in 706 (Whelan, 1986). Another historical mosque built in the 16th century that employed semi circular concave Mihrab is Babri Mosque in India. According to an architect from the 18th century, Graham Pickford, the projection of voice from the Mihrab is considerably advanced for a 16th century building. He also mentioned when one whispers from the Mihrab, he could be heard clearly at the other end about 60 meters away. The acoustic figure had been studied by modern architects and confirmed that the recess in the wall (Mihrab) functioned as resonator and this helps to disseminate the Imam's voice to the congregation (Abdur Rahman, 1987).

Mihrab today is known as a functional space for *imam* and as an orientation device for prayer. Archaeological evidence confirmed the existence of Mihrab which in the form of concaved niche used during Umayyad dynasty and the representation has been interpreted as a prayer niche (Khoury 1998; 2). But Miles (1952) have not confirmed on the real shape of the Mihrab. Mihrab on the Qibla wall carries a double function as an indication of Qibla direction and as a prostration place for the *Imam* when leading the congregations. The existence of Mihrab is found in all the mosques around the globe. The function of Mihrab is unarguably liturgical and as supported by Whelan (1986; 216), the Mihrab still exists even in the most humble and most rural mosques.

This research was carried out with the objectivesto identify the effectiveness of the mihrab design acoustically and to investigate the impact of the environmental aspect and mechanical services system (e.g. fans incorporated into mosque designs) on acoustical quality of traditional mosques in Malaysia.

Assessment of acoustical quality in mosques

Recently, several evaluations have been constructed for speech signals to the listener in enclosures can be explained by contemporary room-acoustic indicators. In difficult acoustic conditions e.g. church (Lewers and Anderson, 1984) (Suarez et at al (2004), the assessment of loudspeakers or sound reinforcement system (SRS) is often used for evaluation. However, there is no specific guideline for a mosque was established (Wasim, 2007). One of the important acoustical interests for satisfactory speech intelligibility is verbal communication. Having same similarity acoustical interest of the church, all activities in the mosques such as prayer, public speaking, preaching, lecturing and *Quran* recitations is related to speech intelligibility. Speech intelligibility (SI) is the accuracy with a normal listener can understand a spoken clarity of word or phrase. The intelligibility of speech in enclosure is measured in the presence of distortion in speech signal caused by noise in transmission path. It also can be influenced by the, ambient background noise (BN), and the reverberation time (RT) of the enclosure. The facilities in operation in mosques e.g. fans, air-condition, indoor noise, etc will attributed to poor acoustical performance of the enclosure. Therefore, Noise Criterion (NC rating), was developed for wider application to evaluate the permissible value obtained in the room or enclosure.

Methodology for physical field measurements

First stage of this investigation was selection of sample of representative of the traditional vernacular mosques in Malaysia. Five mosques were selected to assess their mihrab design and operation status. The selection based on the following: general information of mosque, plan layout and mihrab characteristic. The mosque shape, size, spatial arrangement and other factors contributed to the final selection in addition to mosque accessibility. Out of total 37 mosques, five (i.e. an approximately 14%) were selected for acoustical measurement.

Sample mosques

The mosque volume is important parameter influencing the acoustical characteristics. Table 1 presents data summarizing the main physical characteristics of the five chosen mosques. It includes information such as mosque's length, width, height, volume and expected capacity when full occupied.

However, only measurements of the main halls were recorded.

The selected main halls varied from very small with 215 m^3 and capacity of as few as 75 worshippers to large volumes over 1000 m^3 and a capacity of over 400 worshippers. Actual capacities of each mosque are expected to increase if all areas (i.e. verandah) in the mosques were occupied, such as during Friday prayer. In this study, the rational argument to choose only the main hall as our measurement subject is because the mihrab is located inside the hall; thus it design gives direct impact to the study. Five mosques were selected as the case study, two in George Town and three in Melaka World Heritage Sites.

Case Study 1: Masjid Lebuh Aceh (LA), George Town
Masjid Lebuh Acheh was built in 1808 by a member of a Royal family from Acheh, Sumatera. When Muslim settlements sprawled in Lebuh Acheh, they invited more Malays from around the peninsular and created a centre of Islamic religious study within the vicinity of the Mosque. Consequently, the surrounding area began to develop in line with the growing number of merchants and traders coming from all over Malaysia (or Malaya then), the Arabian Peninsula (Middle-East) and India. The mosque is rectangular in plan; the main hall has three front doors, four side doors, six side windows and another two windows on the qibla wall. The wall is of brick plastered with lime, floor is carpeted and the ceiling is painted timber strip and with six free standing columns. The Mihrab's plan ends with semi-circular and formed in concaved and is also of brick and lime plastered.

Case Study 2: Masjid BatuUban (BU), George Town
This mosque is said to be built in 1734 by the Malays from Buadi Village, Paya Kumbu, Sumatera. It started as a *surau* (musolla) then turned into a mosque when the Muslims increased and formed a settlement. It was also used as a transit point for Muslim traders from India, Pakistan and Middle-east. Similar to other vernacular mosques, the floor plan of Masjid Batu Uban is almost square in shape. There are four columns in the middle of prayer hall to support the pyramidal roof structure and six side windows. Masjid Batu Uban owns a semi-circular concaved Mihrab. The Mihrab and the whole Qibla wall is of plastered brick painted in white with little ornamentation. The arched Mihrab is decorated with multi foil arch which is similar to the mosques built during the Mughal period.

Case Study 3: Masjid Tengkera (MT), Melaka
Masjid Tengkera is recorded as the oldest mosque in Malaysia, built in 1728 with a hybrid design of *Nusantara* and Chinese architecture. The square plan mosque consists of main prayer hall and terrace, covered with three layers of pyramidal roof. Six free standing columns supporting the roof structure. Similar to Lebuh Aceh mosque, Tengkera Mosque is also of brick and plastered with lime, carpeted and timber strips ceiling. The Mihrab niche ends with semi- circular and formed in concaved wall. The concave wall is decorated with geometrical designed ceramic tiles up to 900 mm in height. Measuring 1200mm in width, 1575mm in depth and at 2000 mm in height, this form is sufficient for a single person (prayer leader) to occupy comfortably.

Case Study 4: Masjid Kg. Duyong, (KD), Melaka
Kampung Duyung Mosque is recorded to be built in 1850 and the mosque has faced a few renovations. In spite of the renovations, the original structure and design still remains as close as possible to the original. The pyramidal three layer roof shape was once finished with imported tiles mainly from China. The China tiles were ruined and changed totally with local tiles in 1967.The floor plan of the mosque is almost square and similar to other vernacular mosques in Melaka, there are four columns erected in the middle of the prayer hall supporting the pyramidal roof on top. Main entrance of the mosque leads the users to the prayer hall directly facing the Qibla direction. Mihrab of the mosque shape and form is quite similar to the one owns by Kampung Keling mosque; semicircular plan, flat niche wall and arched ceiling.

Case Study 5: Masjid Kg. Keling (KK), Melaka
Masjid Kampung Keling is situated in the middle of Melaka Heritage trail. "Keling" refers to the Southern Indian folks who married the local Malays. Built in 1748, this mosque was renovated in 1908, with the original structure and design well kept. The roof shape and structure of the mosque gives it the vernacular look; that is pyramidal. Still, some of the interior design and detailing carry influences from British and Dutch architecture. Similar to Tengkera and other mosques with pyramidal roof structure, the shape of the floor plan is almost square with four columns in the middle of the prayer hall. There are two main entrances to the prayer hall, one is directly opposite of the Qibla wall

and the other is adjacent to the ablution pool. The prayer hall is surrounded by verandah on each side except on the Qibla wall side. Masjid Kampung Keling employed a square shaped Mihrab niche which is different from the semi-circular shape of Masjid Tengkerah's Mihrab. The form of this niche is also different as it is a flat niche wall with an arched ceiling.

Measurement procedures

To evaluate the acoustical characteristics of the selected mosques the PC-based acoustic measuring system and analyzer was utilized. The PC-based measuring system (dBBati32) was integrated with sound level meter (01dB Solo Metravib) as analyzer. Based on shape and floor area of each selected mosque, an adequate number of listener positions were chosen for measurement to achieve sufficient coverage of the main hall floor area. It was necessary to measure the mosque BN and subsequently determine the NC rating. The 1/1 octave band setting of BN (dBA) was measured at each selected measurement points using sound level meter (Cirrus). The sound level meter was located 1.4 m above the floor. Time length every 10 sec is employed for one minute and a series of SPL are extracted using commercial software (dBBATI32). So as to provide compact presentation, the SPL is calculated and averaged.

For NC measurement, same measurement was conducted with all ceiling and wall fans operating. A wind screen was used to reduce the effect of airflow due to the operation of fans. The intention of conducting this measurement is to ensure the volume controls were kept remains without any alteration.

To check the effect of the mihrab design in acoustical quality, three modes of measurements were conducted. First mode (SS1), the positioning of the small loudspeaker (BOSE) was used to radiate incoherent pink noises and placed inside and facing the mihrab. Second mode (SS2), the loudspeaker was set inside the mihrab and facing to *saf*. Lastly (SS3), the positioning of loudspeaker was arranged one meter of distance behind from original position of SS1. The SS1 location was chosen based on the typical *Imam* praying position. However, the *Imam* usually utilized the position of SS3 to perform the daily prayer. The measurement points were taken along straight line from the mihrab location as show in Figure 1.

Table 1: Summary of main physical characteristics of the selected sample mosques

No.	Mosques	Mosque Code	On-site measurements			Calculated parameter Nature of Practice	
			Dimensions of hall (m)			Volume (V) m^3	Expected capacity
			L	W	H		
1	Masjid LebuhAcheh	LA	17.10	13.62	4.30	1001.5	410
2	Masjid BatuUban	BU	7.40	7.45	3.90	215.0	75
3	Masjid Tengkera	MT	14.20	13.50	4.10	786.0	300
4	Masjid Kg Duyong	KD	11.80	8.40	4.20	413.3	256
5	Masjid Kg Keling	KK	15.80	13.25	4.60	963.0	393

Figure1: Plan layouts with measurement points location, mihrab plans and sections

Results and discussions

BN and NC results

Table 2 shows the spatial minimum, average and maximum values of SPL in A-weighting of BN and NC with and without fans operating for each main hall of mosque. To ensure convenient to the reader, a comparison of the BN and NC rating is presented in Figure 2.

Table 2: Summary of overall sound pressure level (SPL) and noise criterion (NC) of the mosques

No.	Mosque ref.	Overall SPL (dBA)						Noise Criterion (NC)	
		Fans OFF			Fans ON			Fans	
		Min	Ave	Max	Min	Ave	Max	OFF	ON
1	LA	35.1	38.1	42.5	54.8	59.8	55.5	26	47
2	BU	47.9	49.0	50.3	60.3	61.0	61.9	38	51
3	MT	56.1	58.5	61.6	60.1	61.3	62.5	49	51
4	KD	42.1	44.0	46.7	56.1	56.3	57.4	32	47
5	KK	43.0	45.3	49.7	57.7	57.9	58.4	29	48

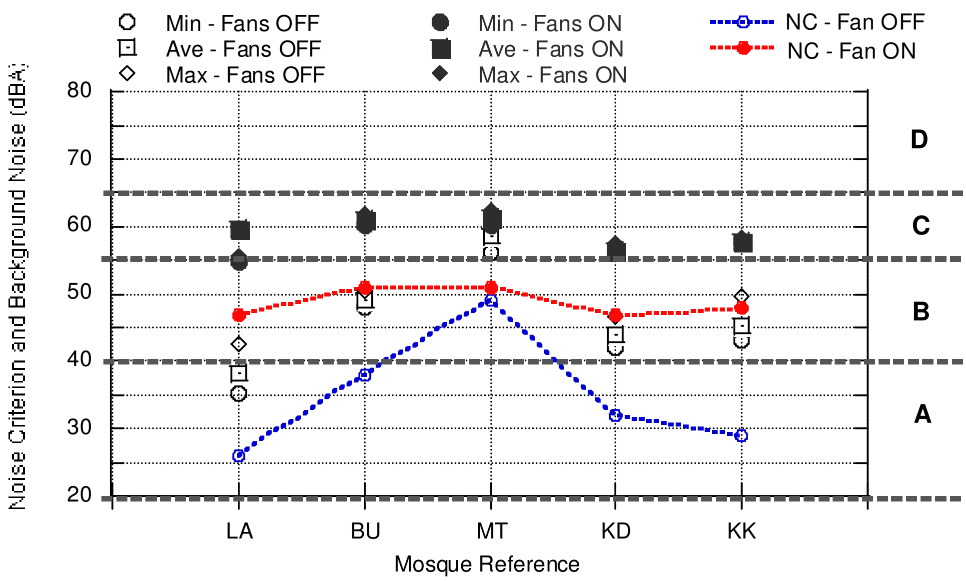

Figure 2: A comparison of the BN and NC rating measured in mosques with and without operating fans. Rating for NC, A = "very quiet to quiet", B = "moderate noisy to noisy", C = 'very noisy" and D = "extremely noisy" (See Table 2)

Table 3: Summary of sound pressure level (SPL) at respective measurement points in all mosques

Pt No.	Mosque Reference														
	LA			BU			MT			KD			KK		
	SS1	SS2	SS3	SS1	SS2	SS3	SS1	SS2	SS3	SS1	SS2	SS3	SS1	SS2	SS3
1	70.9	73.2	72.6	77.7	80.7	79.6	74.0	75.8	76.2	72.9	75.8	74.9	69.8	70.1	70.0
2	67.0	67.9	67.7	75.3	77.3	76.4	71.4	72.0	72.0	71.9	74.5	74.5	66.4	67.5	67.1
3	65.1	66.4	65.9	74.4	77.4	76.4	69.4	70.7	70.3	71.4	74.1	73.3	65.9	67.0	66.5
4	63.7	65.4	64.9	-	-	-	-	-	-	71.7	74.1	73.4	-	-	-
Min	63.7	65.4	64.9	74.4	77.3	76.4	69.4	70.7	70.3	71.4	74.1	73.3	65.9	67.0	66.5
Ave	66.7	68.2	67.8	75.8	78.5	77.5	71.6	72.8	72.8	72.0	74.6	74.0	67.4	68.2	67.9
Max	70.9	73.2	72.6	77.7	80.7	79.6	74.0	75.8	76.2	72.9	75.8	74.9	69.8	70.1	70.0
STD	2.04	2.38	2.26	1.27	1.49	1.42	1.60	1.98	2.24	0.53	0.61	0.69	1.62	1.27	1.42
MD	5.8	6.8	6.7	3.3	3.4	3.2	4.6	5.1	5.9	1.5	1.7	1.6	3.9	3.1	3.5

Average Standard Deviation (STD) = 1.5 dB
Average Maximum Differences (MD) = 4.0 dB

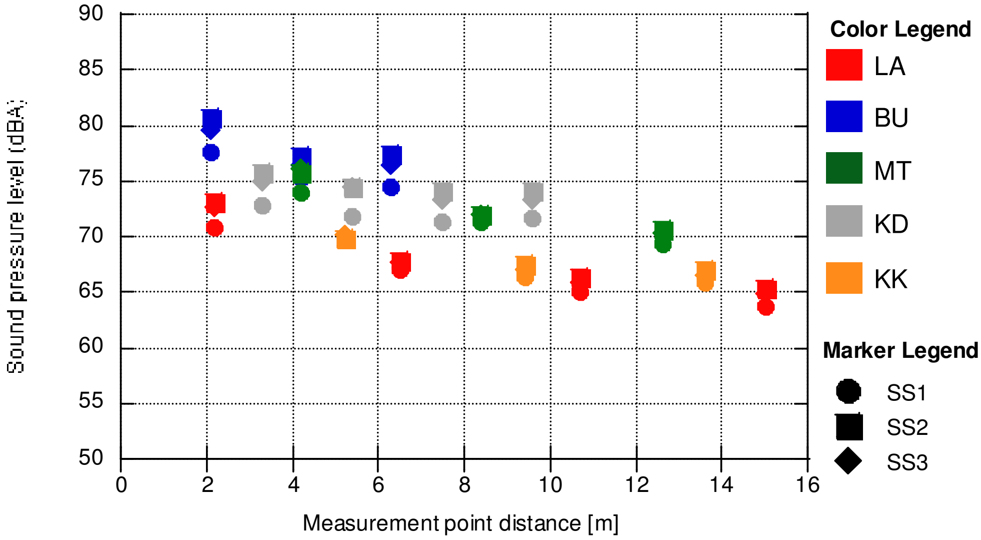

Figure 3: A comparison of the sound pressure level (SPL) versus measurement point distance in three different modes for all mosques (See Table 3)

Figure 3 depicts the BN values are mostly below than 40 dBA. However, the mosque referenced MT mosque shows the maximum value of SPL over than 60 dBA. The MT is near to the busy main road where the effects of traffic noise give significant influence to the result.

The NC ratings of measured BN indicate a *very quiet to quiet* environment except the MT mosque where the value (NC-49) indicates a *moderate noisy to noisy* environment. Furthermore, the NC ratings is higher when the fans in operating condition which all NC rating of the mosques fall under a *moderate noisy to noisy* environment. However, the preferences of NC rating are ranging between NC-25 to NC-30 based on condition in spaces such as conferences halls. It is should not be exceeded from NC-30 because the noise can interfere the speech delivered by *Imam*.

The effect of Mihrab design

It was possible to characterize the effect of mihrab design by measured the SPL in different distances. Although the materials, shapes and the volume of the mosque give significant effects to the acoustical quality but these were not taking into consideration in our first stage of study. Following the measurement procedure mentioned in Section 4.2, three modes of measurement was taken to determine the effect of the mihrab design into the SPL at selected measurement points as illustrated in Figure 1. The volume control to radiate the pink noise was set to 85 dB for all mosques. The SPLs of each point at different modes for all mosques are shown in Table 3. Figure 3 comprehensively compare SPL in all modes with respect to distance from the sound source. The results show similar basic tendency of the SPL for their respective modes with some differences values relatively independent on the distance. From these results, the good agreement for the measured SPL obtained in mosques referenced KD as observed in Figure 3 where the difference of SPL is almost identical whereby the maximum difference value is 1.7 dB for SS2 mode. Furthermore, we found the maximum difference (MD) of measured SPL between 3 modes is lower than 7.0 dB and resulting in average MD with 4.0 dB. Moreover, all mosques can be considered as having fair agreements based on the value of standard deviation (SD) being below 2.5 dB. On the whole, we consider the differences of measured SPL yield plausible agreements to show the effectiveness the mihrab design into acoustical quality in all mosques at first stage of the study.

Conclusions

In this study, pilot measurements in five main halls of mosques have been performed. A series of measurement revealed that the operating facilities in mosques resulting higher rating NC-49 which is reducing the performance of speech intelligibility. However, this phenomenon indicates the used of SRS can be an effective way to improve the intelligibility of speech. The investigations on the mosque's mihrab offer good characteristics to confirm the tendency of fair acoustical performance whereby the resulting in average maximum difference with 4.0 dB. Further investigations and comparative simulations are now being pursued intensively.

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