A Study of the Acoustics of Worship Auditoria

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Abstract

The importance of achieving proper acoustics quality for worship auditoria has long been recognised. The Roman open air auditoria and amphitheatres are known for their fine acoustics at a time when no electronic sound amplification system was available. Many of these were used for worship purposes. Closed worship spaces lead to undesirable effects of reverberation but can help reduce outside noise. The recorded works of Turkish acoustician and architect, *Mimar Sinan* as early as 1540 AD reflects that the technology and expertise of acoustics had long been acquired and successfully applied to mosques. It is strange that even today, there appears to be very many instances of acoustical problems which continue to occupy much of our interest. In recent times a great deal of emphasis appears to be placed on sound amplification systems which is sometimes expected to solve all types of problems in acoustics in worship.

Introduction

A study of the worship auditoria used by various types of religions carried out in many countries has revealed that the general acoustic requirement for their worship is very similar irrespective of whether they are classified as churches, temples, synagogues or mosques.

The majority of worship is carried out in enclosed spaces for more reasons than merely keeping out the vagaries of the weather. Various forms of worship at one stage or other combines the spoken word, spoken by one or more of the worship leaders and the congregation in unison or otherwise. The form of the worship and the position of the leader/s has a major impact on the acoustical requirement. Music of one form or other is often a major part of worship although there are some exceptions to this. Some forms of singing and music may be very loud and sustained. The use of burning candles, joss-sticks or other combustibles may affect additional ventilation requirements and the noise associated with the resulting mechanical systems. Many older auditoria have had to have acoustical treatment carried out in the past ten years. Large worship functions have used audiovisual systems linking several auditoria and multimedia presentations are increasingly used.

The very large scale worship congregations often reverts to the outdoor stadia environment for groups of several thousand worshippers. The acoustical requirements to address and to be heard and in some cases to get a response from such large congregations often depends considerably on the electronic sound amplification system.

Ambient Noise Level

In general, all worship spaces would require a very low background noise level although this level may be exceeded for some or most of the time during the actual worship event. This low background noise level is required for a combination of prayer purposes, meditation / contemplation as well as auditory purposes. In many cases this background noise level is determined by the limits imposed by environmental comfort requirements such as ventilation and cooling or heating. In warm climates fans are often employed to keep the worshippers cool and windows are also often kept open for natural ventilation. Noise from the fans as well as from outside road traffic, rail, aircraft as well as community noise often invades the quiet of the auditorium.

It is found that nowadays, cost permitting, more and more naturally ventilated worship spaces are being replaced by sealed auditoria where ventilation, temperature, and humidity are carefully controlled to provide a comfortable worship environment. Noise is often cited as one of the reasons for the change. Here, air conditioning noise should also be carefully minimised to preserve the silence preferred in order not to create further unnecessary disturbances to the worshippers.

The low ambient noise levels requires that any potential noise source either inside or outside the auditorium should be properly evaluated and necessary steps taken to ensure sufficient attenuation. Several cases have been found where remedial treatment in this area was required. The AHU room (air handling unit) of the air conditioning system should be carefully located away from and structurally isolated to avoid structure borne noise from being transmitted to the main worship area. In addition, the air-condition ducting should be properly treated to minimise airborne noise transmission and the outlet vents properly designed to prevent excessive noise generation. Where noise from the air conditioning system is detected, attention should be given to the installation of attenuators at the duct air outlet to maintain the necessary quiet ambient noise levels.

Actual design ambient noise levels used range from NC 25 to 30 or NR 25 to 30 although in practice general levels of up to even 50dB(A) have been found to be acceptable in many situations. In some cases surveys carried out have found that some situations the local population seems to be used to higher ambient noise levels and may find the lower ambient too quiet for their listening comfort.

Reverberation

The acoustics of large old churches especially those of the Catholic tradition can often be recognised immediately even by a layman as soon as he walks into one even if he was blindfolded. A Catholic cathedral church traditionally tends to be a large and very reverberant enclosure with hard walls, ceiling and floor. There is very little in the way of acoustics absorption and even the solid timber seats or pews are acoustically hard.

The resulting length of reverberation in these massive cathedrals encouraged the development of the magnificent Latin Mass, which is perfectly suited to the highly reverberant acoustics of these beautiful old churches. In a similar manner the lengthy reverberation enhances the singing sometimes to the accompaniment of musical instrument in many churches. Modern music may however not be ideal in such environments.

The importance of the spoken word in worship and the intelligibility of speech however requires a short reverberant time. The RT60 should not be too high so as to avoid masking of successive consonants due to the late decay of earlier consonants rendering speech unintelligible. Providing sufficient speech intelligibility in a reverberant space is a perennial challenge faced by most acousticians. This is often compounded in practice by limited funds available for the remedial treatment to bring down the reverberation times.

A combination of additional acoustic absorption and electronics has provided a reasonably cheap solution in the less demanding situations. Large cloth banners hung from the ceiling provide additional absorption at a reasonable cost and directional loudspeakers focusing directly on the congregation and sufficient numbers of them to cover the congregation would suffice.

Similarly a mosque is primarily a speech hall where the main languages in use are the slow and somewhat rhythmic Arabic of the *Quran* used universally and the local language of the congregation which could be English or any other ethnic language. The main activities inside mosques are speech related, primarily the daily prayers and Friday congregational prayers and sermons, besides regular talks and discourses. These activities require good speech intelligibility and generally low reverberation. It should be noted that the optimum RT60 value for speech found in most acoustic handbooks and design guides are based on the mainly monosyllable European languages. Studies carried out where non-European languages are in use suggest that the optimum RT60 in such cases may be slightly higher than the values proposed.

The acoustics in a synagogue are similarly determined by audibility requirements. Prayer is both spoken and sung by the congregation as well as the prayer leader. The Torah is chanted in Hebrew and the sermons and announcements are spoken in English or any other local language. Also some degree of acoustical support is required for the enhancement of the congregational singing. This is provided by sound reflected back to the worshippers from nearby hard surfaces. It lends an additional richness and communal effect to the worship.

A delicate balance must be struck in this and the reading of the Torah which is an inspired method of clearly presenting information in a beautiful manner. The chanting of the Torah aids the intelligibility of the text. By slowing down the pace of the words, and by exaggerating the pitch range, chanting takes advantage of room acoustics to enhance both the intelligibility and the beauty of the text.

Other worship religions and traditions require spaces where worship often include the use of chanting accompanied by gongs or the tinkling of bells such as in temples and pagodas and in general very little reverberation is encountered.

Reflections and Echoes

An echo exists when a sound or a spoken word is distinctly heard to be repeated. This was found to be considered undesirable in all types of worship. Reactions to these were that it can be extremely disturbing, reduces speech intelligibility or that it causes hearing fatigue.

In order to achieve optimum speech intelligibility, it is crucial to ensure that the direct sound and early reflections occurs within about 30ms to enable the hearing mechanism to perceive the spoken words uniquely and distinctly. Any significantly high level of late reflection sound energy occurring 50ms after a direct sound, must be avoided to ensure that echoes do not occur.

Ray tracing techniques are often used to ensure that any path difference between the direct sound and reflected sound greater than 17m be carefully controlled. Where these occur, adequate sound absorption material should be used to treat the surfaces of reflection so that the energy of the reflected wave be minimised to levels considered to be sufficiently inaudible above the ambient noise level.

Elimination of Focusing Effect

Another problem often found in many worship auditoria is the effect of focusing. It is found that many worship auditoria including mosques and churches are designed with a domed top. Untreated dome surfaces have a focusing effect which can cause perceivable sustained high sound pressure levels which may appear to the listener as sustained reverberations and echoes. This will greatly affect the quality of the perceived sound which is often made worse by a poorly designed sound system. The actual focusing effect is affected by the dome shape, height and size and is often exaggerated by the reflection of its hard surface finish.

It is interesting to note that domed mosques built in the middle ages, particularly those attributed to *Mimar Sinan* and his students, are reputed to have excellent acoustics even though the dome surfaces are reflective. Apparently, they were able to utilise or control the focusing effect in a positive way so as to amplify and maximise sound distribution from the *mehrab* (a cavity in the direction of Mecca towards which a prayer leader faces during congregational prayers) and the *mimbar* (pulpit) to the praying area under the dome. This would be ideal especially without the aid of modern day electronic systems.

Sound System Design Criteria

The main requirement of the sound system in the worship environment is to provide a sufficiently amplified sound loud enough for the audience to hear and understand.

The problems generally encountered in worship auditoria included microphone feedback, echoes and flutter. In some cases the sound system installed was found to make the existing poor acoustics worse. Often it was found that acoustics was not considered during the design of the worship area due to budget constraints. In some cases because of the poor acoustics evident after the hall was built, the sound system was added to try to remedy this as an afterthought. Needless to say there was no budget set aside for it either and a supplier was found to put one in as quickly and as cheaply as possible.

It is often at this stage that the acoustics consultant is brought in. To remedy this it is essential to advise the client to treat the acoustics first and then provide a sound system which gives a comfortable listening level above ambient noise. In less severe cases the modern sound system can have sufficient sophistication to overcome known acoustical problems.

The basic sound system consists of loudspeakers, power amplifier, graphic equaliser, mixer and the microphone, piano or other musical instrument as an input. The selection of the other components of the sound system will eventually be determined from the complexity of the proposed sound system which in turn is determined by the complexity of the worship programme. The sound system technology available can also sense the ambient noise level and adjust the overall gain automatically to provide a comfortable level of hearing and at the same time eliminate any potential feedback problems.

Depending on the design of the worship hall, the two main sound system design approach used are the central cluster and the distributed sound system mainly for high ceilings and for low ceilings respectively. In some cases a combination of both may be used especially where varying ceiling heights are encountered in the hall. In reverberant environments attention should be paid to the sound distribution pattern of the loudspeakers. In some cases a narrow vertical and very wide horizontal dispersion may be used so that the energy from the loudspeakers cover maximum floor area and provide sufficient amplification to ensure audibility. In general it is found that a figure of 12dB above ambient is quite acceptable.

Finally the general design emphasis should be on realism where the audio system is not intrusive in use and the sound appears to come from the natural source at a comfortable level with maximum intelligibility.

Computer Simulation and Auralisation

With the current computer technology, there are now many computer aided design software packages which can be used to model the auditorium. This gives us the ability to predict the acoustics of the auditorium given the size and shape and surface finishes and also plots sound level contours on selected planes for given sound sources and allows sound system performance to be determined. In recent years it is found that the acoustics of a contemporary worship space are often driven by the sound system. Almost all sound is amplified except for the

congregation so the priority in this spaces appear to be towards a very complex and sophisticated sound system aided by modern computer software.

Although it is important to understand that these computer aids cannot replace the knowledge and skill of a competent acoustics and sound system consultant, they can however help speed up the design process considerably and leave more time for the final fine tuning and commissioning.

Conclusions

A study of the worship auditoria used by various types of religions carried out in many countries has revealed that the general acoustic requirement for their worship is very similar irrespective of whether they are classified as churches, temples, synagogues or mosques. Many have been found to have acoustical problems to some degree and some quite severe. These are often caused by lack of acoustical planning at the design stage often because of budget limitations. Some of the typical problems encountered are described and the general solutions often to meet limited budgets for the treatment are discussed.

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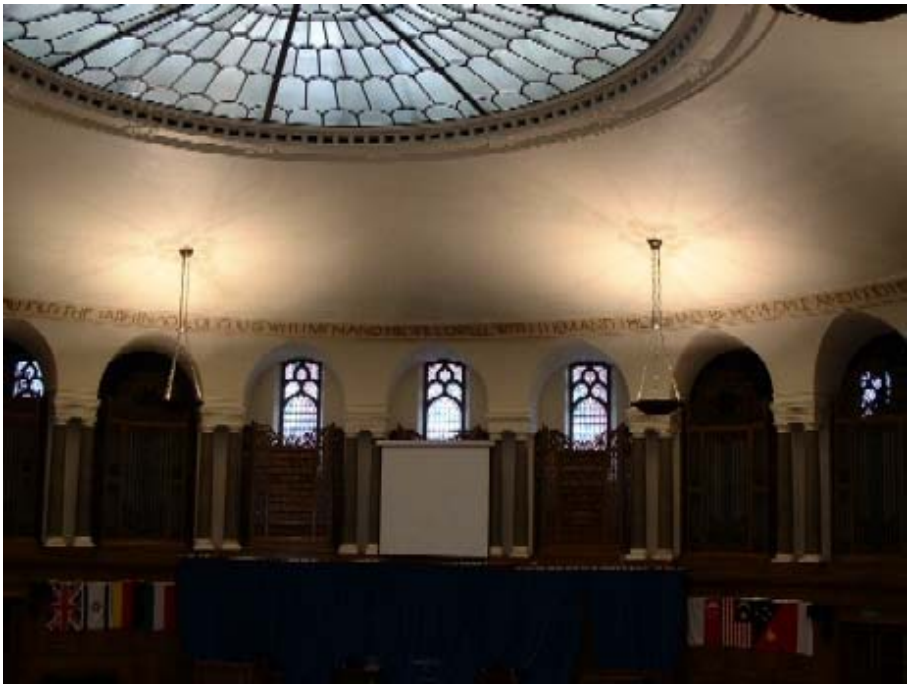

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Figure 2

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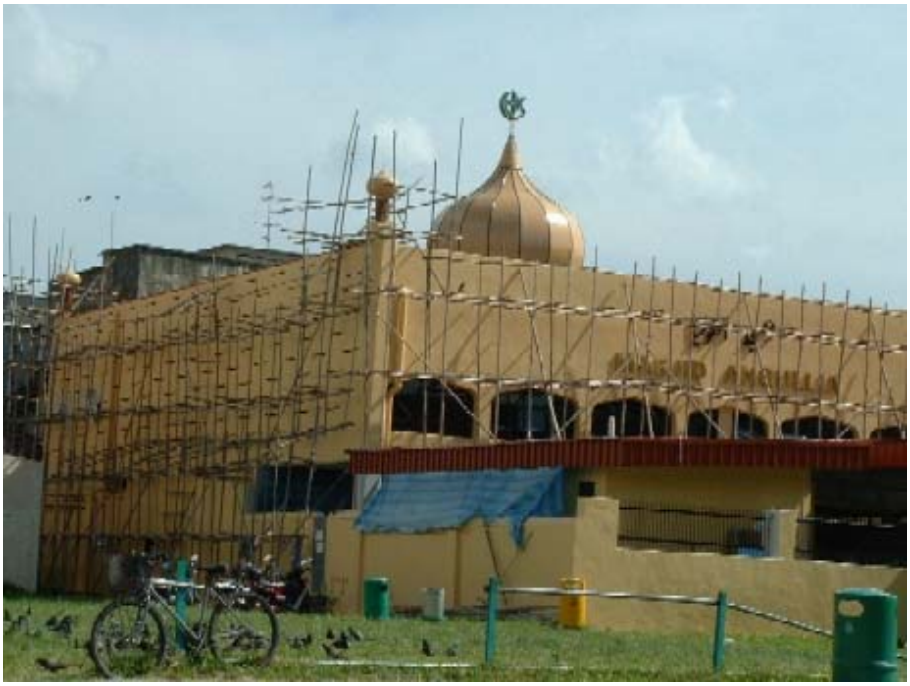
Figure 5



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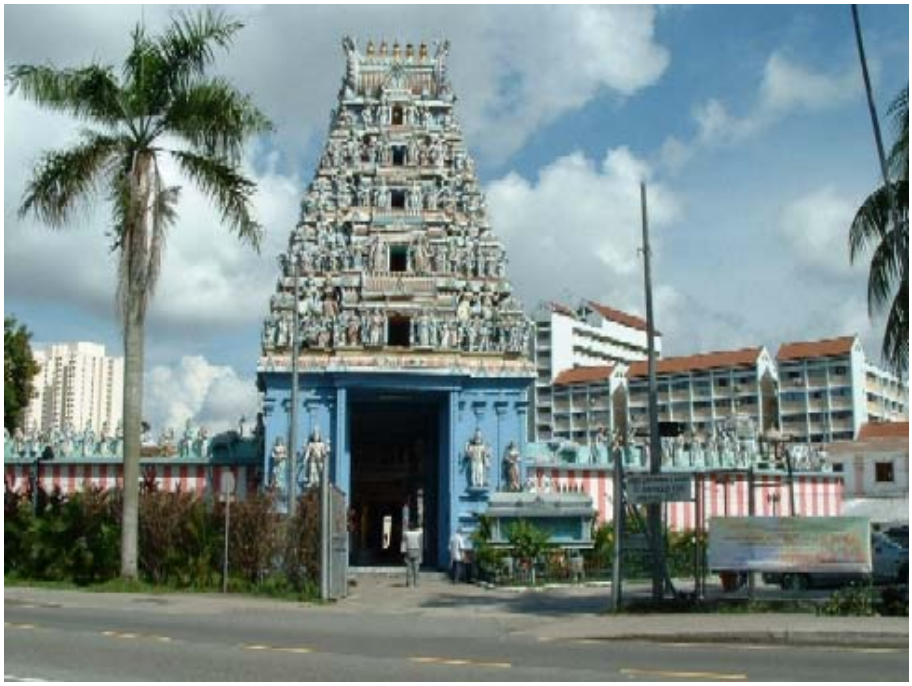

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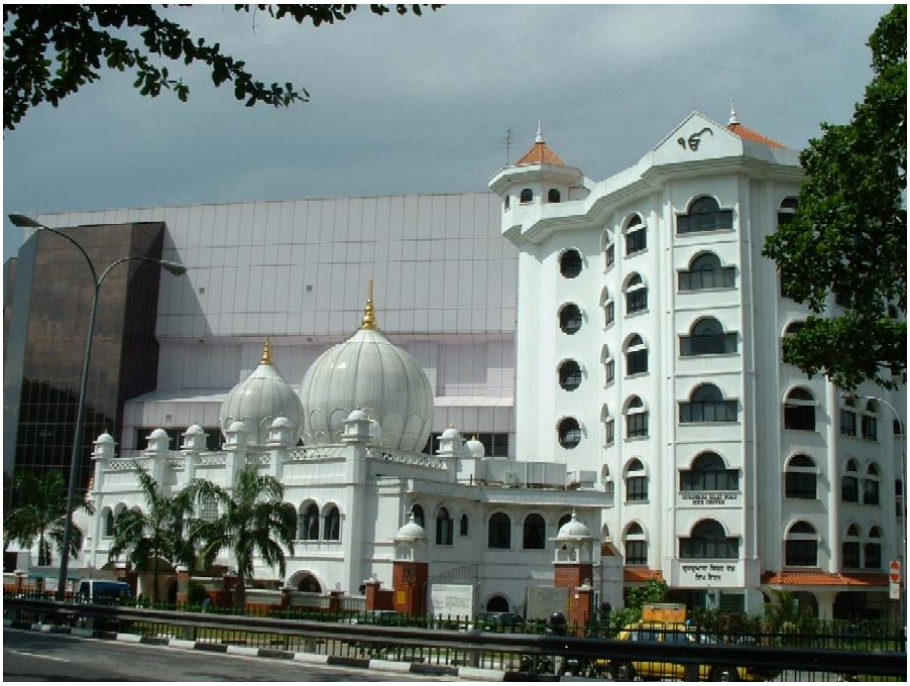

Figure 8