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Sound quality of historical mosques in Tabriz in accordance with international standards

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ABSTRACT

Sound is one of the important factors in creating a good feeling in a mosque and it can play a role as a sensory medium to communicate spiritually with God. Therefore, the acoustic standards have defined the optimal level for the mosque in the field of various variables. In order to compare the acoustic conditions of the use of the mosque with the standard limits, the present research has carried out field measurements and software analysis of the standing position in order to simulate the prayer position. Form and volume are the two considered architectural parameters and Background Noise (BN), Reverberation Time (RT), and Sound Pressure Level (SPL) are the three acoustic variables of the study. A total number of 15 historical mosques in Tabriz are divided into three large, medium, and small volume categories and five form categories have been tested. The reference of the study is ISO3382-1 and ISO3382-2 and the measurements were made with B&K equipment. In addition to the direct achievements, the results have been adapted to international standards and show that the acoustic situation in the historical mosques of Tabriz, regardless of their volume and form, produces sound in the range of 60 to 90 phones, and in terms of RT, have the suitable design from the volume point of view, but the lack of carpet flooring in some of them has increased the RT. The background noise in these examples is less than NC-25, which provides a quiet space for the user and provides the necessary concentration for individual worship.

1. Introduction

The range of acoustic studies in architecture includes all types of functions in this field. Places of worship are examined in the two general perspectives of speech and music, and the standards of worship spaces define the desired limits by separating speech worship spaces and musical worship

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spaces. Mosques are considered spaces for speech that have carpet floors and acoustic variables are explained to provide clarity of speech.

To analyze the sound condition of the historical mosques of Tabriz, 56 samples registered in the cultural heritage organization were cited. The first stage is devoted to the analysis of their architecture and among them, 15 examples that can be categorized into three volume groups and five form groups have been selected. Another selection criterion was the minimum of intervening variables in sound analysis, and therefore, more homogeneous spaces were considered. The measurements were done in the field and the final results were obtained with Excel software.

2. Materials and methodology

ISO3382-1 and ISO3382-2 for acoustic field measurement provide some limits for the placement of loudspeakers and microphones. The height of the source will be at least 1.5 meters from the ground and the distance of the microphones from the reflective walls will be at least 1 meter and 2 meters from each other [1, 2]. Considering all the above, this study has used B&K equipment, which is the most widely used by researchers in this field (Fig. 1).

Fig. (1) Used equipment

The installation of the microphone in the axis of the Qibla is considered in all samples and depending on the area of the plan and the size of the sample, their arrangement is different in the samples, which varies from 38 points in the largest sample to 4 points in the smallest one. The final results of each sample is a graph of each variable obtained from averaging the data in Excel software.

The measurement of the background noise in all samples was the first variable to be measured and therefore it was done in the morning between 9 and 10 (in larger samples until 11). Since the number of samples is large and the measurement requires many days; In all measurements, the same weather conditions are considered. The measurements were made in January and partly cloudy weather conditions (neither snowy nor rainy). SPL is the second measurement variable and is considered after the background noise. It has been measured from 10 or 11 until finally 2 pm. Other weather conditions are similar to BN measurements. The samples are considered empty of people so that laboratory conditions can be applied according to ISO 3382. On the other hand, the amount of sound broadcast from the omnidirectional source is in the full frequency range and covers all possible sounds in the samples. The gain of the device is 40 dB higher than the background noise, to cover the conditions of the ISO 3382. RT is the last measured variable and it was measured in the samples after 3 pm. After measuring it in the distribution network in the plan of the samples which is given in Table 1; It has been averaged in different frequencies and a specific RT value has been obtained for each frequency. The sound source in all samples is set to Gain 0 with a certain octave banding to ensure background coverage. The frequency band of the source in all samples is 1/3 octave band and according to ISO 3382, it is considered from 100 to 5000 Hz.

3. Case study

Sabin's formula as the most important equation in the acoustic quality of architecture shows that volume is the most important architectural factor in the analysis of the sound of the architectural space. On the other hand, in order to categorize the samples, the form is also considered in this research and there are five categories of longitudinal columnar (longitudinal strain along the Qibla axis), transverse columnar (transverse strain along the Qibla axis), square columnar (equal length and width), arched and domed forms have been considered in the selection of samples (Table 1).

Tabel. (1) Case studies of the present research

	Small	Medium	Large
Longitudinal columnar			
Transverse columnar			
Square columnar			
Arched			
Domed			

HojjatolIslam, Shahidi and Khalkhali mosques in the first formal group, 63 Sotoon, Shahada and Shahid Sadouqi in the second formal group, Imam Juma, Qizilli and Haj Ghaffar in the square columnar group, Jame, Jame Kochak and Haj Ghani in the arched category and finally the Kabood, Haj Safar Ali and Milli have been analyzed as selected examples in the domed group, among which HojjatolIslam, Jame Kochak, and Kabood mosques do not have carpet flooring in all their parts (Table 1).

4. Comparative results and discussion

4.1. Background Noise and NC curves

The NC curves, which are projected to provide the Background Noise standards, show that spaces with an NC lower than 35 are classified on the spectrum of very quiet to quiet [3-7]. Mosques from Tabriz that were selected for the current research are lower than NC-25 in environmental noise measurement regardless of their location, volume, and form (Fig. 2). The Background Noise is close to the hearing threshold in arched, longitudinal columnar samples and a sample from the square columnar group at low frequencies, which shows that environmental noise in these samples is basically not heard in the majority of frequencies. The rest of the samples have noise equal to NC-15 in the lowest case, and the highest noise value of the samples corresponds to NC-25 in the worst case. As mentioned, studies by other researchers have often registered NC-35 for mosques [8-11], which shows the more favorable BN level of historical mosques in Tabriz. Meanwhile, researchers in acoustic reference books consider NC less than 30 suitable for acoustically sensitive spaces such as recording studios and concert halls. NC-25 to NC-35 is suitable for sleep, and relaxation that is recommended for spaces such as bedrooms, hospitals, and hotels [4, 6]. This shows that the historic mosques of Tabriz are like sensitive acoustic spaces from the point of view of BN, and the quietness inside them is even less than the sleeping and resting spaces. This proves that there is silence and solitude necessary to create concentration and peace in the user’s mind [10], and the domain of solitude for individual worship is provided in the samples regardless of their location, volume, and form.

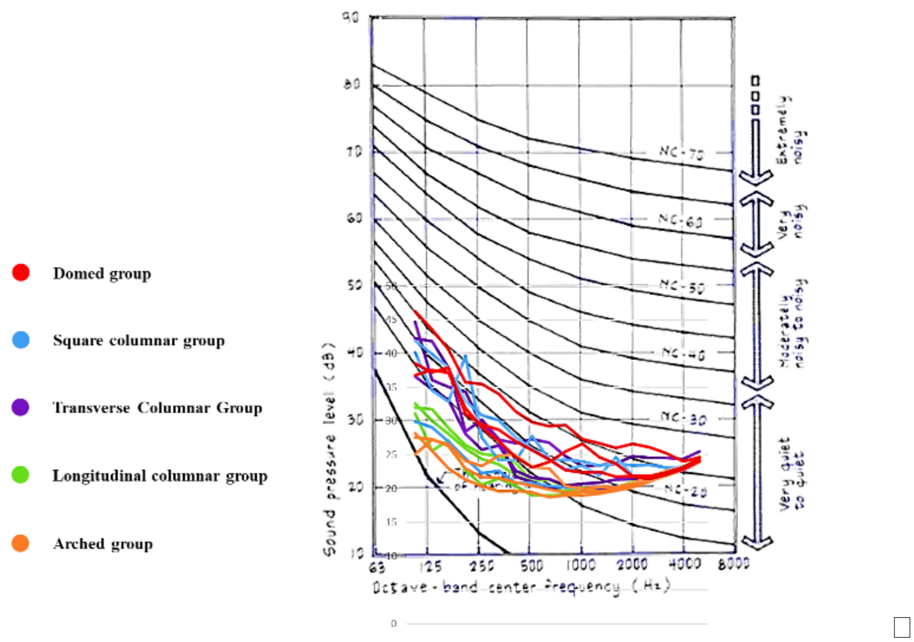

Fig. (2) Adaptation of the Background Noise of historical mosques of Tabriz with NC curves

4.2. Reverberation Time in accordance with volume

Based on the scientific theories of architectural acoustics and referring to Sabin's formula, which defines the volume in direct relation with RT; Normal ranges are provided for different types of architecture based on space volume. The mentioned charts show that recording studios for speech should have the lowest average RT at 500 and 1000 Hz frequencies based on the volume of the space. Lecture halls are in the next rank and theaters in which sound clarity should be high are defined in the next category. In the meantime, places of worship with emphasis on speech are considered in the middle rank and places of worship with a focus on music are considered at the highest place of RT. This achievement is for a situation where the space is full of people, and therefore the absorption coefficient of people is also considered in the graph below [3-5, 12-14].

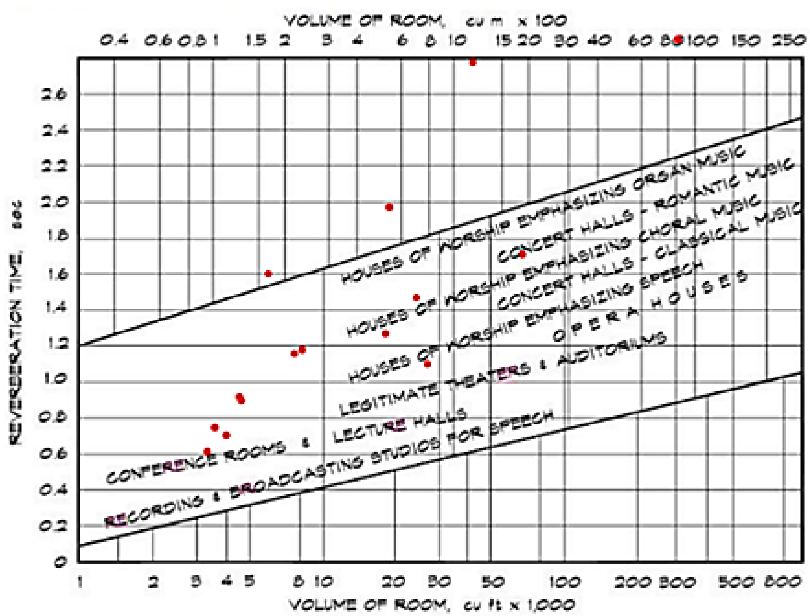

Fig. (3) Adaptation of Reverberation Time of study samples with RT ranges according to volume

The current research and its field measurements show that historical mosques in Tabriz that were empty of people in the test conditions often are places of worship focused on speech and music within the scope of lecture spaces. Three examples that are significantly far from the internationally defined limits include Kabood, Hojjatoleslam, and Jame Kochak with no carpeted floors (Figure 3). In the studies of researchers and the international view of mosques, a mosque is a space that is covered with a carpet, and in addition, as mentioned, it is considered to be completely full, but in this research, samples are empty of people. Most of the researchers admit that filling and covering with carpet reduces a mosque’s RT and improves its acoustical condition [15-24]. With this approach, in the samples studied in this research, high RT is for low frequencies. The presence of the user is a definite factor in improving the acoustic conditions. Another example outside the defined limits, which of course is slightly different from the standard is Haj Safar Ali mosque. Despite its volume, it shows a high RT. The ratio of width to height in this sample is the lowest among the study samples, and this can be the reason for the higher RT in the sample. The results obtained from other samples of the research show that small mosques are suitable for speech, and as the samples become larger, the capacity of the space for resonant applications such as reciting the Quran increases.

RT60 calculations, which are based on the optimal RT formula, are based solely on the volume and assign a lower RT to speech [7, 25]. This shows that the historical mosques of Tabriz are designed suitable for speech in terms of volume, and if a few examples are not included in the proposed standard limits, is due to the type of flooring and has no obvious connection with architectural factors (Fig. 4).

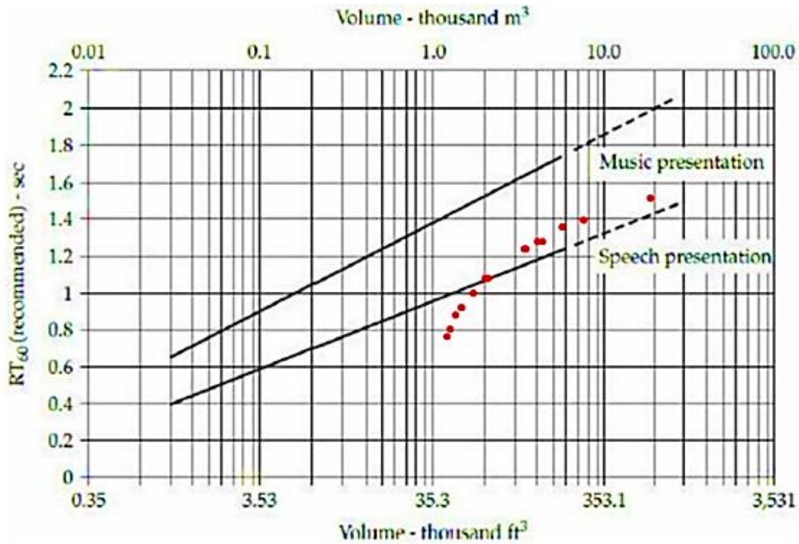

Fig. (4) Adaptation of Reverberation Time with appropriate RT ranges for speech and music

4.3. Sound pressure level and auditory perception curves

Comparing the results of the present research regarding the Sound Pressure Level with the auditory perception curves [13, 14, 26-28] shows that the user hears the sound played in the study samples between 60 and 90 phones (Fig. 5). The level of listening to quiet human speech and the limit of hearing the sound of cars and electrical equipment are respectively 60 and 90 phone [4, 6, 29, 30]. The 90 dB is an unpleasant and undesirable sound however, since it only occurs in a small frequency range, it will be tolerable, and in combination with other frequencies, the heard sound will be satisfactory and will not be annoying. This means that the sound in the historical mosques of Tabriz, regardless of their volume and form, is at the level of quiet human speech and finally the sound of motor equipment. On the other hand, sound in each sample is heard at different frequencies in different phones, and this causes the sound to not be "ear-hurting" in any sample. The larger the samples, the more suitable they are for speech and listening in the entire frequency range. On the contrary, smaller samples, in limited low frequencies, make a higher sound. The fact that this is limited to certain frequencies causes the overall desirability of the sound in the space. If the users hear a high phone at some frequencies with the help of other frequencies that are in lower phones, it brings to mind a favorable general analysis of the acoustic quality of the sample.

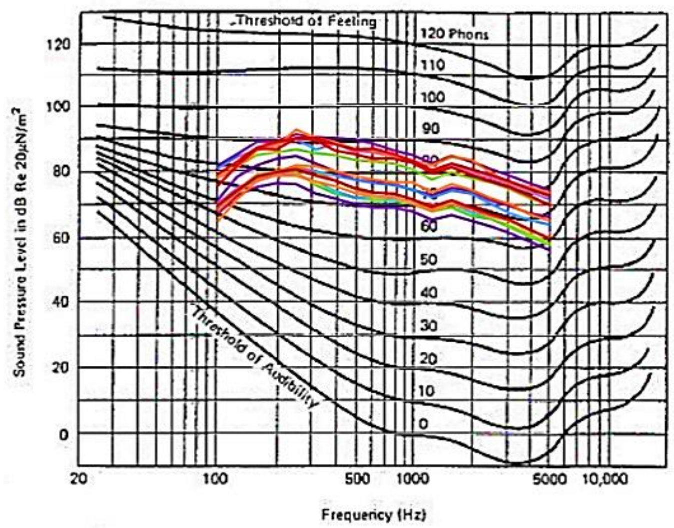

Fig. (5) Adaptation of the Sound Pressure Level with the auditory perception curves

5. Conclusion

The results of the study explain the general condition of the samples in accordance with the international standards and prove that about BN, the form of these samples, regardless of their locations, creates an optimal level of solitude and concentration, which is suitable in international standards for sleep and spaces that require relaxation. RT in these samples varies with the volume, but in general, it is within the range of spaces suitable for speech and music. The existence of carpet flooring is necessary as an effective factor in reducing the RT. The volume of these examples is completely defined for speech, and what makes some examples out of the standard limits is the layout factors and furniture in the interior of mosques. The Sound Pressure Level in the samples is generally between 60 to 90 dB, which is equal to the sound of human speech and the sound of machines. Because the sound played from the device has a full octave band and is also played from an omnidirectional speaker; is the maximum level that can be contained in the sample. Therefore, the sound emitted in mosques is either less than this amount or it is broadcast in limited frequencies at the level of 90 dB and in the full range of frequency band causing the human mind to perceive a favorable state of sound in the historical mosques of Tabriz. The architecture and internal form of the historical mosques of Tabriz is in a way that makes the overall quality of the sound behavior stable and all the selected form categories could not show significant differences in frequency separation. The brick texture, simple decorations, and the general pattern of the executive have led to the provision of sound quality that is in line with global standards and can be a suitable model for building new models in terms of the way it is formed. Moreover, it can be suitable in terms of the amount of surfaces, absorption coefficients, and executive components for building new buildings.

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