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Acoustical Environment of the Al-Rabat Concert Hall in Baghdad

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Abstract
The acoustic parameters (RT_{30}, EDT, C_{80}, G) and noise rating curves for evaluating background noise levels are measured in the Al-Rabat Concert Hall in Baghdad. The aim of the measurements is to investigate the acoustical environment of the hall and compare the results with ISO 3382. The measurement results indicate that all the parameters that were measured in this concert hall are greater than the typical values in ISO 3382. This research resulted in a recommendation to develop the acoustical environment for the audience and the musicians in the Al-Rabat Concert Hall.
Keywords: acoustical environment, concert hall, reverberation time, early decay time, clarity of sound, strength of sound.

1.Introduction

An acoustical environment is known as the combination between the background noise and the useful sounds that can be detected, with this environment depending on the relevant activity [1,2]. The acoustical parameters, such as reverberation time (RT_{30}), early decay time (EDT), clarity of sound (C_{80}), sound strength (G) and noise rating curve (NR), are used to estimate the acoustical environment of all types of closed spaces [3,4].
The purpose of a concert hall is entertainment; thus, the acoustical environment design must take into account the comfort of the audience, which involves not causing noise, annoyance and discomfort. Many recent studies discuss the effects of shape on the acoustical parameters for the acoustic spaces, especially the dome shape, which refers to the acoustic defects, such as sound concentration and the unbalanced sound pressure level distribution that is often considered unsuitable for the effective presentation of the performances because the reflected sound from concave surfaces do not diffuse properly in a room [5,6].
This study presents the first study of the concert halls in Baghdad, which takes into account the practical side of the acoustical parameters and tests these parameters for an example of a dome hall (Al-Rabat Concert Hall) and submits a recommendation to develop the acoustical environment for concert halls.

2. Al-Rabat Concert Hall Description

Al-Rabat Concert Hall was designed at the end of the 1950s with a circular floor plan and a dome ceiling for the audience area and is located at Al-Maghreb Street in Baghdad City. The Al-Rabat Concert Hall was designed as a concert hall for the Iraqi national symphony orchestra to play pieces of music, yet there are also many speech performances played in it. The Al-Rabat Concert Hall is one of five concert halls in Baghdad, but now it is only one of two concert halls that hosts musical activities. During the history of this concert hall, it has been rehabilitated more than two times, and the main rehabilitation includes changing the high absorption texture that covered the entire dome with simple types of absorption texture material, replacing the sound diffuser that was placed in the center of the dome by a wood flower with an iron structure rectangular section to allow the installation of lighting devices, expanding the stage to cover (¼) of the floor area, and placing a large curtain as a picture between the musicians location on stage and the backstage. In addition, the chairs, carpets, and main curtain were changed, along with the addition of synthetic leather chairs in the first row.
Photographs of the concert hall are shown in Figures (1), (2) and (3). The hall accommodates 184 seats plus 62 seats in the balcony. The hall and the stage are circular in shape, with a 16-m diameter hall, and 12-m diameter stage. The height of the center point of the dome ceiling is 8-m from the floor, and the height of the stage 0.9-m. The control room walls are built of glass, and this room is located at the center of the balcony. Note that there is no central heating and cooling system, but six air-conditioner units (split type with 3 tons) are available, being distributed on both sides of the hall, with three units per side.

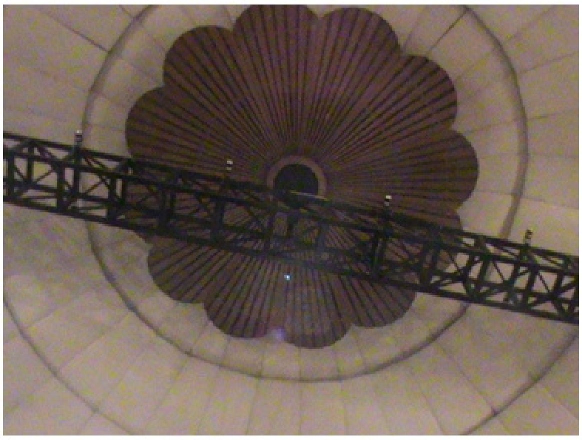


Figure (1): The dome ceiling

Figure (2): Main passage of the hall

Figure (3): View of the hall from the stage

3. Measurement Methodology

All measurements were taken according to ISO 3382 [3]. The instrument used for measurement was a SVAN957 Type 1 sound and vibration meter with analyzer. The measurements for the unoccupied state of RT_{30}, EDT, C_{80} and G were measured using the impulse noise method, and all the measurements were performed in the octave bands. For acceptance, the concert hall to background noise NR was calculated. The sound sources that were used were the same the amplifiers that were standing in the opposite corner beside the stage. Figure (4) shows the plan and section of the concert hall and the positions of the receivers.

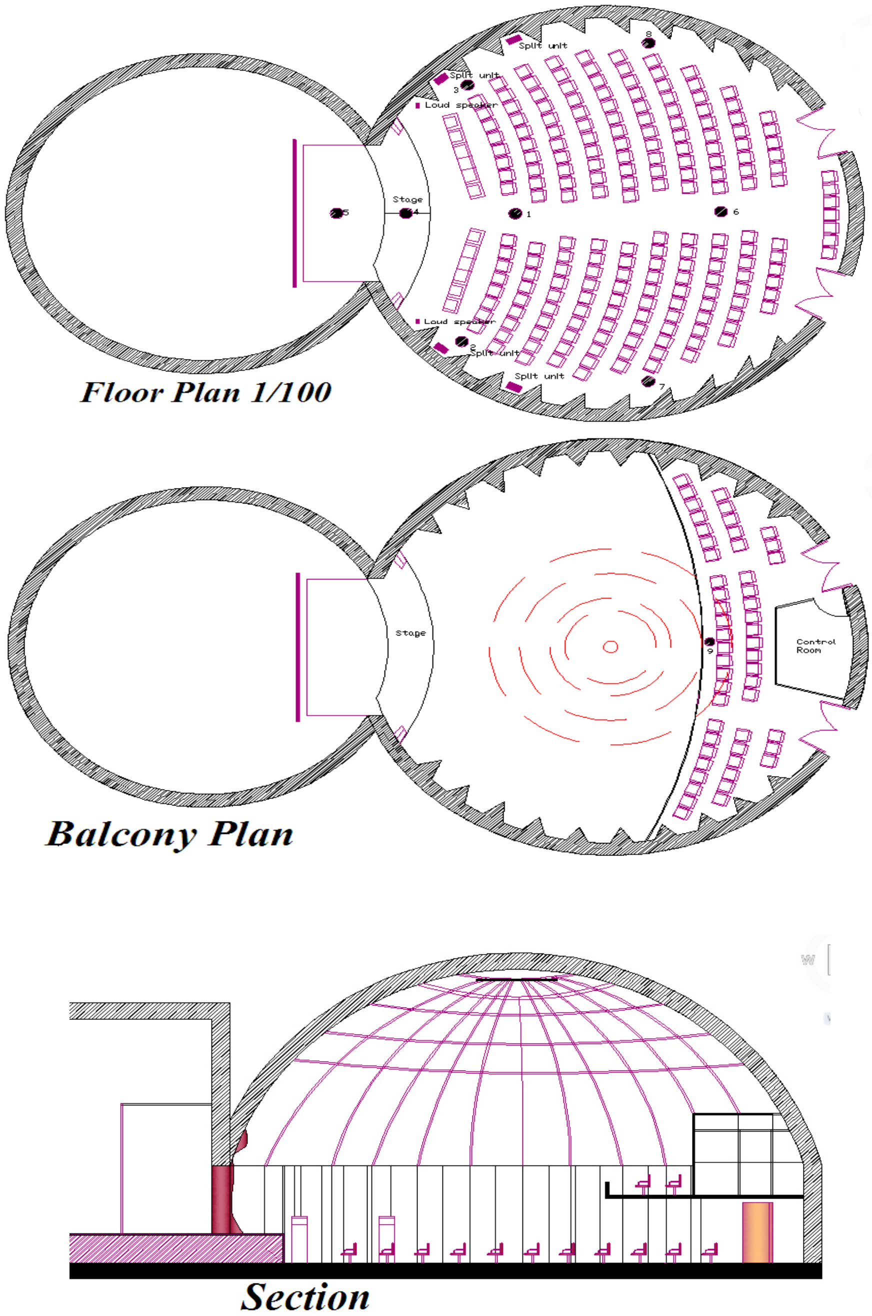


Figure (4): Floor, balcony plan and section for the Al-Rabat Concert Hall

3.1 The Acoustical Parameters

3.1.1 Reverberation Time (RT)

The RT is the time required for a loud sound to decay to an inaudible level after its source is cut off. It is defined as the difference between the sound to inaudible levels of -60 dB, and it is normally evaluated over the -5 to -35 dB (RT_{30}) decay of sound and multiplied by a factor of 2 for conformity with RT_{60}. [3,7]

3.1.2 Early Decay Time EDT

The EDT is a Reverberation time derived from the initial 10 dB of decay. The EDT is the time required for the sound to decay 10 dB after the sound source is turned off [3,7]. The EDT is equal to RT_{30} in a diffused space, and the sound decay is completely linear [8].

3.1.3 Clarity C_{80}

The C_{80} value is the ratio of the energy in the early sound compared to that in the reverberant sound, expressed in dB. Early sound is what is heard in the first 80 msec after the arrival of the direct sound. Clarity is a measure of the degree to which the individual sounds stand apart from one another. [3,7].

3.1.4 Sound Strength G

The G value is the difference (logarithmic ratio) between the sound energy of the measured impulse response to that of the response measured at a distance of 10 m from the same sound source in a free field (in dB). The sound strength, which is related to loudness, is a quantity that must be as uniform as possible throughout the hall [3,7].

3.2 Noise Rating Curves NR

The Noise Rating (NR) curves consist of a set of curves relating the octave band sound pressure level to the octave band center frequencies; each curve is given an NR number, which is numerically equal to its value at 1000 Hz. The NR curves method, which is defined in ISO R1996, was developed to determine the acceptable indoor environment for hearing preservation, speech communication and annoyance.[4,9]

4. Results and Discussion

4.1 Acoustics Parameters

According to ISO 3382, the most effective parameters to evaluate the acoustical environment are RT_{30}, EDT, C_{80} and G. Table (1) represents the mean values of the parameters for all receiver positions over the frequency range from 63 Hz to 8000 Hz, which were measured previously in an unoccupied state.

In ISO 3382 [3], the typical ranges for EDT are (1 sec; 3 sec), for C_{80} are (-5 dB; +5 dB), and for G are (-2 dB; +10 dB). Therefore, all the parameters that were measured in this concert hall are greater than the ideal values in ISO 3382.

Table (1): Values of the acoustic parameters for different frequencies

Freq. Hz	RT_{30}, sec	EDT, sec	C_{80}, dB	G, dB
63	8.25	8.45	-6.53	24.59
125	6.45	6.85	-5.33	23.52
250	6.1	8.02	-5.06	23.28
500	7.4	8.15	-6.01	24.13
1000	7.9	8.00	-6.34	24.42
2000	5.2	4.46	-4.29	22.62
4000	3.75	8.00	-2.58	21.19
8000	7.3	4.51	-5.95	24.07

4.2 Noise Rating Curves

The NR measured in this concert hall and its equivalent NR59 are shown in Figure (5); although the permissible range is NR25, this value is not appropriate for an indoor environment when considering annoyance, speech communication and hearing preservation [9]. The acousticians prefer the NR for concert hall must be smaller than NR10 [10].

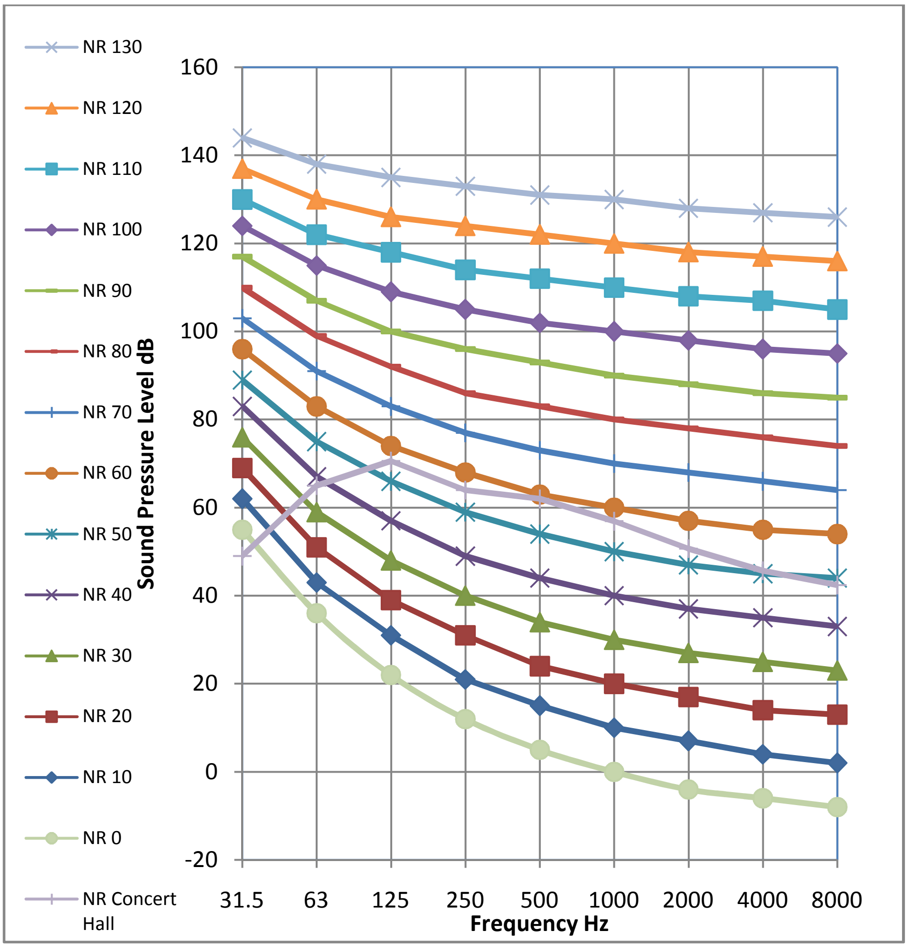


Figure (5): Noise Rating Curves for the hall over all frequencies considered

4.3 The relationships between the acoustical parameters

4.3.1 The relationship between RT_{30} and EDT

Figure (6) shows the results of the measurements of RT_{30} and EDT for different frequencies. The RT_{30} and EDT values were found to be longer at lower frequencies and shorter at higher frequencies. According to Higini [11], for a concert hall, the EDT should be between 0.9 × RT and RT; however, this relationship was not realized in this research.

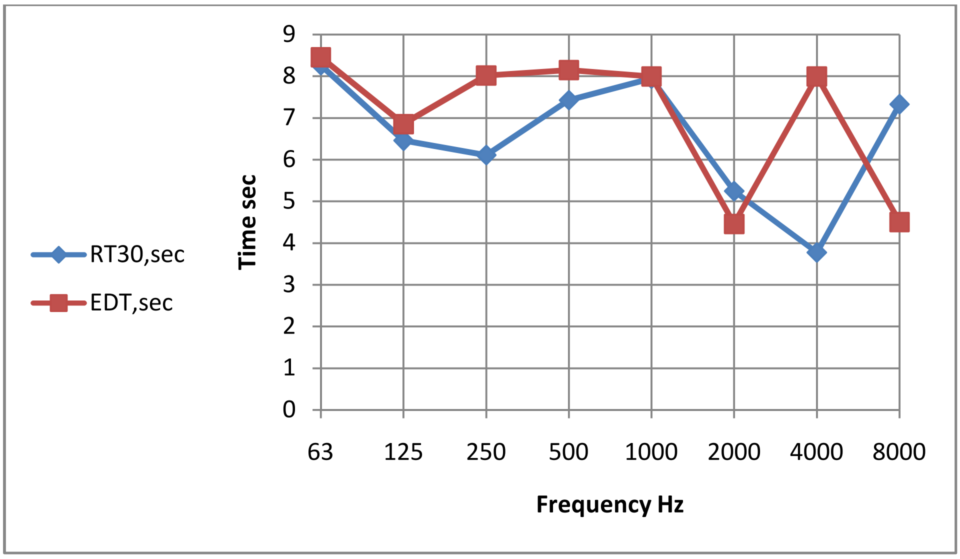


Figure (6): The results of RT_{30} and EDT for different frequencies

4.3.2 The relationship between RT_{30} and C_{80}

The results shown in Figure (7) represent the high values of the reverberation time that cause the music to be unclear and result in C_{80} having relatively high negative values, which is consistent with the results of Beranek [7].

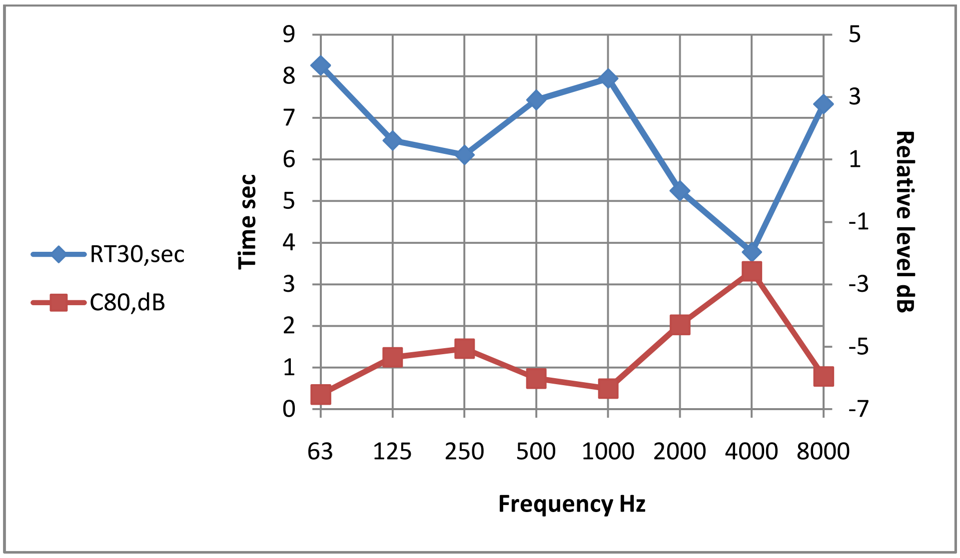


Figure (7): The results of RT_{30} and C_{80} for different frequencies

4.3.3 The relationship between RT_{30} and G

The sound strength, which is related to the loudness, is a quantity that must be as uniform as possible throughout the hall [7]. This value of the sound strength is related to the room sonority impression and depends of the energy of the first reflections and the RT [11]. According to the definition and revised theories of sound strength [12], the G values depend on RT, the hall's volume and the source-receiver distance; thus, the high value of RT with a small volume causes the high values of G and therefore the nonuniformity of the sound distribution in the hall.

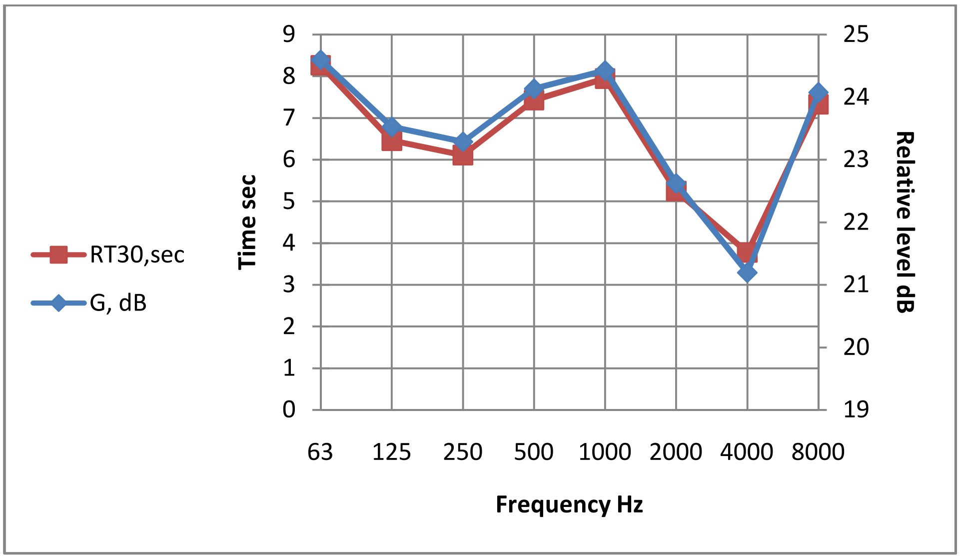
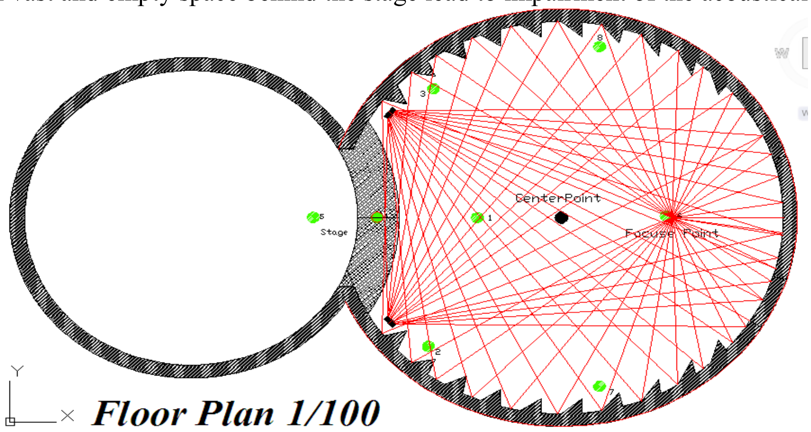


Figure (8): The results of RT_{30} and G for different frequencies

4.3.4 The effect of the concert hall shape

As mentioned previously, the shape of the concert hall depends on the circular geometry of the dome ceiling as well as the reflection from the wood covering the walls, so this shape creates sound focusing zones that are described in Figure (9) as well as the phenomena of whispering-gallery [13]; in addition, the directions of the reflections that are restricted by the circular shape cause defects in the hall's acoustical environment [10], such as a high reverberation time, a lack of sound clarity, and nonuniformity in the sound distribution throughout the hall.

Furthermore, the lack of effectiveness of the absorption material that exists, the unavailability of sound diffusers and the presence of vast and empty space behind the stage lead to impairment of the acoustical parameters.



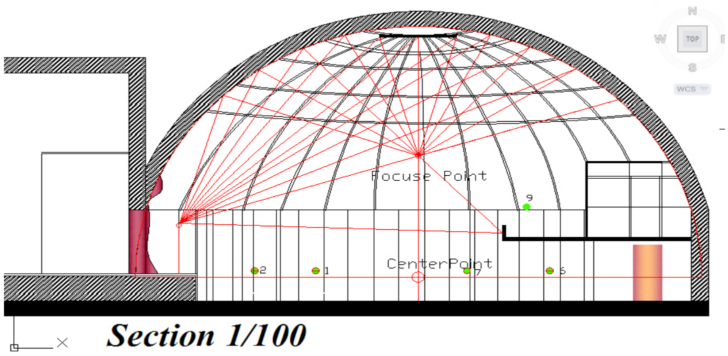


Figure (9) Schematic of the sound focusing zones
for the plan view and the section view of the concert hall

5. Conclusions

To evaluate the acoustical environment for the Al-Rabat Hall, the acoustical parameters and the noise rating curve were measured in this concert hall. The measurement results indicated that acoustic parameters (RT_{30}, EDT, C_{80} and G) are different from the typical values in ISO 3382. In addition, the noise rating curves that represent the background noise exceed the acceptable values.

All the results discussed describe the weaknesses of the hall's acoustical environment that cause annoyance, discomfort, anxiety, and distress to the audience, musicians, and technicians and their inability to enjoy the music in the hall.

6. Recommendation

This hall requires rehabilitation to improve the acoustical environment for the audience and the musicians. The results of the research recommends an increase in the sound absorption and the amount of diffuser materials used in the hall, especially for the wall coverings and at the center of the dome ceiling, with the use of a variety of these materials for the walls and the ceiling to diffuse sound and minimize the ceiling height to reduce the reverberation time.

In future studies, the effects of the audience and the seat absorption must be taken into account, in addition to the study of the acoustical parameters for the hall under partial and full occupancy and further investigations on the absorption coefficient of the materials used in the concert hall.

7.Acknowledgments

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