# ALI QAPU: PERSIAN HISTORICAL MUSIC ROOM

Hassan Azad University of Tehran, University College of Fine Arts, Department of Architecture, http://www.ut.ac.ir/

## 1 INTRODUCTION

The Ali Qapu is a Safavid palace in Isfahan, Iran which originally designed as a vast portal in the early 17th century and then it turned to a six-story palace with a series of additions over a sixty year period to accommodate court functions[1]. Building materials used for this structure are mud brick and baked brick used on the foundation of quarried stone. Vaulted ceilings of mud brick are richly decorated with painted, carved stucco and tiled Muqarnas in the sixth floor 'music room'[2]. As it can be seen in Figure 1 cutouts on the surfaces of Muqarnas in the shape of ceramics and glassware create delicate surfaces which have acoustical specialty due to their diverse and also unique forms that represent a complex Helmholtz cavity absorber.

It has become prevalent these days to peruse and analyze the acoustical parameters of enclosures through the different acoustical simulation software such as Odeon 9, CATT-Acoustics 8, EASE 4.1 and Ramsete 2.5, either before or after their construction. Ancient buildings which have had acoustical specialty have been noticeable for acoustician to be surveyed too. ERATO project (identification Evaluation and Revival of the Acoustical heritage of ancient Theatres and Odea) is one of the most considerable surveys which has carried out in the pertinent field. One of the objectives of this project is to study the acoustical properties of ancient theatres and to discuss their 'excellent' acoustics as they generally are described. As a result it is possible for the first time to listen to these historical buildings as they sounded in the past[3].

Figure 1: Cutouts stucco Muqarnas, Music Room, sixth floor

This paper introduces the components with acoustical properties of the music room of Ali Qapu and analyzes their individual effects by creating different 3D models relevant to each component and then simulating them through Odeon 9 as an acoustical simulation software. Also some pieces of Iranian traditional music which are expected to be performed in the related era have been selected for auralisation. The result provides proper outputs to discuss the historical architectural acoustics thinking and makes it feasible to find that how Ali Qapu has acted as an acoustical enclosure.

# 2 PREPARATION FOR SIMULATION

## 2.1 3D Modeling

The 3D model of Ali Qapu has been created in different stages through the software below:
Auto CAD 2009, Rhinoceros 4.0 and Autodesk 3ds Max 2009 regarding to their capability to construct 3D objects and to export files with DXF or 3ds extension using the data which were originated from historic buildings survey projects carried out by Iran Cultural Heritage organization. In figure 2 a rendered scene of Ali Qapu which has been generated through 3ds Max software has shown.

Figure 2: Bird view of 3D model, Music Room

## 2.2 Structural Components with Acoustical Properties

The Music Room of Ali Qapu has become renowned since it has distinct components with eminent acoustical properties so in order to find out the acoustical effects of these parts, they were pulled out one at the time from the Reference model and the results originated from the simulation of each configuration compared to either Reference model or other ones. The quoted structural components which are displayed in Figure 3 and Figure 4 were modified as below:
Open windows in Reference model have replaced with lattice windows with absorption coefficient of 0.4 in all frequencies in the first modification. In the second one, cutouts on the surfaces of Muqarnas have omitted in order to reveal the effects of the Helmholtz cavity absorber and eventually the role of Muqarnas as a diffuser has discovered by its neglecting in the third modification.

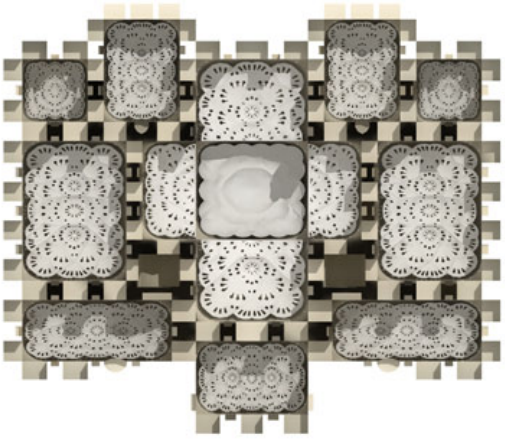

Figure 3: Bottom view, cutouts Muqarnas

The absorption coefficients of the materials were acquired from collating the global material library of Odeon with available documents about materials used in Ali Qapu. One of the most reliable measurements which has been done be Dr. KH. Molana in collaboration with BHRC (Building and Housing Research Center) shows that the reverberation time in Ali Qapu in the frequency range of 100-3500Hz is approximately constant with the amount of 0.85 $s^4$.

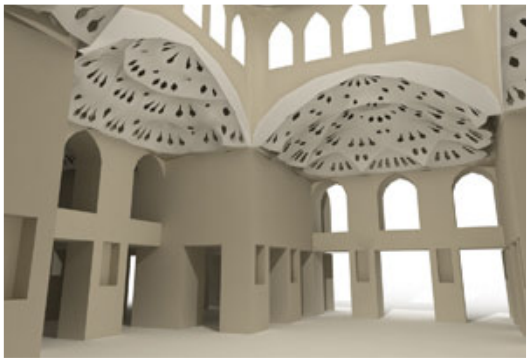

Figure 4: Interior view, interior walls

# 3 SIMULATION

## 3.1 Preliminary Measures

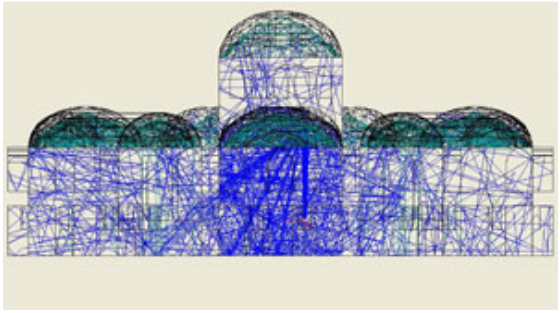

Figure 5: Propagation of rays from source 1

The imported model of Ali Qapu into Odeon with no bug (duplicated or overlapped surfaces) was shown to be owned a maximum surface number of 21577 in Reference model and a minimum surface number of 4264 in No Muqarnas model. Also the room volume factor for corresponding configurations was 847.07 $m^3$ and 1094.82 $m^3$ respectively. The simulation was carried out with a number of 300000 rays as shown in the Figure 5 and two Omni-directional sources in addition to 10 receivers to uphold nearly a precise calculation.

## 3.2 Acoustical Parameters

The Odeon can derive results for 8 frequency dependent parameters ( $EDT_{(S)}$, $T30_{(S)}$, $SPL_{(dB)}$, $C80_{(dB)}$, D50, $Ts_{(ms)}$, LF80, $DL2_{(dB)}$ ) and 3 independent parameters ( STI, $SPL(A)_{(dB)}$, $LG_{(dB)}$ ) while using multi point response calculation and in this paper T30, C80, DL2, STI and LG80 have analyzed and compared in 4 different configurations.

### 3.2.1 $T30_{(S)}$

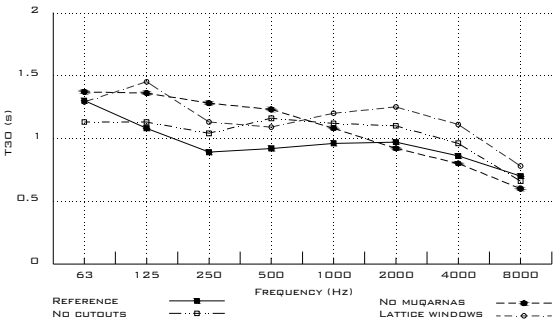


Figure 6: Simulated T30 in 4 different configurations

The Figure 6 illustrates that in all configurations of Ali Qapu the reverberation time is considerably low and it differs from around 1.5s in low frequencies to 0.7s in high ones but there is one notable point that the RT in all configurations except No Muqarnas which decline moderately from low to high frequencies is extremely invariant between 125-4000 Hz 1/1 octave frequency bands and it is principally due to the cutouts Muqarnas. All modifications seem to bring about higher RT than Reference model especially in Lattice windows configuration which has increased T30 up to 1.47s.

### 3.2.2 C80 $_{(dB)}$

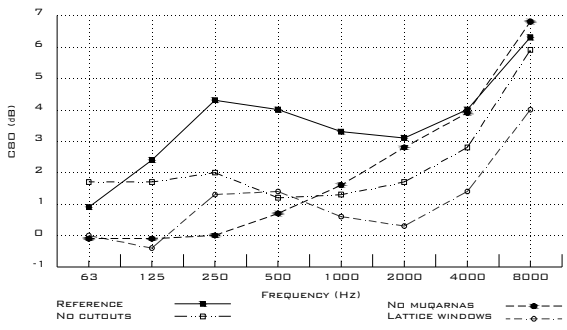


Figure 7: Simulated C80 in 4 different configurations

In Figure 7 clarity is shown to be dispensed between 0 to 6 dB in most of the configurations and the highest amounts are referred to Reference model. When Muqarnas has no cutouts clarity falls by 2-3 dB in mid frequencies and follow by that another changes lessen C80 by the average amount of 1 dB. Quoted reduction can be resulted from diminution in total absorption following by increase in RT.

### 3.2.3 LG80 (dB)

The range of strength shown in Figure 8 is nearly between 0 to 10 dB which is completely good if compared with the amount that proposed by Odeon for existing concert halls (the strength should not be lower than +3dB). Furthermore, in spite of short distances between source and receivers, the level differences between different receiver positions are rather big and this might be due to the specific spatial arrangement of Ali Qapu which has generated different coupled spaces around the main hall.

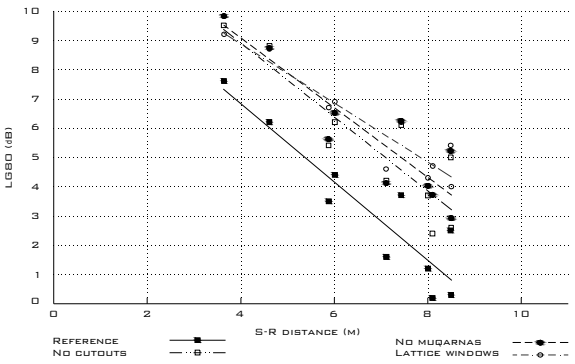


Figure 8: Simulated strength averaged over the 250-4000Hz frequencies in 4 different configurations

The rate of the level reduction over distance is identical in all configurations except Lattice windows. In fact this case has lowest rate and follow that lowest effect on LG80 by S-R distance. The averaged sound decay over distance in Reference model is considerably lower than other configurations. This can be confirmed that the cutouts Muqarnas have an eminent role as a diffuser in addition to its main role of cavity absorber.

### 3.2.4 Averaged Acoustical Parameters

Table 1 indicates that DL2 is very high and comparable to free field conditions in all configurations especially in Reference model. It should be referred to the style of spatial arrangement of Ali Qapu and its coupled spaces. As a result of good STI value in all configurations the Ali Qapu could act as an appropriate place for both music and speech.

The averaged T30 is so close to each other in No cutouts and No Muqarnas configurations with the amount of 1.1s but in No cutouts configuration in contrary to another one the reverberation time is extremely constant over the 250-4000Hz frequencies.

| CONFIGURATIONS | ACOUSTICAL PARAMETERS | | | | |
|---|---|---|---|---|---|
| | T30 (S) | C80 (dB) | LG80 (dB) | STI | DL2 (dB) |
| REFERENCE | 0.95 | 3.93 | 3.12 | 0.62 | 8.03 |
| NO CUTOUTS | 1.11 | 1.55 | 5.39 | 0.57 | 7.50 |
| NO MUQARNAS | 1.13 | 1.28 | 5.77 | 0.58 | 7.68 |
| LATTICE WINDOWS | 1.23 | 0.90 | 6.07 | 0.56 | 6.46 |

Table 1: Simulated acoustical parameters averaged over the 250-4000Hz frequencies and S-R distance in 4 different configurations

# 4 CONCLUSION

The following results could be derived from acoustical computer simulations of Ali Qapu:
The reverberation time was nearly low in all configurations. This means that Ali Qapu has been so suitable for intimate music especially Iranian ballad which is so close to Iranian traditional music performed in that era. However, nowadays there are some styles of Iranian traditional music which perform choral even orchestral.

In spite of the high proportion of room volume to audience between 8 to 10 $m^3$ per person, presence of cutouts Muqarnas brought about low reverberation time to uphold desired music. The maximum amount of C80 and the minimum of LG80 in Reference model discovered the diffuser role of cutouts Muqarnas.

# 5 REFERENCES

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