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THE ACOUSTIC DESIGN OF OPERA HOUSE DUBAI

Mark Howarth and Matt Robinson

Sandy Brown Associates LLP, UK
email: markh@sandybrown.com

This paper describes the acoustic design of Opera House Dubai, a new multi-function auditorium in Downtown Dubai, UAE. The opera house opened on 31 August 2016. The 2000 seat auditorium has variable acoustics utilizing drapes and banners for mid-frequency absorption and inflatable baffles for low frequency absorption. Adjustable geometry, using pivoted side boxes, hydraulic lifts, movable seating wagons and an orchestral shell allows conversion between three configurations for theatre, concert and banquet uses. The building is close to existing and proposed residential sites so the high levels of sound insulation are provided to control amplified music egress. The room acoustic and sound insulation strategies and mechanical ventilation system design are described and acoustic measurements are presented.

Keywords: room acoustics, opera, theatre, concert, orchestra

1. Introduction

Opera House Dubai is a privately funded building in Downtown Dubai developed by Emaar Properties containing a 2000 seat auditorium and support facilities which opened on 31 August 2016 following a four year design and construction period.

This paper describes the key acoustic design features of the building.

2. Design team

The design team members were:

- Atkins - architecture, building services and structural engineer
- Mirage – project management
- Theatre Projects – theatre consultant
- Arts Architecture – theatre interior design
- WA International – front of house interior design
- MLC – cost consultant
- Sandy Brown Associates – acoustic consultant.

3. General description

3.1 Uses

The auditorium is a unique ‘3 in 1’ multi-function auditorium which has three geometric configurations for:

- Theatre/opera

- Orchestral concerts
- Banquets.

The facilities also include a rehearsal room, a rooftop restaurant and a large atrium.

3.2 Location

The building is located close to Burj Park and Burj Khalifa Lake. The area is dominated by high rise hotels and residential towers with adjacent plots to be developed for residential use in the near future.

4. Building envelope

External noise levels were measured in the range L_{Aeq} 55-59 dB and were largely determined by road traffic with occasional music associated with fountain displays within the lake.

The design placed the auditorium and rehearsal spaces in the centre of the building with perimeter areas used for circulation and ancillary spaces. These acted as an acoustic buffer zone for the full height of the auditorium.

At roof level, a restaurant and mechanical plant areas are located above the auditorium and the rehearsal room. The key sound insulation issues were therefore to control noise ingress from mechanical plant and the restaurant to the auditorium and control noise egress from amplified music within the building to residential and hotel buildings overlooking the roof. This was achieved by use of a concrete roof with a floated concrete floors to plant and restaurant areas to provide good standards of low frequency sound insulation. The fly tower has a concrete lid with a wide air void and insulated roof panels above to provide a double leaf build-up.

5. Internal sound insulation

Within the building the main auditorium and stage house were formed from structural concrete which provided high levels of airborne sound insulation. Independent linings were used where sources of structure-borne noise, such as lifts, were located adjacent to walls.

Early input on the design enabled layouts to be planned to minimise adjacencies requiring high sound insulation performances where possible. Although there remained an unavoidable adjacency between the rehearsal room and the stage house of the auditorium. A floated box-in-box construction was used to maximise the achievable sound insulation. This used an inner plasterboard box construction on a floated concrete floor with the outer box formed from structural concrete, as sketched in Figure 1.

The measured sound insulation was limited by background noise but was at least $D_{\mathrm{n}T,\mathrm{w}}$ = 74 dB with a $D_{\mathrm{n}T,125\ \mathrm{Hz}}$ = 68 dB when measured from the stage to the rehearsal room with a reference reverberation time of 0.5 s.

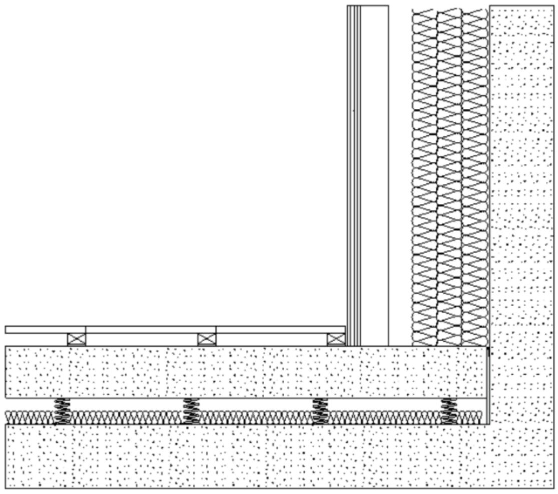

Figure 1: Sketch detail of rehearsal room floor

6. Auditorium acoustics

6.1 Room geometry

As a multi-function space, the room could not be designed as a traditional opera house. The width of the auditorium and stage house was determined by the width required for the banquet mode. This is approximately 33 m which is greater than recommended acoustically for opera and orchestral concerts. The multi-functional use also required a significant amount of technical equipment and gantries at high level which would not normally be present in a concert hall. This led to an overall gross auditorium volume (including the stage with orchestra shell) of 31,000 m^3 which equates to 15.5 m^3 per person. This is larger than would traditionally be recommended for opera houses or concert halls but was necessary to account for the volume taken by a significant amount of technical equipment along with the additional sound absorption it provided.

6.2 Movable boxes

To help to narrow the ‘acoustic width’ of the room, movable boxes were used to the sides of the stalls. These reduced the width between boxes to approximately 23 m. The boxes extend up to upper balcony level and are configured using a pivoting mechanism which allows them to be angled inwards towards the proscenium stage for theatre/opera use. Figure 2 shows layouts for the theatre and concert configurations.

For theatre mode the side boxes are rotated towards the centre to align with a movable proscenium wall and the void behind the boxes is lined with sound absorbent drapes.

For concert use the proscenium opening is widened and the side boxes are rotated to increase early lateral sound reflections to the stalls. An orchestral shell (by Wenger) is used to separate the stage house from the auditorium and provide stage reflections.

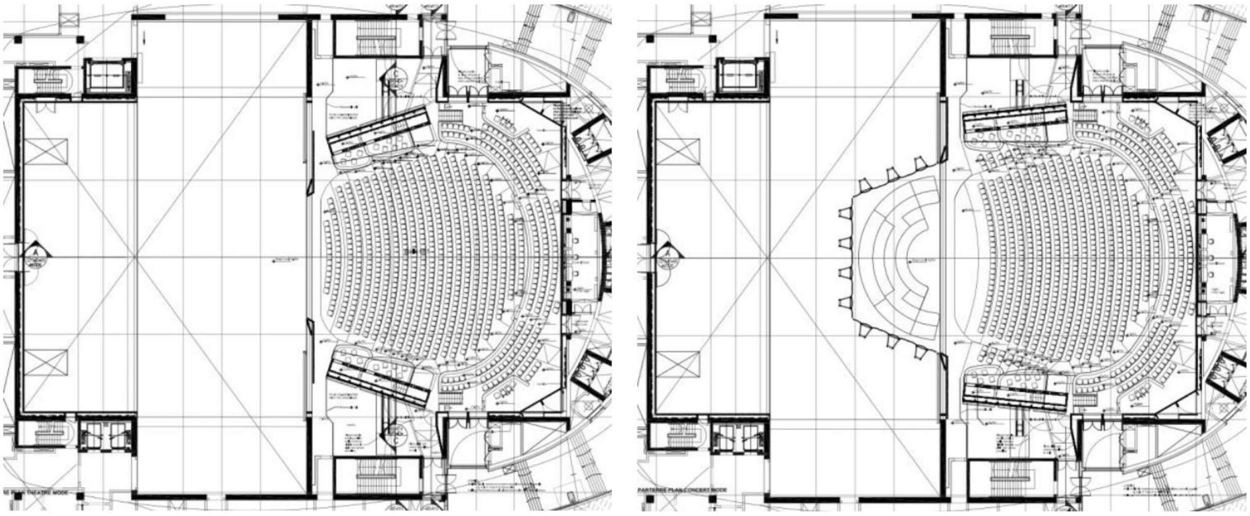

Figure 2: Layouts showing theatre (left) and concert (right) configurations

The angles of balcony fronts to the boxes vary with height and were determined using ray-tracing to maximise early reflections to the audience in the stalls.

Partial screens were introduced to the sides of the balconies between the side stairs and the seating to reduce width and strengthen early lateral reflections while maintaining the larger outer volume for late reverberant decay.

To reduce ‘acoustic shadowing’ under balconies, overhangs were minimised by stepping back the auditorium rear wall with height, as shown in Figure 3. The lower balcony overhangs two rows at the rear of the stalls; the maximum upper balcony overhang is approximately 1.5 x the balcony floor-ceiling height.

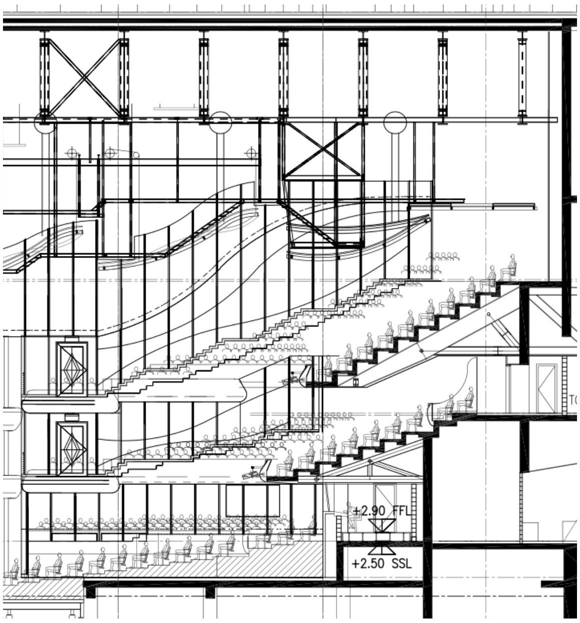

Figure 3: Section showing balcony depths

6.3 Finishes

The floor finish to the stalls is timber to provide reflections, the balconies are carpeted to control footfall noise and provide absorption. The audience seating is leather upholstered. This provides less absorption at high frequencies than fabric would but this was partly balanced by use of carpeted floors to the balconies.

The walls are finished with a bespoke diffusing finish which consists of a mashrabiya lattice arrangement in front of a space for variable acoustic banners and drapes backed by 150 mm deep profiled timber to the auditorium concrete wall.

Variable acoustic absorption is provided by electronically operated banners to side walls and drapes to rear walls, zonal areas are indicated in Figure 4.

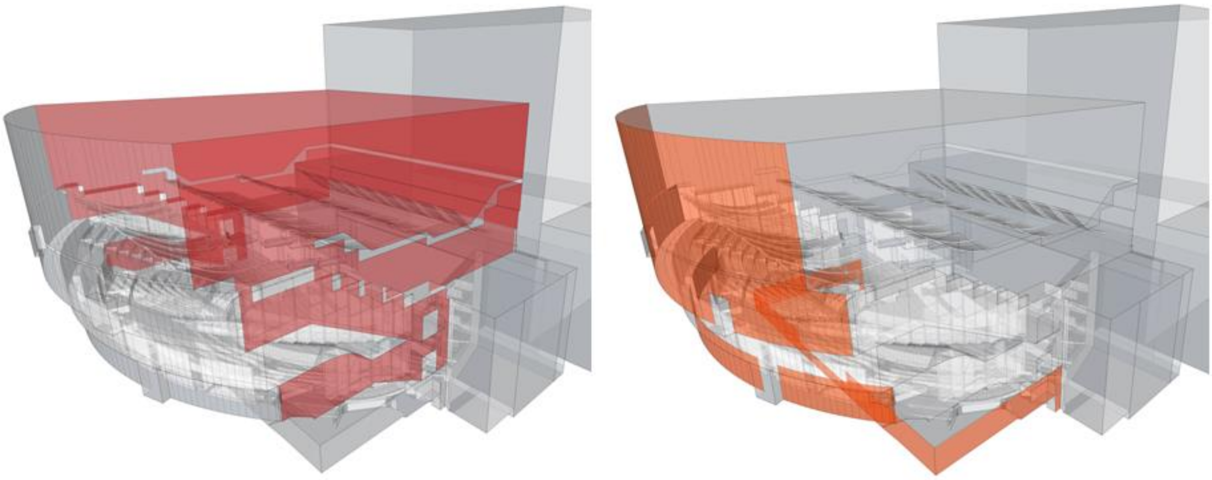

Figure 4: Zones for sound absorbent banners (left) and drapes (right)

Additional low frequency absorption is provided by use of high level inflatable baffles (by Flex Acoustics). It is understood that this is the first use of variable inflatable baffles in a venue of this type. A photograph of baffles in position above gantry level is shown in Figure 5.

All banners, blinds and baffles are linked to a central control system which enables saving of presets for different configurations and quick set up times.

Figure 5: Inflatable low frequency absorbers installed above gantry level

Commissioning measurements in the unoccupied auditorium resulted in mid-frequency reverberation times variable between T_{mid} 1.1 s and 1.6 s. Use of the inflatable baffles enables control of low frequency reverberation between $T_{125\ \mathrm{Hz}}$ 1.6 and 2.1 s. This allows the warmth of longer bass reverberation for orchestral use and a significant reduction to avoid 'boominess' for musical theatre and rock-pop performances.

7. Building services noise control

A twin ventilation system is used for the auditorium. For performance use, a displacement system with underseat air supply is used with extracts located above the ceiling. At stalls level supply air is provided to movable underseat 'wagons' which each support blocks of seating.

For banquet mode, these wagons are stored away and the room converts to a flat-floor function space by use of a series of lifts. The floor is carpeted for banquet use and the supply air is then provided by a separate system using air diffusers on flexible ductwork from ceiling level. The specified noise criteria were:

NR15 – orchestral concert, opera and drama use
NR20 - amplified music use
NR25 – banquet mode.

8. Discussion

The design of multi-purpose spaces is often considered acoustically only in terms of provision of variable mid-to-high frequency sound absorptive treatment. These can result in spaces where the mid-frequency reverberation time may be varied for speech or music uses but where the bass response is fixed. In practice this limits the true flexibility of the spaces because they can be too boomy for rock-pop music when variable absorption is deployed or lacking in warmth for orchestral use.

At Dubai Opera House the additional variable low frequency absorption and the movable geometry enable significant changes to be made to the acoustic response of the auditorium. The large gross volume used with reflective surfaces located within the room provides increased clarity with reverberation for opera and orchestral use. Deployment of the variable treatment provides a significant reduction in reverberation time at low, mid and high frequencies. This provides a very adaptable space. The room volume also allows sufficient space for the technical gantries and equipment required for modern musical theatre and rock-pop shows.

While the technology used for the design increases the capital cost of a project, the additional flexibility allows booking of a wide range of shows and events. This helps the venue operate commercially. Initial responses from audiences, performers and the press have been positive and the approach used could be adapted to other venues.