THE ACOUSTIC DESIGN OF GRAND CANAL THEATRE, DUBLIN

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1 INTRODUCTION

Grand Canal Theatre is Dublin's first purpose-built touring lyric theatre. Its opening performance was on 18th March 2010 following a 3-year design and construction programme. Its striking angular design, by Studio Daniel Libeskind, and red glazed paving (mimicking a red carpet to its door) set the theatre as the focal point of a new commercial development on the waterfront in Dublin's Docklands. The theatre is operated by the UK's largest venue operator, Live Nation.

Arup Acoustics provided full acoustic design services (room acoustics, sound insulation and noise control) for the project. The acoustic design was carefully integrated into the iconic architectural design and responded to the practical constraints of a tight site. The auditorium is designed to accommodate large-scale touring ballet, musical and opera productions.

2 PROJECT BRIEF

The acoustic brief for Grand Canal Theatre was to provide an auditorium principally suited to amplified "west end" shows, but with a good natural acoustic that would enable opera and other unamplified musical theatre and dance performances.

3 ACOUSTIC DESIGN PHILOSOPHY

In their purest form, the preferred environments for amplified sound and opera lead to conflicting acoustic designs. Theatres designed purely for amplified shows generally seek a larger seat count (greater than 2000) massed closer to the stage, lower reverberance and less reliance on the room geometry and surfaces to provide beneficial sound reflections. This leads to a lower, wider room with deep balcony overhangs. Preferred conditions for opera include smaller audiences, greater reverberance, carefully shaped room geometries and shallow balconies.

The acoustic philosophy for Grand Canal Theatre sought to balance the differing requirements of show sound and opera without resorting to a system to vary the room acoustics. The aim was an acoustic that would be sufficiently damped to enable a suitably designed sound system to deliver high fidelity show sound, but one that was sufficiently warm and reverberant and with appropriate clarity to provide a sympathetic acoustic for unamplified opera performance. As a guide to achieving this balance, a target reverberation time of 1.3s was set for the room in its occupied state.

The design intent of the room was to integrate the acoustical requirements into the architectural concept, providing a blend of sound reflecting and sound transparent surfaces in a room geometry that provides good sound clarity whilst maximising the acoustic volume to provide the necessary reverberance.

4 ROOM GEOMETRY AND DESIGN

As can be seen from the stalls plan in Figure 1, the auditorium is gently fan-shaped. This is a consequence of the seating capacity and the desire to limit the maximum distance from stage to seat. This form directs sound from the stage or orchestra pit towards the rear of the room, potentially starving the central seating areas in the stalls of beneficial lateral sound reflections.

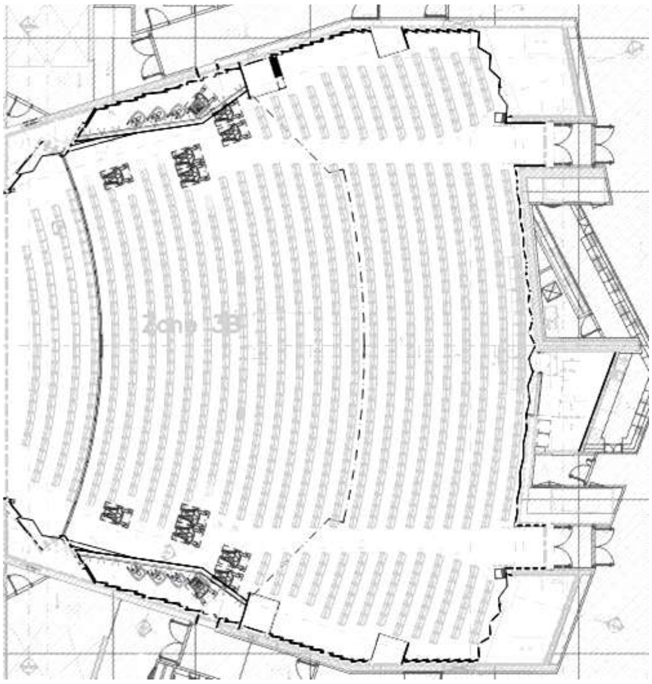

Figure 1: Stalls plan

The zigzag wall shaping on side walls helps redirect sound towards the centre of the room. The sound reflecting surfaces at low level either side of the proscenium and the box fronts are also designed with this in mind, keeping the room as narrow as possible close to the proscenium and providing improved reflection patterns for those in the centre of the stalls.

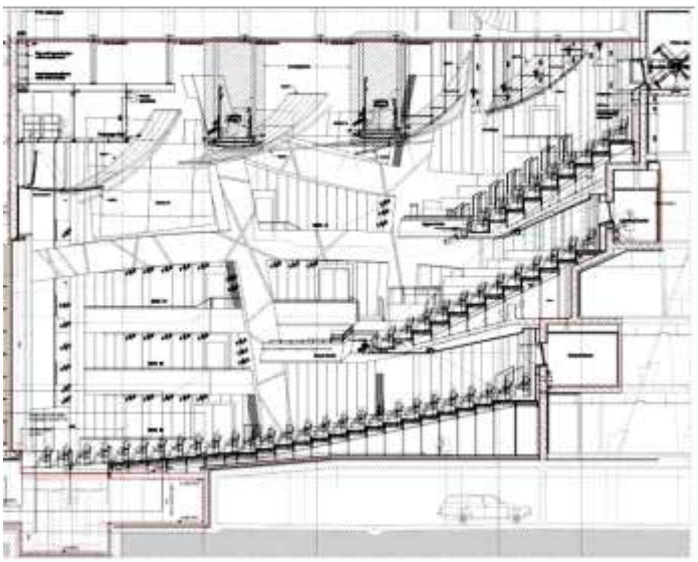

Figure 2: Long section

Larger scale shaping (see Figure 3) on the rear wall breaks up large plane surfaces to diminish potential adverse reflections from amplified sound back to the stage.

The architectural vision for the interior of the room included large “ribs” protruding from the walls (as shown to the right). It was important architecturally that these were substantial and, at 1.5m deep, they extended further out than acoustically desirable. A slatted finish was included (visible to the right, with loudspeaker cloth between the slats) to provide some sound propagation through the ribs, reducing the ‘shadow zones’ that they create. Where the geometry of the ribs is beneficial acoustically (such as where their undersides provide cue-ball reflections) or where there is no benefit of transparency, the ribs are solid.

The auditorium seating areas comprise of a raked stalls, two main balconies and boxes at the sides to populate the walls (see Figure 2).

In response to the brief for the auditorium, Arup set a target volume per seat of around 6.5m^3, ie around 13000m^3. The expansive upper walls that result from such a volume conflict with the theatrical aesthetic desire to “close off” the upper part of an auditorium with a ceiling – which helps to focus the audience on the stage. To couple successfully into the volume above such a ceiling requires it to be acoustically transparent.

The solution at Grand Canal Theatre was to form the ceiling from expanded metal mesh sails (see the image to the left) that allow the sound to pass into the upper heights of the room volume and back out again. To provide the desired sound transparency, the percentage open area of the metal mesh was around 70%. The orientation of the mesh was chosen to maximize the visual opacity of the sails as seen from the audience.

Hidden by the sails, there is a gently-curved sound reflector approximately 12.5m above the orchestra pit (for musician ensemble and overhead reflections from the stage) and sound reflecting surfaces beneath the lighting bridges that reflect early sound to certain audience areas.

The side balcony fronts are oriented to direct sound to the balconies whereas those facing the stage are angled backwards to prevent adverse sound reflections.

5 FINISHES

The walls are lined with painted plasterboard at low level, and are formed of exposed concrete where hidden behind the sails at high level. The zigzag wall linings (see Figure 3) were specified to provide variation in their surface masses (15 – 40kg/m^2) and sizes to avoid reduce the potential same-frequency absorption of repetitive constructions.

The balcony fronts include relief in the form of architectural motifs that provide some limited high frequency scattering. The ceiling is concrete on profiled decking.

Figure 3: Wall shaping on side wall (left) and on rear wall around control room (right)

Variable acoustic surfaces in the orchestra pit provide absorption and reflection on demand, enabling the space to be tuned for orchestra or amplified use. These surfaces in sound absorbing mode also control noise build-up and help create good working conditions for musicians. The balustrade between the orchestra and the audience is adaptable, enabling the string brightness balance to be adjusted.

The seats (left) are lightly upholstered with sound reflecting backs, arms and undersides. There are sound absorbing slots on the underside of the seat pan to help limit the room acoustic difference between times when the room is occupied and unoccupied.

The floor is constructed from dense calcium silicate board and carpeted to help provide acoustic control for the sound system,. The carpet is on thin underlay and is restricted to the horizontal surfaces to avoid excessive absorption in the room.

In common with other Arup designs, sound absorbing treatment (Baswaphon painted in the same colour as the other surfaces nearby) has been included to the underside of the first balcony close to the orchestra pit to reduce image shift. Other balcony ceilings are painted plasterboard over an air space.

As the theatre is a receiving house (it does not produce its own shows) it is likely that the flytower will often be fairly empty for shows. To provide some additional room acoustic control in the flytower, there is approximately $400m^2$ of black sound absorbing foam attached to the wall behind the counterweights for the flying system. The mid-frequency reverberation time in the flytower with the house masking in place (but no set or flown scenery) is 1.7s, meaning that the flytower makes little difference to that measured in the (unoccupied) auditorium. At low frequencies, the lightly dressed flytower is less damped, resulting in the oft-experienced increase in low frequency reverberation when the two spaces are coupled.

6 SUMMARY RESULTS

The numerical results of the commonly-measured objective parameters with the auditorium unoccupied (average values for the measurements from 6 source positions [4 stage and 2 pit] and 21 receiver locations) with a “lightly dressed” flytower are given in Table 1.

As previously mentioned, the bass ratio is affected by contribution of reverberant energy from the flytower. With the fire curtain lowered, the bass ratio in the auditorium is 1.2.

Parameter	**Value**
Reverberation time: $T_{30,mf}$ (s)	1.5
Bass ratio	1.3
Early decay time: $T_{10,mf}$ (s)	1.25
Vocal clarity: $D_{50(500-2k)}$ (stage sources only)	0.63
Musical clarity: $C_{80(500-2k)}$ (dB) (pit sources only)	0.6
Loudness: G_{mf} (dB)	-1.4
Stage to pit ratio: G_{stage}- G_{pit} (dB)	0.2
Services noise level	<PNC15

Table 1: Objective measurement results (unoccupied)

Although no measurements have been carried out in the occupied auditorium, it is expected that the reverberation time in this state is very close to that targeted.

7 GEOMETRICAL DATA

The key geometrical data for Grand Canal Theatre is provided in Table 2.

Acoustic volume (m^3)	13170
Seats (with orchestra pit)	2070
V/N (m^3/seat)	6.36
Maximum room height (m)	21.2
Height of (sound transparent) ceiling above stalls (m)	14.8
Maximum stalls width (m)	30.75 (stalls)
Proscenium opening/width of reflecting surface at proscenium (m)	14.9/16.9
Orchestra pit area (open to auditorium) maximum (m^2)	59
Distance from proscenium to first balcony (m)	17.8
Distance of farthest seat from stage edge (m)	34
Distance between 1^{st} and 2^{nd} balcony soffits (m)	5.8
$1^{st}/2^{nd}$ balcony overhang depth (m)	8.3/ 6.45

Table 2: Key geometrical data

Credit: Architekt Daniel Llibeskind AG/Ros Kavanagh

8 DESIGN TEAM

Principal architect: Studio Daniel Libeskind
Executive architect: McCauley Daye O'Connell Architects
Theatre planning and architecture: Arts Team (RHWL)
Acoustics: Arup Acoustics
Theatre systems engineering: Arup Venue Consulting
Engineering: Arup Consulting Engineers, Dublin
Project manager: Lafferty Project Management
Main contractor: John Sisk & Son Ltd