THE ACOUSTIC DESIGN OF WEXFORD OPERA HOUSE

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1 INTRODUCTION

Wexford Opera House in Wexford, Ireland, is home to Wexford Festival Opera (WFO). The first opera festival was held in Wexford in 1951, and the festival became established as an annual event making the best of the facilities crammed into a site behind a row of terraced houses in the heart of the medieval town. As the adjacent property had become available, WFO decided to redevelop the site of the existing Theatre Royal to provide a replacement opera theatre, a studio theatre and significantly improved front-of-house and back-of-house facilities. In 2001, Arup Acoustics was appointed by WFO to provide acoustic design services for the redevelopment of the site. The new opera theatre seats 781 and the building provides a base for the festival and a venue for local and touring companies. The existing Theatre Royal closed after the last day of the opera festival in October 2005 and opened in time for the festival in October 2008.

2 DESIGN BRIEF

Arup Acoustics worked closely with WFO, theatre consultants Carr & Angier and the Irish Office of Public Works to develop the design brief for the building. Fundamental to the aspirations of WFO was that the theatre should provide high quality acoustic environments to international standard, to support and enhance the creation, production and performance of opera in the 21st century. The emphasis for the room acoustic was that it should support and help to showcase the young vocal talent that has traditionally been a fundamental part of the Festival, but that this should be balanced with a fine orchestral sound.

3 DESIGN PROCESS

The room form and finishes were developed by the team, integrating the functional, aesthetic and acoustic requirements in a homogenous and harmonious manner. The preferred internal dimensions and balcony geometries (to ensure that audience would not be too cut-off from the room) were discussed at an early stage so that the desired auditorium and stage volumes could be massed on the site. Space was also allocated for a studio theatre, front of house and back of house facilities. This building massing process was complex, as the available space on site was limited. The auditorium shape was refined to accommodate circulation and entrances, resulting in a narrowing of the rear of the room at upper levels (see Figure 3).

Acoustic analysis of the developing design was carried out using the ODEON room acoustics software and the results fed back into the design process. The room was commissioned by a series of objective measurements and listening tests in Autumn 2008 through the rehearsals for the first opera festival in WFO's new home.

4 ROOM DESIGN PRINCIPLES

With inspiration from classical theatre design, it was decided that the form should be a more traditional opera form than the previous theatre, which was a narrow "shoebox" with a single deep balcony. The new opera house has two shallow balconies that wrap around the sides of the room creating an intimate space and visually linking the audience and stage.

The team developed the room aesthetic to create a room in which the ceiling was clearly identifiable as a homogeneous surface that closes off the top of the room, with technical bridges hanging below it as designed architectural elements. This is an innovative approach in modern theatre design, expressing the ceiling above the technical walkways as a timber lid on the room volume.

The surfaces around the proscenium are sculpted to direct the sound from the stage and orchestra pit towards the audience. In addition to this, a sound reflector over the forestage, the underside of the lighting bridges and the room's soffit provide useful sound reflections from overhead. These surfaces have been designed with the balance of stage and pit sound in mind. Other geometrical features in the auditorium, such as the recessed side boxes and the bulbous balcony fronts close to the proscenium provide useful sound reflections back to the singers to enhance the support from the room.

An important feature of the acoustic in the previous theatre was the large forestage area that extended beyond the proscenium arch over the orchestra pit. In addition to bringing the action on the stage closer to the audience, this feature helped to provide a strong ratio of sound emanating from the stage to that from the orchestra pit. The new auditorium offers a similar forestage arrangement, but with the flexibility to create an increased open area for the orchestra pit similar to that found in modern (larger) opera house design.

5 GEOMETRY

The room plan is based upon a flattened horseshoe shape for the balconies, inscribed inside a rectangular box. The rear wall is shaped to counteract the inherent focussing of a concave form. There are excellent sightlines to the stage from all seats, giving good direct sound paths. The stalls seating area is raked at around 7°. Sightlines into the orchestra pit start in the first balcony and extend to the rear of the 3rd tier, enabling a bright string sound throughout.

The plans at stalls and 2nd balcony levels and the longitudinal section of the room, identifying the prime acoustic elements are given in Figures 2, 3 and 4.

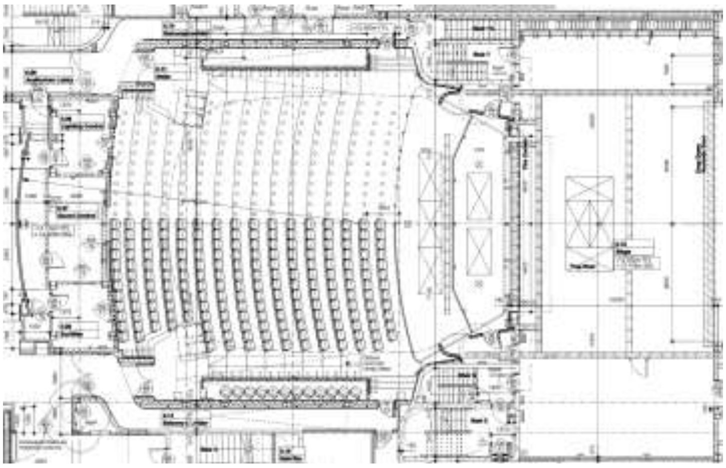


Figure 2: Stalls plan

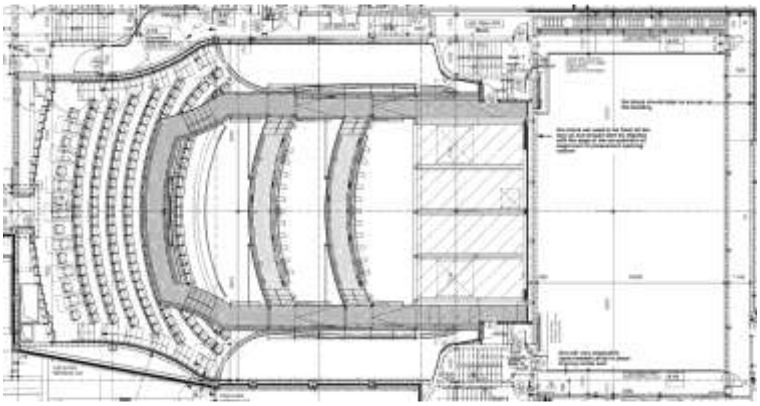


Figure 3: 3rd tier plan (showing lighting bridges)

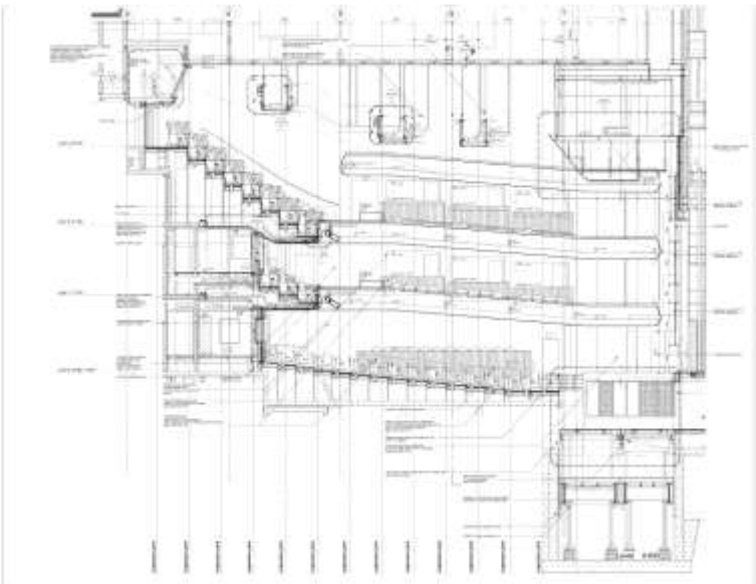
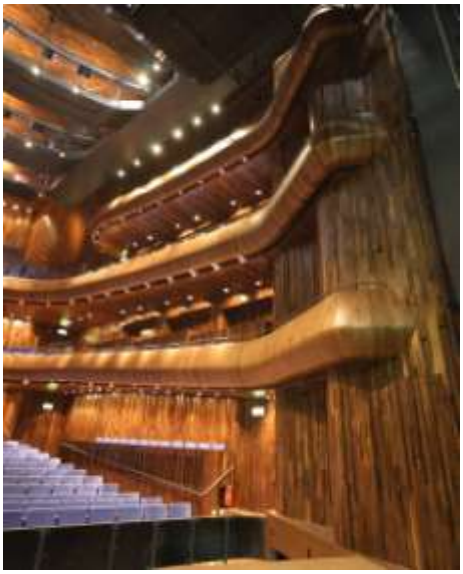


Figure 4: Long section

The acoustically important dimensions of the auditorium are given in Table 1.

Volume (m^3)	4845
No of seats	781
V/N (m^3/seat) (minimum)	6.2
Maximum room height above stalls floor (m)	15.5
Height of ceiling elements above stalls (m)	11.6
Max stalls width (m)	18
Width at proscenium (m)	11
Orchestra pit area (open to auditorium) standard/maximum (m^2)	39/67
Distance from proscenium to 1st balcony (m)	17.6
Distance of furthest seat from stage edge (m)	28
Distance between 1st and 2nd balcony soffits (m)	3.3
Balcony overhang depth (m)	2.8

Table 1: Geometrical data for Wexford Opera House



Angled walls either side of the forestage area fan outwards in two waves to the line of the bounding walls. The lowest surfaces on these angled walls provide useful early sound reflections that reinforce the stage sound. Further up these walls, the geometry is designed to provide a balance of sound reflections from stage into the auditorium, from the orchestra pit sources to themselves and other pit users, and for singer feedback.

The balcony fronts are bulbous and convex in section to help scatter sound. In addition to the two audience balconies, there is also a technical gallery that extends along the walls on each side of the auditorium, maintaining the rhythm of the balcony spacing. In the upper balcony, the side walls offer convex curvature which helps to scatter the incident sound.

6 FINISHES

Aesthetically, it was desired that the auditorium was lined with timber. This is appropriate acoustically, although it is not without challenge. The wall and ceiling panelling has been fixed tightly to the blockwork walls and concrete soffit to minimise the low frequency absorption that exists when a timber layer is installed over an air-space. The floor is a heavy build-up of plywood and timber and the balcony soffits are generally timber on building board, providing a surface mass of 20kg/m^2.

The balcony soffits above the stalls, close to the orchestra pit, incorporate sound absorption behind timber slats to reduce the strength of sound reflections from the orchestra pit (and the degree of the resulting false location that is widely experienced in such places). Other than the seating, this is the only additional broadband sound absorption in the auditorium.

The timber finish includes a pseudo-random pattern of recesses to provide scattering. The recess widths and depths vary and the pattern returns into the soffit. The scattering detail also hides embedded unistrut for ease of fixing theatrical elements to the walls without damaging the timber finish.

The remainder of the soffits and wall surfaces are a smooth timber finish. The balcony fronts are formed from layers of curved plywood with a facing of timber veneer.

The seats provide low sound absorption (to help maximise reverberance), but are also designed to limit the difference in room acoustic between rehearsal (unoccupied) and performance (occupied) states. This was a particular challenge, due to the fact that the seats are upholstered in leather. The perforated metal seat undersides were designed to maximise the sound absorption at high frequencies, replacing some of the absorption usually provided by cloth upholstery and hence minimising the difference between unoccupied and occupied states.

The visual impact of the (relatively) large volume is reduced by the presence of the lighting bridges that are suspended inside the room.

The sound reflector above the orchestra pit is set at a height of 9.9m above stage level. A visual ceiling continues beneath the reflector in the form of aluminium clad mdf strips, spaced to allow the sound to pass through them and reflect off the surface that they hide, as shown in the adjacent image.

7 ORCHESTRA PIT

The orchestra pit is designed to provide the flexibility required by a 21st century opera house. A double-deck upstage pit lift can be raised to create a thrust stage with orchestra playing area under (similar to the previous theatre), or lowered to create a more open pit with the stage edge on the proscenium.

Acoustic flexibility in the orchestra pit, as per other recent opera house designs by Arup, is offered in the form of tracking, reversible reflecting/absorbing panels that form the upstage wall of the pit and sound absorption underneath the overhang soffit. It is also possible to vary the sound transparency of the pit rail between the stalls and the pit by adding or removing solid panels.

8 SUMMARY RESULTS

The numerical results of the commonly-measured objective parameters with the auditorium fully occupied (average values for the measurements from 4 source positions [2 stage and 2 pit] and 7 receiver locations [distributed across all seating areas] with the stage set as shown in section 4 of this paper) are given in Table 2.

Subjectively the auditorium has a warm, rich, spatial orchestral sound, with excellent vocal clarity throughout. The space is also very intimate, both visually and acoustically. It is a quiet space, allowing orchestral textures and vocal nuances to be readily communicated to the audience.

Praise of the acoustics has been received from the client, singers, orchestra players and audience alike, and readers are encouraged to visit the opera festival to experience it for themselves!

Parameter	**Value**
Reverberation time: $T_{30,mf}$	1.1s
Bass ratio	1.0
Early decay time: T_{10mf}	0.9s
Vocal clarity: $D_{50(500-2k)}$ (stage)	0.59
Music clarity: $C_{80(500-2k)}$ (pit)	4dB
Loudness: G_{mf}	3dB
Stage to pit ratio: G_{stage}- G_{pit} (with forestage)	1dB
Background noise level (no audience present)	PNC15

Table 2: Objective measurement results (occupied unless stated)

9 DESIGN TEAM

The scheme design was originally developed by architects and building services engineers from the Office of Public Works, theatre consultants Carr & Angier and acoustic consultants Arup Acoustics. Following receipt of Planning Permission and confirmation of State funding, the Design Team was completed in Autumn 2005, through OJEU competition, with the appointment of Arup Consulting Engineers, quantity surveyors Nolan Ryan and Keith Williams Architects, who developed the scheme design and provided architectural services, in collaboration with the Office of Public Works Architectural Services, through to completion.