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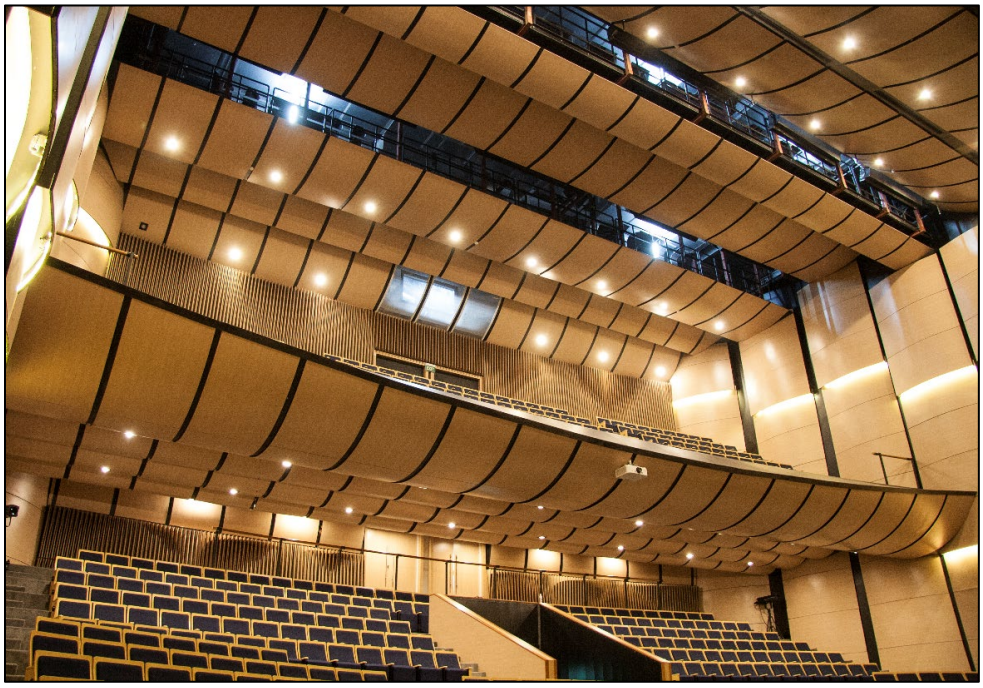
AN INTRODUCTION

TO

THEATRE ACOUSTIC DESIGN



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Palmer Acoustics Australia Pty Ltd

THEATRE ACOUSTIC DESIGN

Good theatre acoustic design requires consideration of the different functional requirements for different theatre types.

The following theatre type acoustic considerations apply:

1. THEATRE ACOUSTIC OBJECTIVES

The acoustic objectives for theatre are dependant upon the intended use and budget. Theatres can typically expect the following specifications:

Criterion	Performing Arts Theatres	Black Box Theatres	Lecture Theatres	Multipurpose Theatres
MEP Plant Noise Leq	NR 15	NR 20	NR 25	NR 25
Rain Noise Levels LAeq	20 dB(A)	20 dB(A)	30 dB(A)	20 dB(A)
Structure borne noise level	15 dB(A)	15 dB(A)	30 dB(A)	20 dB(A)
Reverberant sound RT60 Unoccupied 250 to 2000 Hz	1.5 to 2.2 sec	0.5 sec	1.2 sec	1.5 sec
Speech Intelligibility STIPA	0.55	0.70	0.65	0.55
Clarity C80 (in all areas)	-1 to + 3 dB			3 dB
Early Time Delay ETD / RT	>85%			
Uniformity of natural and public address sound across all seating	+ or - 3 dB	+ or - 3 dB	+ or - 5 dB	+ or - 5 dB
Structural Vibration for occupied areas 1 to 80 Hz RMS	0.1 mm/s	0.1 mm/s	0.1 mm/s	0.1 mm/s
Typical Façade acoustic isolation	Rw 55	Rw 55	Rw 50	Rw 55
Typical Environmental Noise at external noise sensitive areas	50 dB(A)	50 dB(A)	50 dB(A)	50 dB(A)

These objectives should be agreed between the acoustic consultant and the client and form the basis of a quality assurance process in which the design details, specifications and construction works are defined so these objectives are achieved. At the end of the project acoustic testing should be able to confirm that the intended objectives have been achieved. This QA role should be the overall responsibility of the acoustic consultant. Theatre design is not a ”black art” as some people have claimed, but a predictable outcome from planned engineering processes.

2. THEATRE TYPES

A. PERFORMING ARTS THEATRES

Performing arts theatres, are spaces where the acoustics is critical to the space meeting its intended objectives. These spaces rely upon the quality of the sound transmission within the room to provide a high-quality auditory experience and to ensure clear and intelligible speech, with often natural (unamplified) sound as the source. These outcomes are not always easy to achieve and require careful consideration of the basic principles of theatre design.

The acoustics of performing arts theatres using natural sound is one of the most complex and challenging works that an acoustic engineer can be called to work on. The engineer is required to address not only the standard issues of external noise intrusion, noise from mechanical plant, structure borne vibration, reverberant sound within spaces; but also work with the subtitles of speech intelligibility, the uniform distribution of unamplified sound across a large seating area and a fine balance between direct sound and early and late reflections from walls, floors and ceilings. It is important that there is uniform sound quality equally across all seats to create the sense that this is one audience with one experience. Patrons attend theatres to experience a combined and immersive listening experience that cannot be found through television and multimedia.

When a space is required for operatic performances, the room must be highly effective in transmitting an unamplified performer’s voice from a stage equally to all seats, without the disruptive effect of late reflections. However, in this, there must also be supporting reflections from the walls and slightly later reflections from the ceiling. In effect these are what is called “early reflection” concert halls, where concave panels are used to give early reflections from the walls and ceiling.

When a space is required for orchestral performances the theatre becomes an extension to the performers instruments and very much affects the quality of sound received by the listeners. With incorrect placement of sound absorptive and sound reflective surfaces the sound received by patrons can either, be too low or high in level, appear to be coming from areas other than the stage, lose tonal quality, lose clarity, or lose intelligibility. In effect the sound can be “muddy”, lacking the richness and clarity necessary for quality theatre performance. Further to this is the necessity to provide sound that envelopes the audience, with the sense that the auditorium is “naturally” enhancing the experience.

Theatre acoustic design is a fine balance requiring consideration of the following:

- Theatre volume.
- Line of site views.
- Number of seats.
- Sound focusing from the walls, ceiling and any balconies.
- Sound absorption for the rear walls.
- Sound absorption from the floor and chairs.

- Sound reflection from the stage, proscenium arch and/or orchestra pit
- Noise and vibration from mechanical plant, and rain on the roof.
- Acoustic privacy from the surrounding walls, roofs and floors.
- The control of ground borne vibration and hence noise.

Figure 1: Theatre with under balcony clearances and convex reflective panels to focus sound to the lower seating areas.

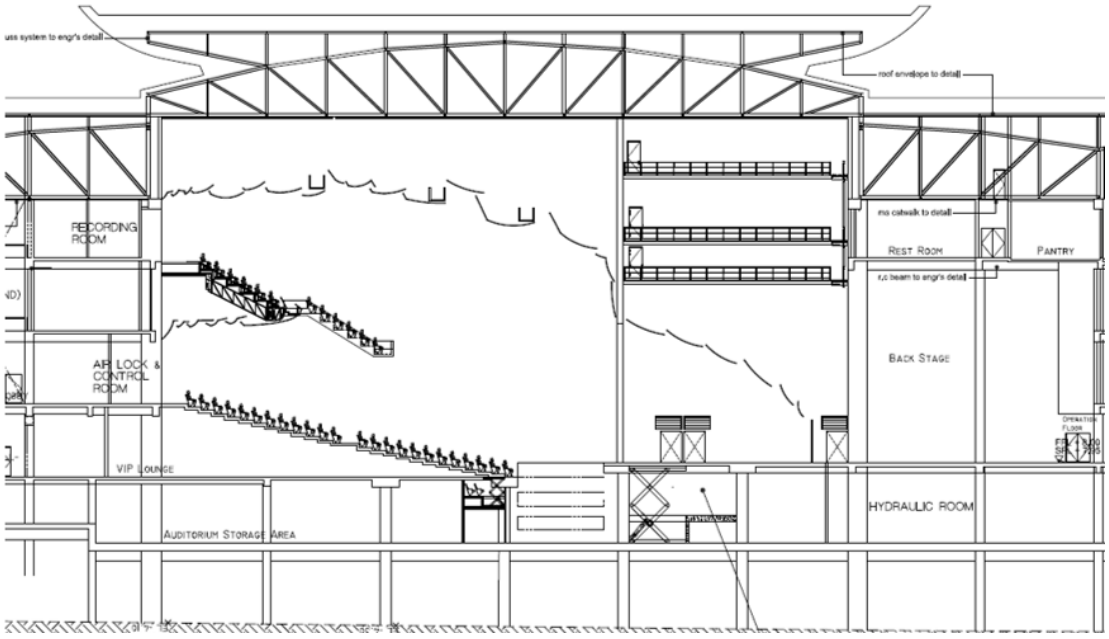

Figure 2: Sectional view showing the application of ceiling convex reflection panels

Such a theatrical experience cannot occur in outdoor venues where, in effect, sound is free field. Without reflections created by the surrounding surfaces music and speech loses its richness, power and quality, the experience is very different. Further to this, the same theatrical performance can be experienced very differently in different theatres, with individual theatres gaining different reputations from different performers. Overall, theatres with poor acoustics will lose favour with both performers and patrons with the result that they do not get used as much and often are demolished. A reverse case of this is a famous theatre that was severely damaged by an earthquake; and because of its good acoustic design, was restored.

The design of theatre spaces should be directed by the acoustic engineer. The engineer must have control of the room volume, wall and ceiling sound reflection panels size and shape, locations and size of balconies, seating specifications and floor linings, line of site views for the patrons. On many building projects the acoustics engineer provides a supporting role to meet simple acoustic performance objectives. This is not the case for performance theatres. The acoustic engineer has a critical role in ensuring that the space meets its intended objectives. In this design work the engineer must address not only the sound received by the patrons but also the performers. If the performers do not receive sufficient or accurate feedback with regard to the sounds that they are generating, it is hard for them to perform well. The theatre must be designed from the inside out, not outside in. The acoustic consultant should have a major input into surface finishes, chairs, baclony shape, balcony location, ceiling and wall construction shape and panels, room volume, entrance passages, location of stage and orchestra pit, design of any procenium arch and doors, positioning of seats and MEP design.

Figure 3: Orchestra shell for feedback to orchestra and focusing sound to audience

It goes without saying that clear line of site view to the stage is important for the quality of the experience. This applies particularly to opera and dance where these performances have a lot to do with the performer's feet movement, and patrons expect to clearly see "feet" from all seats. However, line of site view is also important for good acoustics. People's heads can act as a noise barrier reducing the level and quality of the sound.

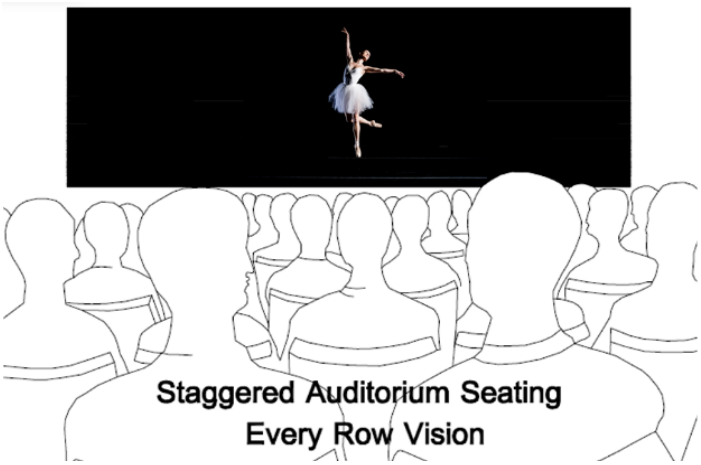

Figure 4: Ideal line of site view

To achieve a clear and uniform spread of sound using wall and ceiling panels, these panels are often best provided in a convex profile with either a smooth of sound dispersing surface. This requires careful selection, positioning and focusing of the panels, so that sound is uniformly distributed. Different panels will be positioned and focused to service different areas of the seating. Concave panels or surfaces are not recommended as these often focus sound to specific locations and leave other areas with low levels of sound.

Figure 5: Ceiling convex panels

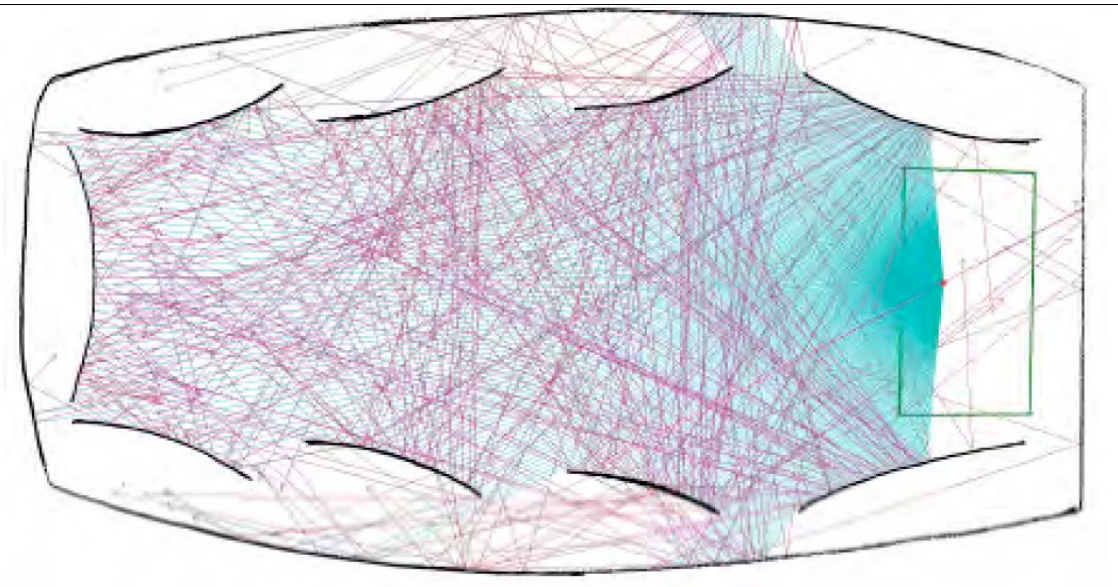

Figure 6: Convex side wall panels used to provide immersive lateral early reflections.

B. BLACK BOX THEATRES

In contrast to more conventional performing arts theatres, Black Box Theatres are spaces requiring low ambient noise levels and low levels of reverberant sound. This is achieved using low noise air conditioning, high isolation walls ceiling and doors, and highly absorptive walls and ceiling. With the basic theatre having a low level of reverberant sound, the acoustics are adjusted with carefully located mobile sound reflection panels positioned around the performance as required.

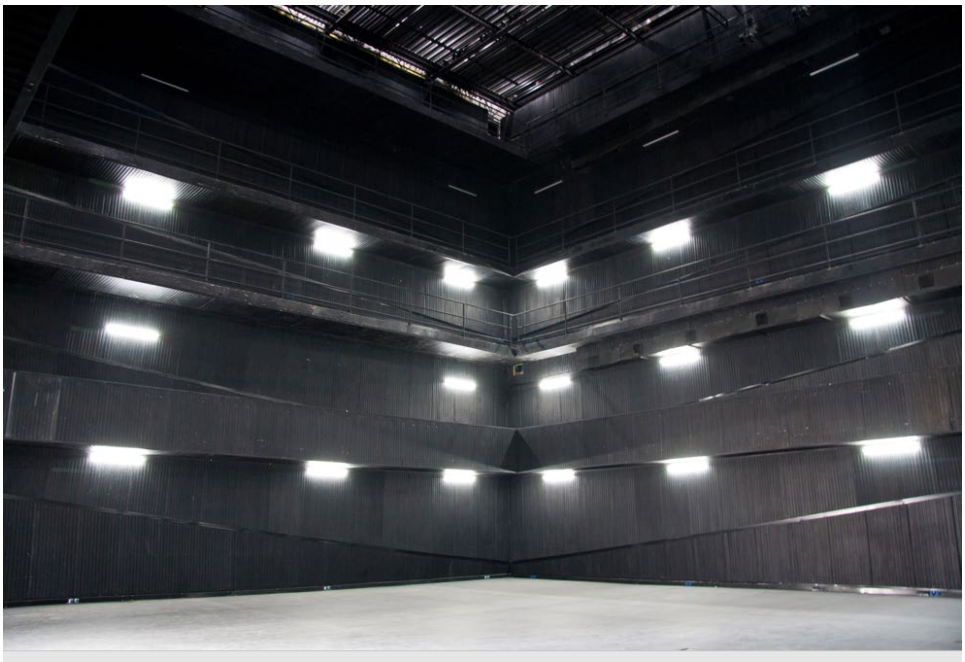

Figure 7: Black box theatre

C. LECTURE THEATRES

In Lecture theatres, clear verbal communication and high levels of speech intelligibility are the most important acoustic consideration. It is important to have a strong level of direct sound from the speakers with reflections arriving after 75 milli seconds being reduced with sound absorption materials. The direct sound is enhanced with wall and ceiling sound reflection panels, again positioned to encourage early reflections across the seating areas.

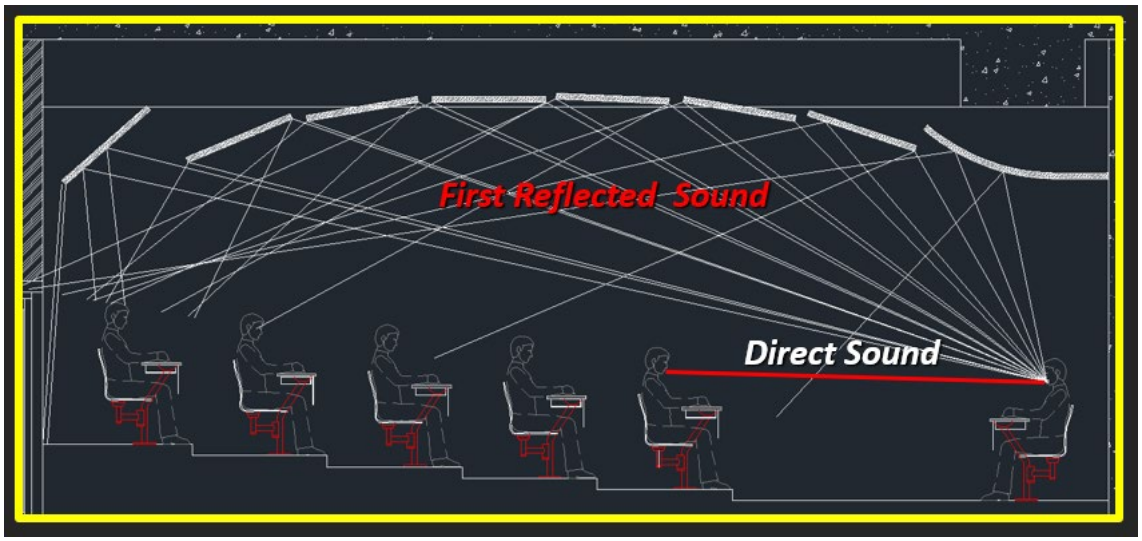

Figure 8: Direct sound compared to early reflection ceiling reflection sound with convex panels.

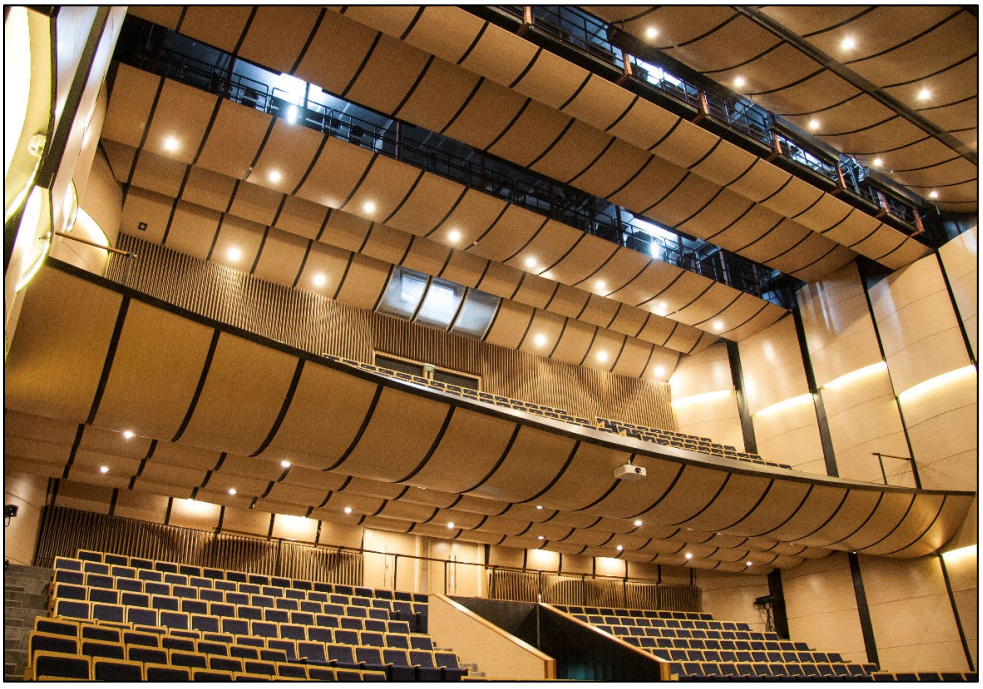

Figure 9: Private school 600 seat theatre using wall and ceiling convex reflection panels.

Ideally these spaces should be able to operate clearly using natural unamplified sound, although a sound system is often included to provide higher levels of sound. Natural sound gives a better sense of presenter to audience bonding, which can be achieved with good acoustic design.

Generally, these theatres will be designed with lower levels of reverberant sound, which will be achieved using carpet on the floor and sound absorption panels on the back walls and some side walls.

D. MULTIPURPOSE THEATRE SPACES

These are spaces that may be used for Opera, Performing Arts, Orchestral events and Lectures, where different acoustic performance objectives apply. The outcomes are a compromise on the different theatre acoustic outcomes and a space where adjustable acoustic treatments may be installed. In making these decisions the dominant functionality should be considered with compromises being applied to the other uses. For operatic performances where naturel (unamplified) sound is important, this is the dominating design consideration and requires careful consideration for sound reflection and sound absorption surfaces. When amplified sound is used, speakers can be specifically located to compensate for poor natural sound coverage.

Figure 10: 1100 seat multipurpose theatre with adjustable 3-sided rotating wall reflective/absorptive/dispersive panels.

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