Proceedings of the Institute of Acoustics

DESIGNING THE ACOUSTICS OF AUDITORIA FOR POWERFUL SOUND SYSTEMS

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1. INTRODUCTION

In this paper we describe some of the challenges of designing auditoria that are used with powerful sound systems for live music performance. We present some of the empirical approaches Acoustic Dimensions has developed and the lessons we have learned while designing over 100 large auditoria in the USA and UK.

2. ROOMS FOR SOUND SYSTEMS

2.1 SOUND FIELDS IN ROOMS

Generally, powerful sound systems sound better outdoors than indoors. This is partly because a semi-free-field will tolerate the directional anomalies of loudspeakers – their tendency to become point sources at low frequencies and their beaming of sound at high frequencies. It might seem that designing a room specifically for a powerful sound system is simply a matter of applying sound absorbing finishes to all surfaces.

In practice, this is not possible. To begin with, it is not practicable to provide 100% sound-absorbing anechoic wedges to the room surfaces of an auditorium for cost and space reasons; and certain room surfaces such as doors often require hard surfaces for safety and usability. As a result, even in a room with much sound-absorbing material, the room acoustic qualities of the sound field must be considered.

2.2 FAN SHAPED ROOMS

We have found from experience that the well-known problems of fan-shaped rooms – such as slap-back echo from the rear wall – cannot be cured simply by treating the rear wall to make it sound absorptive. At best, changing the absorption coefficient from 0.0 to 0.9 will reduce the intensity of the reflected sound by 10dB – which is not a sufficient reduction to eliminate the rear-wall echo. Even modifying the wall shaping with reverse curvature and absorptive wall treatment can be insufficient to prevent an audible rear wall echo.

This is not merely because of reflections from hard surfaces such as doors, nor because practical absorption cannot even achieve a 0.9 absorption coefficient across the audible spectrum. It is because the rear wall echo is not integrated into the room response by the existence of other, earlier sound reflections.

One of the projects were we applied these lessons was a church in the USA. We were faced with the classic 1960's American fan-shaped church design – the ultimate fan-shaped room. Our proposals involved a radical re-shaping of the room to avoid the curved rear wall. Our design approach in this case was influenced by the Philharmonie, Berlin.

We have also had success with less radical changes to room designs: Much of the acoustical problem of the rear wall echo is due to the lack of reflected sound arrivals between the direct sound and the 250ms echo. Introducing deep acoustical fins into the ceiling design provides edge-diffracted waves which help to infill the gap in the echogram.

Thus in rooms for sound systems, just as in rooms for unamplified music, the basic shape of the room, the distribution of the audience, the location of balcony fronts and the absence of focussing surfaces are important considerations.

2.3 ROOMS WITH SOUND FOCUSSING SURFACES

Rooms that have sound focussing surfaces – domes or curved walls – provide no better an acoustic for a sound system than they do for unamplified sound. And with a loudspeaker sound source at a different, generally higher, location than the unamplified performer, focussing effects that are not too much of a problem for unamplified sound can become much more serious.

This was the case for the ceiling dome of the Oriental Theatre in Chicago. This historic theatre is to be renovated as a venue of musicals and Broadway shows. Our studies showed that, with the sound source located at the loudspeaker cluster, the ceiling dome created strong focussing of sound in the audience areas.

Our solution was to replace the entire dome with a stretched-fabric surface with a flat surface located above the fabric.

In rooms with seats on narrow side balconies, it is sometimes necessary to fire quite high levels of sound at these audience locations, while the room surfaces will inevitably reflect a significant portion of the sound. If these walls are concave curved, extremely strong flutter echoes can be generated. This was the case in the design of a convocation hall for a national university. Here, we provided sound absorbing curtains in front of walls that provided a reverse, convex curvature.

2.4 ROOMS WITH GOOD NATURAL ACOUSTICS

2.4.1 GRAND OLE OPRY

Our work on the Grand Ole Opry in Nashville included designing the new sound system and modifying what was already a good room to provide even better acoustics for the sound system.

Originally built in the 1970's, the room acoustics were designed to provide support for a sound reinforcement system. Over the years at this venue, the role of the sound system has changed from that of reinforcement to a full blown PA system. From a room acoustics perspective, the principal difference between these types of sound system is a matter of where the sound is generated: With reinforcement, the sound that the audience hears is generated and balanced by the performers themselves on stage. With a PA system, the musicians hear a dedicated stage monitor sound and the audience hears (or should hear) only the sound from the main loudspeaker clusters which is balanced by the mix engineer.

When we reviewed the acoustics and the sound system of the Grand Ole Opry, we found that the audience was hearing the on-stage monitor mix rather than the mix from the front-of-house clusters.

The changes we made to the room acoustics of the Grand Ole Opry included replacing reflector panels above the stage with sound absorbing panels.

2.4.2 OCEAN MUSIC VENUE, LONDON

Ocean Music Venue is located in Hackney's Town Hall Square. The new venue provides spaces for music performance, training and education. It is a £17 million pound project drawing on a wide range of project funding including major grants from the Arts Council of England's Lottery Fund.

The main auditorium, previously the Methodist Central Hall is rectangular in plan, but has a barrel-vaulted ceiling and originally had deeply overhanging balconies on three sides. As part of the renovation of the auditorium, the front row of the balcony has been cut back, improving the soundlines from the loudspeaker clusters to the audience on the main floor. To address the acoustical problems of the barrel vault, we have designed some sound-scattering reflectors.

As the room is to be used not only with a sound system but also for unamplified music, we have provided a range of adjustable acoustic devices: The surfaces of the side walls and rear wall of the stage and the audience chamber can be changed over from "hard" to "soft" by opening or closing acoustic panels and curtains. On the ceiling, the sound-scattering panels can also be opened, much like giant mussel shells, to expose sound absorbing surfaces inside. The geometry of these surfaces is designed to reflect sound that is not absorbed back towards the stage – improving the separation between the on-stage monitor mix and the main house mix.

3. PRACTICAL SOUND ABSORBING SURFACES

3.1 FIBRES AND FOAMS

We use both fibrous and foam materials to provide broadband sound absorption. Mineral fibre is a particularly efficient, low-cost sound-absorbing material, but it is not suitable for use without some form of surface protection. The fibre has Class 0 surface spread of flame, does not produce toxic smoke and does not contribute to the fire load in a building. However, the fibres are an irritant although there is no evidence of them being carcinogenic.

Acoustic foams are also available, and some of these claim similar fire properties to mineral fibre. Their principal advantage is not an acoustical one, but that they are non-irritant and do not shed fibres. One performance criterion we have encountered for sound absorbing panels is that they should be "beer proof" and washable. The performance of acoustic foam in this respect is not usually quoted in the sales literature, and our tests have shown that actual performance varies from moisture impervious to sponge-like. Foams are more expensive than mineral fibre. The life of acoustic foams is probably less than that of mineral fibre: some foams tend to harden and become brittle as they age.

A new product that we have found very interesting is Woolblock. This is acoustically similar to mineral fibre, but it is made from natural sheep's wool. Its ecological and energy credentials are excellent; it is inherently flameproof and is not an irritant. We have specified this material on a number of new projects including one where the natural surface of the Woolblock is exposed, covered only with a stainless steel woven mesh.

3.2 CARPET / STRETCHED FABRIC

Most fibre or foam materials are not suitable for exposure within an auditorium because of fibre migration, colour or the need for physical protection of the acoustic medium.

Carpet or stretched fabric can form an acoustically satisfactory surface facing for acoustic foams or fibres, assuming it is Class O rated for flame spread. Care must be taken in selecting the fabric as some plasticised fabrics can reflect high-frequency sound.

3.3 PERFORATED METAL

One common type of low-cost sound absorbing surface is perforated metal over mineral fibre. The perforated metal is, ideally, sound transparent, with mineral fibre providing the sound absorbing medium.

Sound absorption coefficients are usually measured for random incidence sound in a reverberation chamber. This turns out to be of little relevance to the first-order sound reflection coefficient, particularly for grazing-incidence sound. We find that perforated metal can produce strong, frequency-dependent reflections, and that in fact it is far from sound-transparent.

In an attempt to decrease the strength of the reflections from perforated metal surfaces we have looked at perforation patterns with large holes versus small holes. Whatever the hole size, the maximum open area of a perforated sheet is about 50%, and this is not adequate.

3.4 METAL MESHES

Expanded metal meshes provide greater percentage open areas than perforated metal, usually in the range 50% to 80%, and are thus more sound-transparent.

Expanded metal meshes have sharp edges and are not suitable for use within the occupied areas of auditoria. Also, because of the shape and size of the metal flats that make up the mesh we again have found that expanded metal meshes produce strong, frequency-dependent reflections.

Woven meshes or weldmesh, formed from round-section wire, are acoustically the most transparent surfaces, even though their maximum percentage open area is about 75%. Round-wire meshes have smooth surfaces and are suitable for use within area occupied by audiences.

3.5 SOUND ABSORBING FINISHES AT OCEAN MUSIC VENUE

The main sound absorbing finishes that we developed with the architects for Ocean Music Venue are as follows:

- woven stainless steel wire mesh – an architectural, hard-wearing finish
- 6mm Pyrosorb acoustic foam – a moisture-resistant, black-coloured finish
- 50 to 100mm mineral fibre – the acoustic medium

These surfaces are used around the audience and stage areas.

4. CONCLUSION

The design of the acoustics of rooms for powerful sound systems draws on the same skills that are needed to design rooms for unamplified sound. While the acoustician can allow the auditorium designer considerable latitude in the choice of design approach, the constraints of designing rooms to be free of echoes and sound focussing remain.