# ACOUSTIC DESIGN OF ARENAS

Jim Griffiths Symonds Group Ltd, East Grinstead, West Sussex, UK

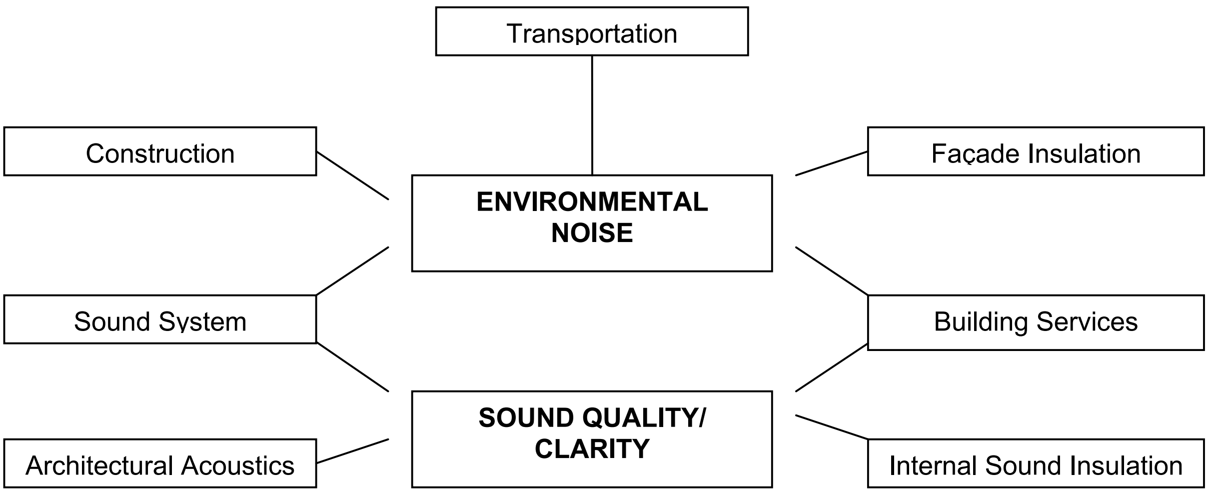
## 1 INTRODUCTION

This paper reviews the scope of work that is primarily involved with the sound, noise and acoustic design of both stadia and arenas. A case study of the Dome Arena is then described to highlight the acoustic design process for this major project.

## 2 SCOPE OF WORK

As reported for stadia design [1], the key acoustic disciplines and their effects that need to be considered for most arenas and stadia are highlighted in figure 1. It is important that these issues are not dealt with in isolation as the noise, acoustic and sound issues are closely inter-related.

### FIGURE 1 - ACOUSTIC DISCIPLINES AND THEIR EFFECTS




Within these disciplines there are a number of specific issues which often need to be considered. These are highlighted in table 1.

## TABLE 1 – TYPICAL EXAMPLES OF ISSUES THAT HAVE AN EFFECT ON ACOUSTIC DESIGN

| Disciplines | Issues | Acoustic issues |
|---|---|---|
| Environmental Noise | EIA | Baseline, construction, operational, noise and vibration |
| Facade Sound Insulation | Environmental – operational<br>Environmental – external activities<br>Future development | Composite sound reduction, flanking transmission, rain noise |
| Architectural | Operational requirements<br>Existing signature<br>Future requirements/legacy | Local RT, long delayed reflections, clarity, acoustic absorption, diffusion, 'bass traps', variable acoustics |
| Sound System (PAVA) | Life safety<br>Event performance requirements<br>Paging needs | STI, SPL, frequency response, zoning |
| Internal sound insulation | Operational use<br>Activity interference | Composite sound reduction, flanking transmission, space planning |
| Building services | Operational requirements<br>Life safety operation<br>Internal/external environment | NR, flanking transmission, vibration isolation, sound reduction, attenuators |

Firstly it must be recognised that the biggest effects that have an impact on the design that are not mentioned above and yet affect all the disciplines, is the budget and other design considerations, in particular structural and architectural. From experience it is important that acoustic consultants convey their views not only to the design team, but also to the client/decision maker when changes due to budgetary constraints or value engineering have significant effects on the acoustics.

Many of the issues raised in the table are fairly standard, however, some are more unusual and warrant further discussion.

## 2.1 Existing Signature

This is sometimes a requirement for major projects where an existing facility is being replaced or refurbished and the acoustic atmosphere needs to be captured such that it can be used as a benchmark for the acoustics of a new facility. This was the case for the old Wembley Stadium, where the client was concerned that the famous atmosphere 'Wembley Roar' should be retained for the new stadium. Clearly acoustics is just one feature of the atmosphere, which will vary from seat to seat, particularly between areas where there are differences due to the location of stand roofs or overhanging balconies. A number of measurements were made at Wembley Stadium to provide an objective record of the stadium acoustics. These included:-

- Time-level-frequency data at various locations in the stands and on the pitch during several national and international football matches.
- Impulse response measurements at 8 locations during a capacity crowd at an international football match.
- Impulse response measurements at 8 locations with the stadium empty.

The majority of the analysis has been completed and documented, however, the information is currently confidential and will form the subject of a further paper following client approval.

When a stadium hosts both sporting and musical events, the general acoustic requirements are different and hence a number of key issues need to be considered:-

- Local reverberation under roofs and balconies,
- Sound reflections from opposite stands,
- Long delayed reflections from balcony fronts, glass executive boxes and risers.
- Noise from building services
- Noise break-out by diffraction at the roof edges
- Direct and flanking noise break-out via vomitories, ventilation systems, etc

Although the original acoustics for the old Stadium were perceived as 'good' for sporting events, significant improvements could be made for concert events which are now included in the new stadium design.

### 2.2 Legacy

Many new stadia and arenas are built for a specific occasion eg Olympic Games, World Cup etc and there is a need to consider acoustic systems for both the opening event as well as the long term operational use of the facility. This usually has an impact on the environmental noise, acoustics and the sound system. For example where an arena is being built specifically for a major one-off Olympic sporting event, as is often the case;-

1. then there will be requirement for additional temporary seating and the sound system will need to cover additional areas. In these cases, a permanent sound system is specified for the legacy mode, but with inputs such that a temporary sound system can be integrated with the permanent system providing additional coverage and zoning.
2. it is likely that in the legacy mode the arena will be used for other events such as concerts. This will require a different acoustic environment and in particular the environmental noise issue needs to be considered at the design stage due to the greater potential noise impact from music noise.

### 2.3 Rain Noise

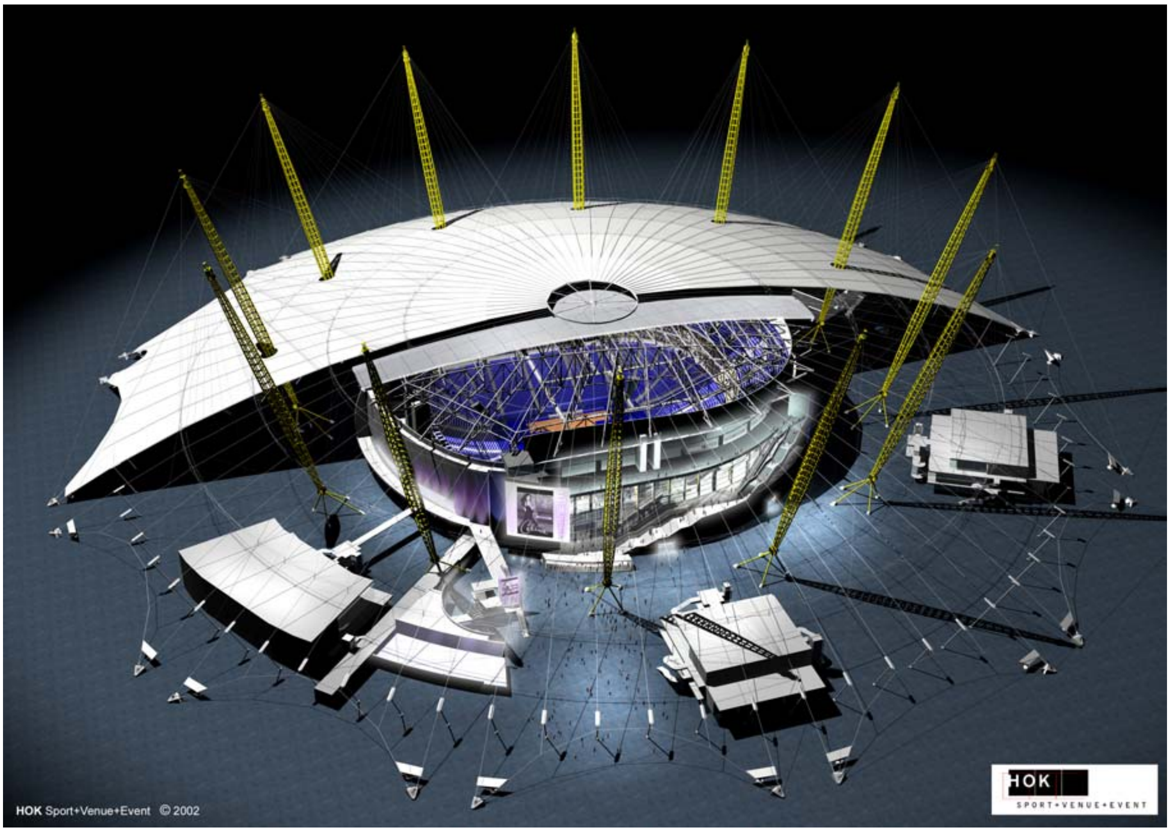
For arenas, the effect of rain noise is not normally an issue as roof construction will provide adequate sound insulation to attenuate the noise from the 'drumming' sound from rain. However, this issue has been raised at facilities incorporating lightweight roofs, where only a single skin membrane roof is under consideration and there is a need for a relatively low internal acoustic environment to minimise activity interference. Clearly double skin insulated roofs need to be considered, however, where light and weight become a design issue, we have tested and provided advice on combinations of single skin membranes with and without external mesh. Details of these tests will form the subject of a further paper following client approval.

## 3 THE DOME ARENA

Having given a general overview of some of the issue related to arenas and stadia, this paper now describes the ongoing acoustic design of a major arena to be built in London. The Dome Arena has currently been submitted for planning approval, which is expected early in 2004, and comprises of a large fully-enclosed arena to operate as a stand alone entertainment facility built within the Millennium Dome, Greenwich, London.

The Dome Arena is one of the largest arenas in the UK, having an approximate volume of 325,00m$^3$, a total floor area of 60,000m$^2$ and being constructed just below the roof of the existing Dome roof which is some 50 metres high. The maximum capacity will range from typically 18,000 to 22,000 spectators depending on the seating configurations. A typical section through the Dome is shown in Figure 2.

## FIGURE 2 – SECTION THROUGH THE MILLENNIUM DOME & DOME ARENA




It is planned that, the Dome Arena will be used primarily for concerts, although the arena's flexible design will allow other activities such as ice hockey, basketball, football, tennis, boxing, figure skating, gymnastics and volleyball to be accommodated. It was agreed with the client at an early stage that the acoustics will therefore be designed primarily for concerts. The project is currently at Stage D (RIBA stages of work) and the main acoustic issues are discussed below.

## 3.1 Environment And Façade Insulation

An acoustic model has been developed to study both the internal and external acoustic characteristics of the arena. Clearly the façade sound insulation of the envelope of the building is governed by the potential internal noise source and the environmental noise criteria applicable for entertainment noise. For events during the day and evening up until 2300 hours the Noise Council Code of Practice has been adopted [2], however a more onerous criteria has been considered for music events held at night and our design target for existing residential premises is that the music $L_{Aeq}$ noise level should be 10dB below the existing external $L_{A90}$ noise level.

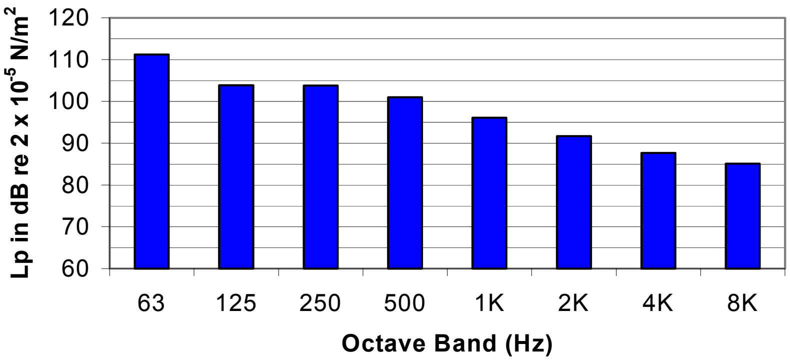
The environmental noise levels have been predicted using a ray tracing model based on:-

Typical noise spectra of music sources
Directivity characteristics of the sound source

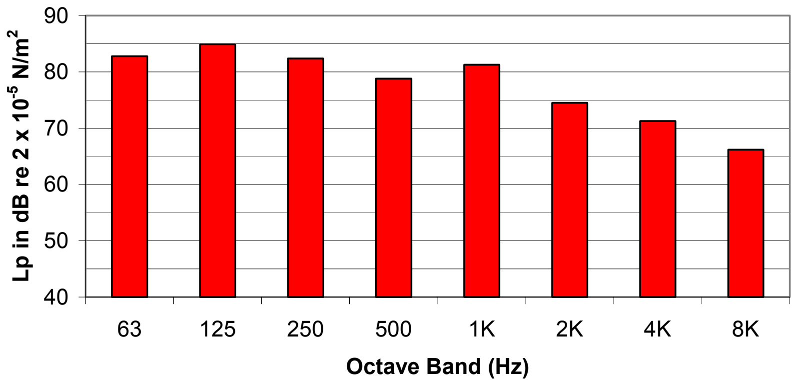
The auditorium acoustics of the arena
The sound insulation of the Dome Arena façade
General noise from patrons within the Millennium Dome area
The sound insulation of the Millennium Dome Roof
Spherical radiation to receptor locations
Acoustically neutral meteorological conditions

The typical spectra used in the model are shown below in figures 3 and 4.

## FIGURE 3 – ARENA ROCK MUSIC SPECTRUM




## FIGURE 4 – PATRON ACTIVITY SPECTRUM

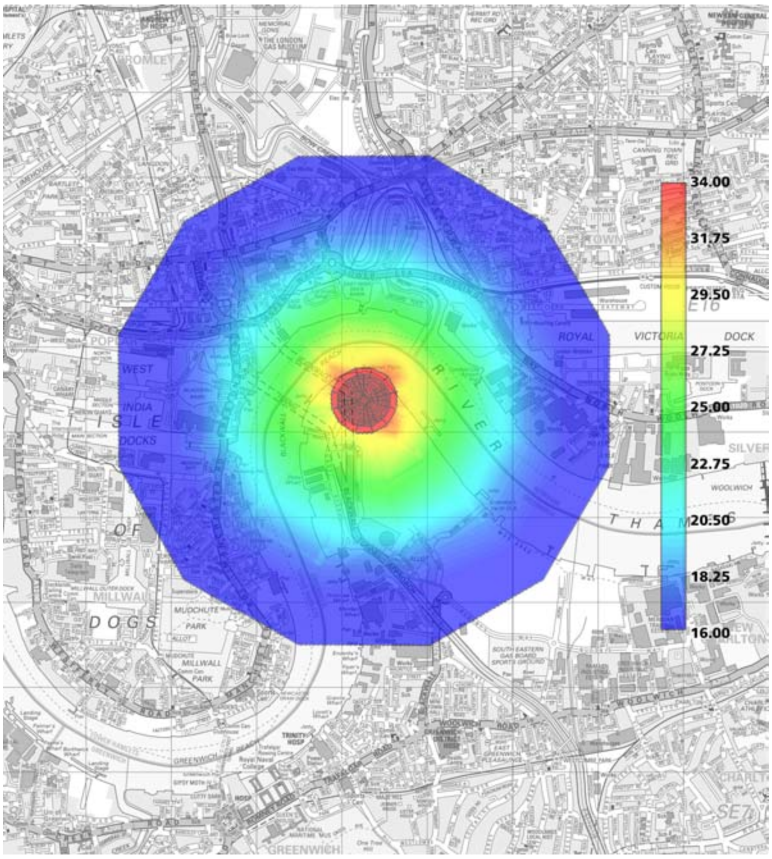



The largest single element which forms a direct external skin to the performance space is the roof. Various roof designs have been considered in particular those which exhibit good performance at low frequencies given the high levels of low frequency exhibited by modern music (figure 3). The current design is based on a cladding build-up having a superficial mass of 62kg/m$^2$ with a sound insulation as specified in accordance with BSEN ISO 717-1 as given in table 2.

## TABLE 2 – ROOF SOUND REDUCTION

| FREQUENCY (HZ) | 63 | 125 | 250 | 500 | 1K | 2K | 4K | $R_W$ |
|---|---|---|---|---|---|---|---|---|
| SOUND REDUCTION R (DB) | 27 | 30 | 40 | 45 | 52 | 56 | 60 | 50 |

Based on these input data, an output from the acoustic model is shown below in figure 5. The results indicate that the event LAeq noise levels will meet the night-time environmental noise criteria for existing residential properties.

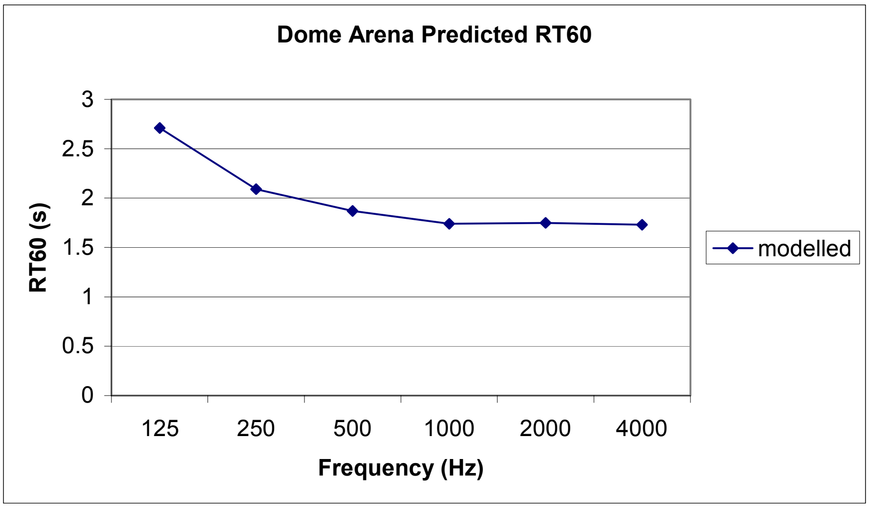



## FIGURE 5 – ENVIRONMENTAL NOISE PLOT OF THE DOME ARENA

### 3.2 Architectural Acoustics

The internal acoustics have been considered in respect of the Reverberation Time and minimising long delayed reflections. The predicted RT60 from 125Hz to 4kHz is as shown below in figure 6.

## FIGURE 6 – DOME ARENA PREDICTED RT60




To achieve this low RT 60, a number of acoustic measures have been implemented.

The Roof has been designed with an internal perforated liner tray, this system allows the whole roof area to be utilised as an acoustically absorbent surface and as the single largest surface area within the bowl this has the most significant effect on the RT time.

The rear wall of the arena behind the upper seating has the potential to provide a sound focussing surface due to its concave form, as such late reflections from this surface can distort the perception of direct sounds. This surface is utilised to provide broadband absorption using perforated sheet finish and low frequency absorption using panel absorbers. This will ensure that reflections from this surface are at a low level relative to direct sounds.

All permanent seating within the bowl area is to be upholstered. This represents the second largest single surface area within the bowl and as such has a significant affect on the predicted RT time. Modelled data demonstrates that replacing the upholstered seating with hard seating in the arena increases the mid frequency RT from around 1.9 to 2.3 seconds.

Balcony fronts do not represent a large enough surface area to have a significant effect on the overall RT time of the space, they do however have the potential to contribute discreet late reflections which can be perceived as “slapback”. The 3D modelling has shown significant late reflections from the balcony fronts as demonstrated by ray tracing. There will be significant coverage of LED screens for advertising, where these are not present surfaces will be acoustically absorptive.

The back stage area currently includes a large air volume above a Dine and View restaurant. Designs are being considered which acoustically isolate this volume from the rest of the main bowl seating area which would both reduce the overall RT and eliminate potentially harmful reflections from the large rear façade.

An assisted reverberation system is currently being considered which will enable the arena to electronically increase the perceived RT using the installed arena sound system. This will allow increase loudness which is often perceived as “atmosphere” during sporting events.

The current programme is that the Dome will be handed over to the client in Spring 2004 with the proposed opening in 2005.

## 4 REFERENCES

1) J.E.T Griffiths, Acoustic performance of entertainment venues for the Millennium, Proc.I.O.A. Vol 20 Part 1, 1998.
2) Noise Council; Code of Practice on Environmental Noise Control at Concerts, 1995.