ACOUSTIC DESIGN FOR SPORT STADIA AND ARENAS

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1 INTRODUCTION

Modern sport venues often require to be used as multi-purpose venues and rarely can be designed to achieve a specific single acoustic environment. Venues designed primarily for sports also need to host music concerts and music venues are often required to host sports events.

This paper discusses the limitations, constraints and compromises of providing the ideal acoustic design for multi-purpose sports arena and stadium.

2 FINDING THE BALANCE

2.1 SPORTS ATMOSPHERE

Acoustical enhancements for sports venues rely on increased energy in the bowl, which for a natural acoustic environment consists of hard reflective surfaces directing energy from the crowd across the audience and field of play.

Even for stadiums and arenas designed wholly for sports, the reverberation time cannot simply be maximised, especially in large venues as there are other constraints that the venue must achieve, notably the intelligibility of the sound systems for production audio and life safety systems.

How can we promote strong reflections for sports with inherently long reverberation times whilst still maintaining the integrity of the speech intelligibility and acceptable concert acoustics?

2.2 AMPLIFIED MUSIC

Good concert venues for amplified music rely on inherently low reverberation times across the frequency range, requiring significant acoustically absorbent surfaces. A balanced reverberation time allows for a good tonal response of the venue, with minimal coloring of the sound. Good concert venues must ensure any late reflections are minimized which can be detrimental to the audience and artists.

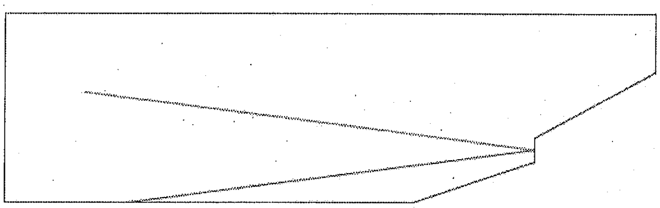
How can we ensure any late reflections are minimized with inherently low reverberation times whilst still maintaining the atmospheric requirements for sports?

3 MULTI PURPOSE VENUES

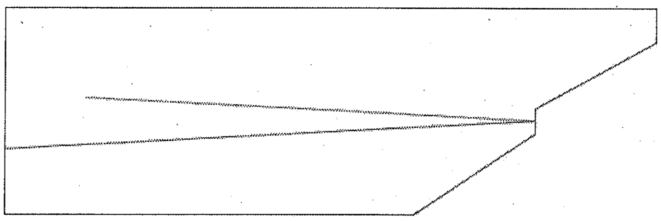
3.1 Bowl Architecture

Where venues are required to provide good (natural) acoustics for both sports and amplified music then careful consideration in the acoustic architecture is required. The arena should provide a good balance across the reverberation range; however, the overall reverberation time is not necessarily the most important acoustic parameter and the importance of long reflections should be the paramount study.

Getting the architecture right in the first place means that acoustic treatment is not required as extensively to 'fix' the venue, allowing a longer overall reverberation time, improving sports atmosphere but not detrimental to concert performances. Surfaces where first order reflections are directed into the audience should be avoided and this can often be optimised through the design of the lower bowl. Long delayed reflections are more detrimental to the sound quality, rather than the overall reverberation time for concert sound. A typical touring sound system has a trim height of 12-18m. The example below shows two examples of a lower bowl audience design and the effect on the reflected sound.



a) vertical surface at 5m height



b) vertical surface at 10m height

FIGURE 1 – Lower bowl at a) 5m and b) 10m above the audience floor

The images indicate the importance of the lower bowl design to avoid first order reflections into the audience (or stage). The first option will require additional acoustic treatment on the vertical surface to mitigate the reflections, which then reduces any useful reflections for sports atmosphere. This approach also eradicates any 'slap-back' from the rear wall, which could especially be detrimental with any focusing surfaces, of which cannot be eliminated with acoustic absorption/diffusion alone.

Avoiding any vertical surfaces within the critical area allows a more flexible approach to the acoustic treatment. Where focusing from curved vertical surfaces occurs this should always be avoided in the critical area, as acoustic treatment alone (absorption and diffusion) are unlikely to provide satisfactory results. Even with a material absorbing 98% of the sound, a reduction of only 18dB is achieved, which with the summing from any focusing can cause a reflection of less than 10dB below the direct sound.

The same approach of avoiding the low-level vertical surfaces in stadiums can be followed, where no acoustic treatment is often applied.

3.2 Venue flexibility and configurations

Limiting a venue to a few configurations allows the venue to be better suited to multi-purpose (sports and concert) requirements. When a venue is designed to many concert configurations, it often requires excessive acoustic treatment to enable this. Although for specifically designed music venues this could be acceptable, for venues also used for sports this can lead to non-exciting 'dead' sounding spaces.

3.3 Stadium acoustic absorption

When designing a stadium which is to be used for sports and music concerts, then a balance between the acoustic absorption (often provided in the roof) and the speech intelligibility needs to be established. As a minimum, stadiums are required to satisfy the intelligibility requirements for life-safety, and this is a good starting point for the design. During the design of Tottenham Hotspur Stadium a study was carried out to find the perfect balance between intelligibility and atmosphere and the placement of the absorption locations to ensure crowd connection between the stands and the players. The absorption location must also ensure that the strong reflections excited by the crowd are not damaging to any music quality during concerts.

By maximising the reflective area for the crowds and the placement of absorption to minimise strong reflections from concerts, the optimum acoustic experience can be achieved for both sports and concert events.

The images below show an example of how the roof area can be used to provide an acoustically reflective area for the crowd noise whilst still providing absorption off the back wall from concert sound.

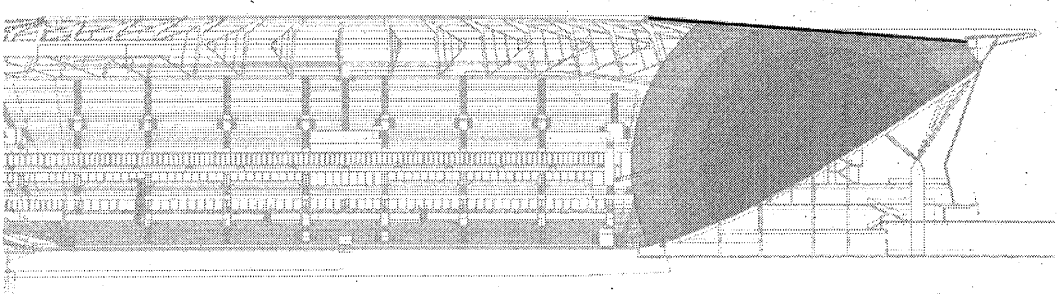


FIGURE 2 – Maximising reflective area from crowd noise (Red shows area of absorption, blue shows acoustically reflective surface).

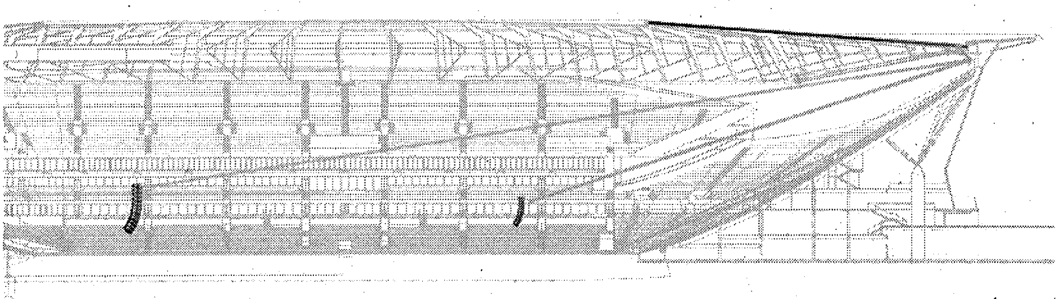


FIGURE 3 – Absorption from end stage concert (Red shows area of absorption, blue shows acoustically reflective surface).

4 NEW TECHNOLOGY

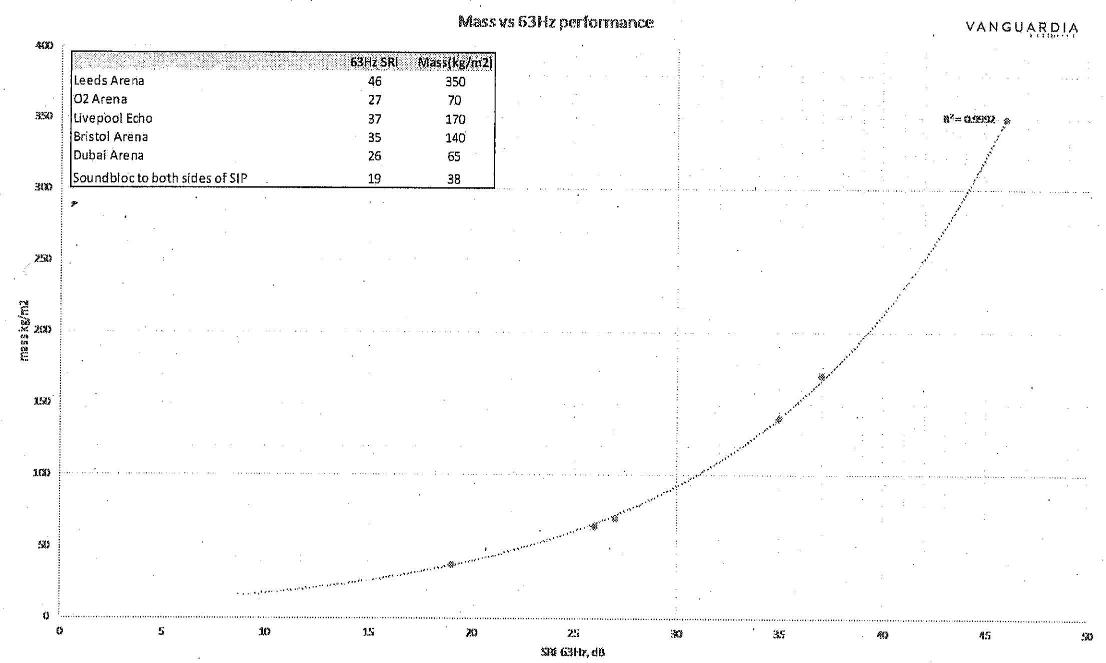
With the advancement of new technology, through improved directivities, immersive audio systems and array processing, it becomes increasingly more important to understand the interaction of the venue and the sound system. All music venues have limitations on the placement of loudspeakers to ensure the optimum sound quality and relying on these technologies alone relies on permanently installed sound systems to ensure the appropriate integration. With venues designed for touring systems, flexible solutions need to be provided. For larger venues it is seldom the case that a venue can be designed in conjunction with a single sound system design.

The advancement in technologies means that venues can be designed with higher mid/high reverberation times than previously because of the improved controlled directivity of loudspeakers, improving the direct to reverberant ratio.

5 ARENA SOUND INSULATION

The sound insulation performance of an enclosed venue is often dictated by the requirement to contain the low frequency sound, often with the venue roof being the significant element. To ensure the cost of the venue is moderated it should be ensured the roof of the venue is not over engineered. For single leaf constructions the mass law indicates an improvement of 6dB for each of the doubling of mass, hence over engineering the roof by 6dB can significantly increase the costs. Conversely, if the roof is not designed with the necessary sound insulation, a retrofit after construction is often prohibitive. The balance of the mass/construction is therefore a high-risk item for the consultant.

Prediction and measurements provide varying results and accuracy in the low frequencies, even with fluctuating values from laboratory to laboratory. With the use of complex multiple layer constructions, the mass law is often exceeded in the construction build-ups. A number of laboratory and venue measurements have been collated and plotted on the following curve. This provides a close fit correlation between the surface mass (kg/m²) and the low frequency performance.



6 STADIUM SOUND INSULATION

Containing the sound within a sports stadium not only enhances the acoustic energy within, but also reduces any noise impact on the surrounding residents. It is essential to minimise any rear tier openings and ensure enough roof sound insulation. A high proportion of the sound from a stadium is propagated through the opening and this architecture has a limiting factor on the overall sound insulation of the venue. Over designing the roof to provide high levels of sound insulation is not necessary and the roof is only required to provide sufficient attenuation to not add to the sound propagating through the stadium opening. For enclosed stadiums with a closing roof, then additional sound insulation might be beneficial.

7 ARENA LOW FREQUENCY ABSORPTION

The best sounding arenas have found to have good low frequency reverberation control, ensuring no muddiness of the sound at low frequencies. This is required to extend down as low as 40Hz for the best low frequency clarity for amplified music.

With floor space a premium in an arena, the idea of a 3-4m bass trap is often dismissed. However, early involvement in the design process and coordination with the arena roof can ensure that enough low frequency reverberation control can be provided in the arena roof. The following example shows how the 'bass trap' can be incorporated into the roof design.

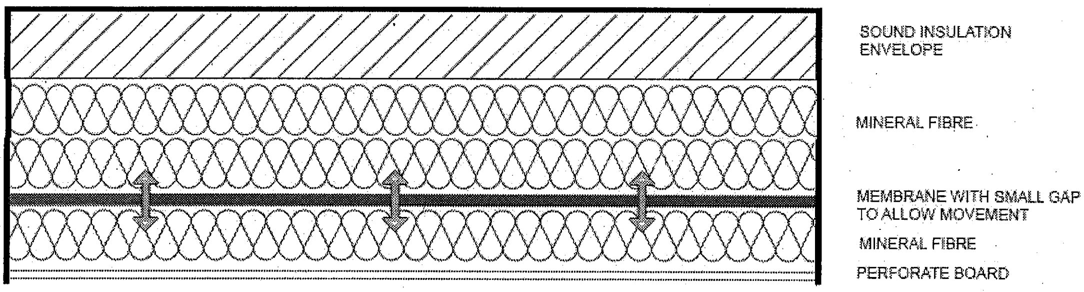


FIGURE 4 – Outline bass trap detail in roof construction.

A balance between the bandwidth of the absorber and the efficiency of the absorber must be calculated to provide suitable absorption response for the room, by altering the mass of the membrane. The fundamental frequency of the membrane can be estimated using the following formula, where *M* is the mass per unit area and *d* is the depth of the porous absorber above the membrane.

$$f_0 = \frac{50}{\sqrt{Md}}$$

The perforated board allows transmission of sound for the mid-high frequencies and the membrane allows further low frequency absorption, extending the response of the broadband absorber.

8 SUMMARY

The pressure on stadia and arena operators to be multi-functional and hold both music and sporting entertainment is ever increasing in order to maximise revenue in a very competitive market. The conflicting balance between reverberant sound (crowd atmosphere) and intelligibility (life safety and concert requirements) over an extended frequency range brings an important challenge for the acoustic consultant. This is further exacerbated by the need to predict and design the correct façade sound insulation to meet the environmental noise ordinance which are increasingly demanding especially when they have to deal with a variety of noise sources for mutli sports/music venues.

9 REFERENCES

1. R. Oldfield, 'Improved membrane absorbers' Research Institute for the Built and Human environment, Acoustics Department, University of Salford.
2. W.A. Utley, 'Single leaf transmission loss at low frequencies', Department of Building Science, University of Liverpool (1968)