DISCREPANCIES BETWEEN AUDIENCE MODELLING METHODS IN PERFORMANCE VENUES

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1 INTRODUCTION

Acoustic computer modelling is an invaluable tool for the design of sound reinforcement and voice alarm systems. Predicting the characteristics of a room or a sound system to room interfaces allows insight into the performance of the system including reverberation time and speech intelligibility. However, performance venues and areas with voice alarm systems are often modelled unoccupied to fulfill contractual obligations and to observe the worst-case scenario. The change in acoustics due to an audience cannot easily be predicted and a number of different methods of modelling have been previously proposed and utilised. This work presents the degree of potential discrepancies between different implementations of standing audiences in performance venues within acoustic models.

Conflicting absorption coefficient data is available for standing audiences, depending on the technique used during measurement. For example, measuring a group of people in a reverberation chamber in accordance with ISO 354[1] cannot accurately be transferred to large audiences due to the difference in audience area and perimeter size[2]. An additional method uses average calculated absorption coefficients from an assortment of performance venues by measuring them occupied and unoccupied[3]. Alternatively, it is possible to calculate two additional coefficients of an audience in a reverberation chamber by measuring them in different configurations. These two coefficients represent an infinite audience area without edges and one for the perimeter length[4]. This was implemented for standing audiences of a variety of densities[5] and their accuracy validated using real measurements of performance venues compared to acoustic models using the derived coefficients[6].

Alongside the difficulty in selecting appropriate coefficients, there are a number of methods used to implement a physical audience within acoustic models. It has been observed that the most common are a floor plane, a floating plane and an 'audience brick'. Each option has logical shortcomings, but little advice is provided within data sets about the intended method. For example, the physical space occupied by the modeled audience will interact differently, where an audience brick is the best physical representation of a group of standing audience members. However, coefficients are measured as surface area absorption which best corresponds to a floor plane which does not take up the same physical space as a standing audience. A floating plane is effectively a combination, where a flat plane (similar to a floor plane) is raised to the approximate height of an audience. However, this does not interact with sound running parallel to the floor.

It is worth mentioning that there are issues with creating geometrically accurate shapes to represent individual audience members[7], as diffraction causes additional absorption of low frequencies for audiences that have a high density of occupation. Therefore, it is best to mimic an overall audience block in industry-standard software which utilizes ray/cone tracing. This work intends to compare differences between common audience implementations to examine whether these issues are significant enough to warrant further investigation.

2 METHOD

Industry-standard modelling software EASE[8] was used to investigate four acoustic models (Fig. 1), which were utilized as case studies to demonstrate the extent of potential differences between modelled audiences. This consisted of performance venues/rooms of varying types, with information found in Table 1. This included a theatre and church template and a constructed and calibrated hall and arena (velodrome) model of real rooms.

Room	Size	AVG unoccupied RT	Measurement points
Hall	1,772m³	1.60	4
Church	2,015m³	1.47	8
Theatre	10,420m³	2.05	10
Arena	126,331m³	2.78	20

Table 1. Room information.

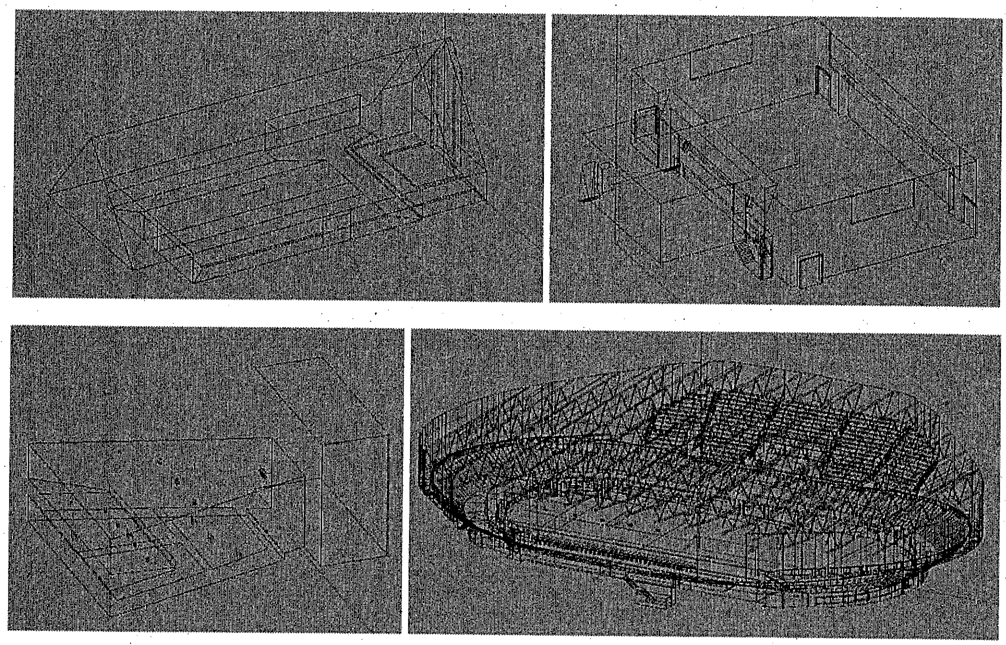

Figure 1. Modelled rooms (top, left-right) church, hall (bottom, left-right) theatre, arena.

The three most commonly used audience implementations (floor plane, floating plane and 'audience brick') were compared in each room to see variances between reverberation time (RT) and Speech Transmission Index (STI). Mean values, over a number of locations evenly distributed across the audience area, as well as individual location values were compared. 'Audience bricks' and floating planes were placed at a height of 1.67m. Each implementation can be found in Fig. 2.

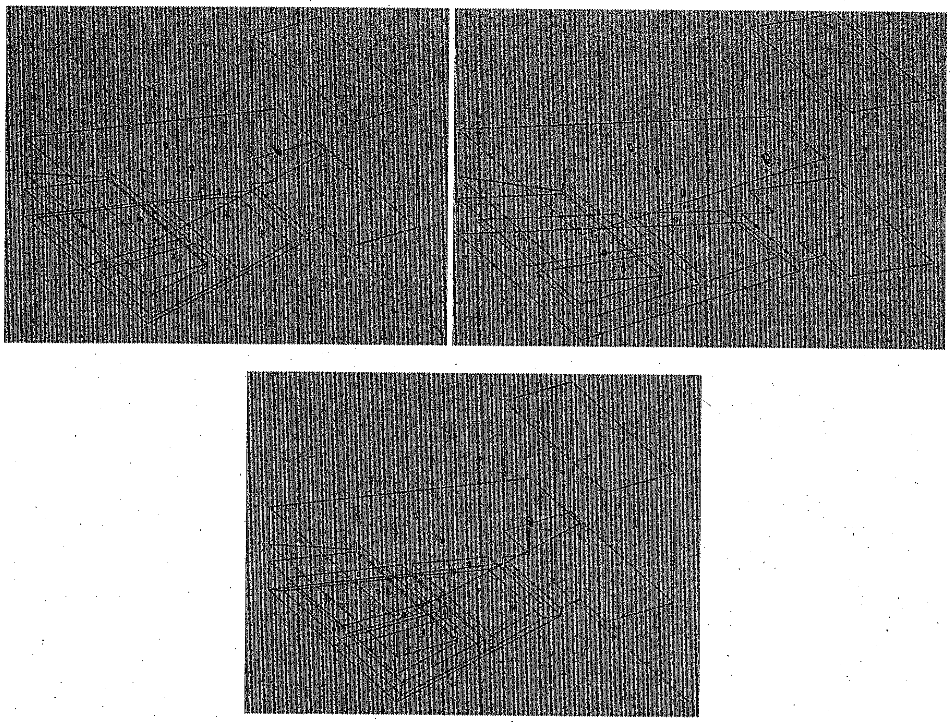

Figure 2. Audience implementations (left-right) floor plane, floating plane, audience brick.

To assess the extent of potential errors as a result of inconsistencies between available absorption coefficient data, a number of data sets from different methods of obtaining coefficients were used for a selection of models and implementations. This included a measured single person in a reverberation chamber[2], coefficients found from determining the infinite area and perimeter coefficients[5], and coefficients created from measuring a performance venue occupied and unoccupied with a standing audience[9].

3 RESULTS

The average RTs for each implementation in each venue are shown in Fig 3 and 4. There are clear differences between each implementation, with significantly less sound absorption from the floor plane. This is not necessarily due to the total absorbing area, since floating planes would be very similar. It is more likely due to the position of the absorbing material in relation to the concentration of sound energy. It is also worth noting the additional absorption provided by the reverse side of the floating plane. The front-face of the audience brick provides additional absorbing material alongside the heightened position of the plane at standing height consequently meaning this implementation provides the most absorption. Individual positions were also compared which exhibit a similar disagreement between implementations removing the possibility that differences are due to averaging.

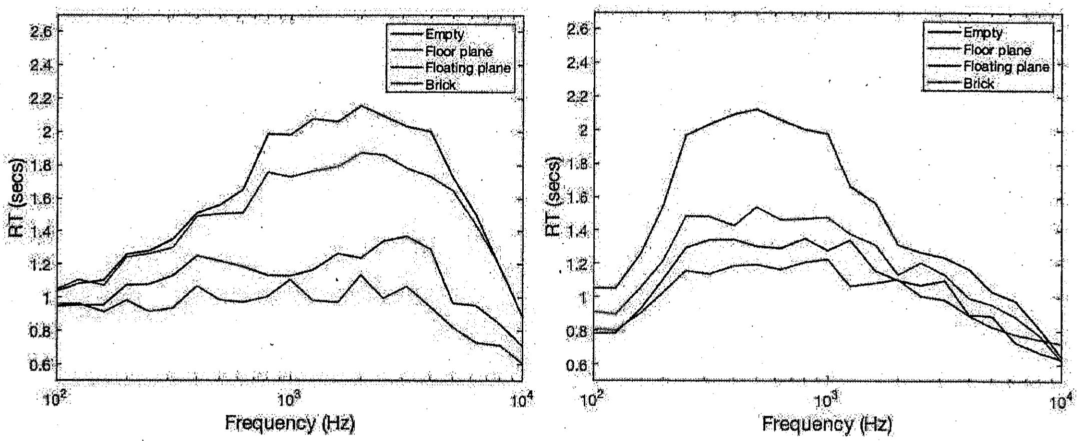

Figure 3. Hall (left) and Church (right) RT for every implementation including unoccupied.

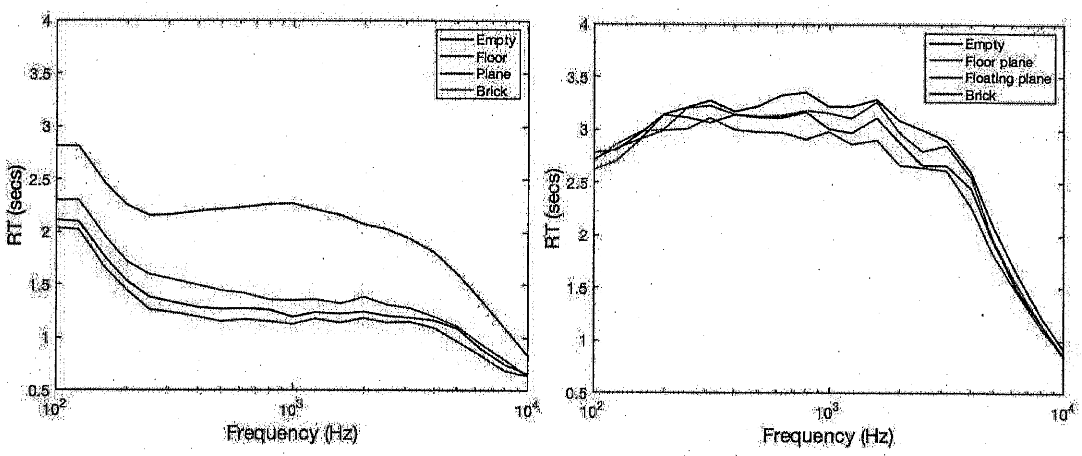

Figure 4. Theatre (left) and Arena (right) RT for every implementation including unoccupied.

Average STI values of measurement positions for each implementation within the theatre and arena are given in Fig 5. Variations exist of 0.08 in the theatre model and 0.034 in the arena between audience implementations. This is a significant difference both perceptually and (potentially) contractually when target STI values need to be achieved. The greater difference between the floor plane and floating plane also suggests that the position of this audience face is of greater importance than the total absorbing area, especially when there are directional loudspeakers and there is not an ideal diffuse field. The reduced difference between floating plane and audience brick is potentially due to the area of the side faces in relation to the overall audience area, providing less relative absorption for the arena model. Additionally, three audience areas are present in the theatre model which further increases the side faces.

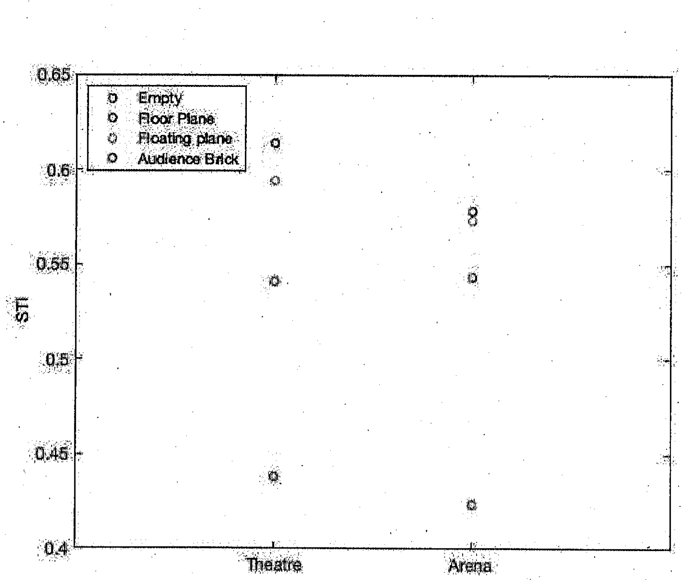

Figure 5. Average STI for Theatre and Arena for every implementation.

Absorption coefficients tested within the arena model with a floor plane (Fig 6) shows slight variations in the RT. This will of course depend on the audience size and the relation to the room size as well as the relative absorption. However, for this specific example where the audience size is conservative compared to the expected audience capacity of the venue, a clear difference can be observed. This demonstrates the practical errors possible from issues with measuring audience absorption coefficients.

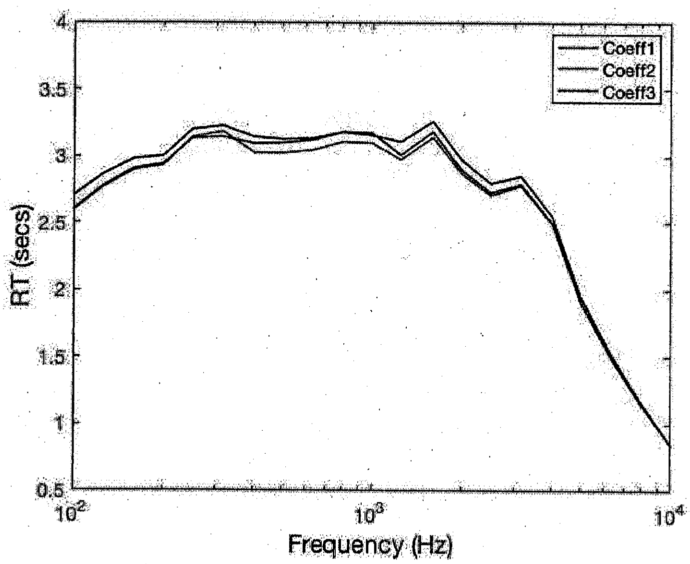

Figure 6. Arena RT for 3 absorption coefficients[2,5,9] with a floor plane.

4 SUMMARY

Practical examples of discrepancies between audience implementations have been presented. It has been demonstrated that the physical geometrical shape of a modelled audience creates variations to absorption and reverberation time. This is due to the total absorbing area as well as the placement of the audience planes. Furthermore, absorption coefficients available for standing audiences were compared with observable disagreements in reverberation time for mid- and low-frequencies. Both of these differences demonstrate a need to better understand which method of audience modelling is most suitable and accurate. This ongoing work will be matched with physical measurements to develop a set of absorption coefficients with a paired audience implementation to try to overcome the observed issues.

5 REFERENCES

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