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A possible acoustic design approach for multi-purpose auditoria suitable for both speech and music

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ABSTRACT

In several auditoria, it has been observed that the reverberation time is longer than expected and that the cause is a horizontal reverberant field established in the region near the ceiling, a field which is remote from the sound absorbing audience. This has been observed in the Boston Symphony Hall, Massachusetts, and the Stadthalle Göttingen, Germany. Subjective remarks on their acoustics suggest that there are no unfavourable comments linked to the secondary sound field. Two acoustic scale models are considered here. In a generic rectangular concert hall model, the walls and ceiling contained openings in which either plane or scattering panels could be placed. With plane panels, the model reverberation time (RT) was measured as 53% higher than the Sabine prediction (frequency 500/1000 Hz), compared with 8% higher with scattering panels. The second model of a 300 seat lecture theatre with a 6 m or 8 m high ceiling had raked seating. In this case, the amount of absorption in the model was increased until the point was reached where speech had acceptable intelligibility, with the early energy fraction, $D \geqslant 0.5$. For this acceptable speech condition with the 6 m ceiling, the measured mid-frequency T_{15} was 1.47 s, whereas the Sabine predicted RT was 1.06 s. The sound decay was basically non-linear with $T_{30} > T_{15} >$ EDT. Exploiting a high-level horizontal reverberant field offers the possibility of acoustics that are better adapted as suitable for both speech and unamplified music, without any physical change in the auditorium. Using secondary reverberation in an auditorium for a wide variety of music might also be beneficial.

1. Introduction

In auditoria, the predominant absorption is due to seating and audience, yet this is concentrated on only one of six possible surfaces (in a simple rectangular space), namely the floor. In larger concert halls, there is often no additional absorbing material on other room surfaces. If the walls of the hall are vertical and there is a region between the highest seating and the ceiling, there is a clear possibility of reverberation in this upper region leading to a curved non-linear sound decay with extended terminal reverberation. In the literature, two spaces are described where this form of non-linear decay has been observed. The possibility of this behaviour is confirmed here in two scale model studies. The opportunity of exploiting this behaviour was investigated in one of these model spaces. We start by discussing an existing auditorium with intriguing acoustic behaviour. Earlier versions of this paper were presented at a DAGA meeting in 2010 [1] and the Institute of Acoustics Auditorium Acoustics meeting in Dublin, May 2011 [2].

2. The Göttingen Stadthalle, Germany

In the 1950s and '60s there were many new concert auditoria with reverberation times shorter than predicted [3]. The Göttingen Stadthalle had the opposite characteristic. With the acoustic consultancy coming from the IIIrd Physikalisches Institut of Göttingen University, it is fortunate that a thorough study of this acoustic phenomenon was published [4]. The Stadthalle was designed as a multi-purpose space. It opened in 1964, seats 1250 in a volume of 8200 m^3, which works out at 6.6 m^3/person. The ceiling height is 12 m. Because of the varied uses for the hall, which include orchestral concerts, theatre, conferences and social events, the main floor is flat, while there is a single balcony. The plan is a regular hexagon, with the stage off one side, Fig. 1. The walls are plane, whereas the ceiling is covered with pyramids 300 mm deep intended to promote diffusion. A similar ceiling was used in the Beethovenhalle, Bonn of 1959 [5,3].

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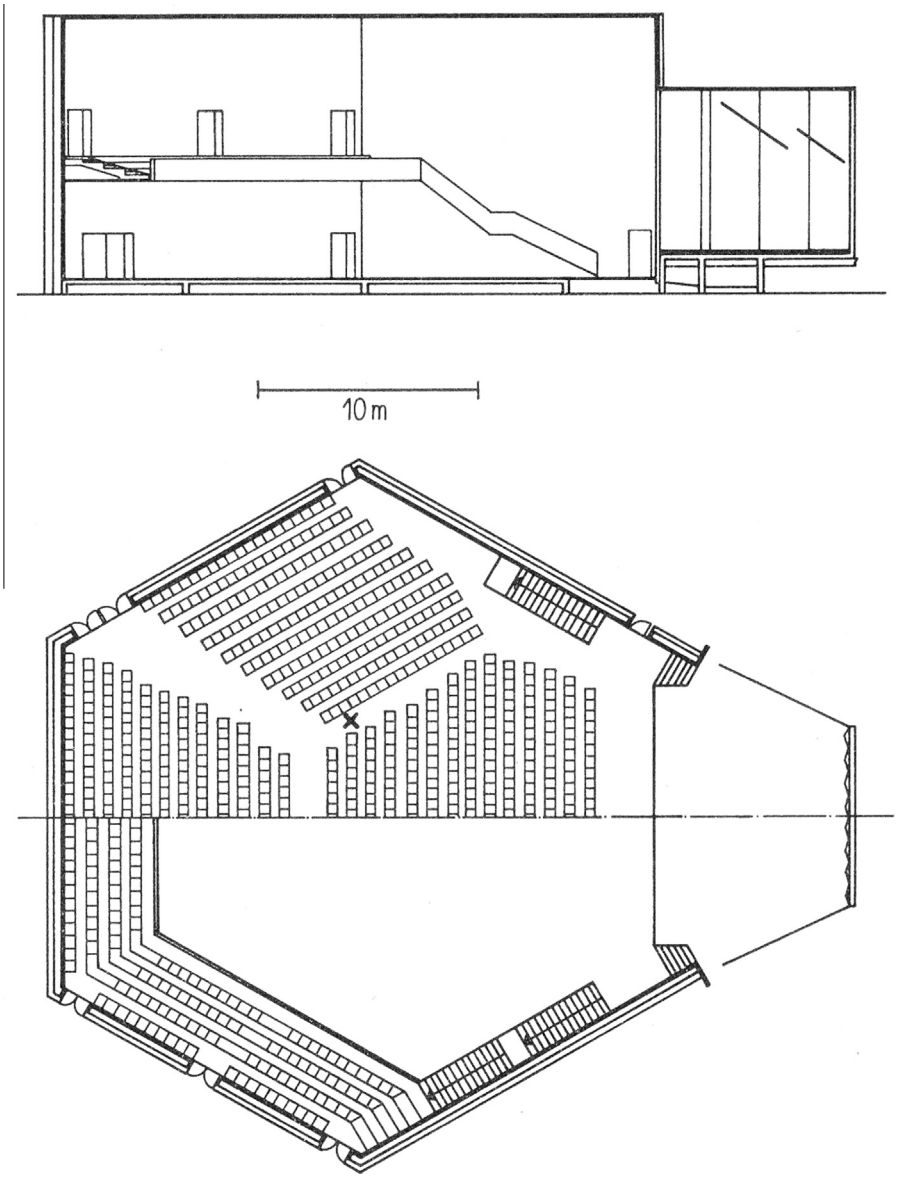

Fig. 1. Long section and plan of the Göttingen Stadthalle [6].

The predicted occupied reverberation time (RT) was 1.6 s, whereas the measured value at mid-frequencies was around 2.0 s, a 25% increase. A high proportion of the decays were sagging and higher reverberation times were measured near the ceiling than in the Stalls. Extensive measurements were made in both the actual hall and in a 1:15 scale model [6]. These established that a horizontal sound field was developing in the upper region of the hall with sound reflecting between the plane vertical walls; it was little influenced by the absorbing audience and scattering ceiling. For sound to reach this region of the hall, reflections off the balcony fronts and the risers of the steps which linked the Stalls with the Balcony were isolated. Fig. 2 shows the results of RT measurements in the unoccupied hall first in the condition as built, then with absorption applied to the central balcony front, thirdly absorption on the whole length of balcony front and then the stair risers as well. The original authors point out that absorbing material is more effective than geometrical changes (such as inclining the balcony fronts or making them scattering) because the former is unaffected by diffraction. One notes that making the ceiling highly scattering did not result in a diffuse sound field; this design had resulted in a subdivided acoustic space.

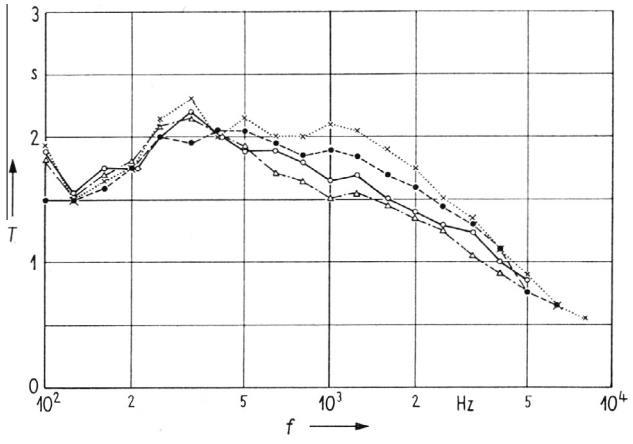

Fig. 2. Measured reverberation times in the unoccupied Göttingen Stadthalle [6]. ×···×, as built; •---•, with absorption on central balcony front; ○--○, with absorption over whole balcony front; Δ– – –Δ, with absorption over whole balcony front and stair risers.