INVESTIGATION OF ACOUSTICS FOR UNAMPLIFIED MUSIC IN A CATHEDRAL-TYPE SPACE WITH A FLAT FLOOR

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1 INTRODUCTION

Larger churches are often used for concerts of unamplified music. Yet listening conditions are frequently not ideal. This study concerns a church with side aisles either side of the nave and with a flat floor; both common conditions in churches in Britain and beyond.

This study was conducted in Bath Abbey, the results may well apply to other churches. Poor acoustic conditions in larger churches are often blamed on long reverberation times. This is certainly a contributory factor but one that is difficult to remedy. Reducing a long reverberation time is likely to require large areas of sound absorbing material, often visually difficult in a space with significant architecture.

The measured reverberation time (RT) in Bath Abbey is 4.5s unoccupied (mid-frequency), calculated occupied as 3.9s. These values are long but not as high as in some churches. The main argument in this paper is that the reverberation time is not the only concern in churches.

The volume of Bath Abbey is 23,220m^3, similar to that of many concert halls. The plan of the Abbey is the conventional cruciform, with nave and chancel (containing the altar) and two transepts on either side of the crossing. Orchestral musicians are generally placed just in front of the crossing, on a flat floor, which continues into the nave. Musicians and listeners are therefore on the same level. In spite of the volume of the space, much of the floor area cannot be used for concerts; the audience capacity in the nave is only around 370.

Good acoustics for concerts depends on an appropriate balance between early and late received sound for the audience. Early sound in a concert hall should contain side reflections but in churches with side aisles the bounding surfaces for the nave are columns. The columns are basically convex in cross-section, hence scattering sound. Most large churches have high ceilings, so ceiling reflections tend to be weak due to arriving relatively late. In conclusion, early sound is generally weak in the nave of a large church. With a long RT, the later sound is stronger than in a concert hall. The net result is a low ratio of early-to-late sound, hence poor clarity.

It was not possible to conduct a considered subjective survey in concerts in the Abbey. The subjective observations are limited to a few listeners. Subjectively the sound in the Abbey lacks musical definition/clarity, particularly for faster tempos. Sound in the front few rows of audience is acceptable, beyond is not.

2 COMPUTER SCALE MODEL STUDY

The Abbey space was modelled by computer model (CATT), for which I am indebted to Evan Green for creating the model. As in usual concert spaces, most surfaces are hard, stone and window glazing, with the audience representing the major absorbing surface, Figure 1.

As well as reverberation time, the principal objective quantity used for this study is what can be called "Objective clarity", the early-to-late sound index, C80 dB (= 10.log(early energy/late energy)). The index is frequently used for music venues. Recommended values between -2 and +2dB are considered suitable for classical music[1]. In this case, it is the minimum value of -2dB which is the issue.

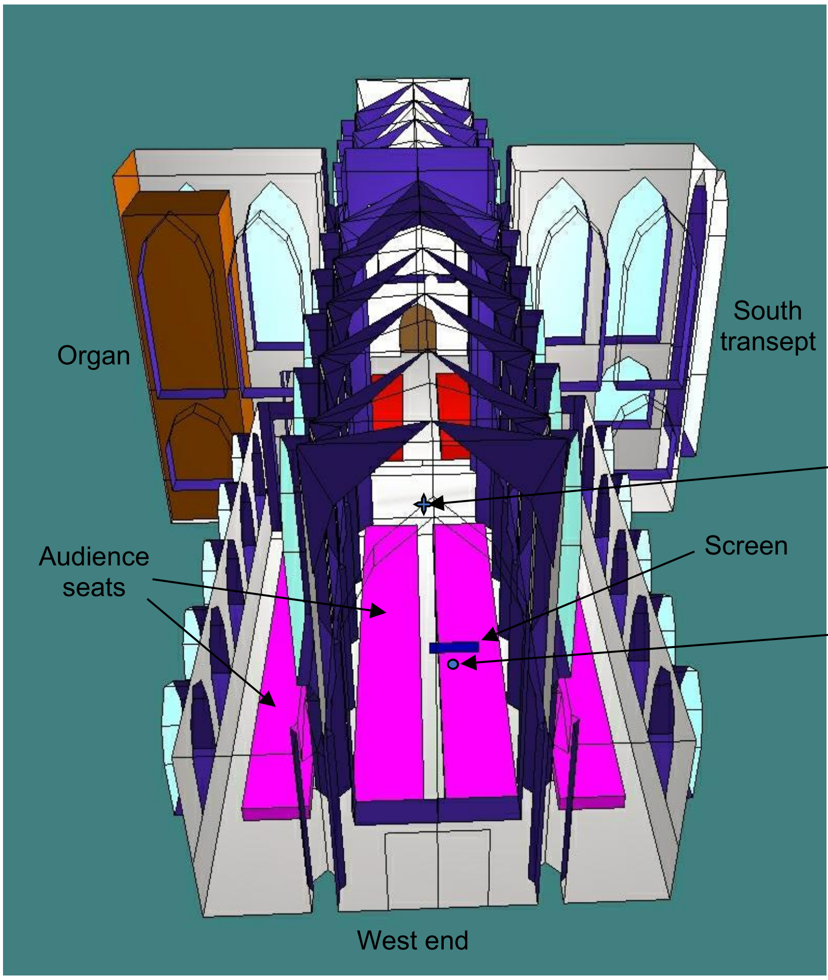


Figure 1. Computer view of Bath Abbey, viewed from the west end.

Figure 2 shows calculated values of C80 at a series of source-receiver distances in the nave (for a fixed source). As expected, high values are found near the source. For most receiver positions, both for the unoccupied and occupied conditions, objective clarity is below the criterion of -2dB. (Lower values of C80 in the unoccupied condition occur mainly due to the longer RT.)

Though in the occupied situation, values are only just below the criterion. The subjective situation is more severe than that, poor clarity becomes a significant issue. Should the poor sightlines which arise with both musicians and audience on a flat floor be taken into account?

RT unoccupied = 4.5s
RT occupied = 3.9s

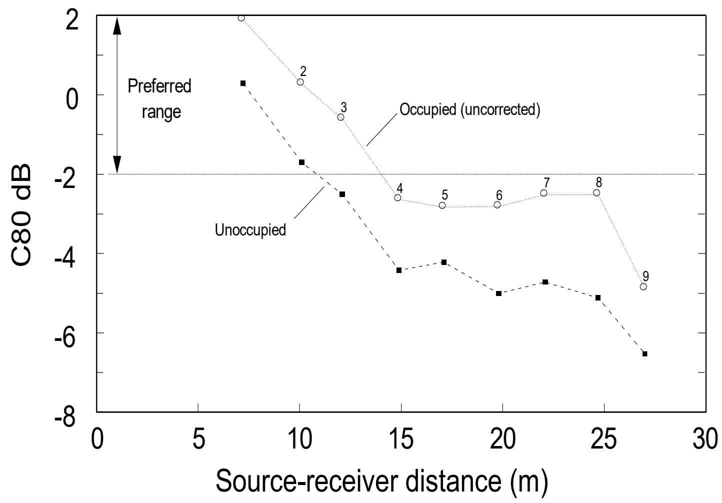
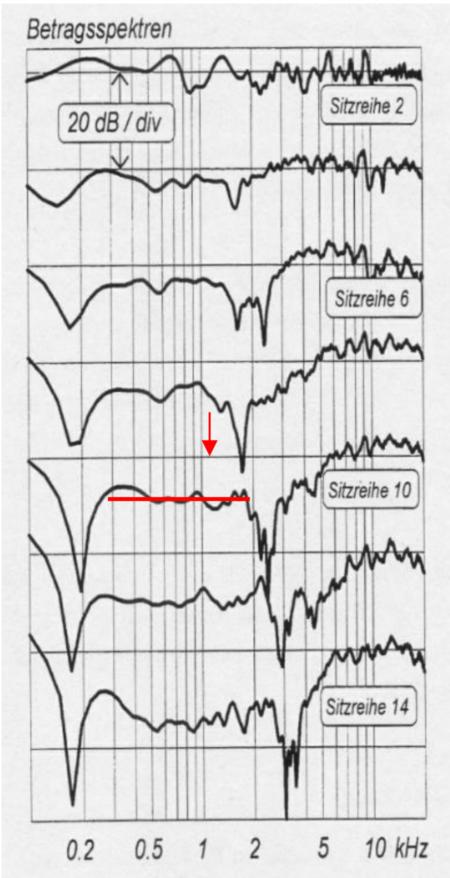


Figure 2. Predicted values of objective clarity, C80, without correction for grazing incidence.

3 ATTENUATION OF SOUND AT GRAZING INCIDENCE TO AUDIENCE



Measurements of sound attenuation at grazing incidence to audience show two prominent characteristics, Figure 3. The most obvious is called the “seat dip effect”: the strong attenuation at frequencies around 200Hz There is however also a mid-frequency attenuation of several decibels (indicated in red for ‘Sitzreihe 10’ in Figure 3). This will be the concern here. It has fortunately been studied exhaustively by Mommertz[2,3]. In particular, what physical parameter determines the attenuation? Mommertz isolated the angle, ε, to the plane of people’s shoulders as the key variable, Figure 4.

Figure 3. Measured spectra for sound across seating over different numbers of rows (Sitzreihe).

With a method for determining the attenuation of the direct sound, how can this be implemented in the computer model, when no means for this was included at that time in the model software? A crude method was employed using a semi-transparent screen that lay on the direct sound path, Figure 1. The transparency of the screen could be specified. This approach ignores the situation for early reflections from other vertical surfaces in other directions.

The significant effect of introducing grazing incidence attenuation for the direct sound is illustrated in Figure 5. Satisfactory clarity does not extend beyond 10m; grazing incidence affects clarity in 60% of audience seating in the nave.

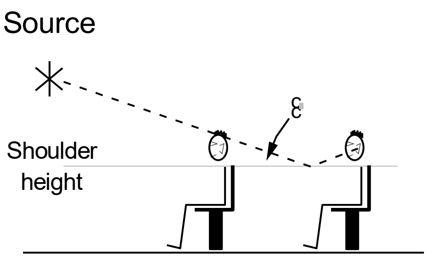
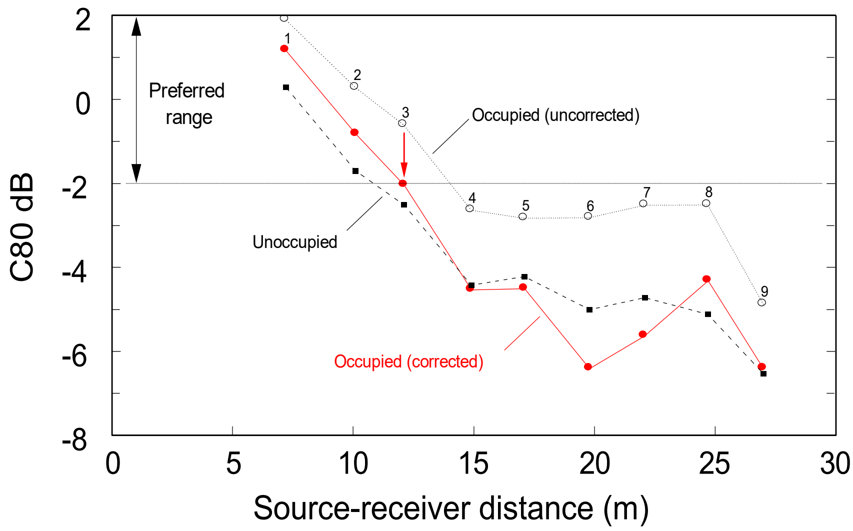


Figure 4. The angle, ε, determining grazing incidence attenuation.

Figure 5. Predicted values of objective clarity,C80, with correction for grazing incidence.



4 POSSIBLE REMEDIAL MEASURES FOR POOR CLARITY

The following remedial measures were investigated with the computer model:

1. Covering pews behind the crossing with drapes to increase their absorption
2. Raising the orchestra platform above the floor
3. Moving the stage to the west end
4. Moving the stage for music-in-the-round
5. Introducing suspended reflectors

Of these, the 1st, 3rd and 4th offered no worthwhile improvements. The 2nd and 5th are discussed further below.

4.1 Raising the orchestra platform above the floor

A raised platform is the norm in larger concert spaces and offers much improved sightlines. The acoustic improvement depends on the amount that the platform is raised, as shown in Figure 6. There are improvements for heights of 0.3m and beyond, but even with a 1m raised platform only a few more rows have sufficient clarity. Raising the platform is certainly desirable but not adequate to offer sufficient acoustic improvement.

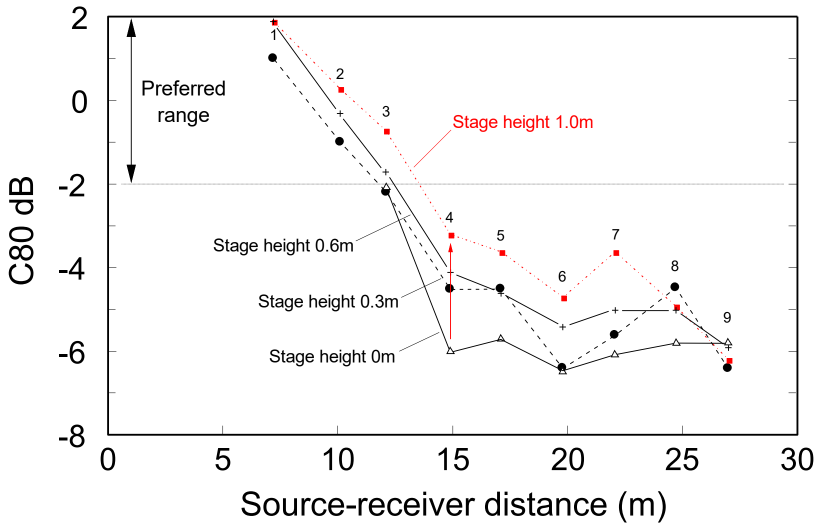


Figure 6. Predicted values of objective clarity, C80, for different height platforms.

4.2 Introducing suspended reflectors

For reflectors to assist, it is necessary to create reflections on paths remote from the audience. It is common to place a reflector above the performers. A secondary location is above the rear of the audience, a sort of mirror image position of the other reflector. The positions used are shown in Figure 7.

The objective clarity with suspended reflectors is given in Figure 8. A single reflector above the performers provides worthwhile improvements, while a second reflector complements the first, especially for the rear of the seating block.

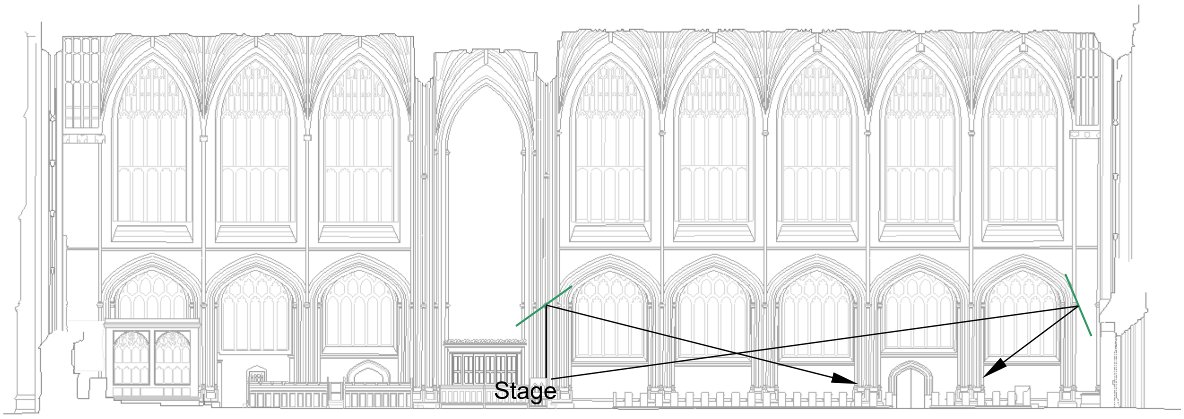


Figure 7. Long section with reflectors

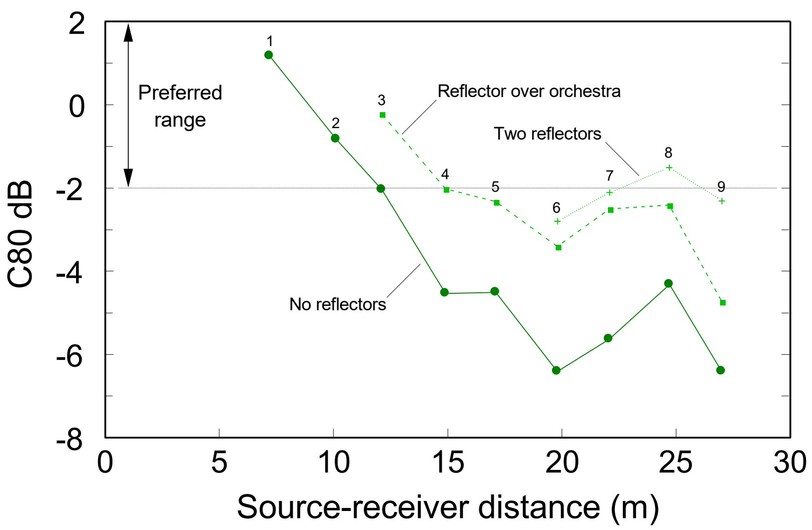


Figure 8. Predicted values of objective clarity, C80, with one or two reflectors.

5 CONCLUSIONS

When large churches are used for unamplified concerts, the traditional acoustic concern is the long reverberation time. However the two other important components of sound for the listener are also compromised. There is little early lateral sound when the side surfaces are dominated by columns and the ceiling is often high leading to late overhead reflections. The direct sound is also reduced in strength when performers and audience are on the same flat floor. The overall acoustic result is poor musical clarity.

The situation in Bath Abbey was studied by computer model and showed that attenuation of the direct sound contributes adversely to the listening situation. Fortunately this could be studied using the results of objective measurements by Mommertz. Various possible remedies were tested but only overhead reflectors, one above the performers, the other above the rear of the seating, showed potential for worthwhile improvement of clarity.

Bath Abbey is a fully operational church so remedial measures need to be removable. It is possible that reflectors of thick plastic sheet could be effective. A temporary reflector (canopy) built of timber was constructed in 1961[4] for the Abbey to be placed above the performers. This must have disappeared long since!

6 REFERENCES

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2. E. Mommertz, Einige Messungen zur striefenden Schallausbreitung über Publikum und Gestuhl. *Acustica* 42-52 (1993).
3 E. Mommertz, *Ph.D. thesis* (1996)
4. *Architect's Journal* 13.9.1961.