AN ACOUSTIC AND AUDIO SURVEY OF SOME ENGLISH CHURCHES

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ABSTRACT

A consultancy project lead to the realization that there is very little published information concerning the acoustics (and audio performance) of traditional UK churches. A survey was undertaken so that a benchmark could be established. The paper discusses the results of the survey which shows that whilst there are some consistencies, there is also a wide variation in the acoustics of typical churches and an even greater variation in the performance of their installed sound systems. Parameters such as Reverberation Time, the potential intelligibility of natural speech transmission and the volume per seat were investigated and are reported. Comparisons are also made with a number larger churches and UK Cathedrals. The paper provides a unique insight into the acoustic and audio performance of these buildings and variations in system requirements and operation.

1 INTRODUCTION

As a part of an exercise relating to the re-ordering of a relatively small traditional church, the potential changes to the acoustics and the impact this might have on the activities held within the church were investigated. The study concluded that the reverberation time would increase and the Nave would be become more acoustically 'lively'. However, no data could be found as to what was 'normal' acoustically for a church of this type and size. Whilst it would have been possible to apply general acoustic criteria for speech intelligibility to the space, it was felt that this might be overly restrictive – particularly with regards to choral singing and playing of the pipe organ. The 'Optimal RT values' e.g. as suggested by Smith, Peters & Owen [1], often vary as a function of room volume, as indicated in figure 1. For a church, with a volume of approximately 2000m^3, they recommend the RT to be around 1.3 to 1.4 seconds. Interestingly for speech the recommended RT for this volume is just over 0.8 seconds but for organ music it is 1.6 seconds. As the measured RT for the church in question was already around 1.5 seconds and predicted to increase to 1.7 to 1.9 seconds at mid frequencies (1.75 sec Tmf) it was decided to see how this compared to other churches of a similar size. A review of the literature showed there to be surprisingly little appropriate data. An acoustic survey of a number of both local and some more distant comparable churches was therefore undertaken and is still ongoing. Comparison data from a number of larger chapels and churches was also incorporated into the work, to provide a wider database and context for the research.

2 ACOUSTIC SURVEY

It was recognised form the outset that the surveys would have to be carried out quickly and efficiently both to minimise disruption to the churches involved and to keep the cost to PMA under control. It was therefore decided to limit the surveys to the following parameters.

- Date of building
- RT T20 and or T30 (source to be balloon bursts and compact active loudspeaker)
- Background Noise Level
- STI transmission from lectern to rear of seating (repeated with sound system where applicable)

- C50 and Ts (Centre Time) where possible (Via loudspeaker with nominal head directivity)
- Measurement of building dimensions and associated acoustic volume
- Calculation of volume per seat
- Calculation of total mid frequency Absorption A
- Measurement of STI and frequency response of sound system (where possible)

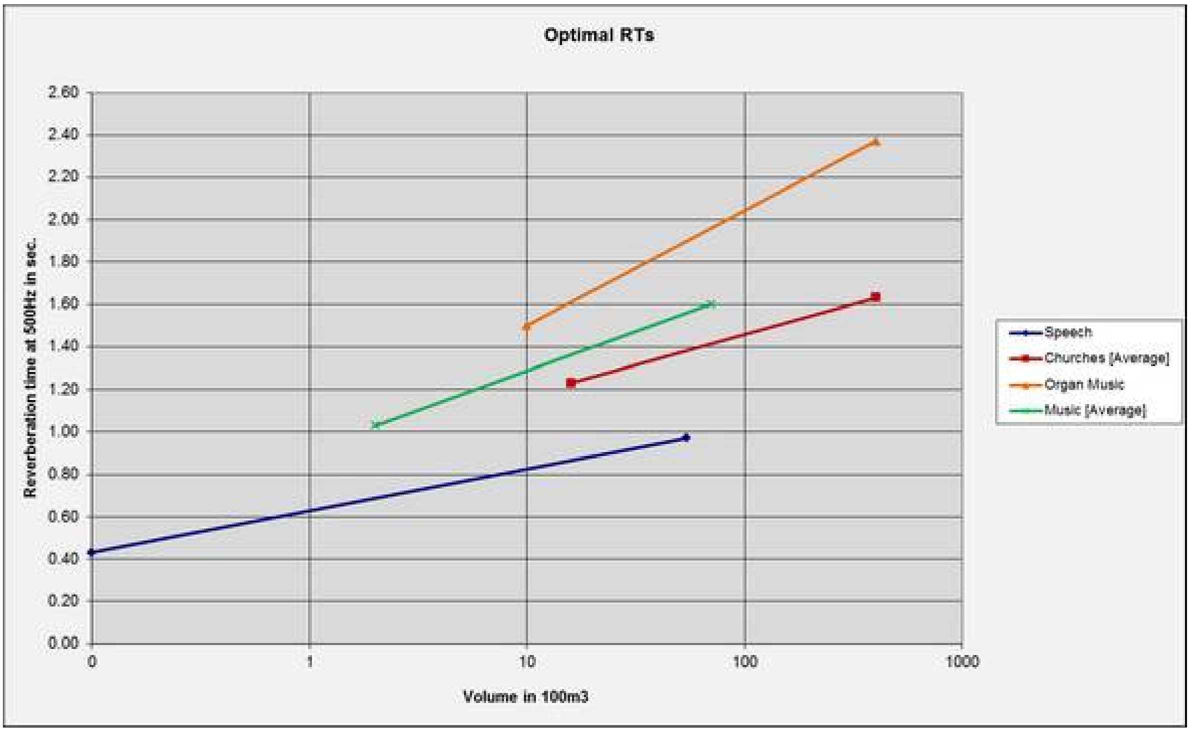

Figure 1 - Recommended RT values as a function of use and volume (after Smith, Peters & Owen)

In a number of cases it turned out not to be possible to measure the installed sound systems but loudspeaker and equipment details were noted, which proved to be instructive in its own right.

At the time of writing, a total of 10 churches and a cathedral (for comparison) have been included within the survey with a number of other churches are still waiting to be surveyed.

3 SURVEY RESULTS

3.1 Acoustics & Room Data

The primary data is summarised in table 1. As can be seen, the churches ranged in age from 1100 to 1904 (with one being re-built in 1995) and were all of traditional stone / timber construction. Some had pews, whist others had loose seats. Some were carpeted whilst others just had stone floors (marble in one case). This therefore enabled a wide range of acoustic environments to be encountered.

The mid frequency Reverberation Times varied between 1.2 and 3.5 seconds, with the cathedral coming in at 5.1 seconds.

The Volumes varied from 920m^3 to 10,500m^3 and 23,000m^3 for the cathedral. However, the primary buildings of interest had a much tighter range of values, extending from 920 to 2,800 m^3.

The volumes per seat ranged from 6.0 to 34m^3, though this range reduced from 6.0 to 12.0 m^3 for the set of churches of primary interest. In some cases determining what the effective acoustic volume proved to be quite difficult. Therefore the volume per seat for the Nave was calculated separately.

Table 1 – Summary of primary Survey Data

Church	Age (AD)	BGNL dBA	500Hz Oct RT (s)	Vol m^3	0.161V/RT	Vol /Seat Nave	Vol /Seat Total
St Andrews Mt	1100 / 1300	32	1.6	920	92.5	6.0	11.5
St Leonard's Col	1832 / 1897	29	1.25	2,750	354	9.0	15.7
St Michaels Col	1854	33	1.25	2,100	270	6.0	14.0
St Mary's Wv	1340	30	1.5	2,150	230	6.6	10.8
St Mary's Btn	1100	22 dBA	1.5	2,800	300	12.0	14.0
St Mary's WBH	1904	30/51*	1.2	1,325	177	9.5	9.5
St James Mltn Ab	1786	29	1.6	1,450	146	8.4	10.4
Trinity Coll	1554	29	2.7	6,850	408	34	34+
St Augustine's Ton	1900 / 1995	32	3.5	10,500	483	16	16
ST Luke's Wat	2005	35	2.7	2,200	131	9.8	10
Wells Cathedral	1176 - 1450	~30	5.1	23,000	726	29 Nave 53 Trans	34.2

Figure 2 shows the recommended RT plot with the primary church volume / RT data superimposed. Three of the churches follow the curve fairly closely with four more having an RT around 15-30% greater than recommended. Two churches have RTs more than double their recommended values.

Figures 3 – 11 compare the results in greater detail. Figure 3 presents a summary of the measured RT data and compares the main churches of interest to two large collegiate chapels.

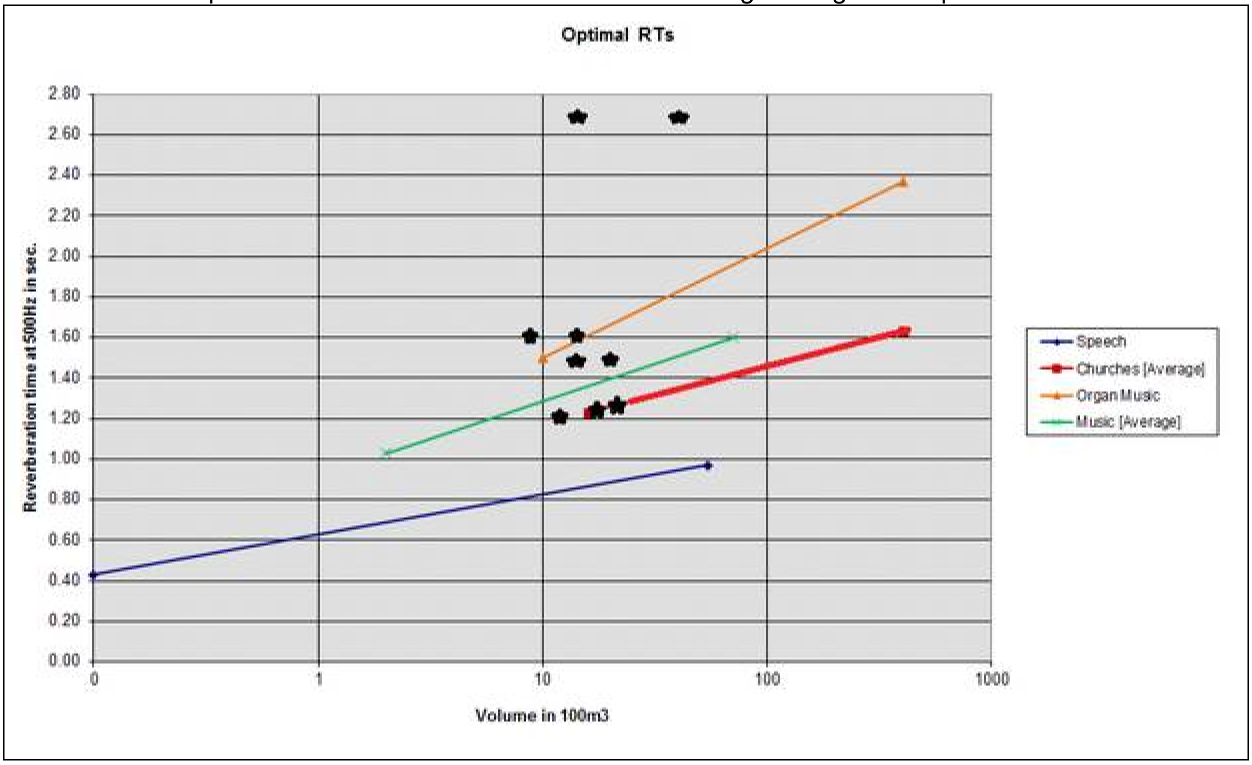

Figure 2 – Recommended RTs with church survey data superimposed

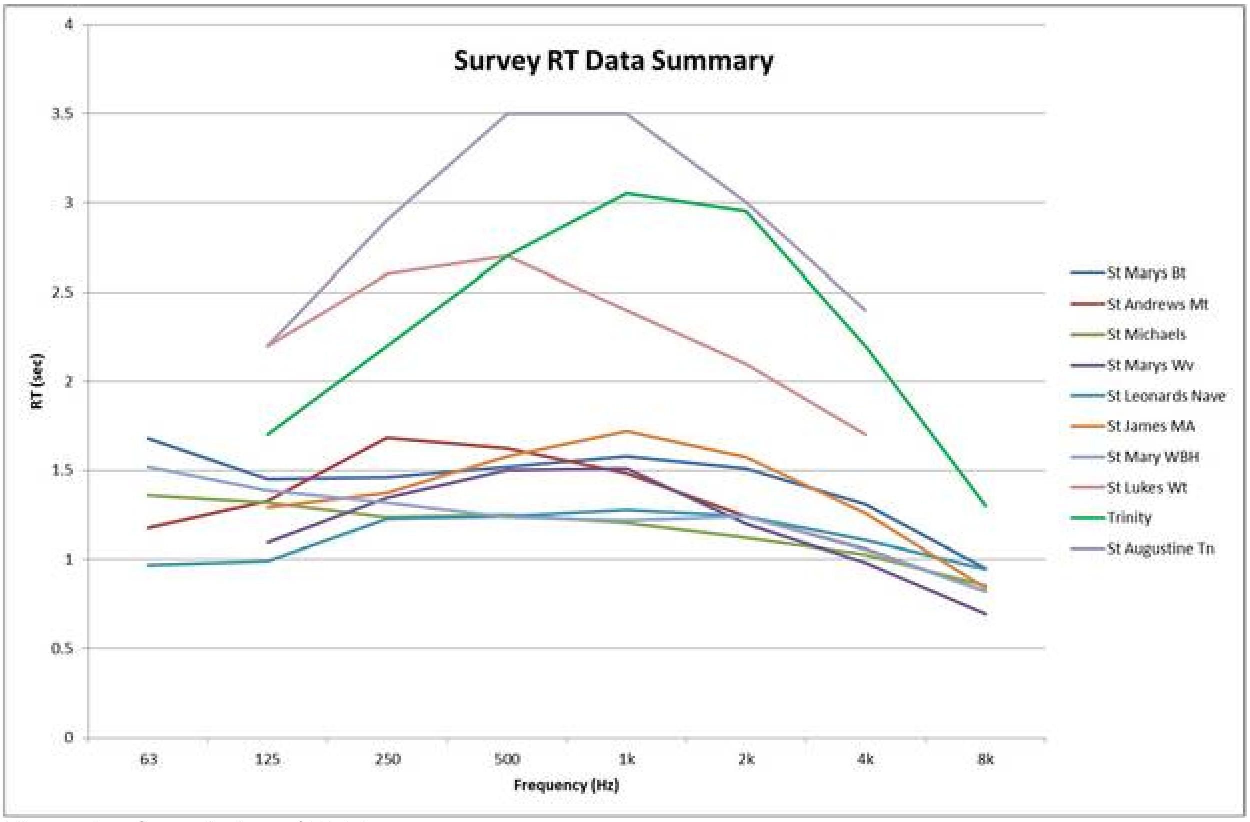

Figure 3 – Compilation of RT data

The differences with the higher volume chapels are immediately apparent as are the RT characteristic for an overly reverberant modern church (St Luke's). The remainder of the RT curves otherwise lie within a reasonably narrow range and have an unexpectedly fairly flat characteristic. Two exceptions to this are the RT curves exhibited by St Andrews and St James, shown in figure 4.

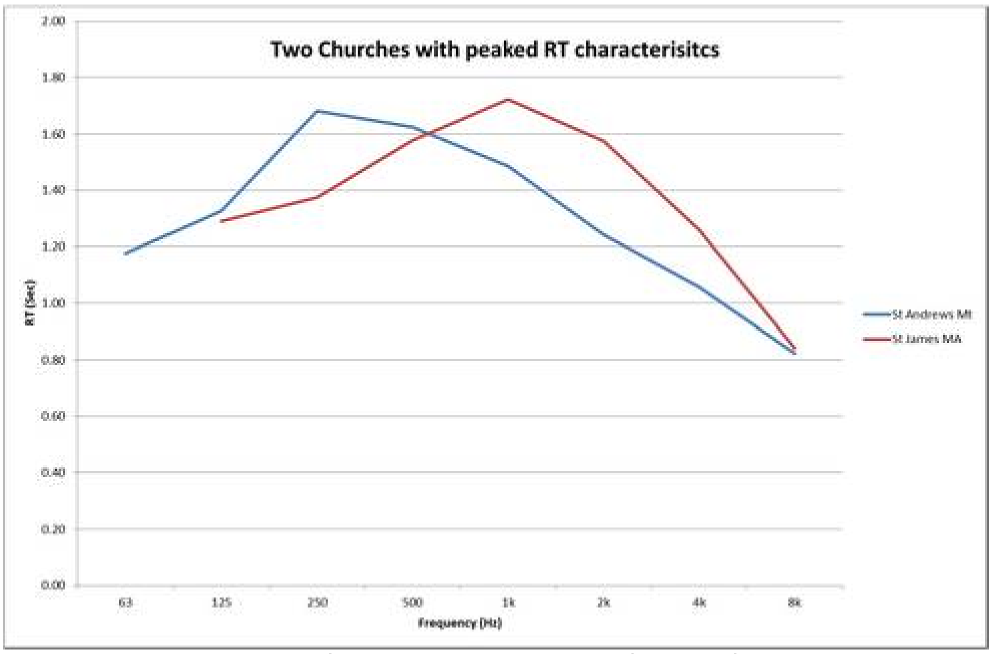

Figure 4 – variations in RT frequency characteristics for two of the smaller churches

Figure 5 compares the measured Reverberation Times categorized into those churches with and without carpet. As might be expected, the churches without carpet exhibited the longer reverberation times, as indicated by the blue curves. Those with carpet are the red curves. The green curve is the RT characteristic for a church with a solid timber floor but with well-padded chairs, which proved to be very effective at controlling the reverberation.

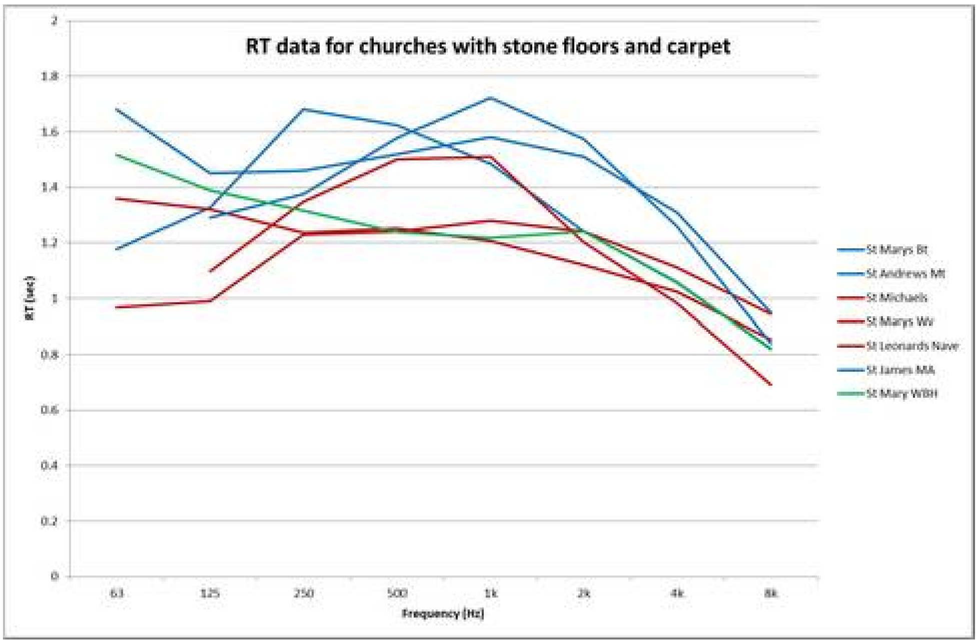

Figure 5 – RT characteristics for churches with / without carpet

Figure 6 compares the measured reverberation time values at 500Hz for all the churches

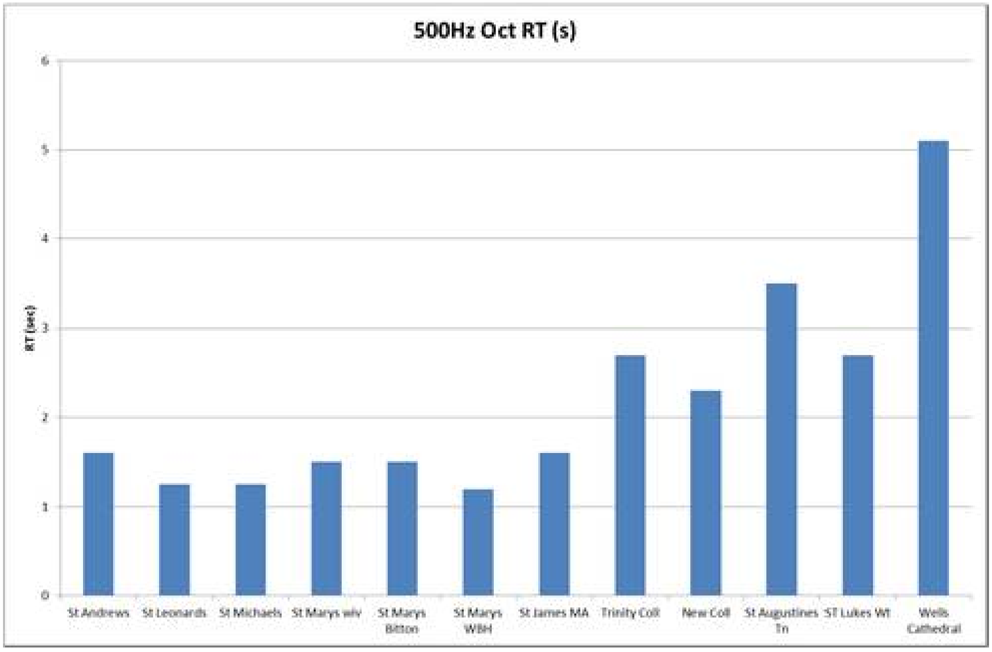

Figure 6 – RT for 500Hz octave band

Figure 7 provides a comparison of the volumes of the smaller churches of interest.

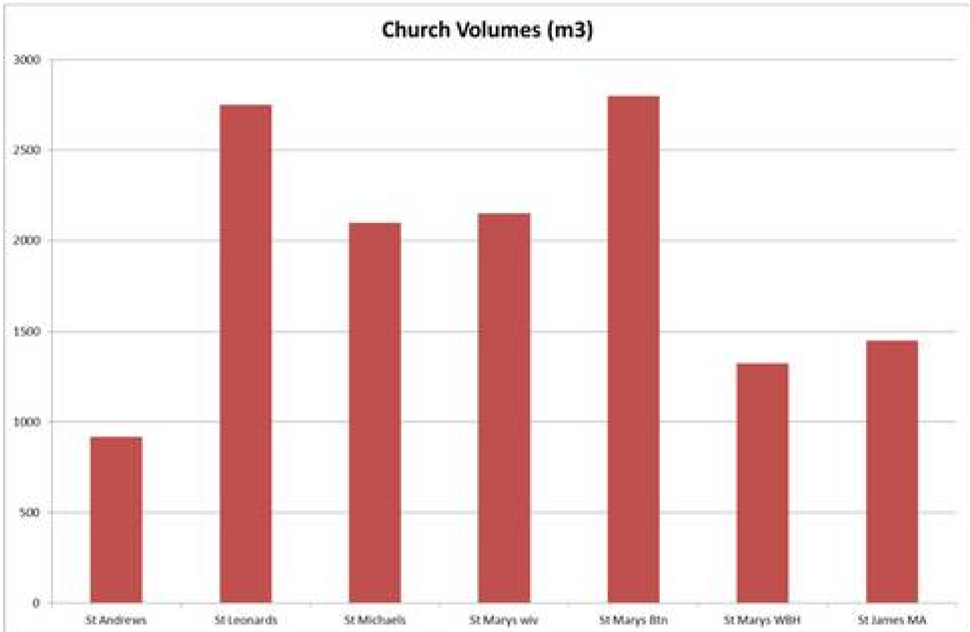

Figure 7 – Volumes of smaller churches

Figure 8 provides a comparison of the volume per seat for the above churches

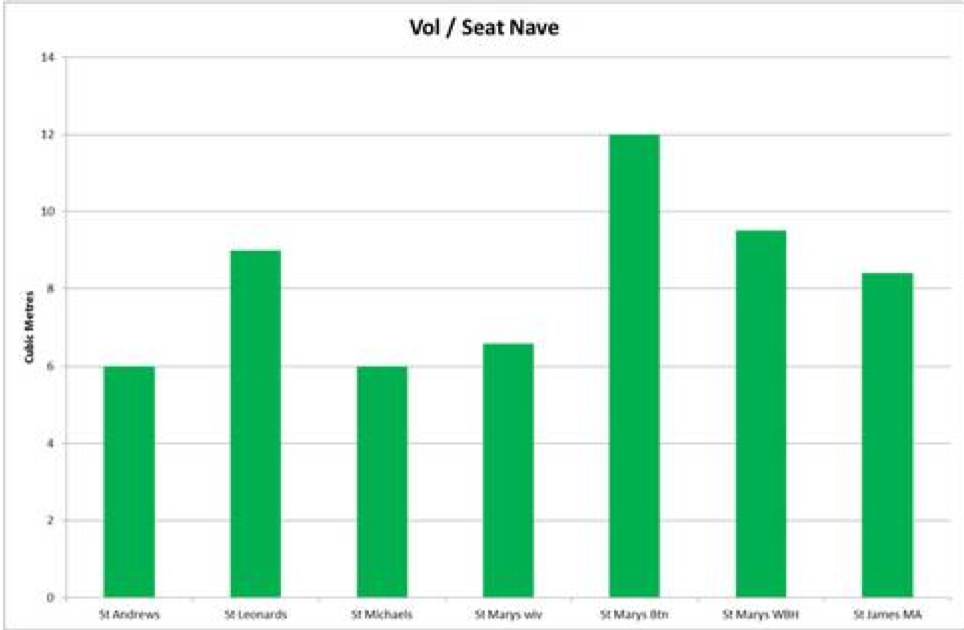

Figure 8 – Volume per seat for smaller churches

The average volume per seat for the above group of churches is 8.2 cubic metres. It is interesting to compare this to a s typical equivalent space for speech - which would typically have a recommended value of 3 - 4 m^3 and a concert /recital hall at 7-11 m^3. Looking at the number of seats available within the Nave (including side aisles) is instructive, as the largest volume (Wells Cathedral) doesn't actually serve the largest number of people. This was St Augustine's but this was an exceptional case.

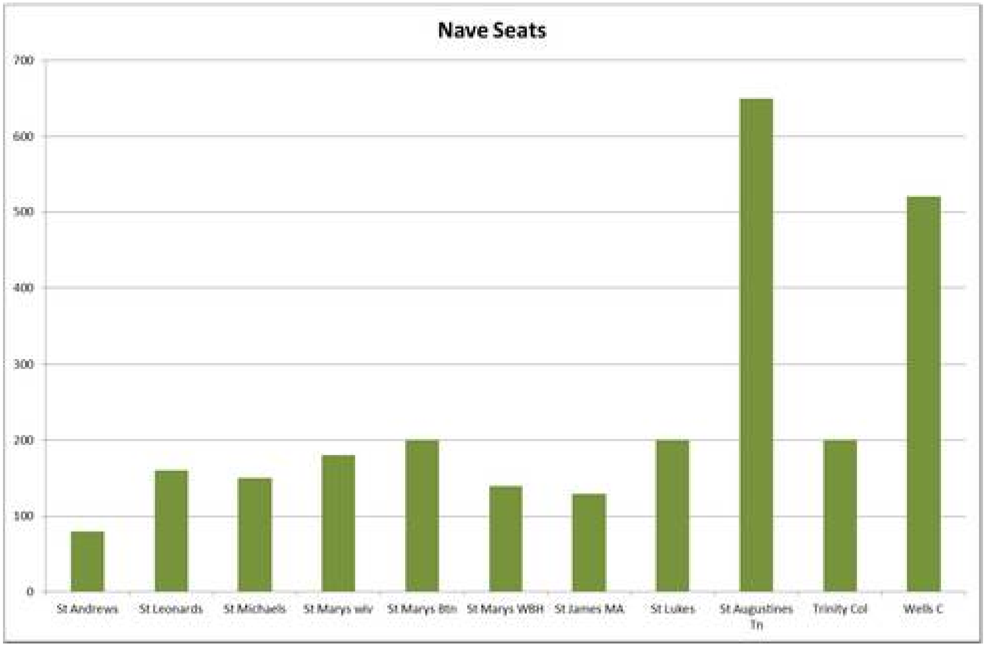

Figure 9 – Summary of Nave seating capacity

The width of the nave and associated side aisle(s) was found to vary considerably and significantly affected the generation and distribution of lateral sound reflections. Although 8m was a common width for the nave itself, most extended into side aisles. Figure 10 summarises the measured widths.

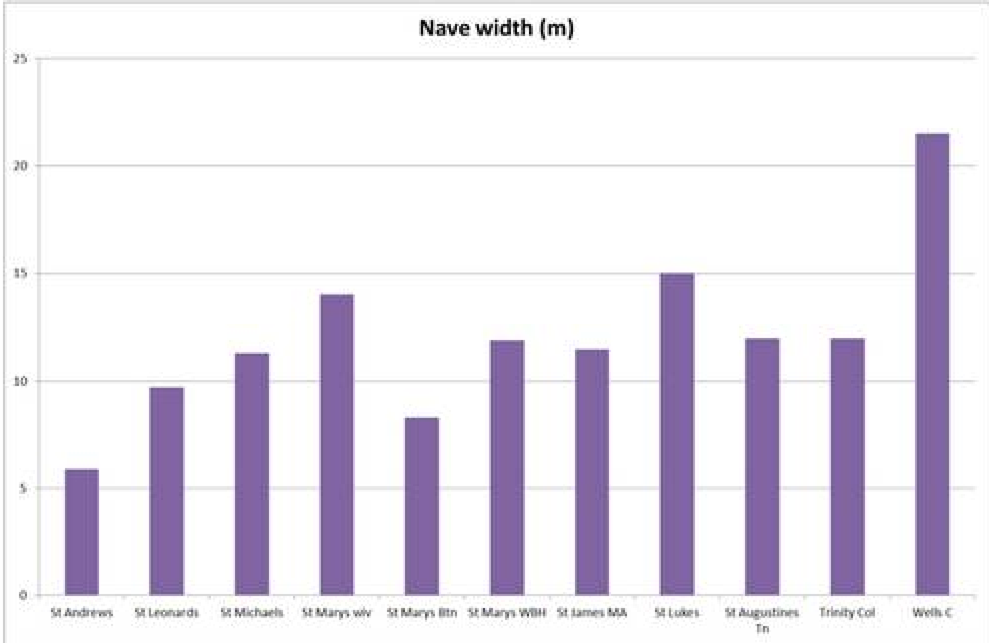

Figure 10 – Nave widths

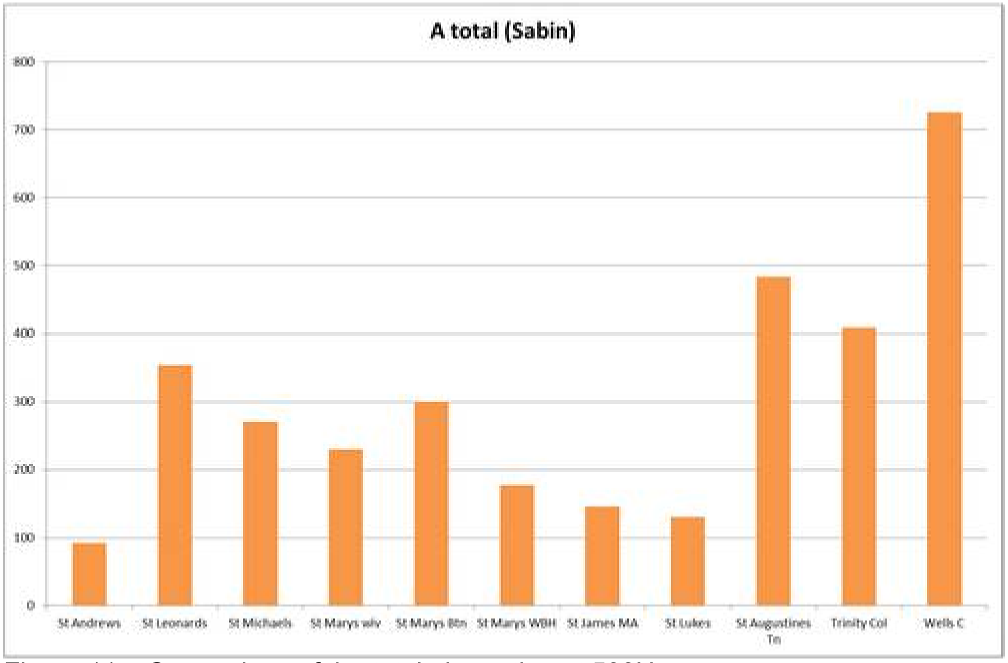

Figure 11 – Comparison of the total absorption at 500Hz

3.2 Speech Transmission & Intelligibility

Apart from measuring the physical and general acoustic properties of the churches, their ability to provide natural speech intelligibility was also investigated. In other words, how well did these buildings work without a sound system ? An example of this is shown in figure 12, which plots the

STI vs distance and associated sound level. The plot extends over a distance of 11m, being from the lectern to the rear row of seats.

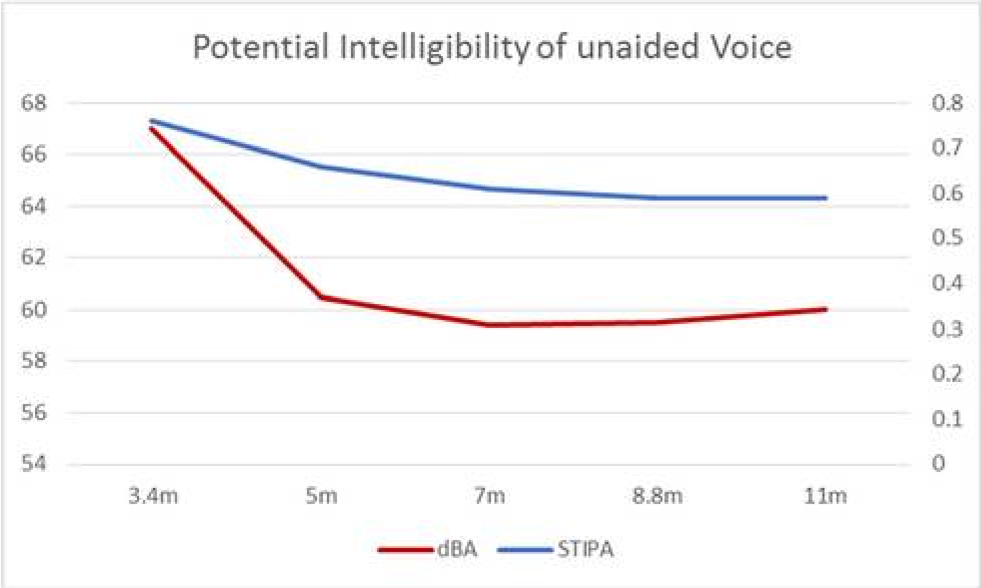

Figure 12 – Speech Transmission from Lectern to rear row

The voice source was a calibrated ‘Talkbox’, having similar directivity to that of a human talker, set to output 70 dBA at 1m.

The natural intelligibility is remarkably good, achieving 0.60 STI at the rear row with an SPL of 60 dBA. [The mid frequency RT was 1.2 seconds]. In this particular case, the possibility existed to compare the intelligibility performance of the unaided voice with that produced by the sound system. As expected, given the loudspeaker positioning, the sound system actually produced lower STI values but with a more consistent SPL, as shown in figures 13 & 14.

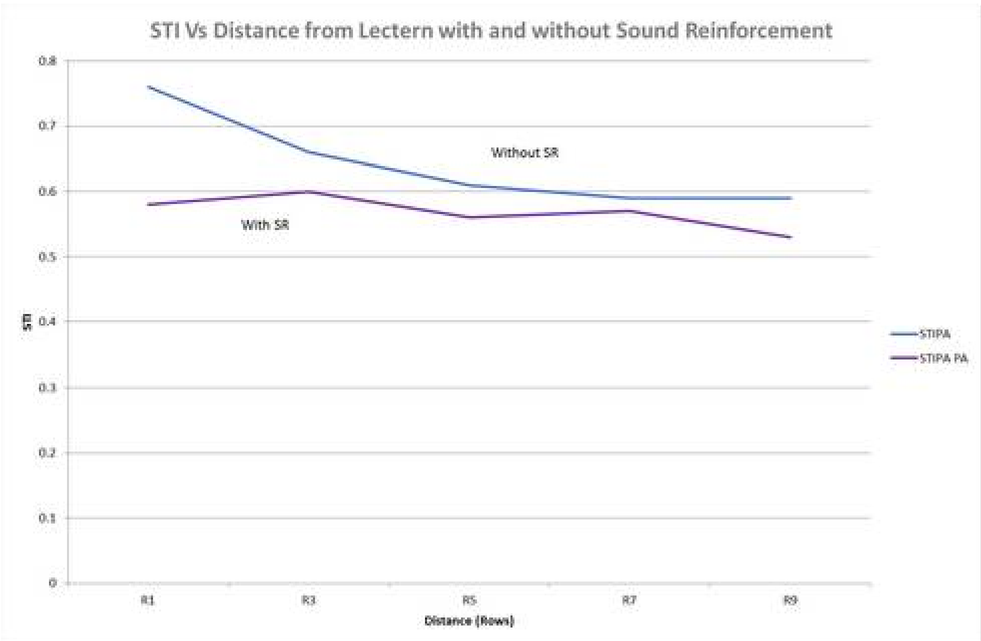

Figure 13 – Potential intelligibility with and without sound reinforcement (1.2 sec RT)

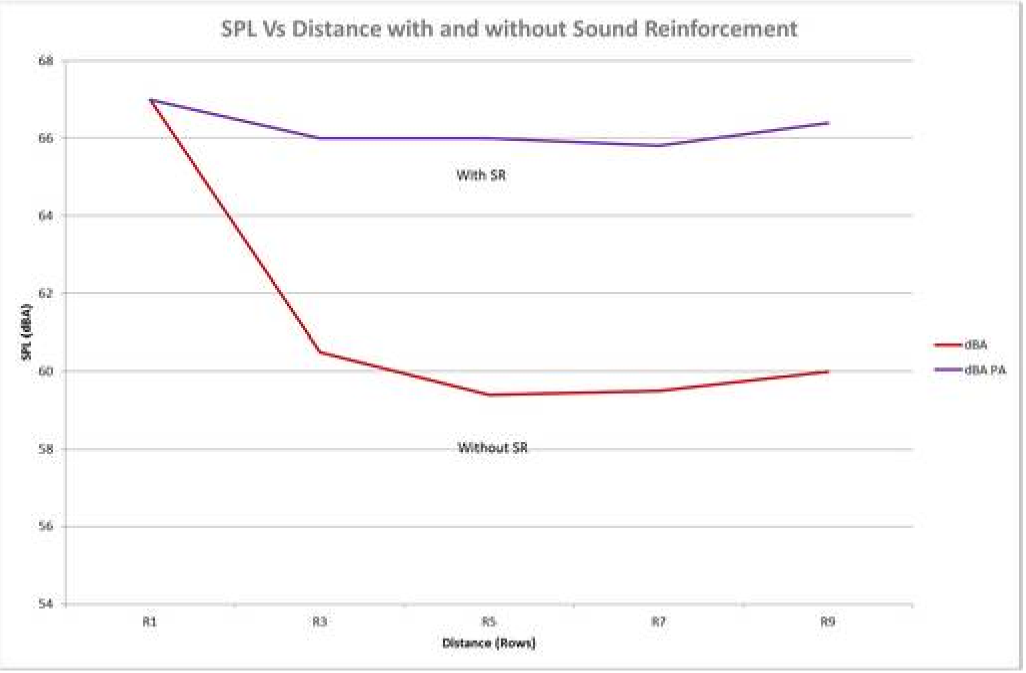

Figure 14 – Voice Level vs Distance with & without sound reinforcement

A second example of the effectiveness of a sound system is shown in figure 15. Again the loudspeakers were placed higher than would be thought to be effective – but they actually provided useful reinforcement.

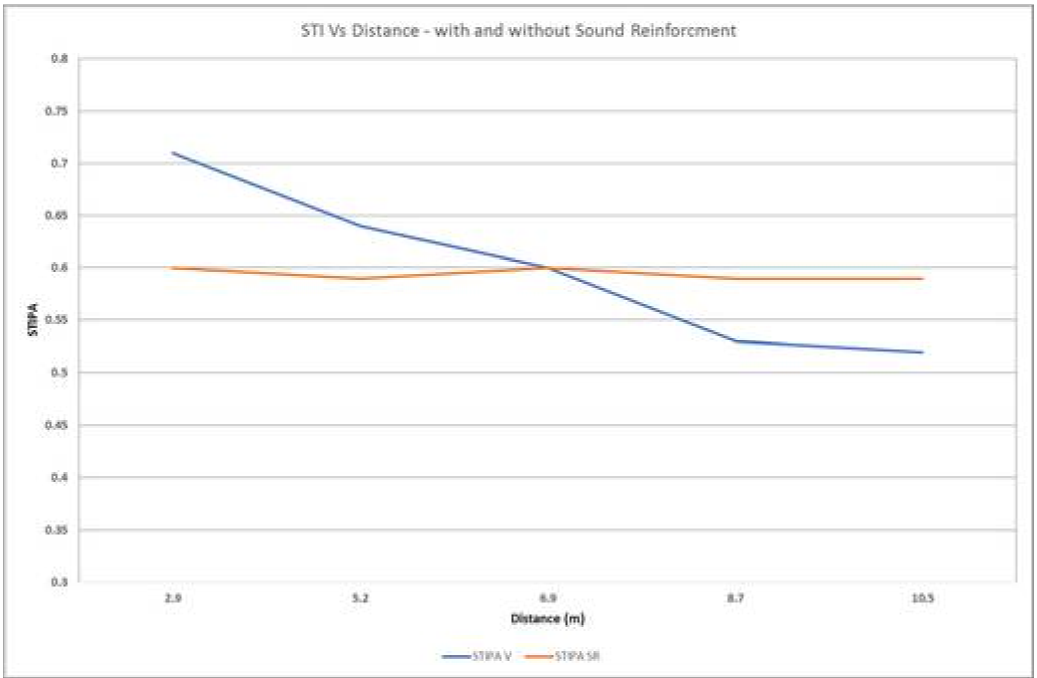

Figure 15 – Potential intelligibility with and without sound reinforcement (1.6 sec RT)

The potential intelligibility was measured at a distance of 10-11m for a number of the churches and the results are summarised in figure 16. Interestingly, in all cases, the STI was adequate, averaging 0.58 at 10.5m whilst the average voice level at this distance was 58 dBA, based on a voice level of 70 dBA at 1m. It is therefore probably reasonable to conclude, that provided the talker (preacher) used a raised voice and didn't mumble, that this would be both audible and intelligible in most if not all seats of the smaller churches surveyed.

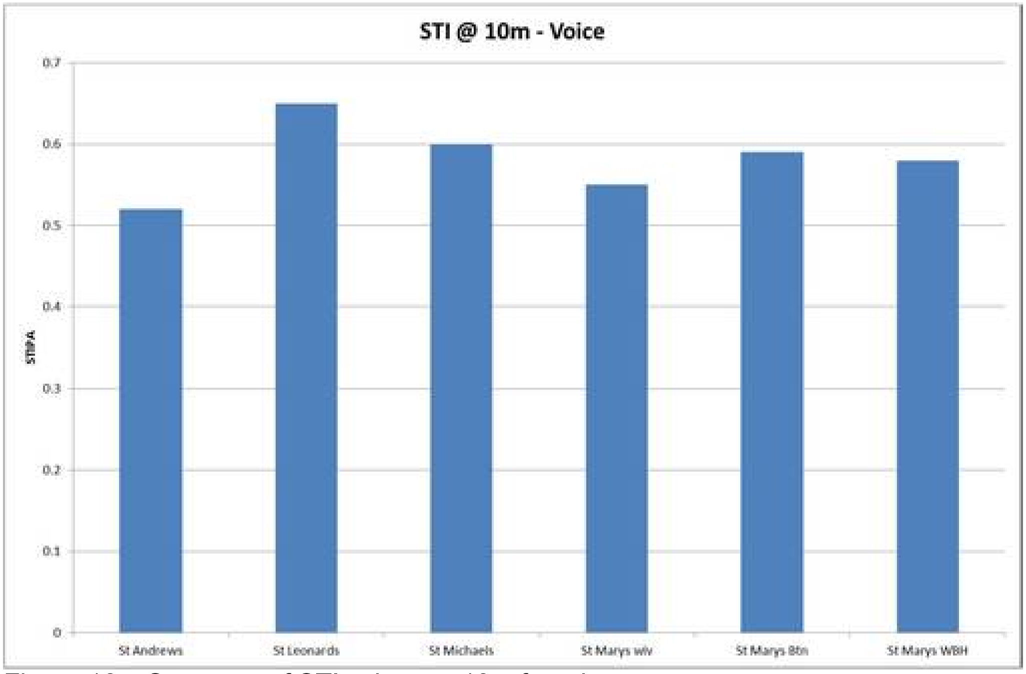

Figure 16 – Summary of STI values at 10m from lectern

4 CONCLUSIONS

The survey has provided a useful insight into the acoustic environment of small to medium sized traditional English churches and provides a useful database for future work.

The reverberation time characteristics were generally more benign that expected, particularly when compared to larger churches and cathedrals.

The finding that speech is likely to be intelligible and audible in the rear seats shows that the smaller buildings are effective in providing a supportive acoustic environment for speech.

The sound systems in the churches surveyed were generally fairly simple ones and whilst generally provided useful reinforcement, it was also found that there was considerable scope for improvement. The interesting and surprising finding was that loudspeakers could be located in far from optimal potions but due to the benign acoustic conditions, worked better than might be expected.

5 REFERENCES

1. Smith, Peters & Owen : Acoustics & Noise Control, Pub Longman