Reflection and Analysis

The reverberation time, RT forms the analysis of the four impulse responses, IR. Comparisons of each RT30 have been made along with a brief introduction to Sabine's RT equation. The importance of this section illustrates the acoustical characteristics in each religious building. A graph has been used to visually demonstrate the difference their builds and from the average RT30 indications to its proper uses i.e. good speech intelligibility can be given.

The fundamentals of reverberation time, RT

Reverberation time, RT is one of the basic fundamental parameters in acoustics. By calculating this parameter, identifications can be made into the characteristics of the building. Mathematician Wallace Sabine developed the method for calculating the RT. He understood that the RT was proportional to two factors, the dimensions of the room ad the amount of absorption of the room's surfaces (Chen, 2011). The equation he gave was:

$$R_T = \frac{0.161 \cdot V}{\mathrm{S} \cdot \alpha}$$

V is the room in cubic meters, *S* stands for the total surface area of the room in square meters, and *a* is the average absorption coefficient in the room.

The RT equation is referred to as the Sabine equation, after Wallace Sabine. This equation has been used to calculate the four IR's measured for this project, it has been calculated through Fuzz-measure software [1]. Due to limits with the Fuzz-measure software the RT measurements were restricted to either RT20 or RT30. RT30 was chosen to represent the RT.

RT30 has been used to measure the amount of reverberation in each religious building. It has not been possible to measure the full 60dB due to limits with the Fuzz-measure software. This means that the first 30dB decay (T30) can be used to

approximate the RT60. The RT30 measurements can be used to derive the T60, by simply using multiplication, "T60 is approximately twice the T30" (Watson and Downey, 2008). I will not be making this multiplication, as the results are perfectly fine.

Table 1.0 - *shows the RT30 of four different religious buildings*

Location	32Hz	63Hz	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	8kHz
Hereford Cathedral	10.89	15.03	7.27	5.81	5.61	5.20	3.84	2.77	1.47
Belmont Abbey	4.77	5.47	3.68	2.57	2.60	2.60	2.33	1.94	1.28
St. Mary's Church	5.82	5.23	6.36	1.70	1.79	1.79	1.51	1.25	0.80
Gorsley Chapel	3.34	1.89	1.40	1.34	1.20	0.95	0.83	0.76	0.56

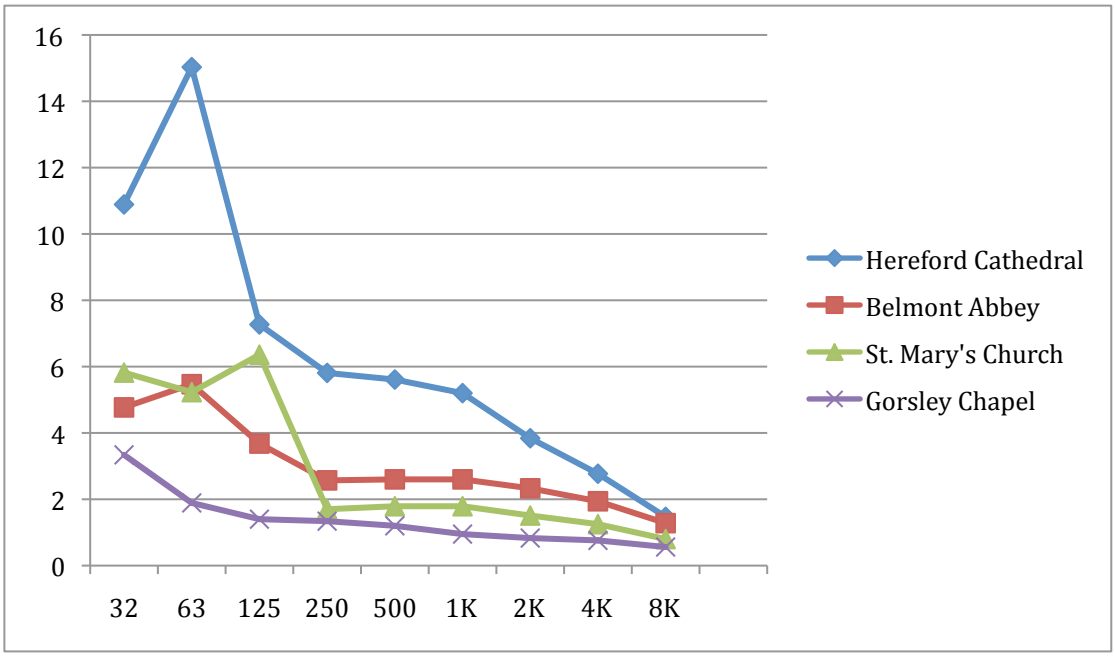
*All results are in measured in time, seconds.

Table 1.1 – *shows the average RT30 of four religious buildings.*

Location	Average Value
Hereford Cathedral	6.4s
Belmont Abbey	3s
St. Mary's Church	2.9s
Gorsley Chapel	1.4s

*All results are to one decimal point.

Figure 1.0 - *shows the reverberation time (T30) of four different religious buildings*



Note: The Y-axis – Reverberation time (s), X-axis – Frequency

Analysis of the Impulse Responses RT30

The analysis of the reverberation time (RT30) in Hereford Cathedral, Gorsley Chapel, St. Mary's Church and Belmont Abbey provide evidence to support which building best acoustically suits, speech, contemporary music and choral singing. Reference is made to figure 1.0, it shows the RT30 of all four religious buildings.

Overview of the RT30 Results

The results displayed in figure 1.0 accurately show the reverberation time, RT, of four acoustically different religious buildings. When viewing the graph it is easy to see that Hereford Cathedral has a much longer RT than Gorsley Chapel, this is because the reverberation depends wholly on the room size and the type of surface materials [2], Hereford Cathedral is approximately 10 times larger than Gorsley Chapel in terms of their volume. It was intentional that all four RT30's looked differently. This was because I wanted to show a contrast in the IR's for the convolution reverb patch, I found four religious buildings with different acoustical properties [3].

To understand what is going on in figure 1.0, look at the higher frequencies, here it illustrates the space of each building. St. Mary's Church and Belmont Abbey have a similar RT30 (0.1 average difference) this is because of their similar size and both have been decorated in an early English style with slender columns, pointed arches and large stained glass windows [4]. However at the time of measuring the IR in Belmont Abbey it was lent, this meant that all monuments were covered in purple drapery. This would contribute to its RT30 as the absorption coefficient for drapery (at 4kHz) is approximately 0.35 [5].

I would like to note that during the measurements of all four buildings there was only a maximum of four people present. This was to ensure minimal background sound however in a live situation where a choir was singing each building would be full thus decreasing the RT30 as people must be included in the absorption coefficient [5].

Speech

To identify which religious building supports the best acoustical characteristics for speech, the average RT30 must be derived from each building. Table 1.1 illustrates these results. It shows that Gorsley Chapel with an average RT30 of 1.4 seconds is the

best for speech intelligibility. Speech intelligibility is greatly affected by reverberation [6] so unlike Hereford Cathedral with its highly reflective surfaces i.e. stonewalls and floors [3] Gorsley Chapel is much more suited to speech due to it being a dampened space because of it increased absorption coefficients i.e. plastered walls, large curtains and carpet.

Supporting the RT30 results is reverberationtime.com [7], here time bands have been created to show if the reverberation time is good, fair – good, unacceptable or optimum. In terms of speech the individual buildings have been categorized as,

Gorsley Chapel (1.4 seconds) – Fair

Belmont Abbey (3 seconds) – Unacceptable

St. Mary's Church (2.9 seconds) – Unacceptable

Hereford Cathedral (6.4 seconds) – Unacceptable

Contemporary Music

To discover what acoustical properties best suit contemporary music an investigation into the RT30 must be made. Contemporary music can be classified as mainstream music, it is the opposite of classical and orchestral music. The main difference with contemporary and orchestral music is that contemporary music does not suit highly reflective buildings this is due to its excess reverberation. Instead of sounding legato (orchestral music), it would sound washed out. This is mainly due to the style of music. The best building for playing contemporary music is Gorsley Chapel. This is evident in figure 1.0 where the Chapel has the least reverberation. It was interesting to discover that Gorsley Chapel feature a contemporary band in their weekly Sunday service compared with the traditional organ present in most historical religious buildings. The contemporary band has survived in this building, compared with the traditional Belmont Abbey, as the Chapel is a plain rectangular shape (reefer to appendix D for all the measurements of the IR's and all the floor plans) with highly absorbent coefficients.

Supporting the RT30 results is reverberationtime.com [7], here time bands have been created to show if the reverberation time is good, fair – good, unacceptable or optimum. In terms of playing contemporary music the individual buildings have been categorized as,

Gorsley Chapel (1.4 seconds) – Fair

Belmont Abbey (3 seconds) – Poor

St. Mary's Church (2.9 seconds) – Poor
Hereford Cathedral (6.4 seconds) – Poor

Choral Music

When demining which building best acoustically suits a choir, a look at the RT30 indicates that St. Mary's Church, Belmont Abbey and Hereford Cathedral all provide enough reverberation to support a choir. The traditional religious buildings, of most religions have been intended for choral music. This is seen in Hereford Cathedral, it has housed its choir since the 13th century [8]. Large and highly reverberant buildings have poor acoustics for speech, the excessive reverberation overlaps the sound making it unrecognizable. However for singing these grand buildings provide the correct amount of reverberation. This is because the long RT allows choral singing to be enhanced, as the notes blend together [7].

Supporting the RT30 results is reverberationtime.com [7], here time bands have been created to show if the reverberation time is good, fair – good, unacceptable or optimum. In terms of choral music the individual buildings have been categorized as,

Gorsley Chapel (1.4 seconds) – Fair
Belmont Abbey (3 seconds) – Good
St. Mary's Church (2.9 seconds) – Good
Hereford Cathedral (6.4 seconds) – Fair

Bibliography

-Chen. Zhixin, Investigation on Simulation and Measurement of Reverberation for Small Rooms. Pp 69. Vol 2, No. 7, 2011.USA

-Watson, R., Downey, O. The Little Red Book of Acoustics: A Practical Guide. Published by Blue Tree Acousitcs, 2008. Pp 66.

[1] http://supermegaultragroovy.com/products/FuzzMeasure/

[2] http://www.soundonsound.com/sos/sep98/articles/acoustic_3.html

[3] Reverberation time measuring methods

[4] http://www.rtm.org.uk/rosshist.html

[5] http://www.sae.edu/reference_material/pages/Coefficient%20Chart.htm

[6]Comparing the acoustics of mosques and byzantine churches

[7](http://www.reverberationtime.com/)

[8] Hereford Cathedral website, May 3rd 2012.