Modelling baffle configurations in virtual rooms

Brendon Shanks

Marshall Day Acoustics, Auckland, New Zealand

ABSTRACT

The use of suspended baffles to provide acoustic absorption is an increasingly common option where the building design requires the underside of a slab to remain exposed. Test data for sound absorption is provided by some suppliers for specific configurations of baffles i.e. depth of baffle, spacing between baffles, and hang distance from the slab. However, often the demands of a project require baffle arrangements that have not been tested. This paper explores the possibility of using the Odeon room acoustics modelling software to calculate the absorption coefficients of different baffle configurations without relying on physical laboratory tests. By using a virtual reverberation chamber, the laboratory test procedure from ISO 354: 2003 has been replicated in Odeon. The predicted absorption coefficients have been compared to data from suppliers' tests in an attempt to validate the modelling process.

1. INTRODUCTION

The purpose of this exercise was to explore the possibility of using a virtual reverberation chamber to approximate the sound absorption performance of different vertical baffle configurations. This subsequently developed into two key areas of investigation.

The first was to understand and experiment with the possibility of using the room acoustic modeling software package Odeon to create a virtual reverberation chamber. Odeon uses ray tracing to calculate the acoustic properties of a digital room. It can calculate the reverberation time, along with other parameters required for assessing room acoustics. By definition, a reverberation chamber is an extreme acoustic environment and not necessarily the type of space that a room acoustic modelling package is designed to replicate.

The second part was to investigate the possibility of modelling the change in average absorption performance of baffle arrays in the virtual chamber. This involved comparing measured reverberation time data from real world tests, with the calculated reverberation results from the virtual chamber in Odeon.

2. REASON FOR THE INVESTIGATION

Vertically hung baffles are becoming more commonly used to introduce acoustic absorption in modern spaces. Many building fit-outs now prefer that the underside of the structural slab is exposed. This can be purely for aesthetic reasons, but it may also be as a result of a passive chilled beam systems, which requires the slab to be exposed to provide cooling.

Some suppliers of baffle systems have tested a number of configurations of baffles, with varied spacing, depth of panel and hang distance below the slab. However, it is not possible to cover all combinations, and suppliers will tend towards presenting data for configurations with a small spacing gap, as these tend to provide better absorption. In reality, the design often requires a wider spacing to accommodate other elements such as lighting, mechanical services, and the architectural aesthetic.

The intention is to develop a method of calculating absorption performance of a full range of baffle systems without requiring a real world lab test.

3. CALIBRATING AN EMPTY REVERBERATION CHAMBER

The initial part of the investigation was to create virtual model of an existing reverberation chamber. Chamber A at the University of Auckland Acoustic Testing Service was chosen. It is the chamber most commonly used for ISO 354 tests in New Zealand.

The absorption coefficients of the chamber surfaces were adjusted to calibrate the virtual reverberation chamber with measured 'empty' reverberation time results. The other variables in this process, besides the absorption of the chamber surfaces, were the air absorption in the chamber and the calculation settings in the Odeon software.

3.1 Chamber physical properties

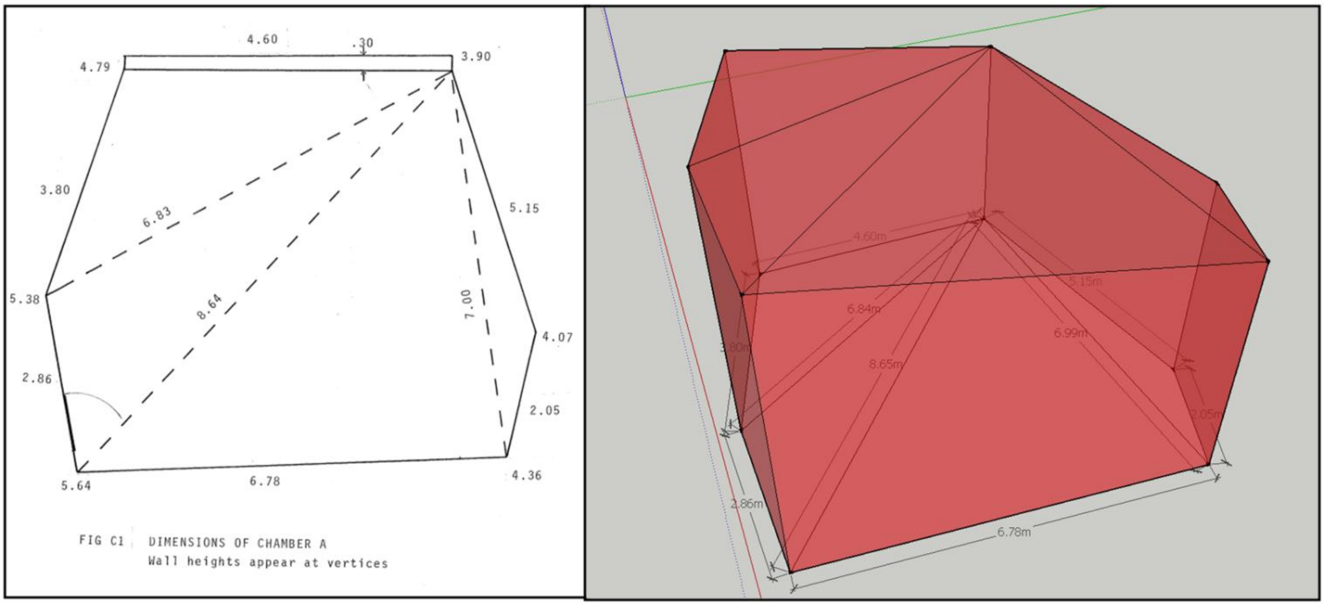

Figure 1: Chamber A dimensions and 3D Sketchup model

The surfaces of the chamber consist of painted concrete and a heavy steel door. For the purposes of this exercise, the same absorption coefficient was assumed across all interior surfaces. The sound source in Chamber A is two loud speakers mounted from the roof and oriented to the upper corners. The reverberation chamber includes a rotating diffuser suspended in the centre (shown in Figure 2) to reduce low frequency room modes and provide a more reliable diffuse field. It was decided not to include this in the virtual chamber, but to use an omnidirectional sound source and the calculation set up in Odeon to model a diffuse field.

Figure 2: Chamber A with suspended diffusing cone

3.2 Air absorption

Variation in air absorption in the chamber is a function of changes in temperature and humidity. The effect of air absorption is frequency dependent and affects higher frequencies to a greater extent (ISO 9613-1:1993). In a space such as a reverberation chamber, where there is very little absorption from other materials, air absorption is a significant factor.

Odeon includes temperature and humidity inputs in the calculation set up. The calculation settings information in the Odeon help menu states that air absorption is calculated according to ISO 9613-1:1993.

The calculations used to calibrate the model included the same temperature (15° C) and relative humidity (65%) as reported for the real world measurements of the empty chamber reverberation time. Once calibrated, the temperature and humidity was changed in the calculation set up to match another real world measurement (22° C and 57% humidity). Figure 3 shows that the reverberation time of the virtual chamber does not match the real world measurement of the empty chamber after the change in temperature and humidity had been made.

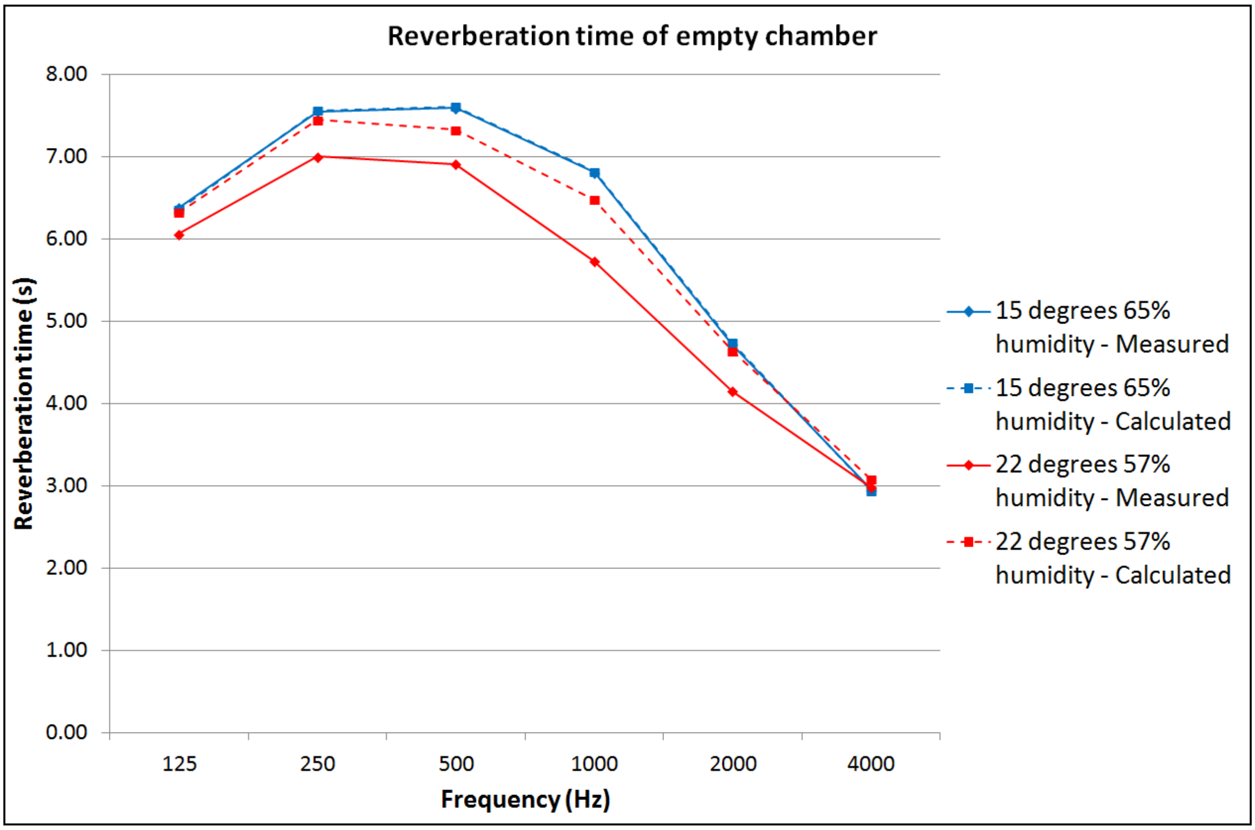

Figure 3: Reverberation time of empty chamber for difference temperature and humidity

The measured (real world) results were compared with other empirical data of air absorption to see if it was consistent. Table 1 shows the expected air absorption from ISO 9613-1:1993 for the two sets of conditions. The anticipated change for 125 Hz is negligible and in fact shows that air absorption should reduce (and therefore result in a higher reverberation time). This does not match with the measured results for the corresponding conditions.

Table 1: Air absorption for temperature and humidity conditions (ISO 9613-1:1993)

Condition	Air absorption dB/km					
	125	250	500	1k	2k	4k
22° C / 57% humidity	0.38	1.25	2.97	5.16	9.55	25.09
15° C / 65% humidity	0.40	1.16	2.34	4.06	9.07	28.16
Difference	-0.02	0.09	0.63	1.10	0.48	-3.07

There is another method for calculating the expected change in reverberation time due to a change in temperature and humidity (Harris, 1966). This method uses decay rates for different conditions, gathered empirically in a room test. It predicts a reduction in reverberation time at 2kHz of 0.03 s, as opposed to the measured change of 0.49 s.

This suggests that the calculation algorithm used by Odeon may not adequately deal with air absorption in an extreme acoustic environment such as a reverberation chamber. It is noted that this exercise used only two sets of conditions. Further investigation would be required to fully understand the limitations of the software in this regard.

As this was not the intended subject of investigation, it was decided to recalibrate the empty chamber to each set of temperature and humidity conditions by altering the surfaces' absorption coefficients, before investigating absorption of products introduced to the chamber.

3.3 Calculation settings

Along with the test/model conditions, the calculation settings offered another variable. Odeon offers many options for controlling how a calculation is run. On a basic level, the set up allows control over the level of precision in a calculation based on how many ray traces it performs in the room. On a more detailed level, it allows control over the type of scattering and how early on in the ray tracing process scattering is applied.

To better represent a fully diffuse field, a high level of scatter was applied to the surfaces of the reverberation chamber and the transition order (point at which the software moves from specular reflections to more diffuse methods) was set to zero. As a cross-check, calculations were run using a high transition order and minimal scattering. The results of the diffuse method better represented the real world results so those settings were adopted.

4. BAFFLE CONFIGURATIONS

4.1 Test data

The investigation of baffle array absorption was based on a set of tests conducted in Chamber A using Autex Cube 12mm thick polyester panels. A series of tests were conducted using these panels as vertically mounted baffles. The tests included panels of 200mm, 300mm and 600mm height, spaced at various distances. Two sets of tests were conducted;

- Standing vertically without the surrounding barrier, identified as 'as installed', and
- Panels mounted with a surrounding barrier (in accordance with the Type J mounting procedure from ISO 354:2003, *Acoustics – Measurement of sound absorption in a reverberation room*), identified as 'J mount'

Figure 4 and Figure 5 show examples of the modelled configurations.

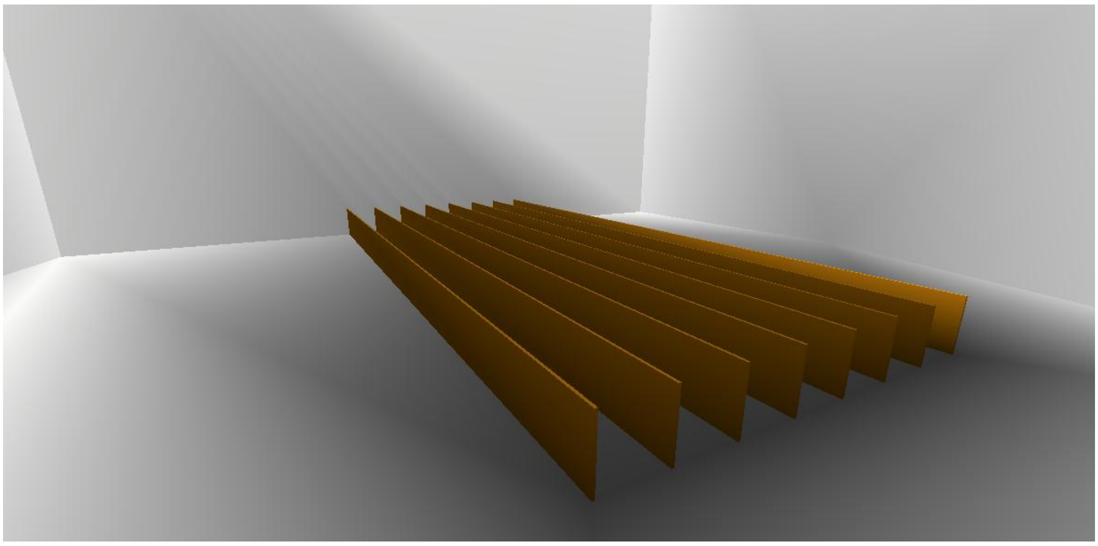

Figure 4: 'as installed' configuration

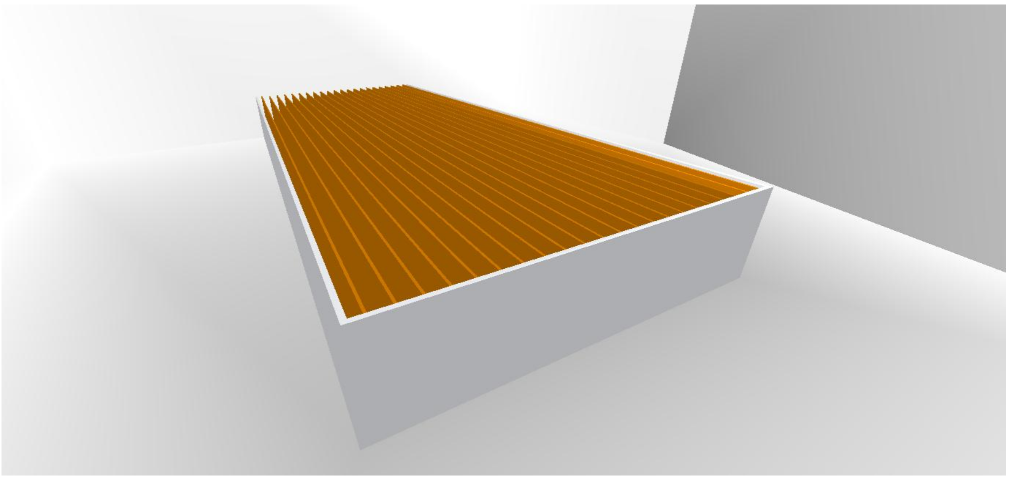

Figure 5: ‘J mount’ configuration

The ‘J mount’ configuration minimises absorption from the sides of the outer panels. However, the perimeter walls are not high enough to remove the “edge effect” from absorptive surfaces (Kawakami & Sakai, 1998). The edge effect refers to additional absorption that occurs at the edge of an absorptive panel. In the area near the edge of a panel sound appears to be ‘sucked’ towards the absorption material. This effect can give rise to absorption coefficients with values higher than 1.

The ray tracing function of Odeon does not account for this effect. Discrepancies as a result of the edge effect may be magnified by an array such as this, which involves significant lengths of panel edges. Testing in a deeper well would minimise the edge effect at the perimeter of the sample. However, it may not reduce the effect at top edges of the panels in the centre of the array. Data for a deep well configuration was not available for this study.

Comparing measurement data of the same panel height and spacing, with and without the barrier shows that there is a noticeable difference in the reverberation time. Figure 6 shows the reverberation time measurements for 300mm high panels spaced at 300mm and 200mm.

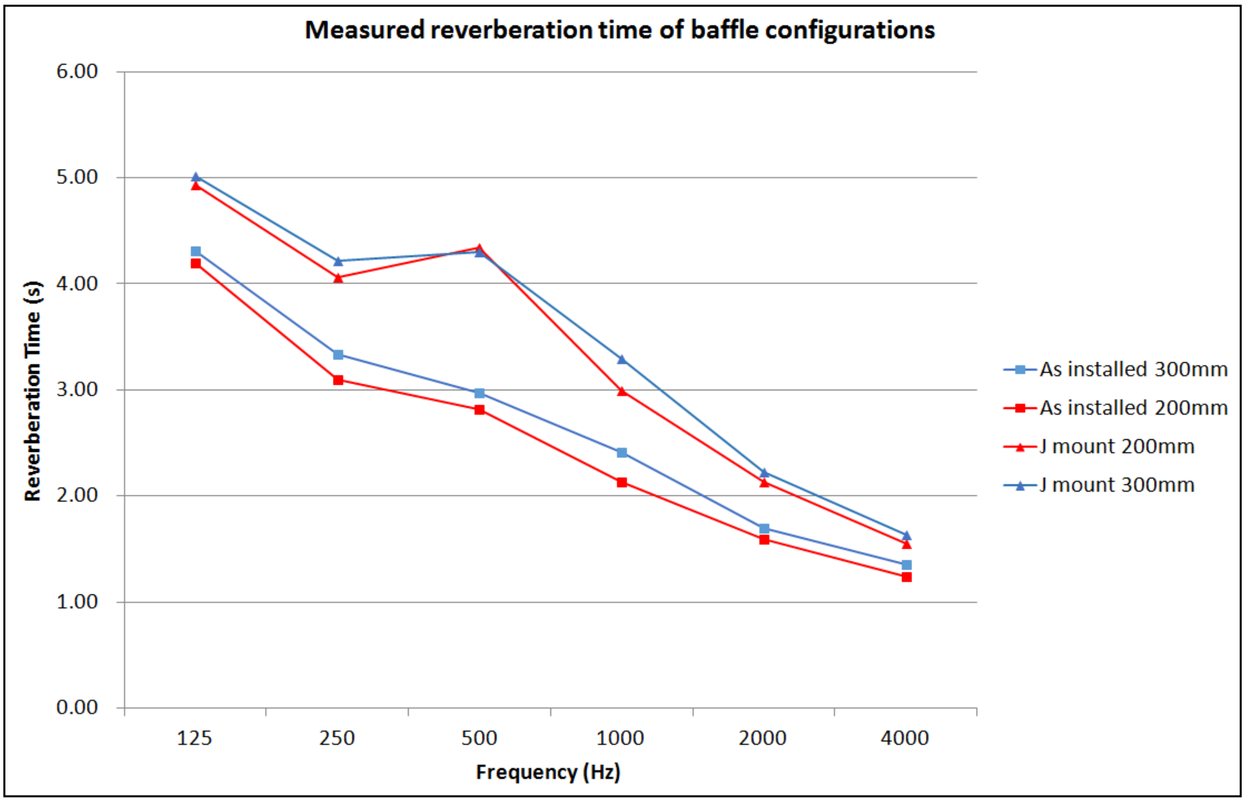

Figure 6: Measured reverberation time of ‘as installed’ and ‘J mount’ configurations

The reverberation time in the ‘J mount’ configuration is 1.3-1.5s higher at 500 Hz than the ‘as installed’ configuration. This raises an interesting question about which method is most appropriate for representing the absorption performance of these type of products in real world scenarios.

4.2 Modelling configurations

To model the baffle configurations, an absorption coefficient must be applied to the surfaces of the baffles in the model. Previous tests of the Autex Cube product have been conducted when mounted directly against the chamber floor or with a 25mm gap. This is useful for situations where the product is installed as a wall panel. However, neither of these results would represent the performance of a free standing (or suspended) panel.

Ideally, test of a single fin of the panel would be used to determine the absorption coefficient when not installed against a wall. As this data was not available, the absorption performance of the 12mm panels in a vertical configuration was determined by adjusting the absorption performance of the panels until the calculated reverberation time matched the measured reverberation time of the ‘as installed‘ 300mm spacing configuration.

Using this panel absorption calculations of ‘as installed‘ 200mm and 100mm spacing were compared to the measured results. Figures 7 and 8 show the measured and calculated reverberation times plotted together. The model results match the measured reverberation time reasonably well, particularly around 1kHz and 2kHz.

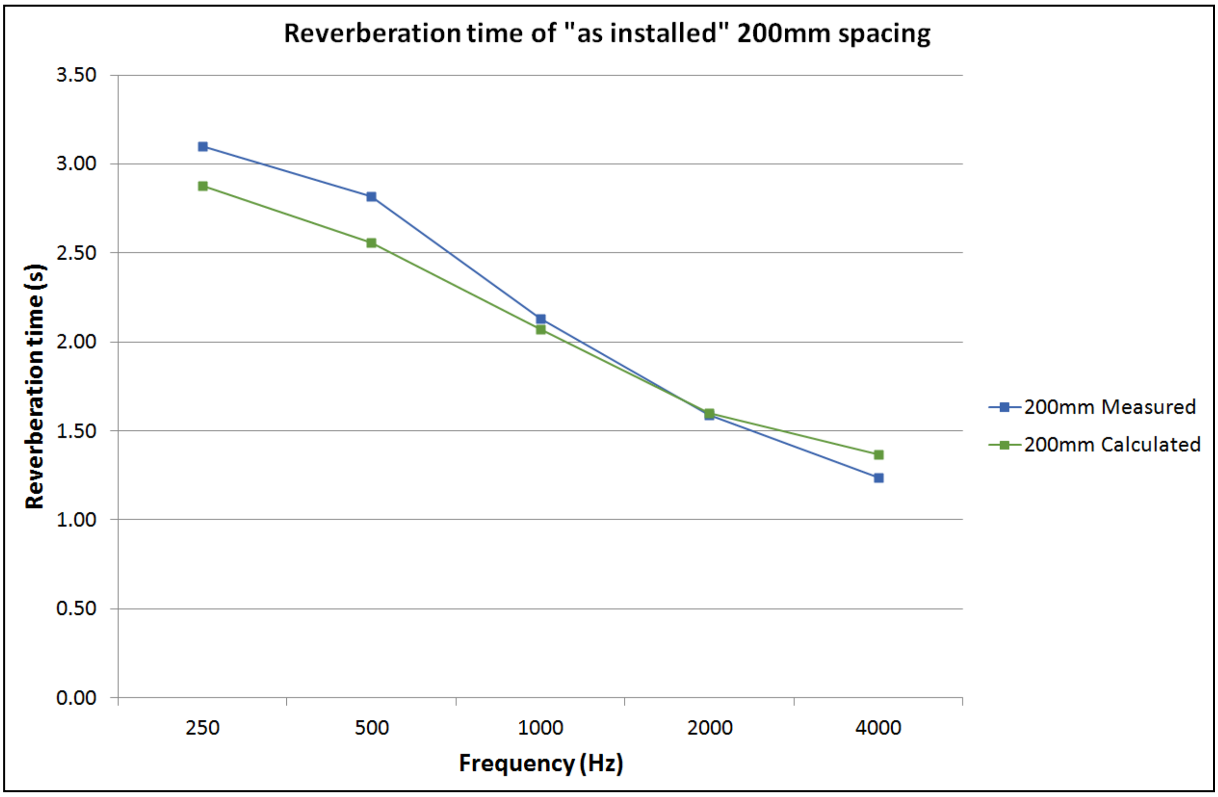

Figure 7: Comparison of measured and modeled ‘as installed’ 200mm spacing

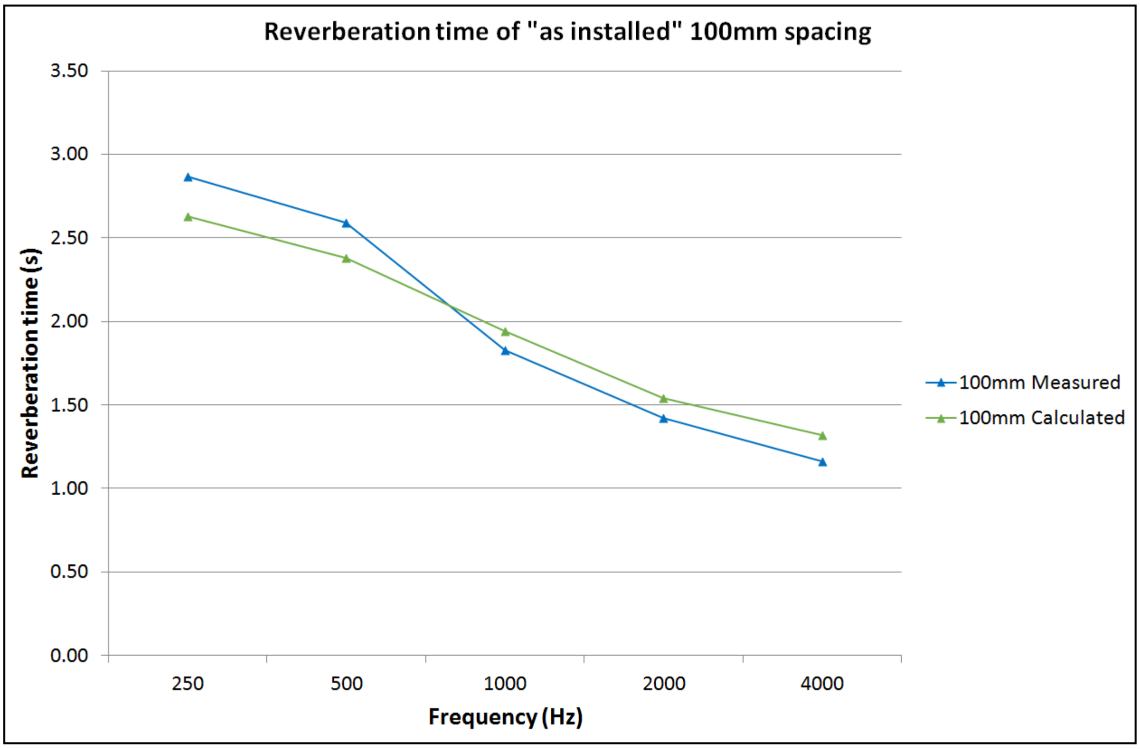

Figure 8: Comparison of measured and modeled ‘as installed’ 100mm spacing

Figures 9-13 show that the calculations for the ‘J mount’ configurations did not correlate as well. The main discrepancies are at 250 Hz and 500 Hz. These are the same frequencies where the measured results for ‘as installed‘ and ‘J mount’ differed (see Figure 6). The absorption performance of the panel had been calibrated to the ‘as installed‘ configuration and it appears that the modelling process is not able to replicate the effect that the barrier around the panels creates in the real reverberation chamber. The higher frequencies generally correlate well.

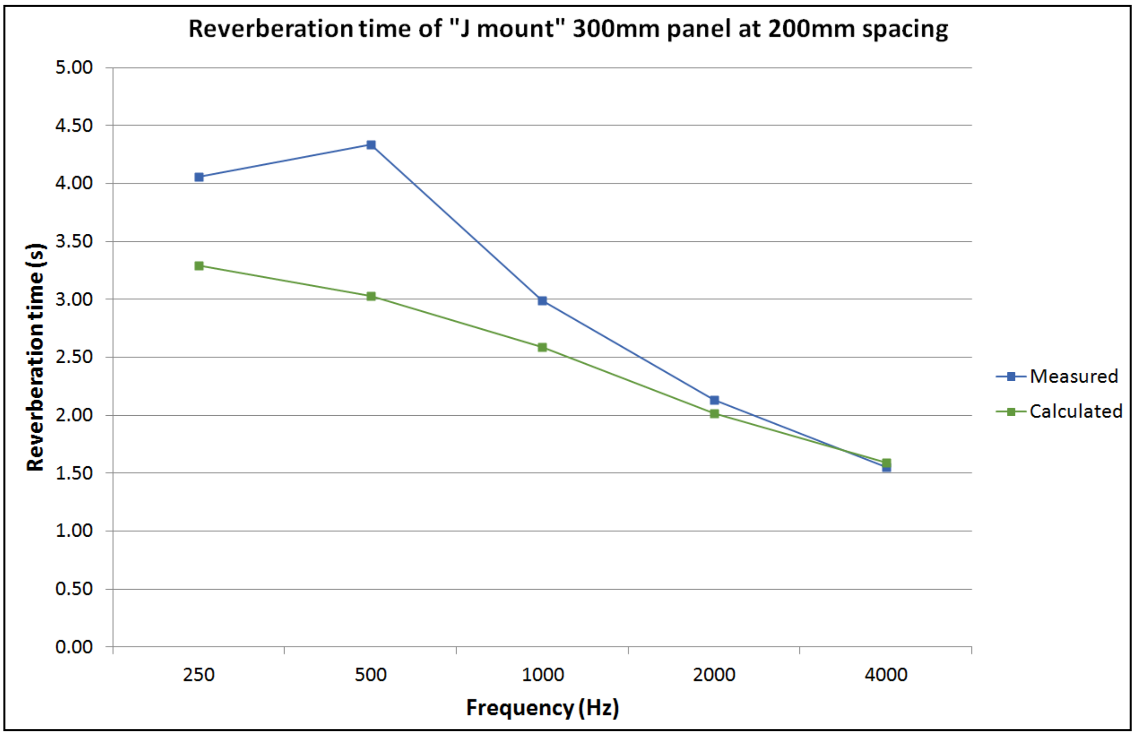

Figure 9: Comparison of measured and modeled ‘J mount’ 300mm panel at 200mm spacing

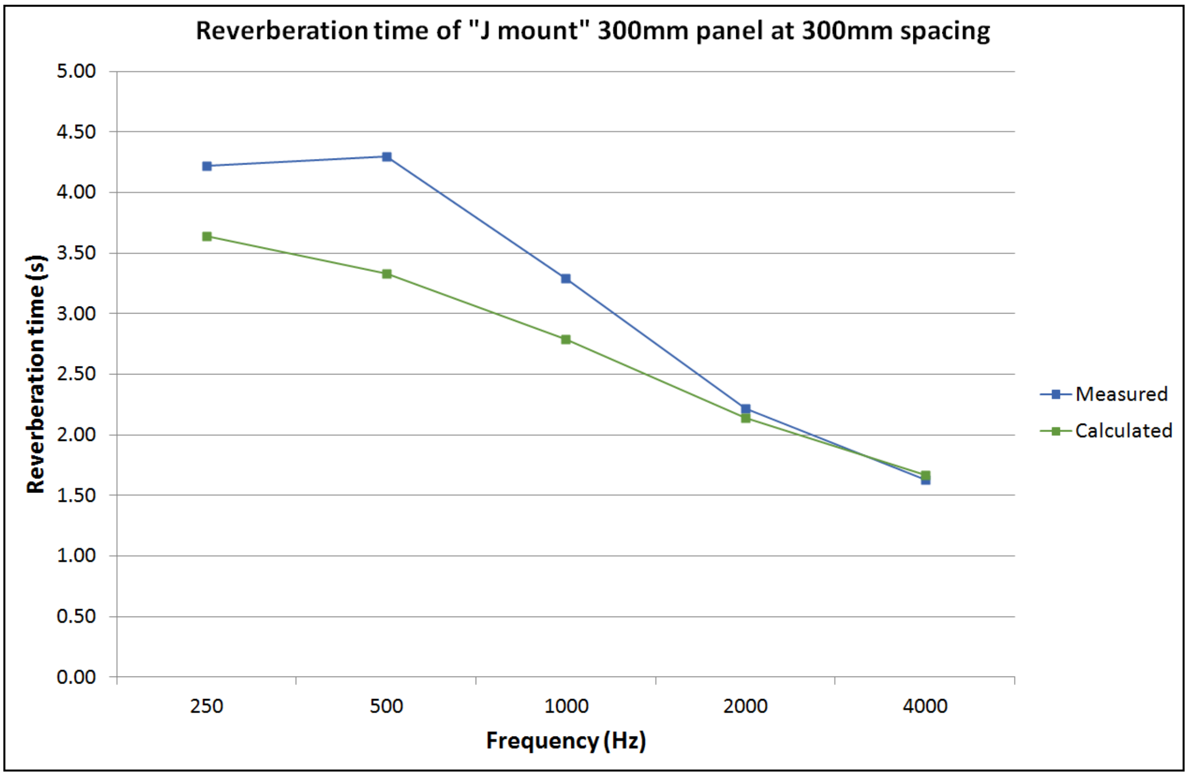

Table 10: Comparison of measured and modeled ‘J mount’ 300mm panel at 300mm spacing

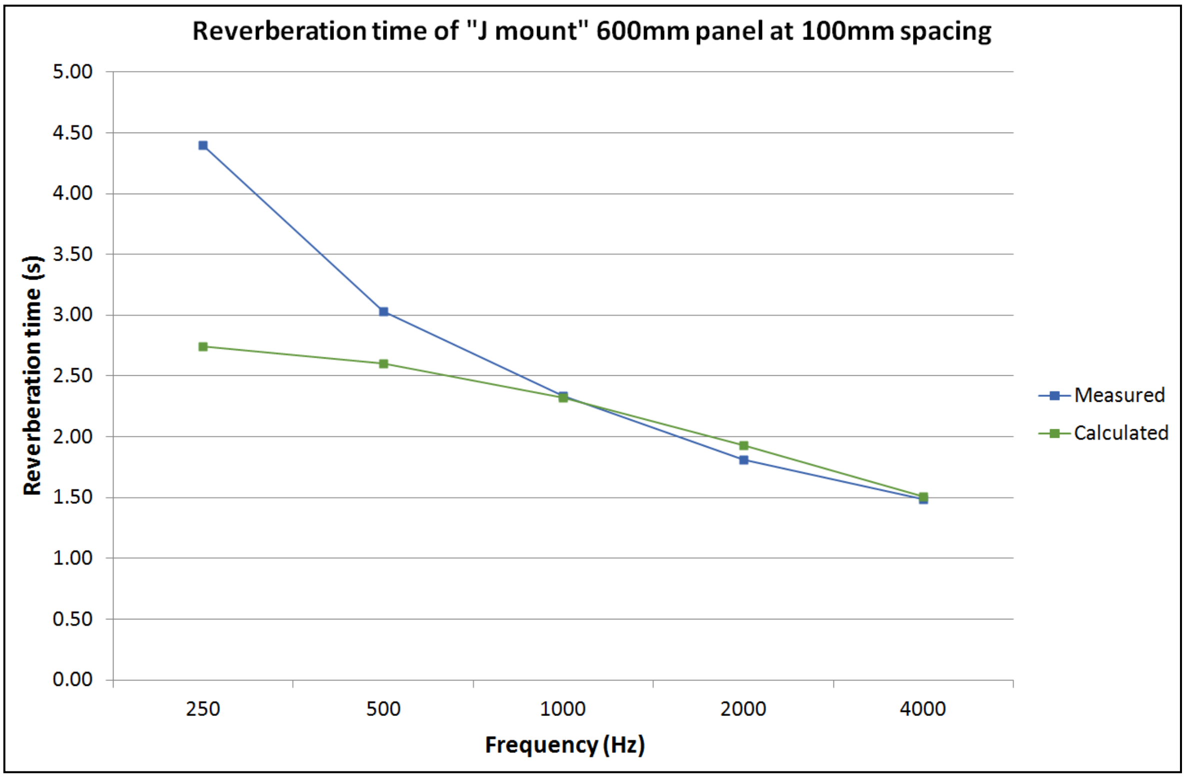

Table 11: Comparison of measured and modeled ‘J mount’ 600mm panel at 100mm spacing

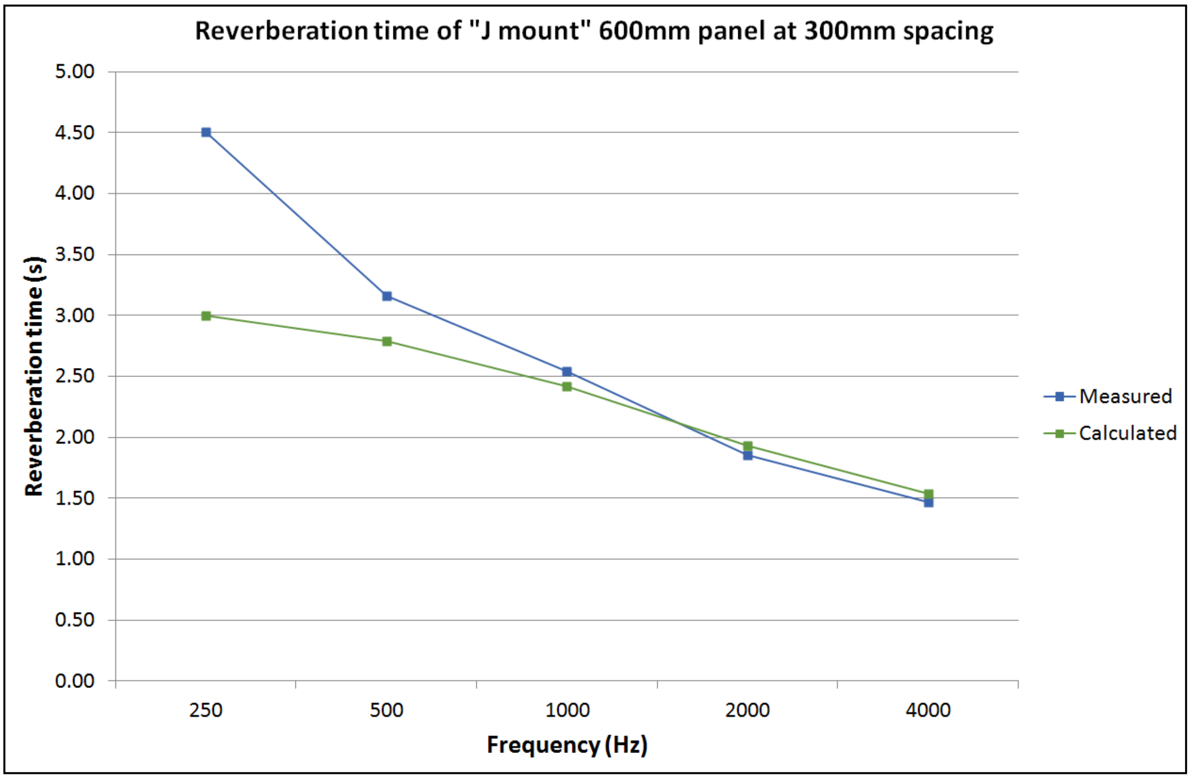

Table 12: Comparison of measured and modeled ‘J mount’ 600mm panel at 300mm spacing

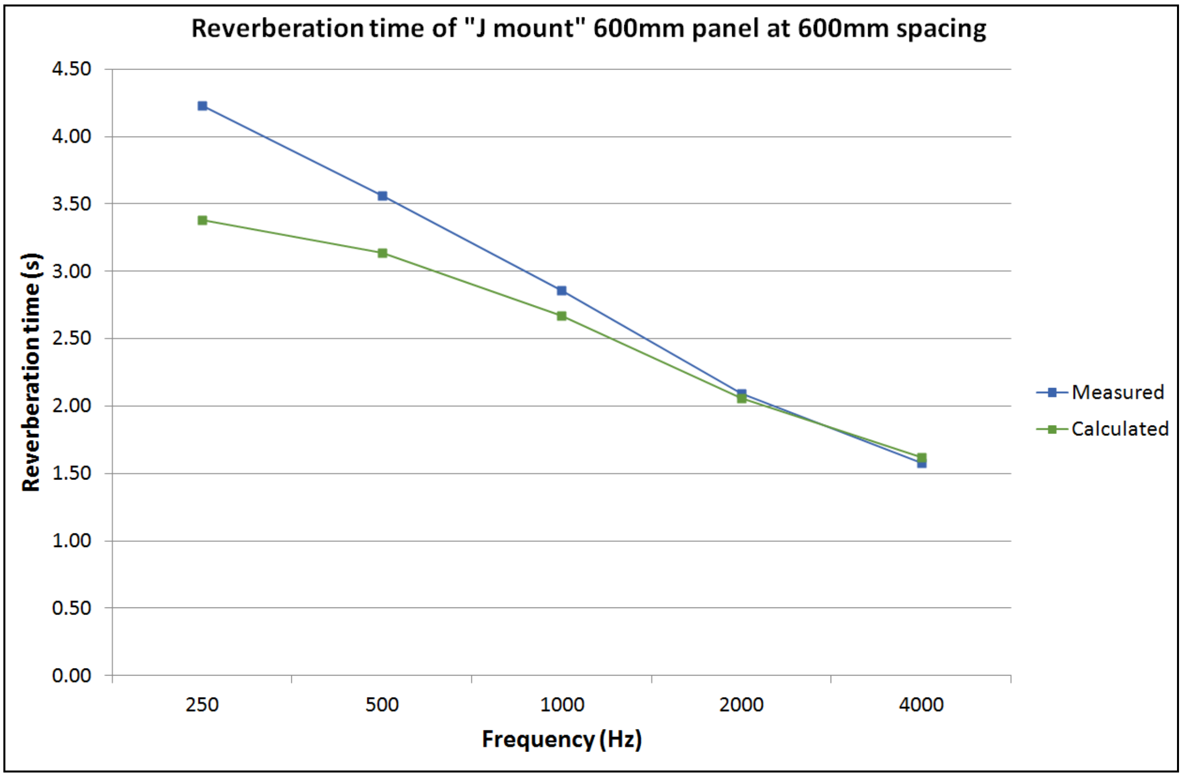

Table 13: Comparison of measured and modeled ‘J mount’ 600mm panel at 600mm spacing

5. CONCLUSIONS

The modeling exercise indicates that a virtual reverberation chamber can provide an approximation of the absorption performance of baffle configurations at mid to high frequencies (1kHz-4kHz). Due to the discrepancies between real world and predicted effects of air absorption in the chamber, each empty chamber scenario must be calibrated to real world a test condition. This requirement is not an issue, provided test data for at least one configuration is available.

There is a significant difference in the absorption performance of baffles depending on the mounting method used. Much of the test data for baffle products is presented based on the J mount method, as this is the method described in ISO 354:2003. The J mount method removes side absorption but not the edge effect at the perimeter of the sample. Discrepancies between measured and modelled results may be partly due to Odeon's inability to model this effect.

It is possible that tests conducted in a deeper well would minimise the discrepancies by removing more of the edge effect from real world tests. However, this would not represent the average absorption performance achieved in a real world application, where the edge effect would offer additional absorption.

The virtual chamber does not accurately reproduce the effect of enclosing the baffles with a barrier (J mount). Therefore, calibrating the panel absorption coefficient using the same mounting method as the real world application will provide a more accurate approximation.

ACKNOWLEDGEMENTS

Thank you to Jonathan Mountfort of Autex for providing full test data of Autex Cube for analysis.

REFERENCES

Harris, CM 1966, *Absorption of sound in air,* The Journal of the Acoustical Society of America, Volume 40 No.1

International Organization for Standardization 2003, *Acoustics – Measurement of sound absorption in a reverberation room*, ISO 354:2003, International Organization for Standardization, Geneva.

International Organization for Standardization 1993, *Acoustics – Attenuation of sound during propagation outdoors- Part 1: Calculation of the absorption of sound by the atmosphere*, ISO 9613-1:1993, International Organization for Standardization, Geneva.

Kawakami, F & Sakai, T 1998, *Deep-well approach for cancelling the edge effect in random incident absorption measurement,* The Journal of the Acoustical Society of Japan, (E) 19, 5 1998