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ACOUSTIC MODELLING AND TESTING OF A MUSIC REHEARSAL FACILITY

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1 INTRODUCTION

Specialist acoustic modelling software has been utilised for a number of years in the design of auditoria and similar facilities. The use of such software is now expanding as a result of the reduction in the relative costs of software and computer processing power.

The imminent redrafting of the touchstone educational design document; BB93: *Acoustic Design of Schools – A design guide*[1] is likely to recommend proving STI (speech transmission index) and other parameters using modeling software at the design stage. The applications for such modelling are therefore expanding further, and will become more important in a variety of projects in the future.

In order to examine the effectiveness of such approaches, modelling was carried out for the acoustic design of a new music facility. The efficacy of the model was then assessed following pre-completion testing. The full analysis is ongoing, therefore this paper forms an interim report into the project.

2 PROJECT BRIEF

The chosen project was a new, purpose-built rehearsal and recording room for a military band. The room under investigation was proposed to be around 2000 m^3 in volume, with a raked stage area for musicians to perform on, and a flat floored area for the band leader. The client had a detailed vision of what was required in terms of acoustic qualities.

The existing facility, which was to be replaced, was benchmarked in terms of acoustic qualities, and a suitable specification produced for the new facility. The intention was to retain the favourable characteristics of the existing facility, and improve on those qualities that were deemed unsatisfactory.

These requirements produced a complex set of design aims for the new room, in terms of acoustic performance. Given the large dimensions of the room it was important to minimise long path reflections, as well as producing as diffuse field behind the musicians with an absorbent field behind the conductor, to approximate a concert hall with audience.

There was a need to retain clarity and good speech transmission, a balance between diffusion and directivity in the space, and control the overall reverberation time. The reverberation time was to be in the order of 0.9-1.3 seconds at mid frequencies with uplift at lower frequencies and overall a smooth spectrum shape. In addition diffusion was required to control undesirable room responses, and there was a requirement to provide flexibility in terms of sound absorption. These multiple considerations made modelling the practical option for developing the acoustic design of the facility.

Modelling would be particularly useful in determining the coverage, type and positioning of diffuser elements in the room, and could be used to identify and counter long path reflections. These long path reflections could be examined for a variety of source and receiver positions, ensuring that all users of the room would experience good acoustic conditions in use. Furthermore auralisation would allow a subjective impression of the different possible configurations of absorption to be garnered.

3 MODELLING

The acoustic modelling was carried out using *CATT Acoustic*[2] software. *CATT* can be considered as one of the established modelling packages, along with those such as *Odeon*[3] and *Ease*[4]. The *CATT* software utilises a ray tracing based method, allowing a three dimensional model of the room under consideration to be imported from a CAD program, e.g. *Google Sketchup*[5], or created directly in *CATT*. In order to produce a working model quickly, the architectural drawings were used to produce a scale model in *Google Sketchup*.

Once an accurate model has been created, material properties, in terms of absorption and scattering coefficients can be defined for the different surfaces, along with source and receiver characteristics and locations within the space. Calculations can then be performed using the software, to examine room responses for a wide range of parameters.

This allows for fast, efficient modifications to materials, areas of treatment and treatment locations to be made, and the resultant changes to the room characteristics to be examined. Thus enabling the acoustic design to be changed dynamically and developed quickly.

The room was modelled for sources in a variety of positions, as the musicians could be sited at any position on the tiered staging, and for a variety of receiver positions, reflecting the location of the band leader, microphones, other musicians and the like. The source and receiver positions were as per the methodology of BS EN ISO 3382-1:2009 *Acoustics-Measurement of room acoustic parameters Part 1: Performance spaces*[6], and are shown in Figure 1.

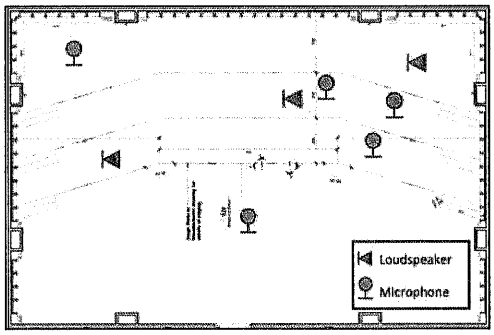

Figure 1 – The Source and receiver positions used for modeling and measurements, in accordance with BS EN ISO 3382-1:2009.

The acoustic design developed using the model, is shown in Figure 2.

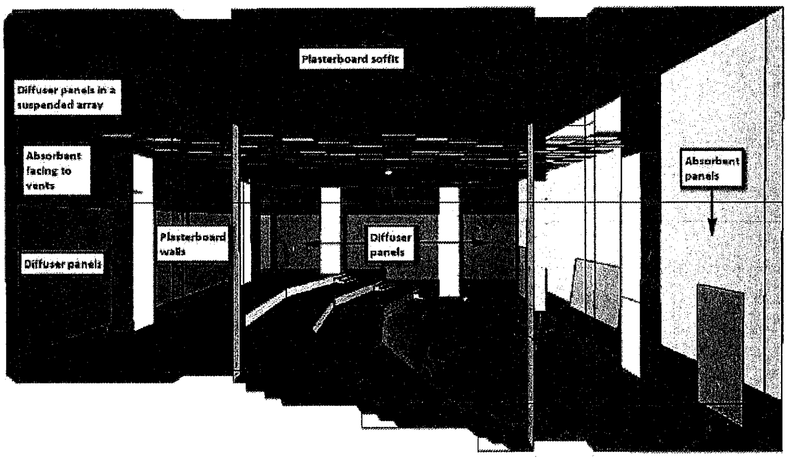

Figure 2 – Image of the *CATT Acoustic* model, complete with annotation showing the main features of the acoustic design

The final design was based on the following strategy[7]:
Absorbent panels with high absorption coefficients were located on the front wall (behind the band leader) to control long path reflections, similar panels were placed on the vent risers.
The side and rear walls (behind the musicians) were divided laterally at a mid point, to the lower section diffusive elements were used to ensure an even distribution of sound throughout the staging area, to the upper section the walls were plasterboard to provide an acoustically reflective finish.

There was a requirement to incorporate variation in the reverberation time, to allow for different uses of the facility. The most cost effective method for providing this was to use heavy curtains which could be drawn over the plasterboard upper wall areas, and also separately, curtains to cover the lower diffuser panels. This gave four room treatment configurations and was deemed a viable solution.

The soffit was a plasterboard finish, with a lay in grid ceiling beneath. The suspended ceiling was 50% open area and the tiles were a diffusive type. The option of a suspended ceiling with full coverage of diffuser tiles was modeled, as part of the value engineering process it was found that 50% coverage was sufficient to provide good diffusion in the room.

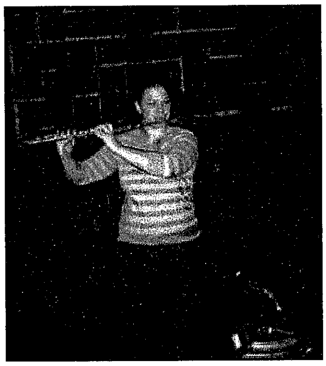

Figure 3 – Recording audio for auralisation in the LSBU Anechoic Chamber

The *CATT* software allows for full auralisation to be carried out, anechoic recordings were made of a musician playing short flute and clarinet passages in the full anechoic chamber at LSBU.

These anechoic recordings were then used to subjectively appraise the various room absorption configurations that were proposed.

4 TESTING

As part of the pre-completion testing of the facility, reverberation time measurements were carried out, which enabled the same parameters as those modelled using the *CATT* software to be measured.

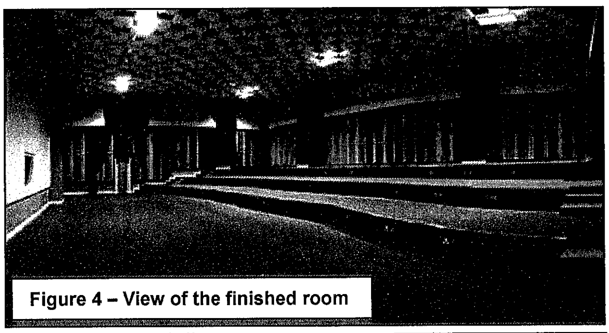

Figure 4 – View of the finished room

The measurements were carried out using a *WinMLS*[8] system and an omni-directional source. The measurements were carried out in accordance with BS EN ISO 3382-1:2009, the source and receiver locations being the same as those used in the modelling process (see Figure 1), to enable direct comparison. The test system allowed a variety of parameters to be measured including T20, T30, D50, C50 and C80.The measurements were repeated in all four states of variable absorption, in an unoccupied condition. Subjectively the room was very even in terms of sound diffusion, with no perceivable focusing or cancellation effects.

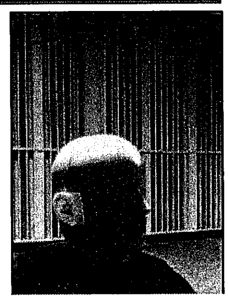

Figure 5 – Recording using the Binaural Head

The finished room is shown in Figure 4, the diffuser tiles to the lay in grid, and wall mounted diffuser arrays can be seen.

Recordings were also undertaken using a binaural head, shown in Figure 5, and a directional loudspeaker, at source and receiver positions that had been auralised using the *CATT* software. The source audio for these recordings was that of the anechoic recordings made previously.

5 PRELIMINARY RESULTS

The full analysis of the results is still ongoing, however preliminary results have been produced and are included in Figure 6.

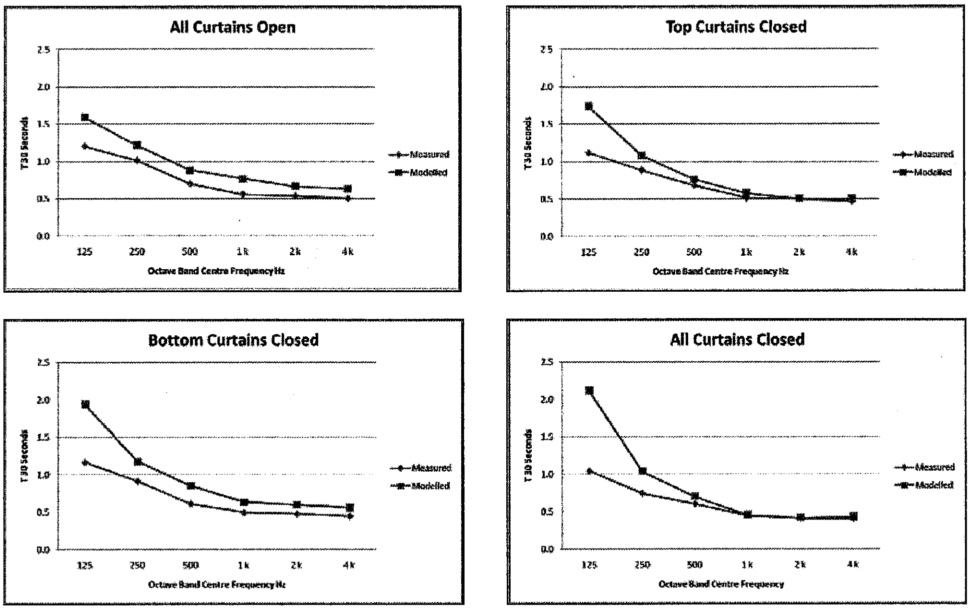

Figure 6 – Measured and modelled T30 values for the different room conditions

In all room configurations, the measured T30 reverberation times are marginally lower than those modelled, across the frequency range.

In terms of use of the space, a slightly shorter reverberation time can be accommodated, as additional reverberation can be added to the recorded signal, but cannot be removed if the room has a reverberation longer than the ideal.

The preliminary results indicate that additional sound absorption is present in the room compared with in the model, this is particularly the case at frequencies <500 Hz. At higher frequencies, in the conditions with some or all curtains closed, the difference between the modelled and measured T30 reduces, this indicates that additional low frequency absorption is present in the room.
There are a number of possible reasons for this;

There is extensive duct work within the room associated with the mechanical ventilation systems, this could be providing additional low frequency absorption, which was not allowed for in the model. The curtains, even when open, remain part of the surface finish of the room, whereas some area of curtaining was allowed for in the model to represent folded, open curtains, the absorption properties of curtains folded to this extent were not known, and therefore not accounted for in the model.
Similarly the absorbent properties of closed curtains with a gap between them and the diffuser panels were not known, and were not allowed for in the modelling process, though this would provide additional mid and high frequency absorption, rather than low frequency. Generic absorption coefficient data was used in the modelling for the carpet and plasterboard linings to the walls and soffit, the absorption performance for the carpet installed in the room, and the plasterboard construction as built may differ from those used in the modelling process.

6 CONCLUSIONS

The use of modelling in this project proved very useful in the development of the acoustic design, and allowed investigation of parameters that would be very difficult and time intensive to undertake by traditional means.

The modelling proved particularly invaluable in developing the treatment for long path reflections, with the ability to see the path that these delayed signals were taking and control them by treating the reflective or non-diffusive surfaces.

With all computer systems, the results are dependent on the data inputted by the user, and acoustic modelling is no exception to this rule. In this case the modelled performance of the space was marginally different to that measured in the actual hall. As discussed there are a number of factors that may have contributed to this variation, further analysis is required to confirm this.

The project required a balance to be struck between providing sufficient absorption to the wall behind the conductor to control reflections, introducing sufficient diffusive elements to produce a diffuse field for the musicians, and controlling the overall reverberation time.

The full processing and assessment of the results is still being undertaken, this paper forms a summary of the work and results to date.

7 REFERENCES

1 Department for Education and Skills. Building Bulletin 93 Acoustic Design of Schools - A Design Guide. London: The Stationary Office.

2 CATT Acoustic v8.0f available at http://www.catt.se

3 Details available at www.odeon.dk

4 Details available at http://www.easefocus.com

5 Google Sketchup v7 available at http://sketchup.google.com/index.html

6 The British Standards Institution EN ISO 3382-1:2009 Acoustics – Measurement of room acoustic parameters Part 1: Performance spaces.

7 Supervised by Dr. Rory Sullivan, Sharps Redmore Partnership.

8 WinMLS 2004 acoustics measurement software by Morset Sound Development, details available at http://www.winmls.com.