Predicting the performance of hanging baffles in large swimming pools

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ABSTRACT

The need for internal acoustic treatment to public spaces such as swimming pools are becoming a common practice with the increasing need for acoustic comfort from the general public. Selection of acoustic material will need to be based on the acoustic properties, ease of installation, resistant to corrosion and heavy duty. This paper presents the performance of the installed hanging baffles and the limitations of modelling hanging baffles in a large swimming pool with the room modelling software EASE. The predicted reverberation time (RT) in the swimming pool modelling in EASE and the measured reverberation time (RT) post installation have been compared in order to determine the limitations of modelling hanging baffles in swimming pools.

1 INTRODUCTION

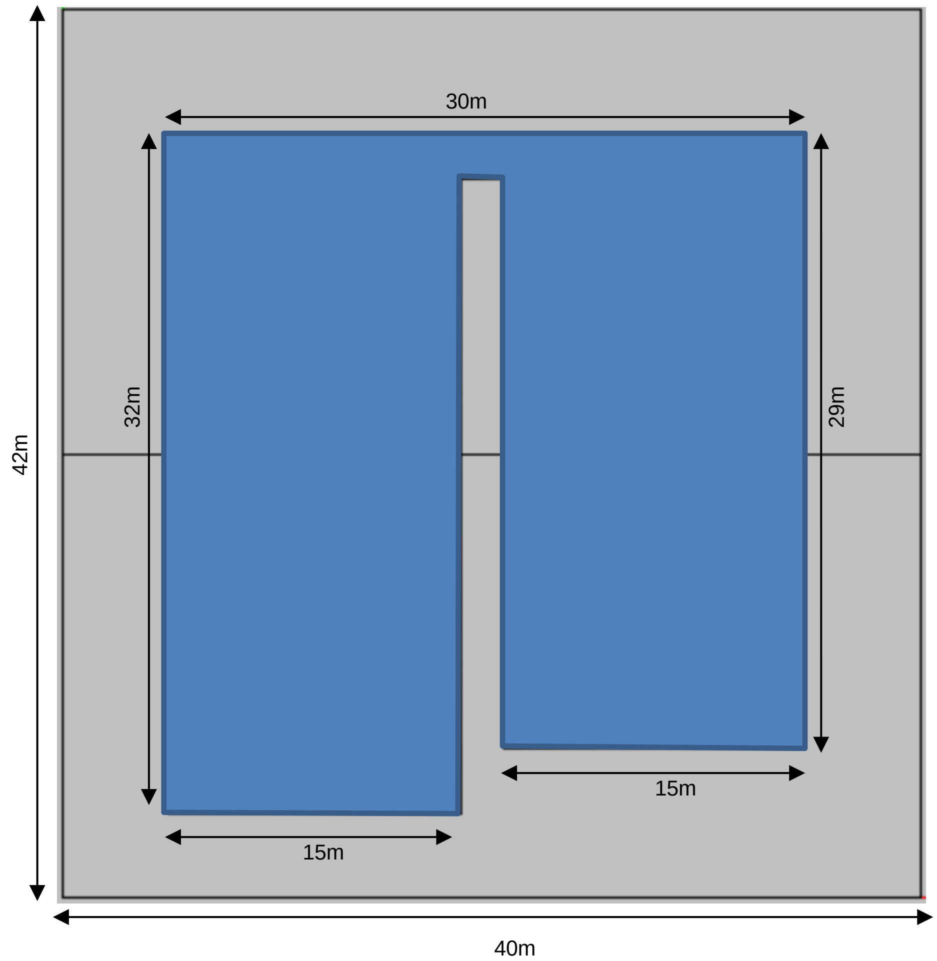
This paper presents the performance of hanging baffles and the software modelling conducted within a large public swimming pool. The need for this investigation arose from the requirements of our client, Wollondilly Leisure Centre, to acoustically treat their large swimming pool to reduce the reverberation times to acceptable levels.

The process for the investigation required modelling of the swimming pool to reasonably predict acceptable reverberation levels within the swimming pool, selection of appropriate materials and location of the acoustic materials. A decision to hang baffles was made as theoretically it would suggest that the hanging the baffles would absorb noise from two surfaces of the panel rather than one surface if the panels were stuck on the wall or ceiling.

In order to provide any treatment options or validate the performance of the hanging baffles, the swimming pool will need to be modelled. The use of the modelling software EASE was considered and utilised for the purposes of modelling the swimming pool using the Sabine calculation method.

2 THE SWIMMING POOL

The Swimming Pool is located at Wollongdilly Leisure Centre in New South Wales. The Swimming Pool is the larger internal swimming pool. The dimensions of the swimming pool complex presents as 40m x 42m with a height varying from 12-16m and consisting of 2 pools with surface areas of 480m^2 and 435m^2.



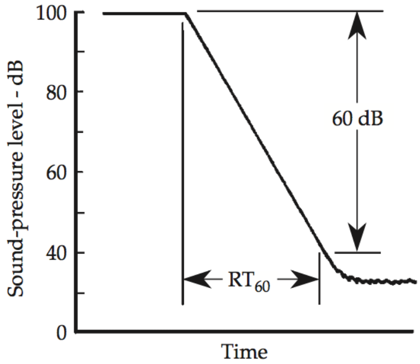
EASE Floorplan (RSA, 2017)
Figure 1: EASE Floorplan

The eastern wall of the swimming pool consists of glass doors and windows in the form of 6mm glass.

3 MEASURING EMPTY SPACE

Reverb testing was conducted on 2nd September 2016 while the swimming pool was empty. The purpose of the reverb testing was to measure the Reverberation Time (RT) of the swimming pool, determine the decay rate and use the data to identify the acoustic characteristic of the swimming pool.

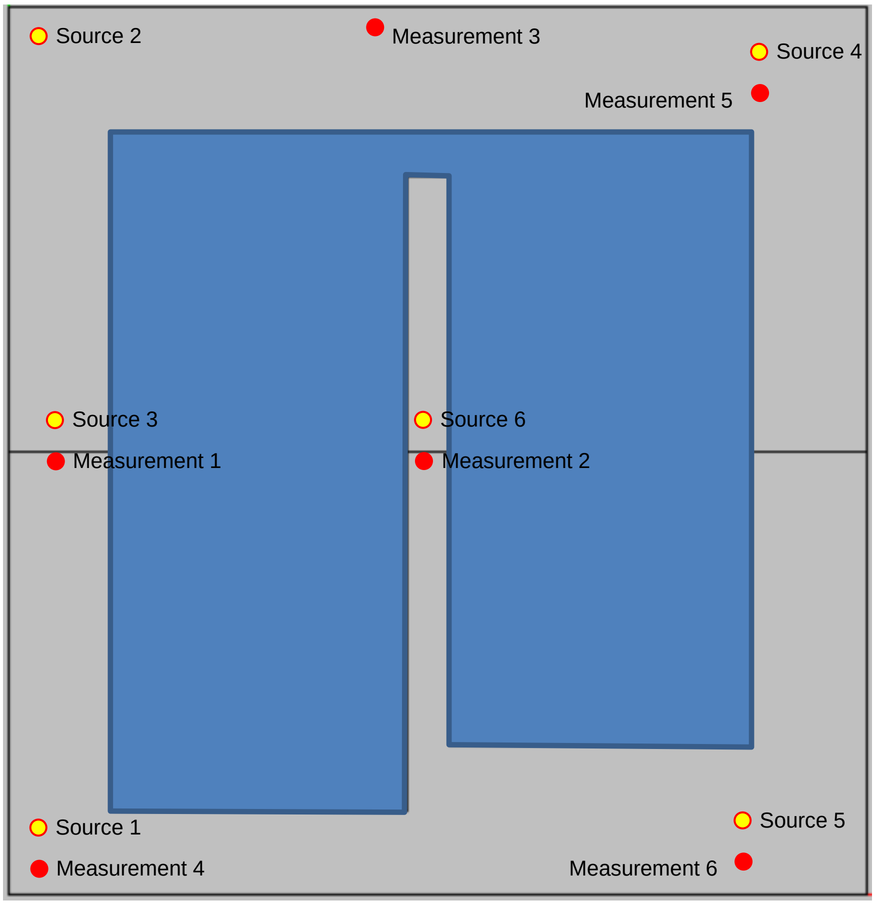
Reverberation Time (RT) is defined as the measure of the decay time from the direct sound and the time it takes for the sound intensity to decay by 60dB. 60dB has been used as this correlates to a loud sound decaying to inaudibility.



Master Handbook of Acoustics (F.Alton Everest & Ken C. Pohlmann, 2009)
Figure 2: Measuring Reverberation Time

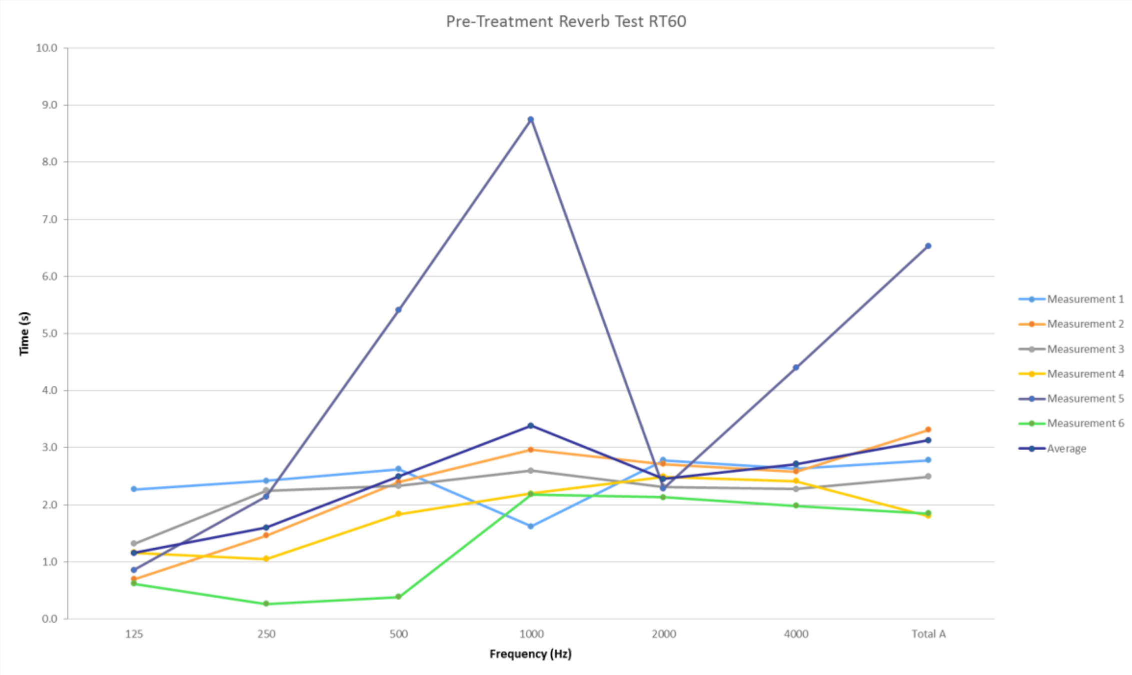
Figure 2 above illustrates the decay time for a sound source by 60dB. Factors influencing the measurement of reverberation time can include the sound source, the room dimensions and the background noise levels. For the purposes of the measurement at the swimming pool, the first 30dB of decay has been used rather than 60dB. Research within the Master Handbook of Acoustics and Room Acoustics concludes that 30dB of decay is the most important to the human ear. As the space is a large swimming pool, in practice, a 30dB of decay would be easier to measure without a notable margin of error.

The reverberation time measurements were conducted inside the swimming pool after the pool was closed. The noise included impulse noise in the form of balloon pop and the data was measured using a Svantek Model 979 Type I Sound Level Meter (serial number 34075). All equipment carried appropriate and current NATA (or manufacturer) calibration certificates.



Floorplan (RSA, 2017)
Figure 3: Pre-treatment reverb testing

The process for the included creating an impulse noise and measuring the decay at various locations as illustrated in Figure 3.



The graph above shows the results of the measured RT60 data in seconds. The overall average was calculated to be 3.1 seconds. Measured reverberation time at location "Measurement 5" shows a large decay time of 8.7 seconds at the 1kHz and 5.5seconds at the 500Hz Octave bands. This was due to the glass windows, doors and water being the reflective surfaces.

4 MODELLING IN EASE

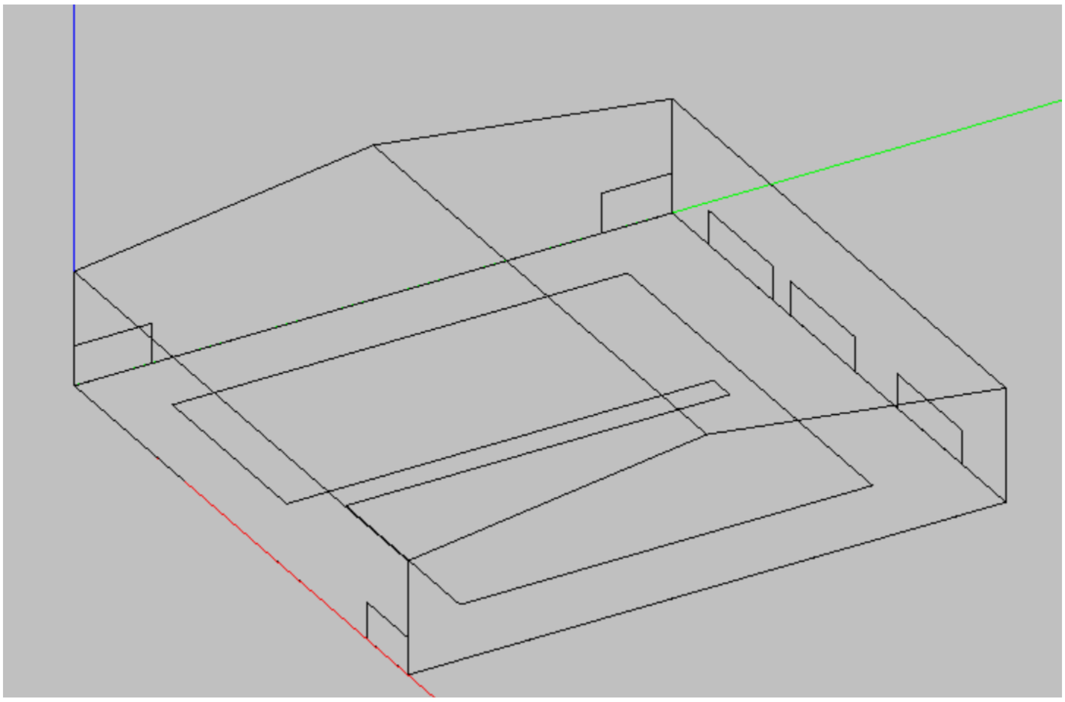
The initial step to model the swimming pool was to draw the swimming pool and detail the varying surfaces. Most of the surfaces had data available, for example, the tested data for concrete, glass and plasterboard. Absorptive coefficient for the water in the swimming was difficult to obtain as there is limited resources and the difficulty to accurately measure the absorptive coefficient of water in swimming pools which includes the varying depth of water and temperature. National Association of Broadcasters Engineering Handbook: NAB Engineering By Graham A. Jones, David H. Layer, Thomas G. Osenkowsky Section 3 page 430 provides tested data for Swimming Pools as tested to ASTM C 423.

Materials along with the absorptive coefficients used for the purposes of modelling are presented in table below.

Table 1: Absorptive Coefficient of materials

Material	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
Swimming Pool	0.01	0.01	0.01	0.01	0.02	0.02
Exposed Brickwork	0.05	0.04	0.02	0.04	0.05	0.05
Concrete	0.02	0.02	0.02	0.03	0.04	0.04
6mm Glass	0.10	0.08	0.04	0.03	0.02	0.02

Using the data in Table 1 and the physical dimensions of the swimming pool, EASE was able to simulate the swimming pool when empty using the Sabine calculation method.



Floorplan (RSA, 2017)
Figure 3: Pre-treatment EASE modelling

Sabine equation for determining the reverberation time RT60 considers the absorption contributed by each surfaces. Sabine approach looks at the absorption coefficient of each surface area, total surface area of the room and the volume of the room. Sabine's equation for RT60 in a room can be expressed as:

$$RT_{60} = \frac{0.161V}{A} \tag{1}$$

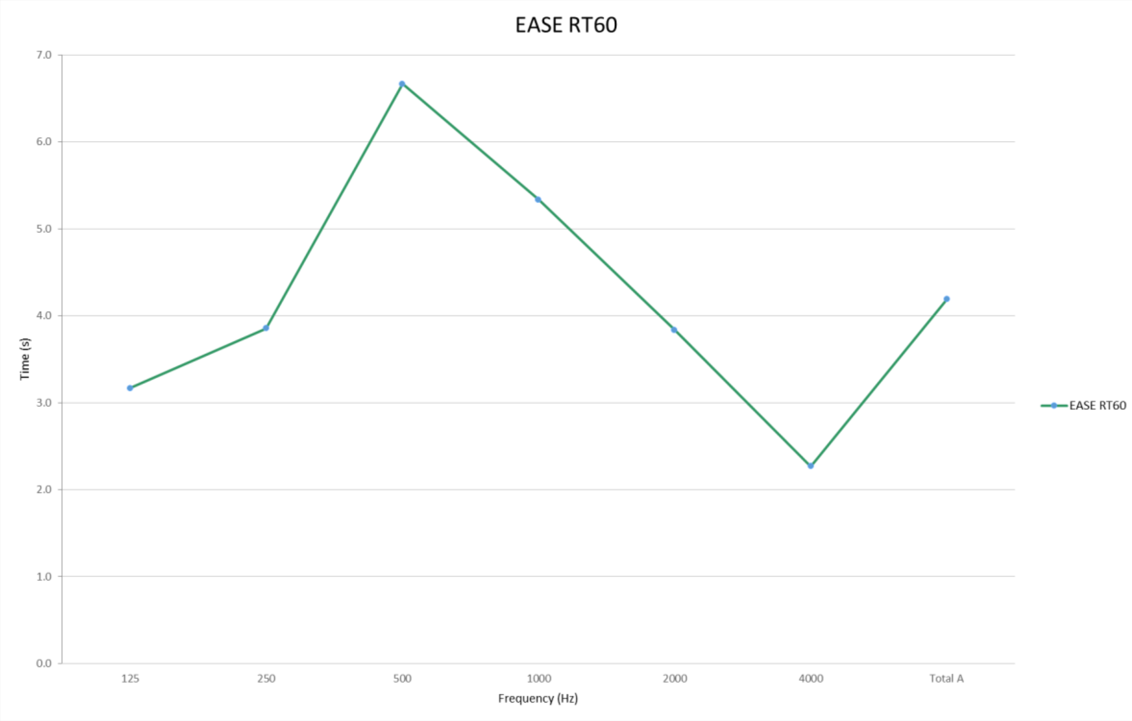
Where RT_{60} = reverberation time (s)
V = volume of room (m^3)
A = total absorption of room (sabins)

The simulated reverberation time as modelled in EASE is presented below. The results have been adjusted to present as 60dB decay to compare with the measured results.

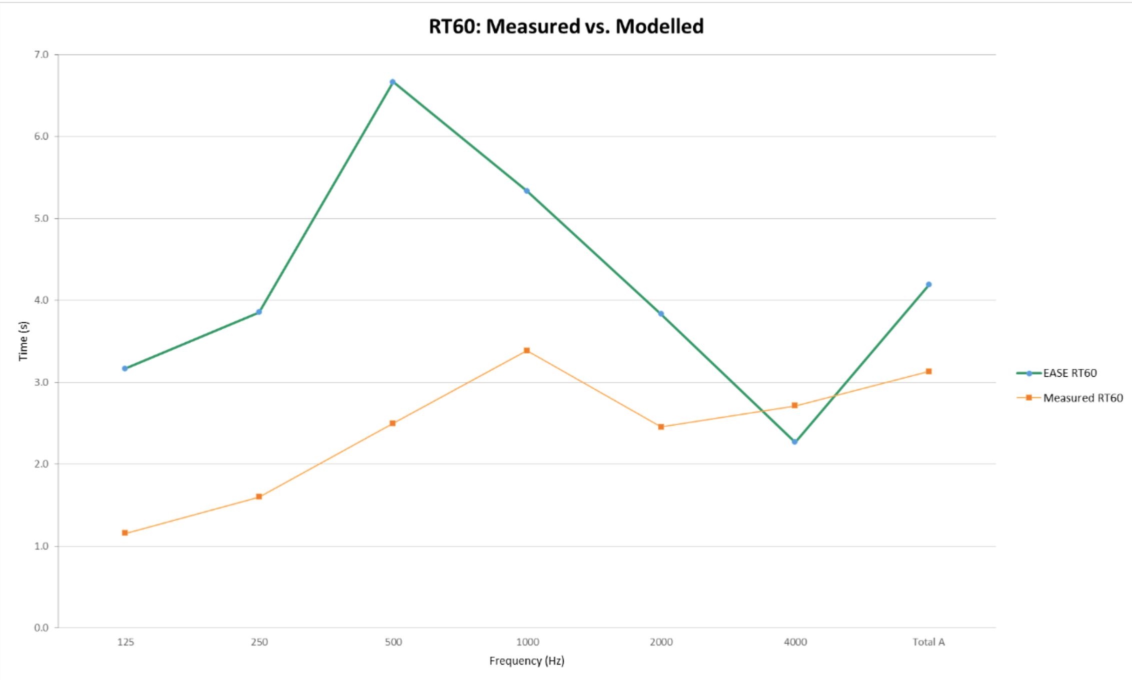
The room specifications used for modelling purposes are presented in the table below:

Table 2: Room Parameters

Parameters		
Humidity	60	%
Temperature	20	°C
Pressure	1013	hPa
Volume	15998	m^3
Effective Surface	5507	m^2
Total Surface	7404	m^2



The modelled reverberation time in EASE calculated an overall RT of 4.2 seconds. Graph below shows the comparison with measured and modelled data.



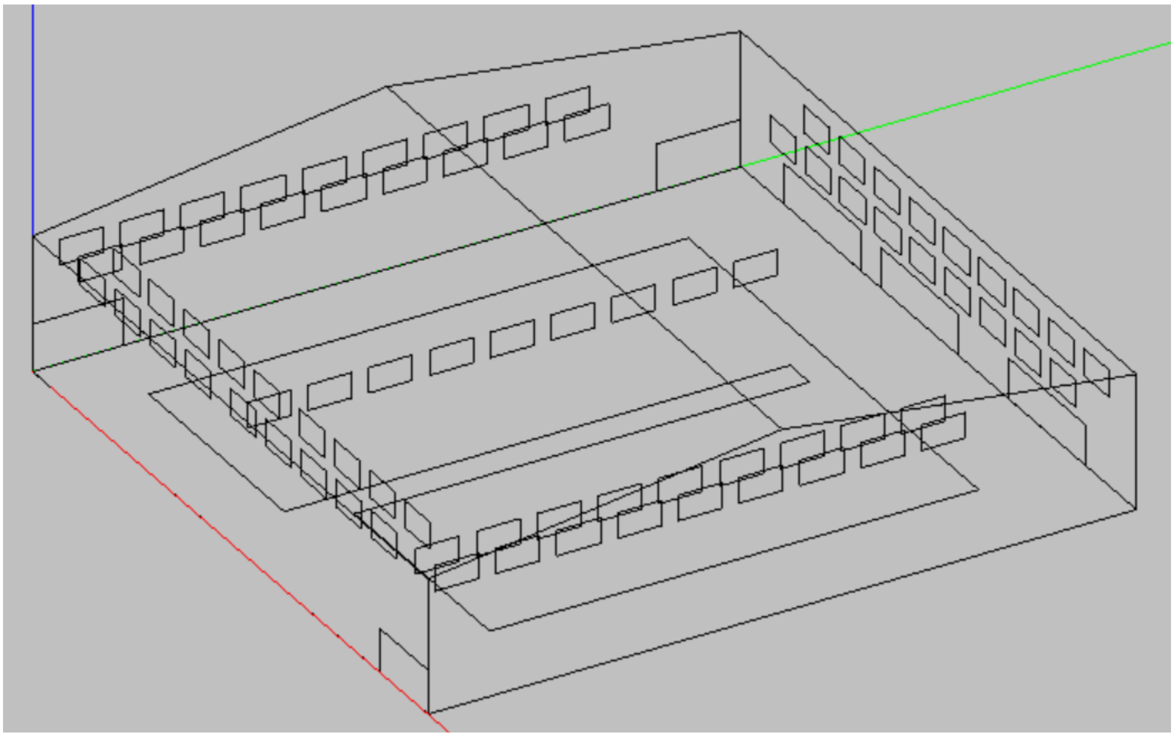
There is a large difference in the measured data and the modelling in EASE. Modelled data shows a RT time of 6.7s in the 500Hz and an overall RT of 4.2s. This is a difference of 1 second from measured data. The spectrum of the reverberation time is significantly different to the measured data. The measured data is preferred and a more accurate method of establishing the baseline reverberation time for the swimming pool. Modelling the acoustic treatment into the swimming pool would need to be considerate of the measured data.

5 SELECTION OF MATERIAL

From the measured data and observations on site, significant acoustic treatment would be required for the swimming pool to reduce the reverberation time to acceptable levels. *AS/NZS2107: 2016 Recommended design sound levels and reverberation times for building interiors* provides a recommended RT of <2 seconds.
The material for the hanging baffle would need to be durable, susceptible to high levels of chlorine, easy to install and have a high acoustic absorptive properties. The material for choice in this situation was the *Stratocell Whisper* closed cell foam panels. Manufacturer tested data claims the product has a NRC of 1.0.

6 EASE MODELLING HANGING BAFFLES

The decision to install the panels as hanging baffles was made in order to allow for both sides of the panels to be used as acoustic absorbers rather than installing it on the wall. The swimming pool was modelled in EASE with the hanging baffles placed in locations where it would be easier to install. The light weight nature of *Whisper* made it easier place the baffles around the swimming pool. Figure below illustrates the 3D modelling of the swimming pool with *Whisper* as hanging baffles.



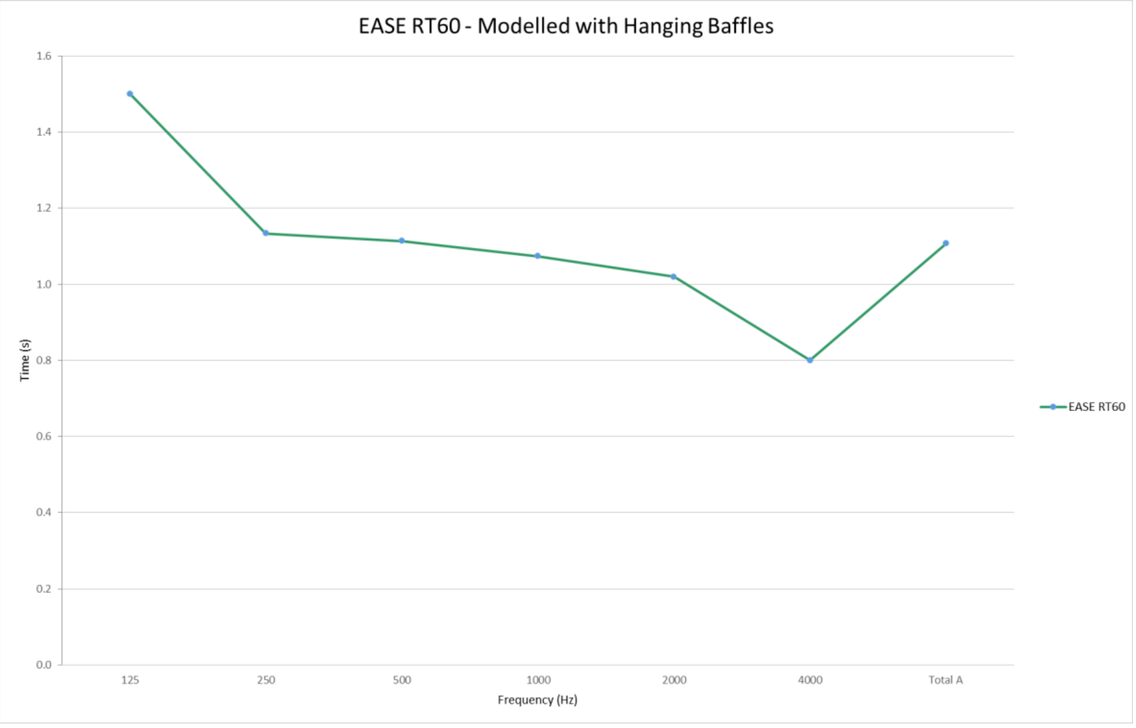
Floorplan (RSA, 2017)
Figure 4: Hanging Baffle EASE modelling

A total of 45 baffles were modelled in EASE. The properties for the hanging baffles were defined as having 2 baffles at each location rather than 1. This provided the modelling with the parameters that we required for hanging baffles. Each of the surfaces had the following absorption coefficient:

Table 3: Absorptive Coefficient of Hanging Baffles

Material	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz
Swimming Pool	0.01	0.01	0.01	0.01	0.02	0.02
Exposed Brickwork	0.05	0.04	0.02	0.04	0.05	0.05
Concrete	0.02	0.02	0.02	0.03	0.04	0.04
6mm Glass	0.10	0.08	0.04	0.03	0.02	0.02
Hanging Baffles	0.48	0.85	1.00	1.00	0.96	0.89

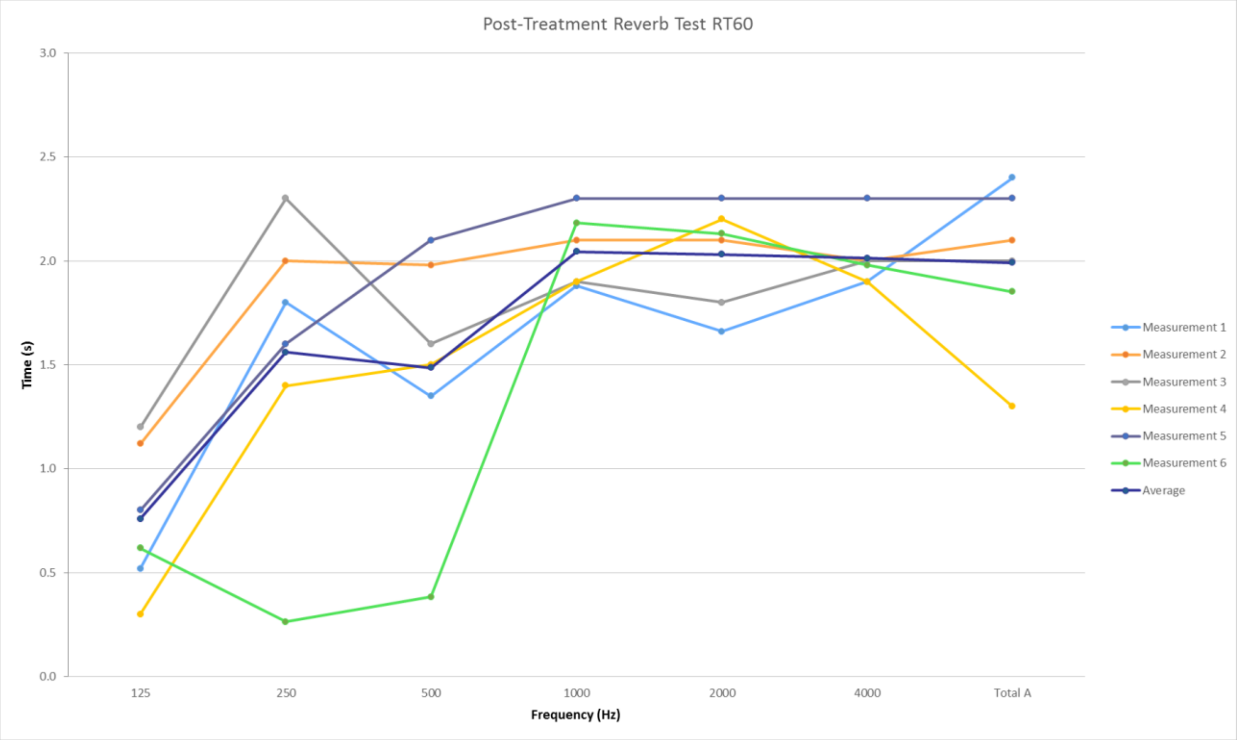
The data for the absorption coefficient of *Whisper* was provided by the manufacturer *Stratocell*. The primary areas of concern were identified with the initial reverb testing being the eastern corner and the centre. The hanging baffles were modelled in EASE and post-treatment reverb testing was also conducted within the swimming pool.



The graph above illustrates the RT results after modelling in EASE. This assumes 45 hanging baffles hanging 4.5m above the ground, humidity 60%, internal ambient temperature of 20Deg Celsius and 1013 hPa. The results show exceptional performance of the hanging baffles. This is in line with the 1.44s reverb time criteria. However Pre-Test measurements and the empty swimming pool showed vast difference in the modelling and testing data.

7 POST TREATMENT MEASUREMENTS

The hanging baffles were installed in the swimming pool as per the modelling conducted in EASE. Once installation was completed, RSA staff was on site to measure the reverberation time (RT60). Measurements were conducted using similar methodology as pre-treatment measurements. This is to ensure that data can be easily compared. The location of the measurements was as per Figure 3. The graph below illustrates the measured results.

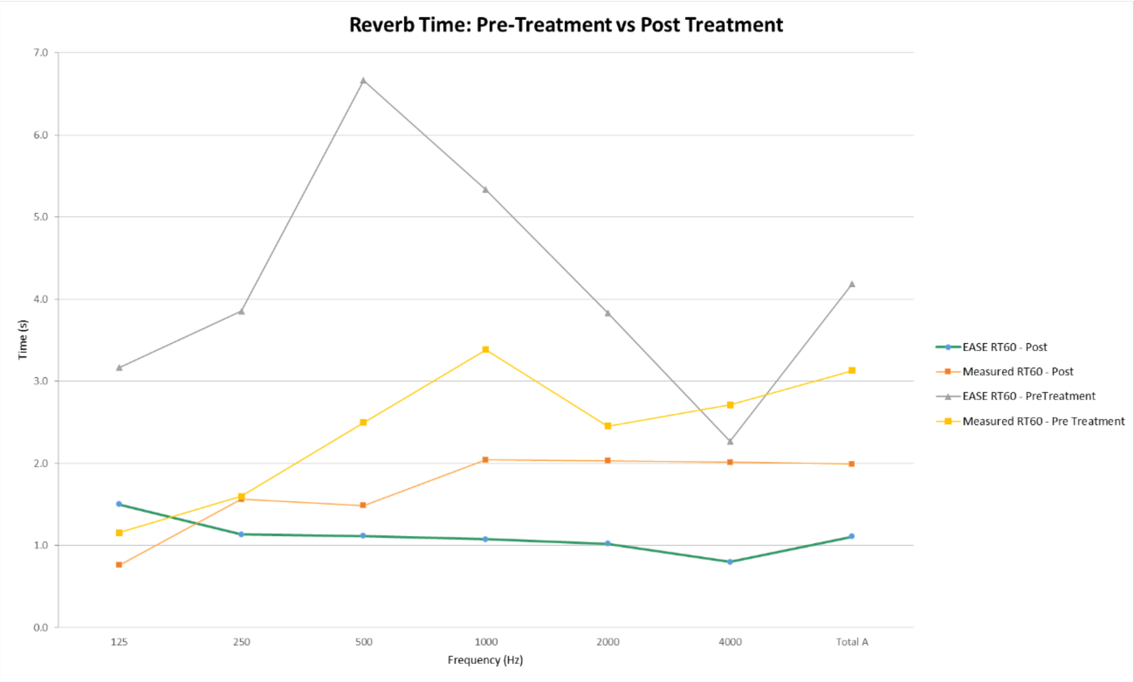


Post treatment reverb measurements have an average result of 2.0s as an overall reverb time. This exceeds the criteria of 1.44s, however, the hanging baffles have eliminated any standing waves and flutter echoes in the large corners of the building. This is a significant decrease in RT from 3.1s to 2.0s.

8 CONCLUSION & DISCUSSION

The purpose of this exercise was to determine the feasibility of modelling hanging baffles in a modelling software such as EASE and measure the performance of the room. On site reverb testing was also conducted to verify the results from the modelling software. The modelling of the room when compared with the measured reverb time showed a large discrepancy in the low to mid-range octave bands. The overall RT60 results had a difference of 1second. Keeping this in mind, acoustic treatment would still be required to the swimming pool to get the reverb times to acceptable levels. Hanging baffles in the form of high performing and light weight acoustic panels would be required in a large space such as the swimming pool. *Stratocell Whisper* was chosen for is light weight properties and high NRC (1.0).

The overall reverb time after treatment decreased to 2.0s with 45 hanging baffles. The EASE modelling resulted in a reverb time of 1.1 seconds. This has highlighted the discrepancies between modelling a large space and measuring the performance. During the EASE modelling, there are parameters that are assumed such as doors being closed, change rooms being unoccupied and no absorption by people. As this was a public pool, and for the purposes of this exercise, we left the audience numbers to zero.



The graph above summaries the EASE modelling before and after treatment and also the measured reverberation time before and after treatment. The EASE modelling showed large flutter echoes and standing waves which were not picked up by the measured data. However, with 45 *Whisper* panels, there was a significant difference in the modelling data and also the measured data.

In conclusion, hanging baffles cannot be accurately modelled in modelling software such as EASE. With a large space such as this swimming pool, the location and selection of acoustic materials is important to ensure satisfactory reverberation times.

F. Alton Everest & Ken C. Pohlmann. 2009. *Master Handbook of Acoustics*. 5th ed. McGraw Hill: New York.
Heinrich Kuttruff. 2009. *Room Acoustics*. 5th ed. Spon Press: New York.
AS/NZS Acoustics – Recommended Design Sound Levels and Reverberation Times for Building Interiors. 2000