Benefits of Reduced-size Reverberation Room Testing

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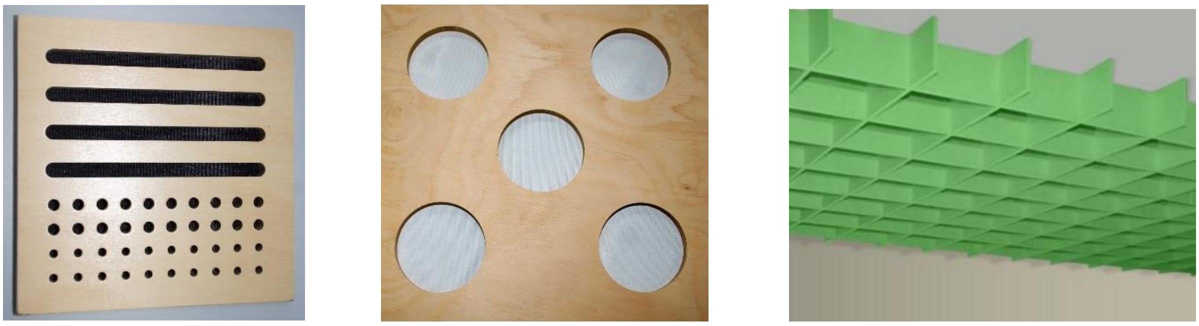
ABSTRACT

A reduced-size reverberation room (also known as an Alpha Cabin or Test Cube) provides fast and accurate sound absorption measurements in a diffuse-field condition. In addition to this, a sample size of only 1.2m^2 is required, compared to that of the standard reverberation room sample size of 10 m^2 to 12m^2. The reduced-size chamber has proven to be an excellent tool for acoustic consultants, engineers and architects to carry out comparison tests between acoustic materials and 3D systems or structures. However, currently there are no standard methods available on how to derive acoustic indices based on the Alpha Cabin test data. This paper presents the preliminary results of a study to obtain reliable acoustic indices; NRC (Noise Reduction Coefficient), SAA (Sound Absorption Average) and α_W (weighted sound absorption coefficient) from such Alpha Cabin data. Utilising a combination of both modelling and testing, the results of three common types of acoustic materials are discussed: (1) homogenous sound absorber, (2) porous sound absorber with flow resistive facing and (3) perforated panel with flow resistive backing. The achieved results are very encouraging and offer a unique tool for assessing single digit values for the overall acoustic performance of sound absorbing materials and systems.

1 INTRODUCTION

Modern architectural acoustics have seen huge varieties of acoustic materials and products in recent years. Traditional homogenous materials, such as rockwool, glasswool or polyester wool are replaced with perforated or slotted panels, rigid boards, moulded to shape panels, three dimensional designed panels and also the completed assembly of acoustic systems.



(a) perforated and slotted panel; (b) MDF panels with large holes and (c) Rigid polyester board system
Figure 1: Examples of some typical architectural acoustic panels and systems

Designers, engineers, acoustic consultants and architects need to have a tool for fast, inexpensive comparison tests on products or acoustic systems.

1.1 The standard methods to measure the sound absorption coefficient

The absorption coefficients of acoustic materials are usually measured using one of the two normalised methods. These are the impedance tube (or tube of Kundt), and the reverberation room.

Figure 2. An example of Impedance tubes

These two methods differ by the incidence angle that the sound waves impinge on the surface of the material. In the impedance tube, the waves arrive at the surface perpendicularly (normal incidence), whereas in the reverberation room the angles of incidence are evenly distributed (random incidence)

(a) Normal incidence (Impedance Tube) (b) Random incidence (Reverberation room)

The sound absorption coefficients obtained with the two methods differ significantly. If comparative tests of the absorption of different materials are performed, the resulting rank ordering can be totally different, depending on which method is used.
As the sound fields encountered in most of the applications are much closer to that existing in the reverberation chamber than to almost perpendicular incidence, this method gives absorption coefficients which are more meaningful to the application than those obtained with the impedance tube.
Although this fact is recognized, the reverberation room is rarely used primarily because a large room and large samples are required. The measurements are also rather time-consuming to obtain.

1.2 The reduced size reverberation room

A reduced-size reverberation test chamber is designed to eliminate these disadvantages while keeping the advantages of the reverberation method. Enormous amount of research work had been carried by the global automotive industries and the Alpha Cabin was designed by Swiss company, Rieter. The design and size of the first Alpha Cabin is 1/3 of the large reverberation room located in Swiss Federal Laboratory of Material Testing and Research Institute (EMPA) in Dübendorf near Zurich. The Alpha Cabin is now the standard method for acoustic measurements of automotive related flat materials, as well as the molded finished parts, such as headliners, bonnet insulators, car seats and so on. It is the only acceptable test results for some of the leading automotive companies, such as BMW, Ford and Mercedes Benz.

The Alpha Cabin name comes from the sound absorption coefficient "alpha". The Alpha Cabin is approximately 1/3 scale size of the reverberation test chamber. The volume is 6.5 m^3 and no two walls are parallel. The sample size is 1.2 m^2. Alpha Cabins provide accurate measurements in the frequency range from 400Hz and 10,000Hz.

Figure 3: Alpha Cabin (or Test Cube) at Megasorber, Melbourne, Australia

In order to fully utilize the benefits of this reduced-size reverberation room testing methods, it would be advantageous for acoustic consultants, engineers, designers and architects to have a single value index of acoustic performance for comparison purposes. At this stage, there is no standard method to obtain the acoustic indices from Alpha Cabin test data.

This paper presents the primary results on how the desired acoustic indices, NRC (Noise Reduction Coefficient), SAA (Sound Absorption Average) and α_W (weighted sound absorption coefficient) could be derived from the Alpha Cabin data. The final results were also compared with full size reverberation room test results.

2. SCOPE OF WORK

2.1. The following sequential steps were adopted:

1.) Create an acoustic model of tested product and compute the sound absorption of the small sample in reverberation sound field
2.) Verify the computed data with the results from the Alpha Cabin
3.) Introduce corrections to obtain the best agreement between tested data and computed data
4.) Propagate sound absorption computation to the full-scale sample (10 square meters);
5.) Compute the indices NRC, SAA and α_W

In simple terms, this is how the diffuse sound field sound absorption coefficient is determined in the reverberation room test. 1.) the reverberation time (sound decay time over 60dB) is measured before and after a test sample has been placed in the room. 2.) From this data, the sound absorption area of the test sample can be determined. 3.) This is expressed as the product of a sample area and a sound absorption coefficient. 4.) If the sound absorption area is taken as a sample area, then the coefficient is a diffuse field sound absorption coefficient.

For modelling and sound absorption computation, we have employed mathematical approach given by Professor Uno Ingard in his book titled NOTES ON SOUND ABSORBERS.

When applying Professor Uno Ingard’s mathematical model, we have noticed that there are more challenges when computing the sound absorption coefficient based on small size sample.

2.2. Sample selection:

There is a wide variety of sound absorbing materials out of which we have selected products as follows:

1.) Homogenous porous sound absorber
2.) Porous sound absorber with flow resistive facing

3.) Perforated panel with flow resistive backing;

A acoustic foam was selected as a simple and stable porous sound absorber.

For a porous sound absorber with flow resistive facing, the same acoustic foam was then laminated with flow resistive fabric, with acoustic flow resistance of about 1.5 times higher than the acoustic air impedance.

The perforated test material nominated has 0.35mm thick aluminium foil perforated with 0.7mm holes and an open area of about 3.6%. Perforated foil was laminated with the acoustic flow resistive fabric with flow resistance equal to a fraction of the acoustic air impedance. The acoustic properties were tested at 250mm air gap between the perforated panel and the reflective surface.

Sample preparation requires 24 hours conditioning at room temperature and thorough covering/sealing of all edges. It is critically important as at 25mm thick product the edge area constitutes almost 10% of the total sample area. Neglecting doing so would lead to a significant overestimating of sound absorption properties.

3. ACOUSTIC ASSESSMENT OF SIMPLE SOUND ABSORBER

The simple sound absorber, acoustic foam in 50mm and 25mm thicknesses were tested in the Alpha Cabin (Test Cube). The mathematical model agreement was subsequently verified with tested data.
Figure 4 shows the sound absorption test results from the Alpha Cabin and computed sound absorption data for 50mm & 25mm thick foam.

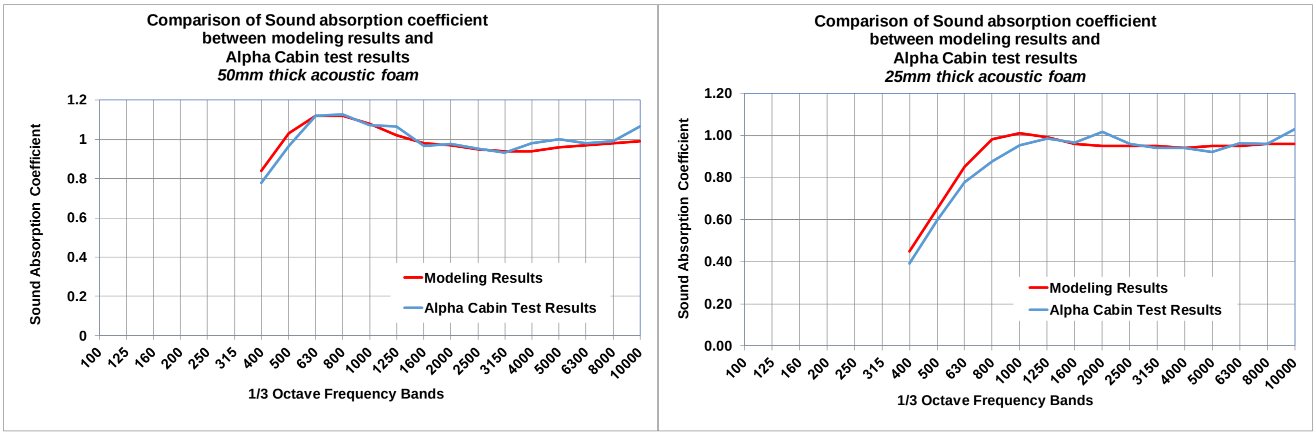


Figure 4: Modelling plain acoustic foam based on test results obtained from the Alpha Cabin

When the satisfactory agreement is obtained between test data and computed data we expand computations from 1.2 square meter sample to 10.0 square meter sample to reveal the sound absorption data in the range from 100Hz to 400Hz.

For this research we have also conducted the sound absorption testing of similar products in the large reverberation room to verify the accuracy of our approach.

Figure 5 shows the comparison between computed data based on the Alpha Cabin results with the data obtained in the full-scale reverberation room.

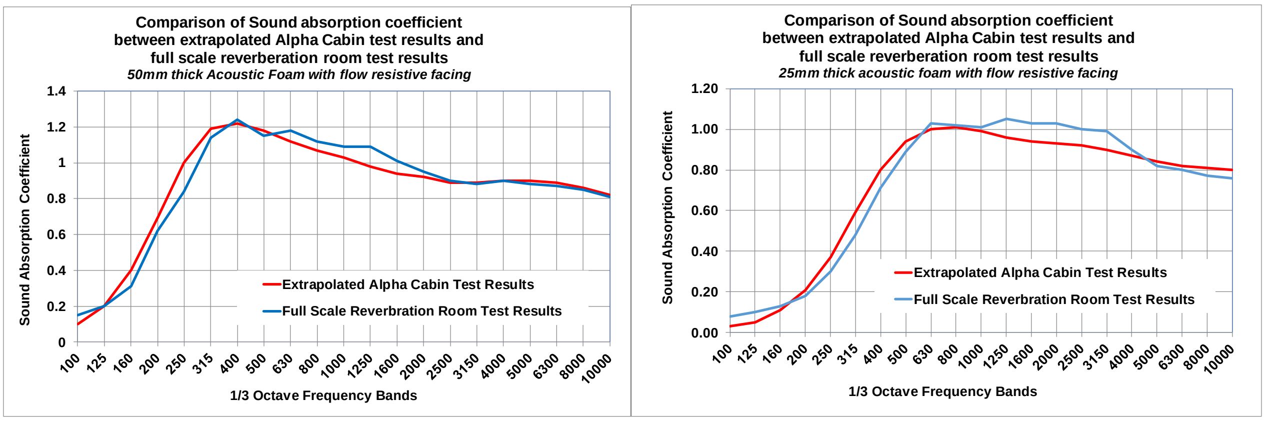


Figure 5: Comparing full scale test results with computed data based on Alpha Cabin measurements

4. ACOUSTIC ASSESSMENT OF POROUS ABSORBER WITH FLOW RESISTIVE FACING

We have selected 50mm thick and 25mm thick acoustic foam laminated with a flow resistive facing. The initial test results from the Alpha Cabin and the modelling data are shown in Figure 6, below.

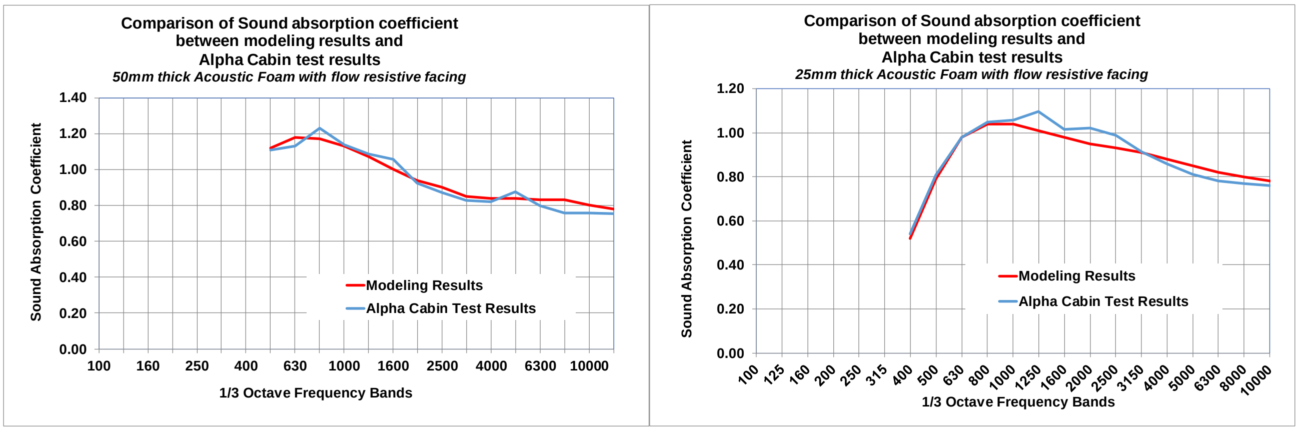


Figure 6: Modelling acoustic foam with flow resistive facing based on test results obtained from the Alpha Cabin

The flow resistive facing is far more complex for modelling than the simple porous sound absorber and therefore the disagreement between test data and the computed values may be higher.
Figure 7 illustrates the full-scale prediction compared with the measured data from the full-scale reverberation room.

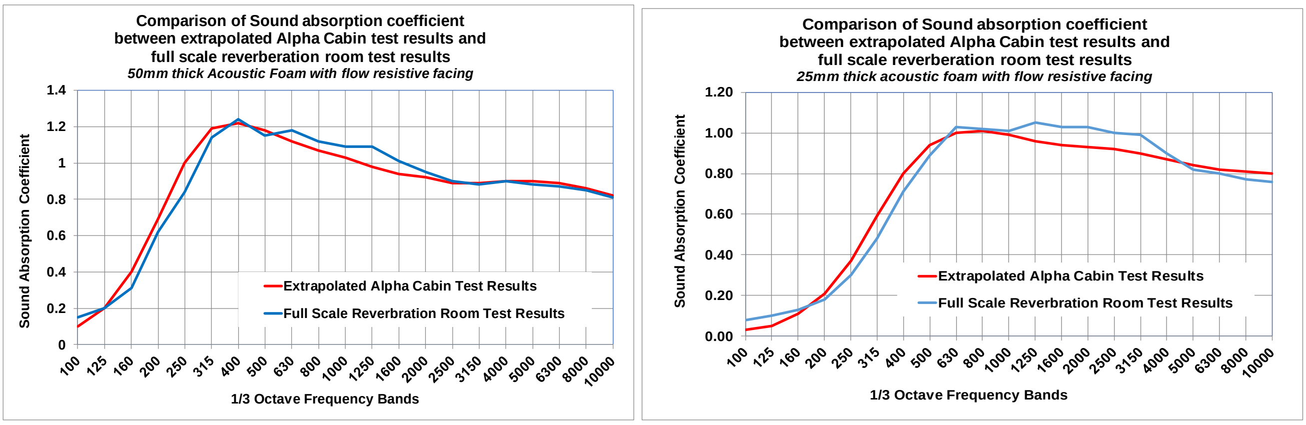


Figure 7: Comparing full scale test results with computed data based on Alpha Cabin measurements

5. ACOUSTIC ASSESSMENT OF PERFORATED PANELS

We have chosen 2 types of perforated panels – 2.4mm holes with 7.5% open area and 0.7mm holes with 3.6%open area – both with laminated flow resistive facing and 250mm air gap between panels and reflective surface. Results for both type of panels are shown in Figures 8 & 9 below.

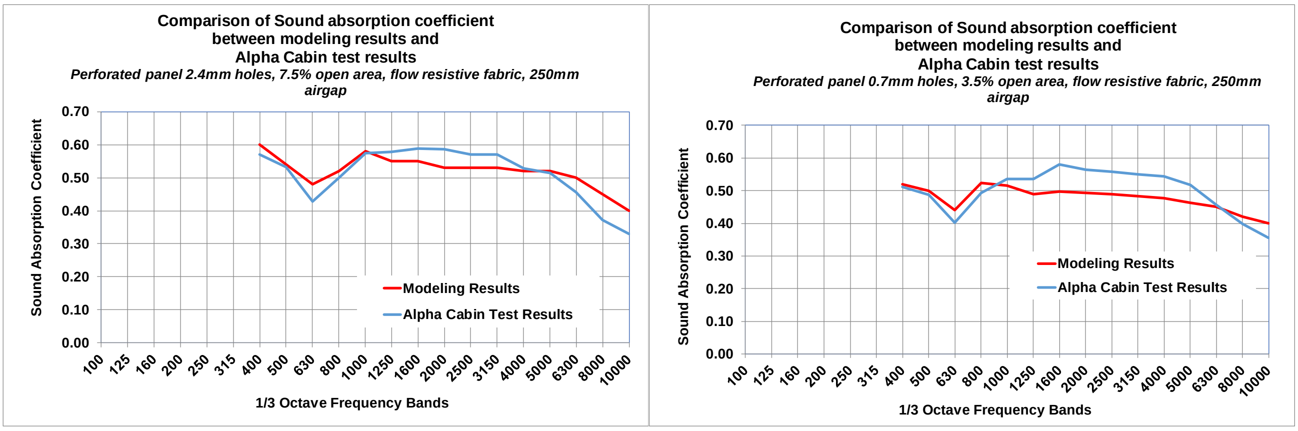


Figure 8: Modelling perforated panels with flow resistive facing based on test results obtained from the Alpha Cabin

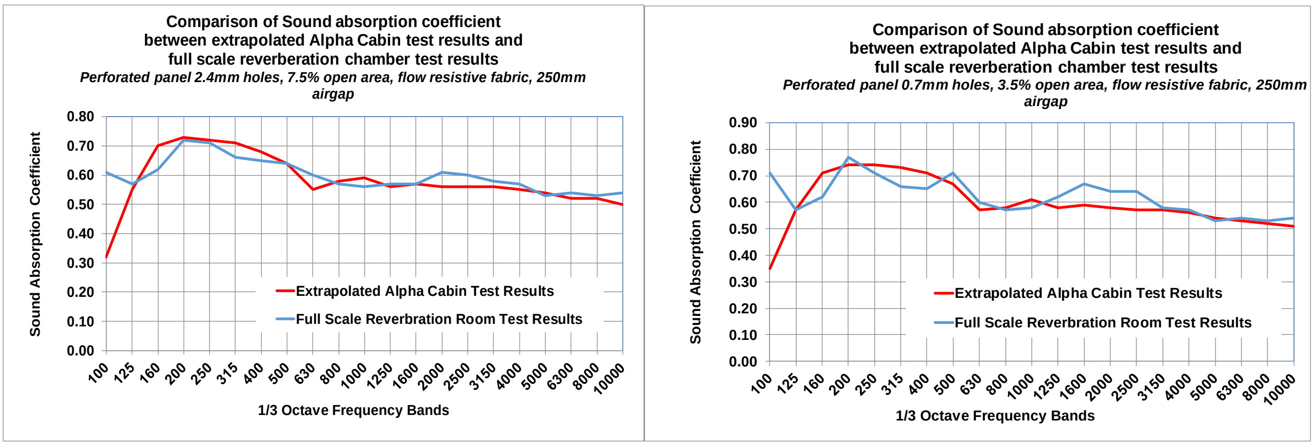


Figure 9: Comparing full scale test results with computed data based on Alpha Cabin measurements

From a mathematical point of view, the perforated panels with a flow resistive facing and an air gap behind are even more difficult to predict. Transition between small test samples and full-scale samples is also more complex due to edge conditions.

6. SINGLE NUMBER ACOUSTIC INDICES

Based on the above results, Sound absorption indices are derived from the above Alpha cabin as follows:

1.) Weighted Sound Absorption Coefficient α_W computed to ISO11654
2.) Noise reduction Coefficient NRC, average of four frequencies: 250Hz, 500Hz, 1000Hz and 2000Hz
3.) Sound Absorption Average SAA average in the frequency band ranging from 200Hz to 2500Hz

The results are listed in Tables 1 to 3 between the tested results in full reverberation room and the computed results based on Alpha cabin test data.

Table 1: Comparison of results for homogeneous porous foam absorber

Specimen	Test method	α_w	NRC	SAA
25mm acoustic foam	Extrapolated alpha-cabin results	0.45	0.5	0.5
	Full-scale reverberation room results	0.45	0.5	0.55
50mm acoustic foam	Extrapolated alpha-cabin results	0.7	0.7	0.7
	Full-scale reverberation room results	0.7	0.7	0.7

Table 2: Comparison of results for homogeneous porous foam absorber with flow-resistive facing

Specimen	Test method	α_w	NRC	SAA
25mm acoustic foam	Extrapolated alpha-cabin results	0.7	0.8	0.8
	Full-scale reverberation room results	0.7	0.8	0.8
50mm acoustic foam	Extrapolated alpha-cabin results	1	1	1
	Full-scale reverberation room results	1	1	1

Table 3: Comparison of results for perforated panel with flow resistive layer

Specimen	Test method	α_w	NRC	SAA
3.5% opening	Extrapolated alpha-cabin results	0.7	0.65	0.65
	Full-scale reverberation room results	0.65	0.65	0.65
7.5% opening	Extrapolated alpha-cabin results	0.6	0.65	0.6
	Full-scale reverberation room results	0.6	0.65	0.6

It is evident that the Alpha Cabin results match well with the test results obtained in a full reverberation room. Out of the all the samples tested, there were only two samples which had a small difference of 0.05, as shown in Table 1.

7. CONCLUSIONS

Single number indices for sound absorption properties are widely used by designers and architects for selection of products.

We have conducted a comprehensive testing and verification for 6 different products. The modelling results correlate well with the Alpha Cabin measured results for all the three key indices: α_W, NRC and SSA.

By providing reliable single number indices, an Alpha Cabin presents as an extremely practical and unique tool for assessing the performance of acoustic materials and integrated systems.

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