EIS Materials Workshop - Building a Semi-Anechoic Room

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Some thoughts on design, build and selection of materials

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What can reasonably achieved

Ask not what I can do for acoustics but
what can acoustics do for me!

What is needed today ?
What about tomorrow ?

- ✓ Can I build what I need and want with low risk of failure?
- ✓ Yes - however you had better be sure that you know what you want.
- ✓ Be careful what you wish for as for every wish there comes a curse!

Target specifications

- ✓ Noise isolation - 10dB quieter inside than the levels that you want to measure
- ✓ Must conform to some, (often changing) ISO standard if the measurements are to be accepted. ISO3744 specifies the environmental criteria for sound power measurements.(in the UK most chambers will have been built to BS EN 60704-1: 1997)

What should we aim for? What can we afford?

It needs to be good enough but not necessarily any better than that!

Historically the cost of construction of acoustic facilities has been high, perhaps too high. The high prices have reflected the high performance goals set by the designers and engineers involved. The desire to provide the best has not always been tempered by the need to build what the client can afford or what is strictly necessary.

Size really does matter then!

Setting out the specification for a noise suite

The key factors determining the type and hence the costs of construction are:-

1. **The intended operating range of the chamber; how quiet must it be inside the room and what are the upper and lower cut off frequencies to be?**
2. **What is the acoustic environment likely to be outside the chamber walls i.e. how noisy will it be outside?**
3. **What will the likely level of vibrations be on the floor when the building is in use?**
4. **What will be the size of the device(s) to be measured?**
5. **What frequency range is to be measured and with what accuracy?**

The basic specifications that everyone will sign up to

- ✓ Isolation at least 50dB
- ✓ Reflectivity/Absorption 10% / 99%
- ✓ But are they what they need?

The things that most people forget about

1. **Usability - fit for purpose?**
2. **Ventilation and heating/cooling**
3. **Access**

The impact of the above on cost!

How do the material work?

Noise isolation.

For all practical purposes the heavier and more impermeable the material the better it’s performance will be. Sound is carried in air and air is light and elastic while heavy concrete blocks, sealed with cement mortar, effectively divide any particle velocity by $10^{\text{something large}}$.

What goes wrong?

The devil is in the detail or rather in the designer and the builder!

The sum of 1000 small building defects = poor acoustic performance.

Noise, especially higher frequency, leaks in through small gaps. If a wall contains 6 inch blocks but the mortar between them is missing 50% of the time then the wall is effectively 5% open space.

You have built a sound barrier with an open window in it!

The cost of mistakes- in terms of lost performance

Assume that we have built a noise barrier of 10 square metres (3m x 3m) that has an Transmission Loss factor of 50dB

Barrier Transmission loss factor after modification = X

Effect of a 3 x2cm hole (or crack of the same area) =40dB

Effect of poor mortar in block work = 40dB

Effect of a solid double glazed window = 44dB

Effect of a cheap hollow door = 26dB

Effect of a good solid door = 36dB

Effect of good solid door with excellent double seals = 44dB

Some gaps and a door = disaster

The First Day:

What goes wrong?

The Roof.

Where the walls meet the roof can be a major problem.

1. Getting a good seal
2. Timber shrinkage causing gaps to appear over the next 2 years - Timber may shrink by 10% over two years and that can mean a large gap appearing.

The Roof:

Anechoic Treatments

Absorption coefficients

Wedges and what they are made of ?

Materials can absorb the energy in a sound wave using different mechanisms. But in all cases the key is to present a slowly changing acoustic impedance; any rapid change will cause a reflected wave.

Wedges provide a graduated impedance change from air to the absorbing material’s impedance over the length of taper.

How long should the wedges be?

This is another way of asking;

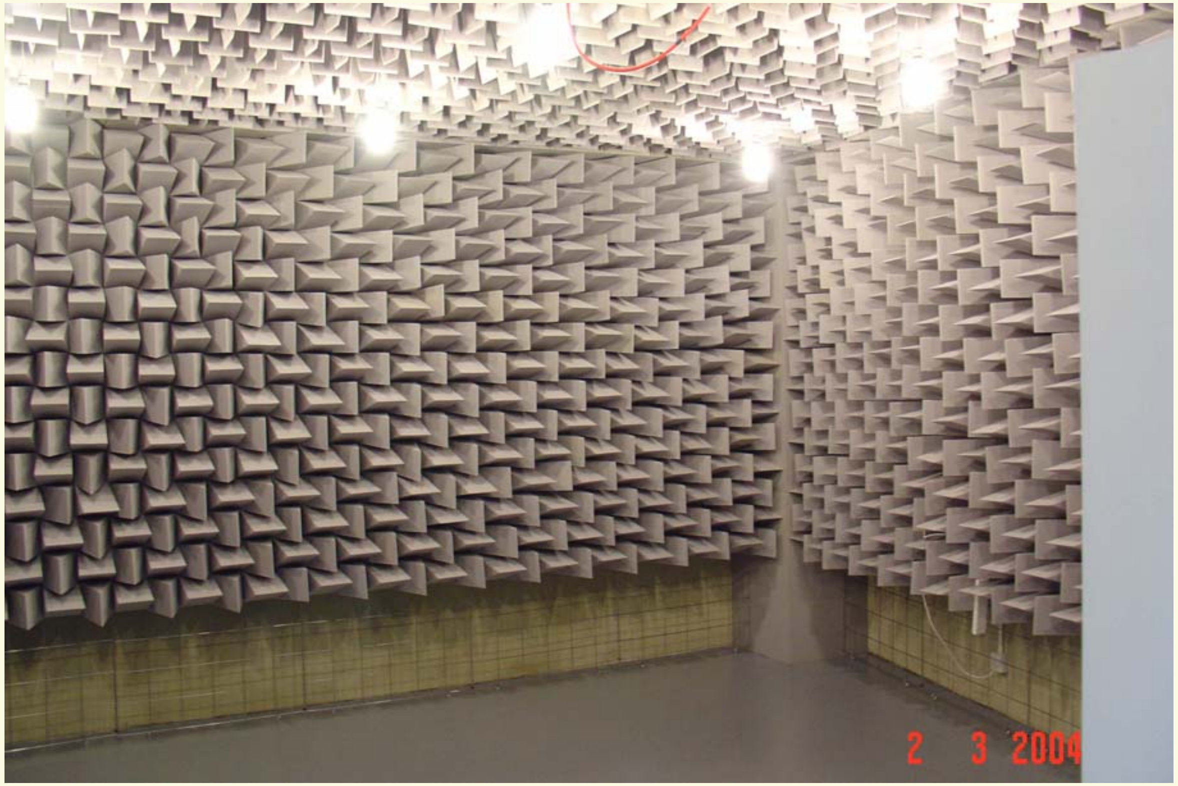
how much money have you got?

The accepted guide is that the wedges will work down to wavelengths = 6 x of their length.

0.5metre wedge should work down to 330/(6x0.5) = 110Hz

1metre wedge should work down to 330/(6 x 1) = 55Hz

After all the hard work only a few wedges needed to complete the project.



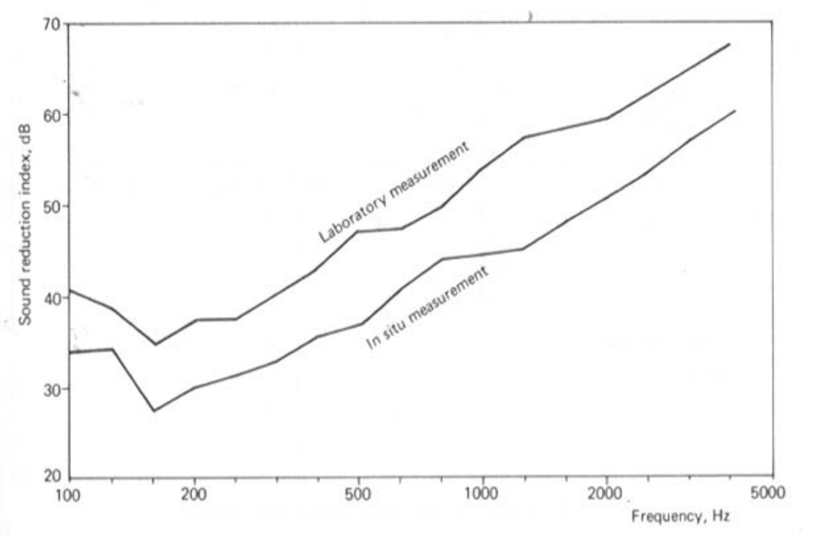
How does the material work

The foam wedges that I have used work by having an open cell structure that allows the sound wave to penetrate deeply into the wedge. Viscose losses occur as the air moves through the cell walls of the foam; locally the air heats as it passes through the cell structure. This heat is then dissipated in the material. A secondary mechanism is the expansion and contraction of the of the foams cell walls due to the pressure wave; the walls stretch and relax and by so doing they translate the sound energy into heat. A final and low frequency mechanism is the excitation of the bending modes of the wedges and of the wedge/grid assembly. Clearly then for high frequencies a lot of closely spaced cells are best but at lower frequencies a very dense foam will reflect the incoming wave. Insufficient depth of foam/length of wedge will mean that the wedge does not have “time” to absorb the pressure wave.

Other loss factors - concrete blocks (15cm)

As a rule of thumb the following can be expected: -

1. For a 15cm or 6inch concrete block wall a 40dB loss.



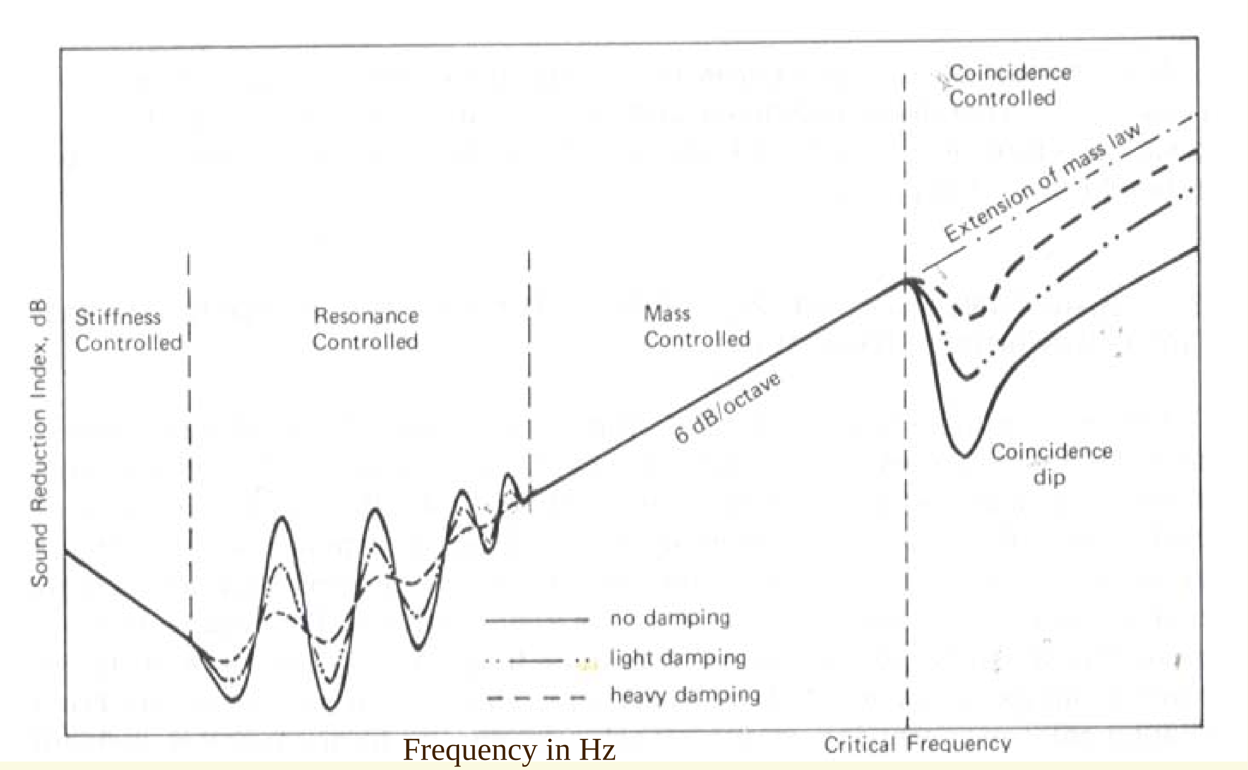
$R=10 \log(W_1/W_2)$

Where R is the sound reduction Index or transmission loss in dB

W is the incident and received sound power across the boundary.

There are three areas; typically below 200Hz where the response is stiffness controlled. 200-5000Hz where the response is Mass controlled and above 5000Hz where coincidence controls the transmission.

The four controlling effects.



As always the construction of a barrier is a trade off but it does make sense to consider the energy levels of the incident spectra!

Consider the acoustic environment

1. The typical sound power levels across the spectrum are not constant and so we can usually afford to sacrifice some isolation at the very high frequencies.

2. If we are making measurements using A weighting then the apparent levels of frequencies below 100Hz will be reduced dramatically.

If these two statements are true (for your case) then you can maximise the MASS line area of the graph!

Furthermore if you are installing wedges you can rely on them to get rid of the high frequencies very effectively!

Basic calculations for the Mass line-

The general rule is that the Transmission Loss (R) is calculated as follows: -

R = 20 log (freq. x Mass per square metre) - 47 dB

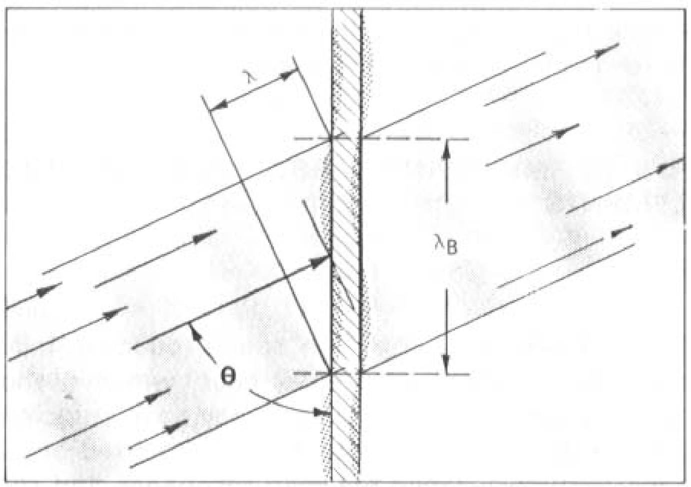
so if we are at 100Hz and our wall is 500kg per square meter of surface area we get: -

R= 20 log (100 x 500) -47 dB

R = 20 x 4.7 - 47 dB

R = 47dB

Coincidence frequency



Coincidence effect

The condition for coincidence to occur is

$$\sin\theta = \frac{\lambda}{\lambda_B}$$

This means that there will be a number of frequencies where there will be strong coupling across the barrier. The exact frequencies that this coupling will occur will be determined by the relative speed of sound in the two media.

Basic material properties - speed of sound

Material	Density g/cm3	Density kg/m3	Speed of sound ms-1
Air	0.0013	1.3	331.3
Concrete	2.2	2200	3500
Brick	1.5 – 2.0	1500	3650
Aluminium	2.7	2700	5100
Steel	8	8000	5000
Oak	0.6-0.7	600	3850
glass	3	3000	5000

The first coincidence frequency for concrete assumes that bending waves of significant amplitude are present in a heavy concrete block wall - this I think is very unlikely!

However in the case of barriers made of “thin” sheets of wooden board or metal sheets these waves will occur.

Material Trade Offs

Material composition

Assuming that foam is the material of choice because: -

1. Fibreglass can shed small particles that are irritating

2. It is relatively easily formed and affordable

The major trade off then is fire resistance against acoustic performance.

The standard upholstery grade foam has a fire retardant that is usually accepted.

There are however higher grades of fire resistance but with each step up the retardation ladder you come one step down the absorption ladder.

To get the same acoustic affect then you will need more material as well as paying 3 X as much for the highest grade of foam, as compared to the upholstery grade.

Performance of a typical facility

In a perfect anechoic room there is effectively no boundary and so every frequency/wavelength can be accommodated. Wedges, however, only work down to their cut off frequency and so at the lower frequencies (typically below 100Hz) we will start to find the room resonance's (BOOM). The problems associated with very low frequency resonance's in chambers are well known.

- The overloading of microphone pre-amps and loss of dynamic range.
- The wrong results at low frequencies
- Standing waves.

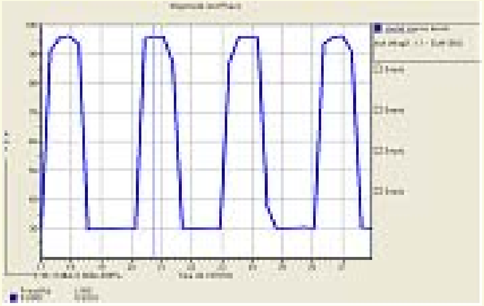
The performance of this particular Chamber.

RT60 time

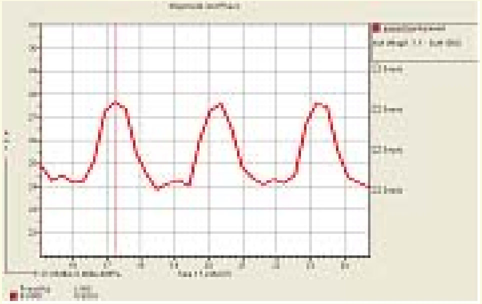
Frequency Hz	milli seconds
80	140
100	120
125	90
160	90
200	60
250	60
315	45
400	40
500	50
630	55
800	55
1k	45
1.25	40
1.6	40
2.0	40
2.5	46
3.2	46
4.0	53
5.0	47
6.3	60
8.0	46
10	60
12.5	50

Isolation

Outside SPL= 96dBA



Inside SPL=28dBA



Average RT60 = 50msec

Isolation 68dBA

Avoidance measures

1. Make sure the chamber is big enough to get microphones out of the near field of the Device Under Test (DUT) and of the wedges.

2. Avoid the obvious room modes by having different length and if possible none parallel sides.

3. Survey the sound field and the ground vibration where the chamber is to be built and consult about further developments that are foreseen for the area.

4. Consider usability and in particular the need for repeated access through a potentially heavy door.

5. Remember the SUM of many small errors can = **Disaster**