MACH ACOUSTICS

Aberdeen University Library

ACOUSTIC DESIGN REVIEW

Ze Nunes
MACH Acoustics
81-83 Stokes Croft, Bristol, BS1 3RD
ze@machacoustics.com   mobile 077730590904
11 Sandycombe Road, Richmond-upon-Thames, Surrey, TW9 2EP

MACH ACOUSTICS

Contents

Introduction.. 1
The Problem 2
On-site Testing and Results.................................... 3
Room Acoustics and Acoustic Treatment.............. 5
Acoustic Modelling.. 6
Coffee Machine Assessment................................. 7
Coffee Machine Modelling Results....................... 8
Occupancy Noise – Optimising Building Layout.... 9
Occupancy Noise – Stand Alone Screens............. 10
Occupancy Noise – Room Acoustics..................... 11
Occupancy Noise – Room Acoustics..................... 12
Occupancy Noise – Room Acoustics..................... 13
Occupancy Noise – Screening & Absorption.......... 14
Occupancy Noise – Noise Control......................... 15
Conclusion 16
Appendix A – Screens... 17
Appendix B – Maximising Screens......................... 18
Appendix C – Acoustic Treatment.......................... 20
Appendix D – Measurement Results...................... 21

Aberdeen University Library

ACOUSTIC DESIGN REVIEW

Revision	Description	Issued by	Issue date
Rev 1	Issue 1	Phil Jordan	15/10/2012

MACH Acoustics Ltd
81-83 Stokes Croft
Bristol, BS1 3RD

t: +44 (0) 1179 441388
e: info@machacoustics.com
w: www.machacoustics.com

MACH Acoustics Ltd
11 Sandycombe Road
Richmond-upon-Thames
Surrey, TW9 2EP

t: +44 (0) 771 771 2603
e: info@machacoustics.com
w: www.machacoustics.com

Consultants
Andrew Rickard andrew@machacoustics.com
Damien Hesnan damien@machacoustics.com
Josh Childs Josh@machacoustics.com
Jeremie Dufaud jeremie@machacoustics.com
Kyran Ebanks Kyran@machacoustics.com
Max Reynolds Max@machacoustics.com
Phil Jordan phil@machacoustics.com
Stefan Hannan stefan@machacoustics.com
Ze Nunes ze@machacoustics.com

Finance
Tracy Toal tracy@machacoustics.com

Introduction

Aberdeen University Library is a stunning building, enhanced with a swirling, round atrium cutting its way up through to the 7th floor of the building. On the ground floor of the building is a cafe, an art gallery, as well as a reception space. The architecture of this building is an important feature, it's style is modern and some what minimalistic and is predominantly finished with hard and reflective surfaces on the ground floor.

Noise transfer from the ground floor spaces is seen to be a key limitation of this building. MACH Acoustics has therefore been appointed to undertake an assessment relating primarily to the spread of noise from the ground floor to the upper floors of the library building.

MACH Acoustics approach has included visiting the library in order to understand how the building is used. During the visit a survey of the existing acoustic conditions was undertaken, as well interaction with the users to fully understand any issues that may affect the performance of the building as a library.

Based upon the results and findings of the site visit, an assessment of possible options of remediation has been undertaken. This assessment has included modelling the performance of these different options using a 3D CATT Acoustics computer model of the building.

This report details the approach and findings of the survey and assessment.

The Problem

Aberdeen library is a modern library with a range of activities taking place within it. There is therefore a number of areas where the acoustic performance could be improved.

Post discussions with the users of the building and also the university management, the following issues where raised.

Introduction to Noise Types

Subjectively there are two types of noise propagating through the building, broad band noises and intermittent/impulse noises. Broad band noise is generated mainly by people talking. Noise from people is seen to be louder than the intermittent noise sources, however due to the way humans perceive sound, the intermittent noise sources could be considered more disruptive.

Coffee Machine and Coffee Grinder

Noise from the production of coffee is understood to be the greatest source of noise complaints. In MACH Acoustics view occupancy noise is seen to be more significant than noise from coffee making. The intermittent/implosive nature of this noise makes this noise source clearly identifiable and disturbing. Due to the importance of this noise source, noise control measures are discussed later within this report.

Ground Floor Occupancy Noise

The use of the cafe spaces and other facilities on the ground floor is seen to be the dominate source of noise within the Library. Where the main source of noise comes from the users of the cafe facilities. The core of our assessment is therefore based around assessing noise control measures for this type of noise.

Trolleys

Trolleys are used to transport different materials through the building, most trolleys take the form of a plastic skip with small caster type wheels. Noise from the trolleys is significant (loud) and can be heard propagating up through the atrium to different parts of the building. A second issue which is caused by the small, hard caster wheels is vibration noise, which is heard within the isolated, quiet, reference rooms, in the basement of the building.

The chosen type of trolleys will always produce high levels of noise, since the small wheels do not ride smoothly over the uneven floor finish. Additionally, the lager plastic flexible sides to these units generate a considerable level of noise.

This noise source is relatively simple to solve, the trolley wheels should be pneumatic, with a diameter ≥250mm. The housing to the side of the trolleys should be rigid, ideally timber, such not to vibrate and generate noise.

The flowing image provides an example of a trolley, already used on site which is quiet and can carry a considerable load.

Hand Dryers

Hand dryers within the toilet located on each of the floors can be heard throughout the library accommodation.

The installed hand dryers use a high velocity air jet to blow the water off of ones hand. This process generates a high level of turbulent air around the hand and subsequently noise. Additionally the hand dryers require high pressure fans to operate, which tend to whine. One option to reduce noise levels form these units would be to reduce air speeds and pressure levels across the fan. However, it is not likely to have a significant impact upon noise levels and is likely to impact upon the performance of the hand dryer.

In MACH Acoustics view, the best option of controlling the spread of noise would be to add a lobby to the toilets. See image below. The alterative would be to select a different type of hand dryer.

Unfortunately, the doors were not inspected on site. There may therefore be a solution to the noise break-out for the hand dryers by adding acoustic door seals to the doors. Please go to http://sealmaster.co.uk for acoustics seals.

Furniture

Highlighted by user complaints and through subjective lessening on site, it was observed that furniture scrapes are a significant noise problem. It was stated that the plastic clips to the bottom of the metal chair legs had fallen off and therefore the chair feet regularly scrape on the hard stone floor. This noise can be heard throughout the library.

The question was also raised as to the fact that this furniture could be made soft such to control noise break-out, however this is not seen to be a practical solution.

The black furniture is already very good.

First floor

The first floor accommodates a range of administrative areas, some cellular spaces and a range of back to back computer work stations for students.

Having spoken to the administration staff, it is clear that noise from the ground floor cafe is a problem, since at times noise levels interrupt communication with students and administration type phone calls. It is also understood that students at the work stations are also interrupted.

Services Noise on the 7th floor

The Atrium acts as a ventilation air return path, hence there is a considerable amount of mechanical extract above the 7th floor atrium. Noise from this mechanical plant is in the order of 49dBA. MACH Acoustics would advise a figure in the order of 40 dBA or 34 dB NR.

Noise from services is often used within office space as masking noise. Masking noise works by increasing the background noise levels within a space to mask or cover up unwanted and distracting noise. Therefore, services noise could be used to mask noise from the cafe area on the ground floor.

On Site Testing & Results

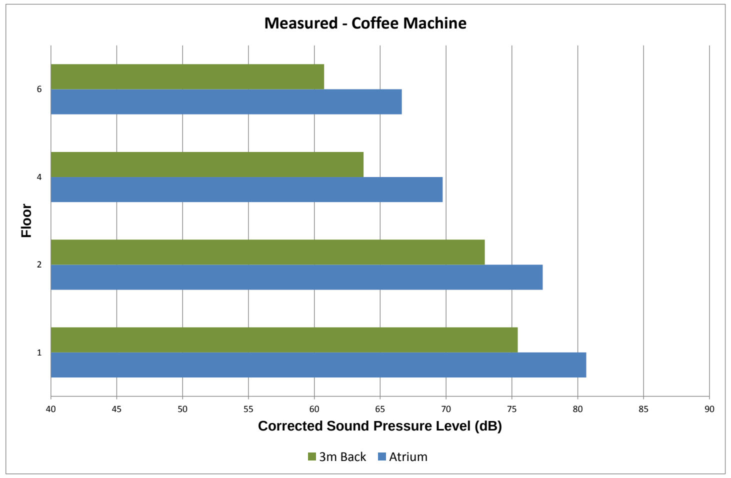
MACH Acoustics starting point in finding a solution to the spread of occupancy noise and coffee production noise, has been to undertake a series of on-site tests. In total of nine sets of tests were undertaken on the 13th August 2012, with each set comprising of a number of measurements being taken across several floors, a number of these tests are illustrated in this report.

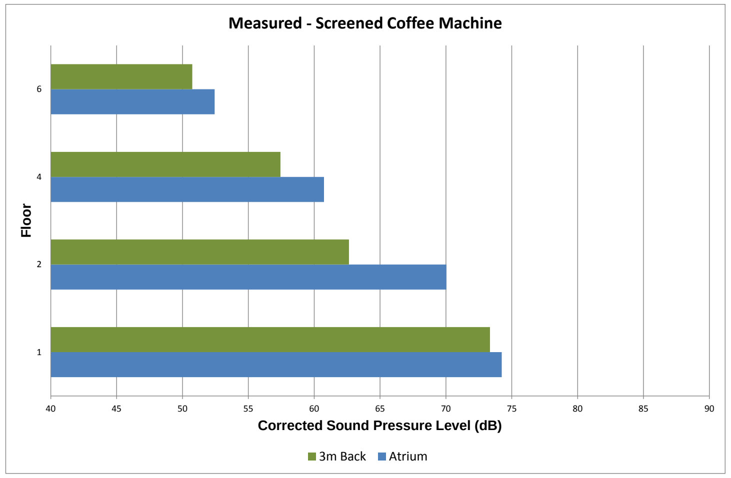
MACH Acoustics undertook two types of assessment, the first assessing the spread of sound throughout the building; the second to determine the level of reverberation.

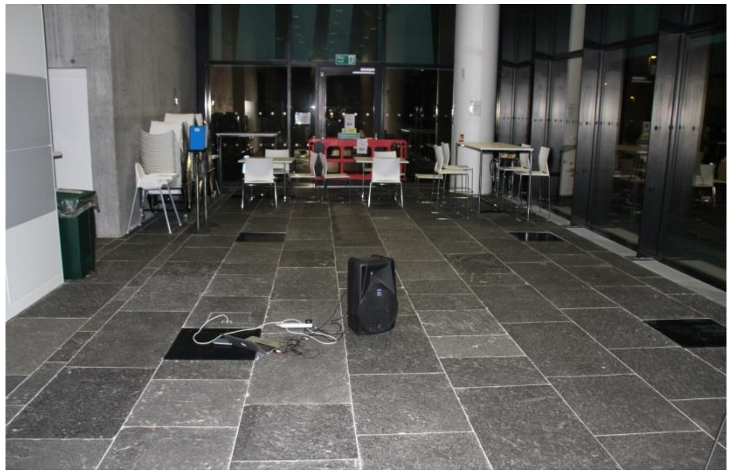
The first set of tests assessed the decay of a sound around the library from different noise source locations on the ground floor plan. These measurements where carried out by taking a reference measurement at 500mm from the face of a high powered loudspeaker. Measurements were then taken at fixed locations on the ground floor and at two locations on a range of floors throughout the library. The results were then corrected according to the reference value.

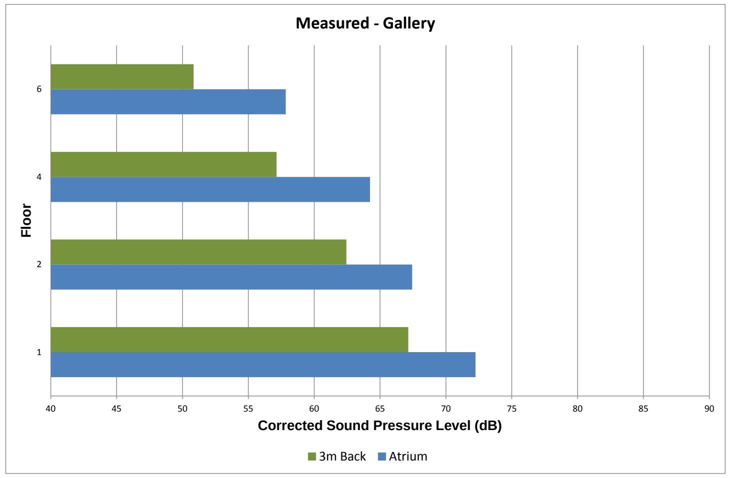
The results of three of these tests are illustrated to the right, where the noise source was either located next to the coffee machine on the cafe counter, in a screened location next to the coffee machine on the cafe counter or in the gallery area. Each graph illustrates the measured noise levels on the 1st, 2nd, 4th and 6th floors at two locations; next to the atrium; and 3 metres back from the atrium.

It can be seen from the three graphs, the measured noise levels were greatest with the loud speaker next to the coffee machine and on the cafe counter. The lowest noise levels were measured with the loud speaker located in the Gallery area on the ground floor. This loud speaker location benefitted from additional distance and screening losses provided by the building itself.









On Site Testing & Results

The second set of tests conducted quantified the reverberation times for a range of locations across the floor plan and over a number of floor levels. Measurements were taken on the ground, 1st, 2nd, 4th and 6th floors.

Reverberation is important in this instance since a hard space (i.e. one with a high reverberation time) will be louder and have a tendency to propagate sound deeper into the building. The reverberation tests were carried out in accordance with the guidance set down within BS 20354:1993 *'Acoustics – Measurement of sound absorption in a reverberation room'.*

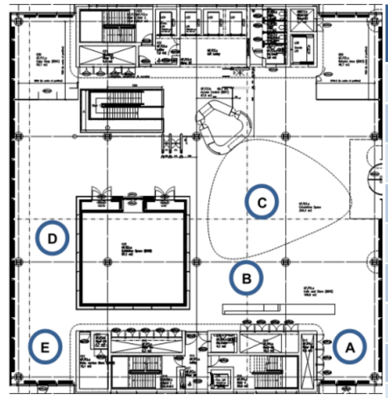
The location and results of the reverberation measurements are shown in the figures and tables to the right.

It can be seen that the reverberation times measured on the ground floor were typically higher than those measured on the floors above. This is considered to be the case due to a limited use of soft and absorptive materials on the ground floor. The average reverberation time for the ground floor has been measured to be 1.7s. It is important to note that a reverberation time of 1.7s is above that recommended by MACH Acoustics for this type of space. We would advise a maximum of around 1.2 seconds and ideally 1.0 seconds.

All reverberation times measured on the upper floors away from the atrium were less than 0.8 seconds. This is seen to be an ideal level of reverberation for those types of spaces. It was observed that all floors above ground level were carpeted and contained a large number of books.

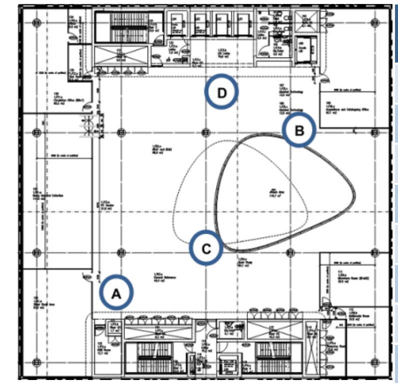
Reverberation times measured close to the atrium were generally longer than those taken at other locations on all floors. The shortest reverberation times were measured amongst the book shelves which provided additional acoustic absorption and diffusion.

Ground Floor



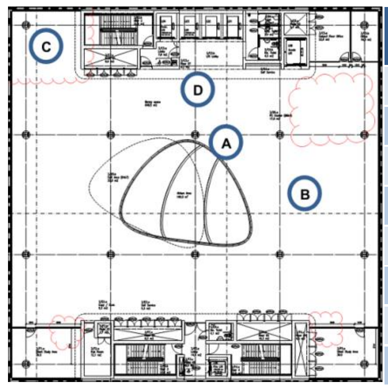
	Location	T_{mf} (s)
A	Corner	1.3
A	Corner	1.3
B	Central Café	1.5
B	Central Café	1.5
C	Central Atrium	1.8
C	Central Atrium	1.8
D	Gallery experience	1.8
D	Gallery experience	1.7
E	Exhibition space	1.8
E	Exhibition space	2.1
F	Floor print room	1.9
F	Floor print room	2.4

1st Floor



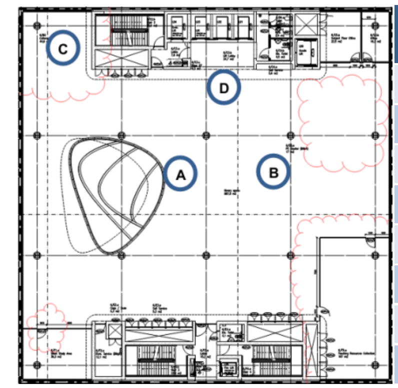
	Location	T_{mf} (s)
A	Corner	0.8
A	Corner	0.8
B	Atrium - Set 1	1.9
B	Atrium - Set 1	1.3
C	Atrium - Set 1	1.3
C	Atrium - Set 2	1.3
D	Central space (lifts)	0.8
D	Central space (lifts)	0.4

4th Floor



	Location	T_{mf} (s)
A	Atrium	0.8
A	Atrium	0.7
B	Within books	0.4
B	Within books	0.4
C	Screened area	0.5
C	Screened area	0.5
D	Central space (lifts)	0.7
D	Central space (lifts)	0.7

6th Floor



	Location	T_{mf} (s)
A	Within books	0.3
A	Within books	0.3
B	Atrium	0.7
B	Atrium	0.8
C	Screened area	0.5
C	Screened area	0.5
D	Screened area	0.7
D	Screened area	0.7

Room Acoustic Treatment

Room acoustics and reverberation times refer to the behaviour of sound within the room/space. Sound takes longer to decay in reverberant spaces and this has two consequences: firstly speech sounds become more difficult to hear as the long decay blurs successive syllables into each other. This is not seen to be an issues within Aberdeen University Library. Secondly and <u>more importantly</u>, a build-up of noise occurs as the sound takes longer to be absorbed. When this build-up of noise occurs, there can be a snowball effect as voices are raised to be heard above the noise as shown in the top figure.

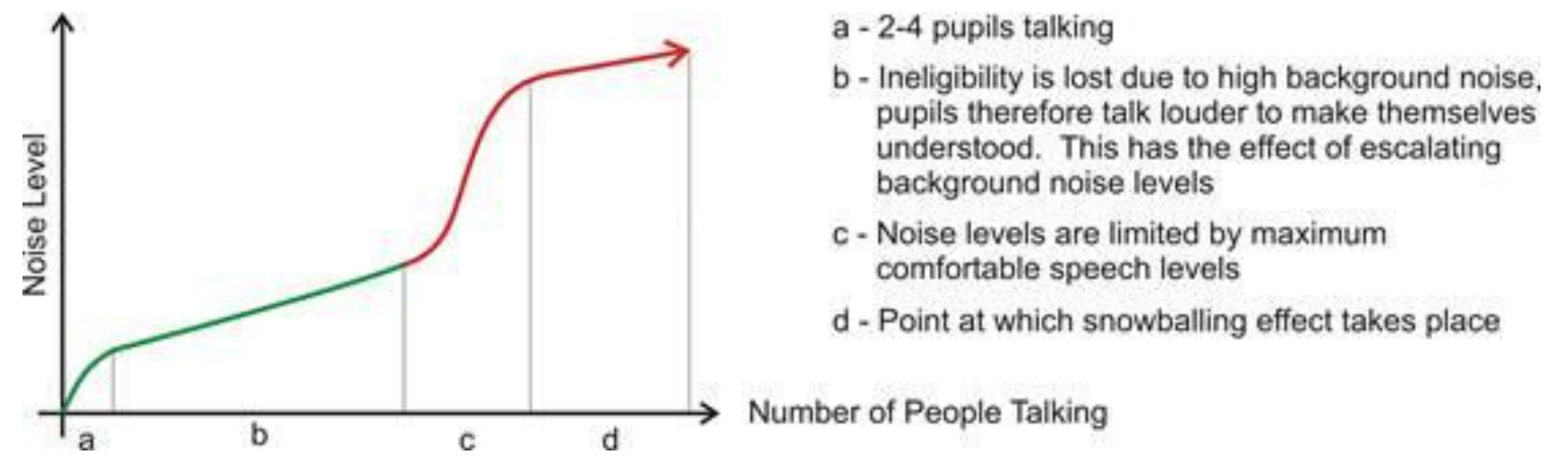
An example of the snowball effect is often experienced in a café / restaurant with tables seating 2, 4, 6 and 8 occupants. If the finishes within this space are hard there will be little or no absorption of sound, this will result in a loud, harsh, stressful and unpleasant space. Additionally, it is difficult for people to talk in large groups as ones voice is masked by the background noise. This typically limits conversations to pairs and a maximum of 4 people around a table.

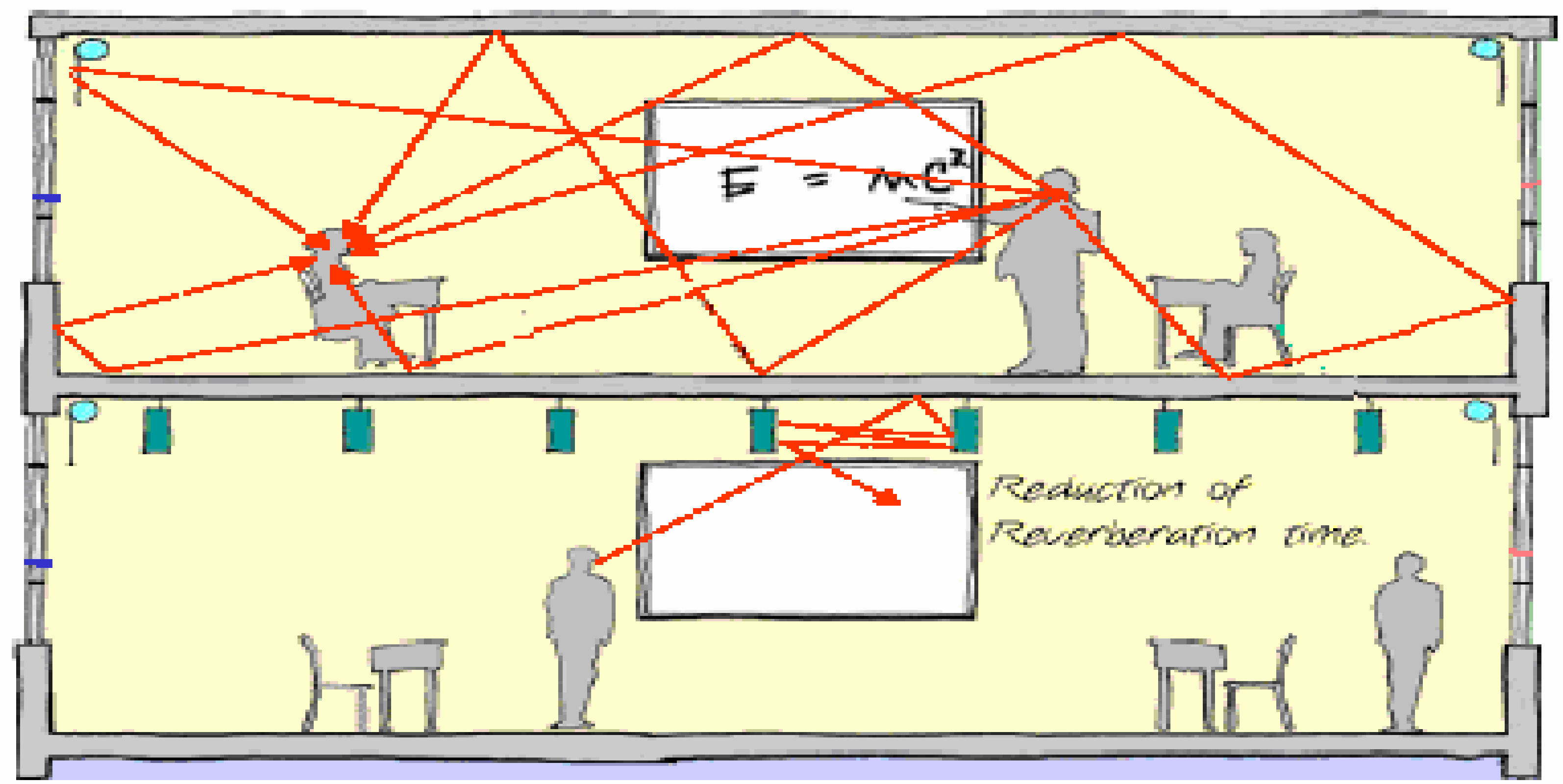
Positioning the same spaces outside prevents sound reflecting off walls and thus reducing noise levels around the group of people. This reduction in noise promotes speech intelligibility, enabling all 8 members of a single table to hold the same conversation.

The café example is a little extreme but does demonstrate the importance of acoustic absorption within a space.

As a real reference of this effect, S. Airey has shown that occupancy noise levels are significantly reduced by controlling the snowball effect. This is achieved by increasing the level of soft treatments within open plan spaces.

S. Airey's research shows that a **9 dB reduction** in occupancy noise can be achieved when **doubling** the level of room acoustic treatments in a conventional classroom.





Modelling Assessments

Measurements only provide data based upon the current form of the building. To predict changes in the acoustic performance of the building, Ray tracing models have built using CATT Acoustics modelling software. Images from the CATT model are shown to the right. In the image of the complete CATT model of the library, the measurement locations are represented by the ID's 01 to 08. CATT Acoustics models a space by sending out thousands of rays representing a specified sound source. This software is exceptionally accurate due to the fact that the position of acoustic treatments are considered. This software also provides a wide range of parameters including the decay of sound over distance, over floors and allows the prediction of reverberation times within different parts of a building.

CATT Acoustics modelling can be used to assess the spread of noise from one part of the building to another. At this stage, a full model has been built, but a full review has not been undertaken in this respect.

A key advantage of this type of software is that it provides clear graphical differences. This allows the readers of this report to easily understand and identify the difference between design options. The results of the modelling using this method is presented in the following sections of this report.

Please note, this type of modelling is limited since it does not include the effects of diffraction, hence small errors with the representation of the performance of acoustic screens may occur.

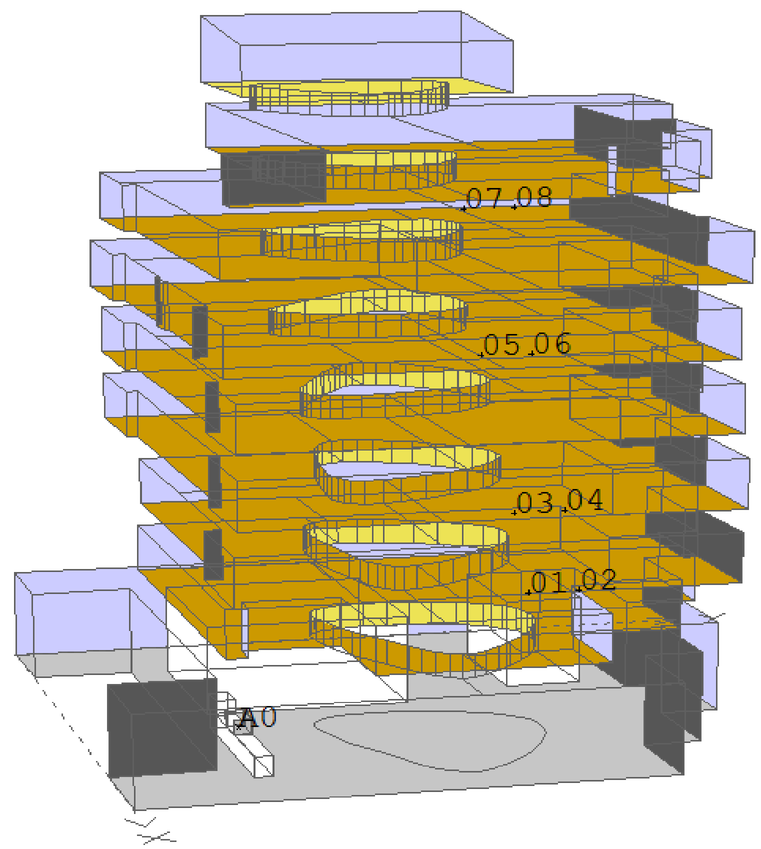
Calibration of Model

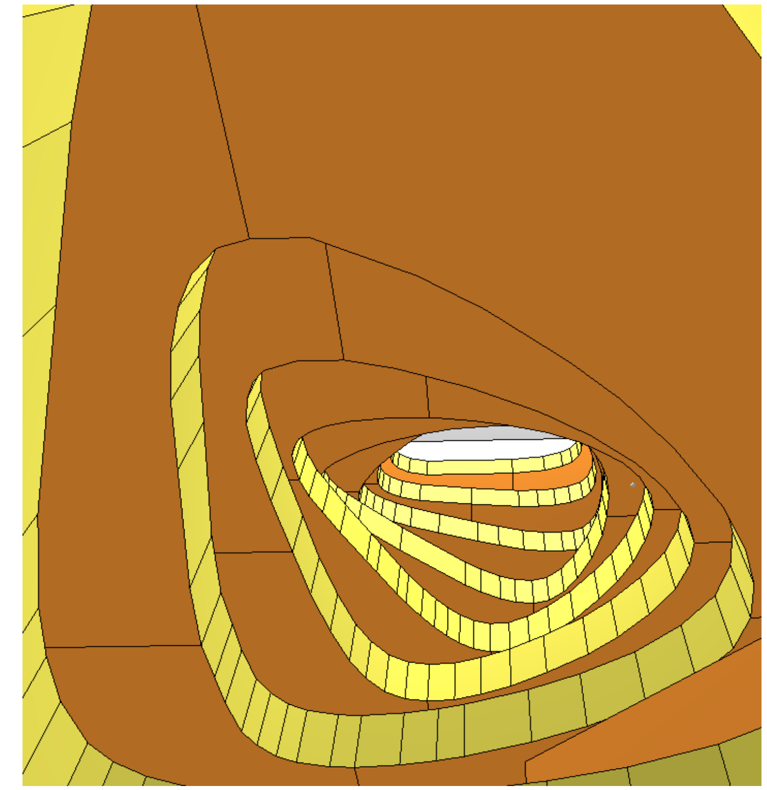
In order to ensure that the CATT model provides an accurate representation of the acoustic conditions within the library, the model has been calibrated based upon the measurements taken during the survey.

Individual models of the Ground and 4th floors were created and then calibrated against the average reverberation time measured for that particular floor.

The results of this calibration process were then used throughout the remaining floors.

A comparison between the measured and predicted noise levels with the loud speaker located on the cafe counter is presented in the table to the right. It can be seen that the differences are less than 3.5dB between the measured and the predicted and is therefore considered to be a reasonable representation of the existing conditions.





Floor	Location	Sound Pressure Level (dB)		Difference
		Measured	Predicted	
1	01	80.6	83.5	2.8
1	02	75.4	78.9	3.5
2	03	77.3	78.9	1.5
2	04	72.9	72.7	-0.2
4	05	69.7	72.1	2.4
4	06	63.7	65.0	1.2
6	07	66.6	66.2	-0.5
6	08	60.7	61.1	0.3

Coffee Machine

Having listened to the coffee machine it is apparent that the production of coffee itself is not a particularly noisy activity. However, the coffee grinder and the milk frother do produce high levels of noise.

Coffee Grinder

There are quiet grinders on the markets, but not whisper quiet grinders. Due to the cost of accurate, acoustic measurements it is unlikely that reliable and meaningful data can be obtained for these grinders. It is also likely that quieter grinders will be slower than a conventional grinder, meaning that they will be on for longer periods of time, potentially causing a different noise nuisance.

With respect to noise control a simple and effective solution would be to install the coffee grinder within a closed cupboard, however it is considered that in practice it is unlikely that this would be used correctly.

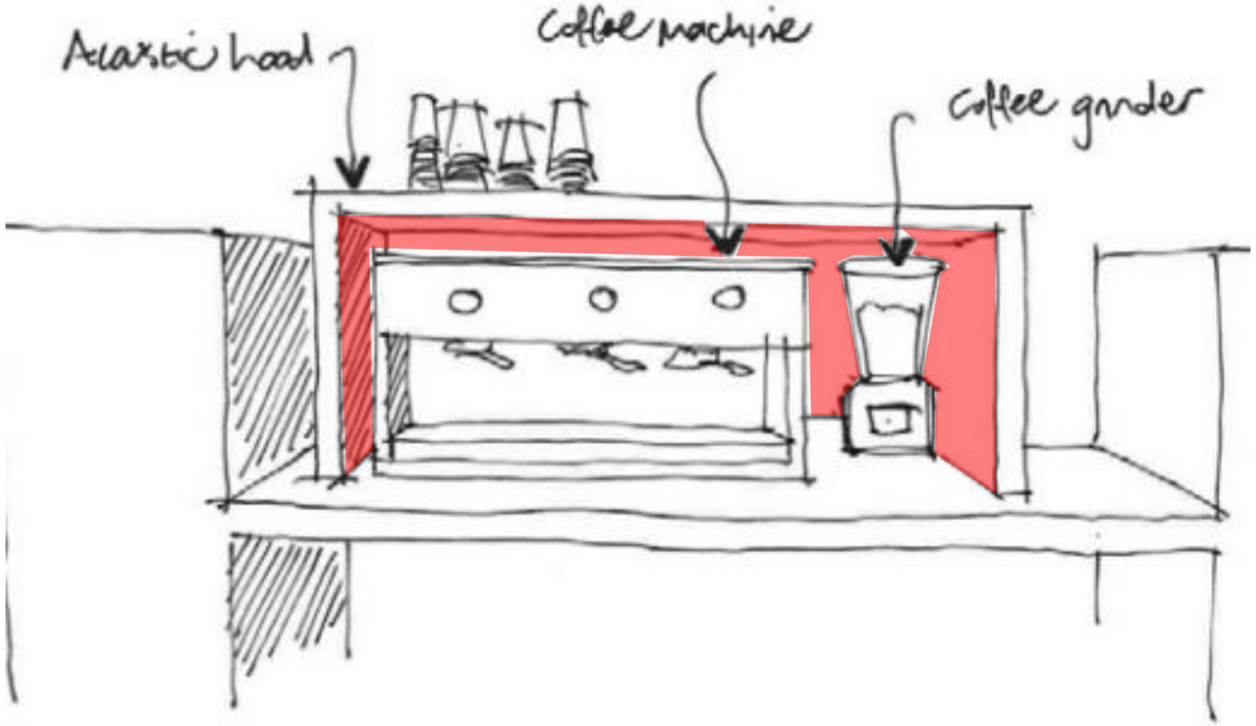
An alternative solution would be to use pre-ground coffee. This may also have a second latent benefit, of reduced occupancy levels in the cafe and subsequently noise levels, as a result of reducing the quality of the coffee.

Coffee machine

The process of frothing milk is simple, a jet of steam is passed through the milk. It is therefore unlikely that this process could easily be made quieter. Since access is required to the frother, the only apparent solution would be to place an acoustic screen around this unit as per the sketch shown to the right.

Such to assess the impact of a screen, comparative sound testing has been undertaken by placing a loud speaker adjacent to the coffee machine, as shown in the photos on page 3 of this report. The loudspeaker was then placed behind the screen in front of the wash basin as per the photo on the right. Note a basic level of acoustic absorption was located between the speaker and the screen. Graphs illustrating this comparison of speaker locations are presented in the top two graphs on the following page. The graphs show the measured noise levels next to the atrium and 3m back on the 1st, 2nd, 4th and 6th floors.

MACH Acoustics has assessed the benefit of a screen through on site testing and acoustic modelling, the results of which are presented on the next page.



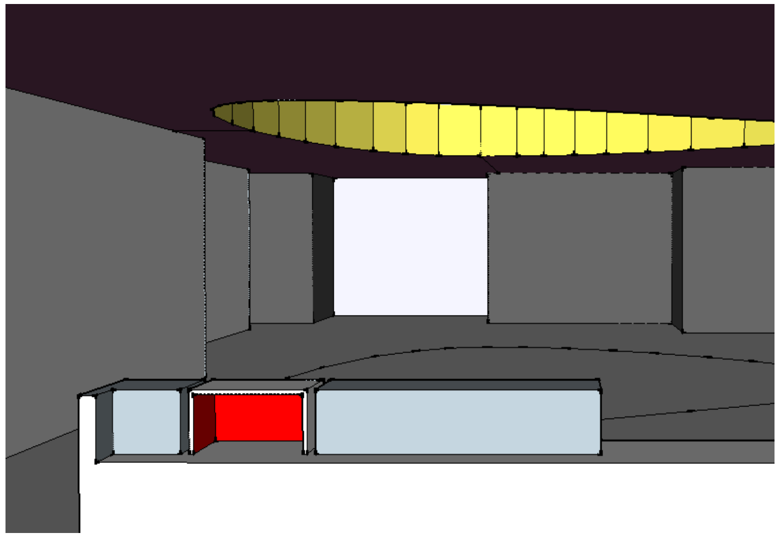
Computer based Analysis

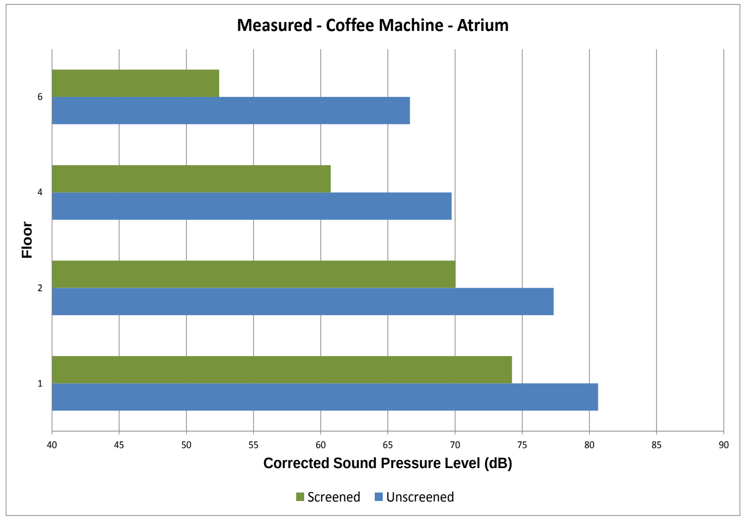
To further assess the implication of using screening in front of the coffee machine, modelling of the spread of noise through computer based simulation has been undertaken. Here a direct comparison has been made between the unscreened coffee machine and the screened coffee machine. Please see the image below showing the CATT Acoustic model representation of the coffee machine screen. Please note that a red finish represents Class A acoustics absorption in all screen images

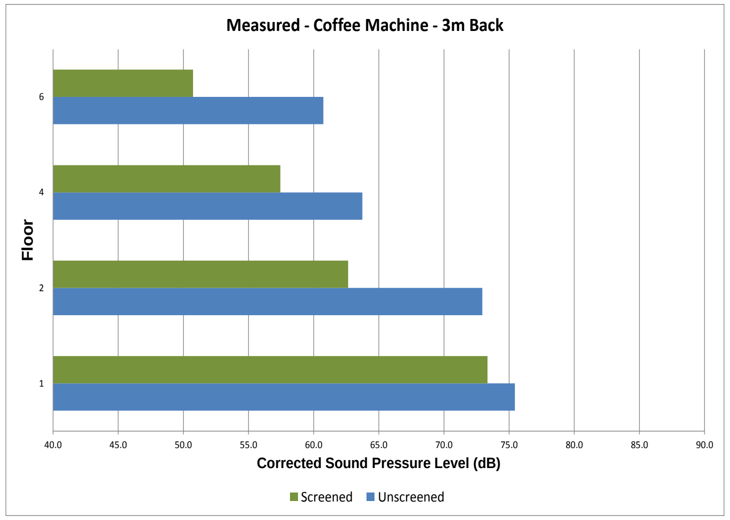
The advantage of a computer based model is that it is possible to review alternative options. At this stage, only one option has been considered. This option is with the noise source (coffee machine) within a treated enclosure. The results of this assessment are illustrated in the bottom two graphs labelled *Predicted - Coffee Machine – Atrium and 3m Back.*

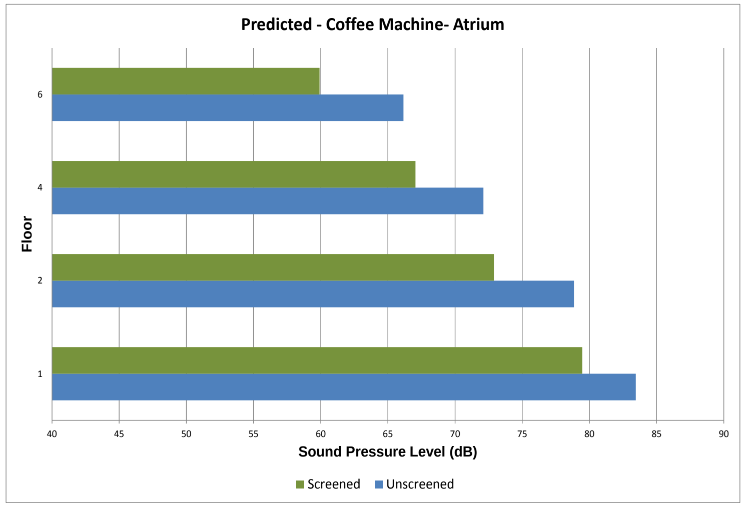
The top two graphs illustrate a comparison of the *measured* noise levels with the noise source on the café counter which is not screened (as it currently is) and also when it is screened.

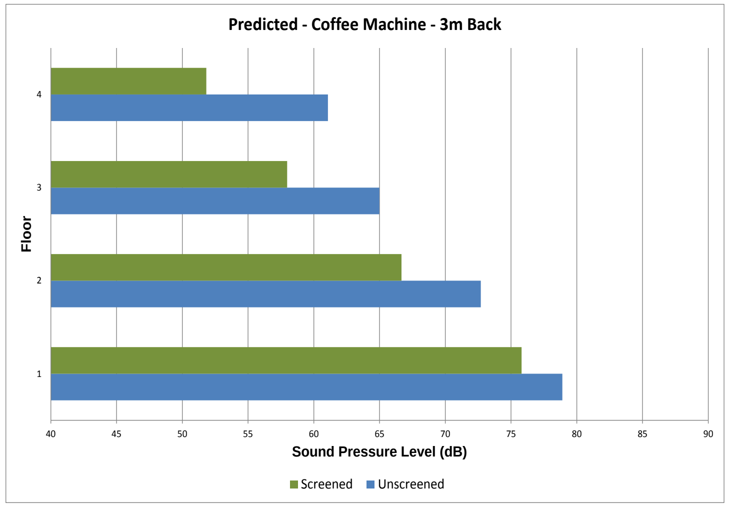
It can therefore be seen that through measurement and prediction, by screening the noise source close to source, noise levels are significantly reduced at all measurement positions on the floors above.











It is considered that with the introduction of an acoustically treated screen around the coffee machine, in reality noise levels would be less than those predicted at the measurement locations due to acoustic benefits of objects not included in the model. However, further improvements to reduce coffee machine noise could include the following:

In addition to the coffee machine enclosure, it would be beneficial to introduce some acoustic treatment to the wall behind the cafe counter to reduce sound reflecting off this wall into other parts of the building.

Relocation of the coffee machine to a more discrete location where screening is provided by the existing building, i.e. within the gallery area would reduce noise levels further.

Please note: A 5 dB change in noise levels will be noticeably perceived, a 10 dB reduction in noise levels is often subjectively described as a 50% reduction in the noise level. A 20 dB reduce is therefore taken to equate to a 75% reduction in noise level.

People Noise

Noise from the users of the cafe is seen to be the main source noise causing a disturbance to the upper floors of Aberdeen University Library.

A subjective evaluation of the library was undertaken during the summer holidays,. At this time, the café was frequented by mature students and staff and is therefore likely to be busier during term time. However, noise from the users of the café was clearly audible and disturbing on 1st, 2nd, 3rd and 4th floors.

During term time it is understood that student numbers increase dramatically, and therefore generating far higher noise levels within the library. Occupancy noise is therefore understood to be the core acoustics issue in this building.

Noise control through Acoustics design

There are two methods to implement noise control measures though acoustics design; 1) placing acoustics screens between the source and the receiver and; 2) by introducing additional sound absorption.

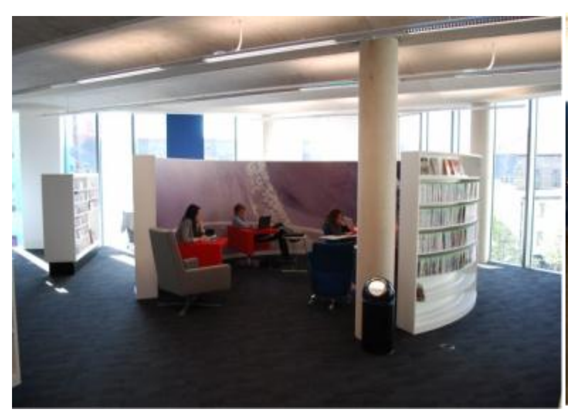
Acoustics Screening

Acoustic screens work by breaking the line of site between the sound source and the receiver position. Acoustic screens therefore typically take two forms, a barrier in the form of a solid, stand alone object placed between the sound source and the receiver. The second more discrete and potentially more effective screen is the use the building itself. This screening effect is experienced on all floors, as one moves back to the edge of the atrium, noise from the cafe reduces considerably, since one can no longer see the cafe on the ground floor.

At this stage, two options are proposed which introduce a screen either near to the source or near to the receiver. These are presented on the following page.

To assess the implication of design changes acoustic modelling has been used.

Screens could be located around the sensitive parts of the building primarily the first floor space.



Stand Alone Acoustic Screens

To demonstrate the effect of introducing screens to reduce noise break out from the cafe, a CATT model has been used to assess two different scenarios. In both cases the noise source was located on the cafe counter, with noise levels being predicted at the atrium and 3m back on the 1st, 2nd, 4th and 6th floors.

Screen around the base of the Atrium

An interesting option discussed on site is to place a stand alone screen around the atrium at the base of the first floor Atrium. This type of screening is effective, since the line of sight to the cafe spaces is reduced. However it is important to ensure that one cannot see the cafe space from the floors above. See the photo to the right.

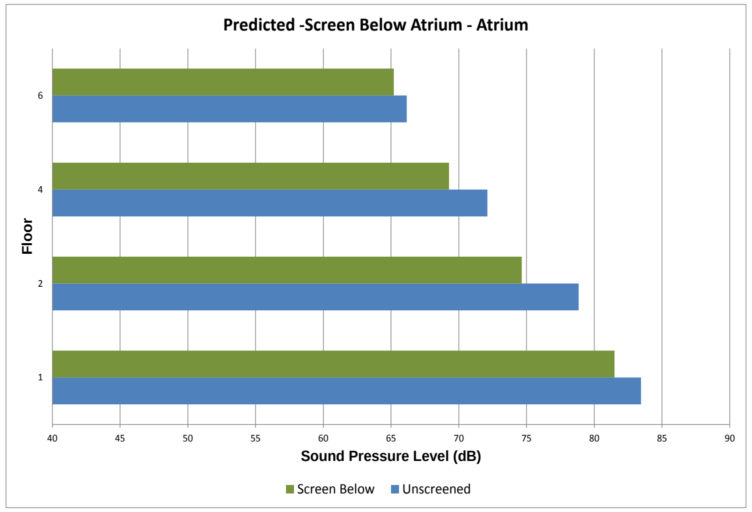
The screen image to the right shows the 2.75m screen below the atrium used in the model. The results of the modelling of this screen are illustrated in the two graphs. These show that the predicted levels were marginally improved with the introduction of the screen. It is considered, that the performance of this screen is limited by the hard and reflective ground floor surface which reflects the sound up the atrium. The introduction of carpet within the cafe are area may help to reduce reflections off the floor up through the atrium.

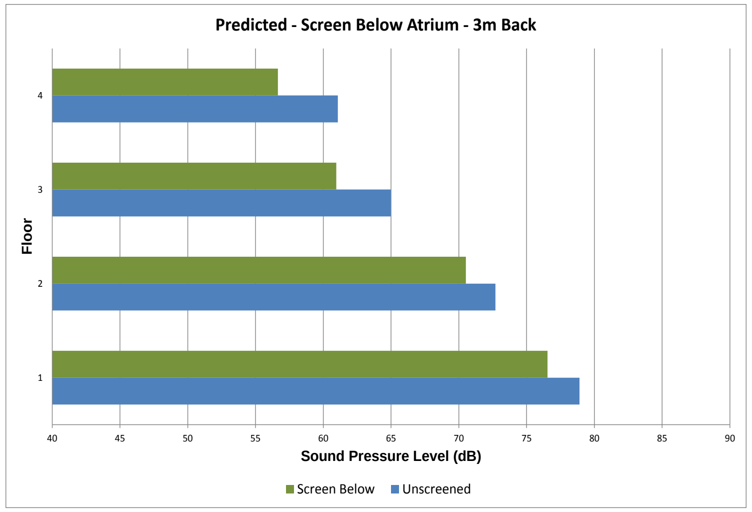
No balustrades have been included within this model and therefore predicted levels are likely to be reduced in reality. However, it would be more beneficial for the screen to continue further around the atrium especially in preventing occupancy noise due to the large areas of hard reflective surfaces within this space.

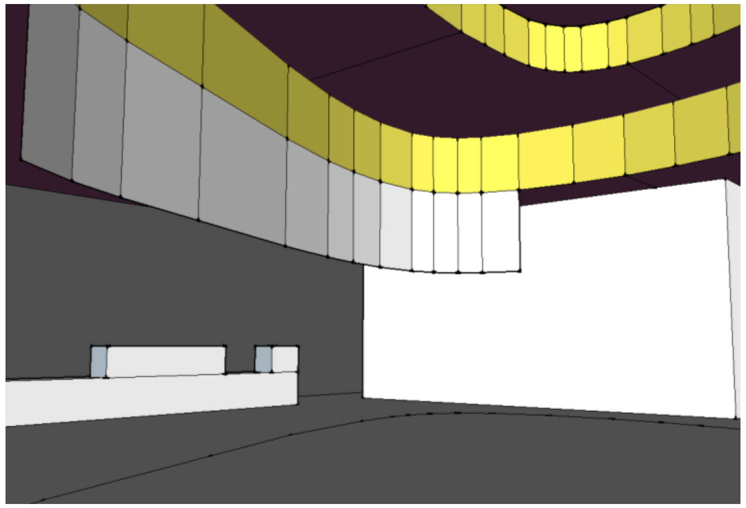
The photograph shows the cafe from a location on an upper floor within the library. It can be seen that the tables and seating encroach into the atrium area on the ground floor. For the screen below the atrium to be effective, the location of these would have to be changed to break the line of sight to the sensitive areas above.

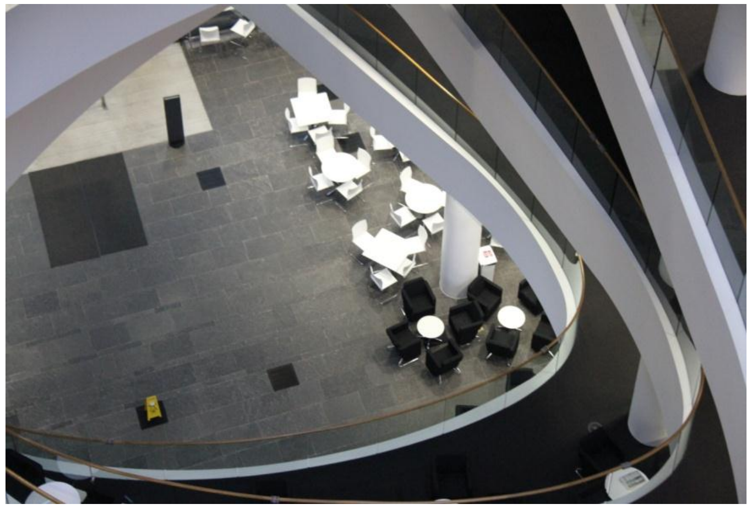
Screening to the Cafe

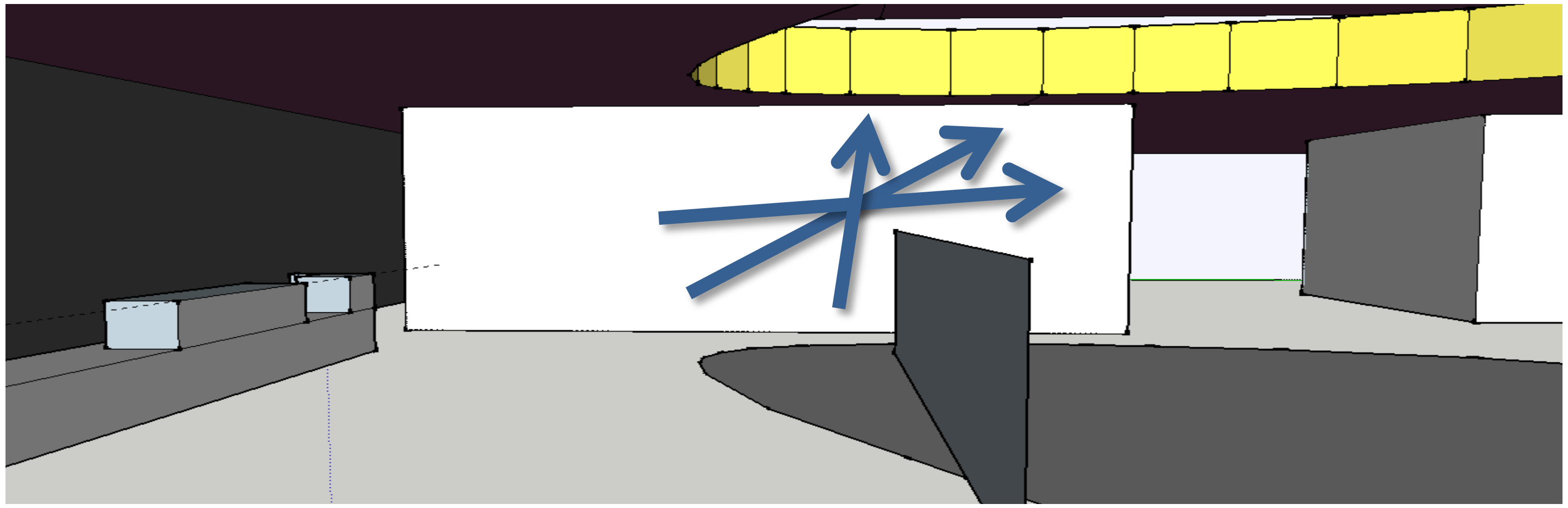
Screening to the cafe spaces is not shown to be effective since the receiver positions are located above the cafe. As such the sensitive spaces above can simply look over the top of the screens.











Screen to the First Floor

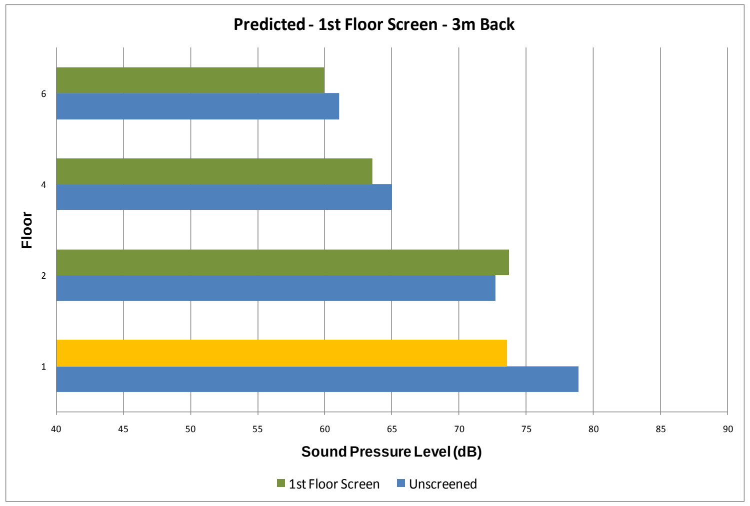
It is understood that noise transfer to the work station area on the 1st floor can be a real issue. A simple solution would be to place a screen between the Atrium and the Work Stations. An illustration of this screen on the 1st floor is shown in the screen image to the right. This screen has been modelled to be 2m high.

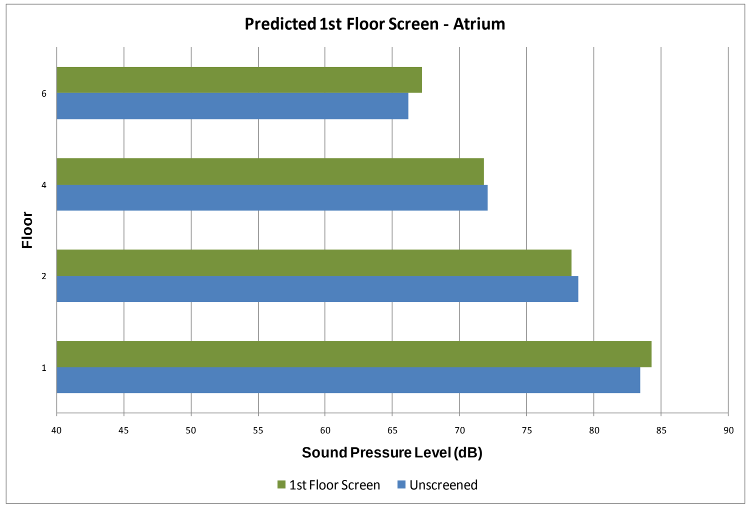
The results of this model are shown in the two graphs. The yellow bar in the left hand graph represents the sensitive areas located behind the screen. It is clear to see that at this location there would be a significant reduction in cafe noise levels with the introduction of a screen. All other locations would not experience any screening benefits.

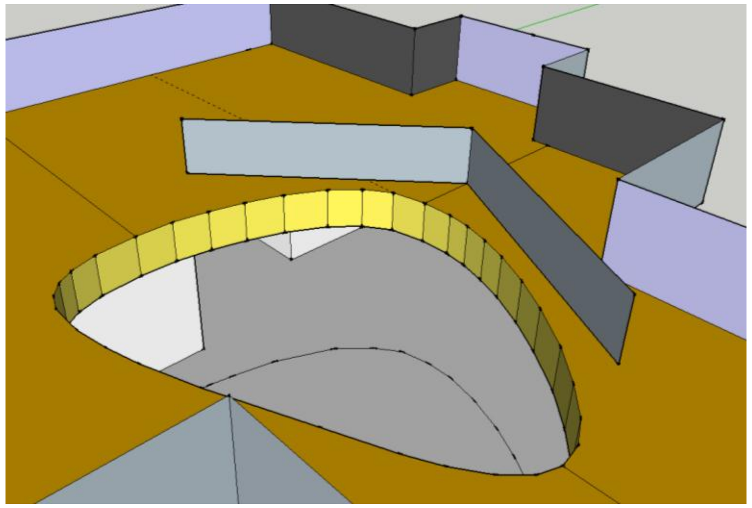
Maximising the Performance of Acoustics Screens

Acoustics screens can be compromised by reflection. Sound transfer could therefore be improved by treating the underside of the ceiling around the Atriums. Note that this assessment at this stage has not been undertaken. Please see Appendix A for further information.

A photo of a screen currently used within Aberdeen University Library is illustrated in the photo to the right.







Acoustic Treatment

Controlling noise by means of acoustic absorption is challenging. Acoustic absorption can be used to reduce noise by preventing sound reflecting off of walls adjacent to the cafe space. It will also absorb sound locally to the sound sources.

To demonstrate the affect of introducing absorptive materials within key areas of the library two assessments have made; 1) within the general area of the café and 2) within the gallery area. The absorptive material introduced in all cases performs as a Class A absorber.

Absorption around the Cafe

The left hand image illustrates acoustic absorptive materials being added to the walls and ceiling around the café area.

The results of this assessment are shown in the top two graphs . It can be seen that all assessed locations would benefit from the addition of acoustically absorptive materials around the café. It is also considered that on each floor, locations back from the atrium would experience the greatest benefit.

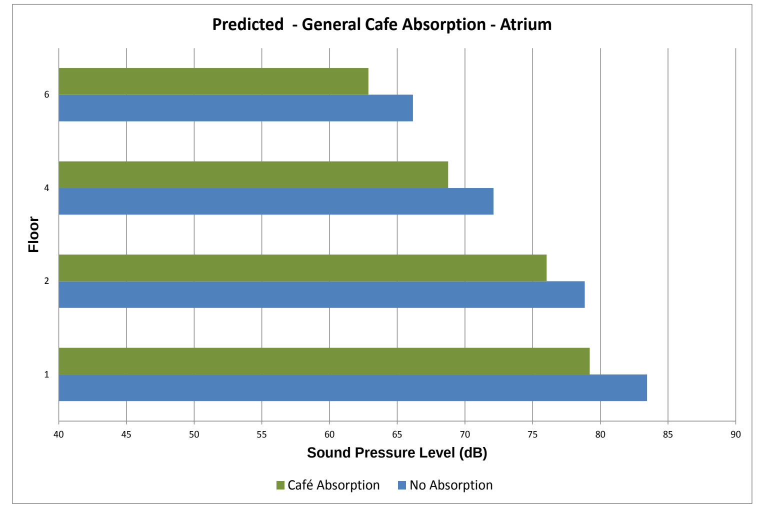
Absorption around the Gallery

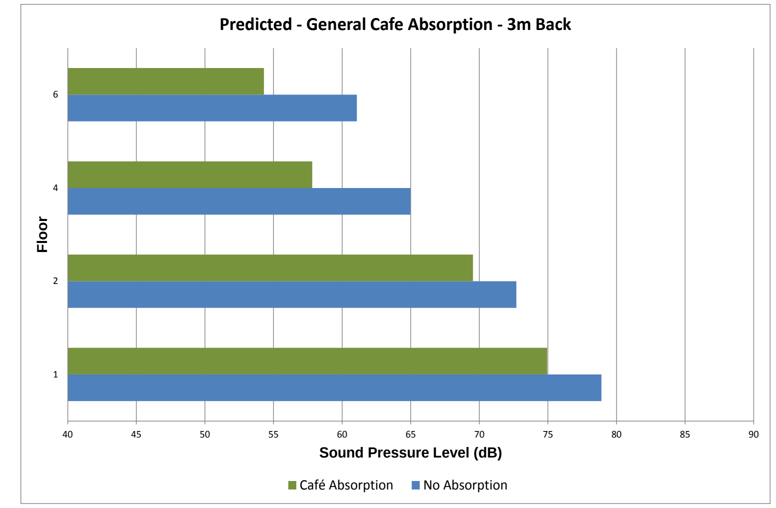
Acoustic treatment has been applied to the walls within the Gallery area. The right hand image illustrates the location of absorption within the gallery area on the ground floor.

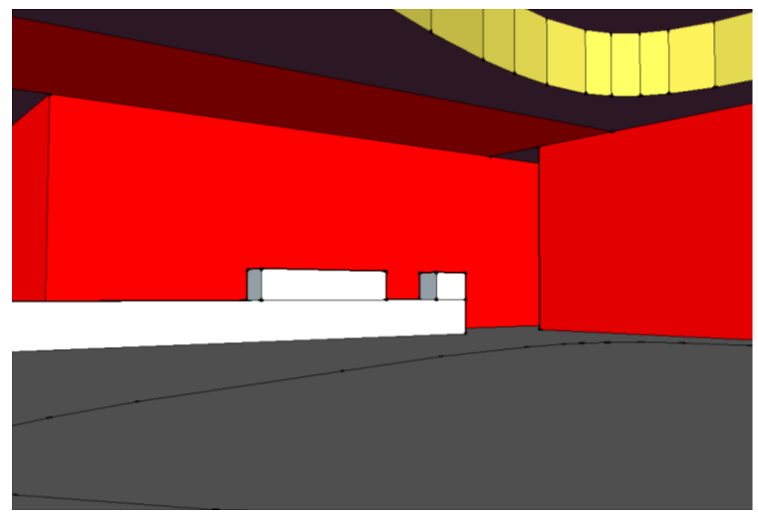
This is seen to provide the largest improvement in terms of noise spreading from ground level up through the atrium above, due the combination of absorption and screening provided by the building.

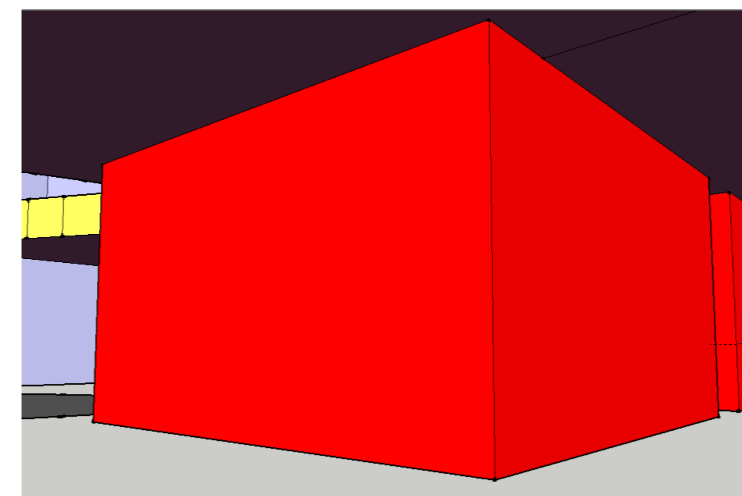
Subjective effect of Absorption

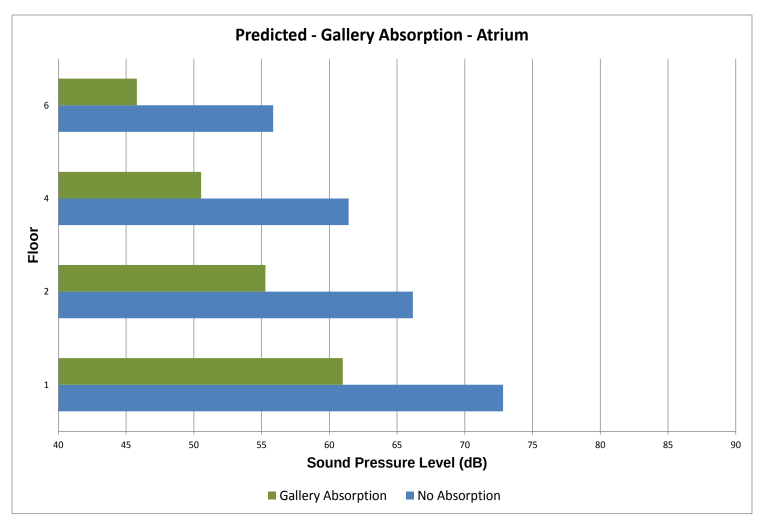
Although it is seen from the modelling results, that there would not be a dramatic reduction in noise levels experienced with the introduction of acoustic absorption in the café area. It is considered the cafe space would become less reverberant, which in turn would help to reduce noise build up and thus reducing overall noise levels within the café and ground floor area.

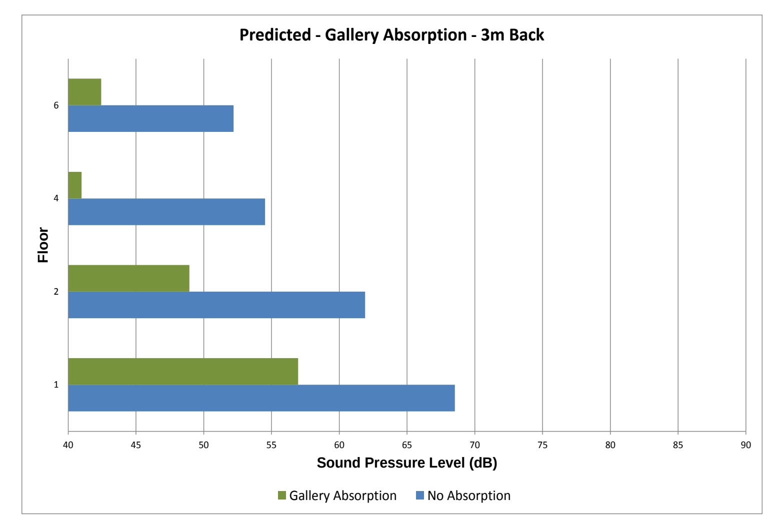










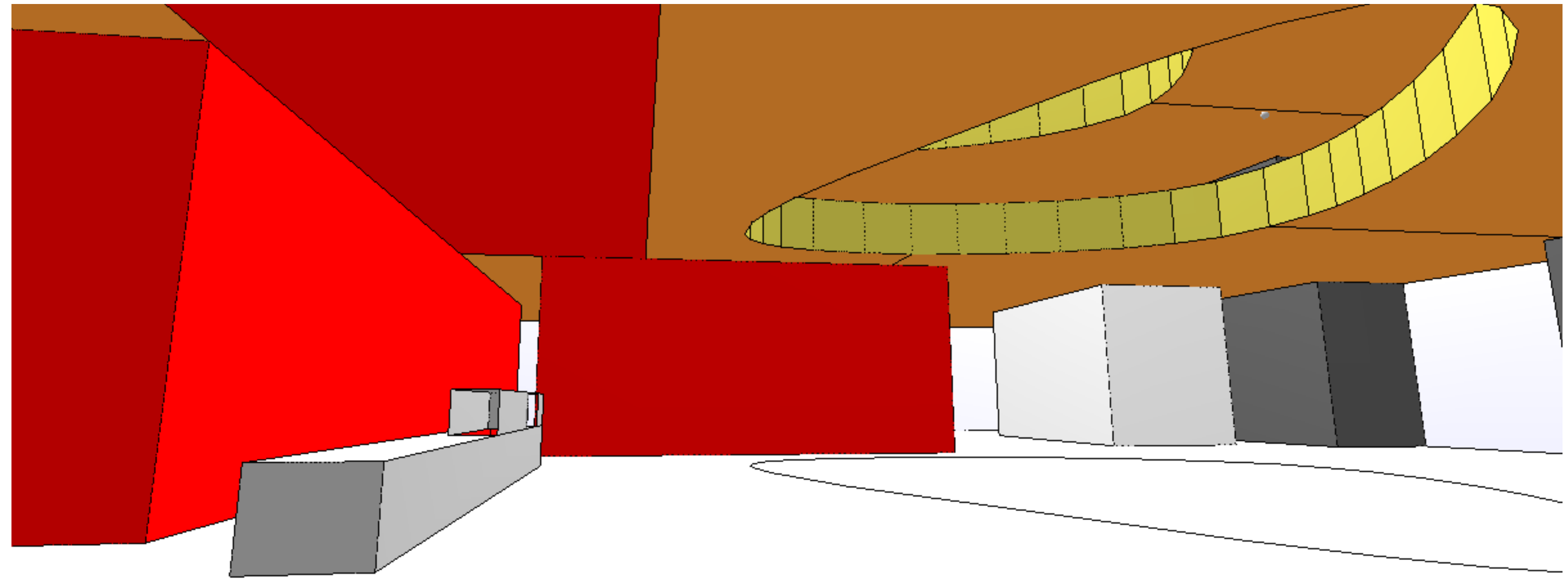


Acoustic Absorption – Modelling

For acoustic treatment to be efficient, it needs to be located where it can easily be reached by the sound. Therefore, acoustic treatment should ideally be located on the surfaces near to source to maximise efficiency.

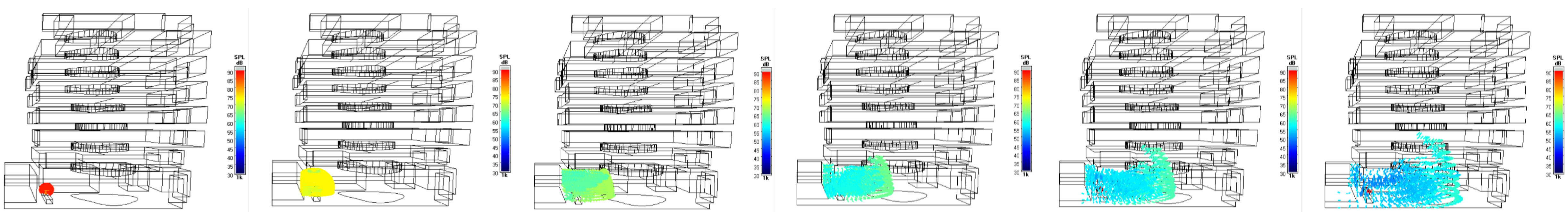
Ray tracing has been used to demonstrate the effect of introducing acoustic absorption in to a reverberant space. In this case within the general cafe area. These two series' of images illustrate sound propagating from a noise source on the cafe counter over a period of 50ms.

The images show that the sound is more readily absorbed where there is acoustic absorption within the cafe area, which results in an improved reduction in noise levels experienced throughout the library.

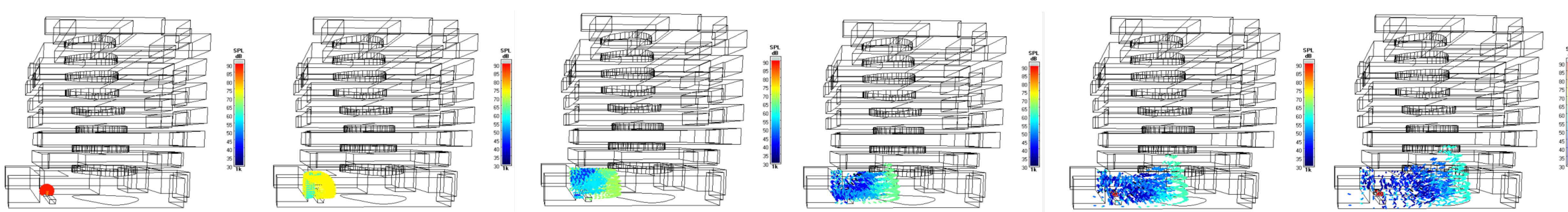


Acoustic treatment represented by red areas in image

No Acoustic Absorption



Acoustic Absorption



Acoustic Absorption Acting as a Screen

One method which combines both the use of screens and acoustic absorption is to place drop down acoustically absorbent screens around the base of the Atrium at the ground floor level. This is shown in the left hand image.

A comparison between the results of the model with and without acoustic treatment is presented in the top two graphs. It can be seen that introducing acoustic absorption to the screen below the atrium will further reduce noise levels experienced on the floors above. Further benefits could be achieved by maximising the performance of the screen or introducing carpet within the cafe space.

Local Absorption Near to the Sound Source

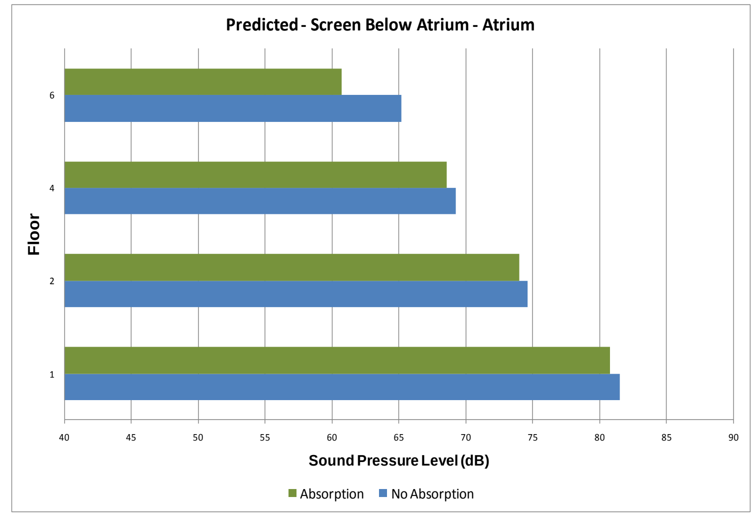
Acoustic absorption placed in close proximity to the sound source can be an effective method in controlling the spread of noise. However, it can be challenging to locate acoustic absorption near to the sound source.

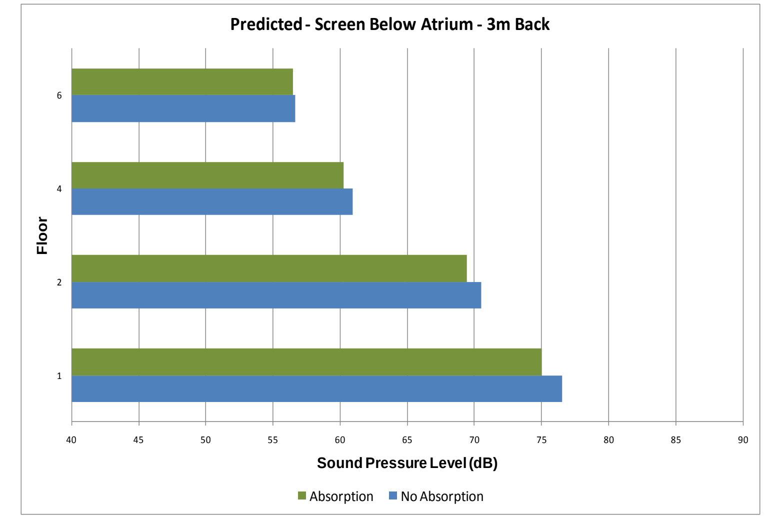
At this stage, simple analysis has been undertaken, where a simple rectangular plan of acoustics absorption has been placed above the cafe seating area 2 metres below the ground floor ceiling. This is shown in the image to the right hand side.

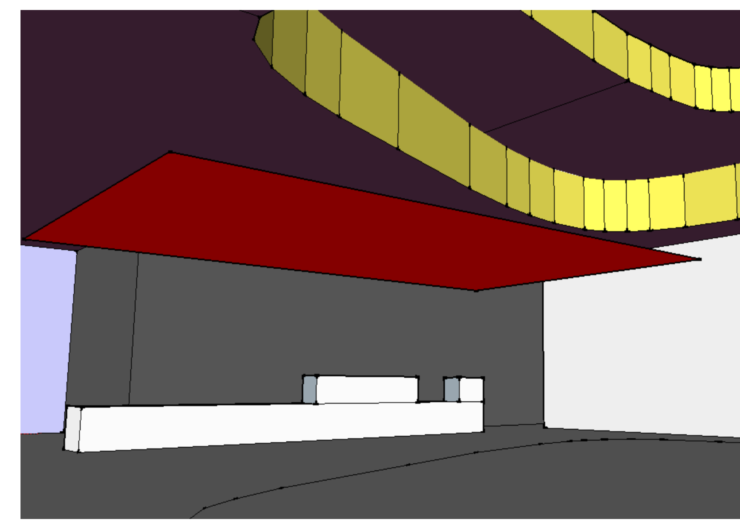
A comparison has once again be made for a screen with and without acoustic absorption, in this example for the screen suspended above the cafe area. It can be seen in the bottom two graphs that applying acoustic treatment to the screen above the cafe provides further reductions in noise levels experienced in the levels above.

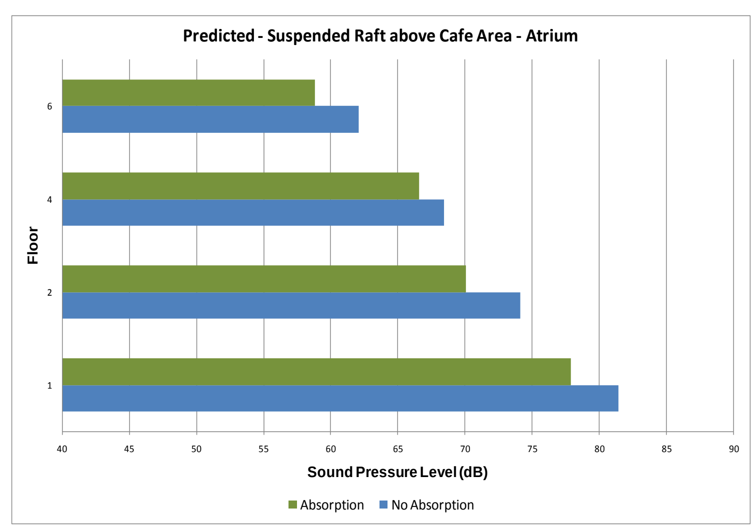
Different Forms of Acoustic Treatment

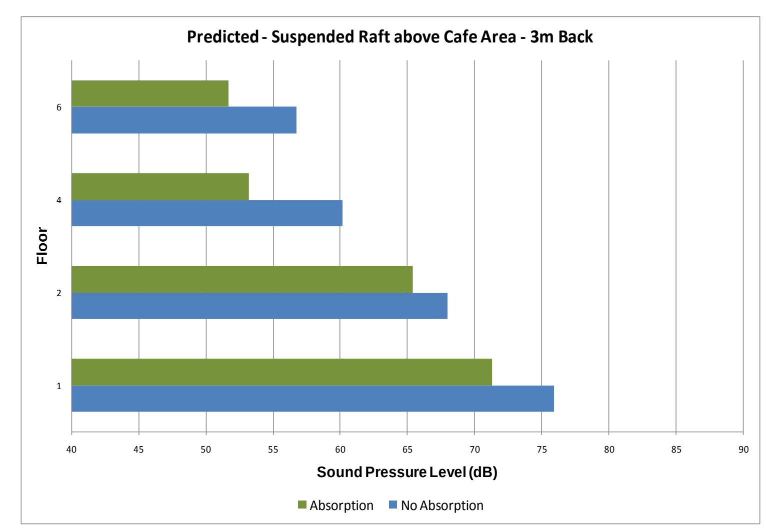
Acoustic treatment can take many forms. It is often the case that it will be located discretely within a room or space as to not affect the appearance of a space. It is however possible to introduce acoustic treatment by more creative means. Some examples of which are illustrated in Appendix C – Acoustic Treatment and includes examples of acoustic artwork and sculptures.











Noise control through management

When the cafe occupancy numbers are low, noise transfer through the atrium is understood to be considered as acceptable. Hence, it can be said that noise transfer could be controlled through a management process. This management process would be based around controlling occupancy numbers in the café, which could be done by:

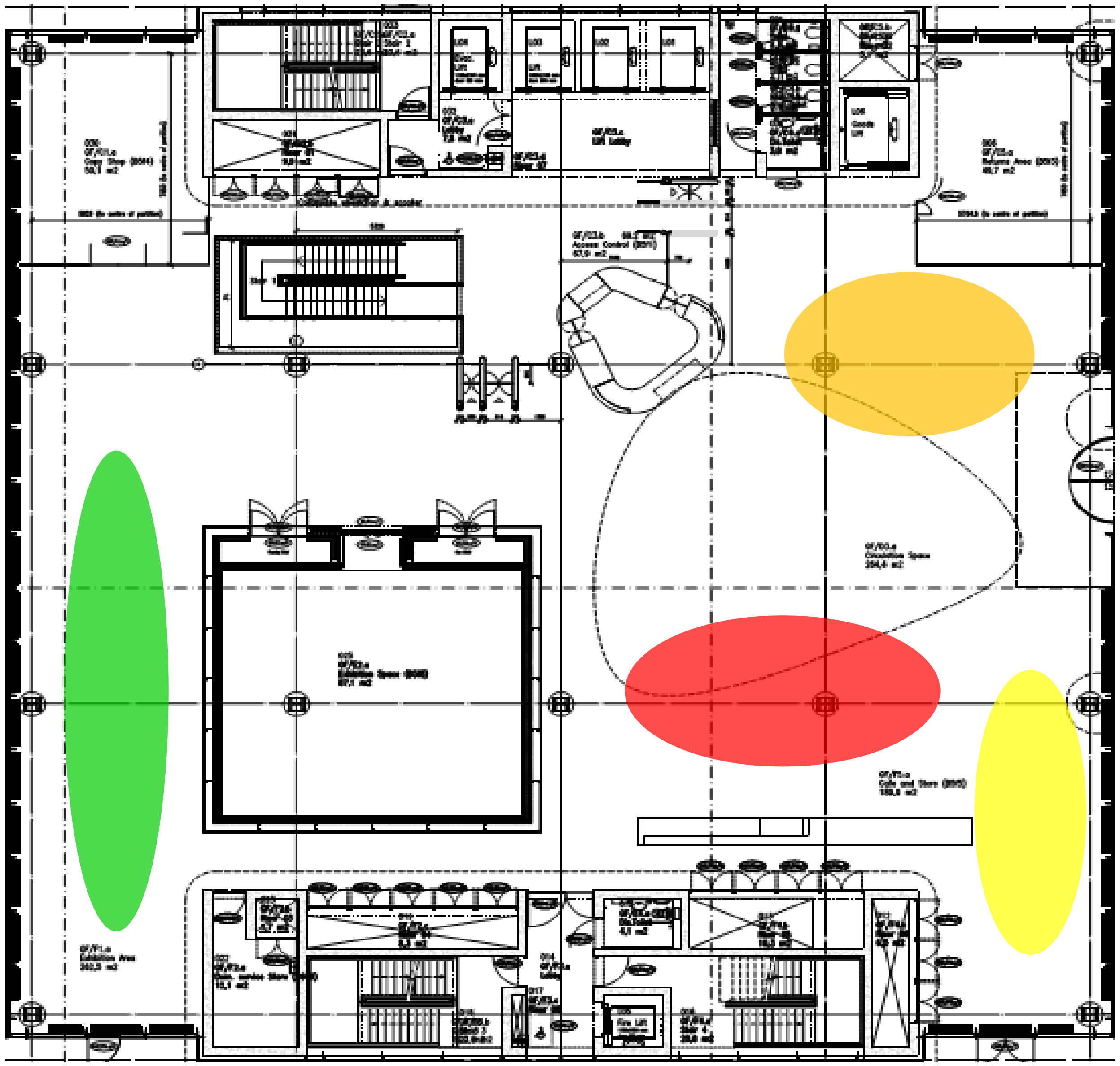
Only servicing the cafe clientele with refreshment if they can provide a table number. Table numbers and seating numbers are easy control, which intern would control pupil numbers. There may be a requirement to have different colour cups for takeout drinks.

Locating people in zones away from the atrium will have the benefit of reducing the level of noise being transmitted up through the atrium. Again, through the selection of cup colours and other tools, different students could be guided to different areas on the ground floor such to prevent the area below the atrium being occupied, i.e. if you have no table number you would be required to sit in the space behind the art gallery.

It may be possible for the staff to restrict people numbers by simply observing if crowd levels are getting to high. If the cafe is full, students may be turned away until student numbers are reduced.

Some types of tables generate more noise than others. Long thin benches along walls tend to prevent conversation. There could be specific coffee cups for these spaces which could be colour coded. Seating could also be fixed and located closer together so communication is easier and requires less effort.

As noted above, the library was observed out of term time, there may be some activities which make more noise than others.



Conclusion

A survey to identify the acoustic problems affecting the performance of the new library at Aberdeen University has been undertaken. The survey included subjective evaluations, as well as measurements to quantify the spread of noise throughout the library and reverberation times across a number of the floors.

The results of the survey identified that a number of noise sources associated with the café on the ground floor were the main cause of disturbance to other areas of the building. The most distracting noises were observed to be from furniture scraping on the floor, coffee production, trolley noise and most predominantly occupancy noise.

An assessment of different options to reduce noise break out from the café area distracting other users of the library has been undertaken through measurement and prediction. This assessment has been based upon the following two methods of noise control, or a combination of the two; 1) placing screens between the source and receiver and; 2) by introducing additional acoustic absorption .

Introducing a screen below the atrium on the ground floor is seen to provide an improvement in the noise levels experience on the floors above. The performance of this screen is considered to be limited by the hard ground floor covering which reflects sound up through the atrium.

Locating a screen on the first floor around sensitive areas has been modelled and predicted to be an effective method in reducing noise levels in this sensitive areas.

The introduction of acoustic absorption within the cafe area and also the gallery area has been modelled. The results of this modelling identified that the introduction of acoustic treatment near to the source reduced noise spreading to other areas of the building. It is seen that locating the source and acoustic treatment within the gallery area on the ground floor provided the greatest reduction in noise levels experienced on the floors above.

The combination of screening and acoustic absorption is therefore considered to provide more desirable results. Based upon this the performance of two different screens located near to the cafe area have been modelled, where a flat absorptive screen above the cafe area achieved the greatest reduction in noise levels experienced on the upper floors. Note that in all models with the exception of the Gallery model, the noise source was located on the café counter.

It is considered that controlling noise through management, i.e. the number of café users at tables or in areas with the greatest impact upon other areas of the library, will help to reduce noise levels on upper floors.

Coffee machine and grinder operational noise is seen to be distracting throughout the library. Through measurement and prediction it is seen that this could be significantly reduced by introducing an acoustically treated screen around the noise source. This is considered to be the most practical method of controlling this noise. Locating the cafe in an alternative area on the ground floor where screening is provided by the building itself, would also improve noise levels experienced throughout the upper levels of the building.

Trolley and trolley wheel noise was seen to be a problematic source of noise and therefore could be controlled by ensuring that the trolleys are of rigid construction and have pneumatic wheels ≥250mm diameter.

Furniture scraping on the floor noise is a common problem and it is seen that this can be avoided through the regular maintenance of the existing chairs, ensuring that the feet and floor pads are correctly installed. Another possibility could be to introduce carpet or rugs below tables and chairs to prevent scraping. This would also introduce a degree of acoustic absorption which would also be beneficial. This however may introduce cleaning and hygiene issues within the cafe area and effect the appearance of the space.

Appendix A – Screen Types – A

Screens are often disregarded during the design stage of a building due to the fact that the appearance of the screens normally does not meet the designers aspirations for design and functionality of the building.

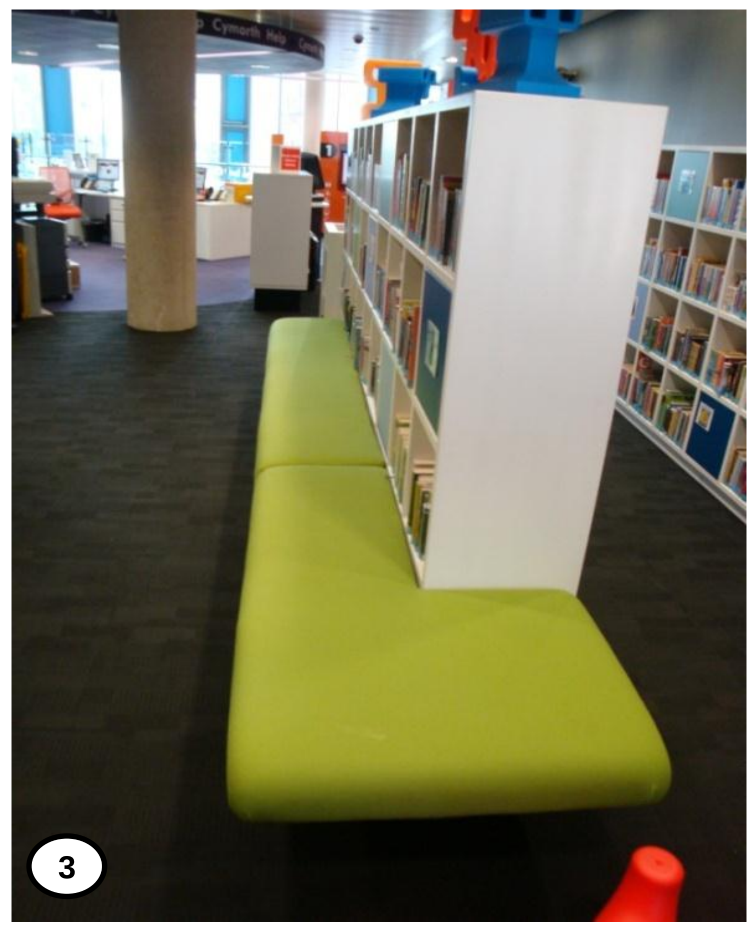
In MACH Acoustics view, the use of screens within open plan buildings can provide an effective and versatile method of introducing separation between different zones and areas.

This Appendix therefore aims to provide an illustration of a range of screen types with very different appearances.

Images 1 and 2 show how shelves have been used to provide exceptionally effective screens. These images show how the line of sight between two working zones can be broken without the introduction of what looks to be an acoustic screen. Note that back of the shelves is required to solid in order to achieve the screening effect.

During the site visit it was observed that the current book shelves do not have a solid backing. This may therefore be a possible option of improving the level of separation between the ground floor and study areas on the floors above. The photo below shows the current shelves within Aberdeen University Library.

Images 3 and 4 demonstrate a more creative type of screen. From here, it is clear that a range of different screen types can be combined with seating to form an acoustics break within an open plan environment. These seats could therefore be used to form a break out zone between work stations.

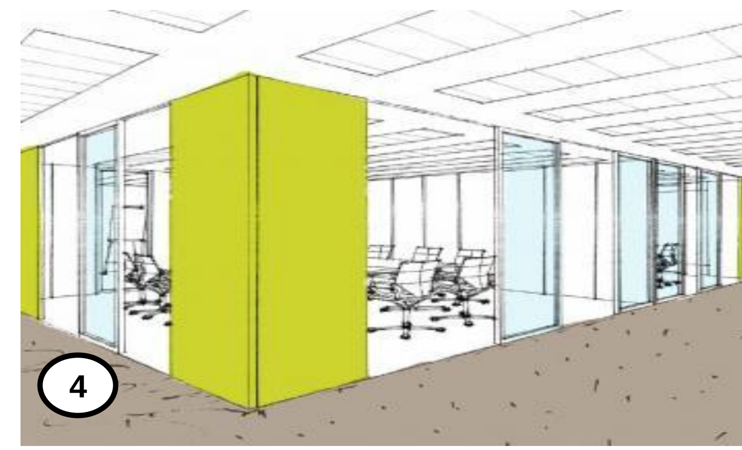


Appendix A – Screen Types – B

Round screens are an interesting method of providing break out zones within an office environment. The advantage of round screens is an increased level of acoustic screening, as the sound source tends to be more enclosed within this type of environment.

A second advantage of the screen shown in image 1 is that two different working zones can be placed on either side of this arrangement. The structure will not only increase the distance between the two different working zones, but will also effectively provide high levels of acoustic screening between these two areas.

Flexibility is an important aspect of these designs. Images 3 and 4 show an interesting concept used to provide flexible screening within an office space. Here, the head track to moveable walls has been installed into a range of locations. Light weight, low performance moveable wall panels can then be moved around to allow for different configurations, allowing for flexible screens to be moved as the function of the space changes over time. Please note that there are many different alternatives to this arrangement.



Appendix B – Maximising the Performance of Acoustic Screens

The purpose of this appendix is to explain the key factors affecting the performance of screens. This information is therefore aimed at ensuring that the maximum benefit from screens is achieved if these units are chosen to be used within this development.

Screen size, height and position (Cases 1 – 2 – 3):

The performance of a screen is dependant upon the distance the sound has to travel over the screen, therefore the higher the screen the better the performance. The minimum requirement for the screen is to break the line of sight between the source and receiver. As a minimum, the screen height should be no lower than head height, to prevent the spoken voice from passing over the screen (see Cases 1, 2 and 3).

Positioning of screens (Cases 4 and 5):

The acoustic performance of an acoustic screen is always limited by the fact that sound can pass over or around a screen. It is generally accepted that a well positioned, appropriately sized screen can provide up to 15 dB(A) of sound reduction, when located in a free field condition i.e. outside in an open field.

By bringing a screen indoors, reflections off hard surfaces are likely to compromise the screen further. Here, the maximum performance of a screen is likely to be limited to 10 dB(A).

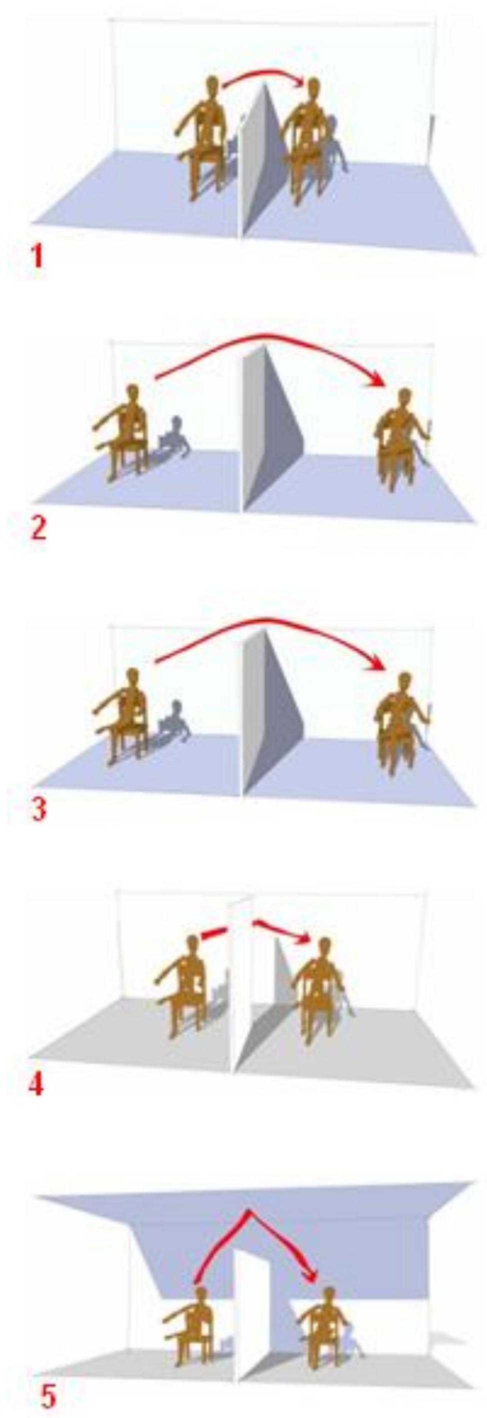
Cases 4 and 5 show the effect of placing a screen adjacent to a hard surface. Such to ensure the integrity of the screen in Case 1, the screen must be placed adjacent to a hard surface i.e. a wall, table or other hard object and sealed with mastic. There should also be no air gaps between the screen and any other surfaces. The alternative to Case 2 is to place an absorbent surface along the length of the reflective area.

Materials:

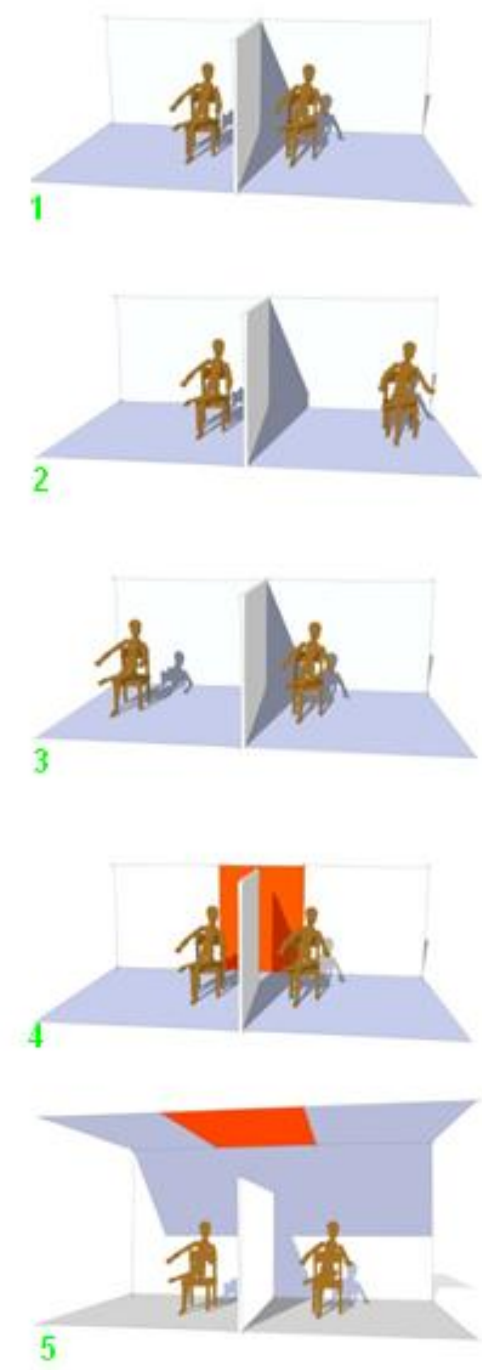
As sound can pass over the top and around the screen, screens are also often compromised by reflection. There is therefore little benefit in provide high levels of acoustic separation through the screen itself. The only acoustic requirement for the screen is therefore to have a mass equal to or greater than 10kg/m^2.

Ideally, the screen would be finished with an absorbent covering, i.e. mineral wool covered with cloth. This requirement is only likely to slightly increase the performance of the screen. On the other hand, finishing the screen with a soft covering will prevent the passage of sound as a result of reflections.

Sound paths around a screen



Maximising acoustic performance



Appendix C – Acoustic Treatment

Some examples of absorption classes A – C are presented in the images below.

Finishes Example – Class A

1 Good Grade Ceiling Tile 2 MACH Products – Cloth covered acoustic panels 3-4 Acoustic Art Work 5 Suspended Ceiling Tile

Finishes Example – Class B

MACH ACOUSTICS

1 MACH Products - Wooden Slats in fabrication 2 Example of Wooden Slats 3 Perforated wood within an Auditorium 4 MACH Products – Perforated wood within an atrium 5-6-7 Perforated Metal 8-9 MACH Products – Acoustic Art Work 10 Wood wool – Attached directly to the soffit of this office space

Finishes Example – Class C

1 Perforated plasterboard 2 Barrisol – A thin film of plastic hiding mineral wool attached directly to the soffit within the space shown 3 Pavatherm – A green and more robust alternative to mineral wool 4 Perforated Leather 5 MACH Products – Reed panels 6 Plastic Mesh 7-8 MACH Products – Acoustic Wall Paper 9 MACH Products – Rubber/Foam acoustic wall panels

Examples of Acoustic Sculptures and Treatment

An acoustic sculpture, i.e. a 3 dimensional object made of an absorbent material, could be suspended in the voids to limit the noise transfer from the Ground Floor to the floors above. The images above, provide examples of acoustic sculptures. This principle could be effective and efficient for providing acoustic absorption whilst adding an artistic touch to the building. To further this some examples of acoustic wall panels are presented below.

Appendix D –Spread of Noise Measurement Results

SPEAKER ON COUNTER

Atrium								
Floor	63	125	250	500	1K	2k	4k	L_{Aeq}
1	63.64	74.54	77.14	73.74	73.74	71.74	73.94	80.64
2	60.24	71.14	74.84	69.14	70.24	70.64	70.34	77.34
4	52.54	61.34	64.94	63.14	64.04	63.64	61.84	69.74
6	48.74	57.74	59.44	57.14	60.34	60.34	59.94	66.64

SPEAKER ON COUNTER SCREENED

Atrium								
Floor	63	125	250	500	1K	2k	4k	L_{Aeq}
1	54.94	68.64	71.94	66.54	65.44	65.94	68.14	74.24
2	51.14	61.84	63.54	61.54	62.14	61.74	64.04	70.04
4	52.04	51.54	52.64	51.34	54.64	55.54	53.04	60.74
6	48.44	47.14	46.64	45.74	46.84	47.04	43.84	52.44

SPEAKER IN CORNER

Atrium								
Floor	63	125	250	500	1K	2k	4k	L_{Aeq}
1	65.24	74.64	73.54	72.64	72.24	72.14	74.24	80.74
2	58.34	72.34	72.74	69.74	68.44	68.04	68.44	75.34
4	54.24	64.44	65.14	63.14	65.04	63.74	63.44	70.64
6	46.34	58.54	56.54	56.14	58.04	57.44	56.54	63.74

SPEAKER IN CENTRAL ATRIUM

Atrium								
Floor	63	125	250	500	1K	2k	4k	L_{Aeq}
1	70.64	79.24	78.84	74.84	75.54	72.94	74.94	81.44
2	71.44	77.74	75.14	72.14	73.54	69.84	70.84	78.34
4	58.94	68.54	67.94	66.34	67.64	66.54	66.04	73.44
6	55.14	62.64	62.24	59.24	61.84	60.74	60.04	67.24

GALLERY

Atrium								
Floor	63	125	250	500	1K	2k	4k	L_{Aeq}
1	54.64	65.24	67.04	64.24	67.04	65.64	65.04	72.24
2	53.44	64.54	62.34	60.94	61.94	60.84	60.24	67.44
4	48.84	58.14	59.44	58.44	58.84	58.04	56.24	64.24
6	43.74	50.34	51.94	50.44	53.24	51.64	49.44	57.84

SPEAKER ON COUNTER

3m Back								
Floor	63	125	250	500	1K	2k	4k	L_{Aeq}
1	38.94	44.84	58.24	63.94	63.04	70.14	67.74	75.44
2	42.44	42.84	54.84	55.84	59.94	64.74	67.64	72.94
4	39.04	39.64	43.54	47.94	50.94	56.54	56.44	63.74
6	52.54	40.94	40.54	43.14	43.04	48.04	49.04	60.74

SPEAKER ON COUNTER SCREENED

3m Back								
Floor	63	125	250	500	1K	2k	4k	L_{Aeq}
1	55.74	66.54	71.44	66.44	65.14	65.44	67.34	73.34
2	47.14	59.14	58.54	55.84	55.84	55.24	56.34	62.64
4	48.94	50.24	49.94	49.44	51.54	52.14	49.54	57.44
6	45.24	48.64	48.84	45.44	45.24	44.54	41.24	50.74

SPEAKER IN CORNER

3m Back								
Floor	63	125	250	500	1K	2k	4k	L_{Aeq}
1	55.04	68.54	71.44	66.54	67.44	68.04	68.54	75.04
2	54.74	66.44	67.44	62.24	63.04	63.84	62.84	70.04
4	46.14	59.74	58.64	57.54	58.04	58.54	57.44	64.54
6	43.84	50.44	50.64	51.34	53.24	53.34	51.44	59.04

SPEAKER IN CENTRAL ATRIUM

3m Back								
Floor	63	125	250	500	1K	2k	4k	L_{Aeq}
1	64.84	74.34	73.94	67.84	70.04	67.94	68.64	75.64
2	62.64	69.54	69.84	64.54	67.84	64.14	63.64	71.94
4	51.04	61.64	62.94	58.34	60.44	59.24	58.64	65.94
6	45.54	54.14	54.34	52.24	54.34	53.94	52.14	59.84

GALLERY

3m Back								
Floor	63	125	250	500	1K	2k	4k	L_{Aeq}
1	52.64	61.24	62.84	59.74	61.74	61.04	59.44	67.14
2	46.14	58.54	59.54	55.64	56.54	56.44	54.34	62.44
4	44.94	50.14	52.84	50.04	51.44	51.34	48.94	57.14
6	50.14	43.54	45.04	44.24	46.24	45.14	41.54	50.84

Appendix D – Survey Results Reverberation

Floor	Location	ID	250 Hz	315 Hz	400 Hz	500 Hz	630 Hz	800 Hz	1 kHz	1.25 kHz	1.6 kHz	2 kHz	2.5 kHz	3.15 kHz	4 kHz	5 kHz	T_{mf}
6th Floor	Within books	A	0.3	0.4	0.5	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
6th Floor	Within books	A	0.3	0.4	0.4	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.3
6th Floor	Atrium	B	0.7	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.9	0.7	0.7	0.6	0.6	0.6	0.7
6th Floor	Atrium	B	0.7	0.7	0.7	0.8	0.7	0.7	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.6	0.8
6th Floor	Screened area	C	0.6	0.6	0.6	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.4	0.5
6th Floor	Screened area	C	0.6	0.6	0.5	0.5	0.5	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.5
6th Floor	Screened area	D	1.1	1.0	0.8	0.7	0.6	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.5	0.7
6th Floor	Screened area	D	1.0	1.2	0.7	0.6	0.7	0.7	0.7	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.7
3rd Floor	Atrium	A	0.7	0.8	0.7	0.9	0.8	0.7	0.7	0.8	0.7	0.7	0.7	0.7	0.6	0.5	0.8
3rd Floor	Atrium	A	0.2	0.4	0.6	0.6	0.6	0.6	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7
3rd Floor	Within books	B	0.4	0.5	0.4	0.4	0.4	0.5	0.4	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.4
3rd Floor	Within books	B	0.3	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.4
3rd Floor	Screened area	C	0.6	0.6	0.6	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.5
3rd Floor	Screened area	C	0.5	0.7	0.5	0.5	0.6	0.6	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.4	0.5
3rd Floor	Central space adjacent to lifts	D	1.1	1.1	0.9	0.7	0.6	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.7
3rd Floor	Central space adjacent to lifts	D	1.1	1.0	0.9	0.8	0.7	0.9	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.7
1st Floor	Central space adjacent to lifts	A	1.0	1.1	1.1	0.8	0.8	0.9	0.8	0.9	0.8	0.8	0.8	0.9	0.8	0.7	0.8
1st Floor	Central space adjacent to lifts	A	1.1	0.9	0.9	0.9	0.8	0.9	0.8	0.9	0.9	0.8	0.8	0.8	0.8	0.7	0.8
1st Floor	Atrium - Set 1	B	1.7	1.8	1.6	1.7	1.7	2.0	2.0	2.0	2.1	2.1	2.0	1.8	1.8	1.5	1.9
1st Floor	Atrium - Set 1	B	1.0	1.1	1.2	1.3	1.1	1.4	1.3	1.4	1.4	1.4	1.3	1.3	1.3	1.2	1.3
1st Floor	Atrium - Set 2	C	1.2	1.2	1.0	1.0	1.2	1.2	1.3	1.4	1.4	1.3	1.4	1.4	1.3	1.2	1.2
1st Floor	Atrium - Set 2	C	1.2	1.2	1.0	1.1	1.2	1.1	1.3	1.3	1.4	1.5	1.3	1.3	1.3	1.2	1.3
1st Floor	Central Space (lifts)	D	1.0	0.9	0.8	0.8	0.7	0.8	0.7	0.8	0.7	0.8	0.7	0.8	0.8	0.8	0.7
1st Floor	Central Space (lifts)	D	0.2	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Ground Floor	Corner	A	1.1	1.1	1.0	1.2	1.2	1.3	1.4	1.5	1.3	1.2	1.2	1.2	1.0	1.0	1.3
Ground Floor	Corner	A	1.1	1.2	0.9	1.2	1.2	1.3	1.3	1.4	1.3	1.3	1.3	1.2	1.0	0.9	1.3
Ground Floor	Central Café	B	0.9	0.9	1.1	1.5	1.3	1.4	1.5	1.8	1.7	1.5	1.3	1.4	1.3	1.1	1.5
Ground Floor	Central Café	B	0.8	0.9	1.2	1.3	1.3	1.3	1.5	1.9	1.6	1.4	1.3	1.4	1.2	1.2	1.5
Ground Floor	Central Atrium	C	1.6	1.6	1.5	1.4	1.6	1.9	1.9	1.9	2.0	1.9	1.7	1.6	1.3	1.2	1.8
Ground Floor	Central Atrium	C	1.6	1.6	1.5	1.4	1.6	1.8	1.8	1.8	1.9	1.9	1.9	1.7	1.4	1.2	1.8
Ground Floor	Gallery experience	D	1.7	1.6	1.5	1.7	1.6	1.9	1.8	1.9	1.9	1.9	1.8	1.7	1.4	1.4	1.8
Ground Floor	Gallery experience	D	1.1	1.4	1.4	1.4	1.6	1.7	1.7	1.9	1.9	1.9	1.9	1.8	1.7	1.4	1.7
Ground Floor	Exhibition space	E	1.4	1.8	1.7	1.6	1.7	1.9	1.9	1.8	2.0	2.0	1.9	1.8	1.5	1.3	1.8
Ground Floor	Exhibition space	E	1.9	1.7	1.8	1.8	1.9	2.1	2.2	2.2	2.2	2.2	2.1	2.0	1.8	1.6	2.1
Ground Floor	Floor print room	F	1.8	1.8	1.6	1.7	1.8	1.9	1.9	2.1	2.1	2.1	1.9	1.8	1.6	1.5	1.9
Ground Floor	Floor print room	F	2.2	2.3	2.4	2.4	2.3	2.1	2.4	2.4	2.5	2.5	2.4	2.4	2.1	1.9	2.4