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The contribution of room acoustic design on control of ambient noise level in atria

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ABSTRACT

The aim of this research is to examine the degree to which the fit out room acoustic design affects reverberant activity noise level in atria, relative to other contributing factors, such as atria geometry and spatial planning. Acoustic modelling outputs are presented to demonstrate the comparative changes in reverberant noise level that result from modifying each contributing design factor, given otherwise consistent conditions. The research is intended to inform the atria design approach in respect to which design element require greater emphasis for the purpose of controlling reverberant activity noise level in atria.

Keywords: Noise, Environment, Annoyance
I-INCE Classification of Subject Number: 51

1. INTRODUCTION

Open atria present inherent acoustic design challenges and limitations, with sound being able to transfer more readily between spaces. In commercial office building projects with connecting atria, controlling excessive activity noise build-up and transfer is commonly a key concern for clients, designers and end users alike. This has been the case for many years, and projects continue to proceed at the risk of atrium noise becoming unacceptably disruptive in the absence of a comprehensive calculation method to determine the most effective design approach for controlling atrium noise, the associated design limitations, and the ultimate sound experience to be expected.

The design approach to meeting atrium activity noise control expectations tends to place emphasis on the acoustic design, specifically the provision of sound absorbing finishes within the spaces. While it is established that providing sound absorbing finishes can significantly lower activity sound levels in connecting atria, addressing this design problem through these means alone might not be the most effective in terms of the performance outcome and cost. Other contributing design factors should be considered for a more comprehensive and informed design approach, including the spatial planning of workstations, the atrium location on the floor plate, and the atrium volume.

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A quantitative calculation method has not been developed to determine the most effective approach considering all of these factors. This research sets out to quantify the comparative contribution and limitations of the room acoustic design in this respect.

2. METHODOLOGY

Room acoustic modelling was completed using CATT-Acoustic acoustic modelling software. A ‘base’ scenario was modelled to define control performance parameters. Several test scenarios were also modelled, each having one type of room condition modified from the base scenario to examine the change in atrium noise level resulting from each room condition modification in isolation.

2.1 Base modelling scenario

The base modelling scenario is four-floor open office space with a full height atrium location at the centre of the floor plate. The total volume is 18,026 m^3, inclusive off atrium and open office spaces.

Five sound sources were used, with one located in the open office space on each floor at 2 m distance from the atrium edge, and one at the base of the atrium. These are shown as A0 through A4 in Figure 1. An average ‘normal’ voice level spectra for male and female talkers was used for each source, equal to 59.5 dB(A) sound pressure level at 1 m distance. The sources are aiming at a 90-degree angle from the atrium. There are two receivers, both located at the base of the atrium and shown as 01 and 02 in Figure 1.

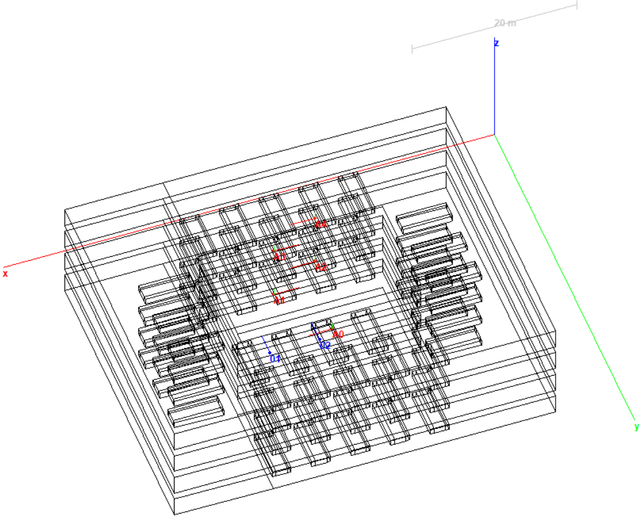

Figure 1: Source and receiver locations for base scenario.

Room acoustic finishes in the base scenario are intended to represent a typical fitted out office, with minimal additional sound absorbing treatment. Room finish locations, types and sound absorption ratings are shown in Table 1.

Table 1: Room finish types and sound absorption ratings for base scenario.

Room finish	Description	Noise Reduction Coefficient
Atrium balustrades	Glass	0.03
Atrium ceiling	Concrete (exposed soffit)	0.02
Atrium floor	Concrete	0.02
Atrium slab edge	Concrete	0.02
Façade	Glass	0.03

Room finish	Description	Noise Reduction Coefficient
Furniture	Timber table Lightly upholstered chairs (occupied)	0.05 0.79
Open office ceiling	Mineral fibre ceiling tile	0.50
Open office floor	Carpet	0.26

2.2 Test modelling scenarios

The test modelling scenarios are described in terms of the difference in room conditions in comparison to the base scenario in Table 2.

Table 2: Room acoustic test scenarios.

Scenario	Description	Specification modified from base scenario
1a	Room finishes have higher sound absorption ratings in atrium	- NRC 1.0 atrium ceiling - NRC 0.5 atrium floor finish - NRC 1.0 atrium slab edge
1b	Room finishes have higher sound absorption rating in open office areas	- NRC 1.0 open office ceiling
1c	Room finishes have higher sound absorption ratings in atrium and open office areas	- NRC 1.0 atrium ceiling - NRC 0.5 atrium floor finish - NRC 1.0 atrium slab edge - NRC 1.0 open office ceiling
2	Open office sound sources located at further distance from atrium	- Sources A1-A4 located at 10 m distance from atrium
3	Atrium adjoins façade	- Atrium adjoins façade on one side
4	Atrium volume increased	- Atrium extends eight floors vertically - One source added on each new floor at 2 m from atrium edge (A5-A8)

3. RESULTS

Figure 2 presents the average sound pressure levels at the receivers for each modelling scenario. The direct and 1st order reflected sound from A0 and A1 sources on the ground level were dominant. This was confirmed by ray tracing analysis. The results are therefore presented with and without sources A0 and A1 active.

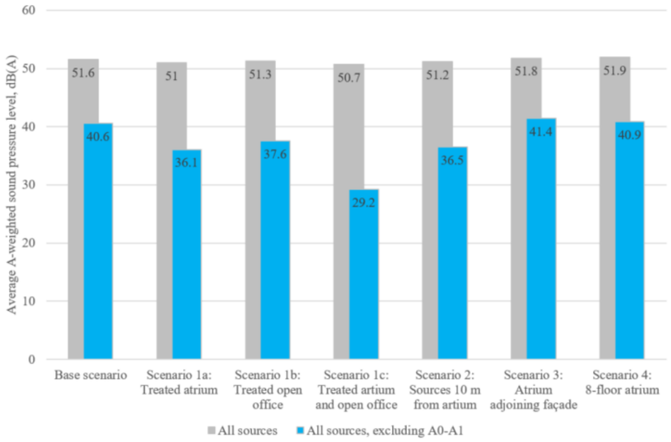

Figure 2: A-weighted sound pressure level results, all sound sources active.

Figure 3 shows results expressed as the difference in average sound pressure level between the base and test scenarios, with A0 and A1 sources inactive and all other sources active.

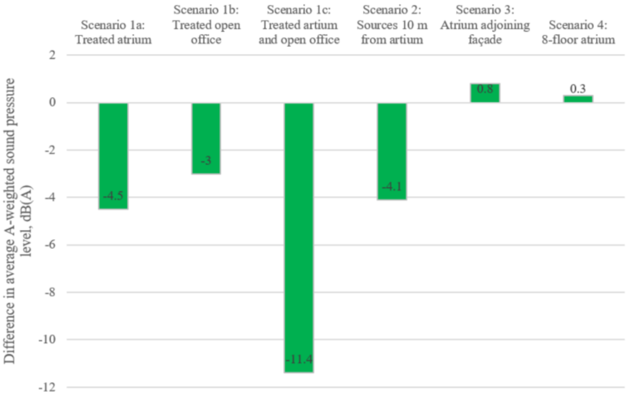

Figure 3: Difference in average A-weighted sound pressure level result from test scenarios in comparison to base scenario, all sources active, excluding A0 and A1.

1/1 octave band sound level results showed uniform amplification/attenuation across frequency bands between the test scenarios, the only exception being Scenarios 1a, 1b and 1c, where there was less attenuation at 125 Hz and 250 Hz 1/1 octave bands. This is due to the octave sound absorption coefficients of the NRC 1.0 ceiling treatment being poorer in those frequency bands.

Note that all image source model results presented and discussed from Section 3.1 onwards are the summed sound level paths of 125 Hz–16 kHz 1/1 octave band sound levels and exclude sources A0 and A1 on the ground floor.

3.1 Sound absorbing treatment scenarios

Providing sound absorbing treatment to both the atrium and open office ceilings resulted in substantially greater sound attenuation than the other test scenarios. It is noted that the sound loss resulting from treating both the atrium and open office in Scenario 1c is substantially greater than the linear sum of the losses from treating the atrium and open office in isolation (Scenarios 1a and 1b respectively). This is primarily due to the presence of strong 2nd order reflections off the untreated atrium ceiling in Scenario 1b (see example in Figure 4) and strong 1st order reflections off the untreated open office ceiling in Scenario 1a being substantially absorbed by the additional treatment Scenario 1c.

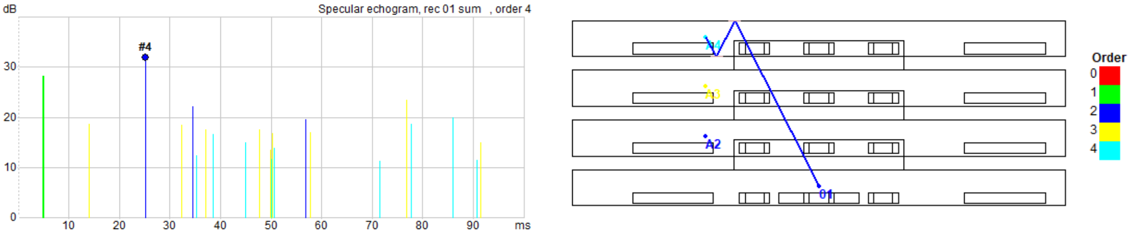

Figure 4: Scenario 1b (treated open office) image source model.

3.2 Source distance from atrium

Moving the sources to 10 m distance from the atrium resulted in a similar amount of overall sound reduction to the treated atrium scenario. The amount of significant reflected sound paths reaching the receivers was considerably reduced compared to the base scenario due to the geometric limitations created by moving the sources further away from the atrium; the increased incidence of sound with sound absorbing finishes (notably the open office ceiling and floor); and the greater distance sound paths required to reach the receivers.

All 1st order reflection paths were eliminated, as shown in Figure 5, and there were no prominent reflections received from the sources on the upper two floors (A3 and A4).

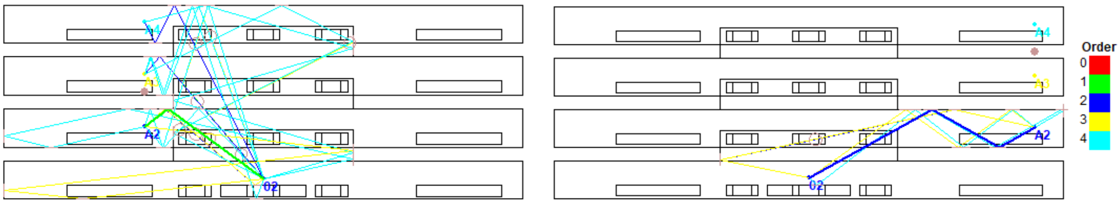

Figure 5: Image source model, sources A2-A4 to receiver 02. Base scenario (left) and Scenario 2 (right).

3.3 Atrium adjoining façade

Relocating the atrium to adjoin the façade in Scenario 3 resulted in a slight increase in sound level at the receivers that would likely be an imperceptible difference. This was because there were no strong reflections off the façade itself that would not have reflected off the slab edge in the base scenario. Figure 6 shows the strongest reflection off the façade at receiver 01 that is not at slab edge height.

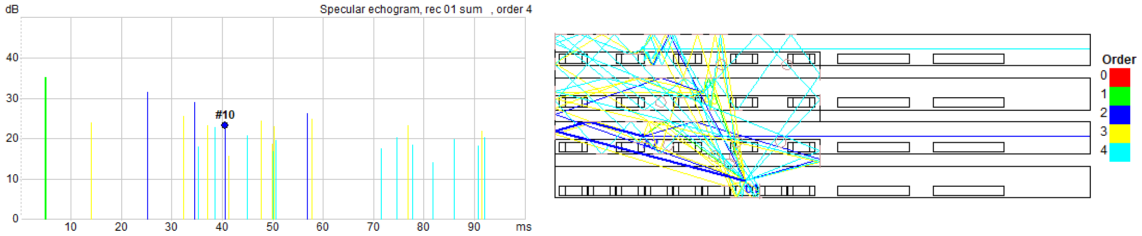

Figure 6: Strongest Scenario 3 façade reflection that is not at slab edge height (#10).

3.4 Atrium volume

Similar to Scenario 3, increasing the room volume while adding a new source on each new floor resulted in a slight increase in sound level at the receivers that would likely be an imperceptible difference. Strong reflections from level 3 (source A4) are lost and there are no strong reflections from the floors above (sources A5-A8). The dominant paths are 1st order reflections from levels 1 and 2 (sources A2 and A3), as shown in Figure 7 below.

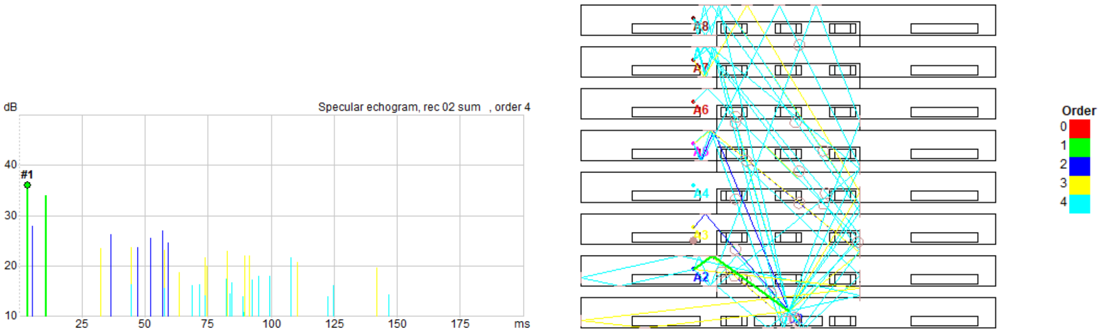

Figure 7: Scenario 4 image source model, receiver 02.

4. DISCUSSION

The results do support the placing of emphasis on sound absorbing treatment to control noise transfer into the atrium from office floors above, while noting that the atrium and the open office room finishes need to be designed in correlation rather than in isolation to provide the greatest noise reduction benefit.

The results do not however support providing sound absorbing treatment as the most effective means for controlling the overall activity sound level at the base of the atrium, as this is primarily driven by sound sources located at the base of the atrium and in adjacent office spaces on the same floor. The designated usage/s at the base of the atrium and horizontally connecting spaces are therefore considered the design factor of greatest significance in this respect. If the designated usage results in an undesirable sound environment, the options for mitigating it via the room acoustic design are limited (short of partitioning the area). Conversely, it is acknowledged that the nature of the sound sources in these locations could be considered desirable in some contexts, which could render the activity noise unproblematic – for example, if the talker and listener's activities are complementary.

Spatially arranging open office workstations to be at a greater distance from the atriums edge (10 m compared to 2 m in this case), providing sound absorbing treatment to the atrium only, or providing sound absorbing treatment to the open office ceiling only resulted in a perceptible difference in activity noise level at the base of the atrium, but not as greater difference as the aforementioned scenarios.

Atria adjoining glazed façades compared to atria located in the middle of the floor plate resulted in a minimal change to the activity noise level in this case. The same can be said for doubling the atrium height and volume. While relocating the atrium to adjoin façade did not result in a substantial change in noise level, it is noted nonetheless that receiver locations in this model are a limitation of this aspect of the study, in that the difference in sound level would have likely been greater for receivers located closer to the façade in this scenario.

5. CONCLUSIONS

The designated usage at the base of the atrium and horizontally adjoining spaces and the provision of sound absorbing finishes bared the greatest influence on activity noise level at the base of these atrium of the modelled scenarios. Sound absorbing treatment is significantly more effective for controlling noise transfer when provided to both the atrium and open office areas. Whereas providing sound absorbing treatment to the atrium only or open office areas only reduces the benefit substantially.

The current work is the starting point of a more substantial study, with next stage of research being to include model similar scenarios with a greater number of sound sources. In addition, investigating the change in activity sound level at additional receiver locations within the atrium and open office spaces is warranted.

6. ACKNOWLEDGEMENTS

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