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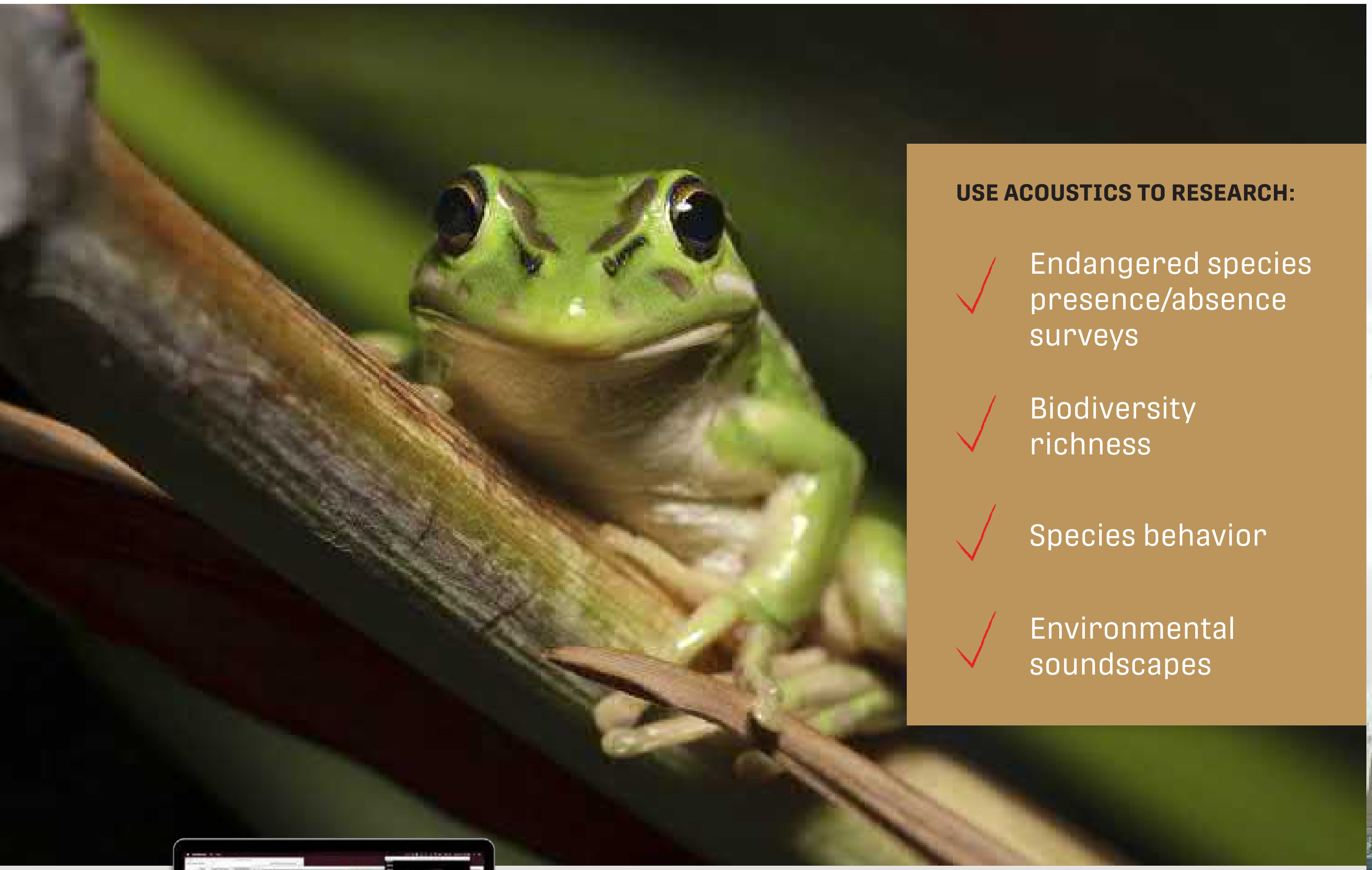

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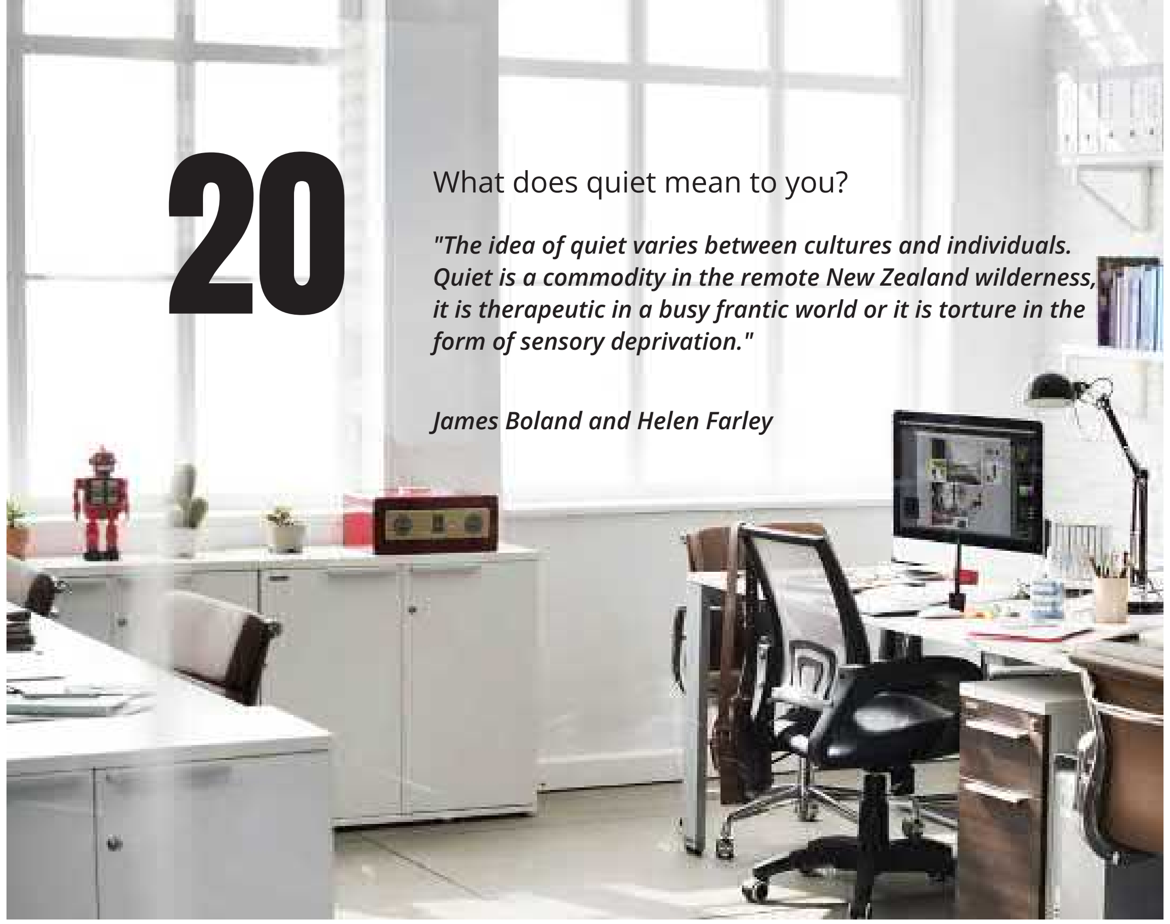

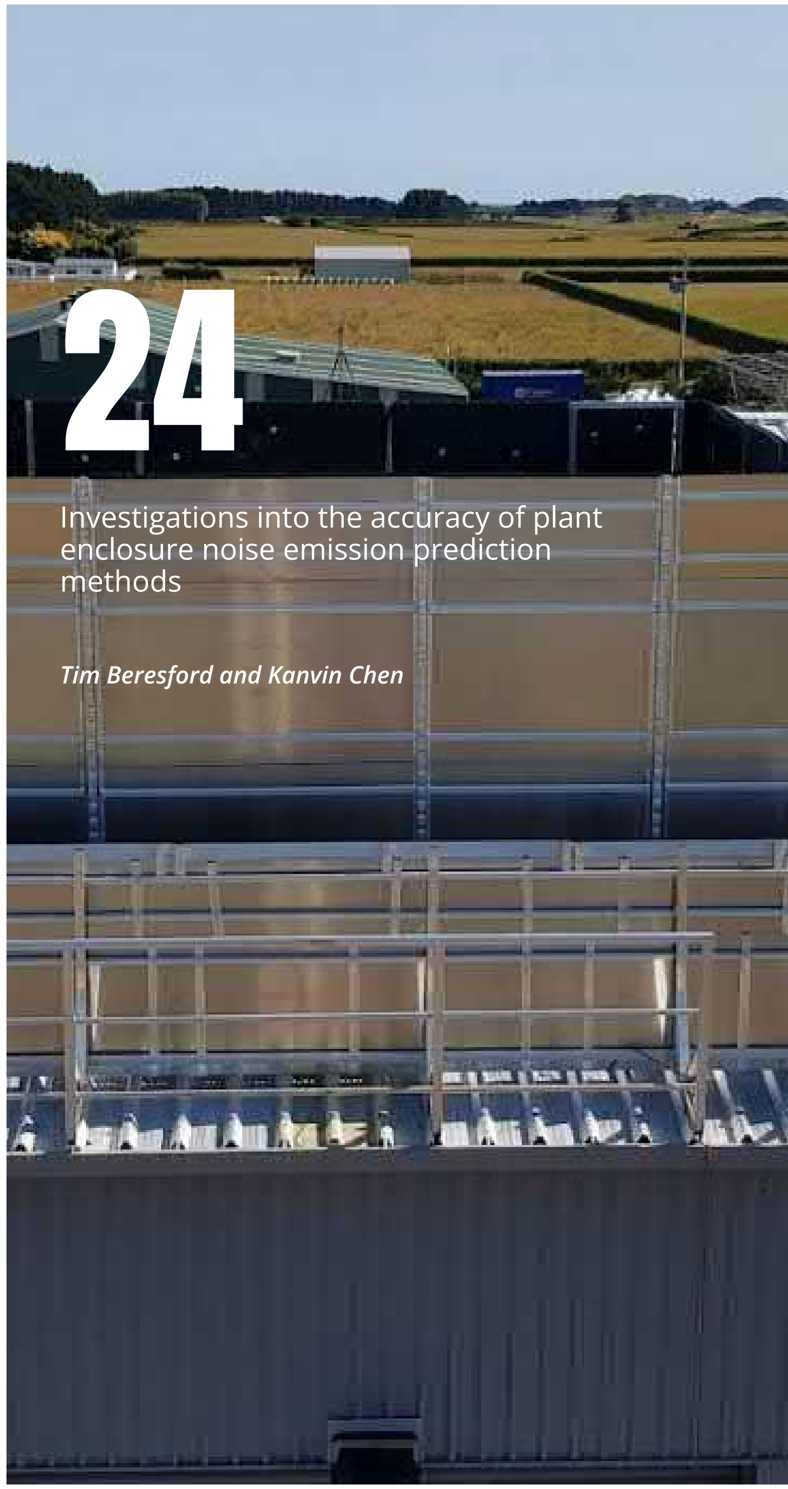

Greetings all,

I trust everyone had a great break over the festive season. It's probably a distant memory for most now that the frenetic pace of work has resumed as the New Zealand construction industry continues to boom in early 2022. Hopefully everyone is managing to stay safe during the Omicron outbreak and is able to go about their business as normally as possible. It's hard to know whether we are living with the "new normal" already, or not.

It is with some regret that I must inform our readership that the joint ASNZ/AAS 2022 Conference has been abandoned in favour of a New Zealand only conference. The Conference dates and location remain unchanged (31 Oct to 2 Nov 2022, Te Papa). This decision was a difficult one for the organising committee to make, but the risk of significant financial losses for the Society ultimately meant a joint conference was untenable in 2022 with the ever-present threat of Covid and travel restrictions. Never-the-less, we are forging on with organising what will be an outstanding conference later this year. A huge thanks goes to Tracy Hilliker for her efforts in negotiating our contractual obligations with Te Papa and for breaking the bad news (as gently as possible) to the AAS. I urge all ASNZ members to make the effort to attend our upcoming conference this year – it will be a good one. Get writing those research papers!

I would like to congratulate Jon Styles for his appointment to the Association of Australasian Acoustical Consultants' (AAAC) executive committee in the role of administering the AAAC Guidelines. Having a New Zealander on the executive committee is a crucial step in helping the AAAC gain traction over this side of the ditch. As some of you will know, the AAAC Guidelines have for years (in Australia, at least) served as a valuable resource for acoustic consultants on many aspects of design which fall outside of Building Code, Local Council, Standards or other regulations. The AAAC Guidelines, however, need significant adaptation to the New Zealand market – a challenge in which, I'm sure, Jon will make great progress. (Check them out: https://aaac.org.au/Guidelines-&-Downloads)

And finally, further development of the CRAI mobile phone application is being made, which I'm looking forward to unleashing on the ASNZ membership later this year.

All the best,
Tim Beresford
President of the Acoustical Society of New Zealand

Welcome to the first edition of New Zealand Acoustics for 2022. We have started another year again dealing with the on-going challenges of Covid and its wide spread effects this has had on our community, families and friends for the last two years.

We want to remind all our members that your mental wellbeing and health is paramount and if you need help or need to simply talk to someone please reach out to a colleague, friend or family member, if they don't listen, then repeat this until you find someone who will listen. If you feel you can't speak directly to a friend, family or colleague then please reach out to one of the support agencies listed on the Ministry of Health web page. Hopefully we start to see the back of Covid as the year moves on and we can all start to try and move towards what we once called a normal life again.

In this edition we have a host of varied papers across various technical subjects. We also have news updates as well as our quiz. We have started to introduce QR codes into the journal which allows members to click on the link and review articles or items directly.

Lindsay Hannah & Wyatt Page
Principal Editors

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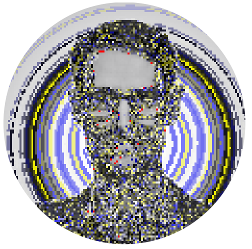


Tim Beresford

Lindsay Hannah

Wyatt Page

NEWS

The sounds of space

World Hearing Day 3 March 2022

World hearing day this year was on 3rd March. The Theme was 'To hear for life, listen with care!'

On World Hearing Day 2022, there is focus on the importance of safe listening as a means of maintaining good hearing across the life course. In 2021, WHO launched the World report on hearing that highlighted the increasing number of people living with and at risk of hearing loss. It highlighted noise control as one of the seven key H.E.A.R.I.N.G. interventions and stressed the importance of mitigating exposure to loud sounds.

Go to https://www.who.int/campaigns/world-hearing-day/2022 to get your media brief on safe listening.

Find out what an F-Hole is

This article by acoustician Nicholas Makris and his colleagues at MIT review how a violin's f-holes serve as the perfect means of delivering its powerful acoustic sound.

The Acoustical Society of New Zealand becomes member of World Health Organization's (WHO) World Hearing Forum (WHF)

CERTIFICATE

OF MEMBERSHIP

This is to certify that

The Acoustical Society of New Zealand

Is a member of the World Hearing Forum
for the period 2022 - 2024

The Secretariat of the World Hearing Forum (WHF) has announced The Acoustical Society of New Zealand as a new member of the World Hearing Forum.

The WHF envisions a world in which no person experiences hearing loss due to preventable causes and those with hearing loss can achieve their full potential through rehabilitation, education and empowerment.

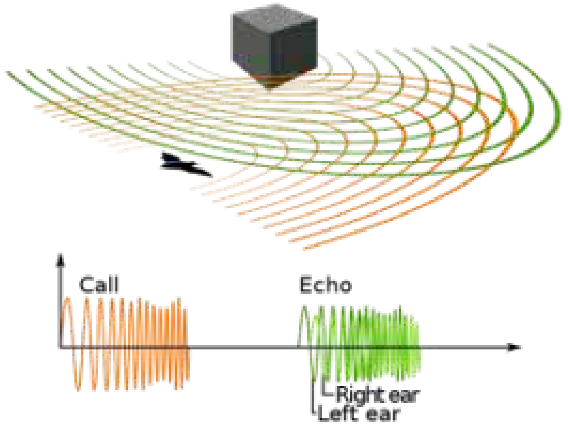
The goal of the Forum is to facilitate the implementation of the WHA70.13 resolution and support.

Misophonia - when certain sounds drive you crazy

A warning regarding the overlooked health hazard associated with hearing loss

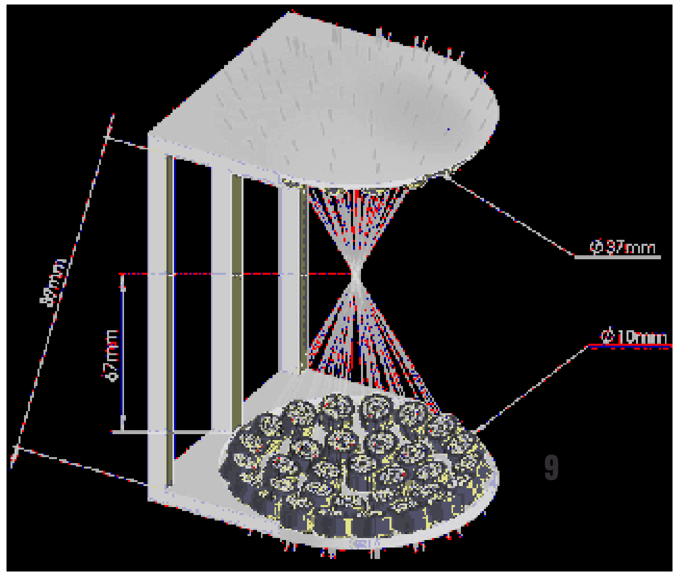
Tech experts are warning of an often-overlooked health hazard associated with one of our most common accessories.

Chinese studio Open Architecture unveils Chapel of Sound "We wanted to see the shape of sound"



Learn how to Echolocate

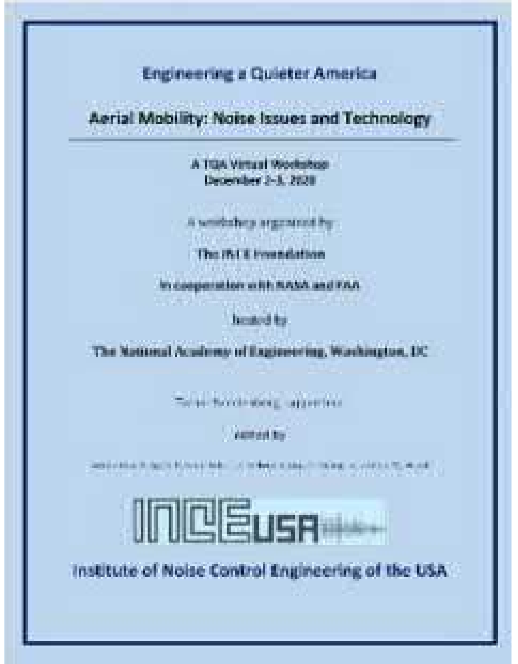
Build Your Own Acoustic Levitator!



Artificial Intelligence, Music and Feelings

Music makes us want to dance, but how else does it affect our body? Jessica Sharmin Rahman, a PhD candidate in the School of Computing at the Australian National University discusses how she conducts experiments using advanced sensors to record the physiological reactions of the participants when listening to music.

Cracking the mystery of the 'Worldwide Hum"



Engineering a Quieter America

Aerial Mobility: Noise Issues and Technology

A TQA Virtual Workshop
December 2-3, 2020

A workshop organized by

The INCE Foundation

in cooperation with NASA and FAA

hosted by

The National Academy of Engineering, Washington, DC

edited by

Institute of Noise Control Engineering of the USA

NAE Report: Aerial Mobility Noise Issues and Technology

The National Academy of Engineering (NAE) have recently released their Engineering a Quieter America – Aerial Mobility: Noise Issues and Technology report.

A copy can be downloaded from https://www.inceusa.org/

How urban soundscapes affect humans and wildlife – and what may have changed in the hush of lockdown

Find out how soundscapes affect the well-being of inhabitants — both human and non-human. This article discusses how lockdowns have changed these soundscapes, both positively and negatively.

A New Material Can Block Out 94% of Noise Even in a Jet Engine

"Last May, researchers at the U.S. Naval Research Laboratory in Washington, DC revealed that elastic response and engineered gradient materials could be combined to make extremely efficient acoustic metamaterials, according to Physics Today.

What are acoustic metamaterials? They are advanced materials that can effectively block out sound using only their geometry. The question is, can they do it without disrupting airflow?

In March of 2019, Boston University researchers, Xin Zhang, a professor at the College of Engineering, and Reza Ghaffarivardavagh, a Ph.D. student in the Department of Mechanical Engineering, submitted a paper demonstrating an acoustic metamaterial that could effectively cut out sounds while maintaining airflow.

"Today's sound barriers are literally thick heavy walls," said at the time Ghaffarivardavagh. The researcher decided that there had to be a better more material-efficient way to silence noise and proceeded to engineer it.

This new method is particularly useful in situations where thick heavy walls cannot be used like a jet engine's exhaust vent. Barricading a jet engine is not an option, so, the crew surrounding it wear earplugs to protect their hearing from the powerful roar instead.

But, what if there was a way to allow the airflow of the jet engine while blocking the sound? Zhang and Ghaffarivardavagh invented an acoustic metamaterial that could do just that.

They used 3D printing to materialize an open structure made of plastic and proceeded to test it with a loudspeaker. The trial was a hit as the loudspeaker blasted at an irritatingly high noise level but nothing at all could be heard! The noise-canceling acoustic metamaterial was working.

Zhang's team reported being ecstatic about the success of their test. "We had been seeing these sorts of results in our computer modeling for months — but it is one thing to see modeled sound pressure levels on a computer, and another to hear its impact yourself," said Jacob Nikolajczyk, a study co-author and former undergraduate researcher in Zhang's lab.

The team's further explorations indicated that they could block out 94 percent of the noise of absolutely anything. The new development has many applications from airplanes to drones to construction. The study is published in the journal Physical Review B."

Source: https://interestingengineering.com/new-material-can-block-out-94-of-noise-even-in-a-jet-engine

Updating the connection between Airborne and Impact insulation measurements of building partitions

George Dodd

Dept of Mech Engineering, University of Auckland

Abstract

The well-known relationship between R and Ln for floors first published by Heckl and Rathe in the 1960s comes with the limitation that it is only valid above the critical frequency (fc) of the floor and assumes the floor to be of high impedance (i.e. rigid) and heavy. In this presentation I'll discuss whether this relationship can be extended to cover constructions that are lightweight, have input impedances that are low (e.g. have a resilient covering), and don't need to be horizontal. This raises the prospect of introducing impact insulation performance criteria for walls as well as floors. Because these structures will have a significant part of the audible frequency range below their critical frequency it is necessary to establish that the relationship also holds for frequencies below fc and this is the primary purpose of this presentation.

1. Introduction

Designers, constructors and acousticians know that attached dwellings (e.g. flats and townhouses) in New Zealand are required to meet sound insulation minima as specified in our building code. These concern sounds generated by building services and those produced by the activity of the dwellers. In the case of sound resulting from occupants' activities – circulation (movement in and through spaces), vocal (speech, shouting etc) and entertainment (amplified music from wide range loudspeakers being a particular concern) - code requirements consider these in two categories airborne sound and impact sound. This results in specifications in the code for the Sound Reduction Index, R, of partitions (walls and floors) and the Normalised Impact sound pressure level, Ln, of floors. This requires that two types of test are needed to be carried out to verify that a dwelling, or a construction specified as an acceptable solution, do in fact fulfil the minimum requirements. Because these tests require specialised equipment and qualified operators (and are therefore costly) and, in addition, are somewhat tedious to undertake we do not find that they are carried out as a matter of course as a quality control for our housing stock. It would be beneficial for increasing the recognition of sound insulation and acoustic privacy as an essential feature of private dwellings if matter of course testing was required. This would help to establish acoustic quality categories that are published to potential buyers when properties change hands and raise expectations for true acoustic privacy in dwellings rather than the current culture which is one where neighbour noise is expected to be tolerated!

We acousticians can help to promote this if we make testing more attractive to carry out (both for ease and speed) and less costly. One way would be to reduce the amount of testing required and one possibility would be remove the requirement for impact testing.

2. How impact testing might be avoided

Since the process of transmission for impact sound and airborne sound for a floor involve the same structure we might expect that a relationship between the two insulation measures – R and Ln - could exist and therefore a measurement of R might suffice for determining the value of Ln as well.

In a seminal paper in the early 1960s Heckl and Rathe [Heckl, 1963] demonstrated such a relationship – a very simple one

$$R + Ln = 38 + 30\log f$$

(1)

- but because of assumptions associated with its theoretical derivation, assumptions which have been repeated in text books (e.g. [Cremer,], [Rindel,]) ever since, it has been claimed that this simple relationship only holds for certain types of floor (heavy and hard surfaced) and is valid only for a limited part of the frequency range (above the critical frequency, fc, where resonant transmission is assumed to predominate).

In a later paper, Ver, [Ver, 1971] used a different and neater derivation of the same relationship but again only for single leaf structures at frequencies above fc. He showed a more complex relationship for frequencies below fc requiring knowledge of radiation efficiencies, loss factors and speed of sound in the solid material. These would be nearly impossible to know with certainty so in practice a full impact measurement of Ln would generally be required.

However, in an experimental study Dodd [Dodd, 2018] investigated the sum of R and Ln for a range of floor systems beyond single leaf constructions at frequencies both above and below fc. The results suggest that the limitation to frequencies beyond fc need not apply nor be limited to apply only to floor constructions that are heavy and hard surfaced. This led to a proposal for a way of obtaining a prediction of Ln from the airborne sound insulation and thus obviating the need for direct measurement of Ln. It was proposed that this technique would have sufficient accuracy at least for screening purposes in field testing of buildings [Dodd, 2016].

The purpose of this paper is to look for theoretical support for a relationship between airborne sound insulation and impact sound insulation having the simplicity of the original Hekl and Rathe relationship including frequencies below *fc*.

3. Theory behind a relationship between R and Ln

3.1 Sound Reduction Index, R, for random-incidence sound

Japanese researchers have been the most recent to address this question [Yairi et al,20--] [Yairi et al,2016].

In a 2016 paper Yairi et al modelled a thin, elastic plate with a goal of deriving a relationship between airborne-sound excited and point-force excited vibration of the plate. They assumed plane waves at an angle *θ* and, using standard results, obtained an expression for the transmission coefficient, τ, where the plate has surface density *m*, thickness *h*, flexural rigidity D, loss factorη and Poisson's ratio ν

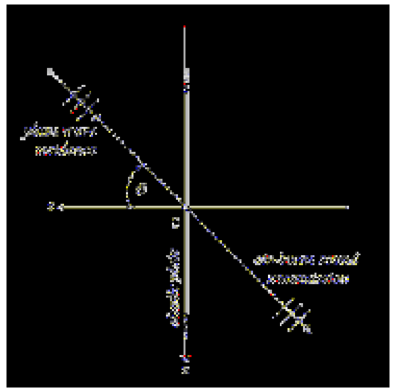


Figure 1: The situation for the thin plate model (based on [Yairi et al, 2016])

$$\tau_\Theta(\omega) = \left[\left(1 + \eta\frac{\omega\rho_p h\cos\Theta}{2\rho_0 c_0}\frac{\omega^2\mathrm{Re}[D]\sin^4\Theta}{c_0^4\rho_p h}\right)^2 + \left(\frac{\omega\rho_p h\cos\Theta}{2\rho_0 c_0}\right)^2\left(1 - \frac{\omega^2\mathrm{Re}[D]\sin^4\Theta}{c_0^4\rho_p h}\right)^2\right]^{-1}$$

If this is integrated over a hemisphere with angles of incidence limited to 78o it results in the transmission coefficient for a 'diffuse' field (often referred to as field incidence) that matches what is found for typical rooms in practice. However, Yairi et al restrict themselves to considering only forced vibrations of the plate. This means they ignore bending wave excitation so essentially their results are relevant to frequencies below the critical frequency (fc) and their expression for the field incidence transmission coefficient becomes

$$\tau(\omega) = 3.28\left(\frac{2\rho c}{m\omega}\right)^2 \cong 3.28\tau_0(\omega)$$

(2)

the reciprocal of which, if expressed in dB, gives the well-known Mass Law for the Sound Reduction Index R of the plate. Yairi et al go no further with considering airborne excitation as obtaining τ(ω) is sufficient for their purposes.

3.2 Radiated sound power under point force excitation

However, Yairi et al do derive expressions for the sound power radiated by the thin plate when being excited by a steady state point source. The first of these is achieved by *"simultaneously solving the governing equations of the sound field and the equation of motion of the plate"*. But this is mathematically complex and to simplify things they use a second approach that of integrating the radial intensity in the far field.

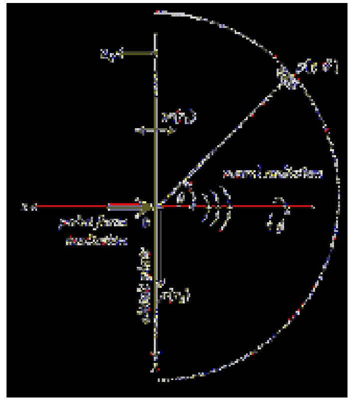


Figure 2: Point force excitation of the flat plate

Certain approximations are introduced but the effect of these amounts to ignoring the resonant transmission from the plate. This gives for the radiated power, *Wf(ω)*, when the plate has a steady excitation of 1 N:

$$W_f(\omega) = [\frac{\rho}{4\pi c m^2}]$$

(3)

Thus their result for $W_f(\omega)$ is only effective for frequencies below f_c. This is the frequency range that we are interested in so it is totally satisfactory. The practical effect of ignoring resonant transmission is that the power $W_f(\omega)$ radiated is only the "near field" radiation from the region of the plate under the point of forced excitation.

3.3 Relating the airborne and impact excitation of a floor

In order to relate Sound Reduction index to the normalised impact sound SPL we need to derive the power that the airborne sound field delivers to the floor when it is producing the same reverberant sound pressure in the room underneath as when the floor is being excited by the standard tapping machine.

Imagine a floor as shown in figure 3 where the airborne reverberant sound pressure p_1 exciting the floor has been equalised so that the pressure p_2 created in room 2 below is the same as when the ISO tapping machine is exciting the floor. The floor has an area S and a surface density m. If the sound intensity radiated by the floor into room 2 is I2 and the intensity incident on the floor in room 1 is I_1 then $\tau = I_2 / I_1$.

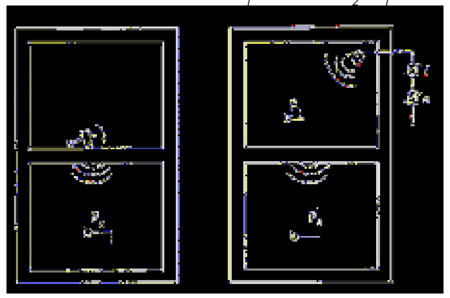


Figure 3: Comparing airborne excitation and tapping machine – based on [Ver, 1971]

Since $I_1 = p_1^2/4\rho c$, I_2 is given by

$$I_2 = \frac{\tau p_{1air}^2}{4\rho c}$$

(4)

The total power, W_{air1} radiated into room 2 is then

$$W_{air} = I_2 S = \tau S p_{1air}^2/(4\rho c)$$

Substituting for t from equation (2) we have

$$W_{air} = \frac{3.28 S p_{1air}^2 \rho c}{\omega^2 m^2}$$

(5)

Since we have specified that p_{2air} from airborne sound excitation of the floor equals p_{2imp} from point source force excitation (choosing this special case does not lead to loss of generality because R remains the same whatever the source strength!) the power radiated by airborne sound excitation of the floor equals the power radiated by the tapping machine, *Wimp*$_1$:

$$W_{air} = W_{imp}$$

W_{imp} is found by multiplying equation 4 (which gives the power from a force of 1 N) by the power spectral density of the Tapping machine. The most recent work [Rindel,] suggests this spectral density has a value of 3.9 N^2/Hz hence if we consider measurements made in 1/3 octaves the power radiated in a 1/3 octave of centre frequency *f* (and hence a bandwidth 0.23*f* Hz) is

$$W_{imp} = \frac{3.9 \cdot 0.23 f \rho}{4\pi m^2 c}$$

(6)

Hence equating (5) and (6)

$$\frac{3.9 \cdot 0.23 f \rho}{4\pi m^2 c} = \frac{3.28 S p_{1air}^2 \rho c}{\omega^2 m^2}$$

from which

$$p_{1air}^2 = \frac{f^3}{S} \cdot 7.35 \cdot 10^{-6}$$

(7)

The General Insulation equation for the level difference between the two sound fields (see [ISO 10140, 2020]) resulting from the airborne sound excitation in room 1 gives

$$10log(\frac{p_{1air}^2}{p_{2air}^2}) = R + 10log(\frac{A}{S})$$

thus

$$p_{1air}^2 = p_{2air}^2(\frac{A}{S})10^{R/10}$$

(8)

The definition for Ln [ ]

$$Ln = 10log(\frac{p_{2imp}^2}{p_{2ref}^2}) + 10log(\frac{A}{A_0})$$

(where A0 = 10m2 standard absorption)

gives

$$p_{2imp}^2 = p_{ref}^2 10^{Ln/10}(10/A)$$

(9)

Substituting this in equation (8) and combining with (7):

$$10^{Ln/10+R/10} = f^3(7.35/4)(10^3)$$

Hence

$$R + Ln = 32.6 + 30log f$$

(10)

This is identical with equation 1 - the original Heckl and Rathe relationship - except that the constant is 32.6 rather than 38.

A quite similar result can be found using the expression for the power radiated by the tapping machine derived by Ver [Ver, 1971] (his equation 5 based on [Cremer, 2005]]. If we ignore the resonant transmission term his result describing the near field transmitted power is a factor 2 greater than derived by Yairi which results in the expression for $R + Ln$ being 3dB greater

$$R + Ln = 35.7 + 30log f$$

(11)

This is closer to the original Heckle and Rathe result but an explanation for the factor of 2 difference between the Ver and Yairi results remains still to be found.

The fact that the derivation of Yairi et al applies to a thin infinite plate as opposed to the finite sized floors of Ver and Heckl and Rathe one might not expect to be significant because we would expect the effect of a finite size to apply equally to both airborne and impact transmission. However whichever of equations (10) and (11) is the one applicable they do provide reason to believe that for frequencies both above and below f_c the sum of the Sound Reduction Index and the Normalised Impact Sound Level for a hard floor can be represented by a straight line having a slope of 9dB/octave.

4. Floors in practice

In practice many floors – especially in domestic constructions – will be either themselves resilient or covered with a resilient surface. Thus we do not expect their measured results to conform to equations (1), (10) or (11). However it is clear from our earlier work [Dodd, 2018] that by the addition of point measurements of the reaction force spectrum to impacts – essentially a measurement of the input impedance difference of the resilient floor from that of a hard floor - we can reasonably satisfactorily extract results for Ln from a measurement of R. For example:

$$Ln = 35.7/38 + 30log f - R_{meas} + \Delta L$$

(12)

where ΔL is the force spectrum adjustment obtained from reaction force measurements.

Examples of this will be shown during the presentation which confirm that in the range below f_c the sum of R and Ln closely follows a slope of 9 dB/octave.

5. WALLS

One potential application of this idea of replacing impact insulation measurements by values obtained from R is to be able to quantify impact insulation of partitions which are not in a horizontal plane. Obviously the operation of a tapping machine relies on gravity and therefore cannot be used to measure and compare how different wall structures protect against the sound of bumps and impacts on them. If it was felt desirable to extend building code requirements to include such a requirement here is a possible way of doing it.

6. CONCLUSIONS

It has been shown that based on theory available in the published literature we can be reasonably confident that a simple relationship for the sum of R plus Ln for partitions can be found which applies for all frequencies not only for those above f_c.

By the inclusion of point impedance measurements from a reaction force measurement on partitions which are not hard (i.e. are resilient) we can extend the idea of using a simple prediction for the sum of R and Ln to obtain Ln values but using airborne sound measurements and thus avoiding potential problems of limited signal to noise ratios in field measurement conditions and obviating the need for carrying and using a tapping machine.

The idea may be used to provide a way of quantifying the impact insulation of walls which, obviously, cannot be impacted with the ISO Tapping Machine and could also be a means of rating the rain noise insulation of roofs against the sound of rainfall thus avoiding a need for special water-based testing facilities.

ACKNOWLEDGEMENTS

Many thanks are due to Gian Schmid for his ideas, construction work, and help with measurements. My thanks to project students Ben Yen, Aiden Clarke, and Ben Collette-Nye for use of their results, also to Andrew Hall for help with LaTex.

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Conference of the Acoustical Society of New Zealand

28-29 June 2021

Auckland

Managing construction noise and vibration across large-scale urban development

Matt Bevington [1]

[1] Tonkin + Taylor and Piritahi, Auckland, New Zealand

Abstract

Piritahi is an alliance of six companies formed to speed up the supply of build-ready land on behalf of Kāinga Ora – Homes and Communities' large scale developments. Over the next 20 years, approximately 10,000 of Auckland's state houses will be replaced by many more thousands of homes. Piritahi is responsible for preparing the land and constructing the necessary infrastructure to support the new housing in the redeveloped neighbourhoods. Managing and assessing construction noise and vibration from these large-scale neighbourhood developments being delivered 'at scale and pace' presents challenges. This paper provides an overview of the presentation provided at the Acoustical Society of New Zealand 2021 Conference. This paper discusses these challenges, the use of GIS tools to provide neighbourhood scale assessments, noise and vibration management processes, low and high cost monitoring methods and extensive stakeholder engagement practices.

1. Introduction

Piritahi's structure consists of Kāinga Ora as the owner-participant and master planner, non-owner participant design consultancies, Harrison Grierson, Tonkin + Taylor and Woods, and civil contractors Dempsey Wood and Hick Bros Group. Over the next 20 years, approximately 10,000 of Auckland's state houses will be replaced by many more thousands of homes. Piritahi is responsible for preparing the land and constructing the necessary infrastructure to support the new housing in the redeveloped neighbourhoods. Each development is within existing residential neighbourhoods that consist of government owned and privately-owned properties. Occupied properties are set amongst the neighbourhood works resulting in a substantial number of properties in close proximity to construction work.

2. Assessments and resource consenting

2.1 Challenges

Piritahi has been tasked with providing build-ready land at scale and pace. When consenting these projects, there are a variety of unknowns at the assessment stage, particularly regarding the staging of works and occupancy of dwellings. Satisfying the assessment requirements of regulators with these unknowns can be challenging, particularly if a level of conservatism, leading to restrictive consent conditions, is to be avoided.

The uncertainty in the construction programme lends itself to desiring consent conditions that provide maximum flexibility in noise mitigation and management, to be able to undertake the work without delay. Due to the scale and repetitiveness of the works a 'global consent' approach provides obvious efficiencies, however this approach may be perceived as providing insufficient detail at specific locations where noise and vibration effects are to be expected. This global approach provides emphasis on the management-based approach rather than an individual site by site basis. There are pros and cons of both approaches and a combination of techniques is favoured depending upon the degree and certainty of the noise and vibration effects.

2.1 Solutions

The construction activities undertaken by Piritahi across the various neighbourhoods are largely repetitive, with the exception of varying ground conditions and specialist infrastructure. These repetitive tasks would in isolation, i.e. for a single redevelopment of a housing site, be considered of low significance but it is the scale of the redevelopment which requires a more comprehensive/detailed approach. Monitoring of these repetitive tasks has provided a reliable noise and vibration dataset of source terms and importantly expected durations of activities.

A benefit of operating as an alliance is the availability of significant useful GIS information. This GIS information combined with known levels and duration of construction works allows opportunities for assessments to be streamlined and across a wide scale. The alternative would be detailed noise modelling, both time inefficient and in comparison, expensive given the number of development sites.

A GIS tool has been developed that outputs maximum noise levels and expected work durations above specified noise levels for each address and activity and at a neighbourhood scale. This tool has been validated across a number of different locations and types of construction activities, i.e. earthworks and infrastructure work.

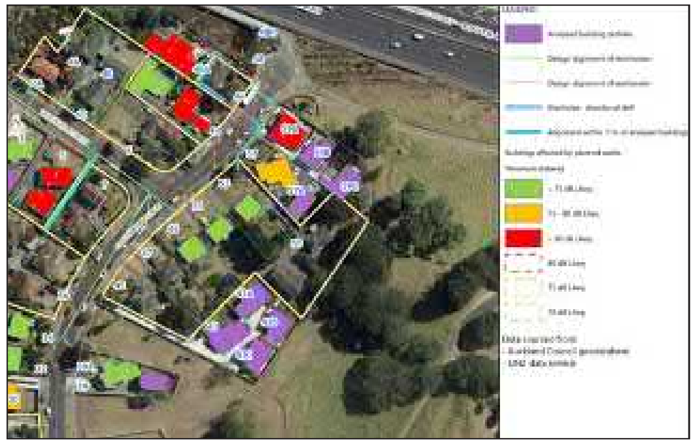
Figure 1 below provides an example output of a noise assessment from land remediation and infrastructure trenching works.

Piritahi (Gabriela Olekszyk and Matt Bevington, 2020)

Figure 1: Neighbourhood wide GIS analysis of land remediation and infrastructure

This tool has been further developed to address the challenge of neighbourhood wide Construction Noise and Vibration Management Plans. The tool automatically colours properties in accordance with the predicted noise levels and the associated risk factor for each activity, i.e. low, medium or high risk of adverse noise and/or vibration. A colour coded hierarchy of mitigation is then provided so that the construction team can identify locations requiring mitigation and determine the correct mitigation measures in a consistent manner across all stages of the works. This is demonstrated in Figure 2 and Figure 3.

This method allows for prescriptive property and activity specific management measures to be communicated easily and effectively across neighbourhood wide developments.



Piritahi (Gabriela Olekszyk and Matt Bevington, 2020)

Figure 2: Example of risk graphic for use in construction management

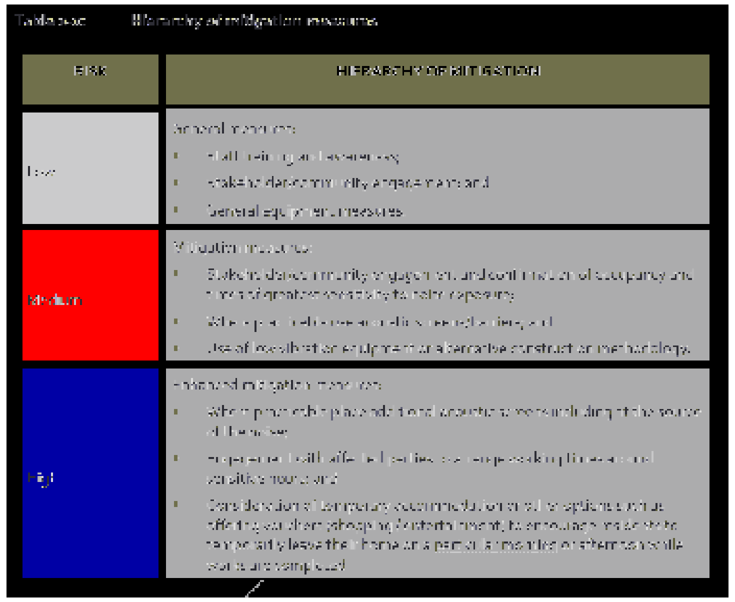


Table x.x: Hierarchy of mitigation measures

RISK	HIERARCHY OF MITIGATION
Low	General measures: ▪ Staff training and awareness; ▪ Stakeholder/community engagement; and ▪ General equipment measures.
Medium	Mitigation measures: ▪ Stakeholder/community engagement and confirmation of occupancy and times of greatest sensitivity to noise exposure; ▪ Where practicable use acoustic screens/barriers; and ▪ Use of low vibration equipment or alternative construction methodology.
High	Enhanced mitigation measures: ▪ Where practicable place additional acoustic screens including at the source of the noise; ▪ Engagement with affected parties to agree respite times and sensitive hours; and ▪ Consideration of temporary accommodation or other options such as offering vouchers (shopping / entertainment) to encourage residents to temporarily leave their home on a particular morning or afternoon while works are completed.

Piritahi (Matt Bevington, 2020)

Figure 3: Example of mitigation measures for use with risk graphics

3. Monitoring

The breadth and scale of the works across Auckland in addition to the relatively high speed at which works are completed on individual sites, presents challenges in efficiently and cost effectively undertaking noise and vibration monitoring which provides the necessary coverage.

Piritahi utilises both low and high-cost solutions to assist with construction noise and vibration monitoring. These devices are selected on the perceived risk and required compliance data. The low-cost devices are discreet, tough and provide ability to upload data via Wi-Fi. They provide a useful indication of construction noise levels at low risk sites. Attended monitoring is often used, especially when engaging with residents and being visible in areas where there have been complaints regarding noise or vibration. The high-cost devices are utilised in higher risk situations where detailed information is required.

Key to the delivery of wide scale monitoring is the training of individual neighbourhood specific site engineers in the deployment of monitoring equipment. With the ability of the monitors to upload to a central database and send out alerts large scale monitoring can be completed continuously and provide real-time management across Auckland with minimal resource.

Photograph (Piritahi, 2019)

Figure 4: Example of low-cost sound logger

4. Stakeholder Engagement

Each neighbourhood has a designated Community Liaison Advisor (CLA), in the larger neighbourhood developments there are more than one. The CLAs role is to act as the point of contact for residents about Piritahi's construction works in the neighbourhood. Having a full-time person in the neighbourhood to liaise with residents has obvious benefits when dealing with noise and vibration issues. Residents are kept abreast of the construction programme, where it is ascertained residents will be affected due to the proximity of works, individual notices are provided and usually door knocks and discussions are held.

Community events

Piritahi is active in the community of each of the neighbourhoods and where possible initiates, supports and contributes to community initiatives run by Kāinga Ora.

Examples of such community activities include:

- Temporary use of completed superlots (work sites) for community spaces such as:
- Community gardens and vegetable growing spaces.
- Community spaces with community information hubs.

Other examples of community initiatives include:

- "Rock" day where the community can come to site and collect excavated stone.
- Community Information Days
- School education days.

Examples of these community events are provided in photographs in Figure 5.

Kāinga Ora's community events and the meaningful use of temporary superlots has received positive feedback to date from the community within the neighbourhood developments.

Photograph (Piritahi, 2020)

Figure 5: Community events

5. Conclusions

Large scale neighbourhood development provides challenges in assessing and managing construction noise and vibration. Piritahi have built on existing GIS capabilities to provide GIS based noise assessments which meet assessment requirements and are efficient. This GIS capability has been extended to provide easy to understand construction noise and vibration management plans.

Low and high-cost noise and vibration monitoring is undertaken using autonomous monitors and a network of trained site-engineers. Providing efficient solutions to gathering noise and vibration data.

The key to the managing neighbourhood response to noise and vibration is the dedicated neighbourhood Community Liaison Advisors and the active community engagement led by Kāinga Ora to build community "buy-in" to the developments.

Acknowledgements

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What does quiet mean to you?

James Boland [1] and Helen Farley [2]

1 Acoustic Engineering Services, Christchurch, New Zealand

2 University of Southern Queensland, Toowoomba, Australia

Abstract

The idea of quiet varies between cultures and individuals. Quiet is a commodity in the remote New Zealand wilderness, it is therapeutic in a busy frantic world or it is torture in the form of sensory deprivation. These differences in perception are not just related to the small space inside the ear of the listener, they are also dependent on the prior experiences of the listener and the feelings and physiological responses associated with noise. With a surge of global interest in soundscapes, we evaluate the accepted approach to planning for noise and examine the impact that sounds have on our lives to see if these approaches are fit for purpose. We probe the tenuous link between acoustic quality and noise level to provide an overview of current moves towards an alternative approach to ensuring acoustic amenity. Finally, we investigate the scientific, artistic and perhaps voyeuristic aspects of field recording and explore the aspirations of on-line communities of academics, historians, scientists and hobbyists (all passionate listeners) to progress our understanding of how deeply we interact with our soundscapes.

1. Introduction

The world population is predicted to continue to rise rapidly in many places and reach 8.5 billion by 2030. At the same time governments are striving to create the conditions that favour continuous economic growth. A growing population means people are living in ever higher density housing, closer to each other and to the noise generating collateral of economic growth. Over 125 million people in Europe alone are regularly exposed to elevated levels of land transport noise. With population numbers rising in most countries and coupled with the idea that growth is an indicator of economic success, the world is becoming a busy and noisy place with governments struggling to draft and enforce guidelines around ensuring acoustic amenity.

Although COVID-19 lockdowns or "anthropauses" have caused temporary but measurable reductions in ambient noise levels across many cities (for example, see Asenio, Pavón, and de Arcas 2020), the corresponding effect on the population has not yet been fully investigated. Under typical non-pandemic conditions, it is known that noise can negatively impact both mental and physical health. Noise can cause sleep disturbances, predisposing the receiver to stroke, cardiovascular disease, diabetes, and hypertension (Singh, Kumari and Sharma 2018). It can also lead to anxiety, depression, and distraction (Ma, et al. 2020). It is too early to tell if the temporarily quieter cities improved the quality of life for their residents, or if anxiety about the pandemic negated any positive effects that could have been gained through a reduction in noise. The lockdowns did provide an unprecedented opportunity to measure and observe the extent and impact of human-generated noise on urban soundscapes. It gave residents the opportunity to reflect on how their cities could sound if background noise could be successfully mitigated or even crafted. Further, it provided the chance for residents to appreciate those sounds so often drowned out by traffic and the suburban hum of people going about their business, those bird sounds, the sound of wind in the trees and the sound of waves crashing on a beach. Perhaps not surprisingly, green-tape reduction has accompanied the economic rebuild efforts as councils and governments try to restart their economies after the lockdowns, with noise limits waived and activity given priority over amenity in some cases (Smith 2020). It is hoped that economic activity does not come at the expense of human health as acoustic amenity is compromised.

While international efforts try to decide how best to define the soundscapes we inhabit (see ISO 12913, 2014), quietness has increasingly become commoditised; there is money to be made, while properties near noise sources typically sell at discounted rates (Szczepańska, et al. 2020). Some Governments have mapped their national quiet areas using parameters such as the Quietness Stability Index (QSI) method (EEA 2014). The European Environment Agency has prepared a Good Practice Guide on quiet area identification and management (EEA 2014) and there have already been localised projects to plan and evaluate quiet areas using a mixed methodology, combining typical noise indicators with anthropomorphic and geographic preferences for a community in Germany (Radicchi 2017). Holiday destinations use the idea of quiet to lure tourists (Fesenk and Garcia-Rosell 2019). There have been calls to regulate the air space above some National Parks in New Zealand to increase the potential for visitors to experience a unique soundscape, without intrusion that could detract or distract from the desired experience of remoteness (Tal 2001). Similar approaches have been happening with light, or darkness, for many years with "Dark Sky Reserves" featuring heavily in tourism collateral for the Mackenzie region of New Zealand among others (Scott 2020).

2. Quiet up close

'Quiet' has not been conclusively defined but can be considered to be the absence of noise or at least what is there when noise is not dominant (Peris, et al. 2019). Instinctively, we think of quiet as being calming. We seek to control or mitigate noise to provide this quiet, but it may not be the absence of noise alone that facilitates calm. Schreckenberg and his colleagues (2017) sought to develop our understanding of annoyance – the antithesis of calm – by proposing a multidimensional judgment model to describe the construct of "annoyance." They argued that our ability to be calmed relies on more than just the absence of noise; it is also dependent on our perception of our level of control over the noise source, and the state of our mental health. They also argued that our history of personal responses to repeated encounters with a particular disturbing noise weighs on our judgment of annoyance. If we cannot readily control the noise, and it has disturbed us repeatedly in the past, then the noise will be more annoying irrespective of its magnitude or quality.

Leveraging this idea, some central city businesses and city councils use pre-recorded music played at intrusive levels in civic places, to deter homeless people from sleeping in public places (for example, see Shahtahmasebi 2018). The people who select the music and the volume at which it will be played are likely making subjective decisions, based on their own history of personal responses, about what will be sufficiently intrusive to deter people from sleeping near the noise source and instead settle in an area that is quieter, and therefore more satisfactory to them. This intervention assumes that homeless people use the ambient noise level as one of their selection criteria when choosing a suitable place to sleep, and that a lack of intrusive noise is a key factor in that decision making process. When loud classical music was used in this way in the Brisbane CBD to deter homeless people from sleeping in King George Square, one of them chose to stay, telling a reporter: "you get used to it" (unnamed person quoted in Lynch, 2019).

While it is well established that diverse people with different lived experiences can have varying rates of hearing loss, an individual's physiological state can also impact not only how well they hear, but also on what they think they hear and how well they think they hear it. Each person has a well-developed sense of the status of their hearing, that may or may not correlate with an objective measured assessment of their hearing health (Angara, et al. 2020).

3. Hearing or listening?

A growing literature suggests that noise can impact individuals in very different ways and that the same noise is likely to elicit a range of responses across a population (Angara, et al. 2020). It is also likely that individuals subjected to the same soundscape will also respond very differently. The ISO 12913-1:2014 Acoustics — Soundscape — Part 1: Definition and Conceptual Framework defines a soundscape as the "acoustic environment as perceived, experienced, and/or understood by people, in context". The study of how we interact with a soundscape is a liminal field often frequented by transdisciplinary academics and enthusiasts, with the common aim to progress our understanding of the area of study that can be termed "Acoustic Ecology" (Wrightson 2000). One method employed to capture and investigate soundscapes is termed "Soundwalking", where people walk through their neighborhood specifically to listen, often recording their journey with a portable recorder. The recordings are often shared among interested online communities, either unedited for discussion and cataloging, or sometimes they are modified to include a music or spoken word accompaniment (O'Keeffe 2014).

The Firenze Soundscapes project presents a collection of field recordings from locations across Florence, with the aim to capture the typical soundscape, that which can be commonly observed, of that city (Orlandini 2017). The location of each recording is shown on a web map, but images of the recording locations are purposely excluded, allowing the listener to imagine the physical settings by starting with the sounds. Soundwalking, and sound mapping using recorded audio samples, feature an element of preservation. Just like we can listen to London traffic sounds recorded in 1928 (Brazee 2020), we feel it is important to record and preserve the soundscape for future listeners. Recordings of the soundscape, excluding any visual cues, can provide unique insights into the prejudices of the listener. They can also conjure powerful memories, in the example of demolition noise recorded during the post-quake rebuild of Christchurch (see Cities and Memory 2020).

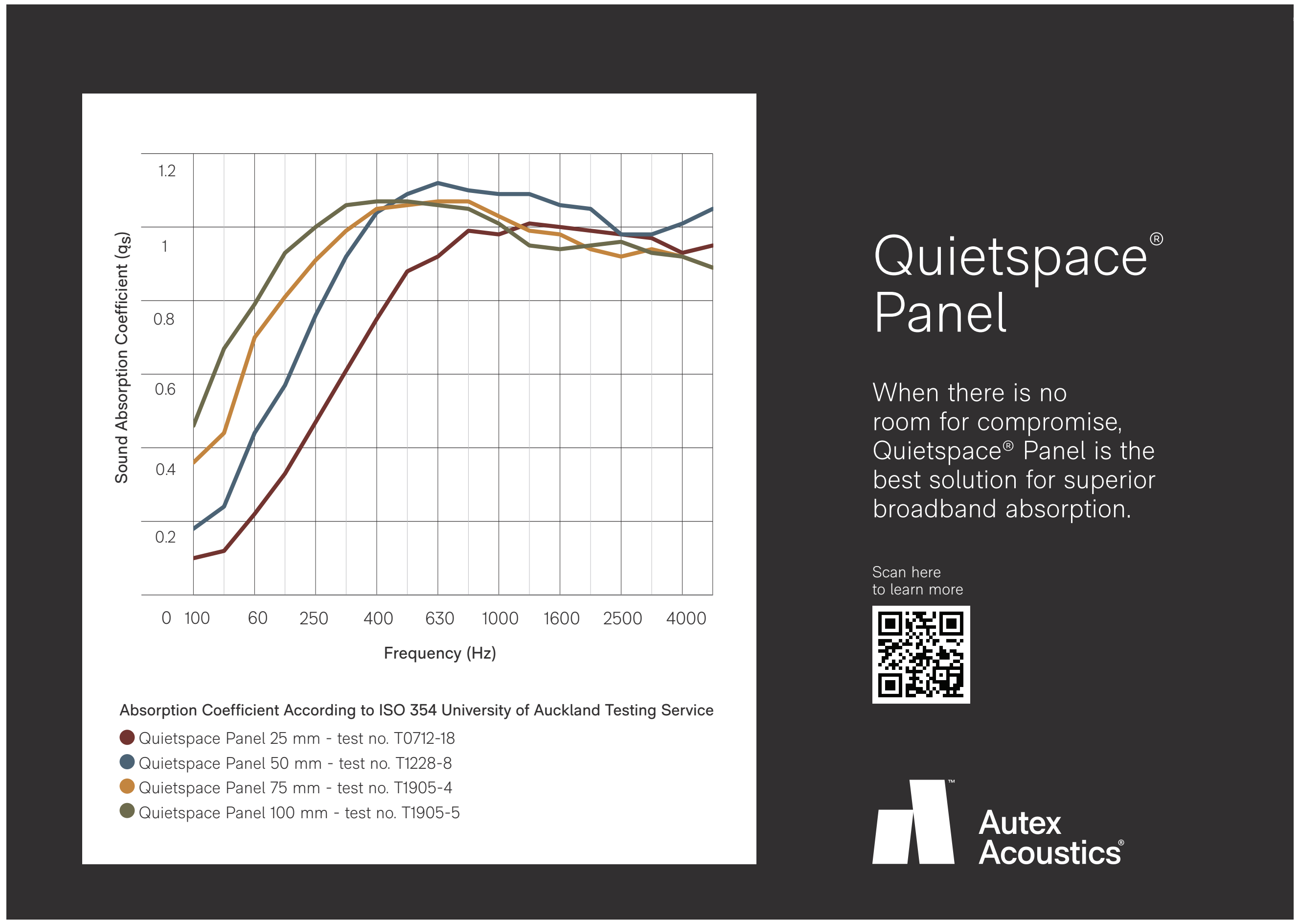
The recent COVID-19 lockdowns have provided a unique opportunity for before and after recordings with astonishing results. During our socially distanced afternoon walks in the New Zealand South Island city where we live, in an area high above the city, the typical city hum that typically dominated the ambient noise environment was replaced by the sound of the nearby ocean for a period of weeks. The contribution of transport noise had reduced so significantly that the ocean noise became much more audible. The mix had changed. The return to a post-lockdown soundscape included significantly more contribution from transport noise as the ocean noise returned to a less dominant position as an ambient noise source contributor.

4. Planning for quiet

It is well established that certain types of noise are stressful and are less acceptable to communities, such as industrial noise and noise generated by mass transport (Rudolph, et al. 2019). Together with the level of noise emission, these sounds also have special characters that makes them less acceptable. We use legislation to manage these sources of noise emission where they already exist, and to provide planning methods for proposed new sources of noise. Legislation often aims to limit the contribution of the specific noise to the existing ambient noise levels that would be present in the area without the addition of the specific noise, thus preventing background creep. These legislative mechanisms do typically include an assessment of any annoying character the specific noise may have (such as impulsiveness and tonality) and would impose some sort of penalty where noise that exhibits these more annoying (or perhaps less pleasing) characteristics may be received at a noise sensitive location.

Regarding city-wide noise issues such as transport noise, noise mapping studies are being used in New Zealand and other countries to understand the burden of illness within the population being caused by exposure to transport noise, for people that live adjacent to the networks (for example, see Boland 2019). There is strong evidence that high levels of transport noise can cause adverse health effects, while the correlation between interventions to control noise and the associated improvement in health outcomes is less well understood (Brown and van Kamp 2018). The health impacts from transport noise can include increased blood pressure leading to chronic disease and sleep disturbances which can disturb physiological systems. The potential for sleep disturbance varies widely between individuals and criteria are commonly based on the poorly correlated relationship between intrusiveness and awakening (Monsén and Edéll-Gustafsson 2005).

If you live in an urban area, you are expected to tolerate more noise intrusion than those who live in rural areas. The planning objectives for each zone aim to provide only a certain level of amenity. Interestingly, the upper limit of what is considered a reasonable level of noise for residential activity can vary between adjoining jurisdictions. The historical approach to controlling noise for the wellbeing of communities has been one of "best overall fit". In the previous sections, we outlined some of the vagaries of trying to determine the actual effects that noise



can have on a particular individual. In the next section, we will investigate the potential for alternative approaches.

5. Approaching the limit

Government-commissioned noise mapping studies are commonplace and typically focus on establishing how many, or which members of the population are likely to experience unacceptable noise levels where they live. The findings of these studies have a variety of uses from satisfying internal government reporting and public accountability commitments, to informing planning and funding decisions around retroactive interventions for noise control, harm reduction and urban rehabilitation. The large data sets created by noise mapping studies are also valuable commodities which can be adapted for markets by the commercial sector. One example is the preparation of transport noise maps by a consulting firm to provide noise-based property reports to assist home buyers to make decisions about property purchases based on the level of transport noise (road and rail) expected at that location (for example, see Ambient, n.d.). When purchasing a property, people only spend short periods of time at that property prior to the sale, such as during open houses and follow up inspections, and they may not have the time or clarity of thought to really get a sense of how loud or quiet the area might be, or specifically how their new home might sound. The question of how the area around their prospective home might sound, would mean understanding more than just the level of transport noise they might experience. An appreciation of the composition of the soundscape immediately surrounding the dwelling may also influence their perception of the value of the property. A description of the mix of sounds that contribute to the local soundscape, together with the expected noise levels, could help in the decision-making process.

The Hush City research project originated in Berlin with the aim to provide a smartphone-based platform to enable citizens to measure, store and analyse information about quiet areas in their neighborhoods (Radicchi 2018). The initiative has since been taken up by city authorities. The graph in Figure 1 is taken from the results of the original phase of the Hush City project and shows the sounds that contributed to the participants' sense of quiet when visiting their local quiet areas. The majority of respondents indicated that noise from birds and other people was most influential, followed by noise generated by wind and

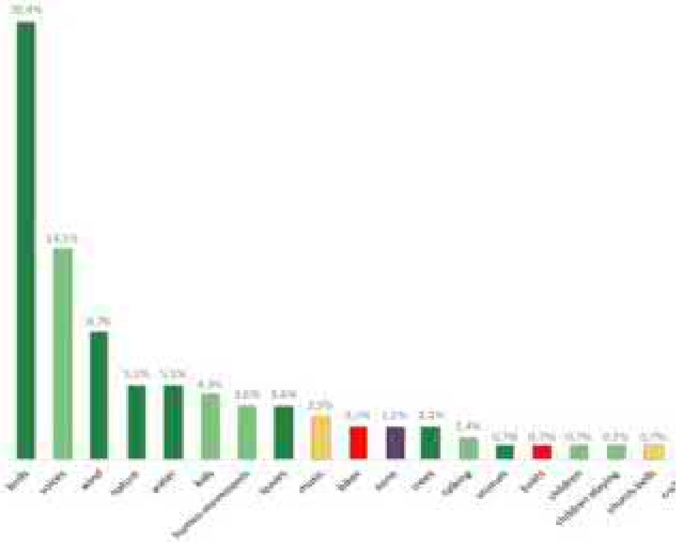


Figure 1 – Sounds that contributed to the sense of quiet in the Hush City project (Radicchi 2018)

With the rapid advancement of Artificial Intelligence (AI) technologies, and the availability of affordable physical computing prototyping platforms such as Arduino and Rasberry PI, we are beginning to see the proliferation of low-cost noise sensor networks. The Dynamap (for Dynamic Acoustic Mapping) projects in Rome and Milan employ low-cost sensor networks to provide real-time noise maps of key transport routes and other strategically important parts of those cities. They have developed the Harmonica Noise Index indicator that includes a correction to the average measured noise levels to better reflect the likelihood of community disturbance caused by transient peak noise levels (Bellucci, Peruzzi and Gambon 2017). In New Zealand, Waka Kotahi New Zealand Transport Agency have engaged a consulting firm to develop transport noise cameras which measure land transport noise levels and use AI to identify what type of noise has been measured, such as heavy vehicle engine compression braking. The cameras are designed to help substantiate land transport-noise related complaints from the community (Dobbyn 2014). The algorithm used for the purpose of identifying the trigger noise (engine braking) is based on accepted methods developed by the National Transport Commission Australia (Wareing, 2019).

It is likely the same approach can be applied to quantify and describe the range of sounds that make up the entire soundscape. For instance, a low-cost sensor network can be used to determine the level of noise generated by the ocean in a coastal suburb and processing can statistically describe how long the ocean noise occurs at a given level, based on the prevailing weather conditions. Synthesizing data collected in this manner with that routinely being collected by the sonic activists and professional acousticians, an area of reasonable coverage could be developed. A simple GIS based infographic could be used to display the acoustic environment spatially, not just in terms of average or maximum noise levels but in terms of the soundscape. We suspect that this approach may lead to a widespread consideration of the effects of planned activity on the existing soundscape, and to discussion around a regulatory approach for planning to protect or promote specific soundscapes that are seen to hold intrinsic value for communities.

6. Conclusion

With the drift of rural populations to urban areas, pressure is put on existing infrastructure and available land such that people are living in closer proximity to each other and to transport infrastructure. Inner-city living is increasingly appealing to those wanting to escape a long commute to employment and who want to enjoy the entertainment and dining options that a modern city has to offer. Even so, people are becoming more discerning and more aware of the soundscapes around them. The emergence from the COVID-19 lockdowns came as a shock to many after they had become accustomed to the sounds of nature such as waves crashing on a beach or native bird song while transport and economic activity had nearly come to a standstill.

In addition, there is ample research to demonstrate that individuals within a population experience and react to noise differently. Already many house buyers shy away from houses on busy roads or main transport routes. The sound of seagulls that to one person represents the sound of the seashore, is nothing more than raucous squawks to another. Our way of planning for noise has to become more nuanced to accommodate these individual differences.

There is clearly the will to promote a greater understanding of the importance of soundscapes, and we have the technology to measure and rate the livability of our cities based on soundscapes.

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Investigations into the accuracy of plant enclosure noise emission prediction methods

Tim Beresford [1] and Kanvin Chen [2]

1 Acoustics, Norman Disney & Young, Auckland, New Zealand

2 Acoustics, Norman Disney & Young, Melbourne, Australia

Abstract

To control noise emissions from equipment outdoors, it is common practice to acoustically shield the equipment inside an enclosure. However, in the case of plant equipment, it is often required that the equipment is well ventilated, meaning that a fully sealed (ideal) acoustic enclosure is not achievable. Noise emissions from partial enclosures with open sides or tops can be modelled in a variety of ways, and this paper investigates the relative accuracy of common prediction methods compared to real-world measurements gathered on a full-scale test rig.

One issue with modelling a partial enclosure is how best to deal with the semi-reverberant noise environment which exists inside the enclosure. 3D computer modelling software (SoundPLAN) was initially used but found to underpredict the resultant sound pressure levels, so a comparison with more traditional computation methods was undertaken. Classical room theory (reverberant + direct component) combined with modified barrier loss modelling methods were used as the basis for comparison. The results of these modelling methods were compared with the real-world test results, and a preferred modelling method proposed.

1. Introduction

Rooftop plant equipment is essential to the operation of, and comfort within, many types of modern buildings and facilities. This plant equipment is often sizeable, can consume a lot of electrical power and, unsurprisingly, has the potential to produce high noise emission levels. To control these noise emissions, it is common practice to acoustically shield the equipment inside an enclosure. However, it is often also required that the equipment is well ventilated, meaning that a fully sealed (ideal) acoustic enclosure is not achievable. A common task for the acoustic designer is to quantify the noise emitted from such plant enclosures, so that early decisions can be made as to the extent of acoustic treatment required to avoid annoyance to neighbouring properties or to meet local authority noise limits.

Modelling noise emissions from enclosures is complex, and oversimplification in the modelling process can lead to significant inaccuracies. These inaccuracies may result in either too much treatment (which can be costly upfront) or under treatment (requiring remedial upgrades, which can be even more costly!). Complex enclosure models can also give inaccurate results if the model does not represent the acoustical environment correctly.

One issue with modelling a partial enclosure is how best to deal with the semi-reverberant noise environment which exists inside the enclosure. A cornerstone of many acoustical calculations is the assumption that the room or enclosure being modelled contains a diffuse sound field, i.e. the reverberant sound is even throughout the enclosure. Such a condition, however, only really comes close to existing in specifically designed acoustical laboratories. Conversely, semi-reverberant environments are much more common, and exist where the absorption that is present within the enclosure is unevenly distributed, or where the total absorption is very high. This is the case for an open top plant enclosure, where the opening is effectively totally absorptive (α = 1), but where the walls are largely reflective. For open top enclosures where the walls of the enclosure are also highly absorptive e.g. covered with acoustic material or open, the sound distribution becomes more uneven.

This paper investigates the relative accuracy of different common prediction methods compared to real-world measurements gathered on a full-scale test rig. 3D computer modelling software (SoundPLAN) was selected representing the current state-of-the-art environmental noise calculation method. Detailed spreadsheet calculations were also undertaken, which make the broad assumption that diffuse sound field conditions exist within the enclosure. The results of these different modelling methods have been compared with the real-world test results.

2. In-situ testing

In-situ measurements of a Monkeytoe aluminium enclosure were conducted to determine the real-world noise reduction characteristics of a typical plant enclosure. An omnidirectional sound source was centred inside the enclosure, with measurements taken at pre-set positions outside the enclosure. The enclosure was altered to give four distinct configurations.

2.1 In-situ test configurations

The 6x5m enclosure consisted of aluminium framing supporting 2mm thick aluminium sheets which formed the perimeter walls. The enclosure had a 400mm gap underneath the front wall, intended to provide better ventilation for hypothetical plant equipment. In some test configurations, this gap was screened off by a secondary 2mm aluminium front barrier, as pictured below.

Monkeytoe (Beresford, T., 2019)
Figure 1: Tested plant enclosure with secondary front barrier installed.

A B&K 4292 omnidirectional loudspeaker was used as the sound source, excited with pink noise. The sound source was placed centrally inside the enclosure, at a height of 1.5m above the aluminium grate floor. The sound source sat 0.5m below the top of the enclosure walls.

Monkeytoe (Beresford, T., 2019)
Figure 2: Sound source inside enclosure with unlined walls (left) and with absorptive lining on walls (right).

In some test configurations, absorption was installed on the enclosure walls. The material used had the following sound absorption coefficients:

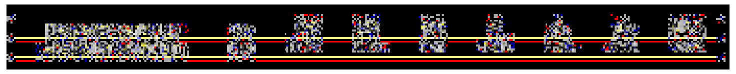
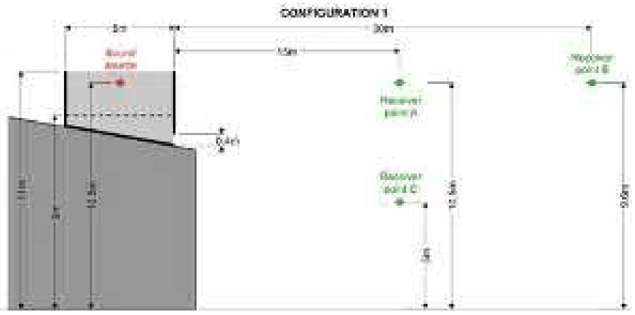


Table 1: 50mm absorptive material absorption coefficients.

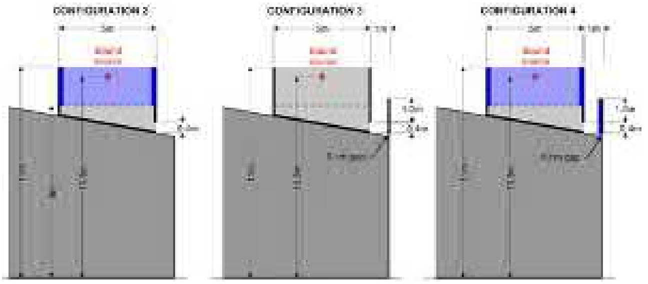
Four test configurations were investigated, each with three sound receiver points, as indicated in Figure 3 and Figure 4 below. In summary, the different configurations were as follows:

- Config 1: Bare enclosure, no secondary front barrier
- Config 2: Enclosure with absorptive lining on walls, no secondary front barrier
- Config 3: Bare enclosure, bare secondary front barrier
- Config 4: Enclosure with absorptive lining on walls, secondary front barrier with absorptive lining

Sound at the receiver locations was measured using B&K 2250 class 1 sound level meters.



Norman Disney & Young (Beresford, T., 2021)
Figure 3: Test configuration 1, receiver point distances shown.



Norman Disney & Young (Beresford, T., 2021)
Figure 4: Test configurations 2, 3 and 4. Absorptive panel locations shown in blue (where fitted). Receiver points as per test configuration 1.

2.2 Measured results

Measured results are summarised in Table 3 below

3. Computer modelling

Two different modelling methods were investigated: Detailed spreadsheet modelling and SoundPLAN software modelling. The input parameters and methodology for each of these is described below.

3.1 Detailed spreadsheet modelling methodology

- Various direct and reverberant sound components were modelled separately and logarithmically summed
- Direct sound components:

    - Distance attenuation modelled as radiation from a spherical point source

    - Barrier losses (DL, see below) over the enclosure front wall and under the front gap (except in configurations 3 and 4 where blocked by the secondary front barrier)

    - Transmission directly through the lightweight aluminium enclosure modelled using the modified barrier insertion loss equation:

[illegible]

(Chen, K., and Beresford, T., 2019:7)

where DL is the diffraction loss of sound travelling over/around the barrier in dB

TL is the transmission loss directly through the barrier in dB

- Reverberant sound components:

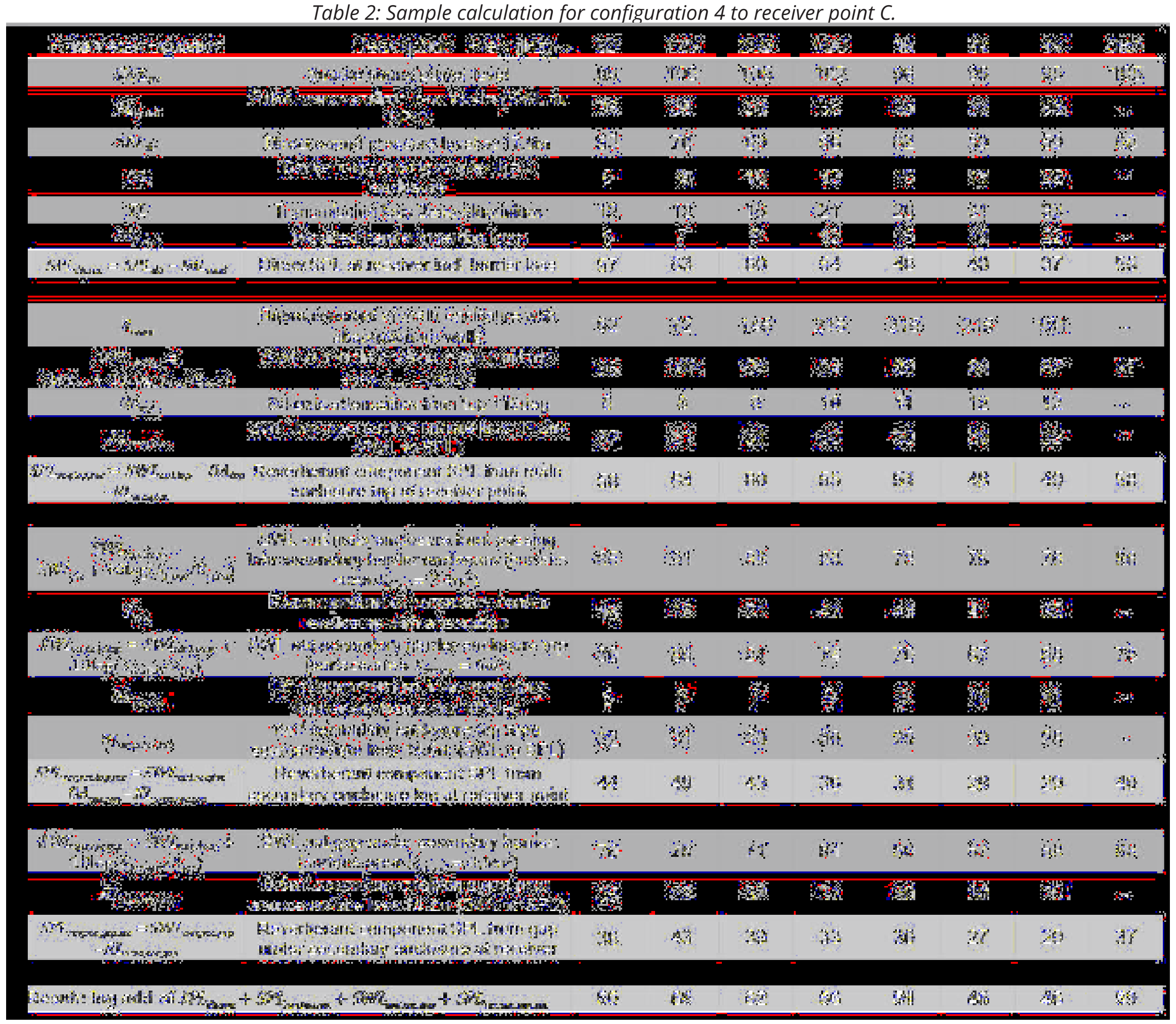
    - Enclosure modelled as a Sabine (diffuse) reverberant room

    - Where installed in configurations 3 and 4, secondary front barrier enclosing volume also modelled as a Sabine reverberant room

    - Sound propagation from enclosure top and front opening to receiver points radiated as an area source (Roberts, J., 1983)

    - Off-axis attenuation calculated and included in sound radiation calculations (SPCC, 1975)

Table 2: Sample calculation for configuration 4 to receiver point C.



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- Sound intensity measurements of various roof constructions.
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- Implementation of lab based, measurement, data processing and report generation for sound absorption measurements. Co funded through a research grant from Callaghan Innovation.

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A Reverberation Room in accordance with:
AS ISO 354-2006: Acoustics - Measurement of sound absorption in a reverberation room.
ISO 15186-1-2000: Acoustics - Measurement of sound insulation in buildings and of building elements using sound intensity - Part 1: Laboratory measurements

Ceiling Flanking Noise facility (CFN) in accordance with:
ASTM E1414-11a: Standard Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling Plenum.

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+64 (0) 21 537 519
mike@acoustic-testing.co.nz

www.acoustic-testing.co.nz

180 Hazeldean Road,
Addington, Christchurch 8024

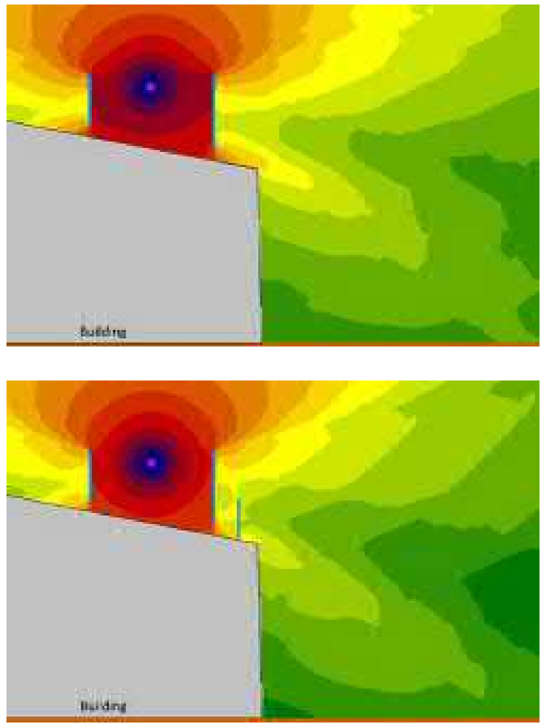
Other unpredicted sound propagation paths were considered to provide negligible contribution to the total sound pressure level at the receiver points.

From this configuration 4 sample calculation, it can be seen that the dominant sound components at receiver point C were the reverberant component emanating from the top of the enclosure, $SPL_{rev,top,rec}$, followed by the direct component, $SPL_{dir,rec}$. The sound components emanating from the secondary barrier enclosure did not contribute significantly to the total sound pressure level. Similar trends were found for all modelled configurations.

3.2 SoundPLAN modelling methodology

- SoundPLAN 8.0 Industry noise module: ISO 9613-2: 1996
- Sound source modelled as a point source
- Reflection order (number of modelled reflections): 12
- Barrier absorption coefficients set per octave band
- Building roof and ground reflectivity set to 1
- For the secondary front barrier, a gap of 0.1m was included to match the in-situ test setup

It should be noted that, although the modelled reflection order has been set relatively high at 12, this is significantly lower than the number of reflections occurring within a reverberant enclosure.



Norman Disney & Young (Chen K., 2019)

Figure 5: Sample SoundPLAN modelling results - configuration 1 (left), configuration 4 (right)

4. Results comparison

The table below summarises and compares the measured and modelled results.

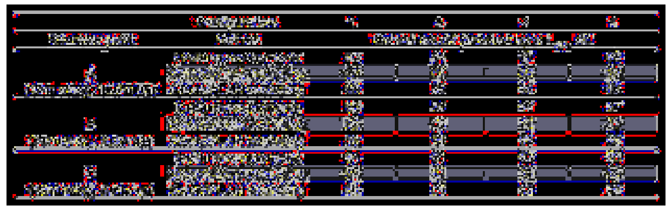
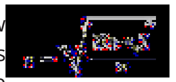


Table 3: Overall dBA results comparison.

From the table above, it can be seen that the modelled overall dBA sound pressure levels aligned relatively closely with measured values, with a tendency for the SoundPLAN model to underpredict the sound pressure levels (especially configuration 2, receiver point C). The spreadsheet model provided surprisingly similar results to the measured values in almost all cases (±1dB).

The tables below show in more detail the differences in spectral results, by subtracting the measured values from the modelled values. At this level of spectral detail, the models do not align as well with the measurements in each individual octave band. A form of standard deviation calculation has been applied as an indicator of the spread of modelled values away from the measured values in each octave band:



Where x_i is the modelled sound pressure level (dB) in each octave band, i

$x0,i$ is the measured sound pressure level (dB) in each octave band, i

N is the number of octave bands

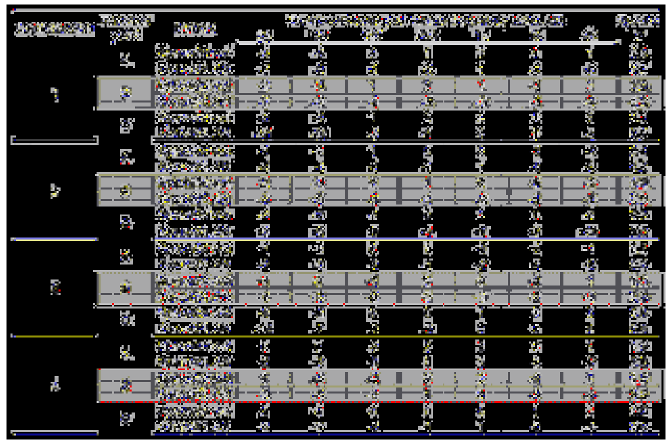


Table 4: Overpredictions in sound pressure level (xi-x0,i).

From this octave band analysis, it can be seen that the differences between the measured and modelled results were very significant in some frequency bands, particularly at the low frequencies. The differences were also noticeably greater in the SoundPLAN model, where the clear trend was for this model to underpredict the sound pressure levels. Depending on the design application, this potential underprediction of the sound pressure level at the low frequencies could result in insufficient acoustic treatment being applied to plant equipment that has a noise spectrum weighted towards the low frequencies.

From a best-practice design perspective, slight overpredictions of the sound pressure levels (positive values in the table above) are much preferred to underpredictions to avoid costly remedial upgrades.

5. Discussion

The results analysis completed in the tables above assumes the in-situ measured sound pressure levels were captured accurately and repeatably. From experience, the measurement tolerance for this type of controlled outdoor testing is estimated to be ±1dB across most of the frequency range of interest. Based on this assumption, the modelling accuracy itself can be assessed with a reasonable degree of certainty.

The accuracy of the overall dBA modelling results, especially of the spreadsheet method, appeared to be very good. The detailed octave band analysis, however, revealed greater differences than expected in the individual bands. Looking at the calculated spectrum spreads (σ) away from the measured results, it is obvious that the SoundPLAN results were considerably less accurate. The average spread for the spreadsheet method was 2.0, whilst the SoundPLAN method was 3.7.

It appears that when combining the octave band results into the overall dBA figure, the variances in the individual octaves bands "average out" to give a result which is very close to the measured dBA value. This was the case for the broadband pink noise source used in this study, however, this pattern may not hold particularly true for real-world plant equipment which could be strongly tonal or have a sound spectrum skewed towards the higher or lower frequencies.

It is hypothesised that the discrepancies in the SoundPLAN results are due to the way the software implements ISO 9613-2 to model the semi-reverberant sound field inside the enclosure. The simplest tool available in SoundPLAN to create a "reverberant" sound field is to increase the reflection order in the calculation kernel. Experimentation with increasing the reflection order from 3 (few) to 12 (many) had little effect on the results, however, with the accuracy improving by between 0dB and 0.5dB only, depending on the modelled configuration. Using a reflection order of 12 or more for large SoundPLAN models is considered to be impractical, given the typically long associated computational times.

The SoundPLAN (ISO 9613-2) modelling method (with low reflection order) is expected to offer better accuracy at predicting basic noise barrier losses where there are few or no other surfaces near the sound source to create a semi-reverberant field.

The spreadsheet modelling method was relatively detailed and time consuming model to set up, although this level of detail was found to be necessary in order for the results to align as well as they do with the measured values. Modelling of the reverberant or direct components only (which can seem desirable to economise on spreadsheet setup time) was found to be a significantly inaccurate approach for the range of different configurations found in this study alone.

6. Conclusions

From an acoustic designer's perspective, modelling approaches which offer accurate results are, without a doubt, preferred. However, without verification of a selected approach against real-world data, it is impossible to know whether the model is providing the assumed accuracy.

This paper has investigated two common computer modelling methods for predicting sound propagation from a rooftop plant enclosure, and compared the results to those obtained from full-scale in-situ testing of a plant enclosure of the same configuration. The modelling methods investigated were the state-of-the-art 3D software package SoundPLAN, and detailed spreadsheet modelling which calculated the direct and reverberant sound components, assuming a diffuse sound field inside the enclosure.

It was found that the spreadsheet model provided greater agreement with the measured results, although a reasonable level of input detail was required to obtain this degree of accuracy. The SoundPLAN model was found to largely underpredict the resultant sound pressure levels, which is alarming from a best-practice design perspective, where slight overprediction is preferred to provide a level of design conservatism.

As stated in the introduction, an ideal acoustic enclosure with a diffuse sound field is rare, and certainly does not exist in any open top plant enclosure. On this basis, using the diffuse sound field assumption should not yield particularly accurate results, however, it appears that calculations using this approach may still be more accurate than other state-of-the-art modelling methods.

Acknowledgements

The authors would like to acknowledge the significant contribution from Monkeytoe for facilitating the testing of the enclosure on the roof of their factory at Normanby, Taranaki.

References

Chen, Kanvin, and Beresford, Tim. 2019. 'Lightweight noise barriers: The real-world effects of panel surface mass and absorption on acoustic performance' *Acoustics 2019*. Australian Acoustical Society.

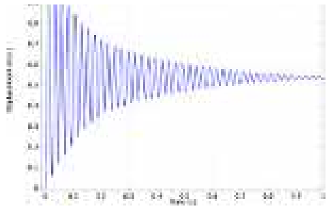
ISO 9613-2:1996: Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation. 1996. Geneva: International Organization for Standardization.

Roberts, J. 1983. 'The Prediction of Directional Sound Fields'. *Mechanical Engineering Transactions*, 16-22. Australia, The Institute of Engineers.

SPCC. 1975. 'Directivity loss in a free field'. *Design Guide*, Acoustics N 1017. 30.9.75

How sound is your acoustics knowledge?

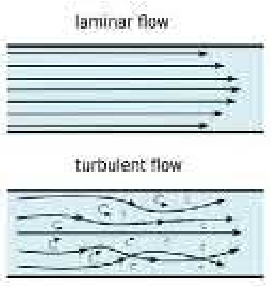
1. True or False? The logarithmic scale may be used to compare and measure vibration levels?



2. True of False? The condenser or capacitor is an electrical component in the condenser microphone which prevents the passage of electric current in one direction (Direct Current) but allows the transmission of electrical current which alternates in direction (Alternating Current)?

3. Complete the standards title 'ISO 140 Part 10: Laboratory measurements of airborne sound insulation of ....'

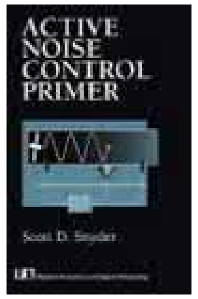
4. True or False? Very little noise is caused by laminar flow however turbulently flow can be very noisy?



5. True or False? Damping is the process whereby because of some frictional processes vibrational or structure-borne sound energy is converted to heat, thereby reducing the level of sound or vibration.

6. True or False? Sound absorbing materials are used to reduce transmission of airborne sound between spaces?

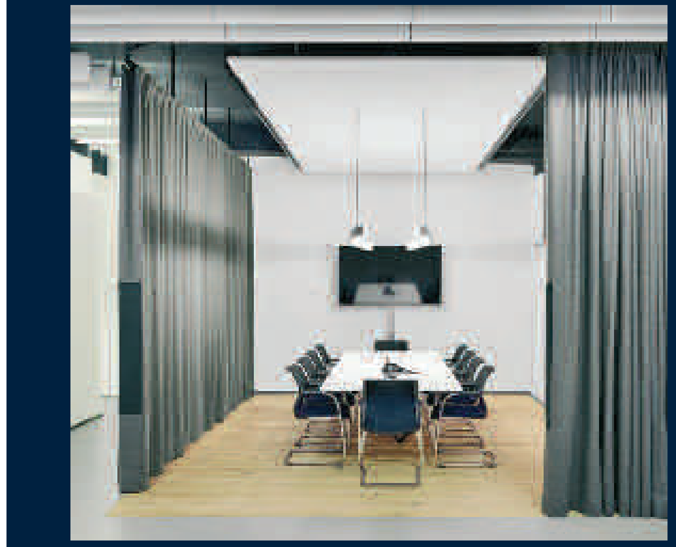
7. True or False? Active noise control systems apply the principle of destructive interference between waves to reduce noise?

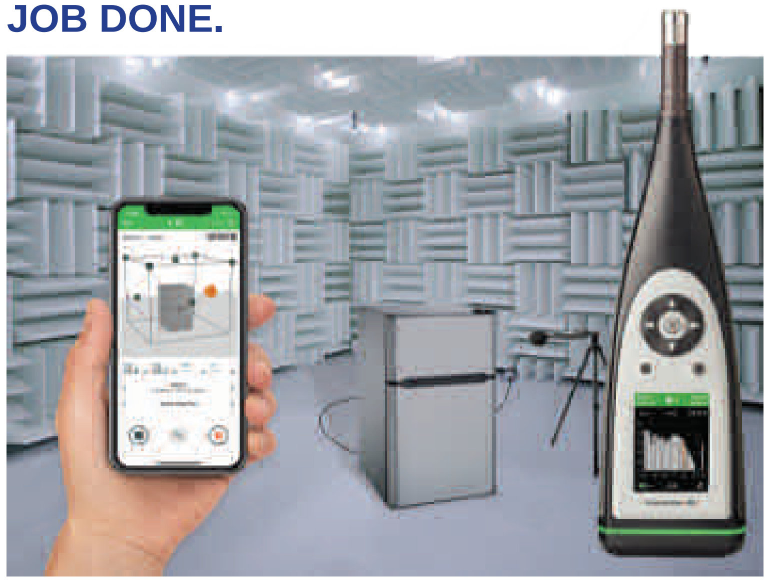


8. True or False? Hearing protection (ear protection) should be seen by managers in industry as the first method for protecting peoples hearing?

9. What does 'HML' stand for in the HML method with respect to hearing protectors and protection?

10. True or False? Evaluation of human perception for exposure to vibration levels for residents in buildings would not be expected to be 'uncomfortable' when levels are 2.0 m/s² or above?





Quiz Answers

1. True
2. True
3. ISO 140 Part 10: Laboratory measurements of airborne sound insulation of small building elements’
4. True
5. True
6. False. Sound insulation materials are used to reduce transmission of airborne sound between spaces
7. True
8. False. Hearing protection should be seen as the last resort, and adopted only if failure to reduce noise by other means has failed such as control at source for example
9. HML stands for high, medium and low frequency
10. False. Levels of $2.0 m/s^2$ would be perceived by most persons as ‘extremely uncomfortable’.

Upcoming Events

All event dates are current as at time of print.

ACOUSTICS 2022 | October 31 – 2 November 2022 | Wellington | NZ

28th Annual International Conference on Sound and Vibration (ICSV28) | July 24 – July 28 2022 | Leonardo Royal Southampton Grand Harbour, Singapore

182nd Meeting of the Acoustical Society of America | May 23 – May 27 2022 | Denver, Colorado USA

INTER-NOISE 2022 | August 21 – 24 2022 | Glasgow | Scotland

NOISE-CON 2022 | June 13 – June 15 2022 | Lexington, KY | USA

EUROREGIO/BNAM 2022 | May 9 – May 11 2022 | Aalborg

International Conference on Underwater Acoustics (ICUA) 2022 | June 20 – June 23 2022 | Leonardo Royal Southampton Grand Harbour, UK