



NEW ZEALAND ACOUSTICS

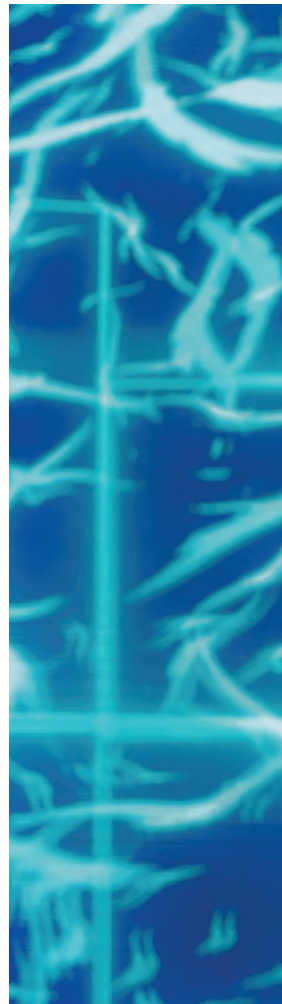
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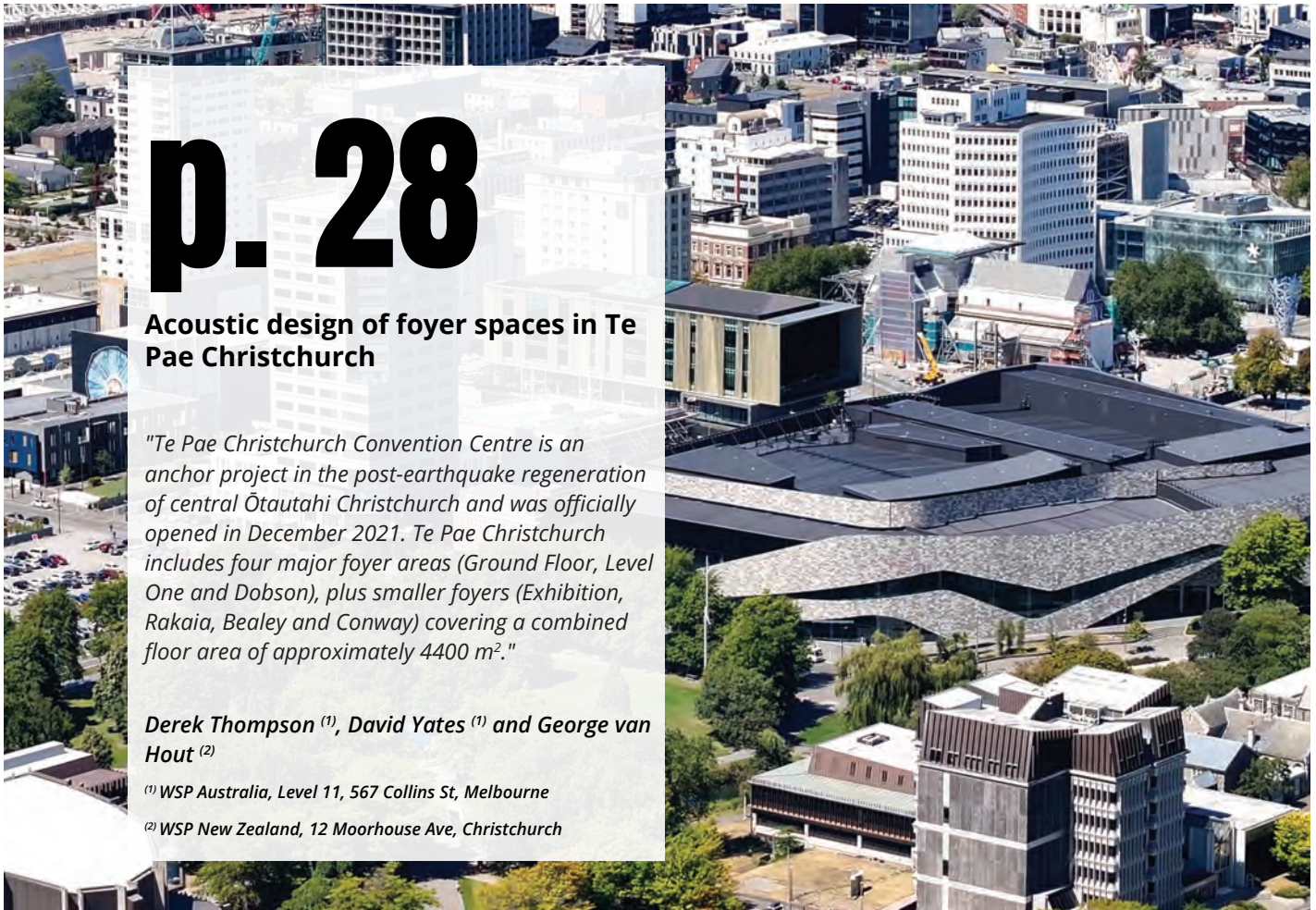
Acoustic design of foyer spaces in Te Pae Christchurch

"Te Pae Christchurch Convention Centre is an anchor project in the post-earthquake regeneration of central Ōtautahi Christchurch and was officially opened in December 2021. Te Pae Christchurch includes four major foyer areas (Ground Floor, Level One and Dobson), plus smaller foyers (Exhibition, Rakaia, Bealey and Conway) covering a combined floor area of approximately 4400 m²."

Derek Thompson ⁽¹⁾, David Yates ⁽¹⁾ and George van Hout ⁽²⁾

⁽¹⁾ WSP Australia, Level 11, 567 Collins St, Melbourne

⁽²⁾ WSP New Zealand, 12 Moorhouse Ave, Christchurch



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Generative AI and Acoustic Reporting

"Generative Artificial Intelligence ("AI") refers to systems such as ChatGPT and Gemini that extrapolate responses based on an enormous set of training data. The results vary in quality, but are rapidly improving. This is already having a substantial impact on a number of industries."

Alister Stubbe ⁽¹⁾ and Jonathan Prins ⁽¹⁾

⁽¹⁾ Acoustic Engineering Services, L3 62 Worcester Boulevard, Christchurch 8013

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An overview of the integration of metamaterials into acoustic building elements

"Transmission loss through a layer of porous media can be predicted by modelling the layer as an equivalent fluid."

Andrew Hall, Vladislav Sorokin, George Dodd, Gian Schmid and Emilio Calius

Acoustics and Vibrations Research Centre, Department of Mechanical and Mechatronics Engineering, University of Auckland, Grafton, Auckland 1010, New Zealand,

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Investigating the Lombard effect in a speaker's voice in noisy virtual environments under varying room acoustics

"When multiple people converse in an indoor environment, achieving satisfactory communication is often challenging due to high level noise caused by poor acoustic design. Communication in noisy environments gives rise to the Lombard effect, an involuntary reflex that causes one to raise their voice in the presence of noise."

Alyssa D'Souza ⁽¹⁾, Yusuke Hioka ⁽¹⁾, Malcolm Dunn ⁽²⁾ and James Whitlock ⁽²⁾

⁽¹⁾ Acoustics and Vibration Research Centre, The University of Auckland, New Zealand

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Tracy Hilliker

Incoming President of the Acoustical Society of New Zealand Inc.

Tēnā koutou katoa,

It is an honour and privilege to assume the position of President, and I would like to express my gratitude to those who have entrusted me with this responsibility. As I step into this role, I know I have big shoes to fill, and I would like to take this opportunity to acknowledge and thank my predecessor Tim Beresford for his dedicated service and leadership, which has set a strong foundation for the future. I am excited to continue to work alongside the wonderful and dedicated members of our Council, connecting with our wider community, serving with integrity and diligence, and collaborating to address the important issues that affect us all.

Our Acoustics 2024 conference held in Christchurch in early September was a great success, and a summary of the event can be found over the page. Regrettably, we mourned the loss of Sir Harold Marshall and offer our condolences to his family and MDA colleagues. Acoustics 2024 provided us with the opportunity to immerse in and celebrate the accomplishments of those before us, reflect on the journey of development, and consider our contributions for future generations. It was delightful to socialise and network at the evening functions, and notably to celebrate the exceptional contributions and achievements of Chris Day, who was honoured with a fellowship of our Society. Congratulations are also extended to the successful recipients of the ASNZ Conference Fund and the ASNZ Student Prize awards. While there are many people to thank, our sponsors deserve special recognition, as without their support our conference simply wouldn't happen. It was a pleasure to be your Conference Chair, and as I hand over the reins to the next conference organiser, I look forward to seeing what we deliver in 2026.

One important aspect impacting the society is the proposed amendments to the ASNZ Rules, which will soon be referred to as our *Constitution*. These changes reflect feedback from our membership and represent a fundamental transition in our governance framework to comply with the new mandatory provisions of the Incorporated Societies Act 2022. There are also updates to our *Rules of Conduct and Disciplinary Measures*, which signal a refinement in our approach to disciplinary matters. This will strengthen the equitable and consistent treatment of all parties involved, and better define the processes and timeframes. The ASNZ Constitution will need to be voted in by our membership, then be re-registered and thus continue in its current form. I encourage you all to attend (or dial in) when we announce a Special General Meeting next year, so we can have a quorum of members and complete this next important step. I extend my thanks to those who have contributed to this process thus far, especially those on the Council who continue to volunteer their time to implement these changes, and those involved in disciplinary reviews, who conduct due process, and exercise care and diligence, acting in good faith and in the best interests of our society and industry.

As many of us are aware, New Zealand acoustical standards have not been kept up-to-date, primarily due to a challenging user-pay model. However, there is active development and maintenance of a large catalogue of ISO and IEC acoustics standards at an

international level. Through Standards New Zealand, a handful of our colleagues represent and contribute to reviews of these standards. Nonetheless, our future participation is at risk, as a significant and sizable fee is now required to retain voting rights. Our profession will need to support and actively work together to ensure this invaluable opportunity can continue. A further avenue for industry participation is to have more NZ companies join the Association of Australasian Acoustical Consultants (AAAC), which, on the back of the recent release of the NZBC Clause G6 guidance, member firms will soon be able to comment on the draft guidance for NZS 6803:1999 Construction Noise. I want to recognise the ongoing contribution of Jon Styles and Tim Beresford, who represent NZ interests as members of the AAAC Board.

As we move forward, I encourage all members to join our LinkedIn group to stay updated on current affairs and networking opportunities, including monthly Lunch Bunch events, and the end-of-year branch celebrations to be held in Auckland, Wellington and Christchurch. Additionally, we anticipate the imminent launch of our new website, offering an enhanced digital platform for our society. Stay tuned for updates on this exciting development.

I want to acknowledge the wonderful, ongoing efforts of Lindsay Hannah and Wyatt Page, who have served as Editors-in-Chief of this Journal for the past 10 years. Their work continues to help document and disseminate information and advancements in our specialised field. We are fortunate to have their dedication, professionalism and expertise, which has been instrumental in maintaining this valuable resource.

The new ASNZ Council has been elected, and it is with great pleasure that I introduce: James Whitlock (Secretary), Hedda Landreth (Treasurer), Michael Kingan (Vice President, Te Ika-a-Māui North Island), Mike Latimer (Vice President, Te Waipounamu South Island), Tim Beresford, Jon Styles, Christian Vossart, Wyatt Page, Mathew Legg, Victoria Raselli, and our newest recruit, Paul Hazard.

As the summer break approaches, I extend my warmest wishes to you all for a safe and wonderful holiday ahead. Enjoy some quality time with friends and family, unwind, recharge, create lasting memories and take care of each other. I look forward to reconnecting again in the new year.

Ngā manaakitanga,

Tracy Hilliker

Incoming President of the Acoustical Society of New Zealand Inc.



Lindsay Hannah and Wyatt Page

Principal Editors

Greetings, talofa and nau mai haere mai

Welcome to the third and final issue of New Zealand Acoustics for 2024 (Volume 37, 2024, Issue #3).

This is a very special edition. We as an acoustic family farewell the passing of Sir Harold Marshall a kiwi legend in acoustics and highly respected architect, engineer and physicist. I personally first learnt of Sir Harold's body of work before entering the field of acoustics when I was a young student at Victoria University School of Architecture and Design. We celebrate all that Sir Harold gave to the world of acoustics not only as a professional but as a mentor and friend to so many. We extend our deepest condolences to Lady Shirley Marshall, Sir Harold's Family and the wider Marshall Day Acoustics family.

This is also a special edition in that it is the 10th Anniversary Edition for Wyatt and I as Editors of 'New Zealand Acoustics'. Wyatt and I want to acknowledge all the other team members over this 10 year period that have been on the Editorial Team or have just helped us with production or admin, there are far too many team members to individually list and I am scared I will forget someone, but they all know who they are. Thanks for all the help we could not have done it without you! We also wish to thank past Editors who developed the journal over many years to the point where they handed the reins to us in 2014.

Last time I wrote to you it was Winter. There was snow in the Tararua Hills and it was fairly cold. What a difference a few months makes. We have now started daylight savings, the weather is much nicer, definitely warmer, and our evenings are longer. Best of all we are now close to the Summer Holiday. Having the extra time in the evenings and Summer weather is a bonus so don't waste it, get out if you can and do something you love.

We have news and a super quiz, as well as all the standard items. We also have a great selection of papers which we have chosen from the new pool of updated papers presented at the recent New Zealand Acoustical Society conference '*Reflecting on the past, innovating for the future*'. From feedback that we have received we are told the conference was a great success.

On review of the conference papers it amazes me for a relatively small Society the talent we have across our membership and the wide range of topics across the papers presented. If you are one of the members that took the time to prepare a paper and share your knowledge with the wider membership at the conference we thank you.

As per normal procedures, at our AGM we have elected our Officers of the Society. We now have new Officers including of course a newly elected President. Congratulations if you are a newly elected or re-elected Officer. A special congratulations to Tracy Hilliker on becoming the new President of the Acoustical Society of New Zealand. We look forward to seeing how Tracy builds on Tim's past successes and work and what direction Tracy will now take the Society as our incoming ASNZ President.. We also look forward to the first Presidential Write up for Issue 3.

Have a great summer break, be safe, be productive and we will see you back hear for Issue #1 Volume 38, 2025.

Season Greetings, Alofaaga and Ngā mihi.

Lindsay Hannah & Wyatt Page
Principal Editors

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Sir Harold Marshall

World-renowned acoustician described as 'a magician in sound'



OBITUARY: In an article coinciding with the May 2024 launch of the film *Maurice and I*, a documentary on the partnership of Sir Miles Warren and Maurice Mahoney and the saving of the Christchurch Town Hall, Sir Harold Marshall is described as the film's "break-out star". Marshall, who died on August 31, two weeks short of his 93rd birthday, is perhaps less well known to the general public than the building's architects but his contribution was critical to its success. From its opening in 1972, Marshall became a star in the field of acoustic design. His theory of lateral sound reflection, developed in conjunction with that project, initiated a paradigm shift in concert hall design around the world.

Marshall, then a senior lecturer in acoustics at the University of Auckland's School of Architecture, was appointed as a consultant to the assessment panel for the town hall design competition in 1965. By 1966, when he received the five finalists' plans, he was enrolled for a PhD in acoustics at Southampton University in the United Kingdom. Traditional "shoe box" concert halls, a form used for town halls in Auckland, Wellington and Dunedin in the first half of the 20th century, had ensured reliable acoustics in the past, but none of the short-listed entries conformed to this model. Marshall's challenge was to identify a design that would combine architectural and acoustic excellence. Following Warren and Mahoney's success in the competition, Marshall was appointed acoustic consultant for the completion of the project. He later observed that their design was of such high quality that he felt compelled to find a way to make it work acoustically.

Marshall's eureka moment came during a concert in the Royal Festival Hall in London. Built for the Festival of Britain in 1951, that auditorium was much wider than traditional concert halls and Marshall realised that its problematic acoustic resulted from the absence of fractionally delayed sound reflections coming from the side walls of the space to enrich the sound emanating directly from the stage. He recognised that the sound reflectors that already formed a part of Warren and Mahoney's elliptical design could be tuned to achieve sound quality comparable to that of traditional auditoriums. Having completed his PhD, and further refined his theories on concert hall design in consultation with acousticians in Germany, he took up a position at the University of Western Australia. There, in collaboration with Mike Barron, he modelled the acoustics of the Christchurch auditorium using a former Nasa computer, the first time such advanced technology had been used in concert hall design.

The opening of the Christchurch Town Hall in September 1972 was a triumph for the design team, none of whom had designed a major auditorium before and all of whom were in their early thirties when the project began. The acoustics of the auditorium

combined a full-bodied, resonant sound with a level of clarity that was previously thought to be impossible in halls of that shape. Since its opening the auditorium has been admired by musicians as diverse as conductor Leonard Bernstein, baritone Sir Bryn Terfel and singer-guitarist Carlos Santana.

Arthur Harold Marshall was born in Auckland on 15 September 1931. He attended King's College where he sang in the chapel choir, the beginning of a life-long involvement in choral performance. He followed his father in becoming an architect, completing a Bachelor of Architecture at Auckland University College in 1956, along with a BSc in Physics. Following time overseas and a brief period practising architecture in Auckland, he was appointed to a senior lectureship in the Auckland School of Architecture in 1960.

He returned to a professorial position at the University of Auckland in 1973. The acoustic research laboratory he led achieved an international reputation. Professor Deidre Brown, a former student, remembers him "as a highly engaging teacher [who] drew all of us into the world of sound transmission and how important this was for intelligibility and the appreciation of music". His architectural training meant that, as an acoustician, Marshall was able to collaborate with architects on equal terms. A hallmark of his acoustic designs is that they are always fully integrated with the architecture of the space.

From 1981, in partnership with Christopher Day, he established the consultancy Marshall Day Acoustics, now one of the world's most respected and sought-after acoustic practices with more than 100 staff in offices across Australasia, in China and in France. The firm's reputation was built on the innovations Marshall introduced in Christchurch and subsequently shared in more than 200 scientific publications.

It was consolidated by the success of concert halls around the world, including the Michael Fowler Centre, Wellington, Perth Concert Hall, Segerstrom Hall, Orange County, California, Guangzhou Opera House, China, in conjunction with the celebrated Iranian/British architect Zaha Hadid, and culminating with the Philharmonie de Paris, designed with renowned French architect Jean Nouvel.

A 2015 profile in *Le Figaro* characterised Marshall as "a magician in sound" and a "star of world acoustics". On its opening the Philharmonie was described as having "dazzling clarity and generous depth of sound that... [is] like a vivid, physical presence". It was, concluded *The Guardian*, possibly the most exciting place to hear music in the world.



The Philharmonie was Marshall's swansong but in 2015 the future of the Christchurch Town Hall remained uncertain. He joined with Miles Warren, Maurice Mahoney and Christchurch's citizens in a campaign to save it, submitting to the Christchurch City Council in person and rallying the international acoustics community to petition the city to save the building. He had the satisfaction of cutting the ribbon alongside his old friend, Sir Miles Warren, on its reopening in February 2019.

Marshall was no dry technocrat; he was fascinated by the intersection between metrics and metaphysics, the point where rational analysis ended and the senses and emotions took over in the perception of sound. He summed this up on camera for Maurice and I: "The sense of presence is a gift; it's of the same family as grace and love – none of those can be engineered."

Harold Marshall was a dedicated family man. He was devoted to Shirley (nee Lindsey), his wife of 60 years who predeceased him in 2016. They had four sons and family life revolved around a wide range of enthusiasms including sailing and fishing. The Mt Albert Methodist Church was also a central part of his life. Following his retirement from the University of Auckland in 1998 he spent seven years in Southland in a horticulture venture growing hydrangeas. Continuing demands for his acoustical expertise brought him home to Auckland, from where he worked on the high-profile projects that culminated in the Paris Philharmonie.

Marshall's family connections to Mt Albert extend back to the early twentieth century and in his late eighties he became involved with the campaign to preserve the mature exotic trees on Ōwairaka/Mt Albert, becoming a patron of the group Honour the Maunga. His wise counsel and dedication to the cause gained him recognition as a kaumatua. The trees still stand. His endless curiosity about the natural world was complemented

by his engagement with the arts; he wrote poetry, painted watercolours and sang in choirs throughout his long life.

Few New Zealanders have made greater contributions to their chosen fields than Harold Marshall. He was knighted for services to acoustic science in 2009 and was the recipient of many prestigious awards, including the Wallace Clement Sabine Medal (Acoustical Society of America, 1995) and the Rayleigh Medal (United Kingdom Institute of Acoustics, 2015). His realisation of the importance of lateral sound reflections in concert hall design, modelled at full scale in the Christchurch Town Hall auditorium, conclusively demonstrated that acoustic excellence could be achieved in concert halls that broke with traditional models. In doing so he helped liberate future concert halls from the strait jacket of nineteenth-century solutions. Musicians and audiences in auditoriums around the world are the ongoing beneficiaries of his dedication to both the science and the art of acoustics.

He is survived by his four sons, 16 grandchildren and 11 great grandchildren.

– Ian Lochhead

Sources: Chris Day; John Marshall; Harold Marshall, *Korowai of Life and Love* (privately printed, 2022); Ian Lochhead, ed., *The Christchurch Town Hall 1965-2019: A Dream Renewed* (Canterbury University Press, 2019).

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ASNZ Conference 2024



It has been a decade since Ōtautahi Christchurch hosted the Acoustical Society of New Zealand's biennial event, when we explored 'Acoustics in a Rebuilding City'. The Christchurch Town Hall suffered significant damage during the Christchurch earthquakes. However, this iconic structure was not to be lost forever and after eight years and a heritage conservation project costing \$167 million, this facility provided the venue for the ASNZ's 26th Conference **Acoustics 2024**. The theme of the current conference being **Reflecting on the past, innovating for the future**.

The Christchurch Town Hall is internationally recognized for its excellent architectural and acoustic qualities. It is within the concert hall known as the Douglas Lilburn Auditorium that Sir Harold Marshall's design imbued some 50 years ago a revolutionary approach to concert hall acoustics that uses early lateral reflections to impart to the listener - wherever they are sat - a musical gestalt that both envelops and provides clarity. This work has profoundly influenced contemporary concert hall design ever since.

With much reflective thought, the conference began on the 2nd September as news spread that Sir Harold had passed away over the preceding weekend. Our thoughts, tinged with sadness were also buoyed by a determination to celebrate the incredible accomplishments and lasting legacy his work and life has left so many in New Zealand and around the world. The Opening Plenary entitled *Concert Hall Acoustics and the Christchurch Town Hall* included video of Sir Harold edited and presented by his friend and colleague Chris Day plus a tour of the Douglas Lilburn Auditorium supported by a concert violinist.

So ensued a programme of 11 technical sessions over three days with a bevy of high-quality papers. Delegates were spoilt to a plethora of interesting, entertaining, confidently delivered and informative presentations. Thanks go to Technical Session (and Keynote Address) Chairs.

Technical sessions were interspersed with tasty lunches and afternoon teas consumed whilst frequenting trade stands

hosted by the ASNZ's invaluable sponsors that showcased innovative products and services. Our sponsors of every metallurgic hue, corporate and barista coffee affiliation, deserve both our gratitude and thanks. Without them, there would not be any conferences. As our sponsors support the ASNZ, our membership must support our sponsors for this symbiotic relationship to continue flourishing.

The Society's Annual General Meeting was held after the Technical Sessions closed on late Monday afternoon. The AGM welcomed the election of long-standing Society Council Officer Tracy Hilliker to President, with James Whitlock and Hedda Landreth remaining as Secretary and Treasurer respectively, thereby rounding out the Executive. Paul Hazzard was also welcomed as a new Council Officer along with returnees Tim Beresford (outgoing President), Michael Kingan, Mike Latimer, Matthew Legg, Wyatt Page, Victoria Rastelli, Jon Styles and Christian Vossart.

A short scenic stroll through the park and along the river Avon, the Welcome Function that followed on Monday evening allowed attendees to network and reconnect with faces old and new in the relaxed setting at Mr Brightside Rooftop Bar. Many then took advantage of a private screening at Lumière Cinema of *Maurice and I* (featuring Sir Harold Marshall); a feature length documentary celebrating Sir Miles Warren and Maurice Mahoney's architectural partnership and their 'brutalist' style that has hugely influenced both architecture and their peers throughout New Zealand. The Christchurch Town Hall is regarded by many, including Warren and Mahoney themselves, as their finest work.

In addition to the Opening Plenary, conference attendees were fortunate enough to have a further three keynote speakers, two of whom spoke on Tuesday. Our international speaker, Jeffrey Mahn started the day with discussion of his current studies. As a Senior Research Officer for the National Research Council of Canada for the best part of the last decade, he focused on the prediction of structure-borne noise in mass timber multi-tenancy dwellings, and shared with us the latest research in developing



guidance to enable sustainable home design to support the Aging in Place Program facilitating people to age in the home or community of their choice.

Emeritus Steve Dawson spoke of his documented acoustic behaviour and conservation biology of dolphins and whales over the last 40 years. Most recently, he quantified sound propagation from recent pile driving in Lyttelton Harbour that resulted in the long-lasting displacement of our endangered Hector's dolphins and discussed how - given the dolphins endemic and endangered status - the effective mitigation of these effects is essential.

The Gala Dinner at the Christchurch Art Gallery on Tuesday evening was supported by our Platinum Sponsor GIB. Dinner speaker and MC for the night Te Radar's infectious energy, gregarious nature and zany enthusiasm filled the venue on an upbeat evening that included the presentation of a Fellowship of the Society to Christopher (tiff) Day. The presentation included personal tributes from James Whitlock of Marshall Day and citation of the impact that Chris' career has made on the Acoustical Engineering community both in New Zealand and abroad. Still currently practicing in a reduced capacity, Chris regaled us with anecdotes from his origins in Melbourne, through his early days at Sound Research Laboratories in Suffolk in the UK, to being the co-founder of Marshall Day and making New Zealand his home. Aply accompanied by the Gwynn Reynolds Jazz Trio, a friendly, fun and collaborative atmosphere was felt by all over the evening.

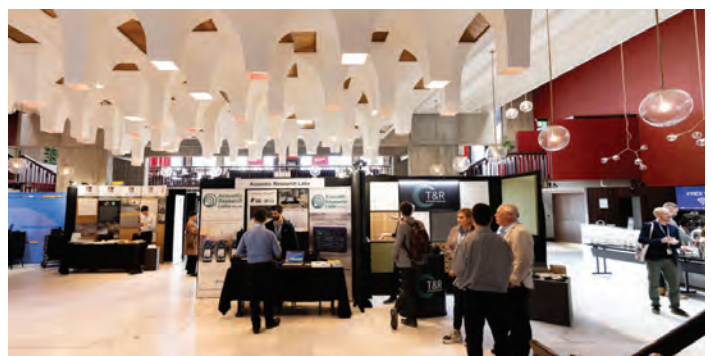
Felicity Haymen kicked-off the last day of the conference with the final keynote address. Christchurch International Airport

Limited's Environment and Planning Manager presented on the 'Modern Airport'. Felicity's presentation touched upon the once in a 10-year project of remodelling Christchurch International Airport's aircraft noise contours and recounted the importance of aircraft noise contours in enabling the modern airport to allow economic prosperity and airport expansion, whilst ensuring inter-generational community protection.

As the final technical session brought a close to the conference on a Wednesday afternoon, the prize for the Best Student Paper presented by Michael Kingan as Prizegiving Chair, was awarded to Yousif Badri for a paper entitled "Sound Absorption Characteristics of Unconsolidated Granular Materials".

The final paper presented at the conference was Thomas Scelo's Recent development in visualisations for acoustics. This received the inaugural Harry Clarke prize initiated by Keith Ballagh (FASNZ) for the Best Room Acoustics Paper. Chris Day presented the prize as representative of the sponsor Marshall Day Acoustics. If the Christchurch Town Hall represented the genesis of a new auditory typology for concert hall design, then surely the Philharmonie de Paris in France was Sir Harold's finale.

And so, it is with thanks to the Conference Organising Committee, and all those others that tirelessly contributed, that we bid farewell to Christchurch (until next time) and thoughts drift to the next ASNZ conference in 2026. Where will it be? When will it be? Will it be a departure from the normal destinations? Did someone mention Tauranga...





Generative AI and Acoustic Reporting

Alister Stubbe ⁽¹⁾ and Jonathan Prins ⁽¹⁾

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Abstract

Generative Artificial Intelligence (“AI”) refers to systems such as ChatGPT and Gemini that extrapolate responses based on an enormous set of training data. The results vary in quality, but are rapidly improving. This is already having a substantial impact on a number of industries. This paper explores the potential impact of Generative AI on the New Zealand Acoustic Engineering industry. This includes a review of the technical accuracy of potential outputs, and the level of proficiency required to achieve appropriate results. The technical accuracy of reports was assessed by qualified acoustic engineers comparing the generated reports against existing test data, relevant rules and standards, calculation, modelling, and New Zealand standard convention. The results indicated that a high level of technical knowledge was needed to generate reports that could be considered usable. However, only a basic level of technical knowledge was needed to generate reports that looked sufficiently detailed to pass a high-level inspection, but that contained multiple errors.

1. Introduction

As Generative artificial intelligence (AI) becomes more widely used among a wide range of industries, its potential effectiveness (as well as any drawbacks) within the field of acoustic engineering should be well understood before it should be considered for use in any professional capacity.

We have therefore considered acoustic reports previously created by Acoustic Engineering Services (AES) evaluating three common topics (traffic noise insulation, residential inter-tenancy wall / floor reviews, and controlling the reverberation time within a space). Using these as a basis, we attempted to replicate them using ChatGPT-4o and Gemini Advanced. We then evaluated each of these generated works in terms of usability, as well as identifying common trends in where these generated reports would run into errors.

2. About Generative AI

Generative AI such as ChatGPT and Gemini are built using a large set of training data, including a variety of mediums such as text, images, and video [1]. The training data are used to form appropriate responses based on the input provided. This involves taking millions of example works created by humans to use as training data, filtering for quality, and feeding the data into a computer model that establishes patterns within that data.

Once the model has been trained, it is able to provide human-like responses to user prompts based on the original training data, and then using that as a basis to respond to each query in

the same way it would expect a human to respond to it [2].

ChatGPT and Gemini are two of the most popularly used Generative AI tools, and tools such as these have already been considered for use within architectural and engineering fields [3].

As generative AI tools respond based on the prompt provided, any responses are dependent on the level of detail and information entered by a user. These responses can be forced to more closely resemble the output that the prompt provider desires by clearly outlining the exact information the generated response should contain. This can be done by either entering an extremely detailed initial prompt, or by using a chain of multiple prompts as part of a single session [4].

3. Methodology

Report Types

In order to evaluate how effectively generative AI tools can be used to create acoustic reports, we have considered three common types of acoustic assessments: traffic noise insulation, residential inter-tenancy wall / floor reviews, and controlling the reverberation time within a space.

Traffic Noise

The traffic noise insulation reports used as examples for this study were typically prepared for architects or developers to present to local city councils to demonstrate compliance with District Plan requirements. Projects included both new dwellings and extensions to existing dwellings. Our study included reports referring to Wellington, Christchurch, Hawke’s Bay, and Greytown

District Plans. These reports considered the noise generated by traffic, compared this to the relevant requirements, and evaluated whether the proposed building construction would be sufficient based on this information.

Inter-Tenancy Wall / Floor System

All residential inter-tenancy wall / floor reviews used as examples for this study considered compliance of wall and floor systems within apartment buildings with Clause G6 of the New Zealand Building Code (NZBC). These reports typically outlined what those requirements were, which walls and floors would need to meet these requirements, whether the proposed systems meet those requirements, and what upgrades were required (if necessary).

Reverberation Time

The reverberation time reports used as examples for this study considered spaces where the reverberation time was currently too long, creating loud, booming spaces. These reports described the existing space, outlined appropriate acoustic criteria to evaluate the space against (typically referring to ASNZ 2107:2016: Recommended design sound levels and reverberation times for building interiors), analysed the existing situation, and provided potential mitigation measures that could be used to adequately control reverberation within the space.

Prompts

We used three different strategies with prompts provided to generative AI to attempt to create reports that could be comparable to the example reports.

Basic Information

This approach used no technical information, instead relying on series of simple prompts to piece together what information would be needed.

- What information is needed for a traffic noise insulation review in [city]?
- What traffic noise insulation rules do I need to meet for [address]?
- How do I work out noise levels from traffic at [address]?
- Based on the above, write a report where [completed with information responding to the above prompts].
- Summarise [the relevant information] from the attached architectural drawings.

This level of prompt detail attempted to replicate a user that does not have specialist knowledge in the field of acoustic engineering, and relies on generative AI for the majority of information within the report relating to acoustics.

Technical knowledge combined with basic prompts

This approach used the information provided by the background information and architectural drawings, and combined these with direct references to relevant rules and standards, as well as data from acoustic analysis (such as noise levels calculated using SoundPlan for the traffic noise insulation review).

- Provide a summary of [relevant District Plan rule] of the [city] District Plan.
- List the requirements from the [city] District Plan relating to noise insulation for a new dwelling containing habitable spaces located [distance] from a [road classification] road.
- Based on the above and expected noise levels of [calculated noise level], write an acoustic report showing the level of compliance with [district plan requirements].

- The attached architectural drawings show [project situation]. Based on this, how does the project compare to [district plan requirements].

This level of prompt detail attempted to replicate a knowledgeable engineer relying on generative AI for assistance in collecting and collating information.

Detailed, Technical Information

This approach took all information from the original acoustic report and used generative AI as a tool to string this together into a coherent report. At no point did it rely on generative AI for research or analysis, instead using the tool to provide a more detailed summary of the work already completed by the acoustic engineer.

Write an acoustic report suitable for submission to a city council summarising the following information:

1. The review is with regards to [relevant District Plan rule] of the [city name] District Plan
2. An existing dwelling is being extended and will have new habitable areas
3. The house is within [distance] of a [road type]
4. The expected noise levels due to vehicles travelling past the site on [Street] have been calculated using the Calculation of Road Traffic Noise (CoRTN) algorithm applied with the SoundPLAN (v8.2) 3D noise modelling software.
5. The noise level received at the most exposed facade of a noise sensitive space of the proposed extension is [calculated noise level] dB LAeq(24 hour)
6. The sound incident on the most exposed parts of the proposed extension is less than [noise level requirement] dB LAeq (24 hour). Therefore, the proposed extension will achieve compliance as per [District Plan Rule]
7. Remove references to [unnecessary information]
8. Add references to [areas where additional information relating to acoustic work can be provided]

This level of prompt detail attempted to replicate a knowledgeable engineer that had already completed all calculation and analysis relating to the work and wanted to use generative AI to report their findings.

Acoustic Report Usability

In order to evaluate reports generated using generative AI, we have considered the following factors: technical accuracy, relevance, and readability.

Technical accuracy refers to whether information provided is correct and lines up with what would generally be accepted as best practice within the acoustic consulting industry. Examples may include correctly referencing standards, identifying correct mitigation measures, and clearly stating where there is insufficient information to draw conclusions.

Relevance refers to restricting the report to information directly relevant to the project and the field of acoustics. Examples may include referencing only the standards that relate to what is being reported on, only referring to the building / project with regard to any mitigation measures, and only providing comment on other fields of engineering (such as fire or seismic design) where they relate to acoustic engineering.

Readability refers to whether that report clearly communicates

key ideas relating to acoustic engineering in a way that can be understood by both specialists and professionals (such as architects) that incorporate this advice from specialists. Examples may include limiting the amount of specialist jargon used, writing using a clear and coherent structure, and using correct grammar.

Where reports generated did not meet the above criteria, this was considered a failure.

Evaluation and Analysis

The resulting reports from the three different prompt types were assessed against the above usability criteria. Where any one aspect of each usability criteria, that prompt / report combination was counted as a failure for the purpose of this analysis.

Where these reports were counted as failures, we recorded what mistakes were typically being made, and whether multiple reports were failing for the same reasons. We have listed the trends we identified for these failures under our analysis and have included the level of prompt detail at which these were found to occur.

4. Results

Where each prompt level resulted in a report that met the usability criteria for each type of report, we have indicated this with a tick. Where each report had critical failures, we have indicated this with a cross.

Examples of what was considered a failure for each category have been included in later sections.

Table 1. Traffic Noise

Prompt level	Technical Accuracy	Relevance	Readability
Basic information	X	X	✓
Technical knowledge with basic prompts	X	X	✓
Detailed technical information	✓	✓	✓

Table 2. Inter-Tenancy Wall / Floor

Prompt level	Technical Accuracy	Relevance	Readability
Basic information	X	X	✓
Technical knowledge with basic prompts	X	X	✓
Detailed technical information	✓	✓	✓

Table 3. Reverberation Time

Prompt level	Technical Accuracy	Relevance	Readability
Basic information	X	X	✓
Technical knowledge with basic prompts	X	✓	✓
Extremely detailed, technical information	X	✓	✓

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4. ANALYSIS OF TRENDS AMONG FAILURES

Cumulative Errors

Generative AI considers its previously generated responses when answering subsequent questions within a single chain of questions [4], referred to in both ChatGPT and Gemini as a “chat”. In one instance, when asked to review a set of architectural drawings, Gemini found a reference to Clause E3 of the NZBC, a section relating to moisture rather than acoustics [5]. After being asked “What noise standards does the building shown in the attached documents need to comply with”, Gemini responded with “NZBC Acceptable Solution E3/AS1”. As Gemini was not then instructed that this was incorrect, it continued to incorporate this incorrect information into subsequent responses, even when not asked to comment directly on the drawings.

When asked to “write an acoustic report about noise insulation from traffic on [street name], [city]”, Gemini incorporated that error, using it to supplement the correct response. Under a section it titled “2. NZBC Requirements”, it stated: “The NZBC (Clause G6) sets out performance requirements for sound insulation in residential buildings. The objective is to safeguard occupants from excessive noise intrusion, ensuring a comfortable living environment. For this project, the relevant standard is NZBC Acceptable Solution E3/AS1, which addresses noise insulation from external sources like traffic.”

This is a combination of two separate errors. First, it erroneously introduces NZBC Clause G6. This section of the building code is used for inter-tenancy walls and floors, and would not typically be considered relevant for a traffic noise insulation review. Secondly, it incorporates its own earlier references to NZBC Clause E3, falsely claiming that it considers noise insulation when it instead considers requirements to control internal moisture.

This was not an error Gemini typically makes. When repeating the same question in a new chat, no reference to the NZBC was made. While this new report was not without errors, it correctly focussed on noise insulation from traffic. To briefly summarise errors in the report, it jumped to conclusions and stated that noise levels received at the residential home would “exceed the recommended guidelines for residential areas”, when the AES report for the same house actually found that noise levels were below what was required under the District Plan Rule.

This suggests that using a single chat as an iterative process, slowly asking generative AI to add more details to a report over multiple requests, also risks adding incorrect or irrelevant details that reduce the overall usability of the final output. Given that this iterative approach is a common strategy to effectively use generative AI [4], this adds additional need for stringent quality assurance of any reports made this way.

This was found to be a potential issue at all prompt levels, as it depended on how many prompts were used within the same chat rather than what level of detail or technical knowledge was provided with these prompts.

Detail Only Provided on Request

Generative AI typically did not expand on details that would be expected in a typical acoustic review unless that information was explicitly requested. This was found to primarily be an issue with the basic prompt level, though could also occur even when using technical knowledge combined with basic prompts. The addition of any level of technical detail resulted in both ChatGPT and

Gemini incorporating references to that topic into the generated reports.

During basic level G6 reviews, the detailing of junctions was never considered unless a simple prompt asked questions where these details would be widely considered as common answers.

For example, when provided with a basic-level prompt such as “What are the acoustic weak points in an inter-tenancy wall?”, Gemini provided the following response:

“Acoustic weak points in an intertenancy wall are areas where sound can easily transmit through, reducing the wall’s effectiveness at blocking noise. Common weak points include:

- Gaps and cracks: Even small openings around pipes, electrical outlets, or the edges of the wall can allow sound to leak through.
- Joints and connections: The points where different materials meet, such as the wall and ceiling or the wall and floor, can be prone to sound transmission if not properly sealed.
- Thin or lightweight materials: Walls made of thin or lightweight materials, like single-layer drywall, offer less resistance to sound than thicker, denser materials.
- Windows and doors: These openings can significantly compromise the acoustic performance of the wall if not adequately soundproofed.
- Flanking paths: Sound can also bypass the wall through flanking paths, such as the ceiling, floor, or connected ductwork.”

This is correct, though none of this information was provided in other basic prompts for inter-tenancy wall / floor reviews that did not directly mention acoustic weakness or enquire into important considerations during constructions.

The same lack of detail was found for ChatGPT, where the following prompt was used:

“Write an acoustic report about an apartment building with regards to meeting Clause G6 of the New Zealand Building Code. It uses GIB system GBTLAB 60b for the walls and GB DFA 60b for the floor. Note all potential weak points in the system that must be considered, and provide a summary of the level of compliance.”

This resulted in a generated report that made no reference to impact noise.

Irrelevant References

When asked to provide references to relevant standards, generative AI was found to pull from standards that shared many related words or topics, but did not apply to the type of report being completed.

As an example, when attempting to generate an inter-tenancy wall / floor review using technical information combined with basic prompts, Gemini was told “Write an acoustic report about an apartment building with regards to meeting Clause G6 of the New Zealand Building Code. It uses GIB system GBTLAB 60b for the walls and GB DFA 60b for the floor. Note all potential weak points in the system that must be considered, and provide a summary of the level of compliance.”

Its response included the following statement:

“2. Assessment Methodology

Review of Construction Documents: Architectural and structural drawings, specifications, and product data sheets were examined to determine the wall and floor construction details.

Field Inspection: A site visit was conducted to verify the as-built construction and identify potential acoustic weaknesses.

Reference to Relevant Standards: Assessment was carried out with reference to NZS 6806:2010 "Acoustics - Classification of building elements," which provides guidelines for classifying acoustic performance."

In addition to multiple assumptions being made around how information had been gathered and assessed, this references New Zealand Standard 6806:2010 Road Traffic Noise. This standard Sets out procedures and requirements for the prediction, measurement, and assessment of road traffic noise for new and substantially altered state highways and local roads [6]. It does not relate to the acoustic assessment of inter-tenancy wall and floor systems.

The same issues were found while using ChatGPT. When provided with the prompt "What traffic noise insulation rules do I need to meet for [address], Greytown, New Zealand?", ChatGPT referenced NZBC Clause G6 and Healthy Homes Standards, and suggested specific fibrous insulation products.

NZBC Clause G6 does not relate to traffic noise insulation [7] while the Healthy Homes Standards only apply to residential tenancy properties and does not relate to traffic noise insulation [8]. Specific products should not be recommended before a traffic noise assessment against the relevant acoustic criteria has been carried out.

These were not found to occur when providing prompts using technical, detailed information, as these would explicitly outline all required references, standards, and sources.

Fake or Irrelevant Products

When making specific requests for product recommendations, generative AI was found to occasionally provide references to products that either didn't exist, or were not relevant to the project. In one instance, Gemini was given a chain of the following basic prompts:

"Please give some recommendations for the internal acoustic environment that will accommodate up to 70 people, which includes meeting rooms and an open office space with vaulted ceilings. There is also an HVAC plant enclosure in the middle of the room above one of the meeting rooms."

"What are some products that you would recommend for cloud panels, wall panels, or acoustic curtains?"

"Could you give some recommendations for commonly available products in New Zealand?"

The response listed two real products (Autex Quietspace Frontier and Autex Composition), a real but irrelevant product (CSR Gyprock Soundchek plasterboard), and one product that the listed supplier did not appear to sell (Sontext Acoustic Curtains).

These same series of prompts were also attempted using the free version of Gemini for comparison and were found to recommend fake product recommendations more frequently. This free version recommended Ecophon ecospace cloud panels, WhisperCube by

Wallace, Rockfon Canestone Wall Panels, and Buzzispace grid (a real product, but the wrong supplier was listed).

Similar results were found for prompts of all levels. These were particularly common for reports generated about reverberation time, where even detailed, technical prompts would result in unrequested product descriptions that included incorrect information.

Reverberation time calculations

Gemini was capable of extracting key information from a question and performing calculations to predict the reverberation time of a space, or the amount of acoustic absorption required for a space to reach a target reverberation time, however some of the calculations were found to be incorrect.

In one instance Gemini was given the following prompt:

"What would be the reverberation time in an open space kitchen dining and living space with polished concrete floors, plasterboard walls and a raked plasterboard ceiling, with a volume of 360 m³, a room width of 10 m and a room length of 11.8 m?"

It made some assumptions about wall surface areas instead of asking for further input, and produced a predicted reverberation time of 6.5 seconds, which was considered to be a conservative estimate: longer than would typically be expected for that space.

When prompted further to specify an amount of acoustic absorption material that would reduce the reverberation time to an appropriate target, Gemini calculated an area of 14,574 m² of NRC 0.85 acoustic product to reduce the reverberation time to 0.5 seconds. Actual calculations for the space confirmed that less than 110 m² of NRC 0.85 acoustic product would be required.

Limited Capacity to Review Drawings

When using Gemini to review architectural drawings, it would identify key words and sentences throughout the drawing set, using these to answer questions provided. This meant that it would provide responses either lacking in important context, or providing answers that added misleading details.

When provided with a sheet of details for an inter-tenancy wall review and asked "What STC rating does the inter-tenancy (IT) wall shown in the Northern Wall detail achieve?", Gemini responds with the following:

"The Northern Wall detail does not provide an STC rating for the IT wall.

However, the detail does specify that the wall is to be constructed according to the GIB® Intertenancy Barrier System Type GBT(L)AB 60d. This system is designed to achieve a two-way FRR 60/60/60 rating. FRR stands for Fire Resistance Rating, and the three numbers indicate the time, in minutes, that the wall can resist the passage of fire, heat, and smoke.

While the FRR rating is related to fire resistance, not sound transmission, it may be possible to infer that the wall is designed to have some level of sound insulation due to the materials and construction methods used. However, without explicit information on the STC rating, it is not possible to state definitively what level of sound insulation the wall achieves."

Within the drawing set, GIB System GBTLAB 60d is referred to as GBT(L)AB 60d, resulting in the generated response doing the same. The drawing set at no point includes the definition of FRR, but the response provides accurate information on the GIB system. Information on the STC rating of this GIB system is equally available, so it is unclear why the response instead chose to focus on the fire rating and why this cannot be used to determine the STC rating.

When subsequently asked “What is the STC rating of GIB System GBTLAB 60d?”, it responds “The document does not provide an STC rating for GIB System GBTLAB 60d. It is specified as a fire and acoustic rated system, but only the fire rating is given (FRR 60/60/60).”, suggesting that it limits its answers to only what is directly within the document, and its attempts to understand that information.

By contrast, asking Gemini the same question without providing a document, it provides the correct answer, alongside a link to the GIB Noise Control Manual, as shown below:

“The STC rating of GIB System GBTLAB 60d is 61.

You can find more information about this system on the GIB website:

<https://www.gib.co.nz/systems/gib-intertenancy-barrier-systems-for-terrace-homes/gbtlab-60d/>”

In another instance, when provided with architectural drawings for a traffic noise insulation review and asked “How far is the building in the attached document from the road”, it incorrectly identified a line in the document referring to the “4.5 m setback from the road”, but was unable to notice that the line had nothing to do with the actual location of the existing building or proposed extension, and simply responded saying the building was 4.5 m from the road.

In this case the tool correctly identified relevant information and presented this to the reader, but did so in a way that incorrectly suggested it was the full answer to the question.

Due to issues such as both of those outlined above, we found that generative AI is not currently an effective tool for reviewing architectural drawings.

This was found to be an issue regardless for any prompt telling generative AI to search for information, as the drawings themselves were the cause.

5. “USABLE” GENERATED AI RESPONSES

Several aspects of the generated responses performed consistently well for each different type of report. We have listed some examples below.

Technical Accuracy

Where the responses created using generative AI discussed complex topics, it would frequently direct the reader to consult an acoustic engineer, while also providing sources for further reading.

For example, when asked “What level of sound insulation does an inter-tenancy wall need to achieve in New Zealand?”, Gemini included the following directions at the end of its response:

“To ensure compliance with the NZBC, it's recommended to consult with an acoustic engineer or specialist who can assess the specific requirements for your project and recommend appropriate sound insulation solutions.

For more information, you can refer to the following resources: NZBC Clause G6 Airborne and Impact Sound: This clause details the specific acoustic performance requirements for buildings in New Zealand.

GIB® Intertenancy Barrier Systems for Terrace Homes: This resource provides information on GIB's intertenancy wall systems that are designed to meet the NZBC requirements.

Medium Density New Zealand - Inter-tenancy Walls: This article discusses the importance of acoustic insulation in inter-tenancy walls and provides information on different types of wall systems.” NZBC Clause G6 is the most directly relevant source, though the other two are useful resources for any potential reader requiring more information.

The GIB Noise Control Manual is a more comprehensive list of available inter-tenancy systems commonly used in New Zealand [9], however the Terrace Homes source cited above does contain relevant information.

Medium Density is a blog relating to the published book ‘Medium’, both written by Guy Marriage, a well-respected architect teaching construction at the School of Architecture, Te Herenga Waka, Victoria University of Wellington [10].

Along with the recommendation to consult an acoustic engineer, this forms a very responsible and useful answer. Similar disclaimers were found at all levels of prompt detail, though were most commonly provided for basic prompts.

Relevance

Generative AI responses were found to consistently provide information related to the topic, even when only provided with extremely simple questions. For example, when provided with the prompt “How do I reduce Flanking Noise”, ChatGPT provided a comprehensive summary of why flanking noise occurs for floors, walls, and ceilings, as well as an extensive list of mitigation measures that each directly addressed an aspect of flanking noise (including sealing gaps and cracks, acoustically resilient systems, and considering HVAC ducting).

For reports providing a reverberation time review, all advice provided was typically relevant. However, often this relevant information was found to be lacking in technical accuracy, and proposed products that didn't exist as mitigation measures.

Readability

Responses were clear and concise, provided definitions for the majority of jargon being used, and made grammatical sense.

Where mistakes were present, these were typically minor, such as paragraphs occasionally ending in a comma rather than a full stop. In another situation, the brand name ‘Phonic’ for a ceiling tile was misspelled as ‘Phonix’.

We note that this high level of readability can make generated reports lacking in technical accuracy or relevant information appear more comprehensive and trustworthy than should be warranted. A reader that doesn't specialise in the field of expertise the report covers may not notice the incorrect details.

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6. CONCLUSION

With regard to the three factors we used to evaluate the usability of an acoustic report, we found that generative AI tools perform well with regard to readability, but struggle with technical accuracy and relevance. This was found to be the case for both of the generative AI tools used for this study: ChatGPT and Gemini.

The technical accuracy of generated reports was heavily influenced by the wording / information provided within the prompt. When used as an information gathering tool, generative AI was found to introduce errors such as incorporating irrelevant information from prior prompts, not providing necessary detail unless explicitly requested, referencing irrelevant information, and poorly interpreting architectural drawings and details.

Instead, generative AI was found to be most effective when an acoustic engineer had already completed all work relating to the project and needed to summarise this information.

Reports created using generative AI were found to be excellent with regards to readability, using clear language and report structure to communicate ideas and recommendations. This was found to be the case even where technical accuracy and relevant information were lacking. This presents the risk of generative AI being used to write reports that appear to be a legitimate source of information, even when not prepared by someone capable of identifying mistakes.

We recommend caution when using generative AI as a tool when writing reports, particularly when used in place of more traditional calculation and analysis. Where acoustic engineers have made use of AI, the subsequent reports should include a disclaimer explaining how generative AI had been used, and to what extent.

7. ACKNOWLEDGEMENTS

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In addition, we would like to acknowledge both ChatGPT and Gemini as the tools used to carry out this study.

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Architectural Acoustics

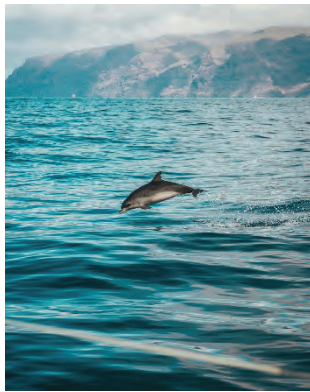
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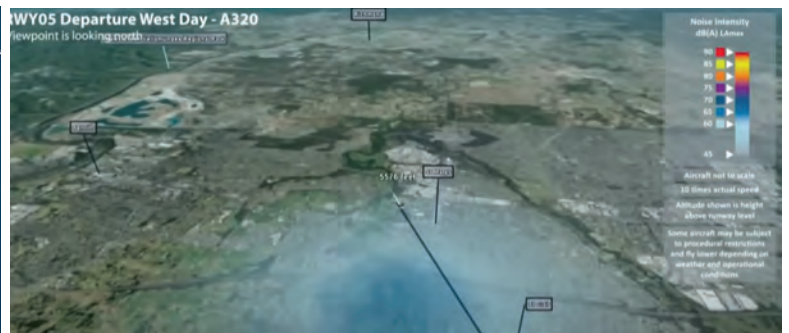
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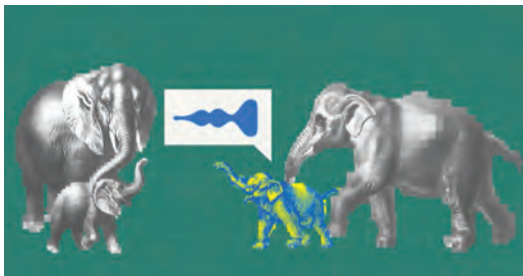
Expert says Noise from vessels may contribute to whale, dolphin strandings ⁵



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How AI could help us talk to animals ⁷

Spanish + English + Japanese + Sperm whale?

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How the Star Wars Sound FX were created ⁸



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8. <https://www.youtube.com/watch?v=BD6KrGRRS-JU&list=WL&index=2>

An overview of the integration of metamaterials into acoustic building elements

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ABSTRACT

In the construction industry, there's a continued reliance on homogeneous materials for acoustic insulation despite ongoing research into acoustic metamaterials. As urban housing becomes high intensity "packed and stacked", noise pollution in residential areas intensifies. While buildings generally offer adequate insulation against high-frequency audible sounds between 1 and 5 kHz, their overall ability to block sound is often hampered by two specific frequency ranges: the mass-air-mass resonance band and the coincidence band.

Our study investigates the application of metastructures and metasurfaces to enhance sound insulation within these frequency ranges, with an emphasis on practical implementation at scale. These metastructures comprise metamaterial systems composed of elements that alter impedance, surface properties, and vibroacoustic resonance. We present findings from our research, showcasing the performance of selected systems. Both experimental and simulation results align well, and diffuse-field testing suggests significant attenuation within the targeted frequency bands.

We analyse the merits of each technique and identify which methods are most effective in either mitigating or relocating the regions of poor sound insulation outside the critical audible frequency range.

INTRODUCTION

As the world urbanizes, mechanizes, and many urban populations intensify, one of the less well recognised environmental impacts has been the growth in noise pollution. Noise pollution is now increasingly recognised as a pervasive physical and mental health issue, leading to annoyance, sleep disturbances, and linked to a growing array of medical conditions including but not limited to hypertension and heart disease [9].

In New Zealand, lightweight construction methods, such as plasterboard and light timber framing (LTF), are favoured as balancing cost-effectiveness and structural performance. However, LTF use in inter-tenancy walls in medium and high-density housing has a major weakness: noise transmission between dwellings. Projections indicate that by 2050, medium-rise, multi-tenancy buildings will make up 30% of Auckland's housing stock. It is also well known that many NZ homes suffer from excessive cold and dampness, leading to respiratory health problems. The solution is ventilation, which removes moisture, prevents mould, and improves heating efficiency. However, mechanical active ventilation is costly, and passive trickle ventilation often provides an insufficient flow rate. Increasing passive ventilation through vents and partially open windows is effective, but noise intrusion, particularly in denser environments, hinders adoption. Most affected are vulnerable groups like children, the elderly, and lower socioeconomic status individuals, including many Māori and Pasifika as clearly reflected in multiple health statistics relating to these environmental issues.

This underscores the critical need for homes to offer acoustic privacy and comfort. But current construction technology does not offer affordable silver bullets. It is time to go beyond evolutions of time-tested solutions. Metamaterials are a potential transformative technology that has emerged in the 21st century, initially in electromagnetics but subsequently has extended to acoustics and mechanics. Acoustic and elastic metamaterials are characterised by their subwavelength-scale structures whose interaction with sound waves and structural vibrations results in unique behaviours, often not previously achievable. These behaviours are controlled primarily by the structure's geometry and therefore can be engineered to, for example, tailor pressure fields within a duct or create desired dynamic stiffness.

The reliance of the construction industry on homogeneous materials has become restrictive and necessitates a transition towards affordable, factory-produced building components. These components can be supplied in large quantities and incorporate innovative techniques to enhance building performance such as metasystem technology.

The core question of our research is: can we develop passive acoustic and elastic metamaterial technologies that minimize the intrusion of noise pollution throughout the building envelope?

METASYSTEMS

Over the past 12 years, we have developed a toolbox of metamaterial architectures, each of which provides a different means of modifying the vibration and acoustic response of a structure through absorption, reflection, and redirection. In this paper we will discuss three key vibroacoustic metamaterial types, giving examples of the research carried out by our team, the pros and cons of each type, their areas of applications and future prospects.

These three types are locally resonant structures (LRS), phononic crystals and acoustic metasurfaces.

LOCALLY RESONANT STRUCTURES

Locally resonant metamaterials use small embedded mechanical oscillators inside a host material to create novel dynamic properties, not available in standard homogeneous materials, and allow it to affect elastic waves with much greater wavelengths than the oscillator size [8]. In acoustic transmission and reflection, we are most interested in the metamaterial's dynamic mass, where the sound wave effectively sees a heavier material than that of its static mass. This results in a high impedance mismatch between the airborne sound wave and the bulk material, resulting in a reflection of the acoustic wave and therefore high sound transmission loss through the medium.

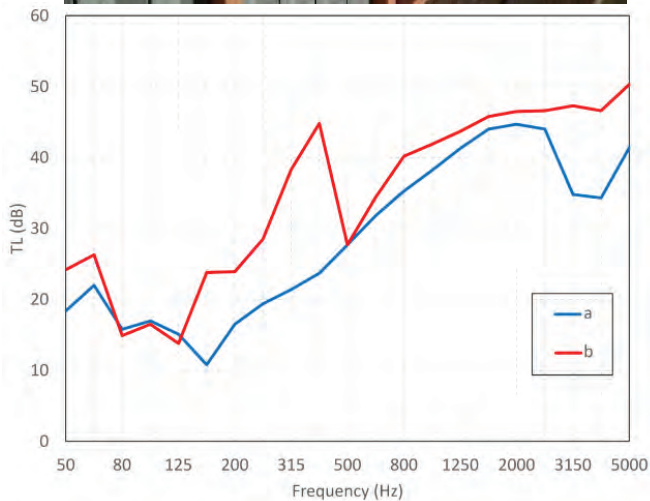


Figure 1: A locally resonant metamaterial double leaf wall system before final layer added. The wall is tuned to 400Hz and the resulting sound transmission loss is shown, a) a blank wall, b) The blank wall with locally resonant units added

Our research (Fig.1 [2-4]) has shown that LRS provide significant sound transmission loss improvements for panels under diffuse field conditions, specifically at low frequencies where conventional materials fall short.

Results shown in Fig. 1 for a partition targeting 400Hz show a 20dB improvement in sound insulation at 400Hz over a standard system. Testing has also been completed for a system targeting the mass

air mass resonance region at 100Hz with comparable results.

These systems are highly dependent on the mass ratio between the host material and resonator/oscillator mass. This means for a higher peak attenuation than concentrating the mass in the oscillator results in a high attenuation band. This is due to the high concentration of mass in the oscillator's imparting more energy on the host layer increasing its effective dynamic mass. The downside is that attenuation outside of this region becomes poor. In frequency regions above the oscillator's frequency of resonance, the oscillators become isolated from the structure which leaves the performance of the material to be determined by the mass of the host material.

For this reason, this metamaterial type is best used for controlling relatively narrow band sound, or situations where there are multiple tones of high amplitude. We see this technology being an ideal alternative barrier system

for low to mid frequency mechanical noise where a barrier of large bulk density and mass would normally be necessary.

Nonlinear, snap-through beams, granular chains [10] and impacting oscillator mechanisms [11] have shown promising improvements in sound and vibration attenuation bandwidth and are an interesting area of development. While these systems show promise, added complexity and the need for high tolerances may limit their applications in practice.

ACOUSTIC METASURFACES

Acoustic metasurfaces are composed of sub-wavelength resonant elements that manipulate sound waves' direction, amplitude, and phase. They enable sound steering, focusing, and absorption, offering applications in noise control, advanced audio systems, sonar technology, and architectural acoustics. Their design flexibility makes them a significant tool in acoustic engineering.

Acoustic metasurfaces commonly use Helmholtz and Fabry-Pérot sub-wavelength resonances to create reflection and absorption. This technique is particularly useful for targeting low frequencies through targeted impedance matching.

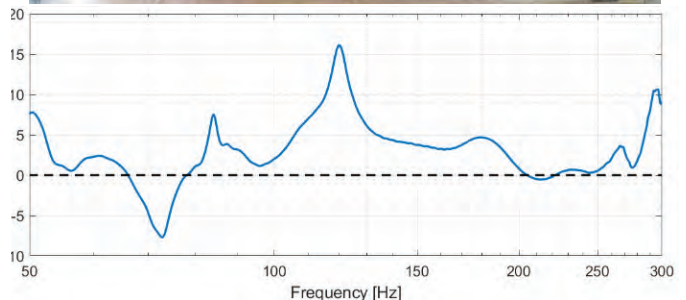
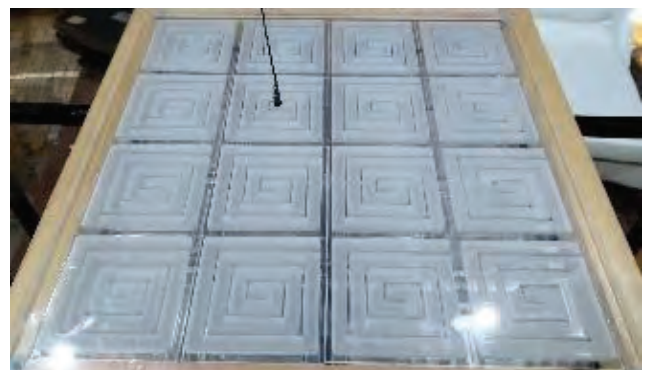


Figure 2: A metasurface double leaf panel using coiled resonators tuned to 120Hz. The system achieved an insertion loss improvement of over 15dB at the target frequency.

Our research (Fig. 2 [5-6]) and others have shown these systems can produce high values of absorption at low frequencies using a compact coiled-like system, with insertion losses of 15 dB at 120 Hz, something not achievable with conventional approaches. We see this technology as being ideal for panels targeting a combination of sound transmission loss and high absorption properties at low frequencies.

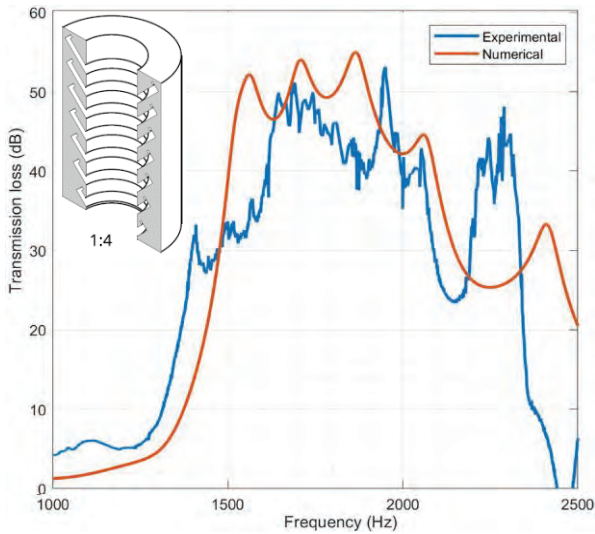


Figure 3. Open duct jacket system using quarter wavelength hook like acoustic resonators and its sound transmission loss performance.

More recent studies have focused on phase gradient metasurfaces, a metamaterial that induces a 180-degree phase shift in an acoustic wave propagation. The phase change and amplitude of the scattering waves can be tuned by varying the geometric parameters of the metamaterial's individual unit.

Phase-gradient metamaterials can be implemented using architectures such as space-coiling structures and locally resonant structures [7], areas of work common to our research. Preliminary results have shown an impressive 40dB of transmission loss over 750Hz bandwidth (Fig. 3).

PHONONIC CRYSTALS

This metamaterial is based around a periodic structure that interferes with elastic bending waves, thereby suppressing panel bending modes. The elastic bending waves associated with these bending modes travel at different speeds depending on their wavelength. When there is some spatial variation in the panel, it has been found that there can be frequencies where propagating waves cannot exist, and this generates a 'band gap'.

The scattering creates interference of the bending waves within the panel which can be designed to occur at the coincidence frequency and is largely dependent on the panel's stiffness.

Our research (Fig.4 [1]) has shown significant improvement in sound insulation performance under diffuse field conditions for a panel using this technique.

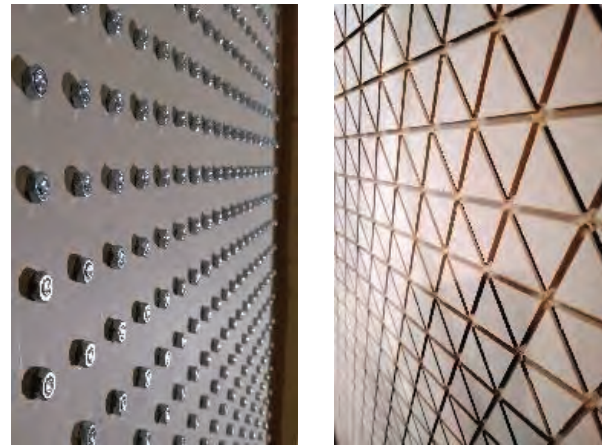


Figure 4. Phononic crystals metamaterial panels using impedance changes through steel pillars and slots.

Figure 5 shows the sound transmission loss of a 45mm spaced pillar lattice indicating an improvement of 15dB in the coincidence region over a panel of similar mass.

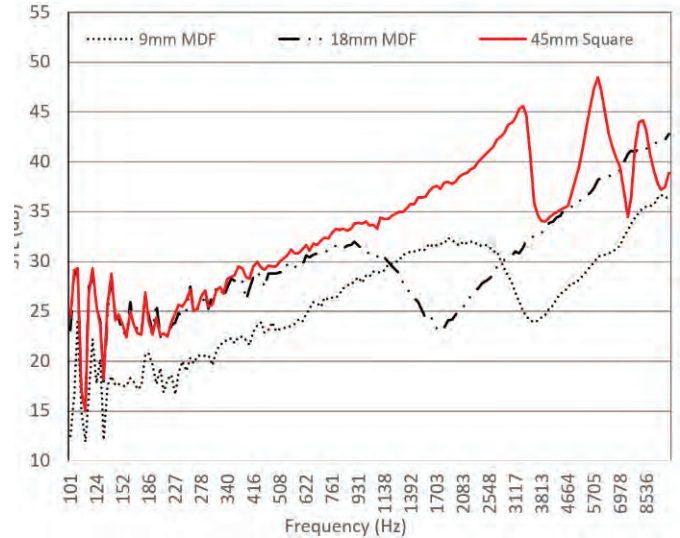


Figure 5. Bragg scattering based metamaterial targeting the coincidence region using 45mm spaced steel pillars.

Figure 6 shows the sound transmission loss of a triangular slotted panel indicating an improvement of 14 dB in the coincidence region. This effect is a combination of a destructive scattering effect and a lowering in panel stiffness.

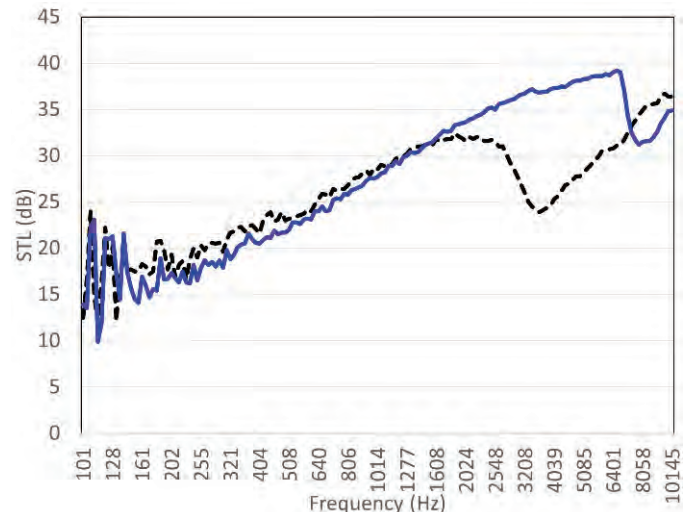


Figure 6. Bragg scattering based metamaterial system targeting the coincidence region using triangular slots.

Slotted panel systems seem to offer a good way of creating scattering and destructive interference of bending waves, but the downside is reduced panel structural integrity.

This may be resolved with double layer systems or by filling the slots in the panel with a second material that is different enough to preserve the impedance change.

DISCUSSION

By combining different acoustic and elastic metamaterial elements with conventional acoustic materials into a heterogeneous, nonperiodic metasystem, it is possible to transform the acoustic performance to achieve wideband suppression of sound transmission.

Fig. 7 shows an example of a metasystem duct jacket designed to dissipate a specific frequency spectrum of broadband white noise and three tonal frequencies. The circular metasystem duct example generated from our research students [5] produces a 60 dB transmission loss peak with an attenuation band of 2200Hz bandwidth and a minimum level of 10dB utilizing acoustic resonance and perforated panels.

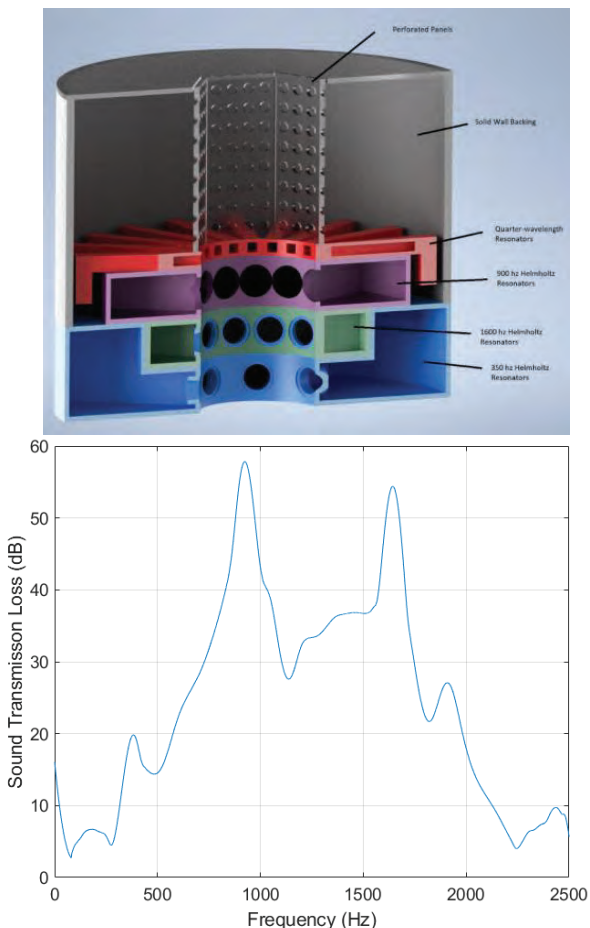


Figure 7 Open duct jacket metasystem using Helmholtz resonators and perforated plates and its sound transmission loss performance.

An area of interest is their application in open ducts and windows. When a window opens, a significant loss in sound insulation occurs. The use of a metasystems designed utilizing metasurfaces, phase gradients, and acoustic resonances will significantly improve the acoustic privacy for open windows.

However, challenges will be faced around achieving adequate broadband suppression levels and compactness of the device within the window reveals.

CONCLUSION

In conclusion, the future of acoustic and mechanical metamaterials lies in the development as building blocks of metasystems consisting of multi-patterned structures that give designers independent control over multiple properties. This includes Locally Resonant Structures, Acoustic Metasurfaces, and Phononic Crystals, each of which offers unique capabilities and application potential.

The integration of multiple metamaterials into metasystems, in conjunction with conventional acoustic materials, has the potential to transform acoustic performance in a sustainable and cost-effective manner. While challenges remain in bridging the gap between theoretical concepts and practical applications, the ongoing research in this field holds great promise for improving acoustic privacy and designing purposeful soundscapes in urban environments. The exploration and innovation within this field move us closer to realizing the full potential of metamaterials and their applications.

ACKNOWLEDGMENTS

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NEWS

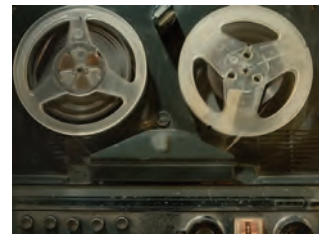
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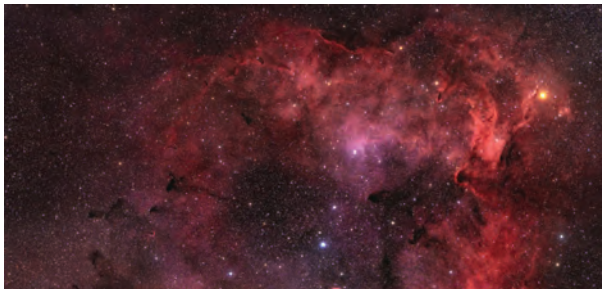
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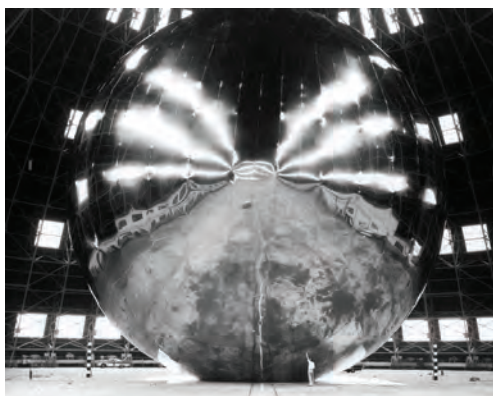


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- 17. <https://www.youtube.com/watch?v=ajvvl3qrXM&list=WL&index=52>



Acoustic design of foyer spaces in Te Pae Christchurch

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ABSTRACT

Te Pae Christchurch Convention Centre is an anchor project in the post-earthquake regeneration of central Ōtautahi Christchurch and was officially opened in December 2021. Te Pae Christchurch includes four major foyer areas (Ground Floor, Level One and Dobson), plus smaller foyers (Exhibition, Rakaia, Bealey and Conway) covering a combined floor area of approximately 4400 m². These areas have been designed as a unified group of connected entrance ways and foyer spaces, including designated areas for informal events and pre-function gatherings. The acoustic design of the foyers included consideration of complex geometry and the palette of interior finishes. The interaction of geometry and finishes was assessed using detailed 3D computer modelling of reverberant conditions, allowing integration of acoustic conditions into the overall architectural design. The final palette of materials used throughout the foyer areas included diffusive timber battens, acoustically absorptive plaster, glass, stone tiles and carpet.

INTRODUCTION

The previous Christchurch Convention Centre was extensively damaged beyond repair during the 2010 and 2011 Christchurch Earthquakes. Development of a new Convention Centre was identified as an 'anchor project', intended to contribute to the recovery and revitalisation of Central Christchurch. It was delivered by the New Zealand Government organisation Ōtākaro.

The general design brief was to design and build a boutique convention centre of international standing to provide exceptional user experience for all occupants, including event organisers, hirers, and attendees. The design was required to reflect the unique physical and cultural landscape of Christchurch/Ōtautahi and the South Island/Te Waipounamu along with integrating Ngāi Tūāhuriri and Ngāi Tahu values and narratives.

The design was inspired by landscapes of Canterbury/Waitaha, including the mountains, rivers, forests, coasts and plains, and Pākeha and Ngāi Tahu histories. The organic forms flow from the exterior to interior front of house spaces through the uses of curved and raking interior wall and ceiling surfaces.

He Aha Kei Roto / What's Inside

The key exhibition/venue spaces within Te Pae are:

- 2,800 m² Exhibition Hall, expandable to 3,300 m². The Exhibition Hall is divisible into seven different spaces, with dedicated food and beverage kiosks.
- 1,400-seat tiered Auditorium, divisible into two 700-seat spaces. The auditorium has full theatre rigging and lighting systems, and support for outside broadcast.

- An 1,100-seat banquet hall, divisible into two 550-seat spaces. The Banquet Hall overlooks the Avon/Ōtākaro river, with integrated audio-visual systems plus lighting and rigging facilities.
- Three separate configurable meeting room clusters. These spaces can collectively accommodate up to 2,000 guests, with 1,600 m² area in total.

These exhibition and venue spaces are all accessed via a series of interconnecting foyers, wrapping around three sides of the facility, across two levels, and covering a total floor area of approximately 4400 m².

The acoustic features and design of exhibition/venue spaces has been presented in a previous paper by the authors [1]. This paper presents the acoustic design and detailing, specific to foyer and circulation spaces of Te Pae.

DESCRIPTION OF FOYERS

In addition to providing essential circulation and access, the project required foyers to enable host pre-function events (such as small musical or local cultural performances), and to encourage informal and small-group interactions.

This required the design to consider a broad range of users and activities, and to create suitable acoustic conditions. The result is a series of interconnecting spaces, with deliberate variations in size, aesthetic, outlook, and acoustic character.

Large Foyers

Ground Floor Foyer

The Ground Floor Foyer is the main public entrance to the facility, and inside the main doors of the glazed façade visitors are greeted by the centre's reception desk – a large marble feature-piece set below a reflective metal ceiling. Adjacent to the entrance/reception are the main stairs that provide access to the Level One Foyer, Auditorium and banquet rooms.

Dobson Foyer

The Dobson foyer is also located on the ground level and provides an expansive circulation and pre-function space close to the exhibition halls, as well as access to the Dobson meeting room cluster.

Level One Foyer

The Level One Foyer provides main access to the auditoriums, banquet rooms and Conway meeting room cluster. This foyer doubles as a significant pre-function space, and is accessed from the Ground Floor Foyer via an expansive stairwell with an open void connecting the two levels.

The main front-of-house circulation areas are identifiable in Figures 1 and 2 as navy in colour, alongside labelled exhibition, venue and foyer spaces.



Figure 1. Ground floor plan. (2)

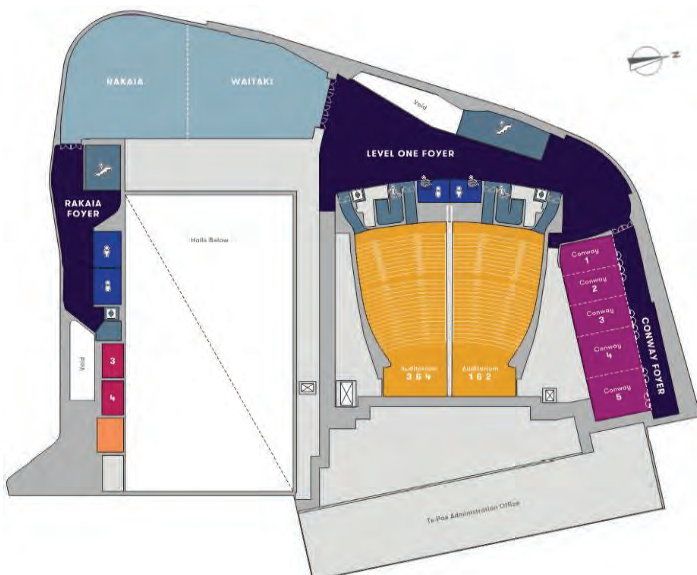


Figure 2. Level One floor plan. (2)

Smaller Foyers

Exhibition Foyer

Access to individual Exhibition Halls is via the Exhibition Foyer, located along the southern façade of the building and connecting with Cathedral Square.

Rakaia Foyer

The Rakaia Foyer is a smaller space at Level 1, providing access to the banquet rooms, and a place for smaller gatherings or reflection, away from the large foyer areas. The Rakaia Foyer is accessed via stairs/escalators from the Dobson Foyer and connected via open void to the Exhibition Foyer.

Bealey and Conway Foyers

Access to meeting room clusters and other spaces such as the Te Pae Lounge and VIP suite is via the smaller Bealey and Conway Foyers. These double as informal break-out spaces away from the main foyers but are not expected to host large pre-function gatherings or events.

DESIGN PROCESS

Brief

The starting point for design – including establishment of acoustic requirements – was a design brief issued by Ōtākaro. The client brief included specific note of ‘pre-function spaces’, however room acoustic criteria for these spaces was limited to a broad statement derived from AS/NZS 2107 [3] to minimise reverberation for noise control.

Concept Design

WSP developed an early set of recommendations to the architectural team including criteria for ambient noise levels, noise ingress and direction for interior finishes across the project. This included high-level advice specific to foyers and pre-function areas, prior to these spaces being settled in size or location within the building.

Acoustic advice at concept stage was kept deliberately broad to enable open exploration of architectural concepts, allowing for anticipated materials for flooring and façade, and giving broad estimates for placement and extents of acoustically absorptive surfaces.

Preliminary Design

The preliminary design process involved confirmation of the size, location and coordinated approach to foyer spaces. Preliminary assessments were conducted of noise from mechanical services and ingress via façade elements to ensure appropriate background noise targets were achievable.

Potential acoustic risks such as acoustic separation and vibration from footfall or dancing in banquet areas were considered with respect to possible implications for architectural and structural design.



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Detailed Design

Through the detailed design phase, acoustic advice was shared via regular design team meetings, formal design notes, drawing markups, sharing of 3D modelling, and collated into milestone updates of the Acoustic Design Report.

Acoustic materials were explored to suit development of architectural concepts and geometry, including focus on fluidity and contrasting textures. This led to use of acoustic plaster and timber batten systems as key acoustic materials. The acoustic plaster enabled significant areas of curved and raked surfaces with integral acoustic absorption. The timber batten systems provided a contrasting range of textures that also allowed for varying degrees of either absorptive or diffusive acoustic properties.

Potential risks previously investigated at high level during Preliminary Design were further developed as the design progressed. Key areas of design focus included acoustic separation and refinement of materials to suit room acoustics.

ACOUSTIC MODELLING

Room acoustic modelling was used extensively during design of all key spaces in Te Pae, including the foyers. This informed design discussions on specific geometric detailing and finishes, enabling the architectural concepts to be accommodated and integrated effectively with acoustic targets.

In addition to general calculation of overall room acoustic parameters such as reverberation time, the modelling was used to assess options and performance for public address and emergency evacuation warning systems. Imagery from 3D CAD models prepared in Rhinoceros3D for acoustic modelling in Odeon Room Acoustic software are shown in Figures 7 and 8.

This process enabled a complete architectural models to be adapted for acoustic analysis, retaining the complete complex of connected foyers, while enabling acoustic parameters to be explored in discrete area according to location of virtual sound sources and receiver points.

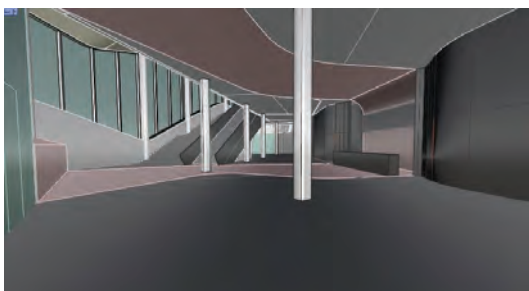


Figure 7. 3D model (Ground Floor Foyer).

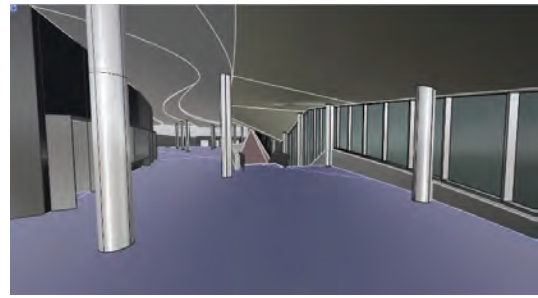


Figure 8. 3D model (Level One Foyer).

ACOUSTIC SEPARATION

A number of sensitive spaces are connected or related to foyers such that design of acoustic separation required consideration of both airborne and structure-borne noise risks.

Sensitive spaces such as the Plenary Hall are separated from foyers via partitions with high performance partitions, buffer spaces and sound-lock lobbies at entry points. However vertical adjacencies such as the banquet rooms over the Dobson Foyer and meeting rooms required specific consideration of:

- Airborne noise transmitting via floor and partition elements.
- Regenerated noise from vibration or impacts including general footfall and dancing.

The structural and seismic requirements provided constraints in the form of adopting a relatively light-weight, profiled floor slab (Comflor 80) with total thickness only 170 mm. Additional controls to the profiled slab were required in specific areas such as the banquet rooms, especially where the design did not include a services zone below. Various options were considered, including a thicker slab, a floated floor, and under-slab treatment.

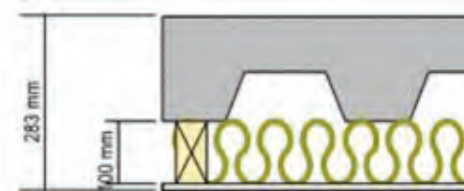


Figure 3. Sketch make-up of lightweight slab and ceiling.

In these areas, the agreed solution included supplementing the lightweight floor slab system with a sound insulating ceiling as shown in Figure 3 and consisting of:

- 170 mm Comflor 80 system with carpet on underlay.
- 100 mm ceiling cavity (timber battens) with infill acoustic insulation, 90 mm thick and minimum density 11 kg/m³.
- 2x 13 mm plasterboard ceiling.

MATERIALS FOR ROOM ACOUSTICS

The selection of materials – including those critical for reverberant control – were integrated into the design such that there do not appear to be any applied panels or materials introduced solely to manage acoustic conditions.

The finalised material palette included:

- Stone floor tiles (Ground Floor level).
- Carpet (Level One flooring).
- Façade glazing (Ground Floor and Level One).
- Timber battens (interior walls).
- Plasterboard (part ceiling).
- Absorptive plaster (raked walls and part ceiling).

Acoustic absorption is provided primarily via extents of acoustic plaster, integrated with the plaster-finished curved and raked sections around the foyer perimeter. This is supplemented at Level One by carpeted floor surfaces that create a distinctive shift from the stone-tiled ground floor areas.

Figure 4 shows an area of curved acoustic plaster during installation, prior to application of a plaster skim coat over the top.

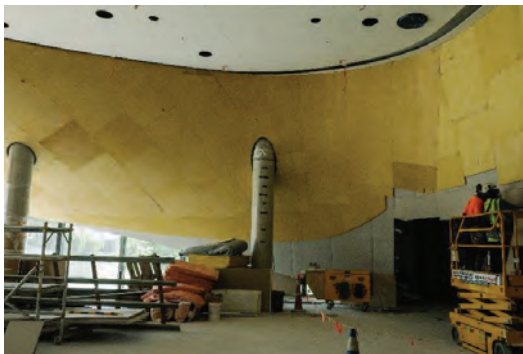


Figure 4. Fixing absorptive substrate to curved surfaces.

External walls include substantial areas of façade glazing – allowing natural light into all circulation areas. Where these present large, acoustically reflective planes, they are countered by the detailing of opposing internal walls.

Internal walls facing the façade, and separating foyers from key exhibition and venue spaces are clad using a system of timber battens over a frame. This system allowed both concave and convex variations to battening, distinguishing the Auditorium from the Exhibition Hall. The system also allowed for the batten width, shape/fluting, and gaps between to be set as desired, allowing fine control of acoustic permeability to an acoustically absorptive lining hidden behind.

The framing of timber battens is shown during installation in Figure 5, and a detail of the fluted timber battens is shown in Figure 6.

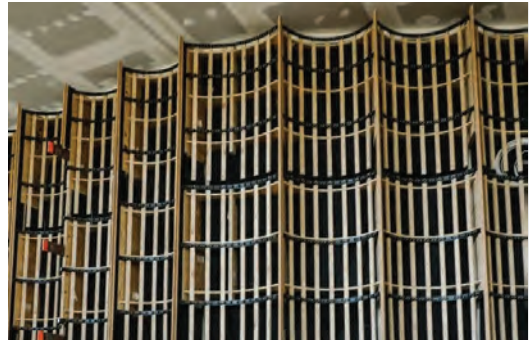


Figure 5. Framing for installation of timber battens.



Figure 6. Detail of fluted timber battens

TESTING AND COMMISSIONING

Commissioning measurements of foyer spaces were conducted along with acoustic commissioning of other spaces throughout the facility in 2021, ahead of the official opening in December 2021 and full operation from 2022.

Reverberation Time

Reverberation Time measurements were undertaken in general accordance with ISO 3382 [4]. Due to the volume of the space, an array of four loudspeakers plus subwoofer were used to produce sufficient diffuse sound energy within the foyers.

The number of measurements conducted varied between spaces, depending on the size of the space. For example:

- Dobson Foyer: Measurements conducted for five source locations, ten receiver positions. With three repetitions per source/receiver combination, 150 discrete measurements were captured.
- Rakaia Foyer: Measurements were conducted for four source locations, five receiver positions, and three repetitions, totalling 60 discrete measurements.

The full set of measurements was analysed, and average reverberation times calculated for each of the key foyer spaces. The measured reverberation times varied as anticipated between foyer spaces, relative to the variations in size, geometry, and surface finishes for each area. Reverberation times ranged from 1.4 seconds for smaller Rakaia Foyer (with carpeted floor and limited glazing); up to 1.9 seconds for the larger Ground Floor and Exhibition Foyers (with high ceilings, tiled flooring and expansive glazing). The mid-frequency reverberation times are summarised in Table 3.

Table 3. Unoccupied mid-frequency reverberation.

Space	RT _{MF} , s
Ground Floor Foyer	1.9
Level One Foyer	1.7
Dobson Foyer	1.8
Exhibition Foyer	1.9
Rakaia Foyer	1.4

Given the large spatial volumes, there had been concern during design that excess reverberation – especially at low frequencies – could impact the connected foyer spaces and risk disturbance between different user groups. Table 4 presents octave-band reverberation times for two example spaces – Rakaia and Dobson Foyers. The measured spectra confirmed the controlled reverberant character throughout foyer spaces, including at low frequencies.

Table 4. Reverberant spectra (five bands).

Space	Octave-Band RT ₆₀ , s				
	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz
Rakaia	1.0	1.2	1.4	1.5	1.6
Dobson	1.6	1.5	1.7	1.9	2.0

Other Phenomena

Other acoustic phenomena such as flutter echoes (multiple reflections of noise between two parallel walls) were considered during design. The potential for flutter echoes was a particular risk identified for foyer spaces due to the significant area of reflective surfaces such as facade glazing located opposite large internal walls. During commissioning, observations were made to identify any potential flutter echoes or other adverse

acoustic phenomena. None were perceived, and so further measurements were determined to not be necessary.

Figures 9 and 10 show 3D modelling of the Rakaia and Dobson Foyers alongside photos of the spaces during construction and commissioning. Key interior features such as flooring, glazing, absorptive plaster and timber battens can be identified in each of the images.

Te Pae was officially opened in December 2021, and has since hosted many conferences, exhibitions and events – including extensive use of the multiple foyer spaces for pre-function gatherings, events and informal gatherings.

ACKNOWLEDGMENTS

WSP acknowledge the collaborative approach of the architects Woods Bagot in association with Warren and Mahoney; the builders CPB Contractors; and suppliers including Asona, Autex and Sculptform.

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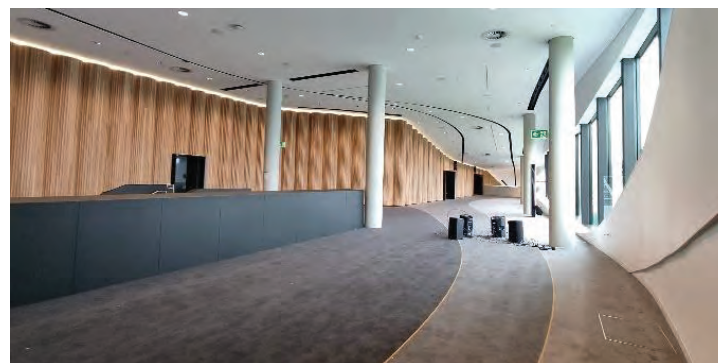
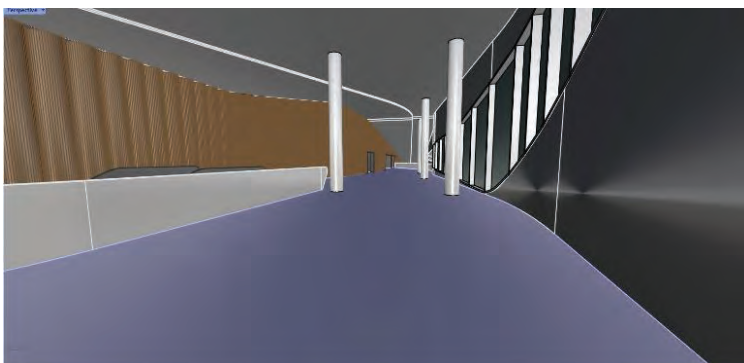


Figure 9. 3D modelling for acoustic analysis (left) and the completed space during commissioning (Rakaia Foyer).

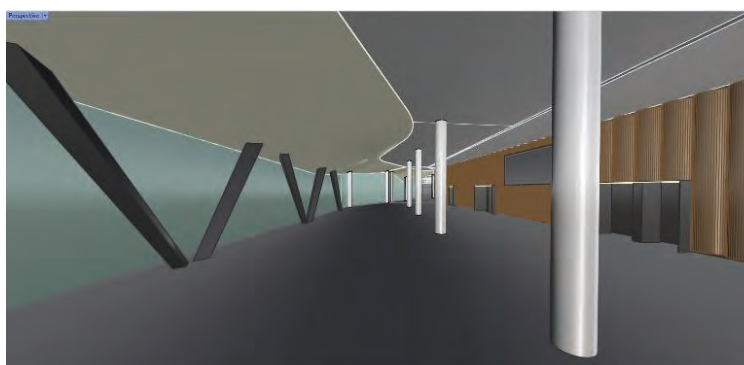


Figure 10. 3D modelling for acoustic analysis (left) and the completed space during construction (Dobson Foyer).

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NEWS

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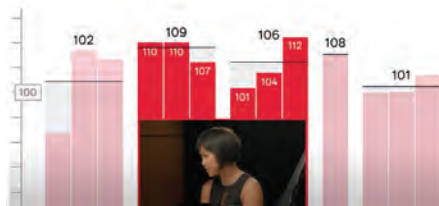




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White and pink noise show promise in enhancing attention in those with ADHD ²⁴



18. <https://www.youtube.com/watch?v=vpjCb2snZck&list=WL&index=18>

19. <https://www.youtube.com/watch?v=rfcQDh9C5qM&list=WL&index=6>

20. <https://www.youtube.com/watch?v=y9-p4Ak gVU8&list=WL&index=65>

21. <https://www.youtube.com/watch?v=Sn07AMCfaA l&list=WL&index=1&t=51s>

22. <https://www.youtube.com/watch?v=-y3RGeaxsY&list=WL&index=74>

23. <https://www.youtube.com/watch?v=SuA9l77ODbs&list=WL&index=43>

24. <https://www.youtube.com/watch?v=dePwODDTPpA&list=WL&index=27>

25. <https://www.youtube.com/watch?v=j0IjnDqff04&list=WL&index=12>

26. <https://www.psypost.org/white-and-pink-noise-show-promise-in-enhancing-attention-in-those-with-adhd/>

Investigating the Lombard effect in a speaker's voice in noisy virtual environments under varying room acoustics

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ABSTRACT

When multiple people converse in an indoor environment, achieving satisfactory communication is often challenging due to high level noise caused by poor acoustic design. Communication in noisy environments gives rise to the Lombard effect, an involuntary reflex that causes one to raise their voice in the presence of noise. This may produce more intelligible speech for listeners, but the increase in speaker sound level eventually contributes to the Café effect occurring in the environment. To control the tendency of noise build-up, it is of interest to investigate the Lombard effect under different acoustic conditions; however, it can be difficult to control variables in real environments, which may affect test reproducibility. This study investigates if the Lombard effect can be simulated by replicating the dynamic changes in sound level of speakers in a real environment, and to what extent speakers change their voice level when immersed into the simulated environment. The study uses spatial sound reproduction to simulate environments with varying acoustics and examines speakers' sound level when the build-up occurs. It will provide a novel method that allows controlled study of speakers' behaviour in noisy environments and provides opportunity to investigate one speaker's effect on the overall sound level within the simulated environment. The results observed show that subjects performed similarly in different virtual acoustic environments. Further statistical analysis will inform development of the simulator for accurately conveying room acoustic design.

1. INTRODUCTION

In noisy environments, an inappropriate noise level may cause adverse effects such as discomfort and disturbance of speech communication [1]. When a speaker is communicating in noisy space, they tend to experience the Lombard effect, an involuntary vocal reflex that causes the speaker to raise their voice. It was first discovered by Étienne Lombard in 1909, where he measured voice levels while speaking in noise, resulting in higher sound levels than in quiet. The raised levels were coined as Lombard speech [2].

The expression of the Lombard effect depends on factors such as the masking noise (i.e. sound level, type, frequency) [3] [4] [5], communication scenario [6] and visual cues available to the listener [7]. The effect is referred to as a communicative phenomenon [8], as producing intelligible speech for others influences speakers similarly to the ability to hear their own voice in noise [9].

When multiple people in the same environment produce Lombard speech, the problem further complicates. The build-up of their voice generates the phenomenon known as the Café effect, which is the vicious cycle of noise breeding more noise [10]. The Café effect is known to be more likely to occur in rooms with longer reverberation times, which commonly occurs in rooms with poorly designed acoustics. To optimise acoustics of these

spaces, it is beneficial to understand how people communicate in these environments and how their voice level varies overtime. Therefore, it is of interest to acoustic engineers to quantify the Lombard effect by measuring change in voice sound level of a speaker in different acoustic environments. Such studies would involve human participants who sit an experiment measuring their voice level while speaking in a noisy space.

Conducting testing in real environments can be challenging due to the inability to reliably control variables (i.e. occupancy, external noise) within the space. This can compromise the repeatability of tests, and consequentially compromises the reproducibility of the collected data. Additionally, it can be logistically costly and inefficient to perform tests in real environments.

The use of virtual reality (VR) offers a solution to overcome these challenges, by simulating the acoustics of real rooms in a controlled laboratory environment. Previous attempts of validation of acoustic VR have successfully shown a clear indication of production of Lombard speech within a simulated environment [11]. To utilise this solution, the simulation requires further validation from real environments as a baseline performance as well as acoustically different environments, both of which have not yet been explored in previous Lombard effect simulator research.

By developing an acoustic VR system that simulates noisy spaces with varying acoustics and immersing participants into the virtual spaces, this study will investigate if the Lombard effect can be replicated by simulating dynamic changes in sound level of speakers in a real environment. It will also provide information about the effect of reverberation on the simulator and explore the extent that speakers change their voice level in noisy virtual environments.

2. THE LOMBARD EFFECT SIMULATOR

Simulator design

The Lombard effect (LE) simulator was developed using the programming platform (Cycling '74 Max/MSP). Figure 1 shows the overall workflow of the LE simulator. The simulator utilises built-in functions for logical expressions and playback and uses external plugins for numerical processing. The simulator design follows the assumption that when there are multiple talkers communicating in a noisy environment, the sound level at which one talker is speaking is the same as the sound level which every other talker is speaking at. This assumption is applied to all talkers in a room. Each talker is said to experience the same noise level, causing them to speak at an identical sound level. The system was run at the sampling rate of 48 kHz.

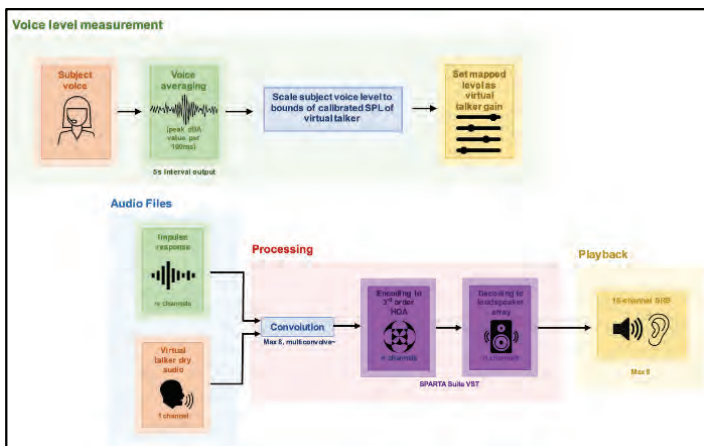


Figure 1. Workflow of the Lombard effect simulator, detailing voice measurement, audio processing and playback

Impulse response measurement

The virtual talkers are simulated from different positions using measured impulse responses (IR) from two acoustically different environments, Café and Foyer, as shown in Table 1. A third order Ambisonics microphone (Zylia ZM-1) was placed at a position near the centre of each environment representing a static listener/speaker (the test participant). A loudspeaker was placed at six different locations, each representing one virtual talker (speakers producing noise), in both environments to measure the impulse responses from virtual talker to the listener as shown in Figure 2 and Figure 3. The locations of virtual talkers and listener were selected by observing typical seating arrangements in both environments.

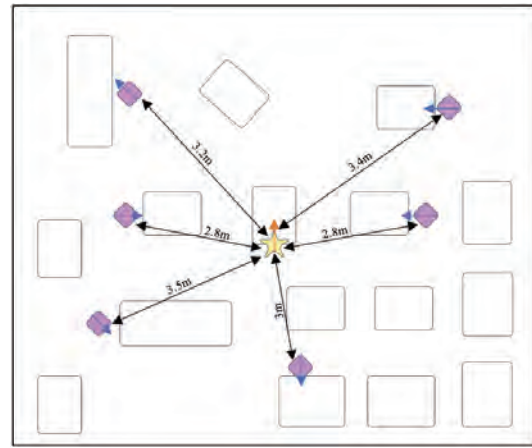


Figure 2. Schematic of Café environment (not to scale), the star represents the microphone/listener and purple symbols represent talker positions

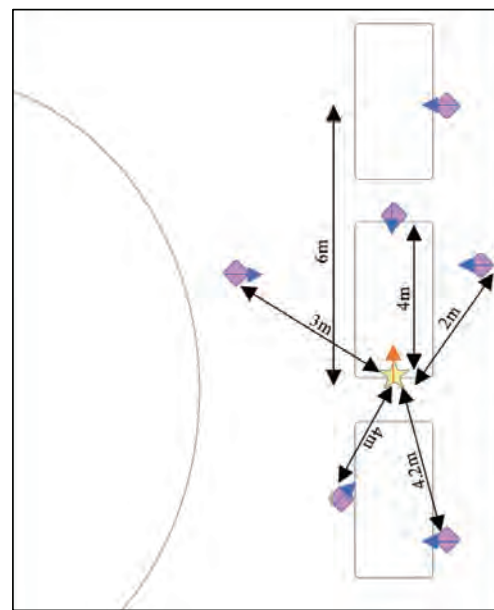


Figure 3. Schematic of Foyer environment (not to scale, cropped), the star represents the microphone/listener and purple symbols represent talker positions

Table 1. Environments tested on the Lombard effect simulator

	Café	Foyer
RT	0.7s	2.5s
Volume	700m ³	2000m ³

Virtual talker functionality

The sound level of each virtual talker is adjusted via a live gain every five seconds, with respect to the speaker's voice level averaged over a five second interval. The speaker's voice level that is sent to the virtual talkers is restricted between 60 – 80 dB(A) to maintain the baseline level of the virtual talkers and prevent the system from reaching unsafe sound levels. The change in sound level of the virtual talkers is exponentially increased and decreased over a two second period using the slide function given by Equation (1).

$$y(n) = y(n - 1) + ((x(n) - y(n - 1))/slide), \quad (1)$$

where $x(n)$ and $y(n)$ denote input and output signals, respectively, and the *slide* is a constant that determines the decay speed of the effect of current input. In the current study, the value was set to 96,000, which was heuristically found to produce the most natural envelope for increasing and decreasing noise.

Virtual talker level calibration

Each virtual talker's baseline SPL is calibrated with respect to the distance between the listener/speaker (microphone) and virtual talker (loudspeaker). Equation (2) below calculates the total (direct + reverberant) sound pressure level:

$$L_p = L_w + 10\log_{10} \left[\frac{Q}{4\pi r^2} + \frac{4}{R_c} \right], \quad (2)$$

where r , Q and R_c denote the distance between the speaker and virtual talker, amplification factor and room constant, respectively. L_p and L_w denote sound pressure level and sound power level, respectively. Equation (2) is used when the amplification factor equalled 2 unless the measured IR is directed towards a wall (where Q is set to 4). When the distance r is much greater than the reverberation radius, Equation (3) is used instead, which calculates the reverberant sound pressure level alone:

$$L_p = L_w + 10\log_{10} T - 10\log_{10} V + 14, \quad (3)$$

where T and V denote the reverberation time (T_{60}) and room volume, respectively. All virtual talkers start at a speech level of 60 dB(A) ($L_{S,A,1m}$) at their position, in accordance with the speech level of normal vocal effort specified in ISO 9921 [12].

Sound Reproduction System

The simulator uses third-order Ambisonics and is decoded onto a 16-channel loudspeaker array configured as shown in Figure 4 using SPARTA Suite¹. The loudspeaker array was installed in the listening room at the University of Auckland Acoustics Laboratory ($T_{60} = 0.3$ s).

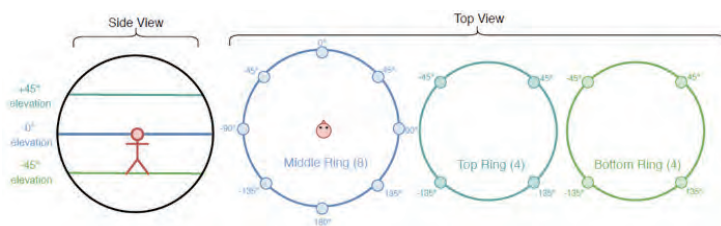


Figure 4. The 16-channel loudspeaker array schematic [13].

System calibration

Each loudspeaker was digitally calibrated through Max/MSP to 60 dB(A) using a calibrated omnidirectional microphone (MiniDSP UMIK-2). The calibration of virtual talkers was achieved by calculating levels using either Equations (2) or (3), and manually adjusting the baseline gain values to these levels and ensuring there is enough headroom to allow for a larger gain (at least 20 dB).

¹ Plugin information can be found at <https://leomccormack.github.io/spartasite/docs/plugins/sparta-suite/>

3. EXPERIMENTAL METHODOLOGY

Aim

The aim of the experiment was to investigate the dynamic sound level changes in a participant's voice when immersed in noisy virtual environments with varying acoustics. Participants also provided insight into their perception of the virtual environments through questionnaire. The study was approved by the University of Auckland Human Participants Ethics Committee (Reference Number UAHPEC27218).

Participants

Twelve female and four male participants (Mean age = 25.5 years old, SD = 3.2 years old) participated in the experiment. All were native English speakers above the age of 18 years old and self-reported no known hearing impairment. Participants received a gift voucher worth NZD 20 for their participation.

Stimuli

The virtual talker noise delivered to participants was the L1 English QNA Set of the ALLSTAR Corpus from SpeechBox². Babble noise of 5 – 10 people was recorded through MATLAB at the Marshall-Day Acoustics Auckland office ($T_{60} = 0.5$ s, $V = 200$ m³) with an omnidirectional microphone (MiniDSP UMIK-2) at a 2 m distance from the group talking. Periods of silence were removed from the audio recordings in a digital audio workstation (Cockos REAPER). This was used as static noise. All virtual talker noise recordings were normalised.

Procedure

Participants completed a demographics questionnaire and were seated at the centre of the 16-channel loudspeaker array at a height of 1.51 m aligned with their ear level and fitted with a headset microphone (Countryman E6 Earset).

They were told at the start of the experiment to "talk to [the researcher] as though you want [the researcher] to understand what you are saying" [14]. Participants were made aware that the researcher would not participate in the conversation and were instructed to maintain eye contact with the researcher.

The chosen task had to allow participants the opportunity to produce spontaneous speech as this is most likely speech produced in noisy environments. Therefore, the task used for this experiment was to speak about any topic(s) of their choice for three minutes. Participants were offered the option of answering a set of questions relating to personal likes and dislikes and retelling past events. Participants spoke to the researcher who was standing at 1.5 m in front of them. The researcher did not show emotion to the participant's conversational material but provided the participant with nodding at the end of *each* sentence. The participant was instructed to stop speaking at the three-minute mark. The recording procedure was repeated twice for each acoustic environment tested (Table 1).

² Speech data can be found at <https://speechbox.linguistics.northwestern.edu/#!/?goto=allstar>

The noise level of the simulated rooms was recorded alongside the participant's voice level (calibrated to SPL at 1 m). Participants were instructed to begin speaking whenever they felt comfortable. The simulated room noise level when participants were first introduced to the room was set to ~50 – 55 dB(A). This did not change for ~30 seconds to allow the participant's voice to settle into the virtual environment. The adjustable virtual talkers were then introduced into the system, in which the participant's voice would control their sound level over the three minute recording period.

4. RESULTS AND DISCUSSION

A linear mixed effect model with a two-way interaction between noise and room type was used to analyse the results. The participant ID was added to the model as a random effect. A significant two-way interaction from the model analysis using the likelihood ratio comparison was found ($\chi^2(1) = 15.3, p < 0.001$).

Figure 5 shows the distribution of the maximum measured speech level (L_{Amax}) of participants in each simulated environment. It shows participants' maximum speech level distributed wider in Foyer than in Café but other than that the distributions look similar. Similar trend can be seen in Figure 6 which shows the distribution of the A-weighted equivalent continuous sound level (LAeq) of participants in each simulated environment. It shows that the overall noise level of the Foyer was more widely distributed. Figure 7 shows the linear regression fit which estimates a participant's voice level based on the noise level of the virtual talkers in each room.

This study hypothesised that speech and room noise levels in the Foyer would be greater than those in the Café because longer reverberation time is known to contribute to degrading speech intelligibility [10]. To test the hypothesis, post-hoc analysis was conducted in RStudio using a one-way ANOVA. The collected data regarding the overall room noise levels and measured voice levels suggest the following preliminary findings:

- The difference in the measured L_{Amax} between environments of 2 dB(A) is not significant ($p = 0.179$) (Figure 5).
- The difference in the measured LAeq between environments of 1.4 dB(A) is not significant ($p = 0.31$) (Figure 6).

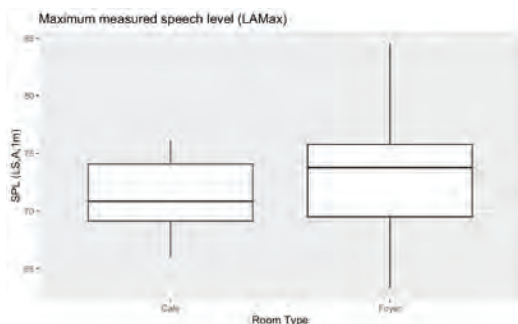


Figure 5. Maximum measured speech level of both rooms

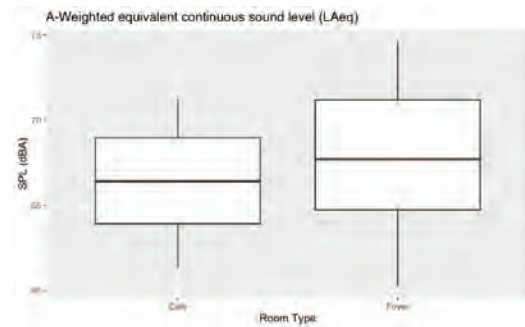


Figure 6. A-weighted equivalent continuous sound level of both rooms

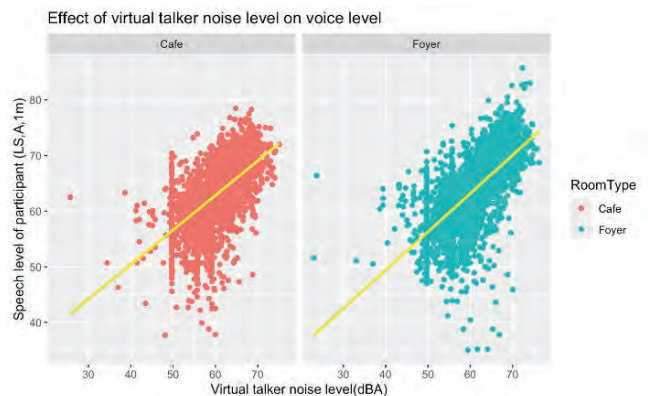


Figure 7. Scatter plot of all participant speech levels relative to virtual talker noise level experienced in both rooms

5. CONCLUSION

This study investigated whether the Lombard effect can be replicated by creating a simulation of the dynamic changes in sound level of speakers in real environments. The results of this study show evidence of the Lombard effect in both virtual environments; however, further statistical analysis is required to compare the real room data against the virtual results to validate whether the Lombard effect of the real room has been replicated. The subjective perception of the participant's experience in the virtual environments will also be analysed. It was hypothesised that the room with a higher reverberation time would cause participants to exert more vocal effort to speak in that virtual environment, and therefore result in a higher Lombard slope and L_{Aeq} . Contrary to the hypothesis, the results show that participants performed similarly in both virtual environments that were recreated by the Lombard effect simulator.

This study focused only on a single participant's Lombard speech and effect on noise in a virtual environment. To further immerse participants into the simulation, visual VR could be introduced. Additionally, another participant could be added to the simulator with their voice level measured alongside the other participant. This would provide insight on the communicative aspect of the Lombard effect.

6. ACKNOWLEDGMENTS

The authors would like to thank Marshall-Day Acoustics for supporting this research. We would like to thank the owners of Kings Garden Café Henderson in Auckland for allowing us to take measurements in their space. We would also like to thank Dr Justine Hui and Clara Zhang for their assistance with analysing the collected data. Lastly, we thank Gian Schmid for his technical expertise needed to conduct the testing for this research.

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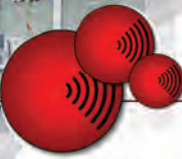
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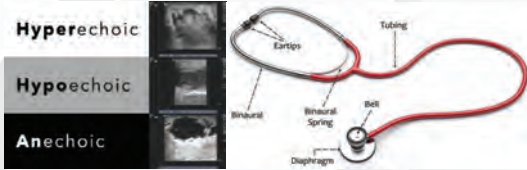
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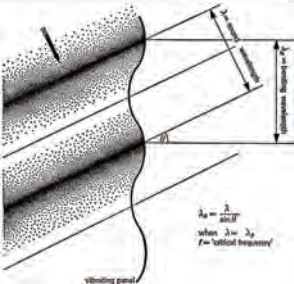
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Funchal, Portugal

SUPER QUIZ

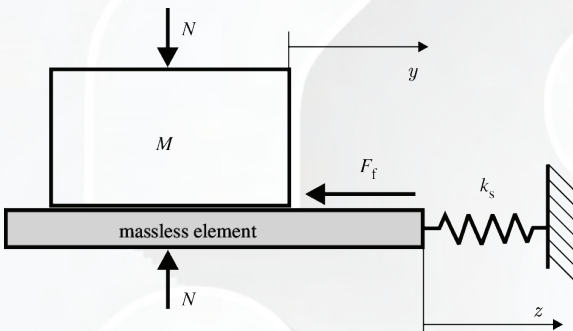
1. True or False – The word anechoic, literally means ‘without echoes;’



2. In a single sentence define the term ‘coincidence effect’



3. What is Coulomb damping?

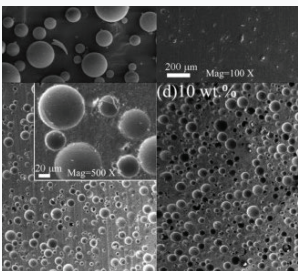


4. True or False – Coulomb damping is also called constant friction damping?

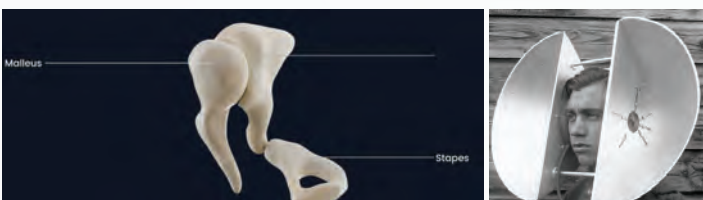
5. What is the day-night level? How do you write day-night level acoustic notation?



6. True or False – A dielectric material is an electrical conductor.



7. What is the incus?



8. Define in a sentence the concept of acoustic ‘insertion loss’?



9. Define what $L'_{nT,W}$ is and what it is used for in acoustics?

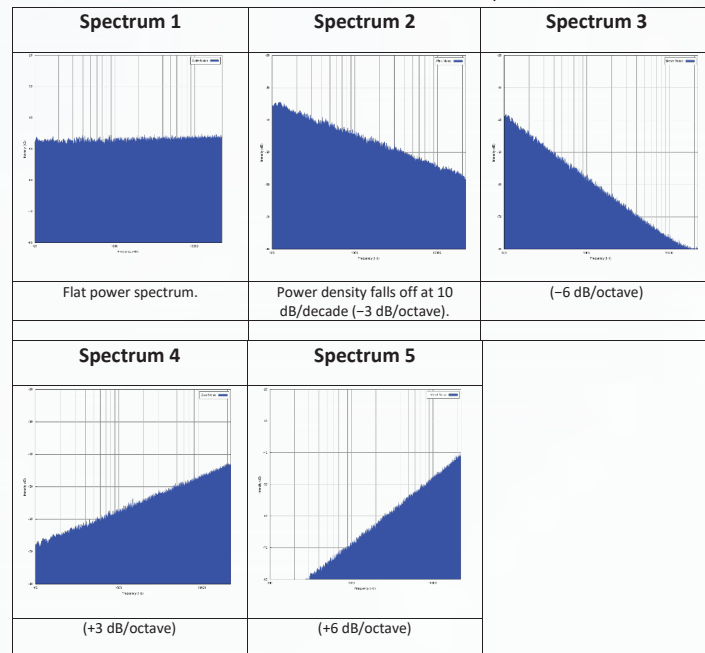


10. Describe what a lower $L'_{nT,W}$ (dB) rating means in a real-life situation.

11. What is psychoacoustics the study of?

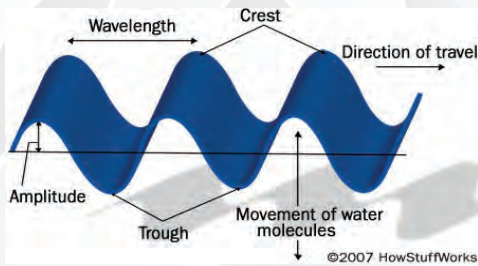


12. Define each of these narrow-band noise spectrums in terms of their colour.



SUPER QUIZ CONTINUED

13. Is the wave shown transverse or longitudinal?

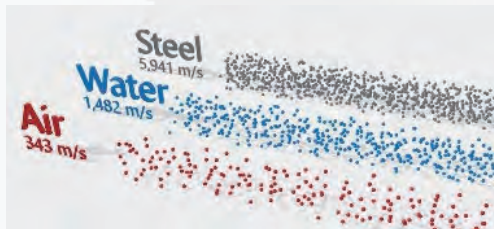


14. What can the following formula be used to calculate?

$$C = 1449.2 + 4.6 T - 0.055 T^2 + 0.00029 T^3 + (1.34 - 0.01 * T) * (s - 35) + 0.016 * z \text{ (m/s)}$$



15. At 20°C which medium; steel or concrete, does sound travel faster through?



16. True or False - For a simple point source in free-field, the sound pressure level decreases by 3 dB per doubling of distance from the source.

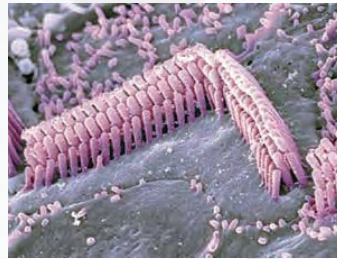
Line Source:
Distance x 2 → Lp -X dBA

Point Source:
Distance x 2 → Lp -Y dBA

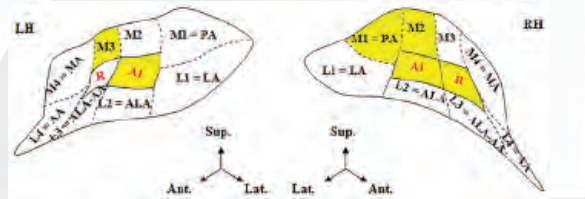
17. Is the photo below illustrating a real-life example of Refraction, Diffraction or Diffusion?



18. What is the photo below of?



19. What is the Franssen Effect?



20. What is Misophonia ?



21. What do the instruments in the photo all have in common?



22. How would you define a woodwind instrument in a single sentence?

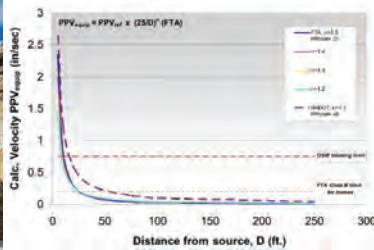


SUPER QUIZ CONTINUED

23. What New Zealand standard is used to assess airport noise?



24. In the international standard 'DIN 4150-3:2016 Structural vibration - Part 3: Effects of vibration on structures' what does 'DIN' stand for in the title?



25. True or False - 'Presbycusis' is hearing loss attributed to the ageing process?



26. What is acoustic shock?



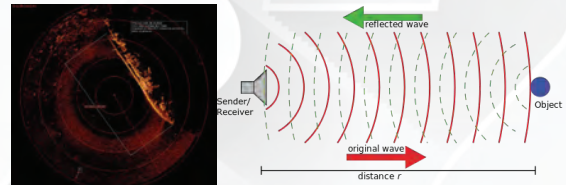
27. NZS 6807:1994 is used for the assessment, management and land use planning for which noise source?



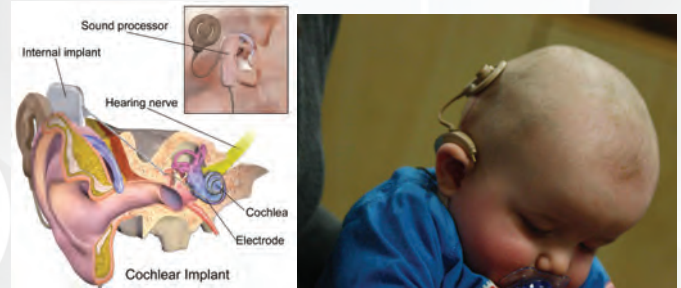
28. How would you describe an integrating sound level meter to a layperson?



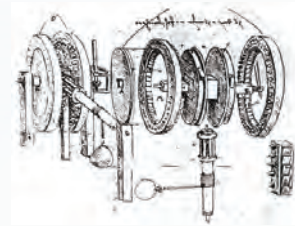
29. What is 'active sonar'?



30. What is a cochlear implant and what does it do?



31. Which famous painter, draughtsman, engineer, scientist, theorist, sculptor, and architect recognized that "there cannot be any sound when there is no movement or percussion of the air."



BONUS QUESTION: John wants to build a new house. The house sits next to a busy railway in a foreign country called Noiseamenia. The railway has, fast express trains, slow suburban trains and heavy freight trains. John needs to calculate the equivalent continuous noise level at the site over 24 hours so he can work out what sound insulation level his façade should have. John took three sets of measurements from each train by-pass, as follows:

1. Fast express train: L_{Aeq} 85 dB measured over 12 seconds
2. Slow Suburban Units: L_{Aeq} 78 dB measured over 18 seconds
3. Heavy Freight Trains: L_{Aeq} 76 dB measured over 24 seconds

During a 24-hour period John counts the following number of trains

Fast express trains = 120, Slow Suburban Units = 200 and Heavy Freight Trains = 80

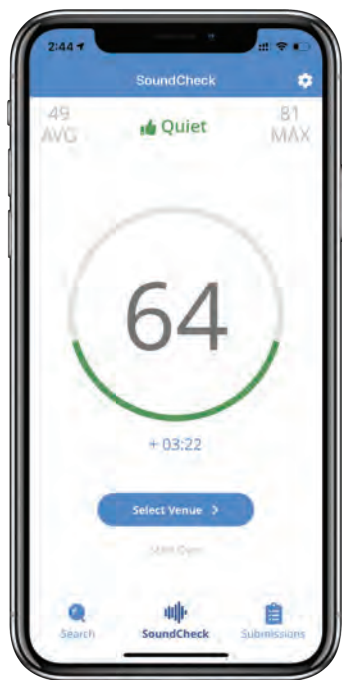
Based on John's measurements and observations, what is the L_{Aeq} (24 hr) at John's site from all trains?

FIND YOUR QUIET PLACE WITH **SOUNDPRINT**

Looking for quiet places to easily connect with others and not worry about too much noise?

Download the SoundPrint app and empower yourself to **find quiet places, measure sound levels, and protect your hearing health!**

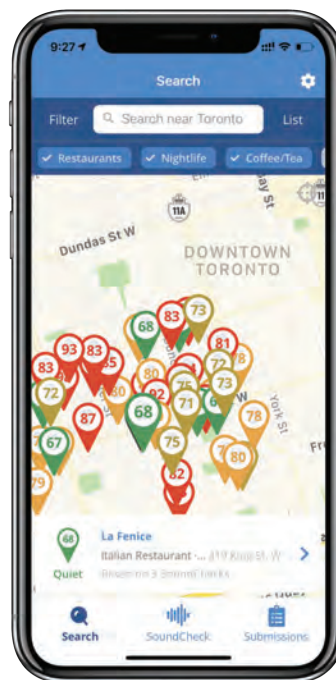
How does the app work?



Measure and Submit Sound Levels

Tap 'Start' and begin measuring!

'Submit' and select your venue to add your sound measurement to SoundPrint's database for all to benefit!



Search for Venues

Search among thousands of venues by noise level, location, and type of venue.

If a venue does not yet have a noise measurement, be the first to take one!



<https://www.soundprint.co>





The ASNZ has teamed up with **SoundPrint** to provide this curated list of acoustic ratings for food and beverage venues across Aotearoa (replacing the previous **CRAI** ratings). This data is collated from submissions made by users of the SoundPrint app, which rates venues based on the ambient noise levels present at the time of review and a subjective impression of how easy it was to hold a conversation. SoundPrint ratings follow a decibel scale, and these correspond with our awarded star ratings as follows:

QUIET		MODERATE	LOUD	VERY LOUD
70 dBA or below + subjectively "great" for conversations	70 dBA or below	70 - 75 dBA	75 - 80 dBA	80 dBA or above
★★★★★	★★★★★	★★★	★★	★

The list below contains submissions from the past 3 years only. The numbers in parentheses are the total reviews over this period.

AUCKLAND			Meshino, Saint Albans	★★	(2)
Ah Ssak, Auckland	★★	(1)	Misceo Cafe & Bar, Ilam	★	(1)
Bellota, Auckland	★★	(1)	Strange Bandit, Burnside	★★★★★	(2)
Birkenhead Brewing Company, Birkenhead	★	(1)	Strawberry Fare, Christchurch	★★★★★	(1)
Brickhouse Espresso Bar, Auckland	★★★	(1)	Super, Lyttelton	★★★★★	(1)
Brothers Beer, Auckland	★★★	(1)	The Rockpool Bar, Christchurch	★	(1)
Charlie Farley's, Onetangi	★★	(1)	Two Thumb Brewing Co Ltd, Christchurch	★★	(1)
Corner Bar, Auckland	★★★★★	(1)	Volstead Trading Company, Christchurch	★★★★★	(1)
Dear Jervois, Herne Bay	★★★	(1)	HAWKE'S BAY		
Deco Eatery, Auckland	★★★	(2)	Hunger Monger, Napier	★★★	(1)
Dizengoff, Ponsonby	★★	(1)	Mister D, Napier	★★	(1)
Ebisu, Auckland	★★	(2)	MANAWATU-WANGANUI		
Kind Cafe & Eatery, Auckland	★★★★★	(1)	Café Cuba, Palmerston North	★★	(1)
Kol, Auckland	★★★	(1)	Spice Guru, Whanganui	★★★★★	(1)
Little Bird Unbakery, Ponsonby	★★★★★	(1)	Viv's Kitchen, Sanson	★★	(1)
Little Creatures Hobsonville, Hobsonville	★★★	(1)	NELSON		
Little Culprit, Auckland	★★★★★	(1)	Columbus Coffee, Nelson	★★★★★	(1)
Manuka, Auckland	★★★★★	(1)	Sprig & Fern Hardy St, Nelson	★★★	(1)
Masala Indian Restaurant, Pukekohe	★★★	(1)	Sprig & Fern Tavern, Nelson	★★★	(1)
McDonald's, Albany	★★★	(1)	The Free House, Nelson	★★★★★	(1)
Nanny's Eatery, Kingsland	★★	(1)	NORTHLAND		
Pocha, Auckland	★★	(2)	The Gables, Russell	★★	(1)
Poni Room, Auckland	★★★	(1)	OTAGO		
Ssam Jang, Auckland	★	(1)	1876 Bar & Restaurant, Queenstown	★★	(1)
St Pierre's Sushi & Seafood, Auckland	★★★★★	(1)	Bacchus, Dunedin	★★★	(1)
Sumthin Dumplin, Auckland	★★★★★	(1)	Farelli's Trattoria, Queenstown	★	(1)
The Brewers Co-operative, Auckland	★★★★★	(1)	Margo's queenstown, Queenstown	★★★★★	(1)
The Chamberlain, Auckland	★★	(1)	My Thai Lounge, Queenstown	★★★★★	(1)
Tok Tok, Hobsonville	★★	(1)	The World Bar, Queenstown	★★	(1)
Vondel, Devonport	★★	(1)	Winnies Gourmet Pizza Bar, Queenstown	★★★	(1)
BAY OF PLENTY			Wolf Coffee Roasters, Arrowtown	★★★★★	(1)
Ohope Charter Club, Ohope Beach	★★	(1)	SOUTHLAND		
CANTERBURY			Bailiez Cafe, Te Anau	★★★★★	(1)
Black And White Coffee cartel, Christchurch	★★★★★	(1)	Speights Ale House, Invercargill	★★★	(1)
Coffe Culture, Papanui	★★★★★	(1)	WAIKATO		
Coffee Culture, Christchurch	★★★★★	(1)	The Vine Eatery, Taupo	★★	(1)
Columbus Coffee, Papanui	★★★	(1)	WELLINGTON		
Doubles, Christchurch	★★★	(1)	1154, Te Aro	★	(1)
Kohan Japanese Cuisine, Lake Tekapo	★★★★★	(1)	Baylands Brewery, Lower Hutt	★★★★★	(1)
Kum Pun Thai Restaurant, Christchurch	★★★★★	(1)	Bethel Woods, Wellington	★★	(1)
Little Poms, Christchurch	★★★	(1)	Boulcott Street Bistro, Wellington Central	★★	(1)
Mac's South Bar & Café, Christchurch	★★★★★	(1)			

SoundPrint can be downloaded from the Apple App Store and Google Play Store. More information and reviews are available at the website: <https://www.soundprint.co/locations/nz>



BurgerFuel, Wellington	★★★★★	(1)
Caffe L'affare, Te Aro	★★	(2)
Crumpet, Wellington	★★	(1)
Dillinger's, Wellington	★★★★★	(1)
Dockside, Wellington Waterfront	★	(1)
Dragon Fly, Te Aro	★★	(1)
Elements Cafe, Lyall Bay	★★★	(1)
Flamingo Joe's, Pipitea	★★	(1)
Foxglove, Wellington Central	★★★	(1)
Fratelli, Te Aro	★★★	(1)
Hashigo Zake, Wellington	★★★★★	(2)
Heaven, Wellington	★★	(1)
Hola Mexican Cantina, Paraparaumu	★★	(1)
Ivy: Underground, Wellington	★	(1)
Logan Brown Restaurant & Bar, Wellington	★★★	(1)
Maranui Cafe, Wellington	★★	(1)
Miyabi, Wellington	★	(2)
Neo Cafe & Eatery, Wellington	★★	(1)
Panhead Tory, Te Aro	★★★★★	(1)
Rasa, Wellington	★	(1)
Rose's Red-Hot Cantina & Taco Joint, Wellington	★	(1)
Rosie's Cantina, Wellington	★★	(1)
Seashore Cabaret, Petone	★★	(1)
Siam Spoon, Petone	★★	(1)
St Johns Bar, Te Aro	★★	(1)
Te Papa Cafe, Wellington	★★★	(1)
Union Square Bistro, Martinborough	★★	(1)
Viva Mexico, Wellington	★★	(1)
Waitoa Social Club, Wellington	★★★	(1)



**Minutes of the Biennial General Meeting No. 26
of the New Zealand Acoustical Society Inc held at the Christchurch Town Hall, Christchurch
on 2 September 2024 at 5.00 pm**

45 Attendees - Quorum present.

Meeting opened 5.06pm by Tim Beresford, President.

1. **Apologies received from:** Vern Goodwin, Lindsay Hannah

2. **Proxy Votes:**

<u>Absentee</u>	<u>Proxy</u>
John Cater	Grant Emms
Lindsay Hannah	James Whitlock
Jamie Exeter	Kelly Leermeyer

3. **Previous Minutes**
Moved that the previous minutes be accepted as a true and correct record.

Jon Styles / Richard Finley

4. **President's Report**
Tim Beresford presented the President's report. Will be circulated to members with the AGM minutes.
Moved that report be accepted.

Tracy Hilliker / Richard Finley

5. **Treasurer's Report**
Hedda Landreth presented the Treasurer's report. Will be circulated to members with the AGM minutes.
Moved that report be accepted.

Thomas Scelo / Christian Vossart

6. **Confirmation of Accountant**
Moved that Hounsell Accounting Ltd be retained as the ASNZ Accountant

Tracy Hilliker / Thomas Warren

7. **Branch Reports**
Mike Kingan gave an off-the-cuff North Island report. ASNZ lunch bunches are occurring regularly each month. They have now moved to Zoom live-streaming and videos saved on the website.

Also noted Siiri Wilkening's fellowship event in August 2023 and Xmas party (combined with Australasian Association of Acoustic Consultants (AAAC). James Whitlock noted Tauranga branch is growing.

Tracy Hilliker gave an off-the-cuff South Island report. They have had some get-togethers and the first ASNZ lunch bunch was held via zoom. Noted that not having a central location for meetings makes them a bit trickier.

James noted that lunch bunches shouldn't be seen as replacing branch meetings. Branch meetings are more formal events that could include evening presentations and visits to interesting places (manufacturing plants, performance spaces etc.).

8. **Election of Officers**
Nominations announced by James Whitlock. Twelve in total.
The following members of the Acoustical Society were therefore elected to office:

President:	Tracy Hilliker
North Island Vice President:	Mike Kingan
South Island Vice President:	Mike Latimer
Secretary:	James Whitlock
Treasurer:	Hedda Landreth
Councillors:	Tim Beresford
	Jon Styles
	Paul Hazard
	Victoria Rastelli
	Mathew Legg
	Christian Vossart
	Wyatt Page

9. **Next Conference**

The 2026 ASNZ conference will be in a smaller North Island city – likely Tauranga.

10. **Updates on general business raised at last AGM**

Student Prizes

Mike Kingan provided an update on the student prizes that have been given out.

ASNZ affiliation with other organisations

James noted that ASNZ are currently members of the following organisations:

- National Foundation for the Deaf and Hard of Hearing (NFDHH) – James noted that they have changed their constitution, and now only require one member from each member group. James has stepped down, and Dr George Dodd will stay on
- International Congress for Acoustics (ICA)
- International Institute of Noise Control Engineers (I-INCE)
- The World Health Organisation's World Hearing Forum

Offering NZ Acoustics journal online

This is now in place. The journal is now uploaded to the ASNZ website soon after it is printed and posted to all members.

11. **General Business**

No general business matters tabled prior to, or at AGM

Passing of Sir Harold Marshall and Graeme Phillip

ASNZ recognizes the recent passing of Sir Harold Marshall (Aug 2024), renowned concert hall acoustician and founder of Marshall Day Acoustics, and Graeme Phillip (June 2024), managing director of John Herber Theatre Supplies.

Thoughts and condolences to their families. Tributes to both will appear in forthcoming NZ Acoustics Journal issues.

Changes to ASNZ constitution

The Incorporated Societies Act has changed, and all societies must reapply for incorporation before 2026. The Council has revised both the Society Rules (now called a Constitution) and Rules of Conduct and Disciplinary Measures, and issued a draft with the AGM pack for member feedback. Have received comments from two members so far and welcome more.

Richard Finley asked whether the rules need to be legally reviewed. Tim Beresford and James Whitlock responded saying that none of the required changes to the Rules have caused legal concern, but legal review of the Rules of Conduct and Disciplinary Measures may be prudent.

Jon Styles asked about the process from this point forward. James confirmed the process as follows:

- Give members a deadline for feedback on first draft
- Issue final draft for comment (with deadline)
- Call an extra-ordinary meeting, or until to 2025 AGM to vote on accepting changes
- Lodge updated Constitution and Rules of Conduct and Disciplinary Measures with the Registrar and reapply for incorporation

New membership grade

Tim Beresford announced that Council is looking at creating a new membership grade, noting that Society Rules provide for two additional grades that we do not currently use. The new membership will likely be for long-standing members of the Society.

New website

ASNZ website refresh is well underway. It will link to our LinkedIn page. James Whitlock will notify members when it goes live.

12. **Closing**

The AGM was closed at 5.43 pm

James Whitlock
(ASNZ Secretary)

2 September 2024

26th AGM of the Acoustical Society of New Zealand
President's Report

Tēnā koutou katoa,

Firstly, I am pleased to present my 2024 President's Report in person this time, without the need for Jon or James to impersonate me as President. The past two years for the Society have been those of growth, achievement, and new initiatives that have further strengthened our society and its commitment to advancing the field of acoustics.

I'll dive straight into a snapshot of what's been going on since the last AGM.

Fellowships: The ASNZ has awarded three Fellowships to honour significant contributions to the Society and to acoustics, generally. These were to Siiri Wilkening at an event in Auckland last year, and to Mark Poletti and Nigel Lloyd at a double award event held in Wellington earlier this year. Rumour has it that there will be a further fellowship awarded at the gala dinner tomorrow night.

New website: We are excited to announce the launch of a new website coming in the next few weeks. The website will provide members and the public with easier access to things like the journal, educational videos, conference proceedings, membership details, CPD submissions, and updates about the Society and its activities.

Membership: Our society has grown to 161 members in 2024, reflecting a strong and engaged community of professionals dedicated to the field of acoustics.

Updated Society Constitution: Recent changes to the government's Incorporated Societies Act have triggered the Council to make updates to our Constitution (previously Rules). The proposed changes have been circulated to all members for feedback, which will then be collated and merged into the new Constitution by the Council over the next few weeks.

Updated Rules of Conduct and Disciplinary Measures: Along with the new Constitution, updates to the Rules of Conduct and Disciplinary Measures are in progress to help clarify the process of dealing with complaints against our Members.

Membership grades review: The Council is currently reviewing our membership grades, with the intention of introducing a new grade which sits somewhere between Member and Fellow.

Social media: Further to the new website, the Society's presence on LinkedIn has increased significantly, thanks to input from key Councillors and members.

SoundPrint: The ASNZ has vetted and officially endorsed the SoundPrint app to replace the previous CRAI ratings for reviewing the acoustic qualities of cafes and restaurants.

Education: ASNZ lunch bunches and other educational events have been held with unprecedented regularity. Traditionally these were hosted at the University of Auckland, but recently other cities have also hosted sessions, all of which have been broadcast via Zoom to all members. Recordings of these learning sessions have been made available on our website.

Student prizes: The award of student prizes has continued steadily over the past two year to encourage new entrants into the field of acoustics. Further student prizes will be awarded later this conference.

Journal: The NZ Acoustics journal continues to be a key component of the Society. Wyatt tells me we have literally just run out of material from previous conferences to publish, which is good timing, since we will have a stack of new papers coming out of this conference

Conference attendance fund: The Council has reinvigorated the ASNZ conference attendance fund to help individuals in need of financial assistance to participate in local and international conferences. We've had strong and immediate uptake of this initiative, and the details can be found on our website if you're interested in applying.

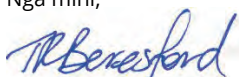
Conference: The local organising committee, led by Tracy Hilliker, has put in a tremendous effort to bring you the conference and facilitate this AGM. On behalf of all ASNZ members, I'd like to thank Tracy and all those involved in bringing us together in Christchurch this year. The next conference will be in 2026 somewhere in regional North Island, with details to be confirmed.

As you may or may not be aware, this is my last day as President of the ASNZ. If the Constitution would allow me to stay on for another term, I would gladly, but the rules state it is time for someone else to take a turn at the helm. I believe the Society has continued to grow healthily over the last four years, with two exceptional conferences, our highest ever membership numbers, increased social media outreach, a fantastic journal, and a tremendous bunch of people. I intend to stay on as a Council member to continue my support of the Society.

In conclusion, I would like to thank my fellow Councillors and all members for the special opportunity for me to lead a society that I feel truly passionate about.

Please enjoy the rest of the conference and I'll see you 'round.

Ngā mihi,



Tim Beresford

2 September 2024

26th AGM of the Acoustical Society of New Zealand

Treasurer's Report

As I stepped into the role of Treasurer in 2022, taking over from Siiri, I quickly realised that I had some big shoes to fill. Siiri, ever the dedicated professional, continued to do much of the heavy lifting as we navigated the endless Red Tape of changing permissions for the bank account and accessing the IRD. It took nearly a year to get everything properly sorted out!

Learning what Treasurer of the ASNZ entails, has been quite the adventure, especially for someone without an accounting background. The most memorable curveball? When I generated subscription invoices for all our Members and Affiliates and I mistakenly left off the GST. My assumption that we were somehow exempt as a not-for-profit led to a flurry of emails from various accounts payable, followed by the realisation of my error. It was possible to fix by manually editing every single invoice—a lesson I won't soon forget!

I'm gradually getting the hang of invoicing, although there's still some uncertainty around the timing for sending out yearly subscriptions and advertising invoices. Sorting this out would help streamline things going forward. And just to echo Siiri's advice from the last Treasurer's report: it really makes life easier if everyone could include their Invoice numbers and pay the correct amount. Trying to reconcile nameless payments, overpayments, underpayments, and amounts sent to the wrong accounts is a bit of a headache. Since we haven't held a conference since the last AGM in 2022, our main income sources during this period have been subscriptions and advertising. On the expense side, the bulk of our outgoings have gone towards the Journal—covering printing, layout and design, and postage—along with some administration charges for accounting and secretarial work.

We've started processing Conference Fund payments and the ASNZ Council have proudly awarded the first four recipients with contributions towards their conference costs.

The balance in both accounts before the conference is \$37,940.13 in the standard account and \$63,270.07 in the conference account.

Hedda Landreth
Treasurer
The Acoustical Society of New Zealand



SUPER QUIZ ANSWERS

1. True. The word anechoic means 'without echoes'. Most people know the word anechoic when used with specific reference to an anechoic chamber, however, in ultrasound imaging, regions appear black because they do not reflect the sound waves.
2. The coincidence effect occurs when the sound wavelength is the same as the length of the bending waves in a partition, exciting the partition (resonance) and increasing the acoustic energy transmission through it at this frequency.
3. Coulomb damping is a form of mechanical damping in which the damping force is constant, independent of either displacement or velocity.
4. False. Coulomb damping is sometimes called dry friction damping as the kinetic energy is absorbed via sliding friction (the friction generated by the relative motion of two surfaces that press against each other).
5. The day-night level is a common metric for environmental noise. It is the power average over a 24-hour period using the L_{Aeq} descriptor with a 10 dB penalty applied to the night-time level (typically between 10.00 pm and 7.00 am) to account for the decrease in community background noise at night. It is usually written as L_{dn} or DNL.
6. False, a dielectric material is an electrical non-conductor (or insulator). A common application in acoustics is in a polarised condenser microphone.
7. The incus is the middle bone of the three bones in the middle ear (the ossicular chain), sometimes called the anvil. The other two are the malleus and stapes (the smallest bone in the human body).
8. In acoustics, insertion loss is a measure of the effectiveness of a noise control device such as an enclosure or barrier. Insertion loss is the difference in dB between the noise level with and without the device present, usually with A-frequency weighting.
9. $L'_{nt,w}$ is the weighted standardised impact sound pressure level. It is a single-figure value used for impact sound insulation performance rating, typically for floor systems. It is the amount of impact noise transmitted through a material. $L_{nt,w}$ is based on laboratory measurements while $L'_{nt,w}$ is based on field measurements and includes sound flanking.
10. The lower the $L'_{nt,w}$ (dB) value is, the less noise is received in the adjacent room. Unlike IIC (Impact Insulation Class) where a higher IIC value is better, with $L'_{nt,w}$ (dB) the lower the value the 'better'.
11. Psychoacoustics is the study of how humans respond to sound. Psychoacoustics combines the physiology of sound (how our bodies receive sound) with the psychology of sound (how our brains interpret sound). Together, these sciences help us understand how and why sounds affect people differently.
12. 1= White Noise. 2= Pink Noise. 3= Brown or Red Noise. 4= Blue Noise. 5= Violet Noise
13. Transverse
14. The speed of sound in water (simplified MacKenzie Equation), where T = temperature ($^{\circ}C$), s = salinity (ppt), and z = depth (m)
15. The speed of sound is faster in steel at about 5000m/s compared to concrete at about 3400m/s.
16. False, the theoretical loss for a point source 6 dB per doubling of distance from the source. For a line source, it decreases by 3 dB per doubling of distance from the source.
17. The photo is an example of diffraction - To bend around the edges of objects/barriers or through holes. Diffraction through a hole results in sound spreading out on the other side as if the hole were a local source of the sound. Diffraction around corners, allows us to hear who is around the corner. Diffraction around acoustic barriers reduces their effectiveness.
18. The photo of the inner-ear hair cells covered in stereocilia that bend against the tectorial membrane when sound enters the ear, triggering an electrical impulse in the auditory neurons.
19. The Franssen effect, sometimes called the Franssen illusion, is an auditory illusion where the listener incorrectly localizes a sound in an enclosed room. It was discovered in 1960 by Nico Valentinus Franssen (1926-1979), a Dutch physicist and inventor.
20. Misophonia literally means "hatred of sound" and is a disorder where you have a decreased tolerance to specific sounds and things you can sense related to them. The effect can vary from irritation to rage or even panic when they hear their trigger sound.
21. They are all string instruments such as a guitar or violins, which make sound with vibrating strings.
22. Woodwind instruments originally consisted of a hollow tube made of wood played by blowing 'wind' into a mouthpiece. Most wind instruments have keys or fingerholes to vary the pitch of the sound, and different methods may be used to create the basic sound such as the inclusion in the mouthpiece of a vibrating reed. Different notes are created by shortening or lengthening the air column inside the instrument. This is usually achieved by covering certain holes on the instrument, either with keys or fingers.
23. NZS 6805:1992 Airport Noise Management and Land Use Planning
24. DIN stands for Deutsches Institut für Normung e.V. (German Institute for Standardization).
25. True, 'Presbycusis' is hearing loss (mostly higher frequencies) attributed to the ageing process and is more pronounced for men until about age 65 and is about the same by age 85 years for both sexes.
26. Acoustic shock is the physiological and psychological symptoms a person may experience after being exposed to a sudden, brief and unexpected loud sound. Acoustic shock is not the same as Acoustic Trauma, the immediate and permanent loss of hearing due to exposure to impulsive or explosive sound with a very high peak level (>140 dB).
27. Helicopter landing areas
28. A sound level meter is a device for measuring the sound pressure level of different sounds in a standard way, usually in the scientific units of decibels. One of the standard measurements involves squaring the pressure changes due to the sound and summing them up (a process called integration) over a period of time, say 15 minutes, to get a time average equivalent level.
29. Active sonar creates a pulse of sound, often called a "ping", and then listens for reflections (echo) of the pulse. This pulse of sound is generally created electronically using a sonar projector consisting of a signal generator, power amplifier and electro-acoustic transducer/array. A beamformer is usually employed to concentrate the acoustic power into a beam, which may be swept to cover the required search angles.
30. A cochlear implant is a surgically implanted electronic device that provides a sense of sound to a person who is profoundly deaf or severely hard of hearing in both ears. Unlike hearing aids, which make sounds louder, cochlear implants do the work of damaged parts of the inner ear (cochlea) to provide sound signals to the brain. Cochlear implants bypass the normal hearing (transduction) process.
31. Leonardo da Vinci [1452-1519]

BONUS ANSWER: 69.4 dB L_{Aeq} (24 hr)

Train sound exposures:

$$\text{Fast Express Train: } 85 \text{ dB } L_{Aeq} \equiv 0.126 \text{ Pa}^2 \Rightarrow$$

$$E_{A_{FET}} = 12 \times 0.126 = 1.52 \text{ Pa}^2\text{s}$$

$$\text{Slow Suburban Units: } 78 \text{ dB } L_{Aeq} \equiv 0.0252 \text{ Pa}^2 \Rightarrow$$

$$E_{A_{SBU}} = 18 \times 0.0252 = 0.454 \text{ Pa}^2\text{s}$$

$$\text{Heavy Freight Train: } 76 \text{ dB } L_{Aeq} \equiv 0.0159 \text{ Pa}^2 \Rightarrow$$

$$E_{A_{HFT}} = 24 \times 0.0159 = 0.382 \text{ Pa}^2\text{s}$$

$$\text{Total sound exposure over 24h} = 120 E_{A_{FET}} + 200 E_{A_{SBU}} + 80 E_{A_{HFT}} = 182 + 90.9 + 30.6 = 303.5 \text{ Pa}^2\text{s}$$

$$\text{Divide by the number of seconds in a day to get the average } \text{Pa}^2 = 303.5 / (24 \times 3600) = 0.00351 \text{ Pa}^2$$

$$\text{Convert to decibels: } L_{Aeq(24 \text{ hr})} = 10 \log_{10}(0.00351 / (20 \times 10^{-6})^2) = 69.4 \text{ dB}$$

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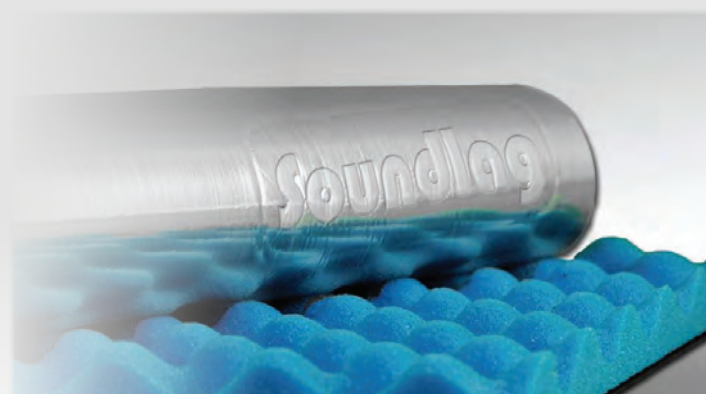
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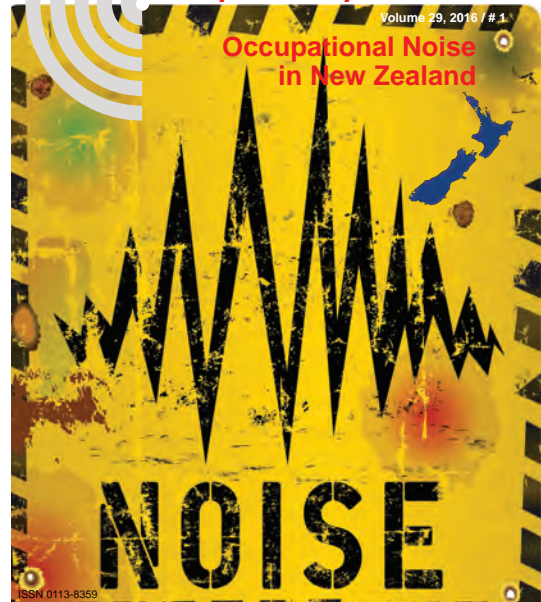


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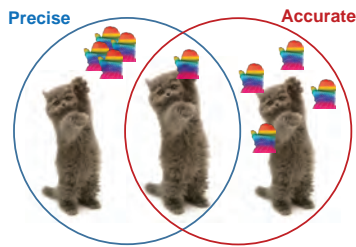
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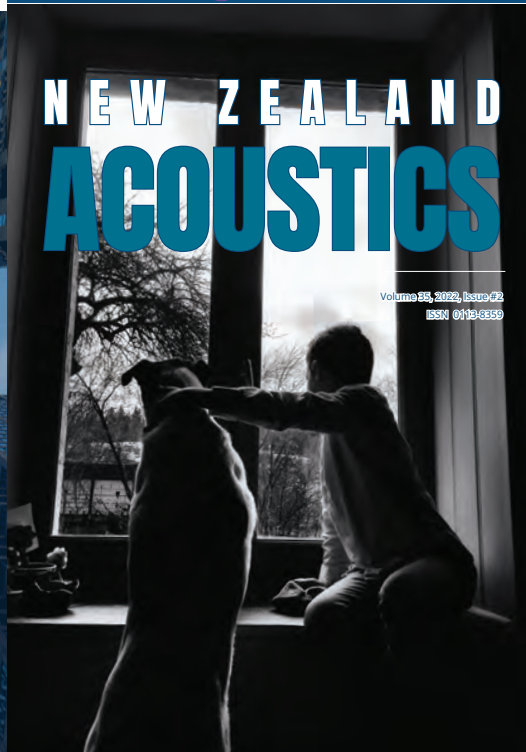
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