New Zealand Acoustics

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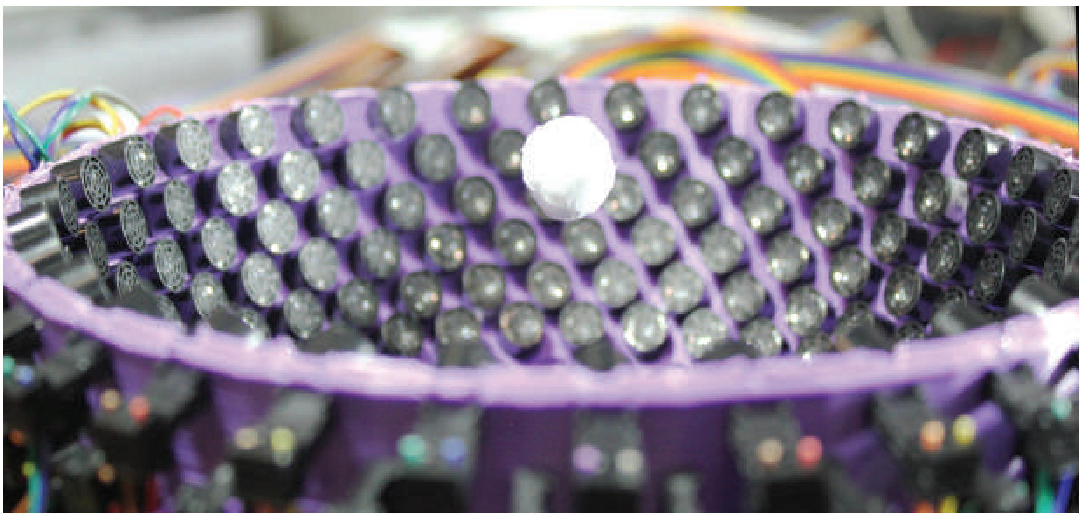

Pro-active use of unattended loggers for noise and vibration monitoring

Noise and vibration design aspects for an indoor theme park

Evaluation of noise exposure levels in a regional commuteraircraft

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Features

Regulars

Cover Image: The world's most powerful acoustic tractor beam

Source: University of Bristol News

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Contributions to the Journal are encouraged, and may be sent directly to the Editors by email (journal@acoustics.org.nz) or by post c/o, the Acoustical Society of New Zealand Incorporated, PO Box 1181, Shortland Street, Auckland 1140.

From the President and the Editors

President's Column

Dear All,

A mostly operational column from me this issue, in full support of the fantastic work being undertaken by some people in the Society.

Planning and organisation of the 2018 ASNZ Conference is moving ahead at full steam, with the call for abstracts now out. A fantastic venue has been secured, with a great and list of speakers is being put together. The conference will have a variety of papers and presenters, as well as a panel-style Q&A session with experts in environmental acoustics, together with some leading environmental planners. The aim will be to facilitate a well-informed discussion about the role that noise and vibration experts play in the planning process; what planners expect of the experts; and what the experts expect from the planners. We are inviting members of the New Zealand Planning Institute to attend to provide a greater depth of discussion and to hear directly from those involved in the resource management processes.

To achieve its objectives and to further its cause, the Society owes much to the effort of the Councils – past and present. In recognition of their contribution to the Society and to the practice of acoustics generally, the Society will be welcoming two new Fellows this year, with presentations and recognition to follow either by branch meetings or at the Conference.

I would also like to thank Dr Stuart McLaren for his excellent service over the past 5-years as sub-editor for the journal

On a more philosophical note, I have personally been involved with and am aware of several recent Environment Court-led expert conferencing sessions which have been, in short, excellent! In my view, the Environment Court processes for facilitating and guiding expert conferencing sessions have led to significant improvements in the speed and veracity of discussions between experts and this would have reduced the overall time required in front of the Court considerably. The discussions are assisted greatly by experts who are willing to discuss the issues openly, frankly and constructively and with the appetite to delve into the detail to seek the greatest extent of agreement possible. If disagreements cannot be resolved, preparing clear reasoning and determining the underlying reasons for any disagreements is crucial for the decision-maker to understand. I am aware of many conferencing sessions between acoustics experts being praised for their constructive and professional nature. I encourage our members to show the way and continue the excellent work in these processes, and to be as constructive and helpful as possible, adhering to Section 7.1 the expert witness Code of Conduct, of the Environment Court's - Practice Note 2014.

Enjoy the end of winter and make sure you get your abstract in on time!

Best wishes,

Jon

Editor's Column

Welcome to New Zealand Acoustics Journal Volume 30, 2018 #2. We are now well and truly into winter and have passed the Southern Hemisphere's winter solstice, our shortest day, thus its getting lighter in the evening (just!) and we are heading slowly towards Day-light savings and summer, so hold on not long now to go!

We want to start off by taking the time to thank Dr Stuart McLaren who is retiring from his role as Sub-Editor. Stuart has given the journal 5 years' service in which the Journal team are grateful for his help and support. Wyatt and I both want to wish Stuart all the best in his future endeavours and his retirement. We thought with the departure of Stuart we would take the time and ask Stuart to be our latest Member to complete the Membership Profile page.

The role of Sub-Editor is somewhat over looked at times but plays an important part in the journal's production and behind the scenes work, including the work done by our remaining Sub-Editor Dr Grant Emms who has been working very hard since last year on the Society's new web page - www.acoustics.org.nz. Wyatt and I also wish to acknowledge the work of Grant and take the time here to formally thank him for all his hard work.

This edition has its regular pieces including News, RMANet and Future Events. We also have a variety of papers covering unattended loggers through to design aspects on an indoor theme park and a student paper on noise exposure on a small commuter aircraft. We wish to remind you that paper abstracts are now open for the up and coming ASNZ Biennial Conference and we would encourage all our members to consider not only attending the conference but also consider preparing a paper and sharing their knowledge, it is well worth the effort (see page 36 for more detail).

Lindsay & Wyatt journal@acoustics.org.nz

The world's most powerful acoustic tractor beam could pave the way for levitating humans

A University of Bristol News article comments that acoustic tractor beams used the power of sound to hold particles in mid-air, and unlike magnetic levitation, they can grab most solids, liquids or even small insects and food. For the first time engineers have shown that it is possible to stably trap objects larger than the wavelength of sound in an acoustic tractor beam. This discovery opens the door to the manipulation of drug capsules or micro-surgical implements within the human body. Container-less transportation of delicate larger samples is now also a possibility and who knows, this could be a step towards levitating humans.

Researchers previously thought that acoustic tractor beams were fundamentally limited to levitating small objects as all the previous attempts to trap particles larger than the wavelength had been unstable, with objects spinning uncontrollably. This is because the rotating sound field transfers some of its spinning motion to the objects causing them to orbit faster and faster until they are ejected. The new approach, published in Physical Review Letters (Wednesday 24 January, 2018), uses rapidly fluctuating acoustic vortices, which are similar to tornadoes of sound, made of a twister-like structure with loud sound surrounding a silent core. Researchers discovered that the rate of rotation can be finely controlled by rapidly changing the twisting direction of the vortices, this stabilises the tractor beam. They were then able to increase the size of the silent core allowing it to hold larger objects. Working with 40 kHz ultrasonic waves, the researchers held a two-centimetre polystyrene sphere in the tractor beam. This sphere measures over two acoustic wavelengths in size and is the largest yet trapped in a tractor beam. The research suggests that, in the future much larger objects could be levitated in this way.

Journal Feedback and Comments

If you have any feedback on what you would like to see in future issues or even things you don't like to see, please share with us via email to journal@acoustics.org.nz, we would like to hear from you! All comments and feedback are treated as confidential by the Editors.

The Acoustical Society of New Zealand

www.acoustics.org.nz

The ASNZ webpage contains a host of information including information on Membership, Journal Information and Journal Articles, Continuing Professional Development, Cafe and Restaurant Acoustic Index, Standards Committees and Standards, the Latest News and Discussion and Contact details of the Society.

Why not visit for yourself?

World Hearing Day 2018

World Hearing Day

The World Health Organization (WHO) 'World Hearing Day' was held on 3rd March this year to raise awareness on how to prevent deafness and hearing loss and promote ear and hearing care across the world. Each year, WHO decides the theme and develops a brochure on the topic based on the best available evidence as well as advocacy materials such as posters, banners, infographics and presentations, among others. These materials are shared with partners in government and civil society around the world as well as WHO colleagues across the Organization. At its headquarters in Geneva, WHO organizes an annual World Hearing Day seminar. In recent years, an increasing number of Member States and other partner agencies have joined World Hearing Day by hosting a range of activities and events in their countries. WHO invites all stakeholders to join this global initiative. For More information see www.who.int/pbd/deafness/world-hearing-day/en

...Continued on Page 10

Pro-active use of unattended loggers for noise and vibration monitoring

[1]Neil Jepsen

[1]Jepsen Acoustics & Electronics Ltd. 22 Domain Street. Palmerston North
www.noiseandweather.co.nz

Abstract

A network of 50 remote noise monitoring stations has been developed New Zealand wide capable of measuring and reporting 1-second L_{Aeq}, $L_{A50(15min)}$, $L_{A90(15min)}$, $L_{A95(15min)}$, L_{AFmax}, L_{AFmin}, one-third octave band data and audio recording in real time to a web server. Fifty SMS commands allow such things as remote calibration, remote configuration and diagnostics from a cellphone. This paper describes a recent application of an unattended noise logger and vibration analyser as an adjunct to hand held monitoring at a bridge building project. Some of the technical advantages of remote monitoring are described, and some technical detail of the equipment used is included.

Original peer-reviewed paper

1. Introduction

In December 2017, the author was tasked with managing noise and vibration emissions from construction of a new bridge across the Manawatu River in Palmerston North City. The site is approximately 70 m from the nearest dwellings. Of major concern was noise from driving of three piles, one of which was 78 m from dwellings in Dittmer Drive and from earthworks during the construction of the bridge abutment on the city side of the river. Construction started in January 2018, with consented noise levels aligned with the construction standard NZS 6803:1999, and vibration limits of 1 ppv (Peak Particle Velocity) at the dwellings. The project is expected to take 18 months, so will not be completed until late 2019.

An extensive noise management plan was developed, which included noise and vibration predictions from the various phases of construction.

2. Equipment employed

In order to more accurately manage noise and vibration and to supplement hand held measurements, a permanent Jepsen noise logger and an RDL-vibe[1] vibration logger were deployed.

The Jepsen noise logger can be mains or solar powered and continuously records 15-minute L_{Aeq}, L_{A10}, L_{A90}, L_{Amin} (L_{AFmin}), L_{Amax} (L_{AFmax}) and 1-second L_{Aeq}. In addition, audio recordings are made whenever the audio level exceeds a preset L_{Amax}, a time trigger, or whenever manually triggered by SMS.

The noise logger was placed on the boundary of a dwelling at 22 Ruhar Street using a heated Norsonic Nor1216 microphone fitted with a wind screen at 2.5 m above ground level. The microphone was in direct line of sight with all bridge piling sites and the city side abutment site works.

Vibration was also monitored continuously (24 hours per day), using the RDL-vibe online vibration analyser (See figure 1). This logger utilizes a 3-axis geophone that can be programmed to sample for alarm purposes at a rate of 10 Hz – 500 Hz. Results of 500 Hz sampling are presented as ppv against time for each axis. The 3-axis geophone was placed in a level position on a concrete pad that was part of the building foundation at ground level, with a 10 kg lead shot bag laid over the geophone, on the side of the building foundation facing the vibration source, in accordance with DIN 4150-3, part 5.4.

Figure 1: RDL – Vibe 3 axis geophone

The construction company communicate the daily work schedule with the author, and manual triggering by SMS is used whenever new works are started, so that representative records of what new sounds are being generated are obtained. These recordings can later be compared with recorded noise levels and used to proactively manage future work and the handling of any noise complaints. For example, it was recently discovered that a subcontractor's trucks were still using tonal reversing beepers. This was missed by hand-held monitoring to date but picked up on a logger recording.

3. Noise Analysis

The bridge construction started in January 2018 and the noise logger was deployed in time to capture noise generated by the vibro-piling of the closest pile to the dwellings. Noise levels from the piles located in the river, and on the east bank of the river are at a greater distance from the dwellings and predictions that these sites would not generate significant noise levels were confirmed by hand held measurements.

Piling was carried out using an ICE 600RF power pack and ICE 55NF vibro-hammer (See figure 2). Preliminary calculations of predicted noise levels at the nearest dwellings suggested that levels up to 72 dB $L_{Aeq(15min)}$ were likely from the vibro-piling and associated machinery.

Figure 2: ICE 55NF vibro-piling rig

Figure 3 is the daily noise record when vibropiling took place. The gradual rise in 15-minute L_{Aeq} and L_{A10} at 6-am to 8-am is due to an increase in local traffic. The two peaks at 9-am and again at 12-pm are uncharacteristic of a daily plot in the absence of piling, and examination of the 1-second L_{Aeq} plot (figure 4) confirmed that piling was taking place.

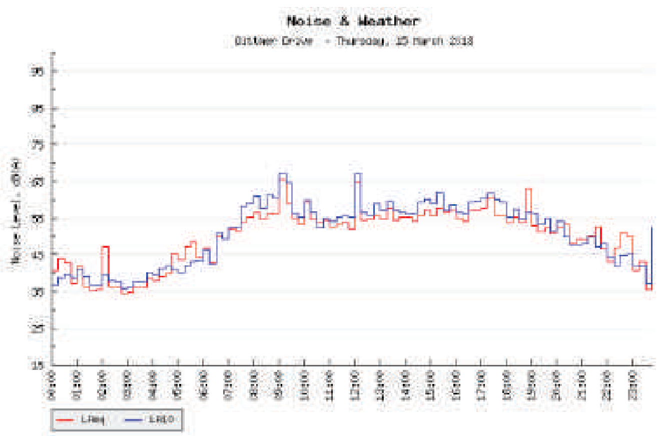


Figure 3: 15-minute L_{Aeq} and L_{A10}

Vibro-piling was very easily identified from the 1-second L_{Aeq} plots (figures 4 and 5) - much more so than from the 15-minute L_{Aeq} and L_{A10} graphs of figure 3.

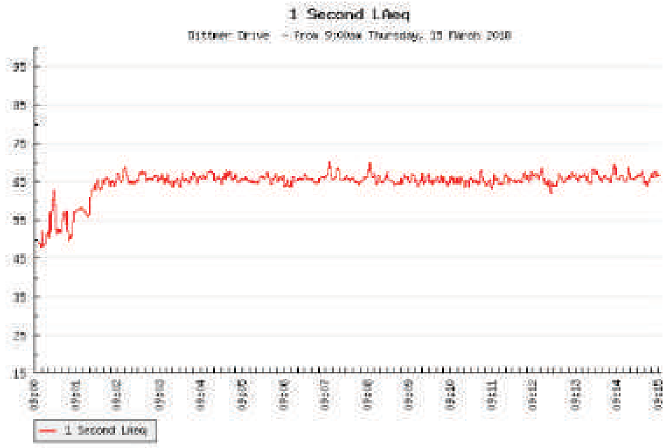


Figure 4: 1-second L_{Aeq} record for a 15-minute period

The small noise peak in figure 4 prior to 09:01 is from a passing car; the vibro-piling began at 09:01 with a noise level of 66 dB L_{Aeq}, and produced a characteristic step in noise level at the microphone. Vibro-piling took place again at 12-pm, seen in figure 5.

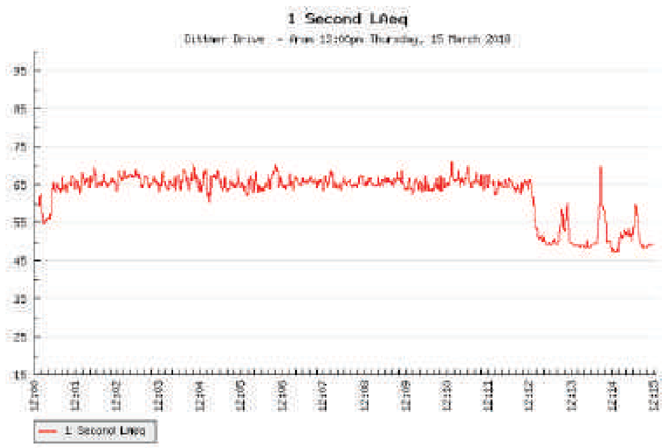


Figure 5: 1-second L_{Aeq} - Vibro-piling starts at 12:00 and finishes at 12.12 pm. Peaks at 12:12 – 12:15 are passing vehicles.

Consented noise levels, in line with the construction standard, are 70 dB $L_{Aeq(15min)}$ and the lower measured result of < 65 dB will give confidence to predictions of other works to come and allow mitigation to be proactive.

4. Vibration Analysis

The consented vibration levels for the project are 1 mm/s ppv in occupied 'Category A' dwellings during the hours of 0730–2000 in accordance with DIN 4150-3:1999. This standard is more appropriate to vibration analysis with respect to building damage, rather than health and annoyance. The standard considers the absolute maximum value of the velocity signals in any one of three directions, and is not the vector sum or root mean square, referenced in the NZTA vibration guide [2].

Vibration was sampled continuously during the vibratory piling process at 500 Hz, and piling was easily identified from the mm/s graph for that day, shown in Figure 6.

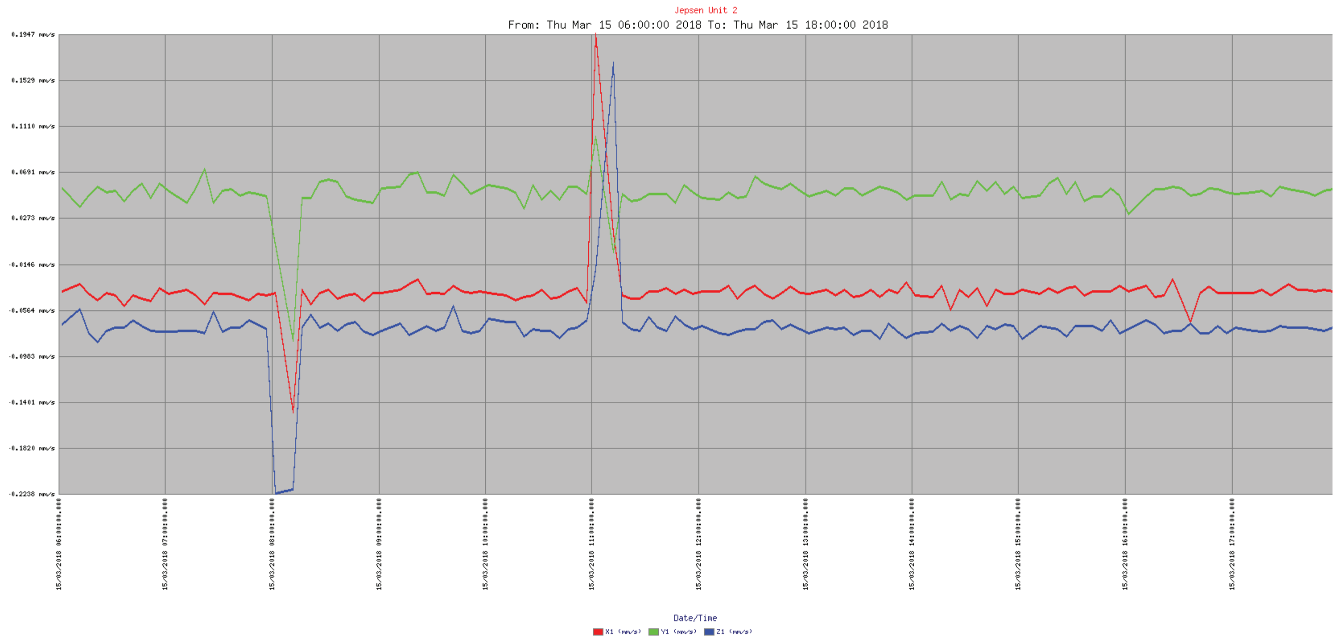


Figure 6: ppv in mm/s for three axes - March 15, 2018. (Time axis does not include DST)

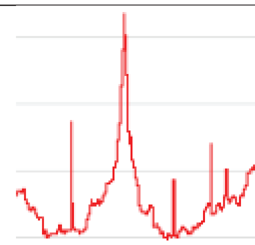
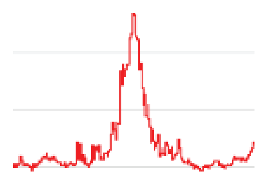
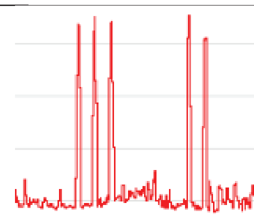
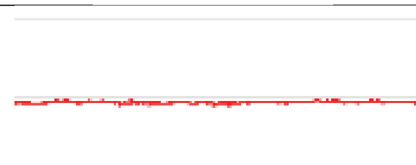
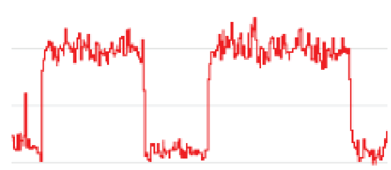
Interestingly, the magnitude of both events was similar, reaching 0.2 mm/s in the morning event and 0.195 mm/s in the midday event[1], but with a phase reversal between events. It is possible that the vibration frequency or the depth of the pile, and therefore the soil structure was different between the am and the pm event. The length of the driven pile was also different between events, because at the end of the first event, which is usually terminated because of increased soil resistance, a clam shell is used to remove stone and sand from within the pile, before the next vibration cycle, and the next pile extension is welded in place. Hence the damping, resonant frequency of the pile, and soil resistance can vary markedly between vibration cycles. Assuming that most of the energy from the piling process is carried by spherical Raleigh waves, at speeds of 50–300 m/s in soil, at the frequency of the vibrating hammer (1700 Hz) the wavelength ($\lambda = v/f$) could vary from 30 mm – 200 mm, which may explain the phase reversal at the geophone.

5. Audio Recording

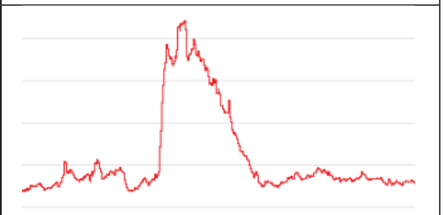
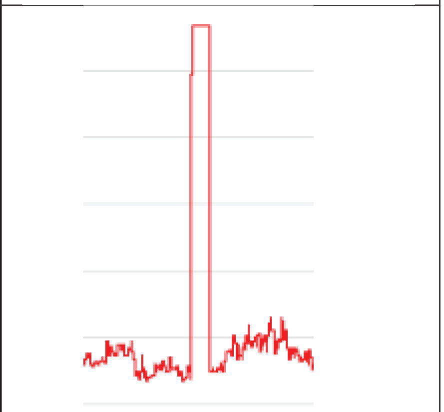
Remote noise monitoring without boots on the ground, or audio recording will only provide noise levels, with no real evidence as to the identity of the source. Common noise sources can with experience be easily identified from the 1-second L_{Aeq} traces (See Table 1).

However, the ultimate is being able to listen to good audio recordings of noise events as well as see the graph. To this end - a huge amount of effort has gone into developing a system where logger noise events can be recorded, and the audio uploaded as MP3 and FLAC (Free Lossless Audio Codec) files to the server. This work has taken several years to develop, and we can now automatically generate noise recordings of virtually any length from 10 seconds to several minutes that are triggered by - date and time,

Table 1: 1-second L_{Aeq} tracings of noise events

Passing car	
Aircraft passing overhead	
Bird sound	
Midnight ambient in the country	
Human made noise	

1 The apparent 1-hr time discrepancy between noise and vibration graphs is due to the fact that the Jepsen noise logger takes care of DST but the RDL-vibe does not.

Pile driving	
Passing train	
92 dB remote calibration	

time of day, noise level (L_{pA}, $L_{Aeq(15min)}$, $L_{A10(15min)}$, $L_{A95(15min)}$, L_{Amax}), rainfall, IR beam, or by SMS. The length of the recordings is only limited by the cost of the cellular data, and the time it takes to listen to these recordings. Happily, recordings each of 5 minutes or so are now significantly less in cost compared to 5 years ago.

At Dittmer Drive, the consented noise level at the dwellings ranges from 55 dB (6.30 – 7.30 am) to 70 dB L_{Aeq} during the day. The noise logger was set to record for 30 seconds every time noise at the microphone exceeded 70 dB L_{pA} (SPL). This setting resulted in many, many recordings of passing cars, but also captured all vibro-piling events and is capturing, at the time of writing, most of the other construction noise. This allows accurate identification of captured noise events and the ability to quantify the noise levels and determine compliance with consented levels on a day by day basis, without huge amounts of time on site. Regular hand-held measurements are still undertaken from time to time to support the remote logger findings.

6. How it works

All loggers use the Norsonic Nor140 Class 1 sound level meter, which has an RS232 I/O serial port. This port is used for serial communications with the meter and all of the Lx data is collected and telemetered via this port to the local processor electronics. A cellular modem transfers this data once every 15 minutes[2] to the server (www.noiseandweather.co.nz); the cellular connection also facilitates 50 text (SMS) remote control commands and interrogation features as required.

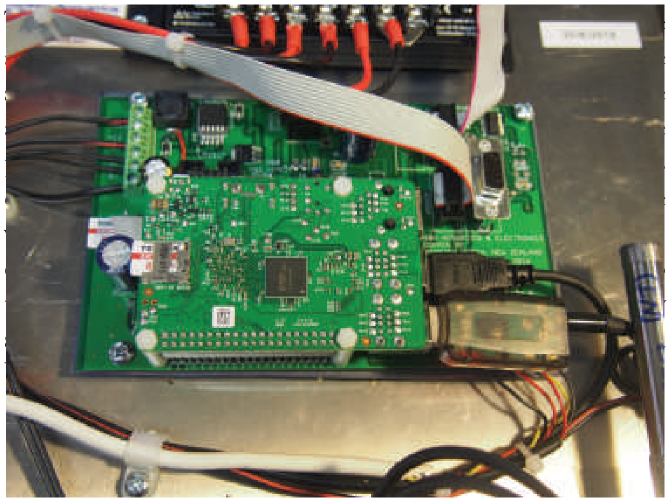


Figure 7: The processor electronics

7. Remote Calibration

From time-to-time, a 'calibration' SMS sent to the remote logger will trigger the Norsonic 'mic cal' source, which injects a calibrated 90 dB signal into the microphone preamp.

8. Sample Recordings

Samples of the noise sources shown in Table 1 can be listened to on line at www.noiseandweather.com\sample. The quality and clarity of NZ native bird song captured during the night at some locations is a pleasure to listen to. Other recordings of aircraft, passing cars, container handling at ports, pile driving, and others are also included.

Figure 8: Photograph taken seconds after a 93 dB L_{Amax} trigger event on June 26 at 10:59 am.

9. Future Work

Dropping of containers at a port is a source of continued annoyance; identifying which container was dropped when, by which straddle loader and how loud was required at a NZ port; this prompted the inclusion of cameras at various sites. An image (see figure 8) is now taken when a noise event is triggered, an email is sent, and the image is date-time stamped, with the L_{Amax} as part of the header. This work is ongoing.

References

1. RDL-vibe remote battery-operated vibration monitoring system, with on-line access. Mfd by Caption Data, www.captiondata.com
2. State highway construction and maintenance noise and vibration guide. www.nzta.govt.nz/assets/resources/sh-construction-maintenance-noise/docs/construction-maintenance-noise-vibration-guide.pdf

2 Once every 10 minutes in the case of wind farm remote monitoring.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...Continued from Page 3

A conversation with Dr Stuart McLaren

Location: Massey University, School of Health Sciences

Position: Senior Lecturer in Environmental Health

Research: Education and acoustics, music and music therapy, occupational noise, environmental noise, noise in early education and affects on vulnerable children

Qualifications: RHS Dip Health Inspectors, MSc, PhD

Stuart has years of experience in teaching acoustics and in research. Stuart originally completed his master's degree in chemistry. However, increasingly over the past years Stuart's research became concerned with early learning and acoustic environments, where he completed his PhD in 'Noise in Early Childhood Education Centres'. Stuart also has a passion for music as a means of therapy, as well as being a passionate piano player and musician. Stuart teaches at both undergraduate and postgraduate levels in acoustics in relation to environmental health, building and housing, water and waste treatment and risk management. Stuart may also be well known by many of our readers as one of the Sub-Editors of the Journal. However, June this year Stuart retired, this is a loss to not only Massey University but also New Zealand Acoustics.

1. When did you first become interested in the field of acoustics and why did you chose to do your PhD in this area? *I have always been interested in Acoustics but I must admit it was learnt on a rather ad hoc basis in those earlier years. It was on joining the Wellington Polytechnic which became Massey, I took over the teaching of that paper and then it was handed over to Associate Professor Philip Dickinson who joined as a part time staff member. It was then I learnt that noise was an issue in early education and that no one was investigating. I further learnt in a special UK programme for parents of young children with autism that noise was a serious issue for them and yet little was known about it. That was a very good reason to undertake the study.*
2. What accomplishment are you most proud of in your professional career? *As part of my PhD I was asked to advise the Ministry on noise provisions for the revision of the early childhood legislation and it was a rare opportunity to influence the law. My recommendations were accepted in full and became of the licensing criteria which underpinned the new set of regulations. I had given children like my son who cannot speak for themselves a voice.*
3. In your opinion, what do you think is the most important acoustic metric and why? *No one in particular. All metrics serve a purpose but I am more concerned about the correct metric being competently used and that the current standards and best practice are used.*
4. Who has inspired you in your life and why? *Many people - those who I have been educated by and those who I have worked with have all set the example to follow.*
5. How do you measure or evaluate success in your teaching role? *By the success of my students. I gained a lot of satisfaction from marking excellent work of my students and seeing how far they had come. I was also affected negatively by those who despite all the help and effort just failed to perform. I never saw marking as low grade work (as it was once described by a former professor). I think it was insulting to the competent and diligent students who make so much effort. That being said I have one regret where I felt I could have done better. Some regulatory authorities will avoid prosecution at all costs because they might lose and in doing so put the public at risk. I failed to impress on students (as happened in the case of the Havelock North water crisis) that they have a duty to protect public health and when it becomes obvious that they are dealing with an operator which is defiant they cannot let it slide or go on after years pleading with them. I was one of the few that had that experience and when confronted by that situation they have to declare that to the authority that they must take enforcement action as they are otherwise failing in their duty to protect public health.*
6. What advice would you give to a student of yours on how to handle criticism? *It would depend on what*

the criticism is. If it is unfair and they know they are right then stand their ground. It never hurts to ask for a second opinion. If it is for negligence or carelessness then they would be well advised to learn from that. There are numerous cases where negligent inspections or evaluations have been conducted in the field by officers and consultants as found in both the Havelock North and Flint (USA) disasters. An Environmental Health Officer some years ago conducted an inspection by "walking past the door". When we conduct field trips there will be those students who don't attend and then disguise the fact by pretending and reporting to have been there. In the real world especially in noise evaluations, it is blatantly negligent and would have serious repercussions if ever in court.

7. Would you rather be liked or respected? *I hope respected by doing the right thing. After a serious clash with the Principal of my son's school who was clearly breaking the law and when we refused we were threatened with his exclusion to which I realised just how vulnerable we were. From that time on I made it a rule that before I preach to my students about breaking the rules then I must obey them myself first and I hope they respected me for that.*
8. What was the last piece of music you listened to? *Music which I have played myself as it has never been recorded. Overture to "Helene and Paris" by Hummel which I hope to bring to life.*
9. What do you like to do when you are not working? *Music-piano and viola, playing in the local orchestra. I also have a lot of maintenance to do around the house.*
10. What was your favourite subject at school and why? *Probably chemistry because the teacher made it interesting.*
11. What do you think some of the biggest challenges are facing the teaching acoustics in New Zealand at tertiary level? *There are not many in the teaching field for environmental health officers and also health and safety officers (occupational noise). They have to go to a much higher technical level than with other scientific work they do, such as water quality where (apart from screening) analysis and some interpretation is done in a registered laboratory. Here the officer has to learn to do everything. Some equipment is not particularly user friendly for students and others have so many software licences. I have given two seminars in Sydney and I was told that Massey is the only university in both countries offering a dedicated advanced undergraduate course in environmental and occupational noise.*
12. Tea or coffee? *Both, but prefer coffee.*
13. If you won the lottery what would you spend the money on? *Never thought about it.*
14. If you could travel anywhere in the world where you have not been before where would you go and why? *I have an interest in Asia and would like to go to South Korea as this is country going ahead in leaps and bounds.*
15. If you could witness any event of the past, present or future what would it be? *Never thought about it.*
16. What are your plans for retirement and what are you going to do all day? *I have some music projects I want to work on such as a concert on musical fantasies where I will hopefully work up fantasies by Bach, Hummel, Kalkbrenner and Beethoven. I am hoping to go overseas for a short period and have lodged an application. I also support and wish to spend time with my severely autistic son while we still can, who has now reached adulthood. He was a significant reason for this choice to retire early so as to give him a quality of life while we are able.*

Good luck with the upcoming retirement!

Equipment for Sale

Hemi-dodecahedron loudspeaker Nor275

1 x Norsonic NOR275 Hemi-Dodecahedron loudspeakers system. L_w = 120 dB for 50 - 5000 Hz.

1 x Nor 280 Class D 500w power amplifier with built-in signal generator with pink, white, red/white noise, complete with radio remote option.

Power Amplifier Nor280

Both units are New Old Stock in original packaging with new warranty. Contact Neil at Jepsen Acoustics and Electronics Ltd. See: www.noiseandweather.co.nz

BRANZ Acoustical design of medium density housing research report now public

The Building Research Association of New Zealand (BRANZ) summary article entitled '*Acoustical Design of Medium-Density Housing: New Zealand Research Summary*' published in the last Journal Vol 31 #1 is now available to

...Continued on Page 36

Noise and vibration design aspects for an indoor theme park

[1] Neil Mackenzie, [1]Bill Dawson and [1]Yong-Keat Lee

[1]Aurecon Pty Ltd, Adelaide, South Australia

Abstract

Doha Oasis theme park is a 25,000 sqm theme park located within a wider mixed use development comprising retail, residential, hotel and four basement carpark levels. The theme park has an elliptic footprint and is enclosed around the perimeter. The theme park is being constructed on a suspended reinforced concrete slab and as such the potential for rides exciting the structure was assessed with regard to both perceptible vibration and structure-borne noise. Airborne noise generated from ride mechanics and patrons was also assessed within the enclosed environment. This paper presents a review of the methods used and the treatment proposed to control noise and vibration within the theme park and from transferring to more sensitive environments adjoining the theme park.

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1. Introduction

Doha Oasis is a 25,000 sqm Theme Experience Centre (TEC) located within a wider mixed-use development (about 130,000 sqm) comprising retail, residential, hotel and four basement carpark levels. The theme park development will provide a vibrant microcosm of themed rides and entertainment attractions located in Doha, Qatar.

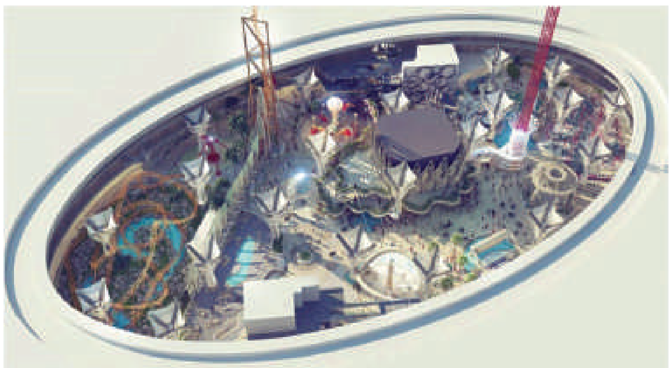


Figure 1: Artistic impression of the development as viewed from above (courtesy Gensler Architects)

The theme park occupies the central area of the podium at ground level and is covered by a steel dome ensuring a clear height of eighteen meters, supporting the landscape garden, and is penetrated by skylights. The theme park also expands well into the peripheral areas of the ground floor level to accommodate a total of twenty six or more different rides and attractions. Other areas of the Doha Oasis development include an extensive retail mall wrapped around the two top floors of the podium with uninterrupted views of the theme park, high end apartment buildings (9 floors), and a 7-star hotel consisting of a twenty eight floor glass tower. Noise and vibration assessment of elements within the theme park to provide an appropriate acoustic environment, along with impact from ride noise and vibration on the adjacent mall and residential structures was of critical importance in the design of the Doha Oasis development.

Figure 2: Artistic impression of the development as viewed from above (courtesy Nabil Golam Architects)

The theme park will house world-class attractions providing the latest in entertainment and themed experiences. The ride types to be implemented within the park include:

- Drop towers: These rides consist of a large central tower with ride occupants on a carriage which travels up and down the central tower. For the Doha Oasis theme park, these towers extend up past the roof structure, giving riders a birds-eye view of the gardens and luxury residential complex above the theme park.
- Rotating / rolling types: One or more passenger carriages which roll, rotate and spin around a number of axes.
- Swinging pendulum: A passenger carriage at the base of a large pendulum which swings about a central pivot point. The carriage can also rotate / spin about its central axes.
- Roller coasters: Roller coasters consist of one or more carriages which travel along a fixed rail path at various velocities / heights.

- Dark rides: Dark rides are themed attractions located within enclosed sections of the park to provide a secluded / stand-alone ride experience, involving a combination of hydraulically operated seats and an audio-visual experience. Some rides also feature a "4D" component where elements such as water mist or fan-forced air is directed at the ride occupants to coincide with the audio-visual component.

2. Previous work and key design issues

Preliminary concept design for the theme park was undertaken based on a review of previous theme park designs and installations, which were used to inform the design and expected acoustic performance requirements for the new Doha Oasis development. Measurements reported by Kaiser and Rohde (2013) summarised below in Figure 3 for an open air theme park show similar average noise levels between 65-85 dB L_{Aeq} (with an average of approximately 75 dB) are possible with appropriate treatment. The key difference between noise measurements undertaken in the open air theme park compared to Doha Oasis are that impact from reverberant noise build-up had only a minimal impact (distinct from the enclosed Doha Oasis theme park, where control of reverberation will be more crucial).

Figure 3: Summary of noise levels at Universal's Islands of Adventure park (Kaiser and Rohde, 2013)

Sound level data in Menge, C W (1999) '*Noise from amusement park attractions: Sound level data and abatement strategies*' which includes noise measurements of roller coaster events at 15 metres, free-fall events at 15 metres, water ride events at 15 metres, and coaster screaming at 15 metres were also referenced for the preliminary acoustic modelling (and later comparison against the benchmarking survey). Figure 4 shows a time history of noise levels within the theme park, in a ride's "pre-show" area, and on the ride, with an average noise level of typically 85 dB L_{Aeq} close to the ride, and maximum noise levels of up to 100 dB experienced by patrons on the ride.

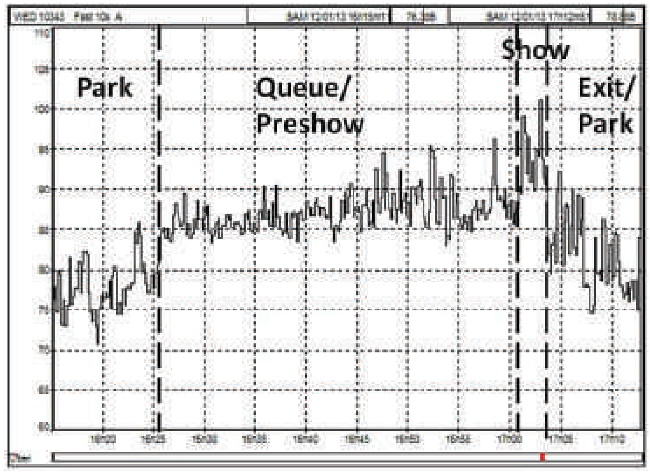


Figure 4: Time trace of a ride including "pre-show" queue and on the ride (Kaiser & Rohde, 2013)

It is considered that a percentile level is more representative of maximum noise levels relative to average noise levels given varying distances from rides, patrons, audio, etc.

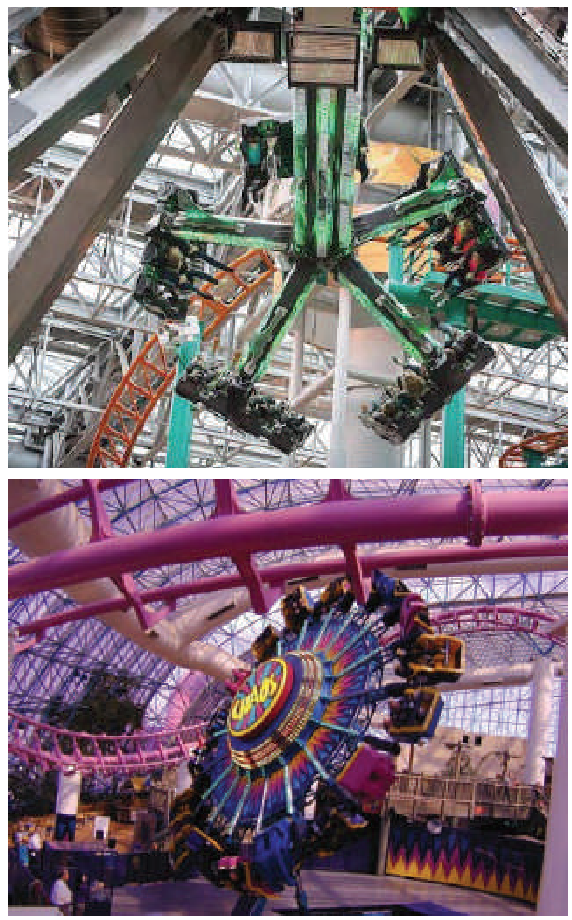


Figure 5: Typical examples of roller coaster (orange/pink tracks on Top/Bottom image), swinging (Monster Mash at Mall of America– Top) and rotating rides (Chaos at Adventure-Dome-Left)

It was therefore considered that a difference of 15 dB between the maximum noise level (L_{Amax}) and continuous equivalent level (L_{Aeq}) be allowed for in the design of sound insulation measures. Further details on L_{Amax} and L_{Aeq} differences are discussed in the following benchmarking survey sections.

Typical enclosed theme and amusement parks include Mall of the Emirates (UAE), Adventure-Dome (Las Vegas, Nevada, USA), Mall of America (Bloomington, Minneapolis, USA) and Galaxy-Land (West Edmonton Mall, Alberta, Canada). Noise levels within enclosed theme parks will depend upon the proximity of patrons to rides (to control direct sound pressure levels), and the volume and finishes within the theme park (to control reverberant noise build-up).

Based on the literature review, the key design considerations for the Doha Oasis project were ensuring an appropriate acoustic environment within the theme park, and control of noise and vibration into the sensitive retail mall and residential/hotel components of the mixed-use development. These design issues were investigated using a combination of benchmarking surveys and noise and vibration modelling to determine appropriate treatment and control methods for all areas.

3. Sources of noise and vibration

Undertaking a vibro-acoustic assessment of the theme park development required a detailed understanding of all noise and vibration sources within the theme park (including individual ride types, specifications and configurations):

- Noise and vibration from rides such as wheel / rail noise interactions, hydraulics, structure-borne regenerated noise from supports, walls, ceilings and other building elements, and screams / yelling from people on the rides. Noise from the rides will also depend on the ride cycle times including passenger loading/unloading times and ride duration, the total number of ride occupants (and the percentage of people screaming).
- Noise from operation of mechanical services plant including duct-borne noise, breakout noise, noise from plant rooms, and casing radiated noise from units.
- Background and theme music played through dedicated speakers as part of the themed rides, in queuing areas, in eating / dining spaces, and in the dark rides (as part of the audio-visual experience).

The primary noise sources throughout the theme park will be noise from rides and associated screaming/yelling, which will generally be dominant over operation of the mechanical services / HVAC systems, and in any areas without music being played.

4. Performance criteria

Noise and vibration design targets were developed based on a combination of ASHRAE and ANSI (noise due to operation of building services plant and equipment), the World Health Organisation (WHO) guidelines for noise in dwellings (for residential components) and public spaces (also referencing the limits reported by Thorburn (1992) for Mall of America), and the ISO 10137 vibration curves. Table 1 presents a summary of the noise and vibration design criteria deemed appropriate for the Doha Oasis project.

Table 1: Summary of noise and vibration criteria for the Doha Oasis theme park

Design element	Theme park noise limit dB L_{Aeq}	Building services noise limit dB L_{Aeq}	Vibration response factor
Theme park open areas	75-80	45-50	8
Theme park food and beverage spaces	70-75	40-45	8
Theme park retail areas	50-55	40-45	8
Theme park offices	40-45	35-40	8
Adjacent retail mall	35-40		8
Hotel residential areas	30		VC-A

5. Benchmarking

To confirm noise sources, appropriate design targets, and determine practical noise and vibration control treatment for an enclosed theme park environment, Aurecon undertook a detailed acoustic survey of several USA theme parks and rides including Adventure-Dome (Las Vegas, Nevada) and Nickelodeon Universe (Mall of America, Minneapolis). Key findings and observations from the benchmarking survey are detailed in the following sections.

5.1 Screaming and Ride Noise Observations

The primary noise sources throughout the theme park will be noise from rides and associated screaming yelling, which will generally be dominant over operation of the mechanical services / HVAC systems, and in any areas without music being played. Control of noise from rides and screaming within the Doha Oasis theme park will therefore be vital in ensuring an appropriate acoustic environment and promoting an enjoyable experience for all patrons.

- The Adventure-Dome consists of a glass dome with limited acoustic absorption to any of the internal surfaces. The ride supports are also fixed directly to the raised concrete slab, and the ride guides appear to be primarily hollow steel channels. The highly reverberant environment combined with increased radiated noise from the hollow steel channels (and potentially re-radiated structure-borne noise from the slab) combine to produce a very noisy environment which was considered unpleasant and borderline distressing, with continuous noise levels of 80 to 85 dB L_{Aeq} measured throughout the park. These noise levels made communication difficult (raised voices / straining to hear).

- Nickelodeon Universe (Mall of America) has a significant portion of the upper perimeter walls covered with acoustic absorption (a spray-on adhesive insulation product), and appears to have all ride rail and guides filled solid to control re-radiated noise. These acoustic treatments combine to provide a much more pleasant acoustic environment within the theme park with an overall noise level of approximately 75 to 80 dB L_{Aeq} in worst-case locations, and a lower level of 70 to 75 dB within the food and beverage spaces which were setback from the rides. It is noted that Nickelodeon Universe did not feature any noticeable or significant noise barriers or baffles to directly shield noise from the rides (or otherwise block direct line-of-sight to the rides), and instead relied upon acoustic absorption and source treatment of the ride guides to control overall noise levels and reverberant noise build-up.
- The difference between measured average continuous equivalent noise levels (L_{Aeq}) and maximum intermittent noise levels (L_{Amax}) was greatest at locations closest to the rides, with the difference much smaller at locations further from the rides (in general public / food and beverage spaces). It is noted that the L_{Amax} noise levels on the Adventure-Dome rollercoasters (El Loco and Canyon Blaster) were greater than those at Nickelodeon Universe (Orange Streak and Rock Bottom Plunge) by at least 10 dB, which is likely due to rumbling / rattling of the unfilled ride guides (and potentially structure-borne radiated noise from the suspended slab of the Adventure-Dome).
- Screaming noise was most noticeable from the rollercoasters and the drop-tower type rides, with significantly reduced screaming / yelling from the rolling and rotating type rides. Screaming noise generally occurred during fast accelerations / drops / roller coaster loops, and is dependent upon the number of ride passengers (as well as age demographic). Generally the screaming was of short duration and while it was noticeable, it was not overly intrusive in the public areas, particularly at Nickelodeon Universe where a combination of general public noise / conversations and music masked a lot of the ride noise and screaming.

5.1 Rail ride design observations

Based on the benchmarking noise survey and site inspection, the following key ride design differences between the Adventure-Dome and Nickelodeon Universe were identified:

- Ride guides / rails at the Adventure-Dome were hollow, whereas at Nickelodeon Universe they were core-filled to provide a more highly-damped structure. The addition of dampening material to the ride guides (such as sand / foam / pellets) resulted in significantly

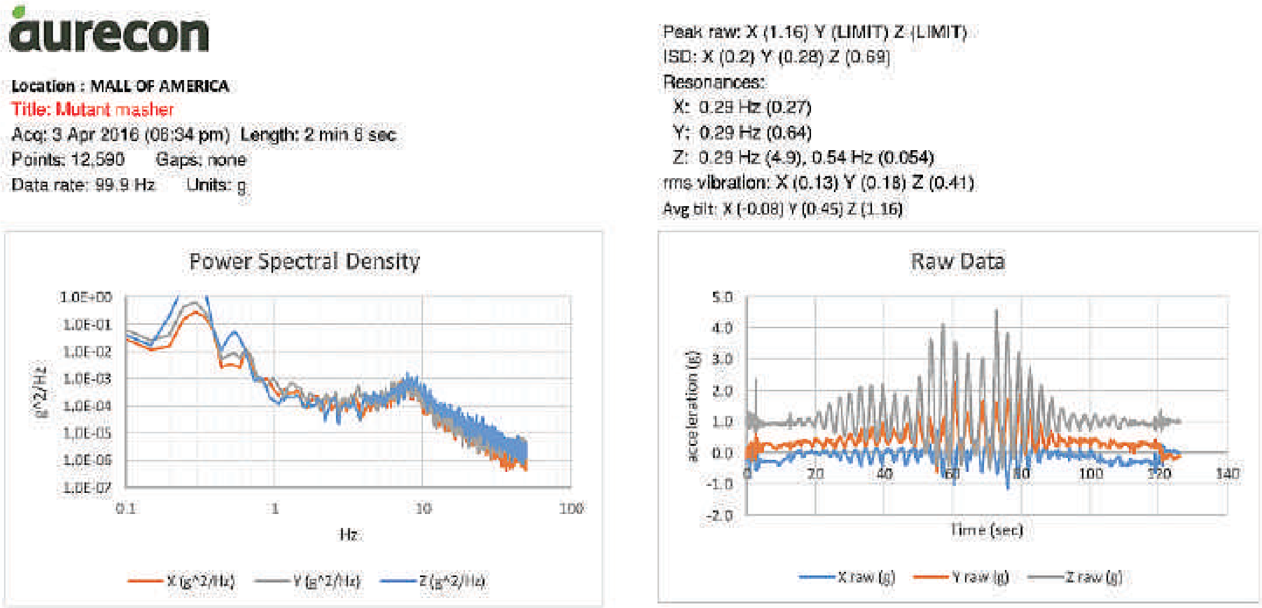


Figure 6: Results of vibration monitoring using the VibSensor App (on the "Mutant Masher" ride - Figure 5)

reduced maximum noise levels due to less rattling / shacking, and reduced structure-borne noise re-radiated from the rails.

- Rides at the Adventure-Dome were directly fixed to the suspended slab resulting in low-frequency reradiated 'rumbling' noise audible within the space. The Nickelodeon Universe rides were mounted on significant plinths / inertia bases with the main slab on grade which assisted in reducing any structure-borne noise.

The above points highlight the importance of the ride guide design (ie filling the guides with sand / foam), and proper vibration support, isolation and damping.

5.3 Vibration measurements

The VibSensor (version 1.3.3) iPhone App developed by Now Instruments and Software, Inc (2015) was used to undertake vibration benchmarking analysis of rides, ride supports and floor slabs throughout each of the theme parks. The VibSensor App uses the iPhone's in-built accelerometers to measure and log acceleration in three-directions, and is able to output Power Spectral Density (PSD) graphs and time-history data (as shown in Figure 6). The App and accelerometer were calibrated using a SoundBook MK2 fitted with a 100 mV/g accelerometer to ensure accuracy of the result.

Based on the vibration survey data acquired using the VibSensor App, the dynamic loads of each ride were measured along with accelerations on the various support and slab arrangements (eg the suspended slab of the Adventure-Dome). Each measurement captured detailed frequency data which was invaluable in calibrating the vibration and structure-borne noise finite element model, and determining vibration isolation and damping requirements for the Doha Oasis theme park.

5.4 Noise measurements

Noise measurements were undertaken using the SoundMeter (version 8.3) iPhone App developed by Faber Acoustical, LLC, utilising an external condenser microphone which was calibrated using an external calibrator. This arrangement allowed for on-ride noise measurements to be undertaken including third-octave band analysis and waterfall plots to be generated (as shown in Figure 8), including calculation of ride sound power levels, without relying on bulky hand-held instruments and mitigating the risk of damaged or dangerous equipment in the ride environment.

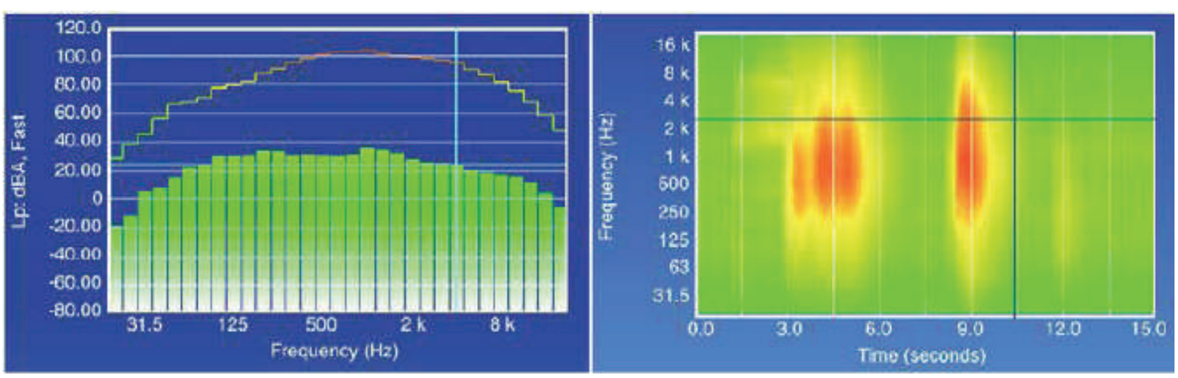
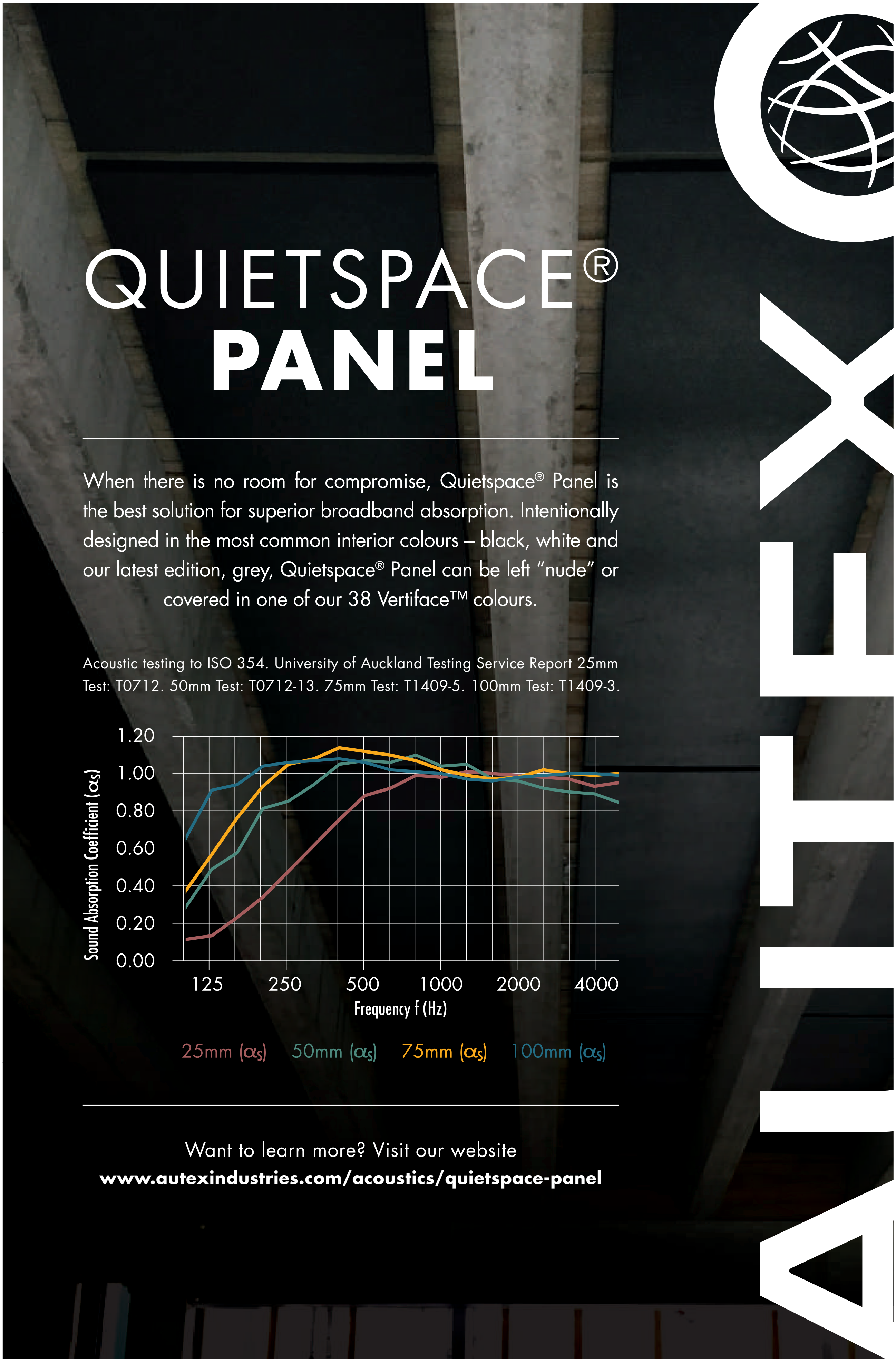


Figure 7: Results of noise measurement using the SoundMeter app (on the pink track rollercoaster - Figure 5)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PANEL
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Acoustic testing to ISO 354. University of Auckland Testing Service Report 25mm Test: T0712. 50mm Test: T0712-13. 75mm Test: T1409-5. 100mm Test: T1409-3.
Sound Absorption Coefficient (αs)
1.20
1.00
0.80
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0.40
0.20
0.00
125
250
500
1000
2000
4000
Frequency f (Hz)
25mm (αs)
50mm (αs)
75mm (αs)
100mm (αs)
Want to learn more? Visit our website
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6 Modelling

To assess the acoustic conditions within the Doha Oasis theme park including noise levels at food and beverage seating areas, noise mapping at various levels within the park, noise impact on the theme park envelope walls (including impact on the adjacent areas such as the retail mall), and vibration impact from the rides, a combination of room acoustics modelling and vibration analysis was undertaken as described in the following sections.

6.1 Airborne noise

To assess airborne noise throughout the theme park an acoustic model of the theme park including noise sources such as rides, screaming and EWIS speakers was developed using the EASE (Enhanced Acoustic Simulator for Engineers) software suite with an example of the noise mapping output shown in Figure 8. Based on the noise source data from the literature review and benchmarking survey, an inventory of all noise sources was developed. For each noise source a continuous equivalent noise level was calculated (taking into account intermittent screaming for the rides), and for the large rides which traverse a significant area (eg. the roller coasters), the noise source was distributed evenly over the expected path to account for the instantaneous change in noise source location.

A number of acoustic absorptive treatment options were implemented within the model to assess the sensitivity of overall noise levels within the park to the extent of treatment (including insulation to the underside of the ceiling, combined with various baffles, screens and walls). Based on the modelling it was determined that a fully acoustically absorptive ceiling (NRC 1.0) would reduce noise levels by between 3 to 6 dB L_{Aeq} compared to an acoustically reflective ceiling, depending upon proximity to the rides and other noise sources.

Modelling indicated that further reductions in reverberant noise level of approximately 3 dB L_{Aeq} can be achieved through strategic implementation of acoustic absorptive baffles and screens localised around sensitive dining and respite areas.

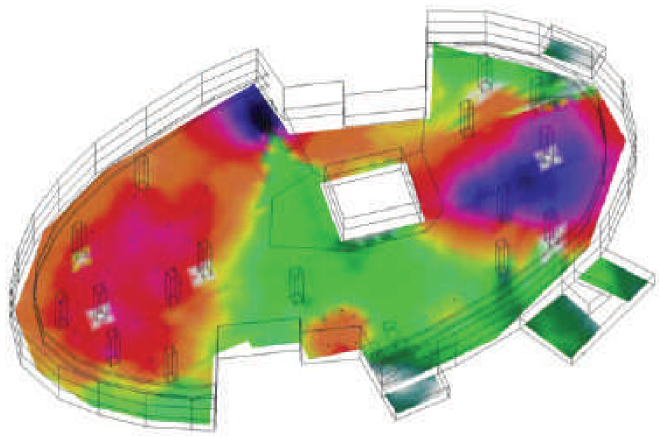

Figure 8: Noise mapping of the Doha Oasis theme park using EASE software

6.2 Vibration and structrue-borne noise

The 3D finite element model was built using Strand7 Finite Element Analysis (FEA) software. The structure includes a section of the retail mall and residential tower, and a section of the carpark basement, as shown in Figure 9 below. The structure consists typically of a base building slab, 600 mm thick generally with edge thickening to 1,200 mm thick and an edge beam 1,000 mm deep interfacing with a perimeter slab nominally 350 mm thick. Ride foundations up to 1,500 mm thick are located directly on the base building slab, with sand surrounding the ride foundations which is constrained beneath a floating concrete slab, providing significant damping.

Dynamic loads (in terms of linear transient or harmonic) for each ride were provided by ride suppliers, calculated from kinematic equations of motion and calibrated/ verified with measurements during the benchmarking exercise. Vibration time histories and spectra were obtained from the finite element model and compared with the design criteria to assess compliance and determine appropriate mitigation measures (damping, isolation, structural modification).

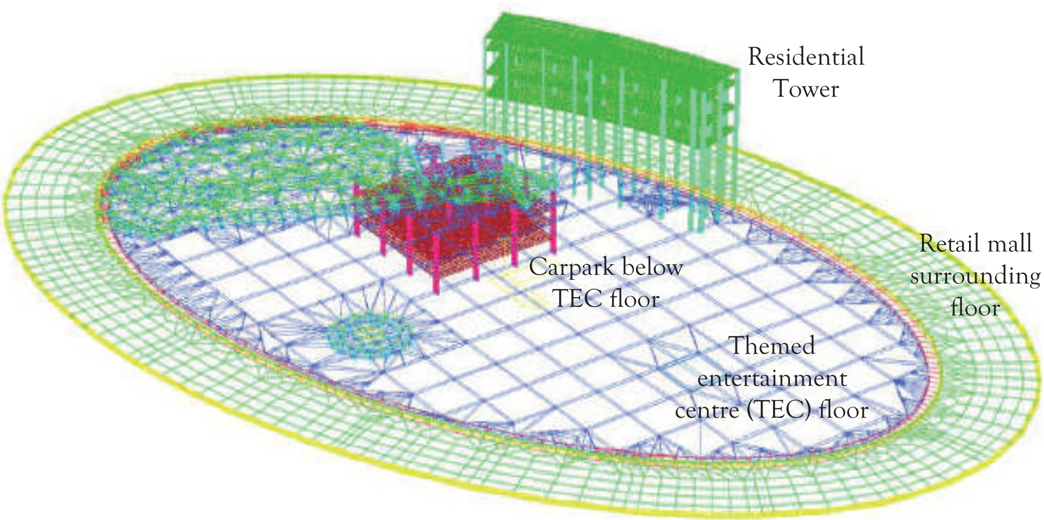

Figure 9: 3D finite element model of showing the components of the development

7 Design Recommendations

7.1 Airborne noise

There are numerous noise producers within the enclosed theme park (including the guests themselves) and for the majority of these it is not possible or practical to control such noise at source, particularly when screaming is an integral part of the guest experience for many visitors. As such, it is important to introduce acoustically-absorptive materials to control the reverberation and build-up of such noise sources.

- Roof soffit: The underside of the roof structure has been identified as the primary location of such treatment. This treatment may be located directly on the underside of the roof or alternatively at the underside of the roof trusses, consisting of 50 mm thick fiberglass batt panels with a suitable facing (most cost effective is a black woven fibreglass cloth) that does not degrade the acoustical properties of the fiberglass. Ideally the insulation should be offset from the roof soffit by 50 mm by way of battens or similar to enhance sound absorption at low frequencies. It is noted that dynamic LED video content will played across the theme park ceiling and rear wall over a 70% open area screen (required for air distribution), however this will not affect the performance of the roof soffit sound absorption (due to the large open area making the screen effectively acoustically transparent).
- Column cladding and "*theme*" cladding: To supplement acoustic lining to the roof soffit, a stretched micro-perforated acoustic membrane which will allow dissipation of acoustic energy is proposed for the columns and selected wall areas. This can be back-lit as required to incorporate lighting effects. Alternatively perforated metal cladding with woven (high flow-resistive) fabric backing for individual rides and other attractions should be implemented.
- "*Rock wall*" cladding: Spray-on acoustic plaster which has a degree of porosity and therefore a good level of mid-to-high frequency sound absorption can be implemented to themed rock wall type surfaces to provide additional acoustic absorption (for example, adjacent roller coasters).
- Suspended Baffles: Suspended acoustic baffles or similar are proposed over noise-sensitive patron seating areas.
- Acoustic Ceilings: Ceilings to the underside of the mall balconies will be sound absorptive, either as a standard mineral fibre ceiling tile, perforated plasterboard ceiling, plaster acoustic tile, or as a more decorative finish such as a perforated metal/timber feature ceiling.
- Sound Insulation: Appropriate level of glazing between the TEC and external elements such as the retail mall concourse, roof plaza, retail spaces (including

cinemas) and surrounding residential towers.

7.1.1 Dark rides

Dark rides located within the enclosed areas of the theme park (similar to a cinematic experience) will have an associated loud sound track with typical noise levels noted by Pelton (2000) of up to 100-110 dB L_{Aeq}. The retail mall floor structure will be 300 mm thick post-tensioned concrete, with a sound insulation rating of approximately Rw 60. For general theme park noise this will be sufficient, however for dark rides directly under the floor with high sound levels (including low-frequency characteristics), a resiliently suspended ceiling under the floor is proposed, along with 100 mm black tissue faced fiberglass or similar insulation to at least 50% of the interior surface area to control reverberation.

7.1.2 Public Address and background music

While there will not be individual soundtracks for various rides and themes, there will be background music being played at moderate volume throughout the park. Typically the loudspeakers used for the background music/paging system should be located near to the park visitors, which is acoustically preferred so as to diminish the overall loudspeaker noise level, and thus the reverberant noise level build-up within the park.

7.1.2 Vibration and structure-borne noise

In addition to the acoustic treatment outlined above, it is vital that the ride guide tracks and rails be filled with damping material (sand/pellets/foam) and wheel rims be hard plastic such as nylon or similar to ensure suitable control of airborne noise from the guide tracks. The use of sand surrounding the ride foundations, which is constrained beneath a floating concrete slab, will also be vital as it provides significant damping of transient vibrations radiated from the theme park floor.

8. Conclusions

This paper has outlined the key acoustic issues associated with design of an enclosed theme park to promote a suitable acoustic environment and achieve a balance of excitement from a combination of screaming, yelling, and background music, along with quieter respite areas for dining, conversation and rest. Also considered is the noise and vibration impact (including structure-borne regenerated noise) on adjacent noise-sensitive mall and shopping areas which are separate from the theme park, but share several walls and floor slabs.

Benchmarking of similar existing theme parks was undertaken to determine appropriate internal design sound levels within the park, and identification of noise control measures. These investigations highlighted the differences in subjective perception of two different theme parks, varying from pleasant and 'enlivened' within a well-designed theme park, through to a noisy and unpleasant acoustic environment where only minimal acoustic treatment had been implemented.

Key acoustic design considerations for the theme park were identified including damping of ride rails through implementation of filled-rails (sand or similar), isolation of ride mounts (vibration mounts / plinths), analysis of the theme park slab for vibration response (Finite Element Analysis), strategic placement of acoustic absorption to control reverberant noise build-up, design of sound insulating envelope elements (eg slabs, ceilings, walls, glazing), and appropriate design of theme park music and public address systems.

Acknowledgements

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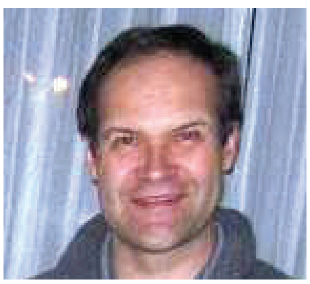

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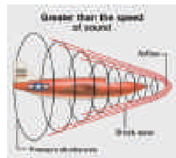
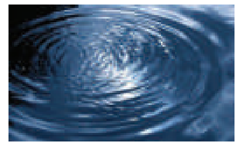
Quiz

5-minute Acoustics Quiz?

See how many questions you can answer correctly in 5 minutes...

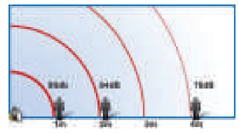


Q1 True or False? Sound requires a medium to propagate?



Q2 True or False? Sound waves in the medium of air are longitudinal waves?

Q3 True or False? The speed of sound in air is the same or approximately the same as in water?

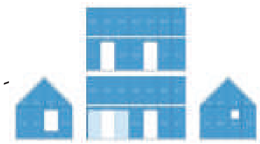


Q4 True or False? The inverse-square law, in acoustics results in a reduction of the sound pressure level by 3 dB with every doubling of the distance in a free field for a point source located at ground level?

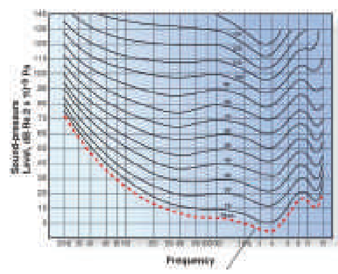
Q5 True or False? Refraction of a sound wave is to bend the sound wave around the edges of objects/ barriers or through holes?

Q6 True or False? The terms anechoic literally means 'without echo'?

Q7 True or False? 'NZS6806' is the New Zealand Standard for 'Airport Noise Management and Land Use Planning'?



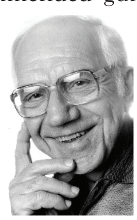
Q8 True or False? The New Zealand Building Code (NZBC) refers to IIC and STC in 'Clause G4 - Sound insulation'?



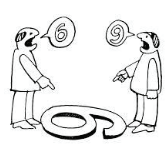
Q9 True or False? The Fletcher Munson curves (a set of equal loudness contours) were created by Bell Labs in the 1930's where researchers where trying to figure our speech intelligibility and how to transmit a phone call economically or the least expensive way thus why the researchers needed to review how people hear and perceive sound?

Q10 True or False? Humans are most sensitive at around 13.5 kHz which is the resonate frequency of the ear canal?

Q11 In what year did the World Health Organization (WHO) published its well-known 'recommended guidelines for protection against noise' in communities?



Q12 In which year did the distinguished Engineer and Acoustician Leo Leroy Beranek pass away?



Q13 What is a 'Phon' a measure of?

Q14 What is meant by the use of the term 'Subjective' in acoustics?

Q15 What is the Weber-Fechner Law'?

Q16 What is meant by the use of the term 'White Finger' in vibration?

See page 39 for answers

We have two Environment Court decisions to bring you this issue. Firstly, concerning a proposal by the Hamilton City Council to stop two roads in Ruakura in order to facilitate the ongoing development of an inland port on land to the south east of Hamilton City, and secondly, an appeal against the grant of consent for a 186 berth marina in Kennedy Point Bay on Waiheke Island.

Following is a summary of these decisions, full copies can be found on the RMA Net website: www.rma.net

In the Environment Court

HAMILTON COUNCIL – Applicant

[2018] NZEnvC 66, 47p, [152] paras, 11 May 2018

Summary of Facts

Hamilton City Council applied to the Environment Court for confirmation of the Council's decision to stop a 700m section of Ruakura Road and a 500m section of Percival Road in Hamilton City subject to certain proposed conditions. Tainui Group Holdings Limited (TGH) supported the decision as the road needed to be stopped to enable it to further develop the Ruakura Inland Port. However, the decision was opposed by the Julians and Goodwins who owned properties at 53a and 23 Ryburn Road respectively, the access to which would be affected by the proposal, including moving a railway crossing point closer to their properties. The proposal also included a new access route to a residential area known as the Percival/Ryburn enclave, which serviced some 30 properties, and linkage, via a new road, with the Waikato Expressway as well as provision for shared paths for walking and cycling.

The main opposition to the proposal was centred around increased distance and travel times for the residents of the Percival/Ryburn enclave with the new travel route, more interactions with heavy vehicles and possible increases in safety issues, increased noise effects arising from the relocation of the rail crossing closer to the residential properties and a break in a landscape buffer due to road realignment.

After considering the evidence the Court was satisfied that the proposal would result in benefits for the residents and wider community in terms of significantly improved infrastructure, increased safety and improved connectivity for walkers and cyclists. In relation to the break in the landscape buffer the Court held that the time for raising issues had passed. The Court acknowledge the distress to the Julians but noted that controls on noise generated by the inland port activities were addressed in the relevant consent application process and consent conditions.

Lastly the Court addressed the objections relating to noise, noting that future noise levels from the Waikato Expressway, the railway and Ryburn Road were uncertain, and outside the control of the Council and TGH. The Court's decision was limited to consideration of any changes in the existing noise environment as a result of the relocation of the rail crossing. The Court considered the effects of the relocation of the crossing arising from both night-time and day-time bell and horn noises, as well as cumulative effects.

The Court acknowledged that there would be effects from the train bells on the residents at the two properties that were not currently experienced, but it did not consider an increase to 45 dB $L_{Aeq(15mins)}$ outside at night to be unreasonable, unusual or unacceptable and would accord with levels recommended in NZS6802. The Court considered any changes in noise effects on both properties during the day would be less, as ambient noise levels would be higher.

In respect to the horn noise, the Court noted that Kiwirail would not use the horn at night unless there was reasonable cause to do so and as such the Court was satisfied that horn noise at night would not result in adverse effects as a result of the crossing relocation. During the day the evidence suggested that horn noise would increase between 5 and 10 dB, but the overall increase would be minimal due to the energy of the train passing which would be dominant. The Court accepted that there would not be an unreasonable increase in horn noise levels overall, nor any change in the overall sound levels associated with train pass-bys that would result in a measurable change in cumulative effects.

Court held:

Court intended to confirm the Council's decision to stop parts of Percival and Ruakura Roads and to impose conditions proposed, subject to certain matters as detailed in the decision being resolved to the Court's satisfaction.

Parties to respond to Court setting out their positions in respect of those matters by 25 May 2018.

In the Environment Court

SKP INCORPORATED, R A WALDEN - Appellants

AUCKLAND COUNCIL - Respondent

KENNEDY POINT BOATHARBOUR LTD - Applicant

[2018] NZEnvC 81, 123p, [296] paras, 30 May 2018

Summary of Facts

Kennedy Port Boatharbour Ltd (KPB) was grant consent to construct, operate and maintain a 186 (maximum) berth marina and associated facilities in Kennedy Point Bay on the south-west coast of Waiheke Island. SKP and Mr Walden appealed the Council decision and sought the application be refused. The bulk of the marina was to be located in the Coastal Mooring Zone, adjacent to the existing car vehicle and freight ferry terminal facilities, and the overall activity status was agreed to be non-complying. The issues of contention related to s 104D "gateway" tests; effects on the environment (positive and negative); matters arising under Part 2 and s 290A RMA and whether a consent was appropriate; proposed and other possible conditions of consent and mitigation.

The Court discussed in detail the location and zoning of the marina, the existing and future environment, and the relevant statutory and planning framework, before assessing both positive and negative effects on the environment. Adverse effects focused around acoustic effects and effects on ecology, in particular on the Little Blue Penguin, effects on the benthic community, potential effects on archaeological sites, cultural effects, effects on navigation and existing moorings and lighting and on effects on natural character, landscape and visual amenity values. The Court also looked at the effects on the future ferry terminal expansion.

In relation to acoustic effects, evidence was presented on both construction noise and noise relating to the operational marina. The evidence showed construction noise from piling would be the greatest, but the Court accepted the proposed Construction Noise Management Plan (CNMP) contained relevant conditions, performance standards and thresholds with methods to ensure those were met. The Court also found that other concerns raised such as halyards slapping mats, noise from berth owners "coming and goings" and noisy parties were adequately addressed by the proposed conditions, marina management plan and a noise management plan.

The noise effects on wildlife, in particular the penguin, were discussed with evidence highlighting that it was not the noise that generally disturbed the penguins, but the associated activity. The Court noted that there currently existed very little problems for the penguins in the current environment, which included the existing ferry terminal. As such the Court accepted that conditions of consent, including during construction, would result in the adverse noise effects being no more than minor.

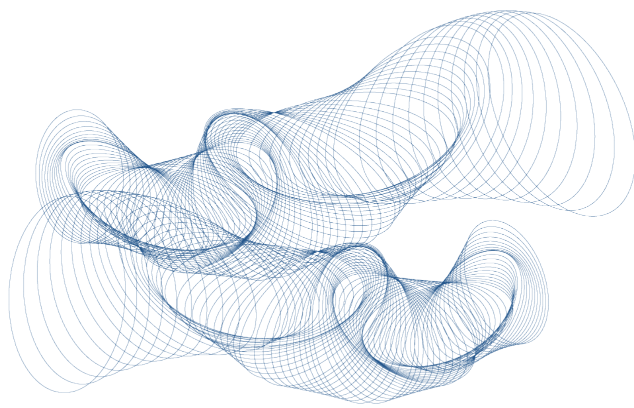
Overall, the Court found that the marina would offer a variety of positive effects for people and communities, in particular providing new access to the coastal marine area for recreational purposes, and also on the physical environment. The proposal was found to adequately serve the higher order and regional policy frameworks and specific regional plan objectives and policies. Therefore, the proposal passed through both gateways in s 104D. With conditions imposed as finally submitted by KPB the Court found that the proposal was suitable for approval through s 194(1) appraisal.

Court held:

Consent granted subject to attached conditions.

Costs reserved

Disclaimer - *This article has been provided to help raise an initial awareness of some recent cases involving acoustic issues. It does not purport to be a full listing of all decisions which have acoustic issues, nor does it replace proper professional advice.*



Evaluation of noise exposure levels in a regional commuter aircraft

[1] Graham Philps and [2] Wyatt Page

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[2] School of Health Sciences, Massey University, Wellington

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Abstract

An occupational noise evaluation was carried out by a Massey University student on passengers and aircrew whilst flying aboard a regional commuter turboprop aircraft. Not all measurements conducted as part of the study showed compliance with the criteria for workplace noise exposure prescribed in Regulation 11 of the Health and Safety in Employment Regulations 1995. The health and safety noise criterion level permit a maximum dose of 100% which is equivalent to 85 dB LAeq for a normalised 8-hour working day. The highest measured sound exposure was 281% of the total permitted exposure. All noise measurements were observed and written accounts were taken by the investigator. The observations were useful in removing any atypical results and reinforced the value of observed real time field monitoring during collection of data. A series of recommendations were made to the airline operator including develop a Company Noise Policy and review the typical daily working hours of all aircrew when flying the subject aircraft.

Original peer-reviewed student paper

About Graham Philps

Age 59, has been a self-employed, independent health & safety and quality management consultant for 5 years. For more than three decades he worked in two highly noise-sensitive industries; aviation – 24 years whilst serving in the Royal Air Force (RAF) – and civil construction. Many of his RAF roles included being responsible for the health & safety of others and led to a three-year role teaching supervisory management techniques to new promotees, including how to identify, assess and control sources of noise. He has also met the required level of performance set by the joint ACC / Auckland University Dangerous Decibels Industry (DDI) Training Workshop. He has now met the prescribed criteria to be recognised and certified as a "Competent Person" in noise management and assessment under the Approved Code of Practice for Management of Noise in Workplace.

1. Introduction and purpose of the assessment

The carrier operating the aircraft which was used for this study is independent and provides services in several New Zealand regions. The investigator used one such service twice weekly for many months; totalling 40 flight legs. Whilst noise is perceived differently by each of those exposed to it, the sound pressure levels experienced during the flights made the investigator feel 'uncomfortable' and after just two flight legs, he started to wear a pair of Class 5 rated earmuffs for personal hearing protection during flight. This situation prompted the question: did the aircrew and other passengers also experience 'uncomfortable' levels of in-cabin noise?

There are currently no regulations in New Zealand that specifically address in-cabin aircraft noise levels. It was determined that the Airline did not have its own policy concerning the protection of aircrew and passengers from potentially 'uncomfortable' levels of in-cabin noise. Also, the Airline did not provide headsets for its aircrew as, being not only a critical item of equipment for the operation of the aircraft but also very personal, they allowed a free choice of noise-cancelling headset. No specification was issued by the Airline as the aircrew's level of professionalism was trusted in making an adequate choice. The Airline's Safety Manager said that high quality headset makes such as Bose and Sennheiser are often chosen. However, Internet research revealed remarkably few manufacturers state the degree to which noise is reduced in their product specifications, and when they do, often prefer quoting percentage reduction, for example 90%, which would correspond to a 10 dB reduction. However, from a review of various sources, it appears that quality 'active' noise-cancelling (ANC) earphones have noise reduction up to 25 dB. By comparison, 'passive' noise reduction by noise-isolating ear muffs would be 26+ dB for Class 5 devices.

This paper includes summary details of a field investigation and related sound pressure level measurements. It is for an Occupational Health and Safety investigation into the cabin sound pressure levels passengers and aircrew of the subject scheduled service were typically exposed to during flight. This investigation was carried out on two representative aircrew members and five passengers, simulated by the investigator using a wide variety of seats, while flying on the aircraft over five separate flights. Measurements were based on exposure to the simulated passengers inside the passenger compartment of the airframe and on the aircrew seated in the cockpit.

The investigation was undertaken in general accordance with the joint Australian/New Zealand Standard AS/NZS 1269:1:2005 *Measurement and Assessment of Noise Immission and Exposure* [1] and Regulation 11 of the Health and Safety in Employment Regulations 1995 [2]. The Regulation requires that "*so far as reasonably practicable*", steps must be taken to ensure workers are not exposed to a time average sound pressure level exceeding 85 dB $L_{Aeq,8h}$ over a normalised 8-hour working day, and not exposed to any single sound pressure level exceeding 140 dB L_{peak} at any time, regardless of their daily sound exposure and regardless of whether the worker is wearing hearing protection. Any sound event equal to or exceeding 140 dB L_{peak} level can potentially cause permanent hearing loss and, although not workers at the time of exposure, any passenger exposed to sound pressure levels exceeding 85 dB during their flight would have to take this into consideration at their own workplace.

The investigation measured sound pressure levels and gathered data to assess whether passengers and aircrew were being unwittingly exposed to occupational noise that exceeded the Regulation requirements. Further benefit was gained by focussing on data whose collection and interpretation was likely to have the most practical application and which offered an opportunity to make relevant recommendations to the Airline to help them to add value to their health and safety and operational processes.

Figure 1: View from the back of the cabin

2. The environment under investigation

The subject aircraft has twin turboprops and is quite a popular, if comparatively old, choice for regional Airline operators throughout the world. Its real value is in its use to 'test' viability and customer up-take of new routes as it is very economical to operate. It has proved to be a safe, fast, and efficient commuter aircraft which is also very versatile, having seating for up to 19 passengers (with minimum seat pitch) and operability as a freighter with a maximum payload of 2 tonne. However, at only 1.45 m, the cabin ceiling is very low.

The investigator heard the aircraft being referred to by other passengers as '*the flying cigar tube*' due to its thin profile (see figure 1). During the data collection phase of this investigation, fellow passengers, on learning of the purpose of the equipment adorning the investigator, offered un-prompted comments regarding the noise levels they had experienced whilst in flight. All of them were negative. As can be seen in Figure 2, at least one passenger adopted the age-old, but effective, method to reduce in-cabin noise to a comfortable level.

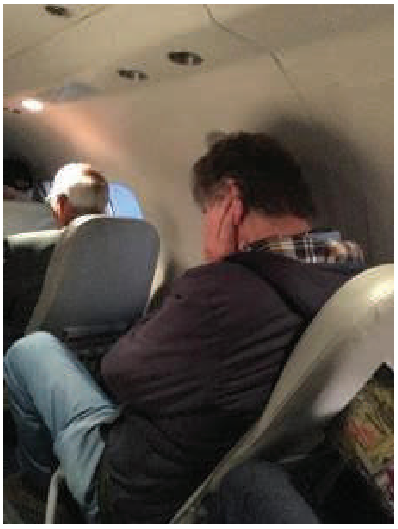

Figure 2: Manual noise control

Recognising that cabin design can have a big impact on noise levels during flight, at least one aircraft manufacturer (Boeing) has attempted to acoustically model sound characteristics of a specific design during the conceptual phase. The main problem encountered doing this modelling, nicely illustrates the issue that must be considered in all aircraft, including the subject aircraft. That problem is determining the boundary conditions for the acoustic model [3]. Additionally, interior design, for example the type of material used on the seats (cloth absorbs more noise than leather) and the texture / materials used on the cabin surfaces, will be factors in the levels of noise received by passengers. Also, the size of the cabin and the atmosphere maintained within it, as these will affect the amount of noise absorbed by the air.

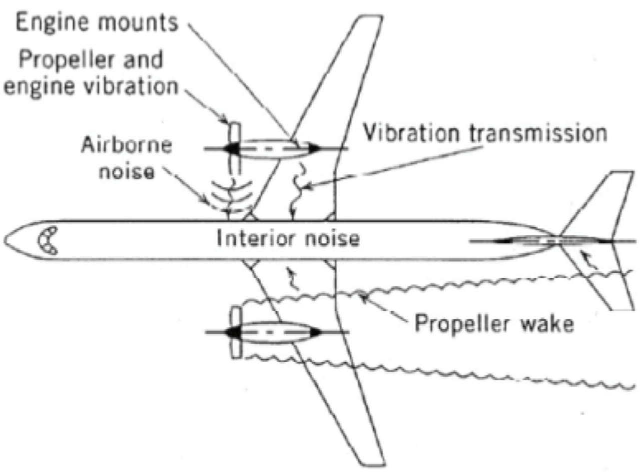

Figure 3: Sources and paths of airborne and structure-borne noise resulting in interior noise in an airplane cabin [4]

Low frequency noise is particularly prevalent due to the interaction of efflux from the engine exhaust nozzles and aircraft turbulence produced by the airframe moving through the air. This noise energy propagates into the cabin at frequencies of typically around 50 to 2000 Hz [3]. Also, as the engines are attached to the airframe, vibration is transferred from the engines into the cabin. Tones produced by two main rotating shafts within the turboprop engines produce frequencies in the range of 40 to 100 Hz and 100 to 200 Hz. These tones combine acoustically within the cabin [3]. Figure 3 demonstrates how the different sources interact to produce in-cabin noise.

Taking 200 Hz as an arbitrary example, the wavelength of a noise tone at that frequency in air is approximately 1.7 m. With the subject aircraft's cabin height at 1.45 m one would expect a reasonably constant distribution of noise energy in the vertical plane. If this is the case throughout the aircraft cabin, and we know that the aircraft is symmetrical about its longitudinal centreline (i.e. the left-hand side mirrors the right-hand side), we can surmise that the only significant variations in noise energy exposure on passengers throughout the cabin will be the variations from front to rear.

So, anecdotally, from observation and personal experience and from aircraft acoustic theory and research, it is likely that, due to its design, the subject aircraft causes passengers to experience, shall we say, '*uncomfortable*' levels of noise in the cabin under normal operating conditions. But will the investigation data support this assumption?

3. Equipment

The noise measuring equipment used for this investigation was supplied by Massey University and consisted of the following:

- Cirrus doseBadges with charging base and mains adaptor
- Cirrus doseBadge Reader and USB cable for data transfer
- Lightweight, plastic backing plates and mounting straps for locating the doseBadges in an area within 300mm of the ear (i.e. shoulder-mounted).

Figure 4: doseBadge reader operation

The Reader was used by following a 'V' pattern on the upper function buttons, as shown in figure 4:

'RESET > CAL > RUN > STOP > RESET'

The 'Noise Tools' software was easily downloaded to enable data recorded by the doseBadges and transferred to the Reader to be captured and interpreted.

4. Methods and constraints

A line of communication was set up between the investigator and the Airline to establish the scope of the investigation and for all parties to understand the requirements.

To demonstrate to the Airline that the data-logging was passive, un-intrusive and would have minimal, if any, effect on operations, the investigator arranged and conducted a trial run. The seat chosen by the Airline for the trial to take place was at the back-left of the cabin. Whether by accident or design, the trial was overseen by an off-duty Airline Captain seated across the aisle. The trial having proved successful and agreeable by all parties, further data-logging commenced 12 days later and continued over the next nine days that included four flight legs. It was arranged for one of these flights to include monitoring of the noise environment experienced by the aircrew in the cockpit. This imposed limitations due to:

- the need to reduce additional actions required from the aircrew to an absolute minimum
- the need for the aircrew to satisfy CAA NZ (Civil Aviation Authority of New Zealand) regulations (specifically regarding the requirement for aircrew to check passenger seat belt security)
- the need for simple and speedy fitting and removal of personal noise measuring equipment to the Captain and Co-pilot

To provide a solution to the above aircrew exposure measurement limitations, the investigator designed and made a pair of special mounts for the doseBadges that fitted over the aircrew shirt epaulettes and rank tabs, as shown below in figure 5.

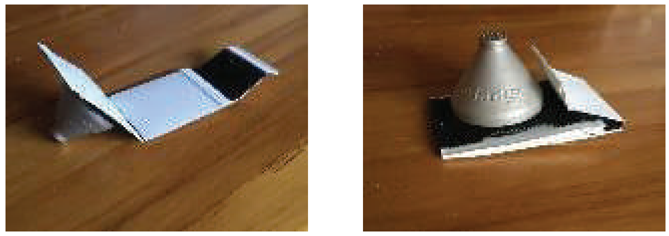

Figure 5: doseBadge special mounts

Also, a brief process was designed and communicated to the Airline's Safety Manager as follows:

1. Firstly, I intend to only ask for one set of data from the Aircrew. Any 'uncertainty' in the measurements can be interpreted from the data collected using myself and applied to the aircrew readings. I think the environmental conditions throughout the cabin are consistent enough for that to be a valid approach.
2. Secondly, I will only ask to locate a doseBadge on the 'inside' shoulder of each crew member. I.e. the right shoulder of the Captain and the left shoulder of the Co-Pilot. This is so that I can fix and retrieve the doseBadges very easily by briefly squatting between and behind the two aircrew seats. The way I see it working is this:
   - I am seated at the front, on the right, with both doseBadges calibrated, 'ON' and ready to be fitted.
   - The Co-Pilot checks seat belts are secure throughout the cabin and returns to his seat.
   - I step forward and fit a doseBadge to the 'inside'

shoulder of each crew member; Captain first.

- Once complete (a matter of a few seconds), I return to my seat and fasten my seat belt.
- The Captain turns his head to the right to check that I have my belt securely fastened.
- Flight proceeds as normal.

3. The doseBadges will be fitted using a Velcro pad on top of a 75 mm wide, light but stiff piece of plastic that is also secured by Velcro to the aircrew right / left epaulette (over the rank tab). The Velcro will have a 'quick-release' tab facing forwards so that either crew member need only reach up and pull to remove the mounting board and doseBadge – should it become necessary.
4. The aircrew belts sit on their shoulders near to the neck line so the doseBadges should not get in the way of any movements during flight.
5. As soon as the engines are shut down, I will quickly step forward and unclip the doseBadges from the Aircrew shoulders then return to my seat.
6. The Co-Pilot continues his 'de-plane process'.

Approval for the above approach was received from the Airline.

Following the success of the earlier Trial, the investigator adopted the following process for taking personal noise exposure measurements:

1. On checking in, seats were requested to gain a suitable coverage of the cabin within the number of flights available for the investigation.
2. Ten to 15 minutes before the flight was due to be called, two doseBadges were chosen at random and a note made of their Serial Numbers in a notebook.
3. The Reader was used to Calibrate both doseBadges.
4. The chosen doseBadges were each fitted to a clip-on mounting strap using the screw-on backing plate.
5. Being careful to keep track of which doseBadge was which (the Serial Numbers are obscured once fitted to the backing plates), they were placed in appropriate pockets; RH pocket for the RH shoulder and opposite for the LH.
6. On boarding the aircraft, the requested seat was taken and each doseBadge was set to 'Run' (switched on) using the Reader before it was secured to the allocated shoulder.
7. A note was made of the time the doseBadges were activated and attached.
8. Notes were taken every few minutes throughout the flight and particularly of any events that were thought to have the potential to show up in the data, such as take-off, landing, crew announcements, spurious cabin noises, etc.
9. Depending on time available, doseBadges were either removed just before or just after engine shut-down following landing and taxi. The doseBadges were set to 'Stop' (switched off) and the times noted in the notebook.
10. On leaving the aircraft, as soon as possible, the doseBadge data was transferred into the Reader.
11. A post-read Calibration cycle was carried out.
12. At a convenient point, the data was downloaded from the Reader to the investigator's PC.

5. Measurement uncertainty

The results from making occupational noise measurements may be uncertain due to both errors and natural variation in the work situation. It is therefore important to recognise the main sources of uncertainty and to attempt to assign a value that appropriately reflects the degree to which any final measured values may be viewed as accurate.

The main sources of uncertainty in this investigation were noted as follows:

- Variations in daily work – Operational flight times varied due to several factors outside the control of the Airline and aircrew. For example, departure times from one airport often relied upon other aircraft movements and, with the Airline operating a scheduled service to a timetable, aircrew may modify a 'standard' flight profile (e.g. increasing speed) in order try to make up lost time. An increase in speed could increase the stress on the engines and therefore increase noise levels. Similarly, adverse weather could add stresses to engines and airframe whose combined effect could increase noise energy levels. Therefore, not only will the period of noise exposure vary but also the levels.
- Instrumentation – One doseBadge Reader was used for the investigation but it's calibration was one year overdue. This fact was known by the Massey University lecturers, but the instrument's accuracy was deemed to be good enough for this exercise. Five different doseBadges were used during the investigation and it was not until the results were analysed that it was discovered that one or two had been set to record slightly different parameters. As it happens, the parameters that all the doseBadges had been set to record were the ones most suitable to meet the investigation objectives.
- Microphone position – Whilst doseBadge microphone positions were within 300 mm of the respective ears, the actual positions on the shoulders varied slightly from flight-to-flight. Also, in terms of reproducibility, the seated torso height of the investigator (and aircrew) determined the spatial positioning of the microphones within the cabin.


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- False contributions – On two occasions the investigator turned his head in such a way to cause jacket or shirt collar to rub against the microphone. This also could have happened on other occasions the investigator was not aware of.
- Lacking or faulty work analysis – Whilst the investigator made every attempt to be systematic and accurate, this was a learning exercise and the possibility of errors was greater than if someone experienced had been conducting the investigation.
- Contributions from nontypical noise sources – During the flights whose data contributed to the investigation, nontypical noise sources included cross-aisle conversations (with raised voices) and, on one occasion, loud coughing, were experienced. However, the investigator experienced remarkably little in the way of nontypical noise sources.

Considered subjectively, only the 'Variations in daily work' source of uncertainty appears to have the potential to alter significantly the 'normal' flight profile readings. However, when the total flight time is compared with an eight-hour working day exposure level even this factor is unlikely to generate any major variance. Nonetheless, an 'associated expanded Uncertainty' figure (U) of 3 dB was determined using a Massey University-supplied Uncertainty Budget spreadsheet. This assumes that the doseBadge and reader hold a current certificate. However, since this was 1-year over due, the uncertainty is likely to increase by a further 2 dB.

6. Results

Data was recorded for each seat position within the cabin and whether the doseBadge was worn on the left-hand (LH) or right-hand (RH) shoulder. Combining the two, noise exposure levels measured on the 'inboard' and 'outboard' sides of the cabin could be determined.

Figure 6 shows the results at the positions in the cabin at which they were determined. Measurement duration averaged 56 minutes. The L_{Aeq} (dB) data is colour-coded blue for '*Inboard*' measurements and orange for '*Outboard*'. Exposure Dose (%) figures are coloured green under each reading.

6.1 Noise descriptors

The main noise descriptors used in the measurements are as follows:

- $L_{Aeq,t}$ – Notional sound pressure level which, if maintained constant over a given time (t), delivers the same (equivalent) acoustic energy as the time-varying sound pressure level would deliver over the same period of time.

  Note: For the investigation, each period 't' differed slightly as this was the length of time the measurements were taken over and this varied according to flight time and other factors described previously.

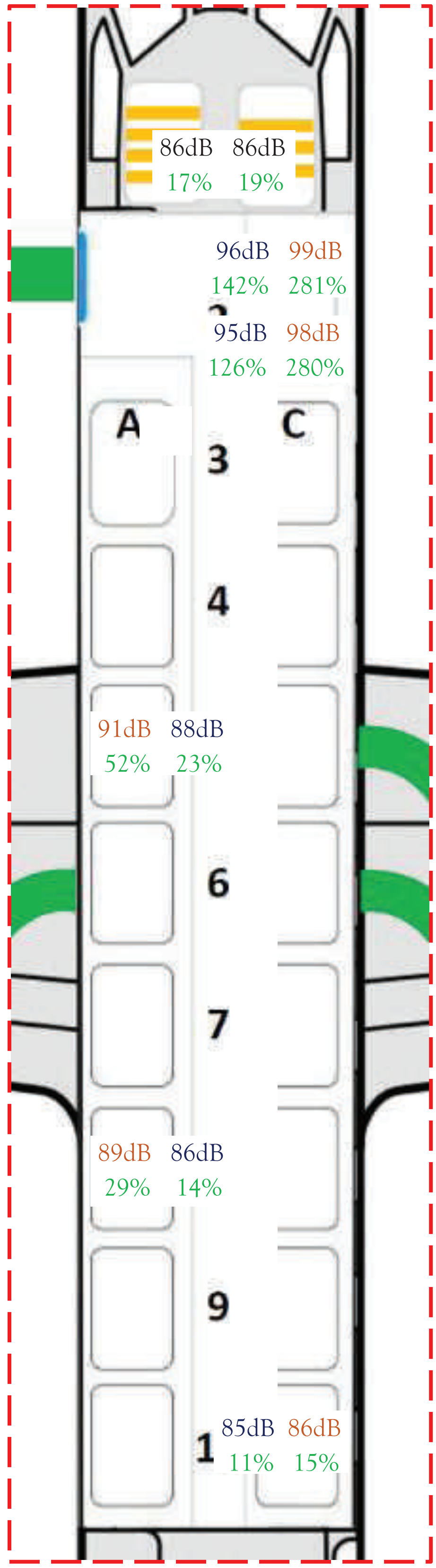

Figure 6: Noise levels and exposure at various locations in the aircraft cabin

- L_{EX8} – Daily Personal Noise Exposure: the averaged A-weighted noise exposure level for a nominal 8-hour working day and is for assessing the noise exposure of an employee during a working day. It is calculated

from the measured Sound Exposure, the Exposure Time and a Reference Time of 8 hours. It may be linked to '$L_{Aeq,\,t}$' (as above) such that if time 't' is 8-hours, $L_{EX8} = L_{Aeq,8h}$.

Note: In New Zealand, consistent with AS/NZS 1269 [1], it is convention to use the $L_{Aeq,8h}$ notation.

- L_{AE} – Sound Exposure Level (sometimes referred to as 'SEL') measures the total (acoustic energy) exposure for the period of measurement. It is essentially sound exposure expressed in dB.

  Note: It is standardly normalised to a period of 1 second, as if all the sound energy was packed into a single second.
- Noise Dose – This is the Noise Exposure expressed as a percentage (%) of an 8-hour working day (100% = 1 Pa^2h)

6.2 Legislation

As referred to in the Introduction, Regulation 11 of the Health and Safety in Employment Regulations 1995 [2] means that it is legal to work an entire 8-hour day whilst exposed to a noise level of 85 dB L_{Aeq}. At this level, the noise exposure would be 100% or the Dose would be 100%.

Peak noise – During the investigation, there were no peak noise levels (L_{Cpeak}) measured that exceeded the legal maximum of 140 dB. Other significant peaks could be tracked back to '*false contributions*' via the notes. Peak data has therefore not been included in the results.

7. Observations

Aside from the data, there were various occasions when the investigator observed passengers attempting to hold a conversation between them when sitting across the aisle from one another (less than 1 m apart). On one occasion, a couple were speaking so loudly the content of their shouted conversation could be discerned three rows in front whilst wearing ear muffs!

All observations were noted, as per the examples shown below in figure 7.

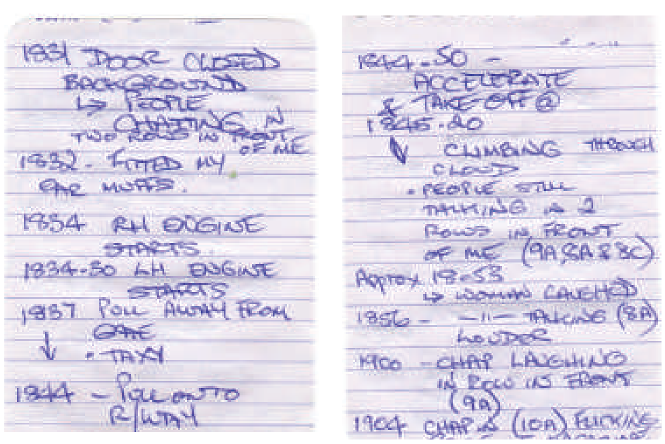

Figure 7: Example observational notes

8. Discussion and Conclusions

The results clearly show that 'outboard' ears are exposed to around 3 dB higher sound pressure levels than the 'inboard' ears. For many people, this would be a barely discernible difference. However, in linear terms, the '*outboard*' ear has twice the exposure of the '*inboard*' ear.

Overall, there are a few interesting findings:

- Of all the noise levels measured, only the inboard 'ear' right at the back of the aircraft cabin was exposed to a level that could legally be sustained for an 8-hour working day.
- Of all the seats measured, Front-Right is by far the noisiest. In fact, in just the period of a single flight (56 minutes), the RH 'ear' was exposed to almost three times the amount legally allowable (Dose = 280%).
- Even the quieter (inboard) side of both aircrew is outside the legally allowable exposure, should they be exposed to this in their work for 8 or more hours per day (regardless of whether they wear their headsets) with 8-hour corrected doses of 127% for the Captain and 143% for the Co-pilot.
- The observations clearly demonstrated that the levels of noise in the cabin greatly interfered with speech and / or made at least some people feel uncomfortable.

In terms of data validity, the inboard and outboard results suggest that the data is valid. One would expect the inboard measurements to be lower than the outboard ones due to the factors discussed earlier (i.e. sound absorbed by travelling through more air and due to the insulating bulk of the body as well as being further away from vibration-induced noise in the aircraft skin).

Regarding reproducibility, given the same equipment and using the same methods, there is a high probability that the results could be reproduced. Asssuming the doseBadges and calibrator are within spec, then the accuracy is likely to be 'U' of ± 3 dB.

So, what does this all mean for the operator?

9. Recommendations

Clearly, no Airline wants to advertise the fact that they operate noisy aircraft. There is no requirement for them to do so either. On the other hand, the subject Airline is a thoroughly responsible one who are proud to support New Zealand's various regions, so there will probably be a strong desire to do something.

The following recommendations were therefore offered:

- Develop a Company Noise Policy – by involving all stakeholders, including at least one representative from the users, a considered approach may be adopted. (For example, this may include introducing a step in the booking or check-in process seeking information on passenger hearing problems and allocating 'quieter' seats, if necessary).

- Review the typical daily working hours of all aircrew when flying the subject aircraft. If working hours meet or exceed 8 hours, it may be worth repeating the noise measuring exercise and focus on the cockpit. Confirmatory data will help to decide on the best way to avoid contravening legislative requirements.
- Include a little packet of disposable earplugs in the aircraft seat pocket. Most people will probably not use them, but they will be available if the wish to. Spare ear plugs can be kept on board to replenish as required.
- Consider placing additional sound-proofing behind the cabin trim around seats at the front of the aircraft, in particular. Whilst there isn't much space, some modern acoustic materials are very thin and very effective.
- If possible, consider trimming the aircraft to allow the 'noisy seats' to be filled last (and therefore possibly flying the aircraft 'tail-heavy' if seats remain empty).
- As it is a legal requirement for companies to provide their employees with all necessary Personal Protective Equipment (PPE), the Airline may wish to consider providing aircrew with a 'standard' headset. If they then wish to choose their own, providing their choice at least meets the standards set down by the Company, that is their decision.

Acknowledgments

The investigator would like to sincerely thank the Airline for their outstanding level of cooperation and specifically the two aircrew members who contributed to this study by wearing the personal dosimeters. The Airline chose not to be identified by name, aircraft type or route as changes have since been made to mitigate the on-board noise.

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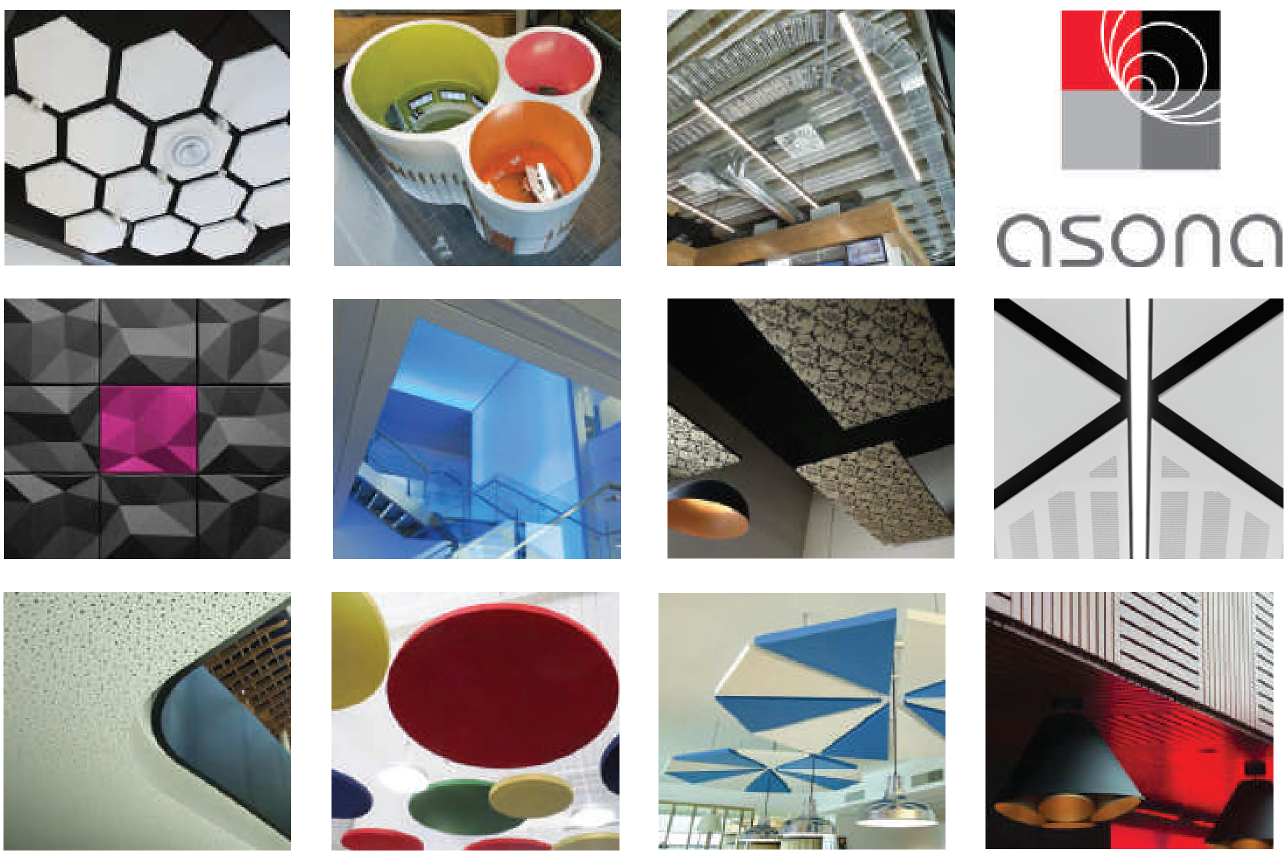

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the public. The research report is available for free download in two parts as ER30a (A4 size) and ER30b (A3 size - industry consultation results) on the BRANZ website. see www.branz.co.nz/study_reports, search for ER30.

EMS Brüel & Kjær now exclusive supplier of Predictor-LimA

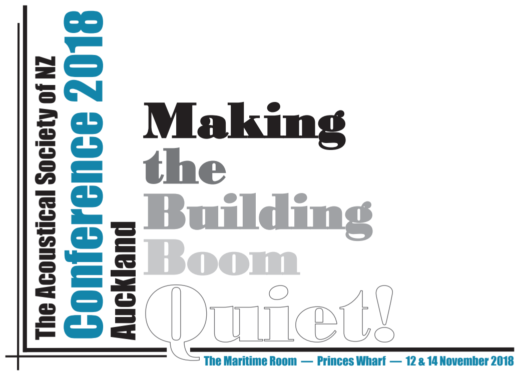
EMS Brüel & Kjær was recently established as a joint venture separating from Brüel & Kjær Sound and Vibration A/S, which continues its focus on noise and vibration instrumentation. EMS Brüel & Kjæ provides Environment Management Solutions covering noise, vibration, weather, dust and air quality. Effective immediately, EMS Brüel & Kjær is proud to announce that it has taken over responsibility for Predictor-LimA noise calculation software. All sales and support for Predictor-LimA is now available exclusively from EMS Brüel & Kjær.

AS:1055 Acoustics - Description and Measurement of Environmental Noise - Review

In December of last year Standards Australia approved a project proposal from its technical committee EV-010 Community Noise to revise AS 1055, Acoustics - Description and measurement of environmental noise. This is one of the basic standards used in Australia for measurement of environmental noise. The project started in May 2016 and a draft is expected for comment review in early 2018.

ASNZ 2018 Conference – Call for Abstracts

www.acoustics.org.nz/conferences/asnz-conference-2018



Registration is open and we are calling for abstracts for papers to be presented at the Acoustical Society of New Zealand's biennial conference for 2018 will be held in Auckland from the 12th to the 14th of November 2018. The location will be the Maritime Room, Princes Wharf.

The theme for the conference is '*Making the Building Boom Quiet!*' All papers for this conference will have the option to be peer reviewed, with authors able to opt in or out of this process. Peer reviewed papers will be noted in the conference proceedings. For updates, including pricing and keynote speakers, please visit the conference website. There will be a trade exhibition at the conference, and sponsorship opportunities are available.

Key Dates

- Abstracts 13 August 2018
- Paper 15 September 2018
- Conference 12-14 November 2018

Please submit your abstract via the web link:

https://conferences.ocpms.com.au/conference-papers/login.php?confID=45

Please contact fadia.sami@earcon.co.nz for information on sponsorship packages.

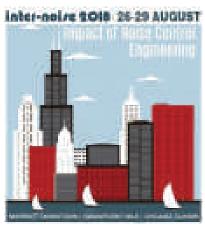
Venue Information: https://www.maritimeroom.co.nz

2018

12-14 November 2018, Auckland, New Zealand. The Acoustical Society of New Zealand Conference 2018 'Making the Building Boom Quiet!'

8-12 July 2018, Hiroshima, Japan. The International Institute of Acoustics and Vibration ICSV25
www.icsv25.org

26-29 August: Chicago, USA, 47th International Congress and Exposition on Noise Control Engineering (INTER-NOISE 2018)
www.i-ince.org



24-26 October 2018, Cadiz, Spain XI Iberoamerican Congress on Acoustics. TECNIACÚSTICA 2018 - 49th Spanish Congress on Acoustics - X Iberian Congress on Acoustics

6-9 November 2018, Adelaide, Australia AAS Acoustics 2018 Hear to Listen
www.acoustics2018.com

5-9 November 2018, Victoria, Canada 176th Meeting of the Acoustical Society of America
www.acousticalsociety.org

11-15 November 2018, New Deli, India WESPAC 2018
www.wespac2018.org.in/conference

2019

13-17 May, Louisville, Kentucky, USA. 177th Meeting of the Acoustical Society of America
www.acousticalsociety.org

09-12 June 2019, Madrid, Spain. 48th International Congress and Exposition on Noise Control Engineering (INTER-NOISE 2019)
www.i-ince.org

Answers

To the 5-minute Quiz (on page 23)

A1 True. Sound does require a medium to propagate.

A2 True. Sound waves in the medium of air are longitudinal waves, where the particle displacement is in the same direction in which the wave is travelling, as opposed to transverse waves.

A3 False. The speed of sound is air is approximately 340m/s, while in seawater the speed of sound is almost 5x faster at 1500 m/s.

A4 False. The inverse-square law, in acoustics results in a reduction of the sound pressure level by 6 dB (not 3 dB) with every doubling of the distance in a Free field.

A5 False. Diffraction (not Refraction) is to bend around the edges of objects/barriers or through holes..

A6 True. Anechoic literally means 'without echo' or non-reflective, non-echoing, echo-free etc.

A7 False. NZS 6805:1992 is the New Zealand Standard for 'Airport Noise Management and Land Use Planning'. NZS 6806:2010 is the standard for 'Acoustics – Road Traffic Noise – New and Altered Roads'.

A8 False. 'Clause G4' of the Building Code is Ventilation. 'Clause G6' is the correct designation for Sound insulation'.

A9 True. Bell Labs in the circa 1930's where researching how to transmit a phone call economically.

A10 False. Humans are most sensitive at around 3.5 kHz (not 13.5 kHz).

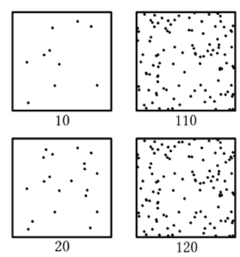
A11 1999.

A12 2016.

A13 Loudness.

A14 Subjective means a response of an individual (which will vary from person to person).

A15 The Weber-Fechner Law is a law in psychology that states that the change of subjective response to a physical stimulus is proportional to the logarithm of the stimulus. An illustration of the Weber–Fechner law is shown to the right, on each side, the lower square contains 10 more dots than the upper one. However, the perception is different: On the left side, the difference between upper and lower square is clearly visible. On the right side, both squares look almost the same.



A16 White Finger is the informal name given to Raynaud's Disease where a person's fingers literally go white and loos blood circulation. This can be caused by sustained cold or vibration.

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Publication Dates and Deadlines

New Zealand Acoustics aims for least three issues per year, in April, August and December.

The deadline for material for inclusion in the journal is the 1st of each publication month, although long articles should ideally be received at least 4 weeks prior to this.

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To join the Society, visit www.acoustics.org.nz or contact the Secretary: secretary@acoustics.org.nz