New Zealand Acoustics

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World Health Organization

International Ear Care Day: 3 March

www.who.int/pbd/deafness/activities/MLS

Limit the daily use of personal audio devices!

Make Listening Safe

1st Quarter 2nd Quarter 3rd Quarter 4th Quarter

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New Zealand Acoustics

Volume 28, 2015 1st Quarter

Features

Regulars

Cover Image: From the WHO 2015 campaign 'Make Listening Safe' - part of International Ear Care Day (March 3, 2015)

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From the President and the Editor's

President's Column

Dear Members,

A belated welcome to 2015! It's already shaping up to be an epic year... there's a definite feeling that everyone is busier than usual for this time of year, in pretty much every sector.

As Lindsay and Wyatt have mentioned in their Editors' column, our ASNZ Conference in Christchurch last November was a fantastic event, which came hot on the heels of Inter-noise Melbourne. I attended both, and thoroughly enjoyed them for different reasons. Internoise is a massive acoustic banquet these days with a dazzling array of papers to suit every taste, whereas the ASNZ Conference was more like sitting down at a café with an old friend for a relaxing catch up.

The team in Christchurch delivered a very well organised and intimate event. I was struck once again by the collegial feeling of the conference... something which I think is probably quite unique among professional societies and worth holding on to!

At the AGM there were some changes made to the ASNZ Council. Past-president Rachel Foster has stepped down as she has moved back to Australia and Lindsay Hannah has relinquished his role on the council to focus his efforts on the journal editorship.

Stuart Camp has also stepped down. This is a very big deal because Stu has been the lifeblood of the ASNZ since I can remember. He has put more time and effort into the modern era of this Society than anyone else I can think of, has always been a voice of reason and encouragement, and I will miss him terribly. I'm not entirely sure how things are going to go without him, but I have his number on speed dial so he won't be able to escape altogether!

This has made way for two new members on the Council, Neil Jepsen from Palmerston North and Robbie Blakelock from Christchurch. A warm welcome to you both on behalf of the Council, I look forward to working with you over the next two years!

Now, with all these thanks and introductions out of the way, there's a little bit of space left to talk about what 2015 has in store for us.

The very first round of CPD submissions is due on 1 July. In order to maintain their Membership Grade within the Society, all Members are required to submit a declaration of CPD that they have undertaken since July 2013 for review. Details and submission forms will be available on the website (www.acoustics.org.nz). I expect there may be some queries and teething problems. We're fully committed to making this regime work, as it adds value to Society involvement and ensures that our Members on the top of their game.

The flip side of the CPD coin is that there must be opportunities to gain points, so please make opportunities in your area by organising branch meetings and lunch time get-togethers!

That's about it from me for this quarter. Enjoy the Autumn season and keep your eye on the website for new CPD information and other content. We also have the joint NZ/Australian Society Conference next year in Queensland to look forward to. I met with members of the organising committee at Internoise and planning is well under way. I'll be in touch with those details too!

Yours faithfully,

James Whitlock

Editor's Column

Welcome back to all our Members and readers to this first exciting issue of New Zealand Acoustics for 2015. We hope you all had a great break and no doubt some New Year's resolutions and goals have been set, good luck with achieving all of these.

The end of 2014 was a busy year with the Society holding its 22nd Biennial Conference in the beautiful garden city of Christchurch. In addition for those who were lucky enough to attend, Inter-Noise2014 was held at the Melbourne Convention and Exhibition Centre, in the stunning city of Melbourne, Australia.

It is with great satisfaction we bring you a mixture of papers from both the ASNZ 22nd Biennial Conference and Inter-Noise2014 in this issue.

We also have up to date news and events which we recommend all Members read as it includes important information about the Continued Professional Development (CPD) Scheme.

We also have regulars like RMA Net and the Acoustics Quiz to keep you engaged.

Finally we would both like to congratulate Ross McBeath for becoming the latest Fellow of the Society, well done! We also congratulate the efforts of the organizing committees and all of those who helped organize and run the 22nd ASNZ Conference and Inter-Noise2014.

Lindsay and Wyatt ¶

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Full Colour Journal

This issue of the Journal marks the start of a new era for the Journal. As you may have noticed this issue [Vol 28, 2015, No 1] is the first ASNZ Journal to be in full colour from start to finish. Previously the Journal had colour front and back pages and selected colour adverting. Utilising full colour will not only allow for colour adverts for all adverstisers, but also improved graphics throughout, including all the feature articles.

Review: 22nd Biennial Conference of the ASNZ - 'Acoustics in a Rebuilding City'

The 22nd Biennial ASNZ Conference was held in Christchurch on 24th and 25th November 2014, at the Waimakariri Room in the Novotel Hotel, Cathedral Square, Christchurch City.

The conference was held over two days and included the presentation of technical papers and tours. The program included a high level of both technical and practical papers. Lunch, morning and afternoon tea were provided allowing all participants to meet, greet and view the trade show and exhibitions on display. The conference dinner was held at the Novotel Hotel. We congratulate the efforts of the Organizing Committee and all of those who helped organize and run the conference.

New Zealand Acoustical Society Inc. Biennial General AGM Meeting No. 21

Held at the Novotel Hotel Cathedral Square, Christchurch 24th November 2014. At the AGM 37 members attended in person with apologises from seven members. The President's, Treasurer's and Brank Reports were presented.

New Committe Members Elected

The AGM of the 22nd Biennial ASNZ Conference saw a number of existing Committee Members step down to allow way for some new Members. Those members stepping down were Rachel Foster, Lindsay Hannah and Stuart Camp. The newly elected Members [2014-2016] are Neil Jepsen and Robbie Blakelock. The following is a brief introduction and Bio of the two new members.

Robbie Blakelock - Marshall Day Acoustics' Christchurch

Robbie has a long history of playing in a range of musical groups; his professional involvement with acoustics began in 2009 when he spent a summer in Marshall Day Acoustics' Christchurch office, while studying towards his Mechanical Engineering degree.

Robbie re-joined Marshall Day Acoustics as a consultant in February 2011 and has since spent time working on a wide range of projects. The key things Robbie states that he would like to see the Acoustical Society of New Zealand develop are: growing cross-collaboration between all elements of the professional community connected to acoustics; becoming a voice to communicate clear messages about acoustical issues to non-professionals and the wider community; and facilitating debate and development of acoustical ideas, practices and technologies. Robbie looks forward to spending the next two years serving on the Council and welcomes any dreams, ideas or opportunities you see for ASNZ, particularly with respect to the South Island.

Neil Jepsen - Acoustics & Electronics Palmerston North

Neil got his commercial pilot's licence in 1973, completed an MSc (Hons) in the same year and started an electronics manufacturing business in 1976. In about 1980, Neil became interested in acoustics and is now 100% committed these two passions with his well recognized noise telemetry stations. Building, developing and improving this technology takes most of Neil's time and passion. In his spare time, of which there isn't much, Neil flies his own Piper aeroplane, works as a pilot instructor in weekends, and also competes in aerobatics with a Pitts aerobatic biplane. Other interests Neil has inlcude shooting, hunting and collecting electric master clocks. Neil is married, has a son in Canada who is a computer software engineer, a daughter in Brisbane, and is the proud Grandfather of five grandchildren.

Review: InterNoise 2014

Internoise 2014 was held at the Melbourne Convention and Exhibition Centre, in the stunning city of Melbourne, Australia.

The congress started with a Welcoming Ceremony in the Plenary on Sunday with the conference being concluded three days later with the Closing Ceremony. There was a large contingent from New Zealand which included consultants through to academics. In total 37 countries were represented at the conference with around 20 percent

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Design & Acoustic Performance of a Spring Isolated Outdoor Rooftop Basketball Court

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Abstract

The proposal of a rooftop basketball court created an issue of significant impact/footfall noise and structural vibration ingress to the sensitive environment beneath. As part of a new building in a dense urban environment, a unique solution had to be designed due to the maximum weight capacity of the underlying rooftop structural slab and FFL design controls. Further challenges were faced in the form of fluctuations of up to 30 mm in the level of the underlying structural slab and subsequent excessive deflection caused by a relatively high live load. The final design incorporated the use of over 300 cast in 'jack-up' style mounts complete with 25 mm deflection springs within a 100 mm secondary concrete slab covering an area of approximately 630 m2. Installation of the court encountered few problems and upon completion small deflections of the slab could be felt underfoot however there were no unfavourable 'trampolining' effects generated by live loads. Completion testing showed a significant reduction in impact noise levels between the isolated court and an exposed portion of the structural slab

Orginally published at the 22nd Biennial Conference of the Acoustical Society of New Zealand, November 2014

1. Introduction

Basketball courts are subject to frequent impact forces from bouncing balls and people jumping. Typically basketball courts are constructed at grade to avoid issues of noise and vibration transmission through connected structures. In this case, a combined basketball/netball/tennis court was to be constructed in a dense urban environment, and limited spatial availability necessitated that it had be located on a rooftop directly above commercial space. Without sufficient vibration isolating measures, the impact forces from activity on the court would likely cause distracting noise to the people below in the connected structure.

A common solution for above ground sports floor isolation is to use plywood under the floor lining with multi-layered pads or rubber mounts regularly spaced underneath. This provides a degree of vibration isolation as well as impact absorption for the comfort of the people using the floor. However, a high level of isolation from the adjacencies in this proposal would likely require deflection which is beyond the capabilities of regular pads. Since the playing surface for this project was outdoor, the surface and isolation needed to be designed to withstand the effects of weather for a long life, and this typical solution was deemed inappropriate.

The structural floor was a 150 mm composite slab with large transfer beam spans which yielded a relatively low natural frequency for the structural slab (see Section 3.1). The natural frequency of the courts system needed to be calculated carefully to avoid resonance with both the underlying structural slab and with activities such as footfall and ball bouncing.

The proposed court size was approximately 630m^2 and the finished court height was restricted to 150 mm from the structural floor. The court system was also to contain several large penetrations for poles which were to be supported from the structural slab. Other design constraints included the support capacity for a live load of 5 kPa and an allowance for appropriate drainage measures.

The final design of the system incorporated a 100 mm thick concrete floating floor which was supported by springs with housings which were cast into the concrete. This design aimed to achieve a consistent air gap of 50 mm between the floor and the structural slab. From the experience of the authors it is much more common to use rubber mount isolation for sports floor applications due to factors such as cost, discomfort from vibrations due to large amplitude deflection where springs are used and resonance at walking frequencies. However, it was believed that the overall effect of these issues could be mitigated, as it was the only solution which satisfactorily met the design constraints.

1.1 Noise level criteria

It was important to develop design criteria which would result in acceptable levels of noise in the tenancies below the basketball court. The tenancies below would be constructed as part of a separate fitout contract. As such, their use was not fully confirmed at the time of design. However, it was known that these tenancies would install a plasterboard ceiling in the space below to conceal structure and building services. Possible uses for the space included a medical clinic or small retail units, etc. From AS2107:2000 [1] a medical clinic has the stricter requirements with a satisfactory design sound level for consultation rooms in health buildings at 40 dB $L_{Aeq,T}$ with a maximum of 45 dB $L_{Aeq,T}$.

The average noise level ($L_{Aeq,T}$) from impact noise on the slab above is unlikely to be the determining factor in disturbance or annoyance to the users of spaces below. The primary factor in this would be the impulsive / maximum noise levels (L_{Amax}). As such, it was considered that if the L_{Amax} levels from activity on the slab above did not exceed the above criteria then the noise was not likely to cause disturbance to occupants.

2. Investigated Alternatives

Due to the likely cost implications of providing an isolated secondary slab for the extent of the Basketball Court area, a number of alternative options were investigated during the early design stages of the project.

2.1 Isolation of the spaces below

The option was explored to structurally isolate the spaces below, such that they did not share a direct connection to the slab above nor the columns passing through the space. Due to a high floor to

ceiling height, this was seen as a feasible design option.

After a detailed investigation, designing the building in this way would have had several consequences. Firstly, it would place restrictions on the layout of the spaces below, likely restricting the ability to have large open floor plans without significant supporting structure. Secondly, there was a risk of vibration generated by the court activities causing re-radiated noise elsewhere in the building. Further complications included the space below potentially needing an isolated facade line, and a limitation of future flexibility and changes to spaces below the court. As a result, mitigating the noise transfer in this way was not seen as a reasonable solution.

2.2 Resilient matting on non-isolated slabs

The use of a resilient layer of 5 mm matting below the finished sports surface had been implemented successfully in a number of education facilities. Two schools with multi-use games areas located above classrooms constructed were visited.

From testing the facilities with a sample basketball bounce, it was clear in both instances that noise from the court was clearly audible above background noise and even audible above low levels of activity noise in both cases. This audible noise was acceptable for the uses where tested, as the games areas were mostly in use when teaching is not conducted in the spaces below.

Furthermore, both facilities had thicker primary structural slabs (circa 250 mm – 300 mm) than the proposed facility (see Section 3.1). As a result, it was concluded that this solution would not provide the levels of noise isolation required for the proposed development.

3. Structural Performance

3.1 Structural Slab

The structure of the building in this location was complex as it needed to contain a large span composite steel framed slab, designed to be constructed over an operating driveway which served the adjacent Etihad stadium. Due to the use of the space as a joint retail and sports facility, despite these large spans the resulting structure needed to be relatively stiff to satisfy the structural and acoustic requirements.

The floor structure is typically a 150 mm composite concrete slab (Bondek II Metal tray), supported at 2 centers by 900WB175 composite secondary steel beams spanning 15 m.

The project structural engineers performed detailed finite element modeling on the full structure in order to assess the resonant frequency of the slabs. This work showed the resonant frequency to be 5.6 Hz on the tenancy level, and 8.9 Hz on the basketball court level above.

3.2 Spring selection

In order to avoid the 5.6Hz and 8.9Hz structural resonances, WSP required the natural frequency of the floating floor to be √2 or greater away from the resonances [2] under purely dead load (DL) conditions. The rationale for this was to ensure that with minimal damping the resonance of the floating slab would not induce a resonance of the two structural slabs. Therefore the system required a natural frequency of less than 4 Hz or greater than 12.6 Hz.

$$5.6/\sqrt{2}=3.96 \text{ Hz} \quad (1)$$

$$8.9\times\sqrt{2}=12.58 \text{ Hz} \quad (2)$$

A single degree of freedom system's natural frequency can be represented in terms of its static deflection as per equation 3. This equation is derived from the ideal single degree of freedom mechanical spring-mass-damper system, and is accurate for helical steel springs [4].

$$d = g/(2\pi f_0)^2 \quad (3)$$

Where g= 9.81 m/s² and f_0= 4.

Avoiding the resonance of the basketball court level slab was considered the most important factor in the design. Additionally, a resonance of greater than 12.6 Hz would

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limit the overall isolation that would be achieved in audible (>20 Hz) frequencies. As such, it was decided that the natural frequency of the floating floor should not be greater than 4 Hz.

Frequencies generated by human motion range between 1.7 Hz for a slow walk up to greater than 3.2 Hz for sprinting [3]. A natural frequency of lower than 2 Hz was not achievable within the constraints, so the floating floor was designed to have a natural frequency marginally lower than 4 Hz under dead load conditions, which required precision in spring selection and load calculations.

The calculations determined that the system required isolation mounts to be used with a minimum deflection of 15.5 mm.

This deflection within the constrained height could not be practically achieved with rubber mounts; typical rubber mounts have a deflection up to a maximum of 12 mm and relatively high damping at high loads, which reduces their isolating capabilities. The above calculations only apply to the dead load of the slab and don't take into account the greater deflection required for the live load. For these reasons it was considered necessary to use spring mounts.

Whilst the structure was required to support a live load (LL) of 5 kPa from a safety aspect, under normal use as a sports court this load equates to approximately six 80 kg people standing in each square metre, which is an unlikely scenario. Achieving this LL condition provided practicality issues with the requirement for a spring to provide the minimum deflection under DL and support DL + LL within the constrained space. For this reason, the upper bound of design load was reduced to DL plus a third of LL as a more realistic loading for normal use. Under this condition, at the full LL the springs would bottom out, which would cause an increase in the transmission of vibration but would not damage the springs, or the structural integrity of the slab. This was considered an acceptable compromise in order to achieve the acoustic requirements under realistic operating conditions.

For selection, springs needed to deflect at least 15.5 mm under dead load without bottoming out under an additional third of live load. The spring range selected had a rated maximum deflection at 25 mm with an extra 50% safety factor designed into it to allow extra deflection from live loads. For a typical location within the playing areas of the court it was calculated that after a third of LL was applied to the spring there would still be 10 mm deflection available before bottoming out. The calculated deflections can be viewed in Table 1.

Table 1. Calculation spring deflection (mm) of a typical spring located inside the court's playing area.

Spring Type	DL	DL + 1/3L	DL + 5kPa
85mm Diameter Spring	16.7	27.6	Bottomed out

Using equation 3 gives a natural frequency of 3.86 Hz under DL and 3.0 Hz at one third LL. In other locations, such as near the corners or edges of the slabs, the springs were selected for similar deflection under the two conditions.

3.3 Concrete slab design

Standard AS3600 table 4.10.3.2 [5] states that the reinforcement in the slab within 50 km from the sea requires 40 mm coverage. This resulted in a minimum concrete

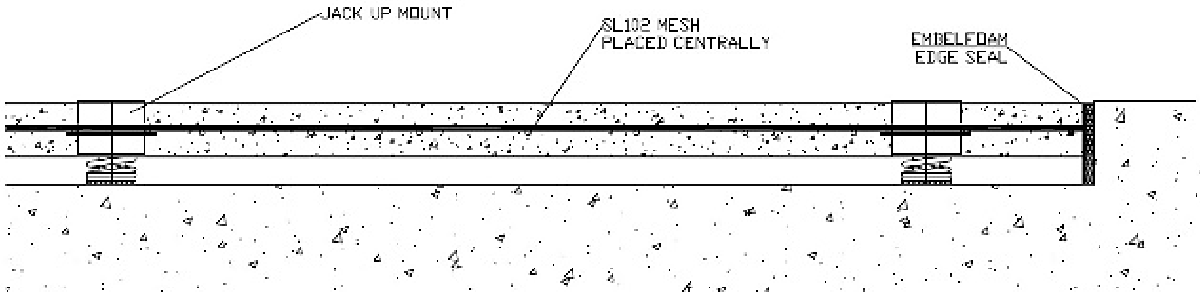

Figure 1. Section drawing of the court slab design

slab thickness of 100 mm so that the reinforcement is adequately covered on top and underneath. The air cavity itself has an important role in vibration isolation, so it was logical to use a 50 mm air cavity with a 100 mm thick slab. This also allows for the full travel of the springs to be used so that the springs will compress to solid before the floating slab touches the structural slab.

A typical construction for a spring-mount supported slab system is for a deck to be placed over the mounts to support the formwork while concrete is poured over the top. However, the required springs would not fit within the 50 mm cavity. The solution was achieved through a jack-up mount system, which would allow a large proportion of the 100 mm height of the slab to be utilised for the springs as well. This had the negative effect of having a reduced airborne noise performance due to the holes required in the floating slab, but since the major concern was for vibration isolation this was felt to be a reasonable compromise.

It was decided that the spacing between mounts should be as large as practically possible to reduce the number of transmission points, decrease the number of penetrations through the slab and increase the dead load per spring. This had the additional benefit of making the project more economical. The maximum practical spacing was to minimise the background noise, however at the time of writing this paper the court was above an unfinished building site. While graphing the results will not give an accurate account of the performance, it will provide minimum values of performance. The measured values were $L_{nT,w}$ 37 dB and FIIC 69 dB.

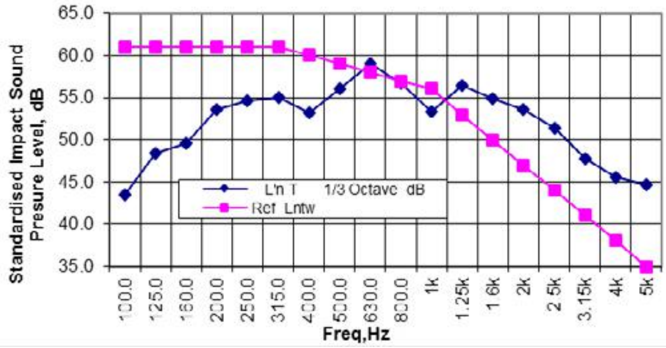

Figure 5. $L_{nT,w}$ measurement on the 150 mm hob, sitting on the structural slab, in dB shown in 1/3 octave intervals

Further tests were performed on the hobs around the perimeter to provide an indication of the improvement of the floating slab as opposed to a solid concrete slab 300 mm thick. The single value results were $L_{nT,w}$ 59 dB and FIIC 46 dB so the floating slab offered a substantial improvement.

them to allow for the floating slab to easily separate from the packer when it was jacked up. The variety of height of the packers used over the floor affected the amount of concrete being supported by each mount substantially. The result of this was that each mounting point had to be carefully recalculated to provide an even deflection over the whole area of the court. Installation of the court system did not encounter any major setbacks or delays.

Figure 3. Typical packing under jack-up mounts

4. Performance Analysis

4.1 ISO10140-1:2010 Impact Noise Testing Results

Field impact testing was performed on the 150mm bare structural slab prior to construction of the floating slab. Impact testing in accordance with ISO10140-1 [6] offers a standardised $L_{nT,w}$ dB rating for the floor. This will provide a numerical value detailing the improvement over the bare slab floor. The test was conducted using a Bruel & Kjaer 3207 tapping machine with a Svantek 958A analyser. 4 tapping machine positions were used with 5 microphone positions for a total of 20 measurements as well as background noise testing and reverberation time.

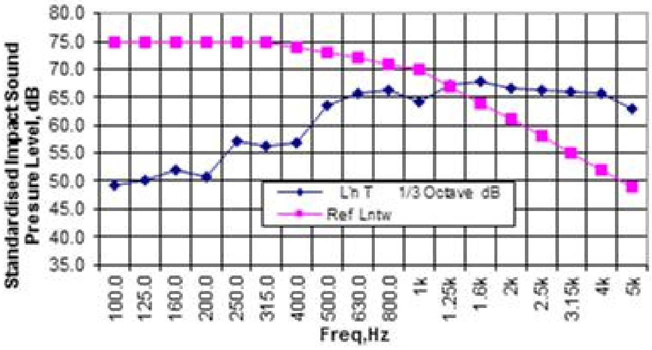

Figure 4. $L_{nT,w}$ measurement on the 150 mm structural slab, in dB shown in 1/3 third octave intervals

These measurements gave an $L_{nT,w}$ 73 dB and an FIIC 15 dB.

Testing was then repeated once the floating slab was poured and jacked up. ISO10140-1:2010 specifies that all measured values must be at least 6 dB higher than background noise and preferably 10 dB above. From the test results, the largest variation was 3.5 dB above background noise, so providing an in depth analysis and graph of these values would not provide any benefit. Testing was performed at night after peak traffic times

1.5 x 1.5 m based on available spring mountings. The corresponding loading required a spring diameter of 85 mm, with 330 mounting locations in total.

The court slab was constrained around its perimeter by a 150 mm high concrete hob, and was sealed with 20 mm thick closed cell polyethylene foam to prevent rigid contact between the slab and the hob which would cause bridging. The edges were also sealed with flexible sealant to prevent water ingress under the floating slab.

3.4 Basketball, netball and tennis post isolation

The posts for the basketball hoop were to be supported on hobs that were not on the floating floor. It was important that these were isolated from the structural slab while not allowing too much movement in the post as any movement would be amplified at the hoop due to the distance from the base.

It was decided to use pads underneath the base of the post with rubber washers located above so that there were resilient elements restraining the post in all directions. To separate the anchor and the base plate a rubber sleeve was also incorporated. This prevented direct contact between the post and any rigid connection to the structure.

The netball and tennis posts were placed in sockets that were recessed into the structural slab. The posts were separated from the floating slab by creating a larger penetration through the floating slab so that the posts could never come in contact and bridge the isolation. The penetrations were capped to resist the ingress of water and sealed around the perimeter with foam.

Figure 2. Basketball post isolation

The netball and tennis posts were placed in sockets that were recessed into the structural slab. The posts were separated from the floating slab by creating a larger penetration through the floating slab so that the posts could never come in contact and bridge the isolation. The penetrations were capped to resist the ingress of water and sealed around the perimeter with foam.

3.5 Installation

The structural slab was greater than 30 mm out of level. To ensure a degree of consistency in the level of the base of the springs, the mounts were packed underneath to allow for the floating slab to be poured flat. Packers were placed in the correct position and a chamfer was created around

Additionally, the unfinished retail space from which measurements were taken was a concrete room larger in area than the court itself with an unfinished ceiling, and glazed door sets which were not sealed. Combined with a lower background noise, it would be expected that the finished space would measure significantly improved values than those shown above.

4.2 Typical activity noise levels

To test the expected noise levels from court activities, an informal basketball game was played on the floating slab with L_{Aeq} and L_{Amax} measurements taken in the space below. Measurements were taken over a 15 minute period during a weekday morning, with background noise registering an L_{Aeq} of 37.2 dB. The results from the testing can be viewed in Figure 7. The L_{Amax} shows intermittent peaks between 48 and 56 dB, which were generated by the basketball posts. As discussed previously, these were not located on the court slab but were separately isolated on the perimeter hobs to decrease vibration transmission. However, during the casual basketball game the ring was tied back to a post which was not isolated but rigidly connected to the hob. It was found that when either a ball impacted or a strong gust of wind rattled the backboard against this post it was clearly audible in the space below. It was expected that when fixed in the proper game position the isolation on the posts would be effective. Shooting for goal was restricted during testing; the peaks in Figure 7 are mostly the result of the wind gusts. Regardless, the L_{Aeq} averaged over the whole 15 minute period of continuous activity was 39.2 dB, which includes the peaks from the backboard. Discounting these spikes, the L_{Amax} reached a maximum just past 46 dB.

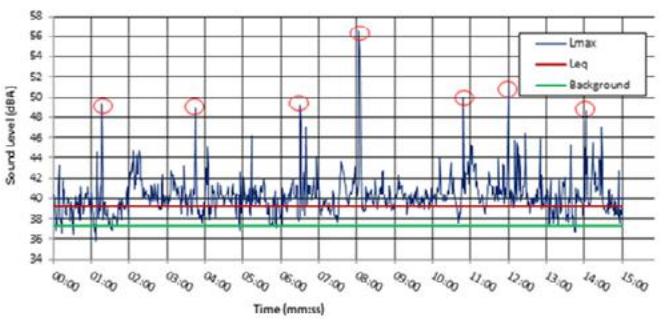

Figure 6. Measurements of sound levels (dB L_{Aeq}) during typical court activity, including bouncing ball, running, passing and occasional shooting

In order to further examine the sound insulation performance and noise mitigation of the floor system a number of scenarios were investigated. The focus of the testing was to obtain L_{Amax} for a number of simulation controlled basketball events that are likely to occur on the court. The three regular activities deemed likely to generate the greatest noise from on court activities were ball bouncing, jumping and shooting.

The environment surrounding the court includes Etihad Stadium and the associated plaza with numerous retail spaces. The plaza contains a number of flag poles which, even in light wind, generate noticeable noise from the chains hitting the metal flag pole.

The condition of the space during this phase of testing was part way through construction. Notably, full height walls had been installed within the retail space, which provided some improvement in reducing the level of background noise.

The results (as shown in Figures 7-9 and summarised in Table 2) indicated the following:

- For bouncing the ball on the court surface, the noise levels although perceptible were similar in value to external noise sources such as the flag poles. The characteristic and change in tone was noticeable above the typical external noise sources.
- Jumping and shooting created peaks in reading of the L_{AMax} that exceeded the typical background readings.
- There was a noticeable difference between the shooting with the hoop fixed back on the holding pole compared to when unhooked and in game position. The noise levels were higher in value and the event would last longer.
- The noise levels measured due to shooting would also be dependent on the outcome of the shot such as whether it hit the backboard or rim, force of the thrower, etc. To simulate this, the shooting style was varied with each attempt.

The main outcome from the testing was that all measured results were within 7 dB of the maximum target for the L_{Amax}. It is expected that the installation of the plasterboard ceiling in the commercial space will reduce peak noise levels in the space from basketball court activity by approximately 10-15 dB. The inclusion of mechanical services to the space will also create a steady masking noise level at circa 35-40 dB.

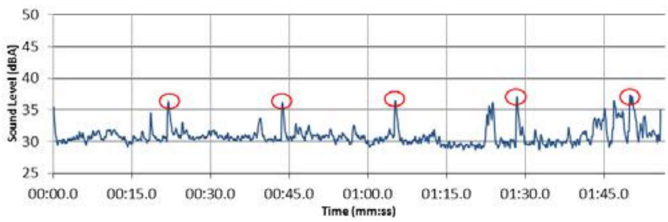

Figure 7. Measurements of sound levels (dB L_{Aeq}) in the retail space during ball bouncing

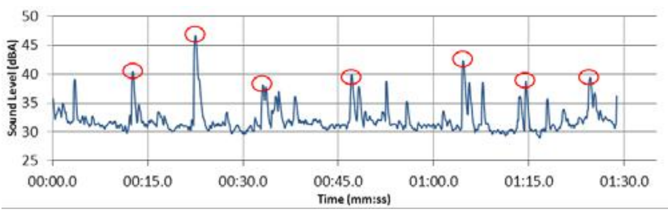

Figure 8. Measurements of sound levels (dB L_{Aeq}) in the retail space during jumping

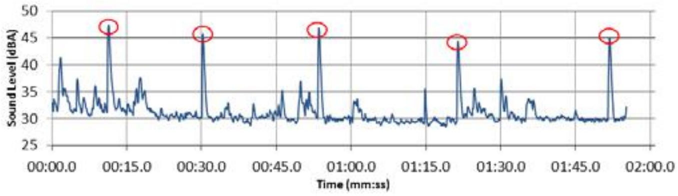

Figure 9. Measurements of sound levels (dBA) in the retail space during shooting with the hoop in game position

Table 2. L_{Amax} in dB for controlled events and typical noise levels

Sound Level (dB)	Ball Bounce	Jump	Shooting-Hoop fixed off court	Shooting-Hoop in position	No activity
Average	37	46	49	41	32
Max	37	47	52	47	39

On court, it was found that when a player jumped near the corners of the slab a small shudder could be felt throughout, even at some distance away. However when this action was repeated within the playing area of the court the response was much less noticeable. Throughout the casual game this was not noticeable and there was no negative feedback regarding vibrations or flexibility of the court. A future design of a court with similar constraints could benefit from the inclusion of internal damping to the springs, which would dissipate the energy in the system caused by impacts more effectively, levelling out the slab faster. However, this damping may reduce the isolation effectiveness in the audible frequency range.

5. Conclusions

This paper has presented a spring mounted floating court system which provides effective noise and vibration isolation whilst meeting strict design constraints. The finished floating court system provided a substantial improvement over the performance of the structural slab with an $L_{nT,w}$ improvement of at least 36 dB. Specific noise testing of typical on court activities resulted in a maximum L_{Amax} of 47 dB. With a future ceiling to be installed, it is fully expected that this value will be reduced to below the established target criteria of <40 dB L_{Amax}. With the inclusion of mechanical services in the tenancies, the noise levels in the commercial space generated by a basketball game above may be inaudible and in any case are highly unlikely to be distracting or disturbing

Acknowledgements

We would like to thank Brookfield Multiplex and CBUS for assisting with site testing and the permission to publish this paper. This paper could not have been prepared without the assistance of Johan Scheuer (Acoustics) and Matt Stapleton (Structures) of WSP Group.

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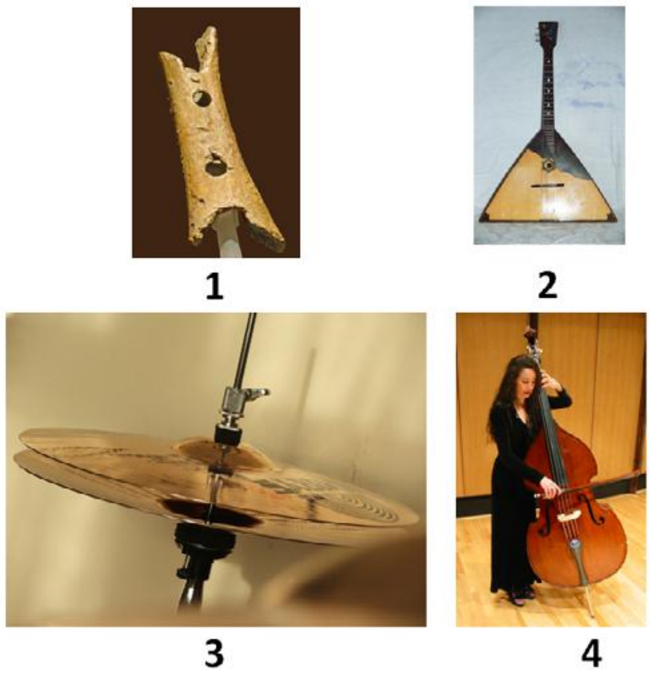
Acoustics Quiz

What are these photos of?



The Acoustical Society of New Zealand

...Continued from Page 3

being from the host country, Australia. In total there were 1106 registrants including 80 accompanying persons.

All papers were presented on the Second Floor Level of the Convention Centre with a large exhibition held in the bay across the corridor from the convention Foyer where a total of 53 exhibitors from all around the world displayed their products and latest technology. Lunch, morning and afternoon tea was provided, allowing all participants to meet, greet and view the exhibitors.

A pre-dinner cocktails allowed those who wanted the opportunity to hold and view Aussie animals which included cute koalas, a goanna, wallabies and dingos. A very successful banquet dinner followed the pre-dinner cocktails which had an Australian bush band as the main entertainment during the event.

We congratulate the exceptional efforts of the organizing committee and all of those who helped organize and run Internoise 2014 it was a pleasure to be able to attend both the conference sessions and dinner. All in all this was an outstanding conference with a great host and high calibre of international papers. Photos from the conference are available from the Internoise website: www.internoise2014.org

Internoise 2015 is in San Francisco, United States of America. Information is available from http://internoise2015.com

Continued Professional Development (CPD) scheme

Following the ASNZ conference in 2012, the then council completed the draft Continued Professional Development (CPD) scheme and issued it to members for comment. Feedback was received from Members and modifications to the scheme implemented on 1 July 2013. The scheme is now operative and the first CPD deadline is July 2015.

The CPD scheme is an important step forward for the society. It provides motivation for society involvement where Members are obliged to seek out or organise opportunities for collaboration with others, and self improvement through attending conferences, technical reading, research and writing papers – particularly for the society journal.

Members are encouraged to start the progress of preparing their record ready for submission. As with any new initiates there may be some teething issues in the first review process so we encourage members to be patient.

ASNZ New Fellow

Congratulations to Ross McBeath who has been announced as the latest Fellow of the Society. Ross has

been involved in the society since its inception in his role as Bruel and Kjaer (B&K) representative. Ross Joined David Reid Electronics in 1981 and took over the sales of B&K in November of that year and continued to represent them until Reids were sold to Dick Smith in 1992. Reid Technology was formed to handle the specialist electronics division, including the B&K range that was not acquired by Dick Smith. After the untimely demise of Mr Reid, Ross formed AVIA Ltd in 2003 to take over the agency for B&K which he ran until his retirement in September 2013, some 32 years of representing B&K. Ross now joins the top rank of the ASNZ along with our current Fellows: Sir Harold Marshall, George Dodd, John Quedley, Mark Johnson, Cliff Robertson and Rod Satory.

ASNZ Standards Involvement

The Society have progressed significantly is its involvement with Standards New Zealand and Standards Australia. ASNZ now has Members on three Standards Committees being AV-001 'Acoustics/Vibration Terms Units and Symbols, AV-004 'Acoustics Architectural' and EV-010 'Acoustics Community Noise'.

ASNZ Member Vern Goodwin is also on AV-004, EV-010 as well as AV-003 'Acoustics Human Effects' in his

...Continued on Page 17

Field Impact Isolation Performance of a High-End Apartment Floor

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Abstract

A timber floor was constructed on a 100mm thick Interspan concrete slab within a high-end residential apartment. The finished timber was nailed using concealed fixings to a plywood substrate. The substrate was atop a 6 mm thick rubber underlay mat which was affixed to the concrete floor system using a polyurethane adhesive.

Impact testing on the completed timber floor / concrete slab was completed prior to the construction of the ceiling in the apartment below. Testing showed that the impact isolation class of the timber floor was much lower than the adjacent tiled areas. The measured impact isolation class (IIC) of the flooring system suggested a shortfall in performance of around ∆IIC 10 in comparison to that calculated for the timber floor system based on available data and theory. Vibration measurements on building elements in the apartment below showed that the floor transmission was the primary, though not only, path of noise transfer.

To determine the reason for the performance shortfall, a hole was cut in the completed floor and testing carried out using a tapping machine. Impact testing on the bare concrete slab showed that the slab was underperforming at high frequencies by around ∆IIC 6when compared to a theoretical prediction model. An initial comparison of IIC values could have lead to the erroneous conclusion that the poorer than expected performance of the slab was the reason for the overall shortfall in performance of the system, however analysis of the measured impact sound pressure levels showed that the timber, substrate and underlay were resulting in a higher level of impact noise at 1 kHz and 1.25 kHz than compared to the bare concrete slab alone. An inspection of the substrate and underlay showed that the adhesive used was significantly harder than expected. The adhesive had also penetrated the rubber matting which had likely resulted in an overall stiffening of the floor system. It was also noted that the use of the adhesive had formed small interstitial voids on both sides of the underlay. It was determined that one of these mechanisms was the primary cause of the shortfall in performance. In order to compensate for the shortfall in performance and to achieve the Building Code minimum level of performance (FIIC 50), a heavy, resilient ceiling and isolated wall linings were specified in the apartment below.

Orginally published at the 22nd Biennial Conference of the Acoustical Society of New Zealand, November 2014

1. Introduction

The construction of quality apartments with appropriate levels of sound insulation requires the design of suitable intertenancy wall and floor systems, the specification of suitable "acoustic" materials and, perhaps most importantly, good on-site workmanship and a strict adherence to the installation guidelines of the product supplier.

This paper summarises an investigation into why a timber floor in a high-end apartment was transmitting significantly more impact sound than would be theoretically expected for the system. This case study is considered to be of interest as it provided a unique opportunity to study the impact isolation class of each element of a floor system insitu, and to compare the measured results with a visual inspection of the floor construction. The case is also considered to be of interest given the potential erroneous conclusions that could have been reached without a careful analysis of the measured impact noise levels in each one-third octave band.

This paper presents the results of our field investigation, dis-cusses our analysis of the measured data and provides an explanation for why this shortfall occurred. The paper con-cludes that the shortfall in performance was due to: the use of a rigid adhesive; adhesive penetration through the resilient underlay; and/or the formation of interstitial voids within the subfloor.

2. Background

2.1 Apartment Shell

In 2006, Marshall Day Acoustics provided recommendations on the construction of a four level mixed-use building in Auckland CBD.

The building was designed to allow apartments to be fitted out on the third and fourth floor of the building, with office and retail spaces on the second and ground floor levels re-spectively. The building was located in a desirable city area and thus a "high quality" level of finish was proposed. In order to ensure this level of quality was achieved, Marshall Day Acoustics recommended that the apartments be designed to improve on the minimum impact isolation requirements of Section G6 of the New Zealand Building Code (i.e FIIC 50 minimum) [1]. The recommended acoustical criterion for the apartments was FIIC 60 to 65.

An Interspan concrete floor system was proposed for the apartments; Marshall Day Acoustics recommended a minimum 100mm concrete topping. The Interspan system consists of precast concrete ribs with timber infill between the ribs. The topping slab is poured on top of this system. The predicted impact isolation class of this system was IIC22 [2].

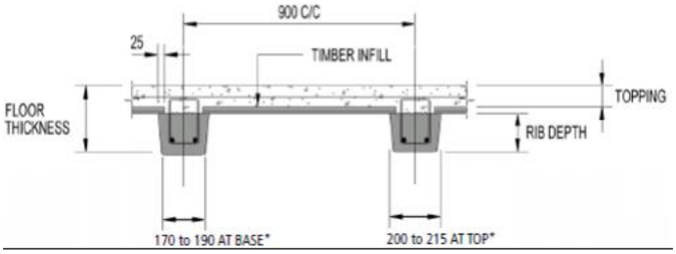

Figure 1. Interspan Flooring System

Based on the above system, it was expected that FIIC60 to FIIC65 could be achieved in the apartment below with the following [2]:

- Solid timber floor or tiles on suitable impact isolating underlay (i.e. ΔLw 16)
- Interspan slab system with 100 mm thick concrete top-ping
- 300 to 500 mm cavity below slab
- Cavity absorption
- Rubber isolation clip between joist and ceiling
- Two layers of 13 mm thick plasterboard (i.e Gib Ultraline or similar)

An alternative construction of 1 x 13 mm Gib Ultraline on a steel suspension system was also suggested as suitable to meet the Building Code minimum requirements.

2.2 Fitout

Fitout of the apartment occurred in 2010. The majority of the apartment floor was proposed to be finished in solid timber, though tiles were proposed in the bathroom areas. A raised flooring system was considered likely to result in the best overall impact isolation class, however this was not considered practicable to accommodate within the apartment shell. Instead the architect and developer proposed to construct the finished floor as follows:

- 19mm thick bleached Canadian Maple timber
- 9mm plywood substrate.
- 6mm thick rubber acoustic underlay bonded to floor slab using polyurethane adhesive.

It was expected that this system would achieve IIC 41 without a ceiling in place [2]. This was based on a theoretical prediction of impact noise transmission together with the claimed impact sound pressure level reduction provided by the underlay [2, 3, 4]. The claimed performance of the underlay was similar to that measured by Marshall Day Acoustics on other projects with similar systems. The claimed reduction was based on field tests performed by the manufacturer rather than laboratory measurements. The field test data appeared to be in accordance with ASTM E1007-97 and ISO 140-7:1998 standards.

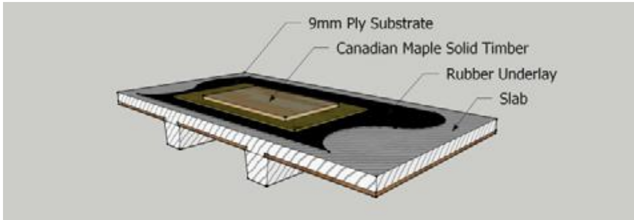

Figure 2. Floor construction schematic

3. Resilient Floor Covering

A rubber underlay was specified for this project. This product consists of flexible rubber sheets made by bonding long, thin rubber granules together to form a rubber mat. The granules are bound in a relatively open matrix with air spaces between the chips [5]. The resilience of the product is considered to depend on the resilience of the rubber itself and the air spaces between the chips. Field test data provided by the manufacturer showed that an improvement of ΔIIC 14 could be expected when the performance of a bare slab is compared to a floor covering of 12 mm Tasmanian Oak floor on a resili-ent underlay[4].

Figure 3. Rubber underlay

Based on the manufacturers data, it was calculated the floor system would achieve an impact isolation class of FIIC62 with the ceiling system discussed previously [2]. This was deemed to be acceptable for the project given the constraints, notwithstanding that it was considered less than ideal for large floor areas.

4. Preliminary Testing Results

4.1 Impact Testing

Auckland Council directed the impact isolation class of the finished floor be tested once completed. Auckland Council required that this testing be completed even though a ceiling was not yet constructed in the Level 3 apartment below. It is understood that no building consent had been lodged for the fitout of the Level 3 apartment at the time the Level 4 apartment was completed.

This testing was completed by an Auckland Council contrac-tor. These results showed that the impact isolation class of the timber floor was between FIIC32 and 34. The same testing on the bathroom tiles (ceramic tiles on Mapefonic underlay) resulted in FIIC40. The Auckland Council contractor noted this discrepancy and raised the potential shortfall in performance of the timber floor as of concern.

Table 1. Comparison of measured and theoretical performance (as tested by Council contractor)

	Measured FIIC	Predicted IIC
Timber floor area	32 -34	41
Tiled floor area	40	42

Subsequent to the receipt of this testing data, Marshall Day Acoustics visited the site and carried out our own testing. This testing gave results consistent with the above. Measurements were conducted and analysed using a tapping machine in general accordance with ASTM E1007-04e1 & E989-06 standards [6, 7].

Figure 4 illustrates the difference between the measured and expected impact isolation provided by the floor system.

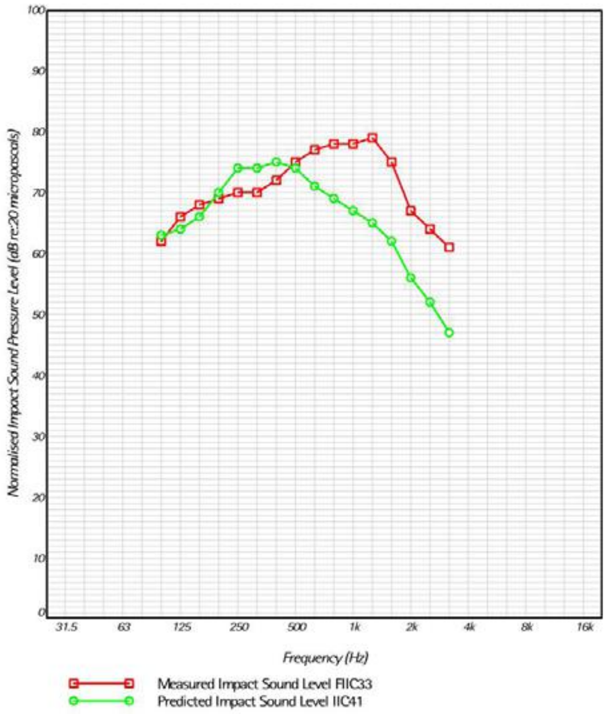

Figure 4. Comparison between measured and expected impact sound pressure levels

It can be seen that the level of impact isolation for the floor system insitu is significantly lower than expected between 630 and 3150 Hz. The shortfall in performance is around 20 dB at 1 kHz.

Impact noise levels would be expected to decrease from around 250Hz onwards, however in this case impact noise levels increase with frequency between 250 Hz and 1 kHz.

4.2 Vibration Testing

In order to determine the reason for this shortfall in performance, vibration analysis of the structure was undertaken. An accelerometer was used to measure the level of vibration in each building element of the downstairs apartment and the contribution to the overall level determined through a consideration of the radiating surface area, frequency and radiation efficiency of the building material as follows:

$$Lw = \alpha + 10\log S - 10\log f^2 + 10\log X + 10 \text{ dB}$$

Where:

S = radiation area (m^2),
f = frequency (Hz),
X = radiation efficiency,
α = Acceleration in dB rel. 10^{-6} m/s^2

The results showed that the main path of impact noise transmission was via the floor slab. However it was noted that flanking transmission was occurring via the plasterboard and masonry walls and other building elements (e.g glazing) and that these may contribute to the overall level once the ceiling was in place. Figure 5 illustrates the measured and calculated contributions to the overall impact sound pressure level without a ceiling in place.

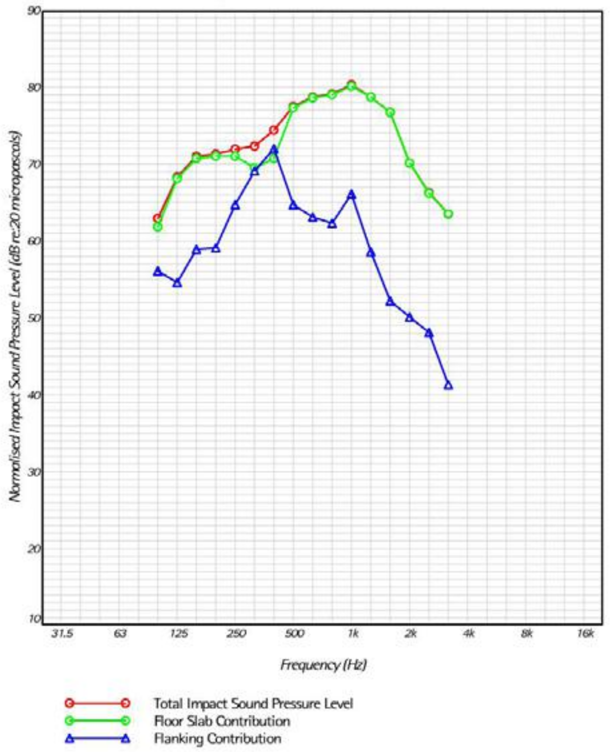

Figure 5. Calculated vibration contribution (from measurements)

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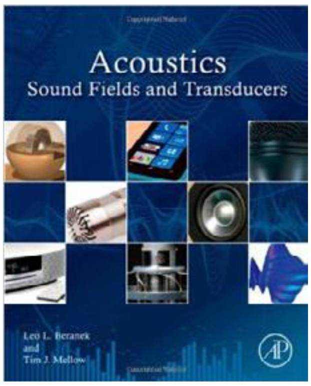
capacity representing the Ministry of Health. One of the most active of these committees has been AV-004 which has been carrying out an update of AS/NZS 2107:2000 'Acoustics – Recommended design sound levels and reverberation times for building interiors'. Members will most likely be aware of this key Standard with many Members providing submission in December of last year.

There are additional Standards Committees which the ASNZ has expressed interest in, but these are inactive at this time. The President continues to actively liaise with Standards New Zealand and look at establishing an ASNZ presence. Development (CPD) scheme and issued it to members for comment. Feedback was received from a from Members and modifications to the scheme implemented on 1 July this time. The President continues to actively liaise with Standards New Zealand and look at establishing an ASNZ presence.

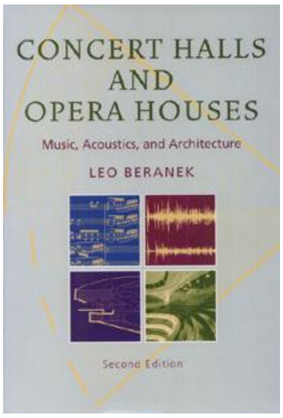
ASNZ Congratulates Leo Beranek on reaching 100 years

The Society belatedly congratulates Leo Beranek on reaching 100 years of age on 15 September 2014 and recognizes his outstanding contributions to acoustics during the century. Leo Beranek was a former MIT professor, and a founder and former president of Bolt, Beranek and Newman (now BBN Technologies).

Leo Beranek authored 'Acoustics', considered one of the classic textbook in this field, and its updated and extended version published in 2012 under the title *Acoustics: Sound Fields and Transducers*.



He is also an expert in the design and evaluation of concert halls and opera houses, and authored the classic textbook *Music, Acoustics, and Architecture*, revised and extended in 2004 under the title *Concert Halls and Opera Houses: Music, Acoustics, and Architecture*.



Here is a sampling of the covers of some of the many other books Leo has authored, co-authored or edited.

The Acoustical Society of New Zealand

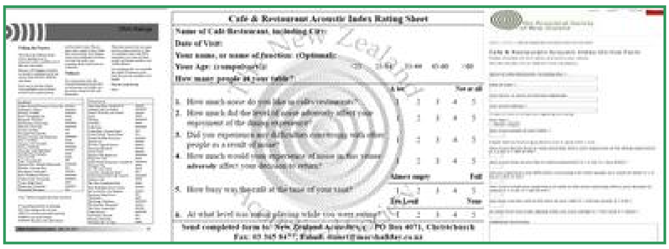
www.acoustics.org.nz

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

Why not visit for yourself?

Cafe and Restaurant Acoustic Index (C.R.A.I.)

The Cafe and Resturant Acoustic Index, C.R.A.I., is now completely online with all results and online forms able to be viewed and download from the acoustics.org.nz website under the C.R.A.I tab.¶



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5. Determination of Cause of Shortfall

In order to determine the cause of the shortfall in performance of the floor system it was determined that a section of the floor would be removed and the impact isolation of the slab measured. It was determined that the bed could be removed and a small area of finished floor below the bed frame could be chiselled out for impact testing. Once the testing was complete, the reinstalment of the bed would conceal the hole in the floor.

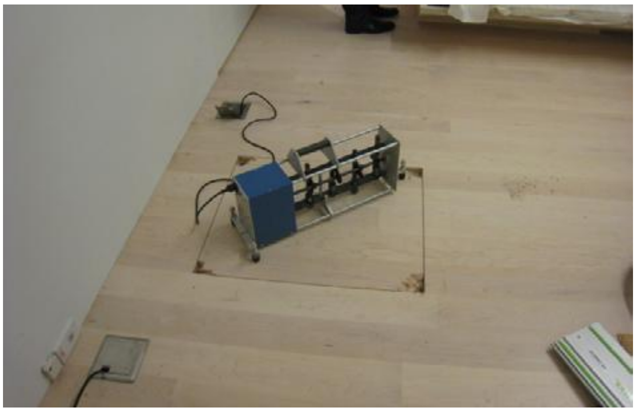

Photo 1. Floor test area with cuts & corners chiselled out

This approach allowed the impact sound level for the bare concrete floor slab to be measured. These measurements showed that the bare Interspan floor slab was achieving only FIIC16 whereas the level of impact isolation that would be expected for a 100 mm thick concrete slab would be IIC22.

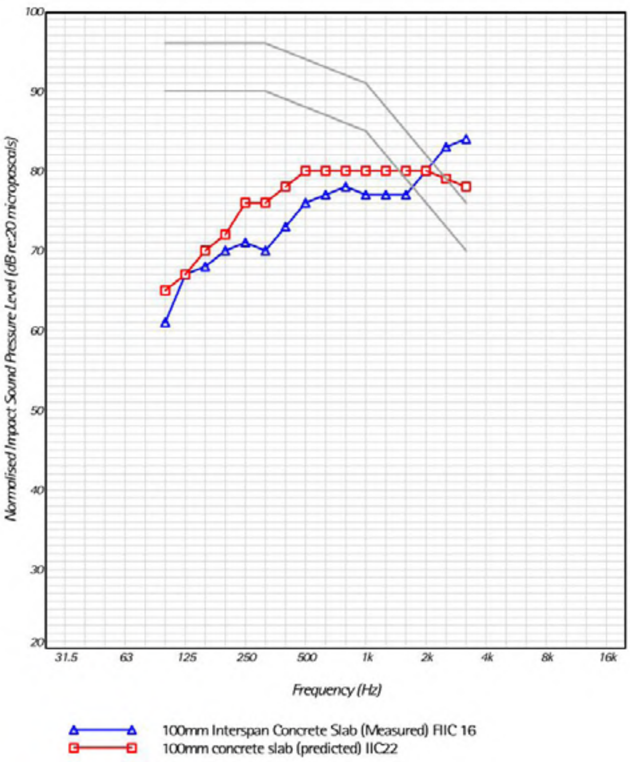

Figure 6. Theoretical vs. measured concrete slab performance

The insitu performance of the slab is compared with the theo-retical level of performance in Figure 6. The measured performance was generally better than that predicted for a 100 mm thick floorslab. However at frequen-cies above 2 kHz the opposite is true: the field performance of the slab is worse than predicted. The Impact Isolation Class of a bare slab is generally determined by the uppermost frequencies of interest and thus the insitu floor slab had a much lower FIIC than expected (FIIC 16 (measured) verses IIC22 (predicted)). A simple comparison of IIC values might have suggested that the shortfall in floor slab impact isolation class was the cause of the overall shortfall in performance of the floor. However this was later found not to be the case when the actual impact sound reduction of the underlay and floor was considered over the entire frequency range. This illustrates the risk of considering only single number rating systems in assessing field performance.

Because the impact isolation of the floor slab was known, the additional isolation provided by the solid timber floor and underlay could be determined through comparing the measured impact sound level from the finished floor with the measured impact sound level from the concrete slab. The difference in these values represents the impact isolation provided by the timber floor and resilient underlay.

As discussed, the manufacturer had previously completed similar insitu testing for the underlay product on a 200 mm thick bare slab.

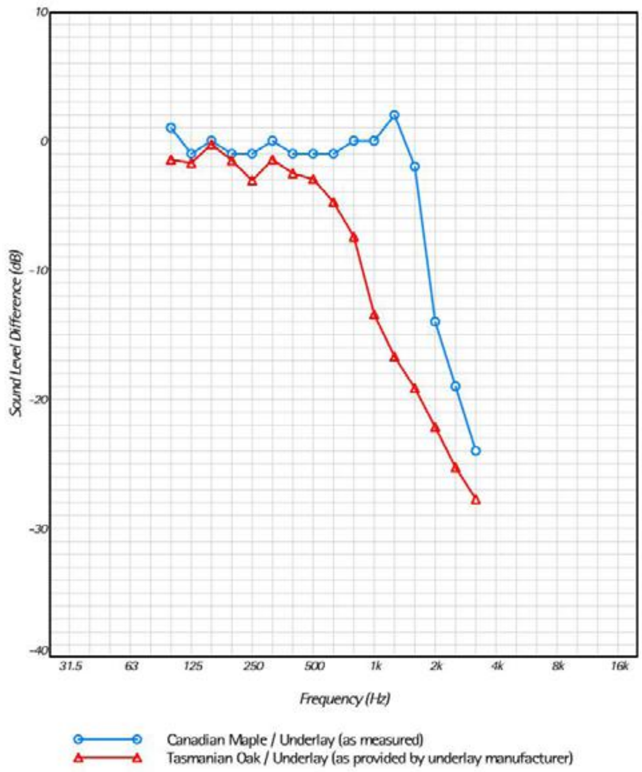

Figure 7. Measured floor / underlay performance vs. supplier test data.

These tests provided a comparison between the performance of a bare slab and the same slab with 12 mm thick Tasmanian Oak on resilient underlay in place.

The difference in sound pressure level for both the manufac-tures test and the subject test is shown in Figure 7. These results demonstrate that there was a significant differ-ence in impact isolation between the subject floor system and that previously measured by the manufacturer.

The difference in performance is most obvious at 1.25 kHz. At this frequency it was expected that the floor / underlay system would reduce impact sound levels by around 17 dB when compared to the bare slab alone, however the measured performance of the system at the subject apartment showed that the system actually increased impact sound transmission by 2 dB when compared to the bare slab alone. The overall difference between the measured and expected performance at this frequency is 19 dB.

The impact isolation provided by the floor system, while not as good as claimed by the manufacturer, does provide isolation between 2 to 3.15 kHz. Reductions in impact sound pressure levels of 14 to 24 dB were measured in this frequency range. This means that while the slab performance was poorer than expected at these frequencies, sufficient impact isolation was provided by the floor and resilient underlay to ensure that the overall Impact Isolation Class is not determined by these frequencies.

Figure 8 shows the effect of the timber and underlay in com-parison to the bare slab together with the fitted FIIC curves. It can be seen that the floor and underlay system (red line) provides negligible improvement over the bare slab (blue line) up to 630 Hz. The increase in impact transmission over the bare slab alone is obvious at 1.25 kHz. The improvement in sound insulation provided by the floor and underlay is significant only above 1.6 kHz.

Also shown is the impact sound level that would have been expected based on the measured performance of the floor slab together with the effect of the underlay as claimed by the manufacturer. There is a significant difference between what was measured and expected at mid and high frequencies.

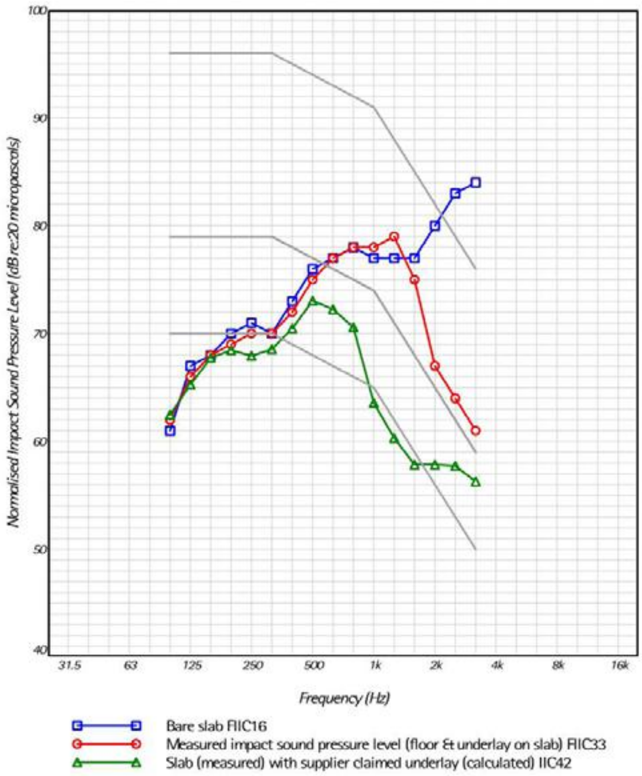

Figure 8. Comparison of a) bare slab; b) timber and un-derlay on bare slab (measured); and c) bare slab with expected performance of underlay as claimed by supplier

6. Site Observations

The removal of a test area of the floor enabled cross-sections of the floor, plywood, underlay and hardened glue to be removed and inspected as samples. Our inspections showed the following:

1. The adhesive used to bond the underlay to the concrete floor was very hard and stiff. The installation guidleines for the underlay specify that the adhesive should be an RLA Polymers RL1017 single part polyurethane adhesive [5]. The manufacturer field test data provided had been measured for a system with Bostik Ultraset as the adhesive. Both of these adhesives are understood to have a low hardness [8]; the Bostik Ultraset technical data sheet states a hardness of "Approx. 52 Shore 'A'" [9]. It is understood that a Selleys Liquid Nails timber flooring adhesive product was used instead of the above adhe-sive(s). This manufacturer is understood to supply several timber adhesives under the "Liquid Nails" brand and it is not clear which exact adhesive system was used. It is noted that some Liquid Nails floor adhesives are claimed to be very stiff while others are claimed to be very flexible. Our inspection showed that in this instance, the polyurethane was very rigid once set.

2. In addition to the above, the adhesive used to bond the resilient underlay to the concrete slab appeared that have been applied generously. A notched trowel had likely been used to apply the adhesive as thick adhesive "ribs" were clearly evident on the underside of the underlay. Because of the generous application, the adhesive had penetrated through the 6mm thick resilient underlay to the underside of the plywood substrate in some areas. The resilience of the underlay was subjectively much lower where the adhesive "ribs" had penetrated the un-derlay. The underlay supplier recommends that the RL1017 single part polyurethane adhesive be used using a 1.6 mm x 1.6 mm "V" notched trowel [5]. RLA polymers state a 3.2 mm "V" notched spreader be used [8]. By comparison, the Selleys Liquid Nails timber flooring guidelines states that a trowel with 5 mm wide by 6 mm high V notch at 25 mm centres should be used for strip flooring [9]. In this situation it is considered likely that a trowel with large, coarse notches was used leading to the significant penetration of adhesive through the underlay.

3. The liberal application of adhesive also resulted in small voids forming between the underside of the underlay and the concrete slab. These voids occurred between the ad-hesive "ribs" where the underlay was not resting in contact with the floor. It is possible that these voids were the cause of, or contributed to, the shortfall in performance observed.

On the basis of our field tests and observations, it was con-cluded that the installation of the resilient underlay was the cause of the shortfall in impact isolation provided by the flooring system.

7. Outcomes of Performance Shortfall

Based on the above results, it was determined that the Building Code minimum level of performance would not have been achieved with the ceiling in place. This was in part due to the level of flanking noise from walls and windows measured using the vibration accelerometer. In order to rectify this, the following was recommended:

- Ceiling to consist of 2 x 13 mm dense plasterboard (e.g. Gib Noiseline or similar) on steel suspension incorporating resilient clips at 900 mm centres (e.g. ST001 clips or similar). 75 mm thick thermal insulation in the cavity)
- External wall linings to be 13 mm thick standard plasterboard on resilient clips (e.g. ST001).
- Internal wall linings as standard. Any full height framing to be resiliently isolated at the head of partition using partition supports at 400 mm centres (e.g. Masons MPS)

It is understood that the above recommendations were not followed; specifically the resilient isolation of the wall linings and internal wall framing was omitted from the fit out of the downstairs apartment. It is understood that only the rec-ommendation relating to the apartment ceiling was followed.

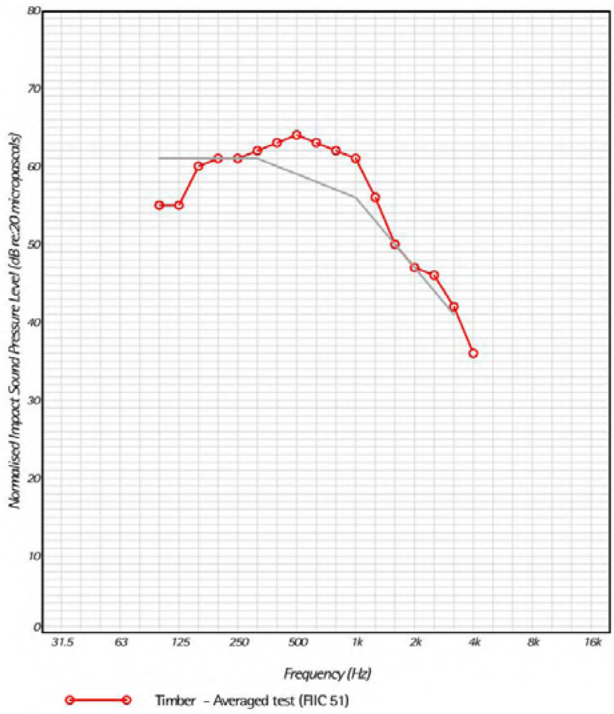

Figure 9. Normalised impact sound pressure levels with ceiling and wall linings in place (FIIC51)

Final measurements performed by Marshall Day Acoustics and the Council contractor showed that the above construc-tions achieved FIIC51. This performance just complied with the Building Code minimum of FIIC50 but did not achieve the high level of sound insulation recommended for the apartments.

8. Summary and Conculsions

This paper summarised an investigation into why a timber floor in a high-end apartment was transmitting significantly more impact sound than would be theoretically expected for the system.

The results of the study showed that adhesive penetration through the resilient underlay was the likely cause of the shortfall in performance. This shows the importance of careful workmanship on-site in ensuring that the project field performance ratings will be achieved.

The study also illustrates the importance of careful examination of field data and shows that simple comparisons of single number ratings (such as FIIC) may lead to erroneous conclusions.

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Happy New Year to all, we hope to you had a relaxing Christmas and we are looking forward to bringing you more Court decisions which involve acoustic issues throughout 2015.

It was a busy end to 2014 with the Court of Appeal decision being released involving Palmerston North City Council and New Zealand Windfarms Limited, as well as two High Court decisions involving the Waimakariri District Council and the North Canterbury Clay Target Association, and the NZ Aviation Museum Trust and Marlborough Aero Club against the Marlborough District Council and Colonial Vineyard Ltd. Following are brief summaries of these proceedings but full copies of the decisions can be found on the RMA Net website at www.rma.net

In the Court of Appeal

PALMERSTON NORTH CITY COUNCIL - Appellant

NEW ZEALAND WINDFARMS LIMITED - Respondent

[2014] NZCA 601, 38p, [104] paras, 9 December 2014

Summary of Facts

In 2005 New Zealand Windfarms Ltd (NZWL) was granted consent by the Council for a windfarm comprising 97 turbines in the hills to the east of Palmerston North, know as the Te Rere Hau Windfarm. After two thirds of the project was completed NZWL discovered that the consent application had significantly under predicted the actual noise generation characteristics of the turbines and their noise impact on surrounding residents. The Council wished to hold NZWL to its prediction of the noise effects under Condition 1 of the consent, and NZWL appealed. In decision [2012] NZEnvC 133 the Environment Court found that NZWL was bound by both its own predictions about sound levels generated (Condition 1) and by the specific noise standards contained in the consent conditions (Conditions 4 and 5). On appeal to the High Court, Williams J held that Condition 1 could not be used in that way and set aside the Environment Court decision ([2013] NZHC 1504) but in a further judgment, [2013] NZHC 2654, Williams J granted the Council leave to appeal to the Court of Appeal.

The Council appealed on three points of law;

(a) Did Condition 1 apply to either or both the noise generation characteristics and performance of the turbines, and the noise effects at receiver locations?

(b) Was it lawful for the High Court, rather than the Environment Court, to determine if the windfarm had been constructed, operated or maintained in a manner which complied with Condition 1?

(c) Was Williams J right as to scope of the application for the windfarm if the answer to a) was no and to b) was yes?

As such the appeal focused on whether Condition 1 enabled the Council to hold NZWL to its prediction of the noise effects which would be generated at source by each turbine or whether the Council needed to rely on the specific noise Conditions 4 and 5.

The Court agreed with Williams J that Windfarms' predictions of the noise effects the turbines would generate at source were not in themselves on the "scope" of the Windfarm, enforceable by the Council through Condition 1. The Court considered the Judge rightly regarded those predictions as components or "inputs" in the calculation for NZS6808 and the Plan required assessment of noise effects to rely on the NZ Standard which was applied through Conditions 4 and 5. The Court agreed with Williams J that when properly interpreted Conditions 1 and 4 were consistent, both saying the wind farm must be operated so as to produce noise effects at the notional boundaries of local residents at no greater than 40 dBA L95 or 5 dBA above background noise, whichever was higher.

The Court note that it was vital that the Council had effective means to control adverse effects on others from the noise generated by the windfarm. This came from Conditions 4 and 5, and then s 128 RMA which enabled the Council to review the noise consent conditions applicable. The Court felt that resorting to Condition 1 was unnecessary and inappropriate in the current circumstances. Overall the Court felt it could be said that the windfarm was not being "operated generally" in accordance with the predictions in the consent application, but it did not consider Condition 1 was intended to be the control on sound levels generated. To suggest that was to render Conditions 4 and 5 largely, if not completely, otiose.

Judge Randerson however, did not agree with the conclusion reached by the majority of the Court. The Judge felt that the Council could not be criticised for seeking to enforce Condition 1 instead of Conditions 4 and 5 as there was insufficient data available at the time of the Environment Court hearing to enable that to occur. The Judge was satisfied that the evidence strongly supported the Environment Court's declaration.

Court held:

Appeal dismissed, by majority.

In the High Court

NORTH CANTERBURY CLAY TARGET ASSOCIATION INCORPORATED - Appellant
WAIMAKARIRI DISTRICT COUNCIL - Respondent

[2014] NZHC 3021, 20p, [68] paras, 28 November 2014

Summary of Facts

In 2007 the Association applied to the Council for a certificate of compliance to confirm that 52 shooting meetings and 52 practices could lawfully be held each year without a resource consent at its shooting facility in the Rural Zone at 269 Boundary Road, Cust. The application was accompanied by a noise assessment report which maintained that the noise at the then nearest dwelling complied with the permitted activity noise limits of the Waimakariri District Plan and as such the activity was a permitted activity under the Rural Zone rules. The Council granted the certificate in 2008, but subsequent lifestyle block subdivision closer to the facility resulted in complaints and the Council applied to the Environment Court for declarations that the shooting activities were not permitted under the Plan and the Certificate of Compliance should not have been granted.

In decision [2014] NZEnvC 114 the Environment Court held that the evidence demonstrated that the activity, as it was and was predicted to be, complied with Plan Rules. However, the certificate of compliance did not allow for the exceedance of the noise limits in the Plan Rules for any dwellings that had come into existence after the date the certificate of compliance was applied for. The Association appealed on two questions of law;

(a) Whether the reference to "any dwelling house in the Rural Zone" in the noise condition was limited to a dwelling house existing at the time of commencement of the permitted activity; and
(b) Whether the certificate of compliance obtained by the Association as a deemed resource consent under the Act exempt it from compliance with the noise limitation rule as a result of changing circumstances in the receiving environment.

The Court accepted that the Environment Court's interpretation meant that the noise standard in practical terms would become increasingly onerous on the Association as dwellings were constructed closer to the site of its incumbent activity. However, the Court noted that the rule was designed to have continuing application across a dynamic receiving environment and the unqualified reference to "any dwelling house" in the condition created an ongoing obligation on an incumbent to control its noise levels. The Court did not accept that in the present context a certificate of compliance could be construed as the equivalent of a resource consent and that the certificate always remained subject to the noise limitation condition whether it was "deemed" a resource consent or not.

Overall the Court found that the term "any dwelling house" in the noise condition was not limited to structures that existed at the time the certificate of compliance was sought and that the rules continued to apply to the activity in the face of changing physical circumstances over time, such as the establishment of dwellings closer to the noise source of the activity. The certificate of compliance, while a deemed resource consent under the Act, remained subject to the conditions specified in the plan. As such the Association was subject to a continuing obligation to abide by the noise limitations specified in the condition, notwithstanding the changing surrounding physical environment.

Court Held:

Appeal dismissed.

undertaken by the Environment Court supported the finding that PC59 was not inconsistent with either Chapter 12 or specifically policy 12.7.2.1.3.

In relation to the future environment the appellants challenged three aspects; the treatment of plan changes 64-71; the consideration of future regulation; and the Court's assessment of likely noise effects on the site. The Court was satisfied that given the early stage of development of the plan changes, the Environment Court reached a reasonable conclusion, and similarly for the assessment of the likely future regulatory environment.

...Continued on Page 30

Prediction of Geothermal Two-phase Silencer Discharge Sound Level

[1]Kim Harwood and [2]Malcolm Hunt

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[1]kim.harwood@contactenergy.co.nz [2]mha@noise.co.nz

Abstract

The operation of a geothermal steamfield or power station requires the intermittent discharge of process fluids to atmosphere to maintain stable operational control or to start-up or shut-down. The energy in the discharge is partially converted to sound which can impact on the receiving environment. Typically the design for two-phase or saturated water flows is a silencer consisting of a inlet jet pipe flowing into a horizontal duct to a vertical barrel. It is relatively simple, cost effective and the sound level design predictions have been approximated on previously installed units of similar size and duty.

With increasing environmental awareness there needs to be more certainty in the sound level prediction so that new plant is not operationally constrained or require modification after commissioning. A design prediction method is proposed that was determined from test data of operational silencers, process industry jet sound power calculations and an adapted model for viscous sound attenuation within the inlet duct. Limitations in the method, designer guidance and future investigation areas are also discussed.

Originally published in the Proceedings of the 36th New Zealand Geothermal Workshop, 24 - 26 November 2014, Auckland, New Zealand.

1. Introduction

The conventional geothermal well steam-water silencer consists of an inlet jet pipe, inlet duct, vertical barrel with tangential entry and water duct (figure 1). This simple design has not changed in 55 years and is in wide spread use throughout New Zealand and the world. It is relatively simple and economical to manufacture. They are used to intermittently discharge either production wells to atmosphere for start-up or output tests, or separation plant discharges to atmosphere for start-up or plant upset reasons.

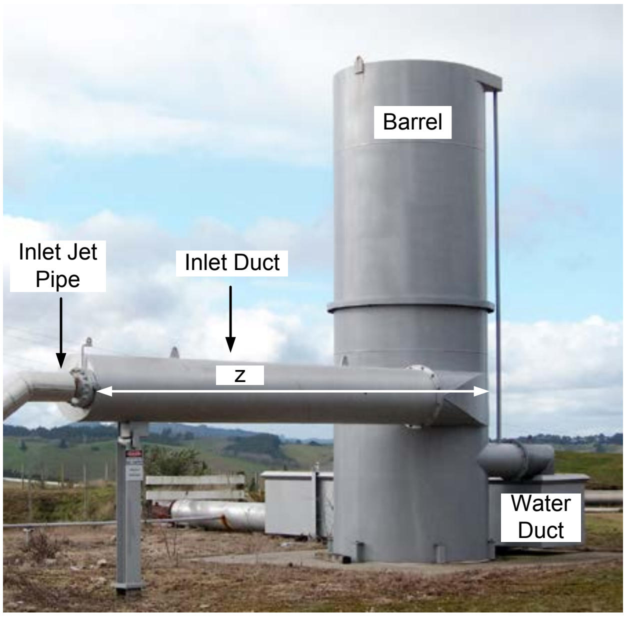

Figure 1: Geothermal Two Phase Silencer

The description as a silencer is relative. It quietens the turbulent flow noise caused by the expansion of steam-water mixed flow into the duct. However to the environment beyond the plant area they less acceptable with a intrusive low frequency rumble. Because of this the steamfield plant owner can be restricted in hours of operation, have difficulty complying with consent conditions and incur greater capital cost to mitigate the sound levels with additional reduction devices or less than ideal plant relocation.

Production well pads which are sited to optimise reservoir production govern the location of well silencers relative to the surrounding environment. Separation plants are located for multitude of factors of which sound is usually one of the lesser. Currently early in the preparation of land use consent applications a sound budget is prepared based upon operating scenarios, expected locations and estimated sound power levels of the steamfield plant equipment. The inputs may be well defined from plant manufacture type tests for example reinjection pumpsets. Other items, for example the conventional well silencer are estimated on historic ad-hoc tests. As the silencer sound levels are strongly influenced by mass flow, enthalpy and inlet duct length as explained in this paper, wide variation of actual sound levels to historic can be experienced. This can be unexpected and costly to correct late in construction, or for example after deepening existing production wells. This could be mitigated by estimating conservatively high but the disadvantage of this can be

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to take too large of share of the sound budget away from other plant areas and impact the project's business case.

2. Process Flow Design

The purpose of a silencer is to discharge geothermal flow in a controlled manner to atmosphere and water drain. The sound source is the sudden pressure drop of inlet flow generating flashed steam and this mixture accelerates up to sonic speed (approximately 500 m/s) at the vena contracta downstream of the inlet jet pipe. The exit velocity quickly decreases as it expands into the horizontal inlet duct. Here the steam superficial velocities are moderate at 70 to 150 m/s and near atmospheric pressure before slowing within into the vertical barrel down to 5 to 15 m/s. The tangential entry to barrel develops cyclone action that separates the water against the barrel walls, before with gravity assistance runs down to the base and out the water duct.

If the inlet duct or barrel is undersized relative to the inlet conditions, water will exit the barrel exit creating nuisance for plant maintenance and hot rain onto personnel. It can also cause increased back pressure in the base of the barrel and blowout the water duct steam seal resulting in inaccurate weir flow measurement and hot water splash hazard to personnel. There are a range of standard model sizes available to the designer whose selection is weighted towards the conservatively larger. The length of inlet duct is normally determined to decelerate the flow before reaching the barrel to prevent excessive cyclone velocity and water droplet exit from the top of the barrel.

Because the duct and barrel diameters are selected on the above flow velocities, and they are relatively large e.g. 0.6 to 3.3 metre for geothermal production wells. Adding this to the inlet jet's pipe size selection of 100 to 250 mm, then most of the sound power is concentrated in the lower frequencies below 250 Hz.

3. Silencer Sound Concept

The kinetic energy in the vena contracta of the expanding jet of steam and water is partially converted to sound. This jet has turbulent shear eddies which for the typical size of jet pipes are heard as a low frequency roar. Although the conversion efficiency is very low in the range of 0.3 to 0.9 % for geothermal inlet pressures, the sound power levels are in the order of 150 to 160 dB. This is a similar source level to a fighter jet engine on takeoff.

The source sound reverberates within the inlet duct containing a mist regime (due to high superficial steam velocity) of two-phase flow travelling to the barrel. The water fraction of the flow in mass terms for well enthalpies in the range of 700 to 1550 kJ/kg is 87 to 50 % respectively. In volume terms it is only 0.4 to 0.06 %. The sound power is attenuated by viscous vibration of water mist. This attenuation dominates over any other silencer effect that may occur due to semi reverberant inlet duct and source sound that has most of its energy in the low frequency region.

The sound is discharged at the vertical barrel exit. There is little attenuation due to directivity to the observer due to the large barrel diameter and low frequencies (Day et al, 2009). The barrel exit sound level is the most dominant because the other sources of sound radiation from the inlet duct and barrel wall (approximately 105 dB) or induced suck leakage at the inlet pipe (approximately 110 dB) are at least 15 dB lower and are not significant in the measured far field levels.

The typical sound spectrum (figure 2) is weighted in the low frequency band with 80 % of the sound power below 250 Hz. The difference between the A and C weighted scale sound pressure levels is at least 10 dB, sometimes up to 20 dB. Distance will filter out the mid to high frequency content compared to the sound at source. This has the effect of emphasizing the low frequencies and the rumble perception. Low frequencies are more efficient at bending over obstacles or terrain and more easily pass through the lightweight fabric of typical New Zealand buildings.

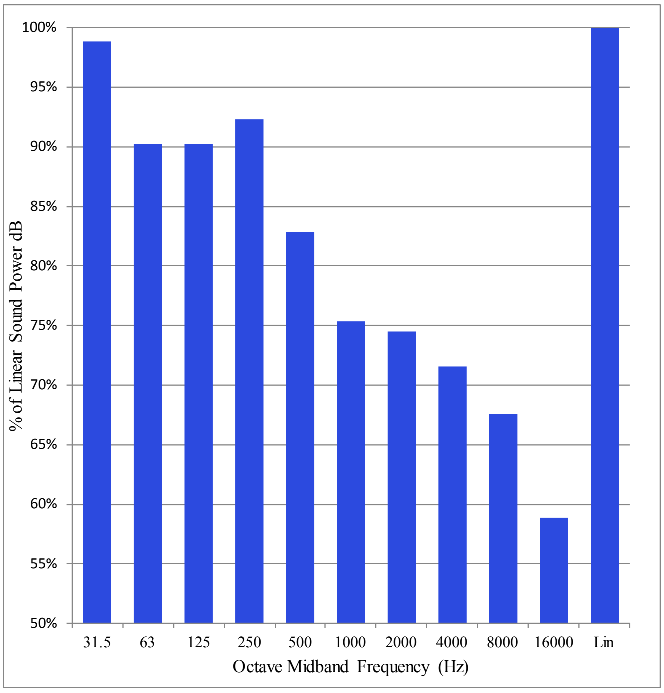

Figure 2: Typical Sound Spectrum

Dry steam sound prediction methods have been published (Lazalde-Crabtree 1985) for silencers using reaction-absorption or plenum designs. Rock pits are widely used in the geothermal industry for power station venting and the performance is known. Additionally vendors have proprietary muffler designs. These designs use various techniques to reduce sound levels and filter low frequencies i.e. pipe diffusers, tortuous plenum passages, absorptive material. These have additional capital or maintenance cost, loss of flow capability, more difficult flow measurement and are not the first selected by the plant designer to reduce two-phase silencer sound levels.

Two-phase sound prediction methods have not been previously published for the geothermal industry and this paper proposes a simple and quick means for the plant designer to judge whether the simple design is appropriate for the process conditions and physical location.

4. Numerical Sound Prediction Method

The aim of this sound prediction method is to improve the accuracy to an acceptable level while using simple process flow and acoustic calculations. It can be simply implemented on spreadsheets or programmable calculators. This calculation doesn't require the inlet pipe, duct and barrel diameters, the number of inlet ducts and barrels, or the thickness and materials of the silencer.

The inlet mass flow, pressure and enthalpy are normally measured during a geothermal wells output test using the James Method (James, 1970). The jet and inlet duct conditions are determined from the assuming adiabatic flashing to atmospheric conditions. The steam pressure in the inlet duct is assumed to be atmospheric and saturated.

$$x = (h - h_f)/h_{fg} \quad (1)$$

$$m_s = m_i\, x \quad (2)$$

$$m_w = m_i - m_s \quad (3)$$

$$V_s = m_s\, v_g \quad (4)$$

If the inlet duct pressure is lower than the critical pressure (P^*) of the jet steam, the vena contracta will be at sonic velocity (~ 500 m/s). Additionally the jet is not confined, isentropic recompression exists and sound emitted is due to turbulent flow shearing. The sound power of steam jet entering the inlet duct can be determined using process industry methods described in standards and recommended practices (IEC 60534-8-3 and API RP 521). These have been adapted for this paper's prediction method. The API method is presumed to use the early work of Franken in the 1950s to determine conversion efficiency of the jets kinetic energy to acoustic.

$$P_* = P_j \left(\frac{2}{\gamma+1}\right)^{\left(\frac{\gamma}{\gamma-1}\right)} \quad (5)$$

$$W_j = \frac{\eta m_s c_j^2}{2} \quad (6)$$

Where c_j and γ are determined from steam properties

η is determined from figure 3 which is an conversion of the API RP 521 chart scale for sound pressure at 100 feet and numerically this is

$$\text{If } \left(\frac{P_j}{P_d}\right) > 2.8,\ \eta = 10^{0.53\log\left(\frac{P_j}{P_d}\right)-2.86)} \quad (7)$$

$$\text{If } \left(\frac{P_j}{P_d}\right) < 2.8,\ \eta = 10^{8.87\log\left(\frac{P_j}{P_d}\right)-6.59)} \quad (8)$$

Sound power is converted to power level (dB):

$$L_j = 10\log\left(\frac{W_j}{W_{ref}}\right) \quad (9)$$

The phenomena of sound wave scatter and absorption by material confined within a tube has been rigorously studied by others. The calculations are complex and so the authors sought a practical alternative and chose to test the analogous phenomena of light waves scatter and absorption.

The Beer-Lambert Law for inverse exponential power law intensity light attenuation through a concentrated solution in a tube has been adapted.

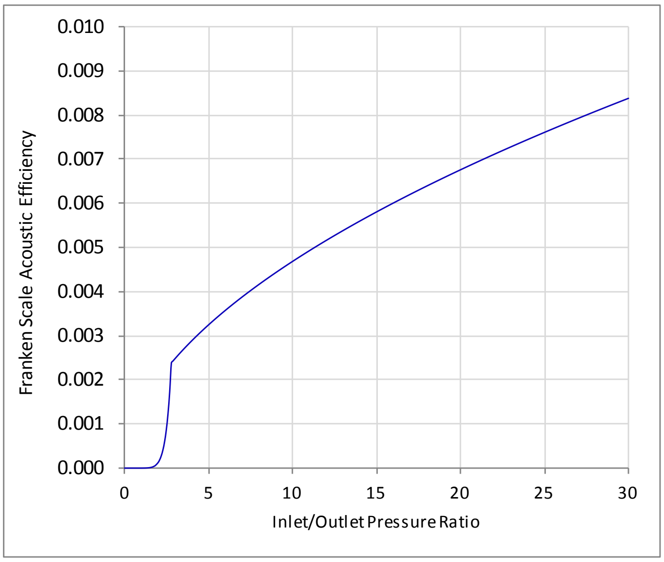

Figure 3: Franken Scale Conversion of API RP 521

The light attenuation coefficient is the mathematical product of absorptivity factor, tube length and concentration of solution in the tube.

$$TR = e^{EzC} \qquad (10)$$

$$Ln(TR) = EzC \qquad (11)$$

where E is the absorptivity factor
z = tube length
C = solution concentration

When adapted for sound attenuation we have

The inlet duct length is shortened by the relative inlet duct and sound speeds. The effective length is

$$z' = \frac{z}{\left(\frac{c_a+u_d}{c_a}\right)} \qquad (12)$$

C = water concentration in inlet duct steam flow

$$= \frac{m_w}{V_s} \qquad (13)$$

The test result data has determined that the absorptivity factor is constant but the transmission ratio has an offset (b) which is apparently constant, due to 1) acoustic attenuation from the abrupt enlargement of the inlet duct into the barrel and 2) sound suppression in gas-water jet mixtures which is not well understood due to the complex physics interactions (NASA-HDBK-7005). Modifying equation (11) for the transmission ratio offset, effective length and water concentration we have

$$Ln(TR) = a(z'C) + b \qquad (14)$$

Where: a is the absorptivity factor = -0.175
b is the TR offset = -3.6066

To determine the barrel exit sound power

$$W_e = W_j TR \qquad (15)$$

Sound power is converted to power level (dB)

$$L_e = 10\log\left(\frac{W_e}{W_{ref}}\right) \qquad (16)$$

To determine the observers sound pressure level at distance requires the observers distance from barrel, directivity index of barrel exit and using the assumption of half sphere sound propagation (i.e. across flat ground and without atmospheric absorption for short distances). Because of the dominant low frequencies and large diameter barrel the directivity index (DI) will only be in the range of 1 to 3 dB (Day et al. 2009, figure 2).

$$L_o = L_e - DI - 20\log(R_o) - 8 \qquad (17)$$

5. Experimental Data and Discussion

Process and sound data was derived from historic commissioning records and recent plant tests by the authors. The data is across a broad range typical of geothermal plant in six locations.

Well output test and plant flow measurement data was correlated to the timing of sound level measurement. Sound pressure measurements were captured at 10 or 20 metre horizontal distance from the silencer barrel wall to calculate the source sound power level. Other sound sources were measured to ensure that they were low enough to not contribute to the field measurement and could be discarded.

Table 1 – Experimental Data Range

	Minimum	Maximum	Unit
Inlet Pressure	7.0	26.6	bar.a
Inlet Mass Flow	27.5	177.8	kg/s
Inlet Enthalpy	713	1545	kJ/kg
Inlet Duct Length	5.6	14.1	m
Inlet Duct Diameter	0.61	1.2	m
Barrel Diameter	1.2	3.3	m
Barrel Exit Sound Power Level	118.8	140.9	dB

Table 2 contains the data inputs and calculation results to validate the prediction method. The empirical linear fit (figure 4) of inlet duct absorptivity coefficients are:

a = -0.1705, b = -3.6066 and fit R^2= 0.96

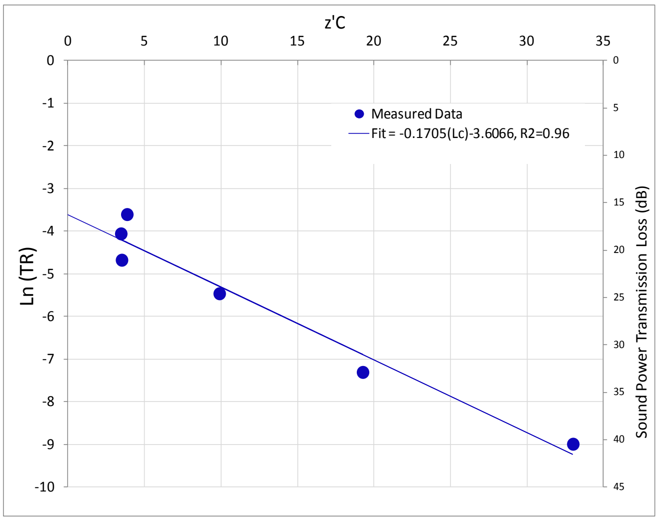

Figure 4: Measured Data Fit

Coefficient b is the apparent offset when the Beer-Lambert Law adaptation is used and it appears to be constant. Some of this offset is due to the abrupt enlargement from the inlet duct to barrel of approximately 4 dB. The remainder of the offset, 12 dB we postulate is due to complex water noise suppression inside the jet, which is beyond the scope of this paper.

We can conclude that the sound prediction model has good accuracy within about 2 dB of the experimental data. It is valid across a broad range of geothermal silencer process conditions.

6. Future Investigation of Method

Future improvements in the prediction method is expected to come from investigation into:

a) very low inlet pressure and low enthalpies where the jet velocity is less than sonic.

b) the difference between dry steam and steam-water mixture sonic velocities. Initial calculations indicated that this factor lowers the prediction accuracy and doesn't reduce the apparent offset in the b coefficient.

c) the influence of sound breakout relative to the transmission ratio when long inlet ducts are used.

d) additional experimental data.

7. Designer Guidance

The greatest influences on the reduction of barrel exit sound power levels given typical geothermal process conditions in priority are –

1) Lower inlet enthalpy
2) Longer inlet duct length
3) Lower inlet flow
4) Lower inlet pressure

During the preliminary design of the plant the engineer needs good pre-estimates of well enthalpy or plant process temperatures to predict silencer sound levels that contribute to the overall sound budget for new projects or existing steamfields.

8. Conclusion

A sound prediction method for geothermal two-phase discharge silencers has been developed and validated for a broad range of process conditions. It is relatively simple and quickly calculated to an accuracy of about 2 dB.

Accurate sound level prediction allows the designer to mitigate the environmental sound impact of steamfield or power station developments.

Table 2 – Data Inputs and Calculation Results

No.	m_i (kg/s)	P_j (b.a)	*h* (kJ/kg)	z (m)	z' (m)	Barrel Dia. (m)	Cal *Lj* (dB)	Field *Le* (dB)	*TR*	*TL* (dB)	*C*	*z'C*	Ln *TR*	Difference between Model & Measured *Le* (dB)
1	27.5	7.0	1363	5.6	4.90	1.83	157.6	141.9	0.02722	15.7	0.79	3.85	-3.60	2.9
2	28.3	12.4	1417	5.6	4.84	1.83	159.3	141.7	0.01732	17.6	0.71	3.45	-4.06	0.6
3	177.8	7.0	713	10.6	8.83	2.6	160.6	121.6	0.00012	39.0	3.74	33.0	-8.99	1.1
4	41.1	26.6	1545	7.25	6.16	2.3	162.9	142.6	0.00934	20.3	0.57	3.50	-4.67	-2.0
5	118.9	15.1	1033	14.1	12.76	3.3	163.9	132.2	0.00067	31.7	1.51	19.3	-7.30	-1.8
6	104.4	17.7	1227	12.9	9.76	2.6	164.9	141.2	0.00425	23.7	1.01	9.89	-5.46	-0.7

Nonmenclature

a	Absorption Attenuation Slope Coefficient
b	Absorption Attenuation Constant Coefficient
C	Water Concentration in Duct Steam Flow (kg/m3)
c_a	Steam Sonic Speed at Atmospheric Pressure (m/s)
c_j	Steam Sonic Speed at Jet Inlet Pressure (m/s)
DI	Sound Directivity Index (dB)
E	Absorptivity Factor
h	Inlet Flow Enthalpy (J/g)
h_f	Inlet Duct Water Enthalpy (J/g)
h_{fg}	Inlet Duct Evaporation Enthalpy (J/g)
L_e	Barrel Exit Sound Power Level (dB)
L_j	Jet Sound Power Level (dB)
L_o	Observer Sound Pressure (dB)
m_i	Mass Flow (kg/s)
m_s	Steam Flow (kg/s)
m_w	Water Flow (kg/s)
P_*	Steam Critical Pressure (bar.a)
P_d	Inlet Duct Pressure (bar.a)
P_j	Jet Inlet Pressure (bar.a)
R_o	Observer Distance from Barrel (m)
TL	Sound Power Transmission Loss (dB)
TR	Sound Power Transmission Ratio
u_d	Inlet Duct Steam Velocity (m/s)
v_g	Inlet Duct Steam Specific Volume (m3/kg)
V_s	Steam Flow Rate (m3/s)
W_e	Sound Power of Barrel Exit (W)
W_j	Sound Power of Steam Jet (W)
W_{ref}	Sound Power Reference Level (10^{-12}) (W)
z	Inlet Duct Length (m)
z'	Inlet Duct Effective Length (m)
η	Franken Scale Jet Acoustic Efficiency
x	Duct Steam Mass Fraction
γ	Steam Specific Heat Ratio at Jet Inlet Pressure

Acknowledgements

The authors wish to thank Contact Energy for permission to publish this paper.

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In the Environment Court

P & I PASCOE LIMITED - Applicants
[2014] NZEnvC 255, 41p, [137] paras, 18 December 2014

Summary of Facts

A direct referral proceeding in which P & I Pascoe Ltd (Pascoe) applied for consent for a new cleanfill site on a 26 ha property at 261 Twilight Road, Clevedon. The site was rural, being predominantly in pasture, but contained a house, and a clay pit which was operating under an existing land use consent, and was zoned Rural 1 under the Auckland Council District Plan (Manukau Section). The contour of the site varied from slightly sloping to moderately steep gullies, with the cleanfill proposed to be located over 4.3 ha in the easternmost gully which contained a small, heavily silted, degraded stream which flowed eventually into the Papakura Stream.

The proposal was for the importation and placement of 650,000m3 of cleanfill over a 20 year period and work and infilling over a length of approximately 160m of a permanent watercourse and as such the Plan required resource consent for a non-complying activity. The main objections were from local residents, a cycle club and the Brookby Environmental Protection Society Inc. The submissions highlighted adverse effects which centred on traffic safety, ecology and noise which the Court discussed in detail.

Noise effects were particularly focused around machinery noise, with the experts disagreeing on the classification of activities associated with the establishment and operation of the cleanfill which attracted different acoustic maxima and duration. The significance being that under NZS 6803:1999 Acoustics-Construction Noise the activities would attract less stringent noise limits than operational activities. The proposal mentioned a successive bund concept which would move progressively upslope to mitigate the adverse noise effects. Normally a bund would be classified under the definition of construction, however the Court requested parties to clarify how the successive bund concept would be achieved in practice. There was also discussion of the operational noise limit applying to the notional boundary of the rural zoned site and details of noise expected from machinery.

The Court concluded that with the mitigation proposed, and enforced conditions, it considered the proposal was not contrary to the objectives and policies of the operative District Plan. It felt that when viewed objectively the adverse effects of traffic safety, operational noise and general amenity effects of the proposal would not be greater than minor. The Court was satisfied that the adverse effects of the proposal could be managed to a point where they were acceptable and that the positive effects would outweigh the disadvantages that would remain.

Result:

The application should succeed and, subject to a satisfactory resolution of the bunding concept, and of issues about draft conditions, the resource consents should be granted.

Acoustics Quiz Possible Solutions (Vol 27, #3)

1. Acoustic tracking tag attached to fish.
2. For a 1 kHz signal in water the loss by medium absorption is approx 0.008 dB/100 m. In air, the loss is approx 1.2 dB/100 m hence sound absorption in water is less than in air at 1 kHz.
3. Sound Power Level is the rated acoustic output independent of environment, it cannot be measured directly where as sound pressure level can be measured and is generally dependent on the location relative to the source, and the environment in which the source is located.
4. 3 dB.
5. Loudness is the characteristic of a sound that is primarily psychological and hence is a perceived subjective quantity where as a sound level in decibels is a physical quantity and may be measured objectively noting that the decibel unit is used not only to measure sound but also widely used in electronics, signals and communications.
6. The phon is a unit that is related to dB by the psychophysically measured frequency response of the ear. At 1 kHz, readings in phons & dB are by definition, equal. For all other frequencies, the phon scale is determined by the results of experiments in which volunteers were asked to adjust the loudness of a signal at a given frequency until they judged its loudness to equal that of a 1 kHz signal.
7. Yes.
8. According to the theory of interference of waves, two waves with exactly the same amplitude & frequency can either reinforce [if in phase] or cancel [if 180° out of phase].
9. STC stands for Sound Transmission Class
10. A hemi-anechoic room has a concrete floor and can be used for testing in an essentially free field over a reflecting plane where as a semi-anechoic room has a carpet floor and is used for various other tests.¶

NOVEM 2015 Noise and Vibration Emerging Technologies. Dubrovnik, Croatia. 13th - 15th April 2015
www.novem2015.sciencesconf.org

Wind Turbine Noise. Glasgow, Scotland. 20th – 23rd April 2015
The Series of international conferences on Wind Turbine Noise started in 2005 and takes place every two years. The 2015 conference will be held Monday 20th April to Thursday 23rd April 2015 at Radisson Blu Hotel, Glasgow, Scotland.
www.windturbinenoise.eu

International Congress on Ultrasonic's. Metz, France. 11th – 15th May 2015
www.2015-icu-metz.gatech.edu

169th Meeting of the Acoustical Society of America. Pittsburgh, USA. 18th – 22nd May 2015
The 169th Meeting of the Acoustical Society of America will be held Monday through Friday 18-22 May 2015 at the Wyndham Grand Pittsburgh Downtown Hotel, Pittsburgh Pennsylvania, USA where a block of rooms has been reserved.
www.acousticalsociety.org/content/spring-2015-meeting

EuroNoise 2015. Maastrict, Netherland. 31st May – 3rd June 2015
Euronoise 2015, the 10th European Congress and Exposition on Noise Control Engineering.
www.euronoise2015.eu

22nd International Congress on Sound and Vibration (ICSV22). Florence, Italy. 12th – 16th July 2015
www.icsv22.org

Inter-Noise 2015, San Francisco, USA. 9th – 12th August 2015
The 2015 International Congress and Exposition on Noise Control Engineering, will be held in San Francisco, California, United States of America, 9 -12 August 2015. The Congress is sponsored by the International Institute of Noise Control Engineering (I-INCE), and is being organized by the Institute of Noise Control Engineering of the United States of America (INCE/USA) and in cooperation with the Korean Society of Noise and **Vibration Engineering (KSNVE). Early bird registration closes 11 May 2015**
www.internoise2015.com

12th Wespac 2015. Singapore. 6th –10th December 2015
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Inter-Noise 2016. Hamburg, Germany. 21th – 24th August 2016
www.internoise2016.org

The Development of a Noise and Weather Monitoring System using the Cellular Network

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Abstract

This paper describes some of the technical and other issues encountered in developing a noise and weather monitoring station. A System of 31 stations has been developed capable of measuring and reporting 1 second L_{Aeq}, L_{A50}, L_{A90}, L_{A95}, L_{Amax}, L_{Amin} and one third octave band data, in real time, to a web server. Fifty SMS commands allow such things as remote calibration, noise alarms, and real time audio recording. The owner/ operator can ring a logger at any time and listen to the site microphone, and the server can be programmed to record audio when noise exceeds alarm limits.

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1. Introduction

This all started in about 2004 when an oil exploration company requested supply of telemetered noise and weather data from two sites in New Plymouth. Early equipment used UHF radio and was quite successful, but was later replaced in 2013 with the internet based system that is the subject of this paper. Hard on the heels of this radio system, Marshall Day Acoustics in New Plymouth asked if we could develop a semi-portable logger for simultaneously monitoring noise and weather in the New Plymouth region, and that's how the current project got started.

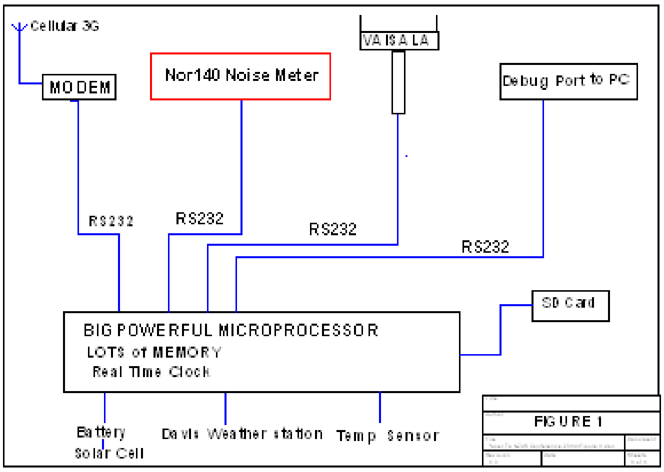

Figure 1

2. Data Collection

Collecting noise data from a sound level meter (SLM) is not all that difficult. Most SLMs will store the data collected and make it available at the serial or USB port for download to a PC, although unfortunately, none of the manufacturers have agreed on a standard set of commands or download format.

The Norsonic class 1 Nor 140 SLM will respond to three letter serial port commands to do anything that can be selected from the keyboard, such as stopping and starting the meter, selecting the measure- ment period, weighting, resolution, third octaves, etc. Simple three letter commands will also instruct the meter to stream the Lx data, third octaves, 1 second L_{Aeq} and other data to the meter serial port, which can be connected to a microprocessor for storage and uploading on the internet. For example, 'UB0,900" will cause 900 sets of 1 second L_{Aeq} values in the format xx.y, to be streamed to the serial port. Lx values are requested separately one at a time. In essence, in a logger, the meter is set to a 15 minute recording period, as if doing a normal noise assessment. At the end of 15 minutes, the microcontroller stops the meter, downloads all of the 1 seccond data and stats from the previous 15 minute period, and restarts the meter.

Once this process was mastered, a microprocessor board was developed that would interface to the serial port of the meter, the serial port of a Vaisala weather station, the data port of a Davis weather station, and the serial port of a cellular modem. The board also had a 4th serial port for debug purposes to a PC. (Figure 1.)

3. How it Works

When the unit is first powered up, the modem contacts the server via the cellular 3G network and the internet and gets the time in GMT from the server. The processor converts GMT to local time (including DST). The internal RTC is set to local time at this point. The processor then starts the SLM for a 15 minute measurement period.

During the next 15 minutes, the processor continuously looks for incoming phone calls and texts, and averages things like weather, battery and temperature. At the end of the 15 minute period, the processor stops the meter, downloads the noise data to its memory, and restarts the meter – all of which takes 15 seconds so 15 seconds is lost from the beginning of the next measurement period.

At this point, two copies of the date and time-stamped data are saved to the local SD card, and the unit then attempts to connect to the server via the cellular radio network and the internet. If the connection is successful, then a copy of the noise and the weather data together with the date and time it was collected, is sent to the server in Palmerston North. If the upload is successful, a message back from the server instructs the processor to delete one copy from the SD card.

If an upload is unsuccessful, the SD card data is retained until a future data upload is successful. About 5 years of data can be stored on a single SD card.

4. First Hiccup

In the early days, company ******* was used as the cell provider. The processor board code was written in- house, but the modem code was contracted out to a Wellington software house. At that time, most of the intelligence was in the modem not the processor, and the modem was responsible for doing all of the communications with the website, getting the time from a web server and managing data flow from the processor board to the web site. Naively the word of the cellular provider - that data communications would be reliable and trustworthy - was taken at face value. It wasn't. Almost every night, the provider would shut down the link at around 1 am for maintenance, or worse, disconnect it entirely without warning or explanation.

At that time, noise data was streamed from the noise meter to the modem without intervening storage, so of course an outage on the cellular data network resulted a hole in the data. Unfortunately at about the same time the Wellington programming experts began having troubles of their own, and their code solutions were not really up to the task, so they were replaced by another larger more expensive Wellington company. Modem software cost alone to date was $ 9000.

However, fortunately before the second replacement started work and incurred further software spend, they were taken over and new policies dictated that outside work was to be discontinued. Development once again was stalled – but it could have been worse.

This was November 18 2010. On that date, it was decided that all software must be written in house in order to maintain control. A new processor was selected, a new board layouts done and four months invested in writing new code (this time in house) for a new modem on the telecom network. This work was completed on 20th of February 2011 and took over 500 man- hours.

5. Realtime Clock - Hiccups 2

It is imperative of course that the date and time of data collection is maintained correctly and accurately. Initially data was stamped with UTC, which is 12 hours behind NZ local time. In some ways this is a better approach in that stations anywhere in the world are all on the 'same page', and there is no daylight savings to take into account.

Initially, the modem collected UTC from a US based time server in Colorado, which worked well until the US Government 3 years ago for fiscal reasons, decided to no longer fund US based world time servers. This was catastrophic because it potentially affected each remote logger, some of which were hundreds of km away and it was not a simple matter to reprogram them. (At that time, remote firmware updates were not possible). Fortunately it was realised that the Palmerston North Inspire server (where the data is stored and the web site is hosted), and all other HTTP servers for that matter, returns GMT after very HTTP transaction so this was read this every 15 minutes, and the local RTC kept GMT. However it's very inconvenient to need to remember that this morning's data is date and time stamped with yesterday's date, but this afternoons date is correct but the time is 12 hours behind, but if it is summer, then the time will be 13 hours behind. After mental gymnastics on a daily basis while doing devel- opment and troubleshooting, it was decided that local time would suit everyone better; now GMT from the server is converted to local time every time the server is contacted, and the logger RTC checked and kept in sync with local time. Even though the logger RTC can maintain time to within a few seconds a month, check- ing the server time every 15 minutes assures perfect time keeping.

Incidentally, the algorithm that decides if the time is summer or winter time is not easy, as DST does not stop and start on a fixed date in New Zealand - it changes on the first Sunday in April and the last Sunday in September, which are on different dates, and may even be in different weeks, each year.

6. SMS Command - Hiccups 3

Because the cellular network is used for communicating with the remote loggers, it is relatively simple to program SMS commands. There are about 50 SMS commands, which allow SMS control of many logger functions from a cellphone. For example:

- Remote calibration check
- Calibration adjust
- Time check of the RTC
- Battery check
- Reset meter
- Reset modem
- Turn noise alarms on and off

- Read cellular signal strength
- Read meter serial number
- Bootload new firmware
- Whoru

The SMS initiated calibration check initiates a known 1 kHz signal to the microphone input on the preamplifier, which generates an output of 92 dB. The level that the meter sees is reported back to the user by text message, and should be the same as previous tests. It is also graphed on the server page. This is a check of the preamplifier, meter, cables and telemetry, and web site display. It will detect serious microphone damage, but only if the damage loads the injected signal voltage.

As in any electronic system software developments are continuous, and it is essential that firmware in the remote loggers is easily changed. Initially, this could only be done by swapping the SD card at the logger, but now, new code can be put up onto the web server followed by a coded SMS to the remote station telling it to download the new firmware (operating code) from the server.

Every SMS to the logger generates a reply to the sender. If the sender makes spelling mistake or sends an invalid command, a response is texted back saying:

> " I'm sorry 027* *** ***, I don't understand that command. Please try again"

In hind sight that may have been a mistake: In 2013, a logger at Pahiatua was playing up, requiring a service call. Plugging a laptop into the debug port at the logger site revealed a message from telecom:

> "Welcome to telecom. To connect to the internet ensure your APN is ....blah blah blah blah blah....",

to which the logger replied:

> "I'm sorry 4227. I do not understand. Please try again".

This had been going on for about two days, and blocked the 3G channel. Telecom (Spark) do not send these unsolicited text messages to our loggers any more.

The "whoru" text is useful in quickly checking if everything is alive and well, and the response includes ID, battery volts, sim serial number and site name.

7. SMS and Email Alarms

The logger will send an email to up to eight (8) email addresses whenever the unit powers up for the first time, or whenever predetermined noise alarm limits are exceeded. All SMS commands to the logger also elicit a text response to the sender.

8. Listen-in Feature

An unattended noise logger has the major disadvantage that attributing noise to particular source can be very difficult. Shape, duration and level of 1 second L_{Aeq} profiles can be used to ID some sources such as aircraft and traffic [1,2,4]. At major airports radar information is also collected for ID purposes [3]. However for most other noise monitoring, audio recording of the source is the ultimate. Unfortunately audio files are too large and expensive to send via the cellular network, and compression to one of the many lossy formats is technically challenging with a non-specialized processor. To overcome this major downside, a new mode has been developed. A codec has been incorporated into each logger, allowing incoming calls to be picked up, in parallel with normal measurements.

Figure 2.

This makes it possible to ring a site from any telephone, and listen to the remote noise meter microphone from the comfort of the office for example- and to identify a noise source by actually listening to it.

A server app also allows the user to pre-program noise recordings several times a day, on the basis of either time of day, or noise level. With SMS, the user can program the logger to instruct the server to ring up the logger and record audio from the microphone.

The automated recording works on the premise that every 5 seconds, the logger looks at the L_{Aeq}, L_{A10} or L_{Amax} (user selectable). When a threshold is exceeded, the logger sends a message to the server saying

> "please record the noise at xxxx{site ID} for the next nn seconds".

The recording is date and time stamped and stored on the server for future analysis and use in identifying the source. The profile and stats curves are of course easily cross referenced to the recording.

There are two minor downsides to this method: currently there is no audio buffer in place so the recording is usually 10 – 20 seconds after the event, and secondly there is a small cost associated with the cellular phone calls. However, these minor problems are overshadowed by the huge advantage of being able to listen a unattended logger at anytime from anywhere.

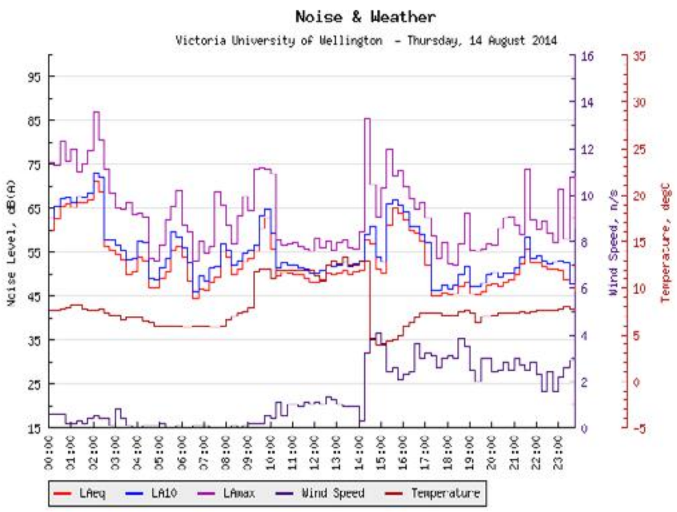

Figure 3

Figure 3 is the day of August 14 2014. At 2 pm, there was a lightning strike in Wellington, accompanied by the classic wind speed and direction shift of a thunderstorm. The L_{Amax} was over 85 dB; except for 5 am September 5, no other L_{Amax} event of this magnitude is seen in the months on either side of this event. The monitor is at Victoria University and the lightning strike destroyed the wind wand at Wellington airport.

9. Future Work

Currently, the loggers find their biggest use in monitoring noise from oil and gas exploration, motor racing, geohermal energy, and sea ports. Future work is aimed at improving audio recording for lower cost real-time recording. The possibility of producing lossy format low sample rate MP3 files at the logger site with a local codec is currently being developed.

Acknowledgements

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