New Zealand Acoustics

Volume 26, 2013 / #1

Why We Should Keep Christchurch Town Hall

Sound Transmission through Triple Panel Walls

European Test Standards for Noise Barriers
& their Relevance to New Zealand

Accuracy and Purpose of Building Insulation Measurements

ISSN 0113-8359

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New Zealand Acoustics

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Features

Regulars

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Contributions to the Journal are encouraged, and may be sent directly to the Editor either by email, or by post c/o the Acoustical Society of New Zealand Incorporated, PO Box 1181, Auckland.

From the President and Editor

From the President

Dear Members,

Somebody please write me an email!

You can make it a letter if you prefer, but I'd very much like to hear your thoughts on the Society and... well anything else related to NZ acoustics. I've had the president@acoustics.org.nz email address for a number of months now, and I'm not sure I've received a single email. This could mean a couple of things but being an eternal optimist, I'll not dwell too long on any negative connotations. You're welcome to write me a negative-connotation email.

What I hope it means is that everybody is happy. You're happy that New Zealand has a society that brings together the acoustically-inclined. You're happy with the new membership regime. You're happy with the journal. In which case, that's great! I like receiving positive email every bit as much the others.

But what I suspect it really means... is that you hadn't really thought about it. Maybe for you, the Society is just something you think about every few months when the journal arrives... or every couple of years when the conference happens (next year in Christchurch, if you were curious). You know it exists, you know that you're a member, but beyond that it just gets buried in the hustle and bustle of every day.

If this is the case, all well and good... but I'd still like to know about it. I think this column is a good way for me to share my thoughts, but the cycle won't be complete until you send yours back. I look forward to it.

In my last column I talked about finding ways to expand membership by increasing the list of benefits we offer to members. One idea I have here is to approach those acousticians who I know have not joined and ask if there's

Publication Dates and Deadlines

New Zealand Acoustics is published quarterly in March, June, September, and December.

The Deadline for material for inclusion in the journal is 1st of each publication month, although long articles should ideally be received at least 2 weeks prior to this.

Society Membership

Associate Membership of the Acoustical Society of New Zealand is open to anybody interested in acoustics.
Members receive benefits including;

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anything we could be doing better, that might help them change their mind.

Also, I often wonder if we could be widening our net to include people in acoustics-related fields, such as audiology, architecture or sound engineering. Would widening the net dilute the focus that we have on environmental, building and room acoustics too much, or is it a case of "the more the merrier"? I'd really like to hear your thoughts on that. Our tiered membership system allows for people with weird and wonderful backgrounds to get involved at an Affiliate level... and I for one would welcome this (although to be honest I'm not sure there are many disciplines that are more weird or wonderful than acoustics).

For those who are involved at a Membership level, Continued Professional Development (CPD) is at the top of our list. We aim to have a system in place at the start of our next membership year (1 July) where in order to fulfil their membership obligations, each Member will be required to record and submit their professional development. The requirements won't be onerous, and we'll have to manage the fact that we have a biannual conference (which conflicts with an annual CPD requirement), but it will be there. This means Members will be thinking about how they can meet the requirements... which means there'll be an incentive for more branch meetings, ASNZ lunches, conference attendance and journal submissions. This will be a good thing.

Speaking of journal submissions, John has put together another enjoyable read for you this issue. We are very pleased to present a paper by Sir Harold Marshall on the Christchurch Town Hall, as well as two other NZ acoustics heavyweights – Keith Ballagh and Dr. George Dodd (et al). Enjoy!

I'd like to notify members that the first draft of the Auckland Unitary Plan has been released for public comment - see the notice on page 29. This may serve as light reading for some of you (it's only 7000 pages long), but I encourage anyone with a professional interest to use the online search function to find the noise rules, and provide feedback to Auckland Council.

Last thing - I've been asking some questions about where the process is at for deciding the future of the Christchurch Town Hall, but the only thing that's clear is that the political wheels are still turning, and it's still hanging in the balance.

Let's hope common sense prevails. In the meantime... please write me an email!

Yours faithfully,

James Whitlock

Editor's Ramble

Dear Readers,

Happy New Year for 2013 and welcome to a new volume of NZ Acoustics!

The first page of this issue contains a short opinion piece from Sir Harold Marshall, who is well known in the New Zealand acoustics community for his involvement in the design of the Christchurch Town Hall. On page 3 he makes a passionate plea for the restoration of this iconic building.

This is followed by an article from Keith Ballagh about modelling sound transmission through triple panel walls; modelling these complex wall constructions is an area in which Keith has a particular interest and he has made several previous contributions to this field.

The next paper is from Giles Parker with information about noise barrier standards, focussing on European standards and how they might apply in NZ.

The final article is from another group of regular contributors at The University of Auckland, led by George Dodd. This work is a consideration of sound insulation measurements for buildings.

I would also like to draw your attention to a job advertisement on page 11. NZ Acoustics is happy to include relevant employment opportunities in future issues; please contact Fadia (details opposite) for more information.

I look forward to bringing you more acoustics news and articles of interest as the year continues.

All the best,

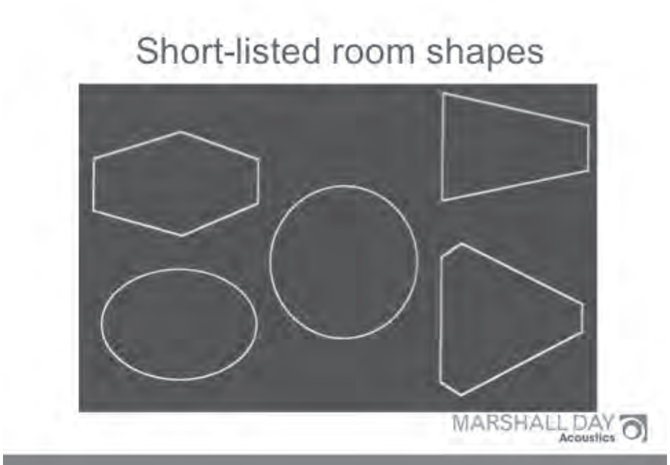
John Cater ¶

Op-Ed: Christchurch Town Hall Should be Restored

Sir Harold Marshall

There is a real risk in writing about one's own work - and that at a distance of 40 plus years - that everything set down will be heavily discounted as being philoprogentive. Be that as it may, if one is an adjunct to the design as acousticians invariably are, perhaps the reflections of the servant class in the grand domain of architecture may avoid the trap. Yes, I feel a sense of ownership of the project but that is as nothing compared to the commitment Warren and Mahoney must feel.

As an architect myself I admired the architectural competence of submission #16, when, in Southampton, I set about preparing an acoustical report on each of the five short-listed designs. There was not a single "shoe-box" amongst them as you can see from my recollections of the designs. Of course the ellipse was faceted even in the first submission. None of these made my task any easier – especially as the request came with a directive to respond by cable within two weeks! The Lincoln Centre debacle had just blown up in New York and cast doubt on the most comprehensive text ever written on the subject, "Music Acoustics and Architecture" by the eminent Leo Beranek. He had been the consultant for the New York Philharmonic Hall, indeed his book was in part preparation for that hall.



There in Southampton I realised that there was no guideline – other than a narrow "shoe-box" - which could produce the excellence the competition sought.. The Royal Festival Hall had started with that basic idea, but failed in its reverberation time prediction (by 40%), and in the production of "Clarity" rather than "singing tone". In fact RFH produce the exact opposite to what was intended. Clearly the hall rectangularity per se was not a determining issue. RFH was also double the width of the halls on which it was modelled. – The Leipzig Gewandhaus, the Vienna Grossermusikvereinsaal, and the Boston Symphony Hall.

My wife and went up to a concert at RFH. As I listened and pondered these issues I realised that there was only frontal sound – the lateral reverberation was inaudible. That started the hunt for a reason for this experience and led to my paper "A note on the importance of Room Cross-section in concert halls". Professor Erwin Meyer to whom I sent a draft, promptly invited me to Goettingen to discuss it and the rest is history. I wrote my reviews of the designs including this insight and sent them off. Number 16 turned out to be the Warren and Mahoney submission.

Thus the Christchurch Town Hall design and the discovery of the importance of lateral reflected sound in concert hall preference are linked in a unique way. The importance of the discovery arises from the fact that for the first time there is an overt architectural implication to an acoustical objective. Prior to that any shape would do – reverberation time has no "form factor" in its derivation or predictions from the Sabine and/or the Norrris-Eyring formulae.

There has followed some 40 years of on-going research, refining the measures: separating aspects of global terms such "Spatial responsiveness" (Marshall), "Spatial Impression" (Barron) and "Räumlichkeit" (Kuhl) into "Apparent Source Width (AWS) (Keet, Morimoto and others) Envelopment (Bradley and Soulodre) and the introduction of a raft of Inter-aural Cross Correlation (IACC) measures as an alternative to the lateral energy fraction, Lf, Barron and I proposed. (Ando, Schroeder, Gottlob and Siebrasse, and Beranek).

It may be worthwhile here to recall my description of the "premium quality of sound" from the "Note" I just mentioned:

1.2.1. *Identification of the quality*

To aid in the identification of the quality sought, it is observed that: (a), as a property of the *sound*, it is related to the loudness attributes; (b), as a property of the *hall*, it carries the idea of spatial responsiveness to the music; (c), for the *listener*, it generates a sense of envelopment in the sound and of direct involvement with it (5) in much the same way that an observer is aware of his involvement with a room he is in.

Nothing in the succeeding 40 years has led me to change my view of these characteristics of the premium quality of sound in concert halls identified in 1967. And that breakthrough is embedded in the design of the Christchurch Town Hall. In this building Christchurch led the world in the design of concert halls. How many cities in the world can boast that their Town Hall provided the acoustical model for the new Philharmonie de Paris, France? This will open next year. It would be an irony indeed if the Christchurch Town Hall no longer existed then.

Only a philistine would shrug off such a cultural Taonga as being of no significance to the city and the wider cultural community. ¶

Sound Transmission through Triple Panel Walls - Low Frequency Model

Keith Ballagh

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This paper was previously presented at the 21st Biennial ASNZ Conference, Wellington, NZ

Abstract

Triple panel walls are used in many situations but there are few readily available methods for predicting their performance. A common example of a triple panel wall is a masonry wall with light weight plasterboard linings on each side. Such walls can have significant transmission at low frequencies. This paper will describe a lumped parameter model for predicting the low frequency performance of such walls.

INTRODUCTION

Sound insulation between rooms or spaces is often very important, and methods of achieving good performance are well known [1]. However, construction methods and materials continue to evolve, and there is a continuing interest in improving constructions, to make them lighter, cheaper, easier to build and more compact.

It is well known that there is a limit to the sound insulation that can be achieved with a single panel, most single panels obey the mass law, and at practical panel sizes of say, 500 kg/m^2 (200mm concrete) the sound insulation is around STC/R_w 55 – 60 dB.

A major improvement can be achieved by using double panel constructions with an air-gap between, even with relatively light panels, performance of up to STC 65+ can be achieved for construction masses of about 50 kg/m^2.

If double panels confer such an advantage might it be that triple panel constructions (3 panels separated by 2 air-gaps) would be even better. Some examples of triple panel constructions that are already used in practice include masonry walls with plasterboard linings fixed over battens on each side, or triple glazing used in very cold climates where 3 panes of glass are used with 2 air-gaps, to maximise the thermal insulation.

There are also some examples of triple panel plasterboard walls intended for inter-tenancy use. However, on the whole triple panel walls have not seemed to provide a significant improvement over double panel walls.

Nonetheless, triple panel constructions continue to be used, particularly now in New Zealand after the leaky buildings fiasco has led to the use of ventilated cavities on external façades.

There have been unfortunately no reliable acoustical engineering tools for predicting the performance of triple panel constructions.

This paper will describe the development of methods for predicting the low frequency performance of triple panel walls. Note that it is often the low frequency performance of such walls that determine their overall effectiveness.

ACOUSTIC MODELLING OF TRIPLE PANELS

For modelling double panel walls it has been found satisfactory to divide the frequency region into a low frequency region where a lumped parameter model is satisfactory, a mid frequency region where wave motion in the air cavity is important, and a high frequency region where structural coupling between panels is important [2]. A similar approach has been taken for triple panel walls [3]. This paper will describe the low frequency model.

At low frequencies, where sound waves have very large wavelengths, it is found that it is the bulk properties of materials such as their mass that are most significant. The components in a wall can be regarded as masses or springs coupled together. This is the classical lumped parameter model. Panels are described by their mass per unit area (surface mass) and air-gaps are modelled as springs. In its simplest form a triple panel wall would be represented by 3 masses connected by 2 springs (Figure. 1).

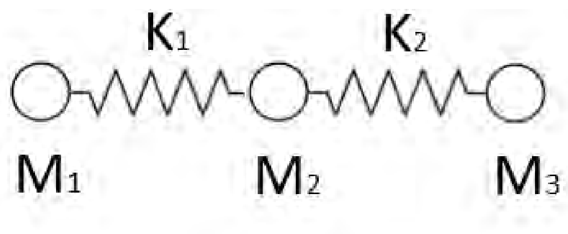

Figure 1. Lumped parameter model of triple panel wall.

Another way of representing such a model is to use electro-acoustic analogs and convert the lumped parameter model into an equivalent electrical circuit, in which masses are replaced by inductances, springs are replaced by capacitors, and damping by resistors. In this view currents represent acoustic velocities, and voltages represent acoustic pressures. The use of electrical equivalent circuits is a well established tool, and allows relative simple solution of the behaviour of the elements in the model, using the impedances of the elements and standard circuit rules

to be able to write out the transfer functions between points in the circuit [4].

The equivalent electrical circuit for a triple panel construction is shown in Figure 2 below. In this resistances have been added to account for damping in the system.

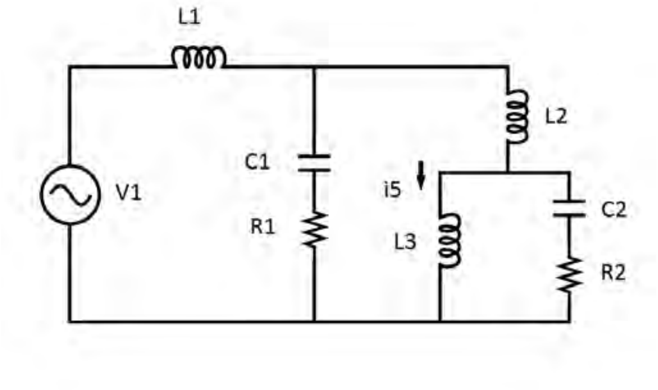

Figure 2. Electrical analogue of triple panel wall.

For the case of sound insulation of a structure (consisting of one or many panels) the transfer function of interest is the ratio of the incident sound pressure (represented by voltage V_1, in the equivalent circuit of Figure 2), to the velocity of the radiating panel (represented by current i_5 in the inductor L_3 in the equivalent circuit).

Now Rindel [5] (after some substitution) gives the transmission loss as:

$$R = 10\, Log \left(\frac{<p_s^2>}{4(\rho c)^2 <v_r^2>} \right) \quad (1)$$

and it can be seen that it is ratio of incident pressure <ps> to velocity $<v_r>$ of the radiating panel that is important. The incident pressure is represented by the applied voltage V_1 in the equivalent circuit, and the velocity of the third panel by i_5, the current through the inductor L_3.

By using standard Fourier transform methods the transfer function can also be derived.

This lumped parameter model is reasonably valid up to a frequency for which the larger air cavity is equal to about 1/6th of a wavelength of the incident sound. For instance, for a cavity of 100mm the highest frequency for which the lumped parameter model should be used is 550 Hz. This still covers a very useful and important part of the frequency range.

Once the transfer function has been determined it is a simple matter to use software to solve for the sound transmission loss of a triple panel system.

As a simple illustration the predicted transmission loss of a triple panel wall is shown in Figure 3. The wall consists of a 13mm thick plasterboard, 90mm air-gap, 13mm plasterboard, 10mm air-gap, and a further sheet of 13mm plasterboard. The transfer function predicts resonant frequencies of 74 Hz and 263 Hz. The predicted sound transmission loss exhibits dips in performance in the 80 and 250 Hz 1/3rd octave bands, coinciding with the two resonant frequencies of the system. Note that above the second resonant frequency the transmission loss curve rises sharply with frequency (30 dB/octave) as you would expect from an ideal 3rd order system. In practice other effects such as wave motion in the cavities, structural connections, bending waves in the panels, will limit the mid and high frequency performance of typical walls.

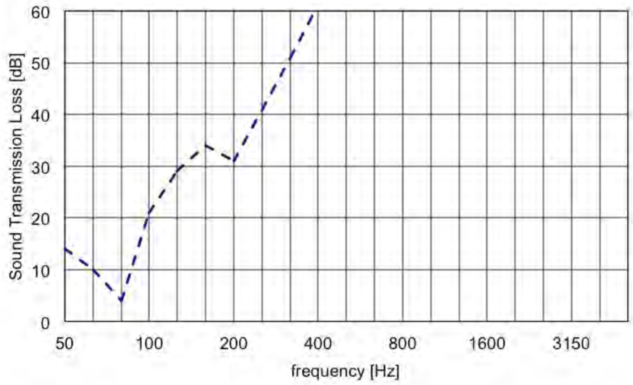

Figure 3. Sound Transmission Loss of simple triple panel construction (gypsum board/airgap/gypsum board/airgap/gypsum board).

EXPERIMENTAL VERIFICATION

We have a relatively sparse set of suitable laboratory test results of triple panel walls that we can use to compare against the model. NRC in Canada has carried out a set of tests on a concrete block wall, with some different linings and these have been used to test the model [6]. In Figure 4 we compare the model to the laboratory test for a 190mm thick solid filled concrete block wall (260 kg/m^2), with 16mm gypsum plasterboard each side, fixed over 38mm thick timber battens, with a 38mm thick fibreglass blanket in the stud cavity.

It can be seen that the model predicts the transmission loss relatively well up to about 250 Hz, above which frequency structural transmission via the timber battens begins to be more significant. In Figure 5 a similar construction is compared, except the 38mm timber battens have been replaced with 50 mm steel Z channels, and in Figure 6 the construction uses 75mm steel Z channels. In the three constructions described above the cavities are filled with a fibreglass blanket.

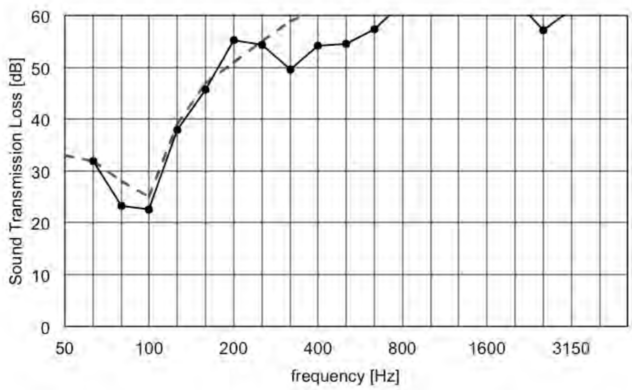

Figure 4. Sound Transmission Loss of 190 mm concrete block wall with 38mm timber strapping and 16mm plasterboard both sides.

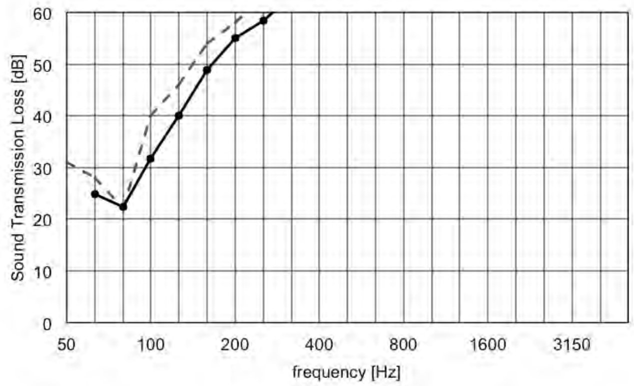

Figure 5. Sound Transmission Loss of 190mm concrete block wall with 50mm steel channels and 16mm plasterboard both sides.

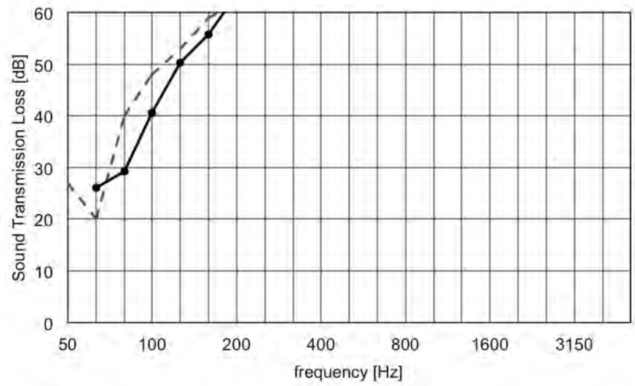

Figure 7. Sound Transmission Loss of Timber stud wall with 14.5mm gypsum board linings and additional layer fixed over resilient channels.

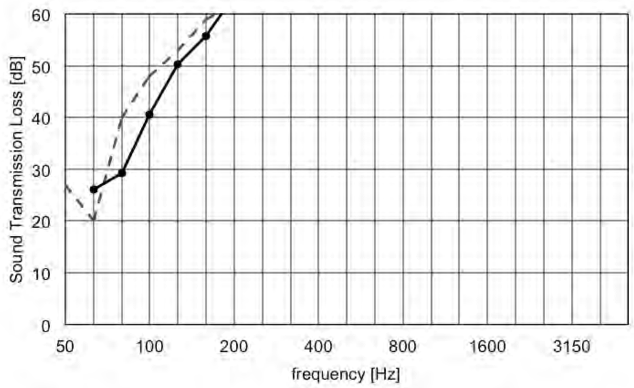

Figure 6. Sound Transmission Loss of 190mm concrete block wall with 75mm steel channels and 16mm plasterboard both sides.

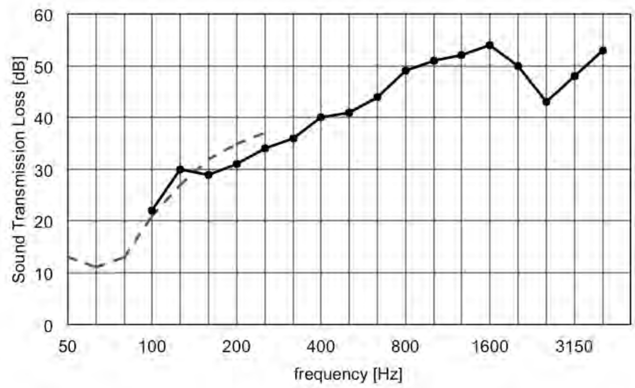

Figure 8. Comparison of Sound Transmission Loss of equal mass and thickness constructions. (blue line --- double panel, black line --- triple panel).

The agreement between the sound transmission loss predicted by the lumped parameter model and the measurements is reasonably good, the dip in transmission loss is predicted with reasonable accuracy. Note that the depth of the dip at the resonance frequencies is governed by the amount of damping. A value of resistance of 2,000 Pa s/m has been chosen for each example as the best overall fit to the experimental data.

In Figure 7 a comparison between prediction and theory is shown for a plasterboard partition consisting of 14.5mm gypsum board each side of a 90mm timber stud, with an additional layer of 14.5mm gypsum board attached via a resilient rail (thus creating a 13mm airgap).

This is an old test (1988) before laboratory testing was extended down to 50 Hz, so only results down to 100 Hz are available. There is reasonable agreement over the range available.

DISCUSSION

Resonance Frequencies

The behaviour of a triple panel system is influenced by two resonant frequencies. These resonant frequencies are not simply the resonant frequencies of each side of the construction. As an example consider a system consisting of a layer of 13mm plasterboard, a 100mm air cavity, and another layer of 13mm plasterboard.

The mass-air-mass resonance frequency is 64 Hz. If we now add another air cavity of 100mm and another sheet of 13mm plasterboard there are now two resonant frequencies, one of 53 Hz and one of 92 Hz. Thus, the modes of vibration can only be determined by taking the interaction of all components of the system.

Even with a heavy panel in the middle, as for instance if we substitute 150mm concrete as the middle panel, the resonance frequency of one layer of plasterboard and the concrete with 100mm air-gap is 46 Hz, but with the same lining on the other side of the concrete the resonant frequencies become 53 and 55 Hz.

Comparison of Triple and Double Panels

It is interesting to compare a double panel and triple panel system where the overall width and mass of the system is constrained. Take a wall which has an overall width of 100mm and consists either of 3 sheets of 13mm plasterboard separated by 2 air cavities of 30mm, or of 2 sheets of 20mm plasterboard (the same mass as a triple panel system) separated by 60mm. Both systems have the same mass, and same overall width.

The results are shown in Figure 8 where it can be seen that although the triple panel system has superior performance at higher frequencies, its performance at low frequencies is markedly inferior. The triple panel system has resonance frequencies of 93 Hz and 161 Hz, and a sound reduction of 12 dB at 100 Hz. The double panel system has a resonant frequency of 63 Hz, and a sound reduction of 22 dB at 100 Hz.

For typical lightweight building components and structures this is likely to be true for most designs. Therefore in general it is best to maximise the main airgap and maximise the mass of the outer skins for the design that is most efficient in terms of overall mass and compactness.

CONCLUSIONS

A simple lumped parameter model of a triple panel wall construction has been developed. The model consists of three masses (the panels) connected by two springs (the air cavities). The model predicts two resonant frequencies, which will produce two dips in the sound transmission loss. Comparison with available experimental data shows good agreement at low frequencies between predicted and measured performance for a limited range of constructions.

ACKNOWLEDGMENTS

I would like to gratefully acknowledge Harry Trethowen, formerly of BRANZ, for drawing my attention to the work of Ben Sharp and thus stimulating my enduring interest in the prediction of sound transmission.

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European Test Standards for Noise Barriers and their Relevance to New Zealand

Giles Parker

Managing Director, Sound Barrier Solutions Ltd, Market Harborough, United Kingdom

This paper was previously presented at the 21st Biennial ASNZ Conference, Wellington, NZ

Abstract

Revisions to the Specification and Acoustic Test Standards for Noise Barriers for use on European Highways have formally been approved and were due for publication in 2013/14. These proposed changes are examined in this paper. Changes include: 1) Defining higher categories for the specification of acoustic performance for tall barriers both in terms of sound absorption and airborne sound insulation, 2) Requiring outdoor noise testing of all barriers under direct sound field conditions instead of the classical indoor laboratory test regime, 3) The potential use of in situ acoustic testing of barrier durability as a tool for barrier maintenance and asset management. This paper also considers how these revised standards may also be of use to the NZ Noise Barrier Industry and the effective future use of barriers on the NZ state highway network.

NOISE BARRIER SPECIFICATION STANDARDS

This paper concentrates on recent proposed improvements to the European specification standards for the acoustic performance of highway noise barriers for the duration of their working life. These improvements respond to the need for acoustically effective, durable, low-maintenance systems as well as taking into account the growing need for the higher acoustic performance of products both in terms of sound absorption and airborne sound insulation.

This paper in part provides an update to the development and implementation of these standards.

VALUE MANAGEMENT

In the current European economic climate where the construction of new highways is deemed harder to justify, the need to maintain the integrity of existing assets on highways is becoming all the more important. Older existing noise barriers, though of a lower specification, are considered primary assets and often require repair, retro-fitting, or in many cases a complete upgrade replacement.

In the UK particularly, any closure of busy operating motorways for routine maintenance is becoming a very costly procedure. The cost impact of lane closures is further compounded in the UK by its impact on the factor Journey Time Reliability or JTR. This is roughly defined as a cost that is set against the predicted increase in journey time due to motorway maintenance work.

It is therefore a priority that the design specification of any replacement barrier system is high performing, durable and as close to zero-maintenance as possible so as to keep the number of maintenance visits for routine repair over the working life of the barrier to a minimum. This in turn keeps the whole life cost of the barrier scheme low.

Recent proposed improvements to existing standards allow for higher noise barrier acoustic performances to be specified at the design stage and also allow for the in-situ assessment of acoustic performance. This enables the value of the barrier-asset to be managed over its complete working life.

EUROPEAN STANDARDS FOR ACOUSTIC PERFORMANCE

Across the continent of Europe highways noise has been dealt with as an environmental problem that requires environmental solutions. Noise barriers have been used to ensure that communities are protected from vehicle noise. In contrast, historically, the UK's policy had been to offer non-environmental "solutions" such as secondary double-glazing or even compensation to residents. Neither of these options solves the problem and are thus being rejected in favour of noise barrier and low noise road surfacing.

As a result the need has grown for Europe to have an agreed set of noise barrier design specifications based on certified laboratory tested performance to ensure that effective long-lasting barriers are built that significantly reduce noise levels and public complaints.

What has followed over the last fifteen years is the emergence of new European EN performance standards for highway noise barriers to serve as the backbone for noise barrier specification and to help create a fair market for barrier products across the continent.

EN 14388 (2005): SPECIFICATIONS

All the current EN standards for highways noise barriers were grouped together under the umbrella standard EN 14388 (2005) – Road Traffic Noise Reducing Devices - Specifications.

This standard covers acoustic, non-acoustic and long term performance, but not aspects such as resistance to vandalism or visual appearance. For product conformity, that is for a noise barrier to be considered for the European highways market this standard required that the barrier product would need to have been assessed and categorised in accordance with the required parts of EN 1793 for acoustic performance and the required parts of EN 1794 for non-acoustic performance (mechanical, structural, environmental and safety).

Proposed Changes to EN 14388

With the emergence of new durability standards for noise barriers, the manufacturer will now be required to declare his product acoustic performance in accordance with EN 14389-1, and also declare the working life of his product with regard to non-acoustic parameters in accordance with EN 14389-2.

EN 1793: Acoustic Performance – Prior to Changes

EN 1793 groups the family of noise barrier standards dealing with intrinsic acoustic performance. These are all product performance tests. Some are internal laboratory tests based in classical reverberation test chambers. Others are in-situ test methods for outdoor test beds or for application of in situ barrier environments. In 2010, prior to any proposed changes the list of acoustic standards was as follows:

EN 1793-1: (1998) Road traffic noise reducing devices: Test method for determining the acoustic performance – Part 1: Intrinsic characteristics of Sound Absorption.

EN 1793-2: (1998) Road traffic noise reducing devices: Test method for determining the acoustic performance – Part 2: Intrinsic characteristics of Airborne Sound Insulation.

EN 1793-3: (1997) Road traffic noise reducing devices: Test method for determining the acoustic performance – Part 3: Normalised traffic noise spectrum.

CEN/TS 1793-4: Road traffic noise reducing devices: Test method for determining the acoustic performance – Part 4: In situ values of diffraction. This is currently a TS or test standard.

CEN/TS 1793-5: Road traffic noise reducing devices: Test method for determining the acoustic performance – Part 5: In situ values of sound reflection and airborne sound insulation.

EN 14389-1(2007): Road traffic noise reducing devices: Procedures for assessing long term performance: Acoustical characteristics. This is now a published standard.

PROPOSED MODIFICATIONS TO THE ACOUSTIC STANDARDS

Standards are always subject to periodic change for improvement. Any changes detailed below are considered improvements but are at present proposals awaiting full agreement of all the member states. They will then be accepted as full replacements to the existing standards.

Primary Changes to EN 1793-1

EN 1793-1 provides a test method to categorize the sound absorptive performance of a noise barrier as a single number rating. Currently these categories range A0 to A4 covering a DLα range from Not determined to > 11dB.

It is acknowledged that under diffuse sound field conditions for high-sided barriers, tunnels and covers, high sound absorption levels may be required. The new draft standard adds a higher category A5 for DLα values > 15dB.

This would give the revised categories of absorptive performance as follows:

Table 1
Categories of Absorptive Performance

Category	DL_{α} dB
A0	Not determined
A1	$DL_{\alpha} < 4$
A2	4 to 7
A3	8 to 11
A4	12 to 15
A5	> 15

Source: prEN 1793-1 (2011)

prEN denotes that this version is currently a working document awaiting full approval as a revised standard.

Primary Changes to EN 1793-2

EN 1793-2 utilises the test facility described in EN ISO 140-3. Because of the reverberant nature of the laboratory it is proposed to limit the scope of standard to diffuse sound field conditions only. The title of the standard would be changed to Road traffic noise reducing devices: Test method for determining the acoustic performance – Part 2: Intrinsic characteristics of airborne sound insulation under diffuse field conditions.

The Scope would clarify that this standard is not intended for noise reducing devices that are to be installed on highways under normal conditions which are almost always non-reverberant. This would greatly reduce the use of this standard in favour of the new standard prEN 1793-6 which is considered a more representative method for direct sound field condions.

EN 1793-2 provides a test method to categorize the airborne sound insulation performance of a noise barrier as a single number rating. Currently these categories range from B0 to B3 covering a DLR range from Not determined to > 24dB.

It is acknowledged that for high-sided barriers, high airborne sound insulation levels may be required. The new draft standard adds a higher category B4 for DLR values > 34dB.

This would give the revised categories of airborne sound insulation performance as follows:

Table 2
Categories of Airborne Sound Insulation

Category	DL_R dB
B0	Not determined
B1	DL_R < 15
B2	15 to 24
B3	25 to 34
B4	> 34

Source: prEN 1793-2 (2011)

prEN denotes that this version is currently a working document awaiting full approval as a revised standard.

Defining Reverberant Conditions

For the purpose of this European standard, reverberant conditions are defined based on the geometric envelope, across the road formed by the barriers, trench sides or buildings but excluding the road surface. Conditions are defined as reverberant when the percentage of open space in the envelope is less than or equal to 25%.

Primary Changes to EN/TS 1793-5

CEN/TS 1793-5 in its previous form gave a test method for determining in situ values of both sound reflection and air-borne sound insulation. The revised methodology for airborne sound insulation defined in EN 1793-6 supersedes the equivalent section in CEN/TS 1793-5 however the CEN/TS is retained as an interim method for determining in situ sound reflection performance.

EN 1793-6:2011

EN 1793-6 is intended for the following applications:

- Determining the airborne sound insulation single number rating of a noise barrier to be installed along roads, to be measured either in situ or under outdoor laboratory conditions.
- Determining the airborne sound insulation of a noise barrier in actual use.
- Comparing the design specifications with actual performance data after the completion of the construction work.
- Verifying the long term performance of a noise barrier with a repeated application of the method. This makes it a useful asset management tool.
- Designing new products, including the formulation of installation manuals.

EN 1793-6 is not intended for determining the airborne sound insulation of a noise barrier to be installed in reverberant conditions as defined above e.g.: tunnels, deep trenches or covers. The scope of prEN 1793-2 would cover this.

EN 1793-6 would provide new categories of airborne sound insulation performance: DLSI. Again these would be presented as a single number rating. Since these are determined by a different method and under different conditions, the values would not be numerically the same as those obtained using prEN 1793-2 however it is intended that they are coincident with them.

The values are as follows:

Table 3
Categories of Airborne Sound Insulation

Category	DL_{SI} dB
D0	Not determined
D1	DL_{SI} < 16
D2	16 to 27
D3	28 to 36
D4	> 36

Source: EN 1793-6 (2011)

Long Term Performance

The acoustic characteristics of a noise barrier can deteriorate significantly over the duration of its working life if it is not installed or maintained in accordance with the manufacturer's recommendations or if the materials are not appropriate for the roadside environment. EN 14389-1 (2007) defines the means of evaluating their acoustic durability.

The sound absorption is characterised by the reflection index DLRI as defined by CEN/TS 1793-5. The airborne sound insulation is characterised by the airborne sound insulation index DLSI as defined by EN 1793-6.

The standard currently only references CEN/TS 1793-5. This will be updated to show the change to EN 1793-6.

EN 1793-6 now provides an agreed method for the in situ acoustic testing of barrier durability with regard to airborne sound insulation.

ASSESSING IN SITU PERFORMANCE OF UK TIMBER BARRIERS USING EN 1793-6

The TRL Published Project Report PPR490 provides an assessment of the acoustic durability of UK timber noise barriers utilising the methodology of EN 1793-6.

With the majority of historical UK noise barriers being of low quality construction typically of single leaf timber fencing, the volume of installations provided useful information on the expected longevity of such designs.

Overall, the results would suggest that for single-leaf reflective barriers, any degradation in acoustic performance occurs during the first 5 years after construction. Depending upon the initial performance, this decrease appears to be of the order of 4-7 dB.

Based on the required performance of many of the barriers, this often renders the barrier almost obsolete after a very short time.

It is recommended in the New Zealand market that more durable barrier designs are specified and installed either in terms of higher quality engineered products, the use of more robust materials or, as in the UK, the use of double leaf timber barrier systems.

Acoustic consultant specifiers should factor in the impact of whole life costs when specifying noise barrier types and should avoid products that might require whole-scale maintenance or even complete replacement during the design life of a scheme.

FURTHER SPECIFICATION DETAILS FOR TIMBER BARRIERS IN THE UK

Having utilised the European Standards in EN 14388 (2005) to produce the most robust contract specification problems can still arise at the installation phase. In the UK this has especially been the case for timber-based barriers.

The need for comprehensive site supervision during the barrier build process has been essential to ensure the built barrier matches the specified barrier. Practical aspects relating to the installation process need to be highlighted within the design specification. Experientially, many of the aspects of workmanship highlighted in this section relate only to timber based barriers. However some of them apply to non-timber schemes also.

Acoustic Tightness

The weakest points of a barrier system's performance are the joints or posts fixings. Noise leakage at posts can render a barrier virtually useless and yet it is a simple to avoid both at the design and installation stage.

It is essential to ensure that the interface between the barrier and the ground is permanently sealed with no potential of gaps opening up in the future.

To ensure that this is the case, it is recommended that the barrier is constructed with a gravel board embedded to a depth of at least 100mm below the ground surface or the barrier itself rests on a concrete sill embedded to a depth of 100mm. The gravel board itself shall be constructed from material resistant to rotting in contact with the ground

Where the barrier is designed to sit onto a concrete sill, the self-weight of the bottom panel should provide a sufficient seal. Supporting a timber barrier panel simply on the post fixings without a solid base is insufficient as it could result in the panel deforming substantially over its working life. It could also result in gaps forming under the barrier panel itself.

Traceability of Timber Sources

Sustainability is a priority for the UK Highways Agency. It is essential to ensure that the barrier manufacturer can fully demonstrate that he has a system for providing timber that has originated from a sustainable source, and also that he is following that system for the given project.

The specification may read as follows:

The contractor shall demonstrate compliance with the specification requirement that timber shall be supplied from legal and managed sustainable sources by providing suitable records of the supply chain for the timber. The responsibility for compliance is with the appointed contractor and not just with their timber supplier.

The contractor shall provide evidence of full compliance with this requirement. Such documentary evidence shall be supplied by the contractor to the over-seeing organisation with the contractor's tender submission, prior to appointment and further substantiation relating specifically to the timber and wood actually used shall be supplied by the contractor to the overseeing organisation during the execution of the Works.

Any timber and wood contained in the products supplied or used, whether used for permanent or temporary works, not complying with the requirements of this clause shall be removed from the works at the insistence of the overseeing organisation and replaced with material complying with this clause at the expense of the contractor.

In the UK, prior to the contract being let, the contractor could provide certification detailing BM TRADA Chain of Custody registration to ensure that the timber they normally use does come from a sustainable source thus demonstrating his ability to comply. It is equally important for the customer to examine the documents that come with the actual timber used for the project to ensure that it has does indeed come from that source.

Cutting of Timber On-site

Correctly pretreated timber will last. Whilst some cutting and drilling of timber on site is unavoidable, wholesale cutting during in-situ installation should be avoided. Furthermore, it is essential that procedures for treatment re-coating of cut surfaces is fully adhered to. Again, this process should be supervised since most of the timber surfaces are hidden in the final barrier.

Panel Storage On-site

Pre-built modular panels do give an acoustic benefit. They are normally far tighter in construction than panels built in situ. However, it is essential that pre-built panels are correctly stored on site. Better still, if possible that site storage of panels is avoided and that they arrive directly for installation.

The contractor should ensure that all panels and materials stored on site or at a designated compound are held or supported in such a way as to prevent warping, damage or deterioration. Finished products such as modular panels that need to be stored on site or in a compound should be supported and protected to prevent damage or deterioration prior to installation.

Again, it is recommended that any panels found to be damaged in storage should be removed and replaced at the contractor's expense. This does require a description and examination of how panels are stored on site.

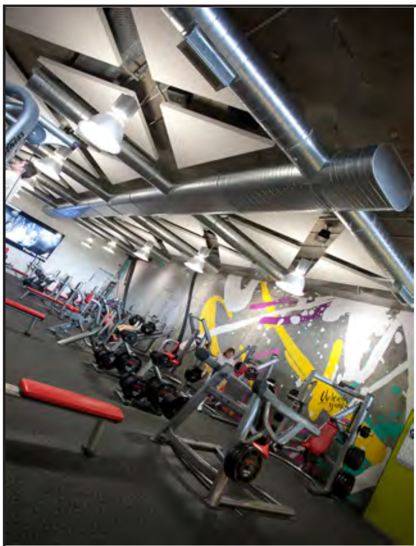
Gates and Openings

Where access is required through a barrier it is vital to ensure that the gate construction is to the same quality and similar acoustic performance as the barrier itself and that there is no leakage through gaps around the gate frame. Often for timber barriers the gate design is an after thought and the resulting quality is very low.

An alternative and preferable solution would be to create an absorptive overlap walkway in the barrier design for the point of access. Designed correctly, this wouldn't even require a gate. Working like a physical silencer, a walkway through the barrier would be created with the inner faces being absorptive. Most of the noise from the road would be trapped in the walkway zone and the overall barrier acoustic integrity is maintained.

Drainage of Mineral Wool

Common to mineral wool based absorptive barriers, is the need to include a drainage path for moisture. Both in timber and metal based absorptive barriers, the wool mattress is tightly sandwiched in the barrier cassette. After a while, rain water

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saturates the mattress and it either slumps in the frame or disintegrates. Since it is internal, this normally passes unnoticed but the barrier is no longer functioning.

This is best avoided in the design of the barrier panel itself by supporting the mineral wool mattress away from the walls of the panel cassette (for example by supporting it in an internal frame). The wool can then drain naturally and saturation is avoided.

COMPLIMENTING THE NZTA STATE HIGHWAY NOISE BARRIER DESIGN GUIDE

Whilst the noise barrier market will differ from Europe to New Zealand some aspects of the updated European standards may compliment the NZTA State Highway Noise Barrier Design Guide:

CE Marking

EN 14388 as the specification standard for highways noise barriers in Europe defines a mark of performance quality or CE Mark by which noise barrier products can be judged professionally.

Section 5.5 Acoustics Specifications of the Design Guide predicts the likely required increased use of proprietary noise barrier systems, such as those in common use internationally. The CE Mark provides a robust means of sifting the quality cost effective systems that will benefit New Zealand going forward.

EN 1793-6 for Airborne Sound Insulation

EN 1793-6 is already an accepted reliable method for rating and assessing the airborne sound insulation of noise barriers. Being an in situ method it is also a more appropriate method for intrinsic assessment for highways noise barriers than the existing EN 1793-2.

It could become the adopted method of choice for highways noise barriers in New Zealand such that manufacturers are required to test to it and consultants to include it in specifications.

As an in-situ test method it is well suited to manufacturers since it is straight forward for them to set up a ‘test bed’ arrangement at their plant. This allows for research and development to be done at their base.

EN 1793-6 for Asset Assessment

Should New Zealand choose to adopt EN 1793-6 as a test method for new barrier schemes, it further allows for on-going periodic assessment to ensure that a barrier is still performing and is fit for purpose. This helps determine and clearly validate when it might require retro-fitting or even replacement.

EN 14389-1 for Acoustic Durability

EN 14389-1 provides an assessment method for durability based on variation of the airborne sound insulation index DLSI as defined by EN 1793-6 with time. With performance values declared by the manufacturer over 5, 10, 15 and 20 years, periodic measurements to EN 1793-6 would enable the NZTA to check on a barrier’s actual ongoing performance against declared product data.

REFERENCES

[1] Giles Parker, “Effective Noise Barrier Design and Specification” (Proceedings from ACOUSTICS 2006, Christchurch New Zealand)

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Accuracy and Purpose of Building Insulation Measurements

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Abstract

In view of the imminent publication/adoption of a revised and expanded section G6 of the NZBC it is timely to consider how accurately we can confirm the acoustical performance of buildings by objective measurement. An obvious extension of this is to consider how our measurements (and their associated accuracy) match up with our ability to subjectively detect changes in the quality of building insulation. This has implications for how we might advance from a concept of a simple pass/fail for buildings based on a minimum building performance (i.e. specified in G6) to a set of categories of acoustic comfort for guiding both designers and (with reliable verification) prospective occupiers. In research to develop techniques for screening the performance of buildings we consider the possibility of measuring the impact insulation of floors by an alternative to the standard tapping machine plus a full ISO 10140 procedure. The success of such techniques depends on the saving in measurement effort and the increase in uncertainty they involve.

INTRODUCTION

The workshop on the proposal for revising section G6 of the NZBC has set a default theme for this conference and in this paper we report on developments in international standards and in our own research concerning the measurement of insulation in buildings with particular focus on the implications of the uncertainty of these measurements.

This is particularly topical in view of the recently issued draft international standard ISO/DIS 12999 -Determination and application of measurement uncertainties in building acoustics [1] which requires NZ's vote for acceptance or rejection by October this year. In the first part of the presentation we consider the main content of this draft, what understanding is needed and its implications for measurements in NZ.

In a second part we look to beyond the enacting of a revised G6 to putting in place a rating system for the acoustical performance of dwellings -as exists in several countries -variously termed Categories of Acoustic Comfort, Acoustic Quality Rating or simply Sound Classifications. These will provide descriptions and goals for higher performance than the minimum legally acceptable specified in G6.

Finally we present interim results from part of a project aimed at developing screening techniques for checking the sound insulation in buildings. Such tools would be valuable for quality assurance programmes and -depending on their precision -as economic means for certifying building performance. In this case we describe a possible alternative to the standard tapping machine for making impact insulation measurements. All three parts in the presentation can be seen to linked via the need for confidence in the measurement results

MEASUREMENT UNCERTAINTY IN SOUND INSULATION

The University of Salford 2001 report on Uncertainties in Noise Measurement [2] begins with the following "Measurement uncertainties tend to be either ignored or, at best, politely alluded to by practical scientists and engineers. This is because they have usually been frightened off by what has in the past been portrayed as a somewhat imperfect science made quite complex by sophisticated statistical mathematics"

For the ordinary practitioner it is perhaps made more complex by the initial hurdle of grasping the terminology used. In some cases this is familiar from everyday language but which now has quite specific and non-intuitive technical meanings. Then there are new terms to embrace as well.

It is evident that many of the revisions of the ISO standards that govern the measurements we make are moving to require our measurement results to include statements of uncertainty. So it is clear that 'polite allusion' is no longer acceptable. Understanding of uncertainty is needed if we are to be confident in providing meaningful and dependable uncertainty statements with our measurement results (both from the laboratory and from the field).

Anyone who wishes to engage with these issues (and, importantly, provide input on how NZ should vote on the draft international standard) is encouraged to read ISO/DIS 12999 [1] but it will not be an easy read. We recommend as an excellent tutor on the subject Kirkup and Frenkel's book An Introduction to Uncertainty in Measurement using the GUM (Guide to the Expression of Uncertainty in Measurement) which is available as a Cambridge on-line book [1]

The following are a selection of the most important terms used in metrology and uncertainty discussions MEASUREMENT:

We colloquially use 'measurement' to mean a numerical value or result but in metrology it is the process of obtaining the value or result. Instead we must be strict about using the terms Measurand and Measurement result

MEASURAND: This is the quantity that is being measured e.g. Sound Reduction Index, R_T, D_{nTw}.

MEASURMENT RESULT: The measured value of a measurand.

ESTIMATE; BEST ESTIMATE: We are unable ever to find the true value of a quantity through measurement (because of errors -see below). What we find from our measurement is an estimate of the true value. Provided that the variation in our measurement results is the result of random sources then the mean of our results constitutes the best estimate of the true value.

ERROR: In everyday usage the import of this is that it is a mistake or a blunder but in metrology it is simply the difference between a valid measurement result and the true value -Error = (Measured value -True value)

ACCURACY: Is a comment on how close we believe a measured value is to the true value (which is, in principle, unknowable) and is quite different from precision.

PRECISION: This is a comment on the likely variability in our results. If, when we make repeat measurements the results show little variation then the values are described as being precise.

UNCERTAINTY: Since errors are unavoidable components of the measurement process their net effect is uncertainty in the value we obtain for a measurand. This uncertainty is given quantitatively as an interval around the best estimate we obtain which (we hope) we are confident (to a stated level) will contain the true value of the measurand. Two versions for uncertainty are referred to in GUM [3] STANDARD

UNCERTAINTY: (Symbol 'u' -lower case).This is merely the standard deviation of our repeated measurement results.

EXPANDED UNCERTAINTY: (Symbol 'U' -upper case) -is the standard uncertainty multiplied by a factor (termed the coverage factor) to expand the interval around the best estimate for containing the true value with greater confidence. The coverage factor (based on the population probability distribution and degrees of freedom in the results) is chosen to give the level of confidence required. For example this might be 95% (i.e. 95 times out of 100 repeats of obtaining estimates this interval round the estimate will include the true value). ISO/DIS 12999 gives values for coverage factors assuming the total errors are Gaussian distributed.

REPEATABILITY AND REPEATABILITY CONDITIONS: Repeatability uncertainty refers to the amount by which measurement results vary when the measurements are repeated with -as far as possible -nothing changing. So, either in the laboratory or for a field test, it means carrying out a sequence of measurements by following closely the same procedure each time (i.e. same transducer positions, undisturbed sample, same source and environmental conditions etc.). ISO/DIS 12999 describes these measurements as being made under repeatability conditions. (Note, the standard also refers to this as Test Situation C)

REPRODUCIBILITY AND REPRODUCIBILITY CONDITIONS: When results need to be compared which come from different locations (measured by different measurers using different equipment and detailed procedures) but on the same, or nominally the same, measurand then the results are described as being obtained under reproducibility conditions and the and the uncertainty is the reproducibility uncertainty.

When the locations are test laboratories which meet the requirements specified in the relevant part of ISO 10140 [4] this is referred to as Test Situation A. The uncertainties in this case are, for example, what would be applicable if comparing the results from the same sample tested by the Acoustics Testing Service in Auckland and by the Engineering Dept at Canterbury University.

IN-SITU CONDITION / TEST SITUATION B: A third situation is described in ISO/DIS 12999 (referred to as an In-Situ condition and also as Test Situation B) which has particular relevance for field measurements. This is where the same item (e.g. wall, or whole building) has repeat measurements made but by different measurement teams. The resulting in-situ uncertainties would be expected to describe the spread of values (i.e. include the differences) that we might expect if in a field verification of a building performance value e.g. $D_{nT,w}$, were carried out by different consultant members of the Acoustical Society of New Zealand!

LABORATORY AND FIELD MEASUREMENT UNCERTAINTIES: The main thrust of ISO/DIS 12999 seems to be to encourage laboratories to closely monitor their repeatability uncertainties and to promote inter-lab comparisons (Round Robin tests) for establishing reproducibility uncertainties.

With only two ISO complying labs in NZ we do not have the minimum number (i.e. 8) required by ISO/DIS 12999 to undertake an inter-lab comparison. In this case the standard gives default values for the reproducibility uncertainties (see Table 1, Situation A) which are mandatory to be used. We can verify that the Acoustics Testing Service does meet the 1/3 octave repeatability requirements (Situation C) and, in the absence of testing to show otherwise we, as required, will apply the Situation A values as 'expected reproducibility uncertainties'.

However it is important to understand that these uncertainties only indicate a range for the differences found between labs when measuring an identical specimen. The variations that might appear in the performance results when different custom built samples of the same nominal construction are tested almost certainly will span a greater range!

This becomes an important concern if, say, for certification purposes an Rw value is obtained from a single, very carefully constructed sample in the laboratory. We might expect that other samples constructed under less carefully controlled conditions could exhibit results which are poorer by important amounts. Therefore if producers of wall systems and/or builders wish to have a good degree security about meeting a specified performance they will need knowledge of reproducibility uncertainties for their range of constructions and systems. Then they can select a system to build which has its best estimate of performance exceeding the performance requirement by the amount of the reproducibility uncertainty.

A similar approach is required by ISO/DIS 12999 when carrying out field measurements to verify that a building component or whole building meets a performance requirement. If, for example, we have a performance requirement of $D_{nT,w}$ = 60 then it is mandatory for the measured result to exceed 60 by the amount of the expanded uncertainty:

$$D_{nT,w} > 60 + U \quad (1)$$

Ideally, U would be found by making sufficient repeat measurements in the building to obtain a reliable estimate of their standard deviation, u, which when multiplied by the relevant coverage factor (e.g. K = 1.6 for 95% confidence -one sided test!) leads to the value for U so:

$$D_{nT,w} > 60 + 1.6u \quad (2)$$

Of course repeated measurements require more time and expense so if only a single measurement is made for economy reasons then the standard provides mandatory default values for u. In the case of the $D_{nT,w}$ = 60 example u = 0.8 (see Table 1). This means that the minimum value required for conformity to be demonstrated (with 95% confidence) is:

$$\begin{aligned} D_{nT,w} &= 60 + 1.6x0.8 \\ &= 61.3. \end{aligned} \quad (3)$$

It is worth emphasizing again that this only indicates the acceptability of that one specific building or construction and not other nominally similar items. But by performing repeat measurements on a selection of nominally similar constructions reproducibility uncertainties could be determined which then could be used to to assess the confidence that a whole family of similar constructions (e.g. an apartment block of replicated units) will meet the performance requirement.

It is worth noting that ISO/DIS 12999 quotes values of dB quantities to 0.1 dB. By implication this is the amount by which buildings could either pass or fail code requirements if this standard is adopted as an 'acceptable solution' for a verification method in G6.

A further development in standards that has implications for measurement uncertainties is the proposed ISO 16717 (see Scholl et al [5]). This is suggested to eventually replace the present ISO 717 which specifies the procedures for processing and expressing insulation performance into single figure ratings. In ISO 16717 we find strong support for extending our formal measurement range down to 50 Hz, the removal of spectrum adaptation terms in favour of separate R values for different source sounds, and the replacement of $L_{n,w}$ for impact sound by a new R value (R_{impact}) analogous in concept to airborne R values. (We might wonder if even this is low enough given the power radiated by woofers and sub-woofers used in home entertainment systems and also given that the question of our sensitivity to the infrasound created by people movement in lightweight buildings remains un-researched.)

CATEGORIES FOR HIGHER PERFORMANCE THAN G6

Since the requirements specified in G6 have their basis in the protection of health they constitute a minimum performance unlikely to be adequate for complete protection of the amenity of dwellings. Both the German Society of Engineers (VDI) [6] and the Association of Australian Acoustical Consultants [7] provide tables which illustrate this inadequacy well (see, for example, the first column in Table [1] from [6])

Table 1: Perception of customary noises from neighbouring dwellings and assignment to three sound insulation classes (SSt)

Column	1	2	3	4
Row	Type of noise	Perception of the emission from the neighbouring dwelling, typical evening background noise level of 20dB(A) and customary large living spaces assumed		
1		SSt I	SSt II	SSt III
2	Loud speech	intelligible	in general intelligible	in general not intelligible
3	Raised speech	in general intelligible	in general not intelligible	not intelligible
4	Normal speech	in general not intelligible	not intelligible	not audible
5	Walking noise	in general disturbing	in general not disturbing	not disturbing
6	Noise from building service installations	unreasonable annoyances are in general avoided	occasionally disturbing	not or only seldom disturbing
7	Music, loudly adjusted broadcasting and tele-vision equipment, parties	clearly audible		in general audible

It was proposed by members from the committee considering the revision of G6 that when this revision was completed the next stage should be the development of a hierarchy of improved levels of performance similar to the systems adopted in overseas countries (see Rasmussen[8]for a review).

It is clear from the increasing number of complaints about noise being registered by local authorities in NZ (e.g. complaint figures for greater Auckland show a rise from 45,80pa to 54,000pa in the last 3 years) that there are groups of people who are not being adequately protected. Some of these will be cases where the buildings do not meet G6 requirements but it is safe to assume that the increase is being driven largely by occupants of the new higher density developments which we must assume do meet G6.

In developing these higher performance categories we suggest that among the issues to be considered are:

- How many categories are needed
- What range should these cover
- What measures should be included
- Should we harmonise with overseas trends
- Do we need to formally establish norms for acceptable behaviours in different dwelling types?

Our thoughts are that we should try to approach these issues initially without being unduly influenced by what's happening overseas. A starting point is to consider the number of levels, or categories, of performance that are desirable. It seems appropriate that this number should accord with any innate categorical sense that we possess. So we must determine whether or not we "feel" or intuit a certain number of subjective divisions (i.e. categories) for ranges.

There are numerous examples in life where we use 3 main divisions, e.g. A,B and C for grading exam papers; Hot, Warm and Cold for water or weather temperatures; Tall, Average and

Short for heights; Child, Youth and Adult for ages; Primary, Secondary and Tertiary for educational establishments; Gold, Silver and Bronze for Olympic winners; (there are even examples from the field of local acoustics: Reasonable, Unreasonable and Excessive for noise severities in the RMA; Good, Better and Best for advertising wall system performances). Of course when required -primarily when numerical need demands -we can divide these further (e.g. for grading we have A+, A and A- etc; Baby , toddler and Infant for Children).

An area we can look to for guidance here is the discipline of Human Geography. In foundational work by Edward Hall ('Man's (sic) use of space in public and private' [8]) it is interesting to note that he suggests that we sense 4 categories for our distance from other i.e. intimate, personal, social and public. On the other hand in situations where star ratings are used it is usual to use up to a maximum of 5 stars.

Whilst this issue merits further research we sense that an appropriate number for levels or categories is in the 3 -5 range. This is what we find in overseas rating systems e.g. Germany has 3 'Classes of Acoustical Comfort' whilst Australia has a 5 tier 'Acoustic Rating' system.

Next in importance is to decide what quantities we want to "rate" and what the extremes of performance should be. Two main approaches are evident overseas which are 1) rating performance by the percentage of people 'annoyed' or 'disturbed', as in Scandinavia, and 2) audibility of sounds, as in Germany and Australia. However, we suggest that audibility of sound is the more appropriate basis for rating dwellings as this more directly links with privacy . What most distinguishes dwellings from other buildings is that their amenities should be private.

Hence we suggest that the bottom and top categories of a New Zealand rating system should be 1) the performance legislated in the Building Code and 2) performance which provides Acoustic Privacy, respectively. Our definition for Acoustic Privacy is that condition where no information about your or your neighbour (including your or their presence) is communicated by sound.

Whether or not we can hear a sound through a party wall not only depends on the insulation it provides but also on the strength and type of sound incident, therefore a 'privacy' approach will require that we consider establishing norms for what is normal and acceptable behaviour in dwellings which have neighbours. It is logically possible to define different qualities of housing stock based on what constraints are necessary to be imposed on dwellers in order to ensure Acoustic Privacy.

We suggest that a committee be established to begin drafting a New Zealand system of performance categories and that the matters outlined above are a suitable starting point for its deliberations.

AN ALTERNATE METHOD FOR RATING THE IMPACT SOUND INSULATION OF FLOORING

One of the main factors limiting measurements of normalised impact sound level is the fixed amount of power delivered to the floor by the hammers. The hammers have a specified drop height, repetition rate, mass and surface area to deliver the impact. This limits the sound pressure level radiated from the floor in the receiving room; in a noisy environment this can make field measurements difficult or even impossible. However, no such limitations exist for measuring the sound reduction index; in a noisy environment you need only increase the volume output of the airborne source or use a synchronous averaging technique.

Making a normalised impact sound level measurement also requires you to occupy two locations at once, both in a transmitting room and in a receiving room. A large amount of heavy and expensive equipment is needed, which in field testing poses a significant deterrent. Other factors that also add to the difficulty of field measurements, include testing on delicate surfaces, such as tiled floors, which can risk damage to property.

As the transmission of airborne sound and impact sound are governed by many of the same mechanical and vibrational properties it is logical that a relationship should exist between them. It is well established that such a relationship does exist and this was shown for a general floor situation by Heckl & Rathe[9] and later developed by Vér[10].

We propose a method of rating the impact insulation of a floor using the readily available airborne sound measurement of the sound reduction index, the theoretical relationship shown to exist between the normalised impact sound level and sound reduction index and an adjustment to the normalised impact sound level from the impulse response of the floor. Accelerometers attached to an International Authority for Standardisation (ISO) standard tapping machine hammer[11] will be used to find the improvement in normalised impact sound level for different surface coverings.

THEORETICAL BACKGROUND

Using a reciprocity method Heckl & Rathe[9] derived a general relationship between the normalised impact sound level (L_n) and sound reduction index (R) as follows:

$$L_n + R = 10\log\left(\frac{k^2 F_T^2}{4\pi A_0 p_0^2}\right) \quad (4)$$

where k = 2π/λ is the wavenumber in air, FT is the periodic impact force of the hammer (with the time period between impacts being T), A_0 = 10m^2 is the normalised room absorption and p_0 is the reference sound pressure (= 20µPa). It is worth noting that this relationship between the normalised impact sound level and sound reduction index is independent of the properties of the floor.

For octave frequency bands with centre frequency f_c, assuming FT infinitely short sinusoidal impulse and by substituting standard values for the ISO standard tapping machine [11], equation (4) takes the form:

$$L_n + R = 43 + 30\log f_c \quad (5)$$

Equation (5) is derived on the basis that the coincidence frequency is low and the surface is hard and has high input impedance. If the floor is soft or has a low impedance, the force produced on the floor is smaller and the time of contact with the floor is increased such that the assumption made to derive this equation may not be valid. Whilst this will cause equation (5) to give higher theoretical values than measured, this is not an inadequacy of the formulation proposed by Heckl and Rathe. With the correct force input, equation (4) still gives valid results.

However, in the case where the airborne sound travels along a different path to the impact sound, equation (4) is no longer valid. This case is associated with a hole in the floor or flanking transmission.

Using a power balance method, I. Vér derived the relationship between normalised impact sound level and sound reduction index [10]:

$$R + L_n = 43 + 30\log(f) + 10\log(\sigma_{rad}) \quad (6)$$

where σ_{rad} is the radiation efficiency of the impacted surface.

When a resilient covering is added to the bare floor L_n + R begins to deviate from equation (5) above a critical frequency f_1. This adaptation term is derived by H & L Cremer [12] and stated by Heckl and Rathe[9] as:

$$L_n + R = 38.6 + 30\log f_c - 10\log\left(1 + \frac{f_c^4}{f_1^4}\right) \quad (7)$$

f_1 can be found from the dynamic stiffness of the floor covering. For the purposes of this work f_1 is chosen empirically to best fit the data set.

It is from these equations that a technique to estimate the normalised impact sound pressure level of a floor is proposed.

It is proposed that the improvement to a normalised impact sound pressure level can be calculated directly from the ratio of the impulse response of the bare and covered floor.

This follow the work done by Ford et al. [13], where the improvement in level is given by the difference in force level:

$$\triangle L_n = L_{F,\mathrm{bare}} - L_{F,\mathrm{covered}} \quad (8)$$

where the force F =Ma(t), where a(t) is the acceleration of the hammer. As the mass of the hammer remains constant the improvement in normalised ISPL is given by:

$$\triangle L_n = 20\log\left(\frac{A_{bare}}{A_{covered}}\right) \quad (9)$$

where A = â is the acceleration spectrum. Using equation (5), the measured sound reduction index (R) and the change in level for bare and covered flooring given by equation (9), a method for making a normalised impact sound level measurement without the need for the usual impact level testing equipment is formulated. The normalised impact sound level of the covered floor is calculated by:

$$L_{n.covered} = [L_n + R]_{theory} - R - \triangle L_n \quad (10)$$

where $[L_n + R]_{theory}$ is the relationship given by equation (5). This is the equation which governs the impulse response method for rating impact sound insulation.

An Investigation of Covered Concrete Floors

Ford et al. [13] investigated the properties of impacting a covered concrete floor and the impact noise transmission characteristics of the floor. However, this investigation did not provide a method for evaluating a floor's impact sound insulation without making an impact sound pressure level measurement.

Ford et al.'s paper also shows an interesting aging effect for soft carpets. There is a considerable difference between the first and 5000th impact of the hammer on a soft carpet. As the hammer impacts the surface the carpet hardens causing the impedance to increase and increasing IPSL of the higher frequencies.

Calibration to a Reference Floor

In addition to the calibration checks required for the Uni-Tapper which are inherent in the ISO standard tapping machine as well and calibration checks of the accelerometer, it is proposed that impulse response methods procedure requires calibration to a reference floor.

In field tests on completed or partially completed floors, where a resilient floor covering is already present, it may not be possible to measure the impulse response spectrum of the bare floor. It is therefore proposed that impulse response methods procedure can be calibrated, given a reference floor that fits the conditions for equation (7), the impulse response method can

Continued on Page 25...


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...Continued from Page 23

be conducted calibrated to this floor given a known impulse response spectrum and f_1 for the reference floor.

EXPERIMENTAL SETUP & PROCEDURE

Testing was undertaken in the reverberation chambers at the Acoustics Testing Service, School of Architecture & Planning, University of Auckland.

The ISO tapping machine consists of five, 0.5kg weights suspended at 4cm, spaced equally over a span of 40cm. The weights are released at a repetition rate of 10 strikes per second (2Hz per hammer). The normalised impact sound level measurements are taken following the standards set by the ISO 140-7[11].

The Uni-tapper[14], shown in figure 1, consists of only a single hammer from the ISO standard tapping machine, and operates as a single hammer does in the complete machine, having a repetition rate of 2Hz. A type 4367 B&K accelerometer is glued to the hammer at the base of the stabilising shaft.

The testing procedure consists of accelerometer measurements made using the Uni-Tapper and normalised impact sound level verified with measurements made using the ISO standard tapping machine. The measurements are averaged from measurements made at minimum of 4 locations as required by the ISO 140 part 6 and 7[15, 11] standards.

The accelerometer measurements are also taken from the same locations and averaged in the same manner. However, as the ISO standard tapping machine consists of 5 hammers evenly distributed over 40cm, further study needs to be preformed as to the variations over this short distance. This effect should be negligible for non-periodic/homogeneous constructions but will become increasingly important for lightweight and periodic constructions.

Measurements are made at 10 locations spanning the area of the floor, 5 of which are oriented parallel/perpendicular to the boundaries of the floor and 5 oriented at 45° to the boundaries. From these 10 positions 210 unique groups of 4 positions are formed, calculated from the Binomial Coefficient expansion, equation (11).

$$C_r^N = \frac{N!}{r!(N-r)!} \qquad (11)$$

where N is the total number of locations and r is the number of locations per grouping. This will give a spread of groupings which are well-correlated to the random location choices for the current testing procedure.

These 210 combinations of grouped positions are used to estimate the mean and error in the impulse response method, and standard method, for calculating a single value rating of $L_{n,w}$.

The inner workings of a simple accelerometer can be viewed as a damped mass on a spring. As the accelerometer is accelerated the mass is deflected from its equilibrium applying a force to a piezoelectric crystal, the larger the deflection the higher the voltage output. There are different configurations to this simple accelerometer but almost all are based on this same principle[16].

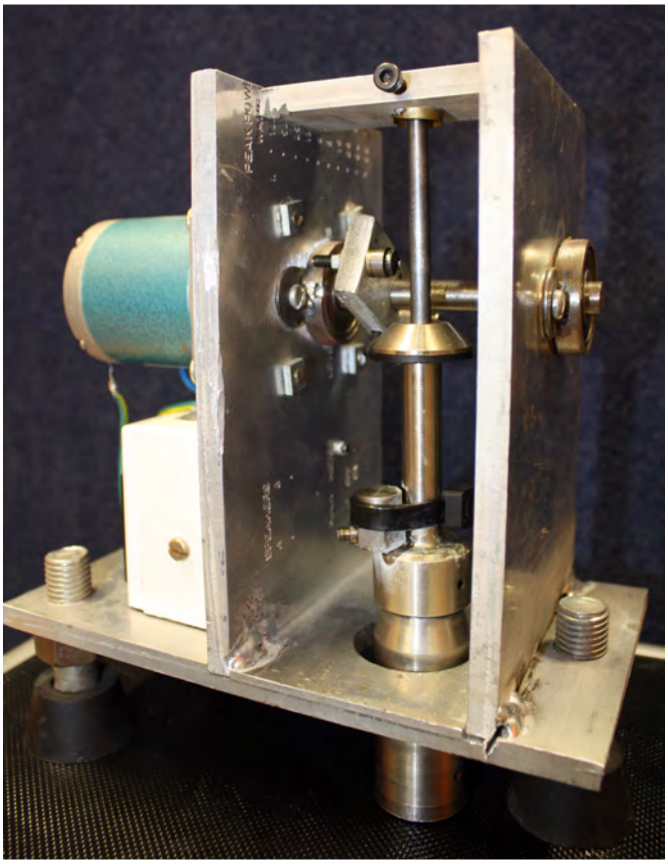

Figure 1. Uni-tapper with attached accelerometer.

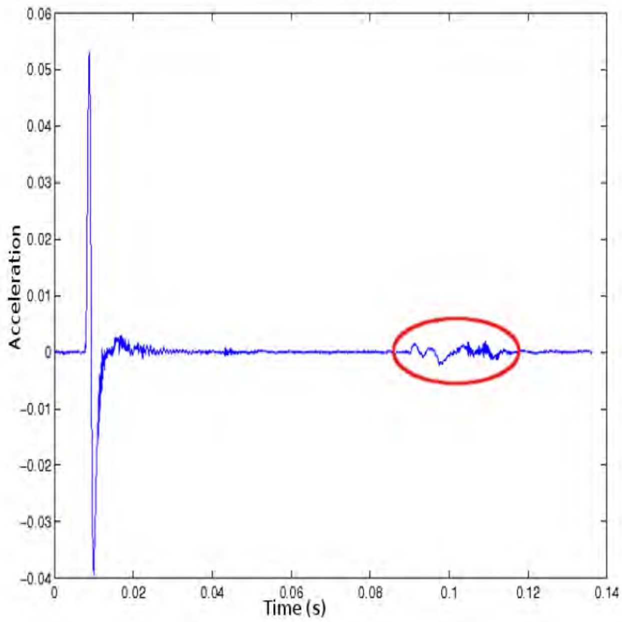

Figure 2.The low-pass filtered acceleration data as a function of time in seconds from the accelerometer on the Uni-Tapper hammer impacting on the ATC bare concrete floor. The acceleration associated with the hammer pickup is circled in red.

Figure 2 shows the acceleration of the pickup measurement and that there is a significant negative acceleration after the primary impulse. A negative acceleration would imply a downward force greater than the force produced by gravity, after the hammer has rebounded and started decelerating while airborne and thus not physical. This negative acceleration is therefore presumed to be due to the inner mechanics of the accelerometer. With such a large impulse the mass inside the accelerometer has enough momentum to be deflected back producing a negative acceleration.

RESULTS & DISCUSSION

VERIFICATION OF L_N +R RELATIONSHIP

Figure 3 shows the results measured using the ISO's standard tapping machine and the results derived from equation (10). The solid red lines show the relationships derived by Vér and Heckl & Rathe, equations (10) and (7), the hollow circles show the measured L_n+R. f_1 in equation (7) has been selected to fit the measured results.

This verifies the relationship shown by Heckl & Rathe in equation (7). f_1 has been chosen to fit the measured sum of L_n+R and is the first step in calibrating the impulse response method.

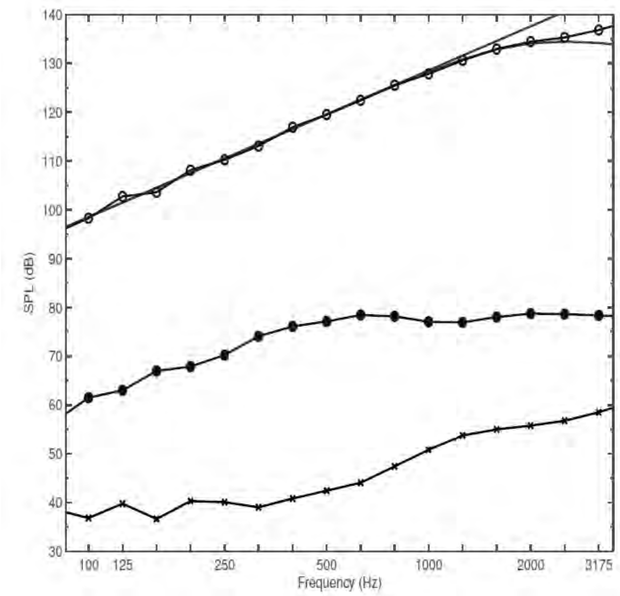

Figure 3. Verification of equation (7) to the measured L_n +R. Measured sound reduction index R (x) and Ln () and their sum L_n +R (o). Equation (10) is the straight red line and equation (7) is shown by the solid red line that begins to decrease to a -30dB/decade decline above 1900Hz.

IMPULSE RESPONSE METHOD

The data is low-pass filtered and as the normalised impact sound level is rated from 100-3150Hz; any data outside this frequency range is irrelevant. Applying a low-pass filter primarily reduces the noise for processing out the unwanted data from the pickup mechanism. The reduction in noise allows for an automated process to remove unwanted data.

Figures 4 and 5 show the normalised impact sound pressure levels (ISPL) on carpet and linoleum respectively. The normalised ISPL for the bare floor has been included in the following figures to emphasize the correction made by the difference in acceleration spectrum level. The normalised ISPL of a covered floor is calculated from the acceleration spectrum difference, between the bare and covered floor, subtracted from the normalised ISPL of the bare floor.

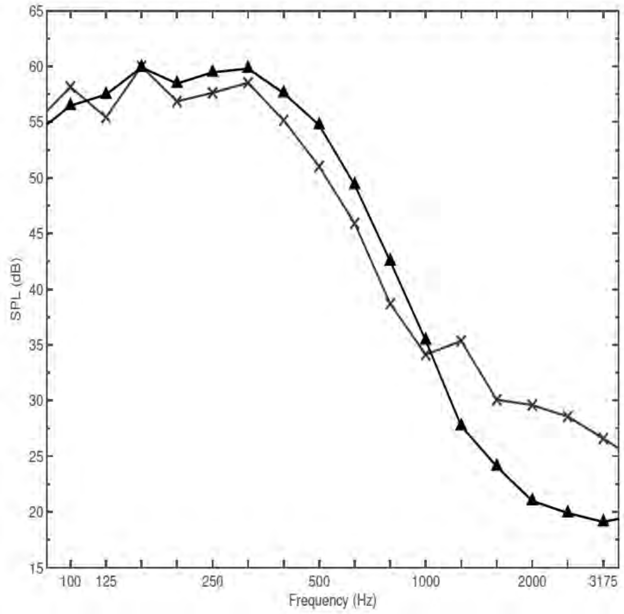

Figure 4. Normalised impact sound pressure level of the woodconcrete floor with a carpet floor covering, using only the acceleration spectrum of the hammer impacting the floor. Standard testing method(◆) and impulse response methods (x).

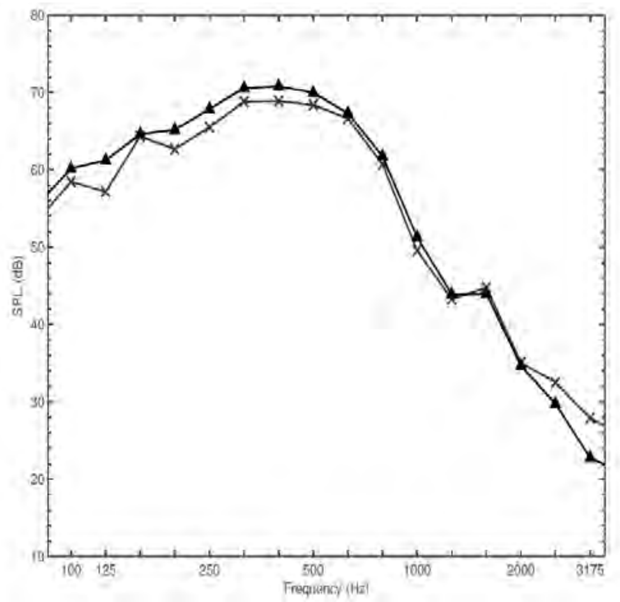

Figure 5. Normalised impact sound pressure level of the wood-concrete floor with a linoleum floor covering, using only the acceleration spectrum of the hammer impacting the floor. Standard testing method (◆) and impulse response methods (x).

This shows very good agreement between the impulse response method and standard method below the cutoff frequency where the acceleration spectrum of the covered floor becomes dominated by the acceleration of the pickup. This agreement can be improved at the higher frequencies by processing the raw data for the acceleration of the covered floors isolating the impact with floor, with any negative acceleration left in tact.

Due to flanking transmission inherent in floating floors the impulse response method does not at all agree with the standard testing method for lock-wood floor. There is an average difference in level between the standard testing method and impulse response method of 9.5dB.

The single value ratings of weighted normalised ISPL, $L_{n,w}$ shown in Table 1, show good agreement with the standard testing methods rating. It shows an approximately 1dB underestimation of $L_{n,w}$ by the impulse response method with the exception of the carpet covering.

The good agreement of the carpet covering is due to the poor agreement in the normalised ISPL in the high frequencies of the impulse response method compared to the standard method.

It needs to be noted that although the ratings of the bare floor and linoleum covering show an error estimation of ±0 does not mean there is no variation to the spectrum level.

The sum of the unfavourable difference between the measured L_n and reference curve can vary by as much as 10dB or more in a single shift of the reference curve, this means that a single value rating can be associated with a huge number of spectra with different curves. For example, the entire spectrum could shift by 1dB, and if anywhere up to 9 third octave bands are contributing to the unfavourable difference it is possible for the reference curve to not shift. It can therefore be very misleading looking at the accuracy of a single value rating.

Overall this shows very good agreement up to the cut-off frequency and shows very good promise as a method for rating floors ($L_{n,w}$) for screening purposes.

The poor agreement throughout the spectrum for the carpet covering will largely be due to a poor signal to noise ratio, as the signal is very low for the very soft floor covering.

Table 1. $L_{n,w}$, from 210 Combinations, of the Wood-Concrete Floor

	$L_{n,w}$ Impulse Response Method (dB)	$L_{n,w}$ Standard Method (dB)
Bare Floor	84 ± 0	84 ± 0
Cork Covering	63.2 ± 0.4	64.2 ± 0.4
Carpet Covering	52.9 ± 0.6	52.9 ± 0.3
Linoleum Covering	62 ± 0	63 ± 0
Wood-lock floating floor Covering	63.2 ± 0.7	70 ± 0

INFLUENCE OF BACKGROUND NOISE ON THE IMPULSE RESPONSE MEASUREMENT

It has been claimed that one of the largest advantages to the impulse response method is that it can be conducted even in places with significant background noise. Work done by A. Rabold et al. [17] showed that vibrations in the floor produced by the impacting hammer can have an effect on the subsequent impacts. This effect was primarily confined to low impedance floors at low frequencies but still raises the question that vibrations in the floor may effect the impulse response measured.

The effect of background noise on the impulse response measurements was investigated by subjecting the floor being tested to pink noise. The A-weighted overall level in the transmitting room is 107dB(A) and in the receiving room is 60dB(A).

Figures 6 and 7 show the mean acceleration spectrum levels with, and without, the background noise. Measurements were taken at 5 locations. It can be seen that even with background noise the difference in level, throughout the frequency range of interest, 100-3150Hz, is at most 3.2dB.

For the bare floor the difference in level between measurements with and without background noise shows a maximum difference of approximately +2.75dB and an average of 1.2dB.

For the cork covering the difference in level between measurements with and without background noise shows a maximum difference of approximately -3.2dB and an average of -1dB.

The aim of this work was to investigate a method of estimating the normalised sound pressure level, for the purpose of rating floors, that has several advantages over the standard testing method with the ISO standard tapping machine, this is the impulse response method.

The case where all the data pertaining to the impact, removing only the acceleration of the pickup catching the hammer and unwanted noise, shows very good agreement with the standard testing method.

One of the main advantages of the impulse response method is the ability to make impact noise measurements in noisy environments. This is a significant advantage in screening floors to ensure compliance to the building code during the construction process, where construction may be continuing within close proximity to the building element being tested.

Other advantages include reduced equipment size and weight. The size and weight of the tapping machine needed for the impulse response method are currently 1/3rd the weight and size of the ISO standard tapping machine. However, the entire testing method does require the measurement of the sound reduction index which increases the total equipment needed. In situations where a sound reduction index measurement were to already be made the total amount of equipment needed to make both measurements would be reduced. In this case the impulse response method provides a quicker and simpler testing procedure.

One of the disadvantages to this technique is the inability to make lateral impact noise measurements. Lateral impact noise transmission is not to the floor below but to rooms connected on the same level horizontally adjacent or below the floor being tested but adjacent to the room directly below.

The Uni-Tapper currently weighs approximately 3.6kg and is still relatively large in size (approximately 1/3rd the size of the ISO standard tapping machine), coupled with all the equipment currently used to conduct tests it is not an improvement to the difficulties and factors that make testing inconvenient. However, the weight of the Uni-Tapper could be reduced by using lighter metal for the framing and a lighter motor, reducing the weight further by approximately one half of the Uni-Tappers current weight. The equipment used to conduct the acceleration measurements could be replaced with a single amplification device exclusive designed to provide and impedance match between the accelerometer and the recording device. This would add negligible weight to the Uni-Tapper and fitted discretely within the electronics of the Uni-Tapper not effecting the size.

The recording device, in the current case a laptop, could also be replaced with small hand-held audio recording device, for field measurements, that would also server as the recording device for reverberation time and sound reduction index. It would also be possible to design a recording device, which once given all the necessary measurements of the sound reduction index, reverberation time and acceleration, could very quickly give a single value rating in the field. A more accurate representation of the normalised ISPL spectrum, could be found by further post-processing of the acceleration data after measurements have been made.

FUTURE WORK

Further tests on a wider variety of floor constructions and coverings need to be conducted to validate this technique for the general rating of floors. Variation of the impacting hammers head, for example rubber instead of steal, or by using a floor covering with a known change to the impulse response, could give a method of calculating the impact sound level of hard (and possibly more delicate) surfaces.

Further investigation of the impulse response method for rating floating floor configurations needs to be conducted. Although results have shown very poor correlation with the standard testing method it is possible a method of classifying the acceleration spectrum of a floating floor could be developed and rating system unique to the impulse response and floating floors could be employed.

With a reduced drop height and weight, a tapping machine which is considerably smaller and lighter could be manufactured. However, it has been shown using work by Lindblad [18] and a model by Brunskog [19] that nonlinear effects are likely to cause poor correlation with the standard testing method. This restricts changes to the hammer and to the drop height, however, it does not mean an expression for the improvement due to a floor covering could not be found. A standalone rating system could be formulated for the modified drop height, weight and even hammer design. It may be as simple as adding an adaptation term to this standalone rating

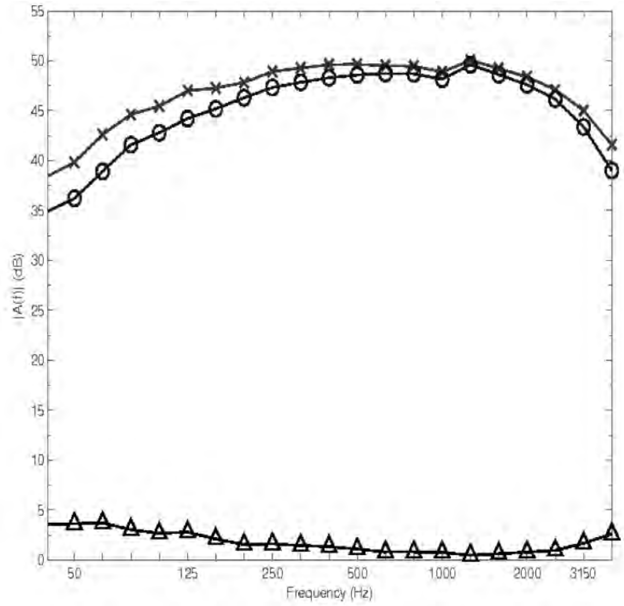

Figure 6: Acceleration spectrum levels of the bare floor with background noise.With (x), and without (o), background noise, and the difference (◆).

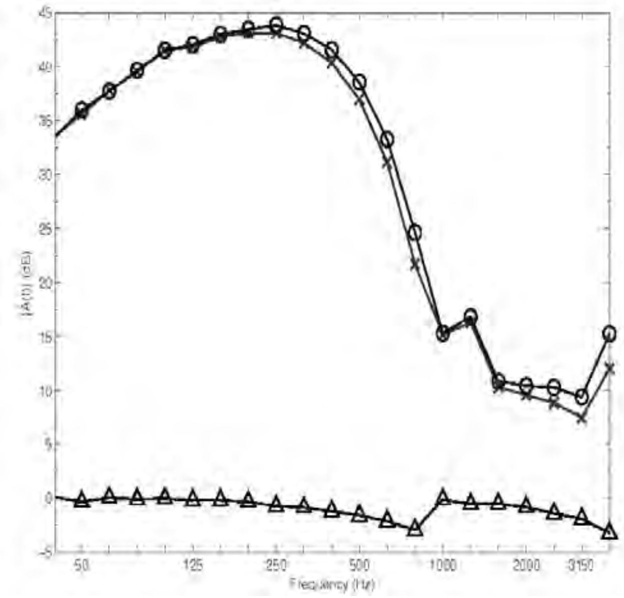

Figure 7: Acceleration spectrum levels with background noise, with a cork covering. With (x), and without (o), background noise, and the difference (◆).

to relate back to a weighted normalised IPSL rating or IIC rating. Further work would be required to investigate these possibilities.

CONCLUSION

All measurements of performance in building acoustics have a need for reliable results. Newly proposed ISO standards are discussed which outline procedures for establishing the uncertainties in such measurement results and new measures of performance to which these will need to be applied. Finally, a possibility for an alternative to the standard tapping machine for measuring the impact insulation between the levels in a multi-storey building is described. Whether or not this will be acceptable as a screening technique will depend not only on its successful practical development but also its ability to produce reliable results having low uncertainties.

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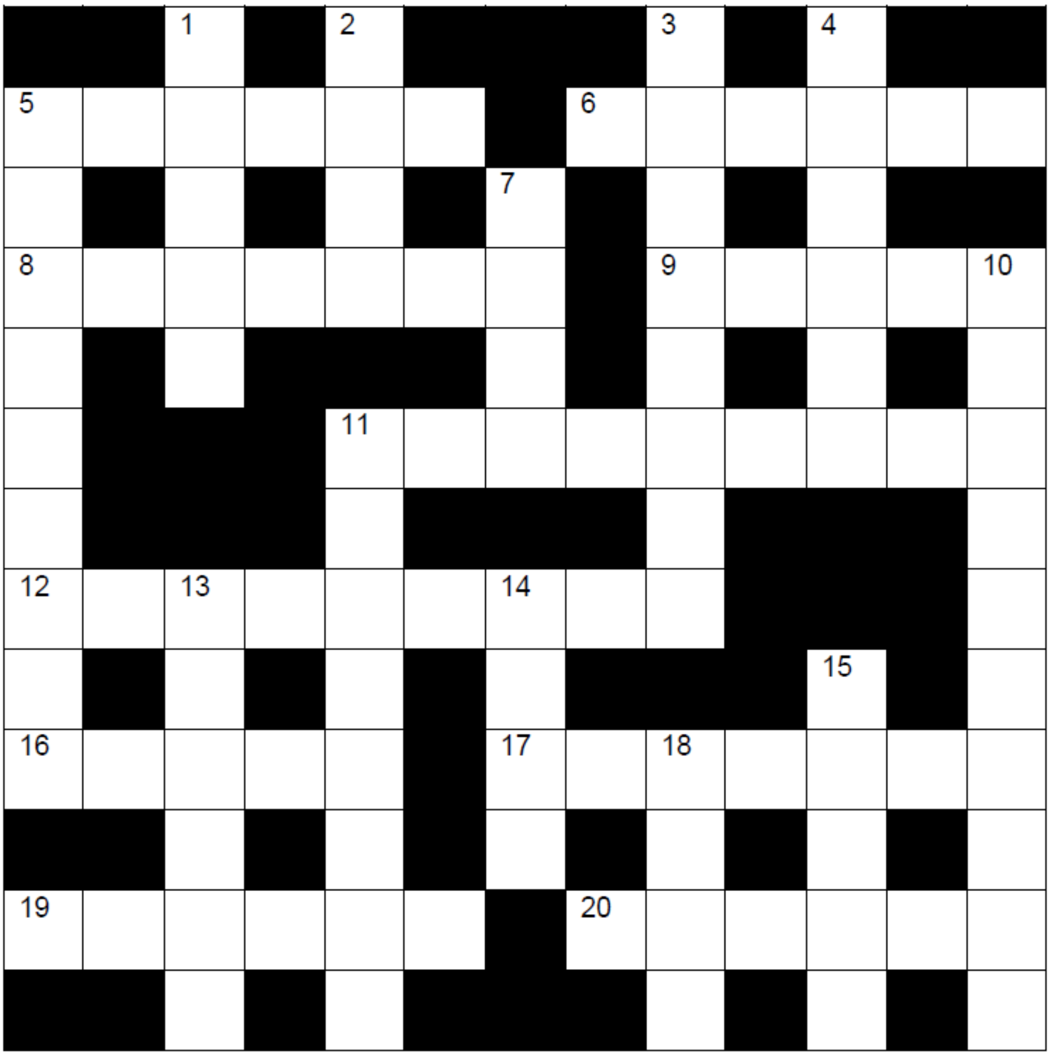
AUCKLAND UNITARY PLAN

The Auckland Council has released the first draft of its Unitary Plan and is inviting feedback. The Unitary Plan is the over-arching planning document that contains all noise rules for the Auckland Region.

http://unitaryplan.aucklandcouncil.govt.nz

The deadline for feedback is 31st May 2013, via their website link. ASNZ members are encouraged to read the draft and respond to council, to help ensure that its noise policies are well considered and robust.

Acoustic Crossword #9



Solutions to Crossword #8

Across:

1. Party Poppers
7. Music
8. Credo
9. Eat
10. Christmas
11. Nature
12. Abator
15. A Cars Horn
17. STC
18. Two Pi
19. Trees
21. Transmission

Down:

1. Peace on Earth
2. Yes
3. Oscars
4. Picosabin
5. Rheum
6. Construction
7. Motet
10. Christian
13. Tests
14. Bottom
16. Amour
20. ECS

CLUES ACROSS

5. Five muddled seers create poetry (6)
6. Lower the value reducing low frequency content (6)
8. Amazed shearer listens again (7)
9. Violently removed, without a penny left (5)
11. Frenchman about to carry a corpse needs a strong drink (9)
12. Old puzzle, it sounds delightful (9)
16. Sounds like "Be Quiet Dobby!" (5)
17. Close a make-up case (7)
19. Listen anyhow, without a sound (6)
20. Play slowly with a dog I have (6)

CLUES DOWN

1. Danish astronomer sounds like a donkey (5)
2. Second Greek describes trial software (4)
3. Apply silencer to buzzer (8)
4. Technically speaking most of cookie container disappeared (6)
5. They check Very lights soundly (9)
7. North Italian wine found in a stiff cardboard box (4)
10. Vain editor conceals source (10)
11. What an 11 Across does (8)
13. Suppressing vibrations, first Queen sounds healthy inside (6)
14. An easy task cut, retains a small advantage (4)
15. Judge the distance between rails (5)
18. Most often the fashionable method of approach (4)

Crossword submitted by:

Jet Anchor

Sound Snippets: Arctic Noise

Much of what is known about marine life in Alaska is the result of direct visual observation. Relatively recently, though, scientists began focusing more of their efforts on what goes on beneath the waves and the ice, when marine life is out of sight.

“In the spring time, in the Bering Sea, it’s kind of like an acoustic Serengeti,” Sue Moore, a biological oceanographer with the NOAA Fisheries Office of Science and Technology, said. Moore has been working with underwater acoustic technology since the 1980s.

She says during springtime in the Bering Sea you can hear the eerie trilling of a bearded seal, or a walrus tapping away. Belugas even make their presence known, calling as they swim by. Even if you ignore the noise created by marine life, Moore says the ocean can still be a very noisy place.

“Sea ice can be quite loud,” Moore said. “Sub-sea earthquakes sound like thunder; they can be very loud, like thunder and lightning.”

“Just the opening of the ocean itself, the open sea – if there’s a lot of wind, if there’s a storm – can be quite loud compared to an ocean covered with sea ice – that can be very quiet.”

Moore says her team in Alaska had a very successful field season from mid-August to the latter half of September in 2012. They deployed 22 sensors in the Bering, Chukchi and Beaufort Seas. The gear will sit beneath the waves, recording the environment until a research ship picks up the sensors to retrieve the data.

Moore is most excited about the ability to couple the audio recorders with oceanographic moorings that typically just monitor physical oceanography – like temperature, salinity, and chlorophyll levels. By using the acoustics, researchers hope to relate how the presence of marine life corresponds to the physical data.

“During International Polar Year, IPY, we were able to get one of these recorders on a Canadian mooring up in the very northern Chukchi Sea, and we were very surprised to get the bowhead and beluga signals there, and it corresponded very well with when we had the signal there was also a lot of zooplankton in the water,” Moore said.

According to Moore, a lot of the things we think we know about whales actually comes from whaling-era observations, and finding things like bowheads and belugas in the often-iced-over Arctic debunk some of those theories.

Moore says for the last 10 years or so, researchers have been in an exploratory phase. She hopes the next step will be to include sound recording devices as a standard information-gathering tool, and to begin focusing in on the more acoustically interesting areas, which could lead to many more discoveries.

© Adapted from an article by Josh Edge

Alaska Public Media

Sound Snippets: Stadium Sound

A good atmosphere at a sports stadium can make the difference for both the players on the pitch and the spectators in the stands. But how easy is it to engineer that sense of crowd magic?

The nickname the Theatre of Dreams for Manchester United's Old Trafford stadium was never intended to evoke a sleepy atmosphere. But the club has taken on an acoustic engineers to see how they can boost noise levels in the ground. A good atmosphere in a stadium matters to the business people who run sport because it can attract even more ticket buyers.

Creating an atmosphere is not only about generating as much noise as possible. It is also about making the fans feel they are part of an event and giving them an experience they could not get by watching it on television at home.

"The sound inside Old Trafford is very localised," says Ian Stirling, vice chairman of the Independent Manchester United Supporters Association. "I've had season tickets in quite a few places and there will be a lot of atmosphere in those areas, but you just won't hear it down at the other end."

Improving the atmosphere in an existing stadium is obviously different to building it up from scratch and one solution for Old Trafford could be to pump noise via microphones around the ground says David Keirle, chairman of

Continued on Page 34...

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...Continued from Page 32

KSS sports architects and designers.

KSS designed a curved and tilted roof for Brighton and Hove Albion's new Amex Community Stadium, which Keirle says retains the noise and reflects it onto the field of play. "You get long reverberations and people respond".

Some new-builds have been more successful than others regarding atmosphere. "Wembley is poor partly due to England's fans, who can be day trippers, and the rake is huge," said Henry Winter of the Daily Telegraph, referring to the slope of its lower tier.

"Inevitably when you do a stadium with more than one purpose you have to compromise. It is a big stadium and seats 90,000. If you changed the rake on the first row by a few millimetres that would have an effect of several metres at the back."

But atmosphere is not all to do with design, says Kevin Miles, chief executive of the Football Supporters Federation, and a Newcastle United fan.

"Ticket prices have gone up several hundred per cent since the formation of the Premier League. The age of the fans has therefore gone up, when the atmosphere was created by the younger working class fans. You have to price it accessibly."

Miles says the loss of standing sections, where most of the atmosphere was created, has also had a negative effect. He says designated singing areas - which can be a euphemism for the toleration of standing - have helped the atmosphere in stadiums, such as Manchester City's and Sunderland's.

"The location of the away fans - who can have a disproportionate effect on the atmosphere - is also important. They can spark a reaction from home fans, while a lot of clubs have moved them up into the corner out of the way."

Architects admit they can only provide part of the jigsaw puzzle that makes up atmosphere. "We can help the process with design, but we can't make it happen," said David Sheard from Populous Architects.

© Adapted from Martin Vennard

BBC World Service

Upcoming Events

2013

2 - 7 June, Montreal, Canada 21st International Congress on Acoustics(ICA 2013)
http://www.ica2013montreal.org

1 - 3 July 2013, International Conference on Recent Advances in Structural Dynamics, RASD 2013
Colleagues,
RASD will be held at the University of Pisa, Pisa, Italy, 1-3 July 2013. The eleventh in the RASD series, the conference will bring together researchers working in all areas of structural dynamics. The ten previous conferences have been held every three years or so since 1980.

As on prevision occasions, this conference is devoted to theoretical, numerical and experimental developments in structural dynamics and their application to all types of structures and dynamical systems. It will be an opportunity to exchange scientific, technical and experimental ideas.

The Call for Papers will be made in June 2012 with the deadline for the submission of abstracts being 28th September 2012. Submission and Registration to the conference will be done through the University of Southampton Open Conference System (www.ocs.soton.ac.uk/index.php/rasdconference/RASD2013).

Dr Emiliano Rustighi (on behalf of the RASD2013 Organising Committee)

Further information is available at https://www.soton.ac.uk/rasd2013

7 - 11 July 2013, 20th International Congress on Sound and Vibration (ICSV20), Bangkok, Thailand
The 20th International Congress on Sound and Vibration (ICSV20) will be held 7-11 July 2013 in Bangkok, Thailand. The ICSV20 is sponsored by the International Institute of Acoustics and Vibration (IIAV) and the Faculty of Science; Chulalongkorn University, the Acoustical Society of Thailand and the Science Society of Thailand; the ICSV20 is organized in cooperation with: the International Union of Theoretical and Applied Mechanics; the American Society of Mechanical Engineers International and the Institution of Mechanical Engineers. The ICSV20 Congress will be held at Imperial Queens Park Hotel, Bangkok, Thailand.

Theoretical and experimental papers in the fields of acoustics, noise, and vibration are invited for presentation. Participants are welcome to submit abstracts to www.icsv20.org and companies are invited to take part in the ICSV20 exhibition and sponsorship. For more information, please visit: http://www.icsv20.org

11 - 12 July 2013 The ISVR at 50
2013 will mark the 50th anniversary of the foundation of the Institute of Sound and Vibration Research, at the University of Southampton, UK.

To celebrate the achievements of its people, past and present, we will be hosting a two-day symposium on the 11th and 12th July 2013.

The symposium will feature talks from key speakers having an association with the ISVR, and will also include our annual E J Richards lecture. The celebrations will culminate in a social function with a buffet supper and entertainment. The tickets for the event are £50 for full attendance, with a reduced cost for partial attendance.

Details of the event are available online at http://www.isvr.co.uk/ISVR-50th-anniversary

26 - 28 August, Denver, USA NOISE-CON 13, 27 - 30 August, Denver, USAWind Turbine Noise 2013
http://www.inceusa.org

15 - 18 September, Innsbruck, Austria Internoise 2013
http://www.internoise2013.com

9-11 October, Hangzhou, China 4th Pacific Rim Underwater Acoustics Conference (PURAC 2013)
http://pruac.zju.edu.cn/index.htm

2 - 6 December, 166th Meeting of the Acoustical Society of America, San Francisco, USA
http://www.acousticalsociety.org

2014

5 - 9 May, 167th Meeting of the Acoustical Society of America, Providence, USA
http://www.acousticalsociety.org

6 - 10 July, 21st International Congress on Sound and Vibration (ICSV21), Beijing, China
http://www.icsv21.org/

27 - 31 October, 168th Meeting of the Acoustical Society of America, Indianapolis, USA
http://www.acousticalsociety.org

16 - 19 November, Internoise 2014, Melbourne, Australia
http://www.internoise2014.org

2015

11 - 15 May, 4th International Congress on Ultrasonics (ICU 2015), Metz, France
http://www.me.gatech.edu/2015-ICU-Metz/

18 - 22 May, 169th Meeting of the Acoustical Society of America, Pittsburgh, USA
http://www.acousticalsociety.org

2 - 6 November, 170th Meeting of the Acoustical Society of America, Jacksonville, USA

CRAI Ratings

Auckland

215, Dominion Rd	(1)	★★★★½
Andrea (form. Positano), Mission Bay	(1)	★★★
Aubergine's, Albany	(1)	★★★★½
Backyard, Northcote	(1)	★★
Bask, Browns Bay	(1)	★★★
Bay (The), Waiake, North Shore	(1)	★★★★★
Bolero, Albany	(1)	★★★★
Bosco Verde, Epsom	(1)	★★★★½
Bouchon, Kingsland	(1)	★★
Bowman, Mt Eden	(1)	★★★★½
Bracs, Albany	(1)	★★★★
Brazil, Karangahape Rd	(1)	★★★
Buoy, Mission Bay	(2)	★★★★½
Byzantium, Ponsonby	(1)	★★★
Café Jazz, Remuera	(1)	★★★★½
Carriages Café, Kumeu	(1)	★★★★
Charlees, Howick	(1)	★★★★★
Cibo	(1)	★★★★★
Circus Circus, Mt Eden	(1)	★★
Cube, Devenport	(1)	★★
Del Fontaine, Mission Bay	(1)	★★★★★
Deli (The), Remuera	(1)	★★★★
Delicious, Grey Lynn	(1)	★★★★★
De Post, Mt Eden	(1)	★★
Dizengoff, Ponsonby Rd	(1)	★★
Drake, Freemans Bay (Function Room)	(1)	★★
Eiffel on Eden, Mt Eden	(1)	★★
Eve's Cafe, Westfield Albany	(1)	★★★½
Formosa Country Club Restaurant	(1)	★★★★★
Garrison Public House, Sylvia Park	(1)	★★★★½
Gee Gee's	(1)	★★★
Gero's, Mt Eden	(9)	★★★
Gina's Pizza & Pasta Bar	(1)	★★★½
Gouemon, Half Moon Bay	(1)	★★
Hardware Café, Titirangi	(1)	★★★★★
Hollywood Café, Westfield St Lukes	(1)	★★½
IL Piccolo	(1)	★★★★
Ima, Fort Street	(1)	★★★★
Jervois Steak House	(1)	★★★
Kashmir	(1)	★★★★
Khun Pun, Albany	(2)	★★★★★
Kings Garden Ctre Café, Western Springs	(1)	★★
La Tropezienne, Browns Bay	(1)	★★
Malaysia Satay Restaurant, Nth Shore	(1)	★★★★★
Mecca, Newmarket	(1)	★★★★★
Mexicali Fresh, Quay St	(1)	★★
Mezze Bar, Little High Street	(16)	★★★★
Monsoon Poon	(1)	★★★★★
Mozaike Café, Albany	(1)	★★
Narrow Table (The), Mairangi Bay	(1)	★★★★½
One Red Dog, Ponsonby	(1)	★★★
One Tree Grill	(1)	★★★
Orbit, Skytower	(2)	★★★★
Patriot, Devonport	(1)	★★★½
Pavia, Pakuranga	(1)	★★★★★
Prego, Ponsonby Rd	(2)	★★
Remuera Rm, Ellerslie Racecourse	(1)	★★★★★
Rhythm, Mairangi Bay	(1)	★★
Rice Queen, Newmarket	(12)	★★★★
Sails, Westhaven Marina	(2)	★★★★★
Scirocco, Browns Bay	(1)	★★★
Seagers, Oxford	(1)	★★★★
Shahi, Remuera	(1)	★★★½
Shamrock Cottage, Howick	(1)	★★
Sidart, Ponsonby	(1)	★★★★½
Sitting Duck, Westhaven	(1)	★★★½
Sorrento	(1)	★★½
Stephan's, Manukau	(1)	★★★★★
Tempters Café, Papakura	(1)	★★★★★
Thai Chef, Albany	(1)	★★★★★
Thai Chilli	(1)	★★★★★
Thai Corner, Rothesay Bay	(1)	★★★★★
Tony's, High St	(1)	★★★
Traffic Bar & Kitchen	(1)	★★
Umbria Café, Newmarket	(1)	★★★★½
Valentines, Wairau Rd	(1)	★★★★★
Vivace, High Street	(2)	★★½
Wagamama, Newmarket	(1)	★★★★½
Watermark, Devonport	(1)	★★
Woolshed, Clevedon	(1)	★★½
Zarbos, Newmarket	(1)	★★
Zavito, Mairangi Bay	(1)	★★ ★

Arthur's Pass

Arthur's Pass Cafe & Store	(1)	★★★½
Ned's Cafe, Springfield	(1)	★★★★

Ashburton

Ashburton Club & MSA	(1)	★★★★½
Robbies	(1)	★★★
RSA	(1)	★★★★

Readers are encouraged to rate eating establishments which they visit by completing a simple form available on-line from www.acoustics.ac.nz, or contact the Editor.
Repeat ratings on listed venues are encouraged.

★ Lip-reading would be an advantage. ★★ Take earplugs at the very least. ★★★ Not too bad, particularly mid-week. ★★★★A nice quiet evening. ★★★★★The place to be and be heard. (n) indicates the number of ratings.

Tuscany Café & Bar	(1)	★★★

Bay of Plenty

Alimento, Tauranga	(1)	★½
Imbibe, Mt Maunganui	(1)	★½
Versailles Café, Tauranga	(2)	★★

Blenheim

Raupo Cafe	(1)	★★

Bulls

Mothered Goose Cafe, Deli, Vino	(1)	★★

Cambridge

GPO	(1)	★★★★★

Christchurch

3 Cows, Kaiapoi	(1)	★★★★
Abes Bagel Shop, Mandeville St	(1)	★★★★
Alchemy Café, Art Gallery	(1)	★★★★★
Anna's Café, Tower Junction	(1)	★★★★
Arashi	(1)	★★
Azure	(2)	★★★
Becks Southern Ale House	(11)	★★★★½
Bridge (The), Prebbleton	(1)	★★★★★
Buddha Stix, Riccarton	(1)	★★★★
Bully Haye's, Akaroa	(1)	★★
Café Valentino (St Asaph St)	(1)	★★★
Cashmere Club	(1)	★★★★★
Chinwag Eathai, High St	(8)	★★
Christchurch Casino	(1)	★★
Christchurch Museum Café	(1)	★★★★
Cobb & Co, Bush Inn	(1)	★★★
Coffee Shop, Montreal Street	(1)	★★
Cookai	(3)	★★½
Cortado, Colombo Street	(4)	★★★★
Costas Taverna, Victoria Street	(1)	★½
Coyote's	(6)	★★★
Curator's House	(25)	★★★½
Decadence Café, Victoria St	(1)	★★★★★
Drexels Breakfast Restaurant, Riccarton	(1)	★★★★
Elevate, Cashmere	(6)	★★★
Fava, St Martins	(1)	★★
Foo San, Upper Riccarton	(1)	★★★½
Fox & Ferrett, Riccarton	(1)	★★★★★
Freemans, Lyttleton	(9)	★★★½
Gloria Jean's, Rotheram St	(1)	★★★★
Golden Chimes	(1)	★★★★★
Governors Bay Hotel	(1)	★★★★
Green Turtle	(1)	★★★★
Harpers Café, Bealey Ave	(1)	★★★★★
Hari Krishna Café	(1)	★★★
Holy Smoke, Ferry Rd	(1)	★★
Indian Fendalton	(2)	★★
Joyful Chinese Rest., Colombo St	(1)	★★★★★
Kanniga's Thai	(1)	★★★
La Porchetta, Riccarton	(4)	★★½
Lone Star, Riccarton Road	(6)	★★★
Lyttleton Coffee Co, Lyttleton	(1)	★★★★
Manee Thai	(6)	★★½
Mexican Café	(6)	★★★
Myhanh, Church Corner	(4)	★★★½
Number 4, Merivale	(2)	★★★★
Oasis	(1)	★★★★½
Old Vicarage	(2)	★★★½
Phu Thai, Manchester Street	(1)	★★★
Portofino	(3)	★★★★★
Pukeko Junction, Leithfield	(1)	★★★★
Red, Beckenham Service Centre	(1)	★★★★
Red Elephant	(1)	★★★★
Retour	(1)	★★★
Riccarton Buffet	(2)	★★★★½
Robbies, Church Corner	(2)	★★★★½

Route 32, Cust	(1)	★★★★
Salt on the Pier, New Brighton	(6)	★★★½
Sand Bar (The), Ferrymead	(2)	★★★½
Speights Ale House, Ferrymead	(3)	★★★★★
Speights Ale House, Tower Junction	(1)	★★★★
Tokyo Samurai	(1)	★★★★★
Tutto Bene, Merivale	(2)	★★
Twisted Hop (The), Woolston	(3)	★★★★½
Untouched World Cafe	(1)	★★★★★
Venuti	(3)	★★★★★
Waitikiri Golf Club	(1)	★★
Waratah Café, Tai Tapu	(1)	★★★

Clyde

Old Post Office Cafe	(1)	★★★★★

Dunedin

A Cow Called Berta	(1)	★★★½
Albatross Centre Cafe	(1)	★★★★★
Bennu	(1)	★★★★
Bx Bistro	(1)	★★★★
Chrome	(1)	★★★★½
Conservatory, Corstophine House	(1)	★★★★★
Fitzroy Pub on the Park	(1)	★★★★★

CRAI Ratings (cont.)

High Tide	(2)	★★
Nova	(1)	★★★★★
St Clair Saltwater Pool Cafe	(1)	★★★★½
Swell	(1)	★★
University of Otago Staff Club	(1)	★★

Feilding

Essence Cafe & Bar0	(1)	★★★★

Gore

Old Post	(1)	★★★
The Moth, Mandeville	(1)	★★★★★

Greymouth

Cafe 124	(1)	★★★

Hamilton

Embargo	(1)	★★★★★
Gengys	(1)	★★
Victoria Chinese Restaurant	(1)	★★★★★

Hanmer Springs

Laurels (The)	(2)	★★★★★
Saints	(1)	★★★★½

Hastings

Café Zigliotto	(1)	★★★

Havelock North

Rose & Shamrock	(1)	★★★½

Levin

Traffic Bar & Bistro	(1)	★★

Masterton

Java	(1)	★★

Matamata

Horse & Jockey	(1)	★★★★★

Methven

Ski Time	(2)	★★★

Napier

Boardwalk Beach Bar	(2)	★★★★★
Brecker's	(1)	★★★★★
Café Affair	(1)	★★
Cobb & Co	(1)	★½
Duke of Gloucester	(1)	★★★★½
East Pier	(1)	★★
Estuary Restaurant	(1)	★★★★★
Founder's Cafe	(1)	★★★★★
Napier RSA	(1)	★★★★★
Sappho & Heath	(1)	★★

Nelson/Marlborough

Allan Scott Winery	(1)	★★★★★
Amansi @ Le Brun	(1)	★★★★★
Baby G's, Nelson	(1)	★★★★★
Boatshed Cafe (The)	(1)	★★★★
Boutereys, Richmond	(1)	★★★★
Café Affair, Nelson	(1)	★★
Café on Oxford, Richmond	(1)	★★★
Café Le Cup, Blenheim	(1)	★★★
Crusoe's, Stoke	(1)	★★★
Cruizies, Blenheim	(2)	★★★★½
Grape Escape, Richmond	(1)	★★★★★
Jester House, Tasman	(1)	★★★★★
L'Affaire Cafe, Nelson	(1)	★★
Liquid NZ, Nelson	(1)	★½
Lonestar, Nelson	(1)	★★★★
Marlborough Club, Blenheim	(1)	★★
Morrison St Café, Nelson	(1)	★★½
Oasis, Nelson	(1)	★★★★★
Rutherford Café & Bar, Nelson	(1)	★★★★★
Suter Cafe, Nelson	(1)	★★
Verdict, Nelson	(1)	★★
Waterfront Cafe & Bar, Nelson	(1)	★★★
Wholemeal Trading Co, Takaka	(1)	★★★★★

New Plymouth

Breakers Café & Bar	(1)	★★★
Centre City Food Court	(1)	★★★★
Elixer	(1)	★★★★
Empire Tea Rooms	(1)	★★★★½
Govett Brewster Cafe	(1)	★★
Marbles, Devon Hotel	(1)	★★★
Pankawalla	(1)	★★★★★
Simplicity	(1)	★★★
Stumble Inn, Merrilands	(1)	★★★
Yellow Café, Centre City	(1)	★★★
Zanziba Café & Bar	(1)	★★★

Oamaru

Riverstone Kitchen	(1)	★★★★★
Star & Garter	(1)	★★★
Woolstore Café	(1)	★★★★

Palmerston North

Café Brie	(1)	★★★
Café Esplanade	(2)	★★★★
Chinatown	(1)	★★★★
Coffee on the Terrace	(2)	★★★
Elm	(1)	★★★★½
Fishermans Table	(1)	★★★★★

CRAI Ratings (cont.)

Gallery	(3)	★★★★
Rendezvous	(1)	★★½
Roma Italian Restaurant	(1)	★★★
Rose & Crown	(1)	★★
Tastee	(1)	★★★
Thai House Express	(1)	★★★★★
Victoria Café	(1)	★★★★

Queenstown

Bunker	(1)	★★★★
The Cow	(1)	★★★
Sombreros	(1)	★
Tatler	(1)	★★★★
Winnies	(1)	★★★★★

Rotorua

Cableway Rest. at Skyline Skyrides	(1)	★★★★★
Lewishams	(1)	★★★
Woolly Bugger, Ngongotaha	(1)	★★★
Valentines	(1)	★★★★★
You and Me	(1)	★★★★★
Zanelli's	(1)	★★

Southland

Lumberjack Café, Owaka	(1)	★★★★★
Pavilion, Colac Bay	(1)	★★
Village Green, Invercargill	(1)	★★★★★

Taihape

Brown Sugar Café	(1)	★★★★½

Taupo

Burbury's Café	(1)	★★★
Thames		
Thames Bakery	(1)	★★★
Waiheke Island		
Cortado Espresso Bar	(1)	★★★★
Cats Tango, Onetangi Beach	(1)	★★★★

Timaru

Fusion	(1)	★★★★★

Wanganui

3 Amigos	(1)	★★★½
Bollywood Star	(1)	★★★½
Cosmopolitan Club	(1)	★★★★
Liffiton Castle	(1)	★★½
RSA	(1)	★★★½
Stellar	(1)	★★★★½
Wanganui East Club	(1)	★★★★

Wellington

162 Café, Karori	(1)	★★★★★
180o, Paraparaumu Beach	(1)	★★
88, Tory Street	(35)	★★
Anise, Cuba Street	(1)	★★
Aranya's House	(1)	★★★★★
Arbitrageur	(2)	★★★
Arizona	(1)	★★
Astoria	(2)	★★★
Backbencher, Molesworth Street	(1)	★★★
Bordeaux Bakery, Thorndon Quay	(1)	★★
Brewbar (function room)	(49)	★★★
Brown Sugar, Otaki Railway Station	(1)	★★★
Buzz, Lower Hutt	(1)	★★½
Brewery Bar & Restaurant	(5)	★★★★
Carvery, Upper Hutt	(1)	★★★★★
Chow	(1)	★½
Cookies, Paraparumu Beach	(1)	★★★½
Cosa Nostra Italian Trattoria, Thorndon	(1)	★★★★
Gotham	(6)	★★★½
Great India, Manners Street	(2)	★★★★★
Habebie	(1)	★★
Harrisons Garden Centre, Peka Peka	(1)	★★★★
Hazel	(1)	★★
Katipo	(1)	★★★★★
Kilim, Petone	(4)	★★★★½
Kiss & Bake Up, Waikanae	(1)	★★★
La Casa Pasta	(1)	★★★★½
Lattitude 41	(3)	★★★★
Legato	(1)	★★
Le Metropolitain	(1)	★★★★★
Loaded Hog	(5)	★★★★½
Manhatten, Oriental Bay	(1)	★★★★
Maria Pia's	(1)	★★★
Matterhorn	(1)	★★★
Mungavin Blues, Porirua	(1)	★★★★★
Olive Cafe	(1)	★★★★★
Olive Grove, Waikanae	(1)	★★★½
Original Thai, Island Bay	(1)	★★★★
Palace Café, Petone	(1)	★★½
Parade Café	(1)	★★
Pasha Café	(1)	★★★★
Penthouse Cinema Café	(2)	★★★½
Pod	(1)	★★½
Rose & Crown	(1)	★★★★★
Shed 5	(1)	★★
Siem Reap	(1)	★★
Speak Easy, Petone	(1)	★★
Speights Ale House	(1)	★★
Sports Bar Café	(1)	★★★★
Stanley Road	(1)	★★★
Stephan's Country Rest., Te Horo	(1)	★★★★★
Wakefields (West Plaza Hotel)	(1)	★★★
Windmill Café & Bar, Brooklyn	(1)	★★
Yangtze Chinese	(1)	★★★★½
Zealandia Café, Karori Sanctuary	(1)	★★★½