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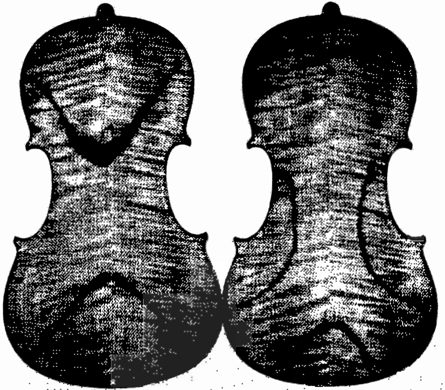

- Control of Eccentric Building Vibrations
- Impact Hammer for Vibration Analysis
- Computer Modelling for Room Acoustics
- Effect of Ageing and Playing on Violins
- Australian Acoustical Society Code of Ethics

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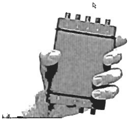

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PAPERS

FORUM

Cover illustration: Two of the resonant modes of a violin back

From the President

Cosmic Noise Conspiracy Shocker!

Firstly, I' d like to extend a planet-sized thank you to all you star gazing thrill seekers for your colourful comments regarding my cheap, but ultimately successful attempt at getting your attention. Not only did it prove that celestial noise is a serious issue, and that a powerful telescope is an indispensable (and tax-deductible) part of any acoustic engineer' s toolbox, it also proved that someone other than my mum reads this column.

Surprisingly, after spending literally minutes poring through my extensive collection of back issues of the New Scientist, I unearthed a confidential draft copy of a report about how to solve the moon noise problem. Published in 1973 by a team of Ethnian physicists wearing sheepskin hats, the report appeared to be a thorough investigation packed with complex theorem, detailed analysis and recipes for Beef Stroganoff. My Ethnian is a little rusty these days, however I was able to deduce that mean moon noise can be calculated as follows:

$$\frac{\text{Mean Orbiting Speed} \times \text{Gravitational Pull}^3}{\text{Wind speed in Stockholm}}$$

The report read and looked like a quality piece of work that any AAS member would be proud of, until I read the far-reaching noise control recommendations:

- Reduce moon speed
- Grind surface of moon smooth to reduce turbulence
- Limit moon travel times to daylight hours
- Construct barrier between earth and moon using materials with a minimum surface density of σ
- Active Noise Control
- Provide hearing defenders to all living creatures

It reminds me how often I have seen spectacularly impractical recommendations in real reports, conclusive proof that we all have to let gravity keep our feet on the ground and exercise common-sense at all times.

So down to business. I would like to extend a warm welcome to the new editorial team, based in Sydney and lead by Joe Wolfe. I look forward to you and your team continuing the excellent standards that have already been set, as well as injecting a fresh perspective on pushing the boundaries and exploring new avenues. Don' t forget there is an Acoustics Forum, for papers which may be of general interest to our members but do not need a formal technical peer review.

Speaking of new appointments, congratulations are in order for Louis Challis who was recently honoured with a Member of the Order of Australia for services to engineering. Louis was also featured in an Institute of Engineers article about the country' s top 100 engineers. Can I just say that it is fantastic to see one of our members being recognised for their skills and contribution to society, we should all be proud.

It' s worth noting that I was ranked 101st in the same rankings. Clearly I should have been much higher, but the judges noted that my entry form contained not a single typographical or grammatical error and thus concluded I couldn' t possibly be a proper engineer.

On a more sobering note, I' m sad to report that due for health reasons, Ken Mikl recently resigned as a NSW committee member. Ken was also a National Councillor and had been President of the AAS for the last 2 years. Ken will now be devoting more time to his family and tennis. I have got to know Ken well over the last few years and even though I knew little of his professional work in acoustics, I knew he was passionate about the industry and the society into which he put an enormous amount of effort. Ken had been the driving force in preparing and winning the bid for the ICA conference in Sydney in 2010 and was planning to chair the event. I hope the AAS can recognise his contribution and do him proud in his absence. Five years seems a long time, but, like a noisy new full moon, it will come around very quickly. In his resignation letter, Ken stated that he always made a conscious effort to " put back in" to all the clubs and societies where he was a member. I think you' ll all agree that we need more people with Ken' s attitude and approach. The AAS will miss Ken' s contribution, he said that he felt he couldn' t do half a job and I said to him at the time that half a job from him would be better than a full job from many.

So how about some of those interesting stories I promised you. I' m disappointed to report that no one has been brave enough to send me any stories so I' m going to start us off with one of my own. Are you sitting comfortably?

Apparently, a brief was received about a new commercial office development in the city. To try and save the client some money it was decided that because background noise measurements had been made almost opposite the site, there was no need to undertake any more. The façade design to control traffic noise and mitigation measures for mechanical plant was reviewed and recommendations made. Once the design was completed, a report was prepared to support the DA and sent to the client before it was issued to Council.

About 2 years later the client required compliance testing, so a technical officer was sent to the new development with a copy of the site plan from the original report. Not being able to find the development at the location on the map, he made a few enquiries and worked out he was at the wrong end of the CBD from the development. Never mind, a quick cab ride later he was at the new building undertaking testing. The next day a report was issued to the client confirming all aspects of the design met the appropriate criteria, in particular the traffic noise ingress. So how come the QA checker didn' t pick the development address and site plan were two different places, more importantly the client never noticed and even more surprising neither did the Council? The mind boggles!! Perhaps fewer people read our reports than read this column, which is saying something. It' s a great reminder that as a profession we should be focused on understanding the big picture and using our ears and heads to make judgments, rather than getting too involved in all the details, when they often make little difference.

So that' s it from me for now. Please don' t forget that if you have any interesting little anecdotes or stories that you want to share with everyone, I would love to hear from you. Unless of course your stories are funnier than mine in which case keep them to yourself.

Neil Gross

From the Editors

This is the first edition of Acoustics Australia to have been produced by the team of Marion Burgess, Emery Schubert, John Smith and Joe Wolfe, all of the University of New South Wales.

Only the newest of Acoustics Australia' s readers will be unaware of the excellent work that has been done, over several years, by the previous editorial team of Marion Burgess, Neville Fletcher and Joseph Lai. They have handed over not only a journal in good health, but a set of carefully written instructions on how to run it. Even better, Marion has stayed on as editor of the News Notes section and adviser on a range of matters. So our congratulations and thanks to her, to Neville and to Joseph. The business manager, Leigh Wallbank, and the printer, Scott Williams of Cronulla Printing Co Pty Ltd, are unchanged, and their expertise has made life easy for the novice team. Our thanks, too, to reviewers, nearly all of whom have been very prompt and helpful.

We have also been fortunate in that both articles and advertising have continued to arrive, which keeps the journal healthy both intellectually and financially. We are pleased to lead this issue with an article from a team of acousticians working in industry, and addressing the topical issue of earthquakes (Scott, hold page one!). This is followed by three papers from academic research laboratories. The Forum continues in this issue, with an essay proposing changes to the Australian Acoustical Society' s Code of Ethics.

So we are happy with the content format of this issue. But are you? What would you like the journal to be? Are there any topics that we should consider for a special topic issue, or on which we should invite an article from an expert?

In scholarly publishing, it is normally the case that one' s experience is first as an author, second as a reviewer, and third as an editor. It is certainly the case for us. Recalling when we were beginning authors, we admit to having regarded editors and reviewers as barriers to be overcome on the way to the goal of publication. We quickly realised, of course, that the changes required make our papers better and so we should be grateful, despite the inconvenience. As authors, one may see editors as umpires arbitrating between one' s clearly reasoned argument and the astonishing incomprehension of the unseen foes, next as finicky style police, and finally as incompetents who oversee delays, who supervise the reduction of one' s works of art to unresolvably small size and who stifle the originality of one' s grammar and spelling.

An old saying counsels: " Never criticise a man until you' ve walked a mile in his shoes. That way, when he hears your criticism, you' ll be a mile away – and you' ll have his shoes." Having walked in the shoes of Neville' s team (and big shoes they are to fill), we have so far no criticisms. But we do have some new perspectives – and some new shoes.

Joe Wolfe, Emery Schubert, John Smith .

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WORKCOVER COMPLIANCE COORDINATION TEAM

CONTROL OF ECCENTRIC BUILDING VIBRATION WITH BASE ISOLATION

Helen Wu[1], Bob Fitzell[1], Bijan Samali[2]

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Base isolation is found effective in reducing torsional response of structures with mass eccentricity when subjected to earthquakes. In this study, dynamic characteristics of an eccentric five-storey benchmark model, isolated with laminated rubber bearings (LRB) and lead core rubber bearings (LCRB), were examined using a shaker table and four different ground motions. The earthquake-resistant performance of LRB and LCRB isolators was evaluated. It was observed that both transverse and torsional responses were significantly reduced with the addition of an LRB or LCRB isolated system regardless of ground motion input. However, the LRB was identified to be more effective than LCRB in reducing relative torsional angle, model relative displacements, accelerations and angular accelerations, and therefore, provided a better protection of the superstructure and its contents.

INTRODUCTION

Ground motions produced by severe earthquakes are often quite damaging to structures and their contents. Conventional earthquake-resistant designs often focus on the strengthening of structures to resist such disturbances and avoid structural collapse, whilst little attention is given to the prevention of damage. Using such design approaches, it is almost impossible to construct completely ' earthquake-proof' structures that are both reasonable in cost and aesthetically acceptable.

Seismic isolation of the building structure is an efficient design scheme that can successfully reduce earthquake loading to improve safety and reduce building damage [1]. A seismically isolated structure can have a fundamental frequency considerably lower than the fundamental frequency of the same structure built without isolation and also lower than the usual predominant frequencies of a typical earthquake [2]. This is achieved by mounting the structure on a set of isolators that provide low horizontal stiffness, thereby shifting the fundamental frequency of the structure to a much lower value. As a result, most deformations occur within the isolation level, allowing the superstructure to remain essentially undeformed and able to move like a rigid body. This technique prevents damage to the structural and nonstructural components of the building [1].

However, a real world structure is usually eccentric, meaning its centre of stiffness is offset from its centre of mass. Some structures are inherently eccentric, due to an asymmetric floor plan (usually dictated by the needs of the building occupancy) leading to an asymmetric layout of the structural members, or may be eccentric due to the location of stairwells and lift-shafts, etc. When a transverse mode is coupled to a rotational mode, arising from the eccentricity, the torsional component of seismic responses will be amplified if certain conditions are met.

Up to now, studies of the seismic behaviour of asymmetric structures, especially using shaker table tests, have been very limited. As a result, understanding of the role and effectiveness of rubber bearings in protecting eccentric structures has remained limited. Consequently, experimental studies on the response of eccentric structural systems with base isolators will provide valuable insight to this technique. Well-conducted experimentation will provide data for analysis and design of such structures isolated with rubber bearings. This paper describes a series of shaker table tests designed to evaluate the seismic performance of an eccentric five-storey building model subjected to various simulated earthquake inputs. The effectiveness of two rubber isolation systems against torsional response is investigated in detail to assist further development of new and effective isolation systems for asymmetric structures.

EXPERIMENTAL STUDIES

Five-storey benchmark steel model

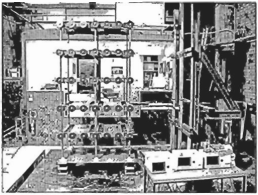

Figure 1. Eccentric five-storey model with isolators

The experimental benchmark building model, having dimensions of 1.5m x 1.0m x 3m, designed by Samali [3], offers the flexibility needed to model and test various building configurations. The eccentric model was created by adding a total of 350 kg mass to one side of a symmetrical concentric steel frame weighing 1200 kg, as shown in Figure 1. The additional 350 kg mass consisted of 140 steel disks equally distributed on the front side of each floor. This produces an eccentricity of 0.125L, where L is the width of the floor. This level of eccentricity is regarded as moderate eccentricity.

CHARACTERISTICS OF RUBBER BEARING ISOLATORS

The laminated rubber bearings (LRB) used in this study consisted of 25 thin rubber sheets with a sheet thickness of 2.2 mm and 25 thin layered steel plates each 1.8 mm thick. The rubber sheets were vulcanized and bonded under pressure and heat so as to alternate with each thin steel plate. The effect achieved by including the inner steel plates is to control the shape factor of each elastomeric rubber layer, so as to prevent lateral bulging, achieving a vertical stiffness approximately 500 times the lateral stiffness of 220 kNm^{-1}. This ensures a large vertical load carrying capacity. Horizontal flexibility is provided through shear deformation of the individual rubber sheets. The overall dimensions of the laminated bearing used for the experiment were 120 x 120 x 100mm. Two thick mounting steel plates (200 x 200 x 20 mm) were bonded to the bottom and top surfaces of each laminated bearings so as to provide for connection fixings to the shaker table and to the superstructure, as shown in Figure 1.

The configuration and dimensions of lead core rubber bearings (LCRB) (Figure 2) were the same as LRB but a lead plug with a diameter of 30 mm was inserted into a machined hole at the center of each bearing. In addition to the elastomeric characteristics of the LRB type, a further energy dissipation mechanism can be achieved with the LCRB due to the plastic deformation of the lead plug. A lead rubber bearing also provides initial rigidity under lateral service loads, such as during wind loads, due to the high stiffness prior to yielding of the lead plug. In that arrangement, however, the energy dissipation mechanism is activated only after the lead plug has yielded. Lead rubber bearings also provide a greater restoring effect to re-centre the isolators at their original locations after normal service loads.

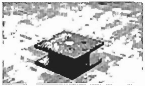

Figure 2. Photo of an individual lead core rubber bearing.

Shaker table testing

Tests were carried out using the unidirectional shaker table facility at University of Technology, Sydney. The plan dimensions of the table are 3m x 3m. The table allows movement in a horizontal direction operated by a hydraulic actuator with a maximum acceleration of 2.5g (bare table), with a maximum stroke and piston velocity of ±100 mm and 550 $mm.s^{-1}$ respectively. As shown in Figure 3, two accelerometer and two LVDT (linear variable displacement transducer) measurement locations were utilized for each survey measurement level. Two accelerometers and two LVDTs were located at each of the rubber bearing level, the 2^{nd} and the 5^{th} floor levels respectively. A further accelerometer and LVDT combination was installed on the shaker table to measure the table response.

A total of 14 channels of data were therefore recorded using two YOKOGAWA Analyzers. The shaker table was driven in the longitudinal direction of the five-storey model. To determine a suitable input excitation to the table, motion records from four earthquakes were used: El Centro (1994), Hachinohe (1968), 50%-intensity Kobe (1995) and Northridge (1994). Measured maximum accelerations on the shaker table were 0.42g, 0.23g, 0.41g and 0.45g representing the above four earthquakes respectively. To maintain dynamic similitude, each record was compressed in time by a factor of 3 to ensure the first mode frequency of the model was consistent with dominant frequency of the earthquake record. That is, the dominant frequencies of the simulated earthquakes were increased by a factor of 3.

The shaker table tests were conducted using both fixed-base and base-isolated structures, with the experimental set-up for the LRB-isolated five-storey benchmark model on the shaker table shown in Figure 1.

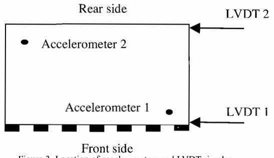

Figure 3. Location of accelerometers and LVDTs in plan.

RESULTS AND DISCUSSION

The effectiveness of the base isolation systems was evaluated by comparing the structural transverse and torsional responses of the two models – isolated and non-isolated – for each load case. This was determined by measuring the variation in maximum relative displacement with floor height in the direction of shaker for each model. For the non-isolated model this was defined as the floor displacement relative to the shaker table, and for the isolated model as displacement relative to the base of column pads.

These results are shown in Figure 4. It can be seen that relative displacement increases with the floor height, as expected. A comparison of maximum relative displacements between front side and rear sides of the models reveals larger values for the front than the rear, attributable to a higher mass distribution on the front side. Time histories of relative displacement at 5^{th} floor level due to El Centro earthquake are shown in Figure 5. Clearly, both LRB and LCRB isolators are effective in reducing the relative movements of the model in both displacement amplitude and time. However, LRB isolator is the superior isolator. The smaller improvement to earthquake

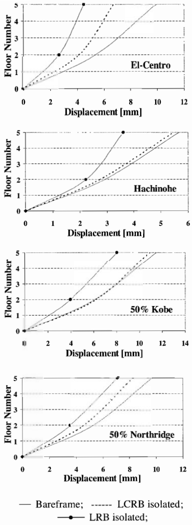

Figure 4. Variation of maximum relative displacement with floor height.

response achieved by the LCRB-isolated model is attributable to its non-linear stiffness characteristic, where high initial stiffness is maintained until the elastic limit of the lead core is reached, however the superior damping effects of the LCRB isolator are visible in the diminished time effects.

Considering Figure 4 further, it is apparent that the high initial stiffness of the LCRB isolator appears to have provided little control of relative displacement for the lower intensity load case of Hachinohe, but also for 50% Kobe where loads were comparable with El-Centro. This may indicate a difference in the frequency content of Hachinohe, however in all cases the improved damping characteristics of the LCRB isolator would be evident in more rapid decay of oscillation in the building structure.

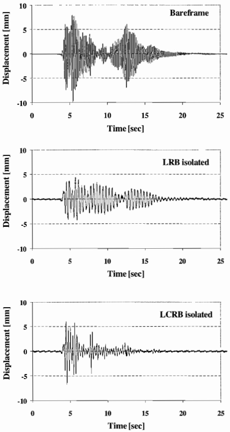

Figure 5. Time histories of relative displacement on level 5 under El Centro earthquake.

Torsional angle was used to characterize the torsional behaviour of the model. This is simply defined as the rotational angle of movement of the rigid floor diaphragm of the model.

Relative torsional angle is defined as the difference in torsional angle between the fifth floor and the base (isolation level), which characterizes the torsional deformation within the building model. Variation of maximum relative torsional angle with floor height for each case is presented in Figure 6. It is clear that a significant reduction in model torsional angle can be obtained when either LCRB or LRB isolators are installed. The isolated models behave more like a rigid body than does the bareframe. In the isolated case, rubber bearings absorb most of the total torsional component, resulting in only a small torsional component of energy being transmitted into the building. Moreover, the effectiveness of LCRB is almost as good as that of LRB. The capacity of isolators to reduce torsional damage is achieved by ensuring the fundamental horizontal frequency of the isolator is far lower than the dominant frequencies generated by earthquakes.

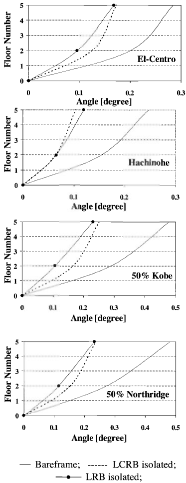

Figure 6. variation of relative torsional angle with floor height.

Time histories of the model torsional angle for the fifth floor under 50% intensity Kobe earthquake are depicted in Figure 7. Maximum torsional angle for the bareframe reaches a maximum of 0.48 degrees compared with 0.23 and 0.25 degrees for LRB and LCRB isolated models respectively. In addition, decay of the torsional angle vibration effects is considerably faster for the isolated models than it is in the bareframe.

Time histories of model acceleration at the back of fifth floor subjected to 50% intensity Northridge earthquake are plotted in Figure 8, and the full test data are presented in Table 1.

Maximum angular accelerations of base floor (rubber bearing), second and fifth floors of bareframe, LRB and LCRB isolated models under the four earthquakes are summarized in Table 2. Angular accelerations of both LRB and LCRB isolated models show considerably lower outcomes for all earthquakes and floor levels, compared with that of bareframe. For instance,

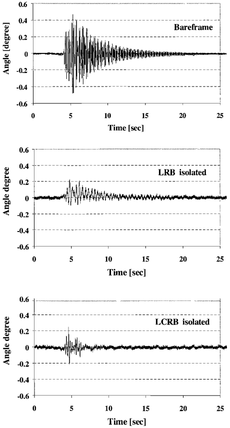

Figure 7. Time histories of model torsional angle under Kobe earthquake.

maximum angular acceleration on fifth floor of bareframe under Hachinohe earthquake amounts to 16.7 rad.s^{-2}, while those of LRB and LCRB isolated models are only 3.56 and 5.36 rad. s^{-2} respectively. It is also clear that LRB is more effective in reducing angular acceleration than LCRB.

In considering the LRB and LCRB characteristics it must be emphasised that LCRB is stiffer at low deflections and therefore more stable than LRB under normal working loads such as wind. This is an outcome of the presence of a rigid lead core. For situations where stability of the structure is of concern, such as with increased height, the use of LCRB over LRB may be preferred.

Absolute deformation and torsional angle of rubber bearings are presented in Table 3. In comparing LRB and LCRB, a larger absolute rubber deformation and torsional angle of the model isolated by LRB are seen which is related to smaller torsional stiffness of the LRB. The results also show that LCRB is more stable than LRB due to the presence of a rigid lead core. Therefore, when stability of the structure is of concern the use of LCRB over LRB is recommended.

Table 1. Maximum accelerations [g].

		Bare	LRB	LCRB
El Centro earthquake				
Base	Front		0.46	0.77
	Back		0.52	0.61
2nd	Front	1.21	0.53	0.82
	Back	0.77	0.49	0.65
5th	Front	2.07	0.60	1.35
	Back	1.15	0.54	0.83
Hachinohe earthquake		Bare	LRB	LCRB
Base	Front		0.31	0.71
	Back		0.30	0.50
2nd	Front	0.63	0.34	0.60
	Back	0.61	0.33	0.39
5th	Front	1.04	0.40	1.04
	Back	1.08	0.40	0.76
50% Kobe earthquake		Bare	LRB	LCRB
Base	Front		0.64	1.30
	Back		0.60	1.13
2nd	Front	1.38	0.68	1.40
	Back	1.42	0.66	1.01
5th	Front	2.26	0.91	2.21
	Back	2.43	0.82	1.72
50% Northridge earthquake		Bare	LRB	LCRB
Base	Front		0.70	0.88
	Back		0.51	0.65
2nd	Front	1.24	0.70	1.15
	Back	1.00	0.54	0.78
5th	Front	1.87	0.79	1.77
	Back	1.99	0.66	1.00

Table 3. Absolute deformation (mm) and torsional angle (degree) of rubber bearings

Earthquake	Base isolator	Absolute deformation of rubber bearing (mm) Front side	Rear side	Absolute torsional angle of rubber bearing (degree)
El Centro	LRB	17.54	18.16	0.374
	LCRB	13.33	12.89	0.109
Hachinohe	LRB	18.06	16.62	0.254
	LCRB	14.02	13.77	0.078
50% Kobe	LRB	26.26	23.27	0.468
	LCRB	17.16	16.15	0.118
50% Northridge	LRB	35.26	34.38	0.402
	LCRB	23.60	22.71	0.085

Table 2. Maximum angular accelerations [rad.s^{-2}].

	Bare	LRB	LCRB
El Centro earthquake			
Base		5.60	5.32
2nd	11.3	5.46	9.24
5th	17.2	5.88	13.7
Hachinohe earthquake	Bare	LRB	LCRB
Base		2.66	4.51
2nd	8.71	2.94	4.72
5th	16.7	3.56	5.36
50% Kobe earthquake	Bare	LRB	LCRB
Base		5.04	8.26
2nd	17.7	5.6	12.18
5th	30.2	6.72	16.80
50% Northridge earthquake	Bare	LRB	LCRB
Base		4.76	13.16
2nd	17.3	4.06	13.30
5th	28.2	5.32	24.36

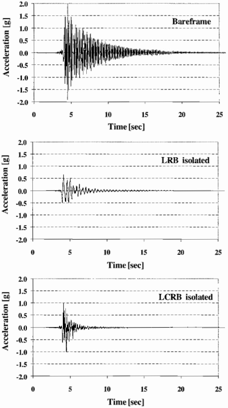

Figure 8. Time histories of acceleration at the rear of fifth floor under Northridge earthquake.

CONCLUSIONS

In this study, a series of shaker table tests were conducted on non-isolated model, LRB-isolated and LCRB-isolated eccentric models. The objective of the tests was to evaluate the benefit to building structures of the incorporation of LRB and LCRB isolators to mitigate against torsional damage under strong ground motions. Both LRB and LCRB have been shown to reduce torsional deformation, relative displacement, acceleration and angular acceleration within the model structures. Important differences between the two isolator types were identified. The LRB was found to be similar to LCRB in protecting torsional deformation of the model but was more effective than LCRB in reducing model relative displacement. LCRB rendered a smaller torsional angle and absolute deformation of the base isolation system, a more stable structural system. Therefore, base isolation can greatly reduce torsional as well as translational response of building structures.

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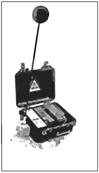

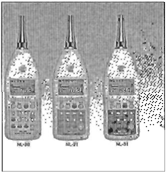

AN INEXPENSIVE DIY IMPACT HAMMER FOR VIBRATION ANALYSIS OF BUILDINGS

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The characterisation of vibration in buildings often involves exciting the building structure with a force and measuring the vibration response. The two common non-destructive force excitation methods are the use of an instrumented impact hammer or an electromagnetic vibration shaker. This paper contains a discussion on how to build a low cost instrumented hammer, and compares the performance of the hammer with a commercially available impact hammer and a commercially available electromagnetic shaker for vibrating buildings. The merits and disadvantages of each of these three instruments are discussed and it is the opinion of the author that for the vibration analyses often conducted in semiconductor manufacturing facilities, laboratories, and offices, the use of an instrumented impact hammer can provide higher quality measurements at a lower cost than the use of an electromagnetic shaker.

INTRODUCTION

The forced response analysis of civil structures can involve the application of enormous forces such as explosive devices and rocket engines to excite dam walls [1], large rotary eccentric mass shakers [2] to excite horizontal motion in the upper levels of skyscrapers (as was used to test the San Francisco Trans-America Pyramid building [3]), to relatively small forces such as a person walking. Each excitation method has its advantages and disadvantages and force / time characteristics that are suited to a particular structural excitation problem. Furthermore, vibration analysts have personal preferences and can justify why their chosen method is more advantageous than another. The focus of the work presented in this paper is the methods used to induce vibration in buildings using relatively small forces imparted by a sledge hammer. Alternative methods might be necessary depending on the type of vibration analysis that will be conducted.

There are several commercially available instrumented sledge hammers that are suitable for vibration and modal analysis of buildings, however they can cost in excess of $5000. An electromagnetic shaker for modal analysis of buildings will cost in excess of $10,000. A cheaper alternative discussed here is the construction of an instrument using a sledge hammer purchased from a hardware store and an accelerometer fixed to the back of the hammer head, which is suitable for some types of vibration analyses of buildings.

The first part of this paper discusses the construction of this Do-It-Yourself (DIY) instrumented sledge hammer. Comparisons between its performance and a commercially available instrumented hammer are used to demonstrate that the DIY hammer has the same results as the commercially available hammer. The second part of this paper contains experimental results of vibration measurements conducted in a semiconductor manufacturing facility using the DIY sledge hammer and a building shaker system. The results show that the use of the sledge hammer gave similar or better results than the shaker system. The last part of the paper contains a discussion of additional factors to consider before selecting the excitation method for a vibration analysis of a building; such as the weight of the equipment and the number of people required to conduct the tests.

Reynolds and Pavic [4] have conducted a similar comparison of a commercially available instrumented sledge hammer and an electromagnetic shaker, and concluded that the use of the electromagnetic shaker gave better quality measurements than the instrumented hammer, based on a single hammer strike. The authors should have compared the average of multiple of hammer strikes to the average of multiple transfer functions using the shaker system. They suggest that a hammer can be used as 'starter' floor modal testing system to obtain results of limited quality. They also claim that the shaker system can impart excitation energy that is many orders of magnitude higher than from hammer impulse excitation. This statement might be true for excitation at a single frequency, however for broadband excitation the results in this paper show the opposite to their findings. The use of a sledge hammer is able to impart greater excitation force to the structure than the shaker system, since the shaker system is limited to vibrating the reaction mass to 1g, otherwise the shaker will lift off the floor. Whilst it is possible to bolt the shaker to the floor, this is usually not permitted by buildings owners. Greater excitation energy can be applied by the sledge hammer by merely swinging it harder, or obtaining a sledge hammer with a heavier mass [2]. Clearly, there is a practical limit for increasing the impact force until the hammer strike can damage the structure, in which case an alternative excitation method must be employed such as an electrodynamic shaker. The findings of Reynolds and Pavic are further discussed at the end of this paper. It is surprising that in an earlier paper Pavic, et.al. [5] describe hammer testing as an " excellent investigative tool..". The use of impact hammers for modal analysis of buildings is well established [2, 5] and this paper shows how one can build a low-cost instrumented sledge hammer.

INSTRUMENTED IMPACT HAMMERS

There are a number of commercially available instrumented impact hammers that are suitable for inducing vibration in buildings. Vendors include Bruel and Kjaer, PCB Piezotronics, Dytran, and Endevco. A commercial-off-the-shelf instrumented sledge hammer can cost in excess of $A5000. An inexpensive Do-It-Yourself instrumented hammer can be constructed using a sledge hammer purchased from a hardware store and an accelerometer glued to the back of the mass of the sledge hammer. The following discussion shows that the DIY sledge hammer will provide results that are of the same quality as a more expensive commercially available instrumented hammer, at a fraction of the cost. The point impedance of a concrete floor was measured using both a commercial and DIY hammer and it is shown that similar results were obtained.

A DIY instrumented hammer was built from a sledge hammer purchased from a hardware store. The mass of the steel head on the hammer was 7.95kg. An aluminium block was glued to one end of a sledge hammer using epoxy glue and a Bruel and Kjaer type 4394 accelerometer was screwed onto the aluminium block. Previous testing using cyano-acrylate (super-glue) was unsuccessful as this type of glue is too brittle for impact loads. The accelerometer can also be attached to the hammer head with a threaded stud, however care must be taken when tapping into the steel head as the material is case hardened and it is very easy to break a tap in the head. A long micro-dot cable was connected to the accelerometer and taped along the length of the handle. The cable was connected to a Bruel and Kjaer type 2635 charge amplifier. A Bruel and Kjaer type 8318 accelerometer was used to measure the vibration response of a concrete slab-on-grade floor and was connected to a Bruel and Kjaer charge amplifier. Both charge amplifiers were set to measure acceleration and their outputs were connected to a two-channel Data Physics ACE signal analyser. The sledge hammer was used to strike two rubber pads, placed on top of each other, that were resting on a concrete slab-on-grade floor. The rubber pads had a total thickness of about 50mm and a durometer rating (the units used to define the stiffness of rubber) of 50. The purpose of the rubber pads is to mechanically filter the impact load so that only low frequency force is applied to the structure, which in this case is the concrete floor. Lower durometer (softer) rubber pads that are thinner are also suitable for impact testing, however care must be taken to ensure that the hammer does not pierce the soft rubber, which will degrade the repeatability of the measurements after several strikes. The useful frequency range for a hammer and rubber pads is a function of the system resonance frequency which is given by the square root of the contact stiffness divided by the mass of the hammer head [2], and can be checked by examining the autospectrum of the force pulse. For frequencies above the system resonance, it is difficult for the hammer to impart energy into the structure. As a guide, doubling the useful frequency range would correspond approximately to one-quarter the pad thickness (for constant material properties). The magnitude of the impact is determined by the mass of the hammer head and the velocity with which it is moving when it strikes the rubber pads [2]. The operator controls the velocity rather than the force level.

The commercially available hammer that was used for the comparison was a PCB Model 086D20 instrumented impact hammer that has a 1.1kg head, an ICP powered force transducer between the steel head and inter-changeable rubber tips of various stiffnesses. The force transducer on the PCB hammer was connected to the PCB ICP voltage amplifier. A Bruel and Kjaer type 8318 accelerometer was used to measure the vibration response of the floor.

It is beyond the scope of this paper to discuss the signal processing methods appropriate for impact testing. There are many references that discuss appropriate testing methods for modal analysis using an impact hammer [2, 5-10].

Figure 1 shows the measured accelerance of the concrete slab-on-grade floor using the two types of hammers. The accelerance is the acceleration response of the floor, in m/s^2, divided by the force applied by the hammer, in Newtons.

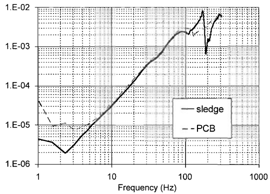

Figure 1: Comparison of the measured accelerance of the floor using the sledge hammer and the PCB hammer.

The results show that the accelerances are similar from 6Hz to 100Hz. Note the expected 40dB / decade increase over the frequency range. The response around 100-200Hz is the contact response. This is a function of the hammer mass and rubber stiffness. The commercial impact hammer has a lower quality factor (which is desirable) due to the prudent selection of material. The difference between the two systems occurs above 100Hz which is due to the different force impulses provided by each hammer. The PCB hammer contains a calibrated force transducer that measured the force applied during the impact event directly. The DIY sledge hammer has an accelerometer attached to the head to measure the acceleration of the head. The impact force from the hammer is calculated by multiplying the mass of the hammer head (7.95kg) by the measured acceleration. The mass of the hammer head is measured by placing the hammer head on weighing scales while holding the end of the handle horizontal. Figure 2 show the comparison of the impact forces applied to the concrete floor.

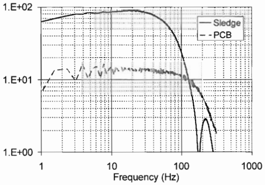

Figure 2: Impulse generated by the sledge hammer and the PCB hammer.

Figure 2 shows that the force exerted by the sledge hammer has a sharp roll off beginning at 30Hz as it approaches a resonance at 220Hz. This resonance is caused by the interaction of the two rubber pads and the hammer head. This is not likely to be an issue for the structural evaluation of buildings as the frequency range of interest is below 100Hz. If the frequency range of interest is greater than 100Hz, an alternative stiffer or thinner rubber pad can be used to generate a different impulse response spectrum.

These results show that the DIY sledge hammer can be used to accurately measure the vibration response of structures such as buildings.

The following section describes the comparison of the experimental results obtained using a DIY instrumented sledge hammer and an electromagnetic shaker to induce vibration in a semiconductor manufacturing facility.

COMPARISON WITH A BUILDING SHAKER SYSTEM

The shaker used to excite buildings in this study was an APS Dynamics Electro-seis Model 113 shaker, that comprises a 13.3kg reaction mass which is suspended by elastic bands, and a flat magnet and electrical coil assembly that is used to move the mass along bearings. The shaker was electrically connected to an APS Model 114-EP power amplifier, which was purpose built to provide high current levels at low frequencies to the electrical coil on the shaker. Typical power amplifiers for audio applications are not designed to generate high current levels at frequencies below about 20Hz.

A comparison was made of the results obtained from the vibration measurements in a semiconductor manufacturing facility using this shaker system and a DIY instrumented sledge hammer. Whilst the building design of semiconductor manufacturing facilities is in a special class of its own, the same comments are also applicable to buildings that use typical construction methods using steel and concrete frames for office buildings, hospitals, sporting stadiums, and car parks.

Semiconductor manufacturing facilities are unique types of buildings that are purpose built for housing extremely vibration sensitive manufacturing equipment. These buildings are designed to have very stiff floors compared to conventional buildings. This is done to support the vibration sensitive equipment and also minimise vibration transmission through the building from vibration sources such as mechanical equipment (for example pumps and air handling units), and from the vibration induced by people walking on floors.

Figure 3 shows a typical design of a building for a semiconductor manufacturing facility. A typical design of the process floor is two-way grillage (also known as a waffle floor, because of the similarity to a cooked waffle) of 60cm thick concrete beams and supported on closely spaced columns. The sub-fab level contains mechanical equipment that generates vibration, such as pumps.

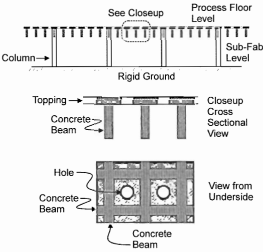

Figure 3: Typical building design for a semiconductor manufacturing facility.

During the commissioning phase of the facilities, often a structural evaluation is conducted to ensure the vibration environment within the building meets the design specifications. Typical investigations involve the measurement of the resonance frequencies of the floors, the ambient vibration amplitude induced by operating mechanical equipment, the vibration attenuation between different floor levels, and the vibration attenuation with distance along the floors [12]. For most civil structures, if the vibration levels are too high, the building owner usually does not care [11]. However, for this type of building if the vibration levels are too high then the manufacturing equipment will not function.

The author has conducted numerous structural investigations of semiconductor manufacturing facilities using an electrical shaker system and an instrumented hammer. Both excitation systems were used at one manufacturing facility to compare the advantages and disadvantages of each system.

Figure 4 shows a sketch of the experimental set up for the vibration measurements in the semiconductor manufacturing facility.

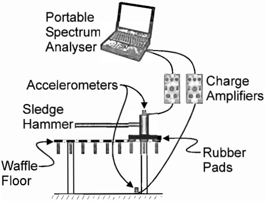

Figure 4: Sketch of the experimental setup for the vibration measurements in a semiconductor manufacturing facility.

The top of a column on the process floor was driven by a vibration source and the vibration response was measured at the base of the column in the sub-fab. This measurement was conducted using both the shaker system and the sledge hammer as excitation sources. When the shaker was used as the excitation source, the ACE signal analyser was used as a signal generator to output a swept sine wave in the frequency range 5Hz to 95Hz into the power amplifier. The shaker's power amplifier was set to the maximum amplification such that the moving mass did not strike the ends stops or cause the shaker to lift off the floor. The limitations on the operation of the shaker are that the acceleration has to be kept to less than 1g, otherwise the shaker will lift off the floor, and the stroke of the moving mass has to be kept below 150mm peak-to-peak otherwise it will strike the end stops. Hence, when using a swept sine wave as a control signal, the maximum displacement of the shaker's moving mass is governed by the acceleration at the highest frequency of the analysis range, which must be kept below 1g. The analyser was configured to collect 30 linearly averaged spectra and the recording was triggered by the start of a sine sweep from the signal generator.

The measurements using the DIY instrumented hammer were conducted using a force-exponential window to capture the dynamic response of the structure. The exponential window applied to the signal for the response of the floor was made as long as possible so as not to distort the results and give the impression of an artificially highly damped structure. This measurement involved collecting 10 linearly averaged spectra. However, usually the results are very repeatable and only 5 linearly averaged spectra are collected for most structural evaluations.

Figure 5 shows the accelerance measured using the two structural excitation methods. Both methods clearly show that the resonance frequency of the column system is about 44Hz. Note that the hammer response compares well against the expected 40dB / decade rise, whereas the shaker driven response does not. The results differ at frequencies below 30Hz, which is due to the loss of signal coherence in the shaker system. The corresponding coherence between the signals for these two structural excitation methods is shown in Figure 6. Figure 6 shows that the coherence using the hammer is consistently greater than using the shaker and extends to a lower frequency range. The reason for the drop in coherence for the shaker system is the lower amplitude in the excitation force compared to the sledge hammer, which is further discussed below.

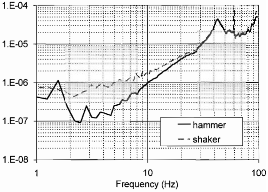

Figure 5: Accelerance between vibration excitation on top of the column and measuring the response at the base of the column in the sub-fab, using the shaker and the hammer as excitation.

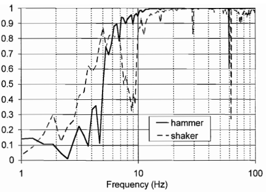

Figure 6: Coherence associated with the measurements shown in Figure 5.

Another comparative measurement was conducted between the two excitation methods by shaking the mid-bay of the process floor and measuring the vibration response at the mid-bay in the sub-fab directly below excitation point. Figure 7 shows the accelerance measured using the two excitation methods, and the results are different at frequencies below 20Hz and above 50Hz.

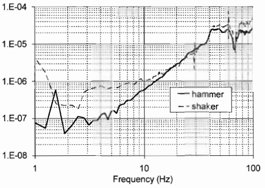

Figure 7: Accelerance measured between excitation of the mid-bay on the process floor using the sledge hammer and the shaker system, and measuring the vibration response of the mid-bay in the sub fab.

Figure 8 shows the coherence for this measurement and reveals that greater coherence is obtained using the instrumented sledge hammer than the shaker system.

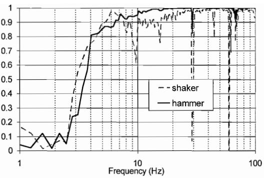

Figure 8: The coherence measurements associated with Figure 7.

Figure 9 shows the excitation force that was applied at the mid-bay of the process floor which is associated with the results shown in Figures 7 and 8. The amplitude of the force applied by the sledge hammer to the floor is greater than the shaker system. This is not a surprising result because greater force can be imparted by the sledge hammer merely by swinging harder, whereas the shaker is limited to the force generated by the reaction mass moving at an acceleration of 1g.

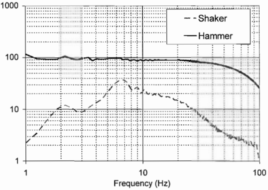

Figure 9: The excitation force from the sledge hammer and the shaker into a mid-bay on the process floor.

These measurements demonstrate that an inexpensive DIY instrumented sledge hammer can be used to conduct structural evaluations of buildings and, in this case, yielded better results than using the shaker system. This is because, in this case, the sledge hammer provided greater excitation force than the shaker system. The acceleration of the shaker system has to be kept below 1g, otherwise it has to be physically attached to the structure. It would be possible to increase the force output from the shaker by using a feedback controller to maximise the force output at each frequency, however this was not available for the testing.

Although results have not been presented in this paper, this sledge hammer system has been used successfully to measure the mode shapes of very stiff floors that support photolithography tools in semiconductor factories, office and laboratory floors and obtain measurements of the horizontal stiffness of buildings such as laboratories and semiconductor factories. The use of an electrodynamic shaker could also provide the same results.

ADDITIONAL FACTORS TO CONSIDERS

The combined weight of the shaker system, power amplifier, carry cases, and instrumentation is in excess of 120kg and is housed in three or four large carry cases. This heavy load requires two people to carry the equipment. The equipment has to be couriered to the building site well in advance of the testing. Upon arrival at the destination airport, the equipment has to be transported in a large vehicle. Vibration measurements on buildings usually occur late at night once all construction activities have ceased for the day. During this time construction lifts are unavailable so people have to carry the equipment up and down flights of stairs.

Reynolds and Pavic [4] describe a similar comparison between building excitation systems using an electrical vibration shaker and an instrumented hammer and reached the opposite preference to that described here, that the shaker system is the preferable measurement method. Reference [13] shows a photograph of their " portable measurement system" that costs between £20,000 [4] and £70,000 [13] and requires three people to operate efficiently [4].

The equipment for the DIY instrumented sledge hammer can fit into a hard cased golf carry bag and transported by air within the luggage limits of most airlines. The equipment can be carried by one person. It is recommended that two people are involved for the efficient operation of measurements [4]. The equipment is relatively light-weight compared to shaker system and is easily carried up and down flights of stairs by a single person.

It is left to the judicious reader to decide on which method is preferable based on the capital and labour costs, measurement efficiency, manual handling, time constraints, and desired quality of results.

CONCLUSIONS

This paper describes the construction of a relatively inexpensive instrumented sledge hammer for use in vibration analysis of building structures. The DIY sledge hammer was compared with a commercially available instrumented hammer to ensure that accurate vibration results could be obtained. The DIY sledge hammer was also compared with an electromagnetic shaker system for exciting buildings. Tests were conducted in a semiconductor manufacturing facility that has very stiff floors compared to conventional buildings. The results show that greater force could be imparted to the building structure by the sledge hammer than the shaker system. This result was not surprising as the greater excitation force can be applied by swinging the hammer harder, whereas the shaker system is limited to a maximum acceleration of 1g before the shaker lifts off the floor. From his experience, it is the opinion of this author that the DIY instrumented sledge hammer is cheaper, provides higher quality results, more easily transported, requires less people to perform measurements, and is quicker to use on-site compared to an electromagnetic shaker. However, in some situations where tonal excitation is necessary, the use of an electromagnetic shaker may be preferable.

ACKNOWLEDGEMENTS

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SOME CURRENT ISSUES IN COMPUTER MODELLING FOR ROOM ACOUSTIC DESIGN

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ABSTRACT: This paper deals with several aspects of the application of computer modelling in room acoustic design in order to promote understanding of this design tool. The first section of the paper describes the results of the three international round robin tests of the validity and limitations of current computer modelling techniques. The second and last sections are concerned with the validity of computer modelling and auralization for the prediction of the acoustic quality of two concert halls in Australia. The importance of assigning suitable values of diffusion coefficients to obtain reliable prediction results, and the validation of computer generated auralizations compared with real recorded music in actual halls, are also investigated.

1. INTRODUCTION

Room acoustic computer modelling has developed greatly since the first trial by Krokstad et al. [1] and has been widely adopted in both research and consulting work. Despite several advantages of computer models over physical models, such as being flexible and cost and time effective, there are some problems with current computer modelling techniques and the selection of suitable input values for these models. These result in unreliable predictions which have been reported in international verification tests [2, 3, 4]. Another issue concerning computer modelling is the validation of auralization techniques. If the prediction results of computer models compared with measurements are within the subjective difference limen, then auralization is likely to be a reliable prediction tool for determining the acoustic quality of a room. Therefore, the validation of computer generated sounds compared with real recorded sounds in actual halls is important for the assessment of current auralization techniques. Such an assessment does not appear to have been carried out previously.

This paper deals with several aspects of current computer modelling techniques in room acoustic design and presents a guide to the software users on how to achieve reliable prediction results. The main issues covered in the following sections are:

- Feedback from three international round robin evaluations.
- The importance of assigning suitable diffusion coefficient values.
- The comparison of computer generated auralizations with recorded sounds.

2. THREE INTERNATIONAL ROUND ROBIN ON ROOM ACOUSTICAL COMPUTER MODELLING

The accuracy of various computer models has been checked, in independent verification tests, to examine their reliability and reproducibility. In this section, the testing procedure and findings of three international round robins on room acoustical computer modelling [2, 3, 4], which were undertaken by the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig, Germany, are briefly summarized.

The first international round robin was carried out on the PTB lecture hall (1,800 m^2, 274 seats) by sixteen participants from seven countries in 1993 - 94 [2]. Eight acoustical parameters were considered: reverberation time (T_{30}), early decay time (EDT, which is a 60 dB decay time extrapolated from the first 10 dB of the impulse response, corresponding to a subjective impression of reverberance); strength (G, which compares the sound pressure level of an omnidirectional source, at some distance in the room, to that of the same source at 10 m in anechoic conditions); clarity (C_{80}, which is the balance of early (<80 ms) to late (>80 ms) sound energy in the impulse response); deutlichkeit (D_{50}, also known as ' definition' , which is similar to clarity and is related to speech intelligibility); centre time (TS, the centre of gravity of the squared impulse response); and early lateral energy fractions (LF and LFC, which are ratios of lateral to omnidirectional sound energy in the first 80 ms of the impulse response). These were calculated in the 1 kHz octave band for ten different combinations of two source positions and five receiver positions. These parameters are defined in ISO 3382 [5], key aspects of which are reproduced in AS/NZS 2460 [6]. The measurements were then carried out by seven different teams for the comparison with the calculated data.

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The test was carried out in two phases. The first phase tested with the information on the room geometry data and surface material descriptions given in words, so that the participants had to estimate absorption coefficients based on their experience and skill in acoustics. After the measurements in the PTB lecture hall had been made, absorption and diffusion coefficients of the hall were estimated and distributed to the participants. In the second phase, the simulations were repeated using these estimated absorption and diffusion data.

The results showed that smaller differences between the measured and calculated data were obtained in the second phase (with estimated input data) than in the first phase (without estimated input data), but the differences were still large compared with the standard deviation of the average measurement results and with the just noticeable difference (JND) for the eight acoustical parameters. It was found that only three participants were able to give reliable prediction results that were approximately within the subjective difference limens. Some participants gave 5-6 times higher prediction errors than the subjective limens for TS, EDT and C. Further information on the averaged prediction errors relative to the subjective difference limens for the eight acoustical parameters can be seen in [2], p.692, Figure 4. The main reason for this appeared to be that diffusion effects needed to be taken into account in the simulation programs. It also appeared that the attenuation of sound at grazing incidence at the audience seats should be implemented in the simulation software if good agreement with measurements was to be achieved.

The second round robin test was carried out in the ELMIA multipurpose hall (11,000 m^2, 1,100 seats) in Jönköping, Sweden, in 1996 - 98 [3]. There were thirteen participants from nine countries in the second test. Nine acoustical parameters referred to in ISO 3382 (T_{30}, EDT, D_{50}, C_{80} TS, G, LF, LFC and IACC), were calculated in six octave bands (125 Hz - 4 kHz) for twelve different combinations of two source positions and six receiver positions. IACC is the absolute value maximum coefficient of the normalized inter-aural cross correlation function (assessed using lag times within ±1 ms, which is roughly the time difference between the arrival at the two ears of a wave from the right side or left side of the head), measured using a model of a human head [7]. Hence, IACC assesses the difference between the sound at the two ears, and has been related to aspects of auditory spatial impression. The measurements were then carried out by three teams for the comparison with the calculated data.

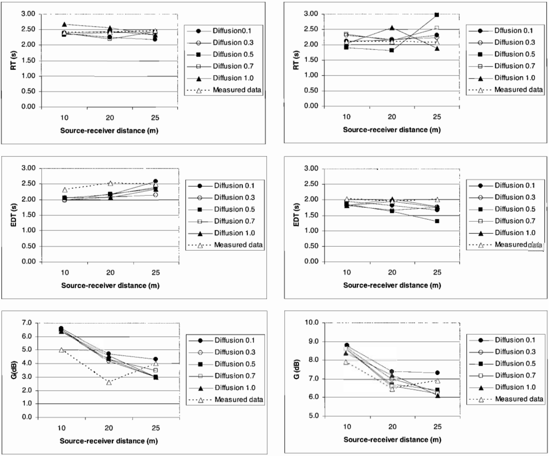
Like the first round robin, the test had two phases. The first phase of modelling was undertaken with geometrical and descriptive data for the hall (e.g. photographs, drawings and verbal descriptions of the surface materials) to examine the influence of software quality and user' s skill on the calculation results. The second phase was undertaken with given absorption and diffusion values, from the organizer, that had been estimated from room measurements, to find out to what extent the different software approaches influenced the accuracy of the calculations.

The results again showed that smaller prediction errors were obtained in the second phase (with estimated input data) than in the first phase (without estimated input data). The prediction errors were approximately 2-3 times higher than the subjective difference limens [see ref. [3], p.953, Figure 11]. One reason for this was due to measurement error as reported in [8] but the main reason was almost certainly due to the computer programs and the associated input data. Overall, the results of the second round robin were much improved on those of the first round robin, but still systemic errors due to the calculation algorithms gave unreliable predictions, especially in the 125 Hz frequency band.

The third round robin was carried out in the PTB music recording studio (400 m^2) by twenty-one participants from 14 countries in 1999 - 2002 [4]. Nine acoustical parameters (T_{30}, EDT, D_{50}, C_{80} TS, G, LF, LFC and IACC) were calculated in six octave bands (125 Hz - 4 kHz) for six combinations of two source positions and three receiver positions. The measurements were then carried out by five teams for the comparison with the calculated data.

The test was carried out in three phases. In the first phase, the studio was modelled to have seven plain walls with all geometrical data and absorption and diffusion values given (without measurement). In the second phase, the measured absorption and diffusion coefficients were given without changing the geometry. In the third phase, all design details and surface geometrical data were added into the modelling. The aim of this phase was to find out whether presenting detailed geometrical data for room modelling improves the calculations or decreases the accuracy of the model.

The calculated results of the second phase compared to the measurements for LF and IACC at source position A1 and receiver position 1 can be seen on the PTB website (**http://www.ptb.de/en/org/1/_index.htm**). Note that although the testing and analysis for the third round robin have been completed, only a few details of the results have been published in ref [4]. Therefore, the results referred to here are directly from the PTB website, where further detailed information about the third round robin can be found. The largest differences between the measured and calculated results were found in the 125 Hz frequency band (excluding one participant result which shows very high LF values compare to others). The difference between the mean measurement values and the computed values was between 10 and 20%. The differences between the calculated and mean measured values in the 500 Hz, 1 kHz and 2 kHz frequency bands were about 8% which was more than the subjective difference limen. Interestingly, the variations in the measurement results were about the same as in the calculated data. The results again demonstrated the importance of the reproducibility of measurements to the evaluation of computer models. A similar trend was obtained for the IACC calculation



(a) Hall A

(b) Hall B

Figure 1. The prediction results for RT, EDT and G at the 1 kHz frequency band as a function of diffusion coefficients in the audience area in the two halls, (a) Hall A and (b) Hall B.

results, although the differences between measured data and calculated values were smaller than those for LF. However, considering that the subjective difference limen for IACC is 0.08, the differences were still large, especially those in the 500 Hz, 1 kHz and 2 kHz frequency bands, which are critical octave bands for this measure. It was also found that well-defined room geometrical data did not improved the accuracy of the prediction results.

The limitations of current room acoustical computer models reported in the three international round robin evaluations can be summarized as follows:

- There are problems with the calculation algorithms especially when dealing with curved surfaces and diffraction effects on finite surfaces;
- The selection of suitable values of input parameters is problematic, especially diffusion coefficients for surface materials; and
- There has been no satisfactory validation of computer generated auralizations – no comparison of computer generated sounds with recorded sounds in real rooms.

3. THE INFLUENCE OF DIFFUSION COEFFICIENTS ON PREDICTIONS

Computer modelling results are strongly dependent on the selection of input parameters, in particular room surface properties. Of those input parameters the particular importance of assigning suitable values of diffusion coefficients for room surfaces, to achieve reliable prediction results, has been reported in the international round robin tests. Although there are standard measuring methods for surface diffusion coefficients devised by two different groups (the International Standards Organization (ISO) and the Audio Engineering Society (AES)), experience in the use of suitable values of diffusion coefficients in computer models is rather limited. As a result, the findings from physical model measurements, e.g. 0.1 for the smooth and plain surfaces and 0.7 for the rough surfaces such as audience areas, have been widely adopted in computer models [9].

In this section, the influence of diffusion coefficients on the prediction results is reported on. Two concert halls in Australia, referred to as Hall A (a large volume hall) and Hall B (a moderate volume hall), were used for the investigation and modelled using the Odeon V.6.0 software [10]. The 3D modelling of the two halls was based on drawings and photographs. Some simplifications for the audience seats, the ceilings and the pipe organ were made in the computer models of the two halls. The absorption coefficients were selected from the material library provided with the program. As described previously, the assumptions from physical model measurements were used for assigning the diffusion coefficients in this study. The calculations were made using 12966 rays for Hall A and 9774 rays for Hall B. The transition order (the number of reflections modeled using the image-source method, after which ray tracing is used) was set at 1 for both halls. The calculated impulse response length was 2.5 s long.

Figure 1 shows the prediction results for RT, EDT and G in the 1 kHz frequency band when different diffusion coefficients for the audience area in the two halls are used. The results at three receiver positions (10 m, 20 m and 25 m distance from the centre stage source) in the stalls in each of the two halls are presented. The variations in the prediction results depend on the hall and the seat position. Overall, larger differences are shown in Hall B than in Hall A and for the more distant seats. The variation in parameter values at a particular seat seems

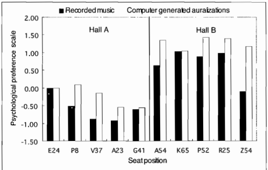


Figure 2. Average subjective preferences obtained from recorded music and computer generated auralization as a function of seat position in the two halls, Hall A (left) and Hall B (right). Note that only the results for five seat positions in each hall which are common for the auralization and recorded music evaluations are plotted.

to be an almost random function of the audience diffusion coefficient used. This issue requires further investigation.

In Hall A changing diffusion coefficients in the audience area influenced the RT and EDT prediction results. The prediction variations are greater than a subjective difference limen of 0.05 s. The predicted G values are varied within a subjective difference limen of 1.0 dB, except for one receiver position at 25 m from the source. The predicted G value at this position is higher than the others when a diffusion coefficient of 0.1 is assigned to the audience area. More significant prediction variations for RT and EDT are found for Hall B, particularly in the two receiver positions at 20 m and 25 m from the source. Assigning a diffusion coefficient of 0.1 in the audience area results in large prediction variations for G at the 25 m source-receiver distance position.

4. COMPUTER GENERATED AURALIZATIONS COMPARED WITH RECORDED SOUNDS

A recent development of the computer modelling technique is auralization. The term " auralization" can be defined as follows; "*Auralization is the process of rendering audible, by physical or mathematical modelling, the sound field of a source in a space, in such a way as to simulate the binaural listening experience at a given position in the modelled space*" [11]. The auralization process can be summarized in the following steps. The Room Impulse Responses (RIRs) for source and receiver positions in a room are calculated using computer simulations. The Binaural Room Impulse Responses (BRIRs) are then computed using a Head Related Transfer Function (HRTF) which is normally taken from a dummy head. Finally, the obtained BRIRs are convolved with anechoic-recorded music or speech. The auralization results are presented to the subjects via either headphones or free field reproduction using loudspeakers with crosstalk compensation [11].

Although auralization has the potential for use as a tool for room acoustic quality evaluation, the validity of the technique is still uncertain due to the limitations of computer modelling and sound reproduction. No international round robin on the comparisons of auralization systems in computer models has been carried out yet. This section reports on a partial validation of computer generated auralizations using dummy head recorded sounds in actual halls.

A subjective assessment of music excerpts was undertaken to examine whether computer auralizations give similar ratings for seats and halls as judgements based on recorded music at the same seats and halls. The recorded music samples were made at seats in the halls referred to in the previous section, Hall A and Hall B. Anechoic recorded music signals [12] were provided from a two channel recorder (ALESIS, Master link ML9600) and emitted by two loudspeakers, a ' Soundsphere' loudspeaker (Sonic systems, model 2212-1) combined with a bass loudspeaker installed with two subwoofer drivers (18 inch diameter 800W P-Audio P180/2242). The music signals obtained from a dummy head microphone (B&K head and torso simulator (HATS) type 4128C) were then digitally stored on a hard disk (ALESIS, ADAT HD24). Impulse response and other measurements (for omnidirectional, dummy head, and B-format microphones) were obtained using the same system. The computer models of the same halls were used to generate computer auralizations at the same seats using the Odeon V.6.0 software [10]. The auralization procedure in the computer models was the same as described previously. The HRTFs used for the computation of the BRIRs were those of the KEMAR dummy head (supplied with the Odeon program). Although the same type of dummy head for recorded and computer generated sounds should be used for the adequate comparison, this could not be undertaken because HRTFs from HATS was not supplied with the program used in this study.

Binaural playback techniques aim to reproduce the sound that was received at in-ear microphones near the listener' s ears, and as such they provide a level of fidelity attractive for empirical testing. A review of these techniques and their limitations is given by Møller [13]. The most common approach, which is non-individualized binaural reproduction (i.e. not using the listener' s HRTFs), yields localization errors, with frontal sound sources typically forming auditory images above or behind the listener in headphone reproduction. Although the present work was done using this approach, Azzali et al. [14] have recently shown that non-individualized binaural reproduction using a cross-talk compensation technique with closely spaced loudspeakers (known as ' stereo dipole') yields more realistic sound imagery for auditorium simulations.

Two sets of subjective judgements based on recorded music and computer generated auralizations were carried out. Twelve seats (mainly in the stalls and circles or galleries) in each hall were selected for assessing the subjective judgements using recorded music. Not all of twelve seat positions (only five seats in each hall) were used for the subjective judgements using computer generated auralizations. Although fewer seat positions were used in the subjective judgements using computer generated auralizations, the results still

Table 1. Seat-averaged measured and calculated

Acoustical parameters	Averaged Values			
	Hall A		Hall B	
	Measured data	Calculated data	Measured data	Calculated data
RT (unoccupied)	2.17 s	2.09 s	2.03 s	2.29 s
EDT (unoccupied)	2.23 s	2.05 s	1.91 s	1.83 s
G	3.4 dB	3.2 dB	7.3 dB	7.0 dB
C_{80}	-2.6 dB	-1.7 dB	-0.6 dB	1.0 dB

Note: The acoustical parameters were averaged in the all frequency bands (125 Hz- 4 kHz).

could be used to examine the reliability of the computer generated auralizations for matching sets of seat positions [for more details on the experimental design of the subjective judgements see 15]. Table 1 presents the average values of the measured and calculated acoustical parameters at five common seat positions in each hall.

The subjective judgements were obtained using a two alternative forced choice experimental design. Eight subjects aged between 20 and 40 identified which one of each pair of recordings they preferred in terms of the acoustics. The subjects were allowed to listen to the music pairs as often as they wished before giving their judgements. The music samples, 10 s of solo cello (Weber' s Theme), were presented via a CD player (Denon DN-C630) and given over open headphones (Sennheiser HD600) in an anechoic room.

The psychological scales of overall preference, based on the subjective responses to the recorded music and computer generated auralizations in the two halls, were obtained using the method of Thurstone' s Case V [16, 17]. Scale units of preference are standard deviations of a normally distributed probability density function. A χ^2 test of goodness of fit showed that the response matrix had significant internal consistency, meaning that the resulting ratings were significantly different to random selection [18]. The averaged preferences of the eight subjects for seat positions in the two halls are plotted in Figure 2. The preference judgements based on recorded music show that most seats in Hall B are more highly ranked in terms of their acoustics than the seats in Hall A. The preference judgements based on computer generated auralizations show similar ratings for the same seats in the two halls as for the recorded music in the same halls: the listeners had a greater preference for seats in Hall B than those in Hall A. Higher preference for seats in the two halls was obtained from computer generated auralizations than recorded music real-hall stimuli. This may be partly because of assessing more seat positions for the subjective judgements using recorded music than the judgements using computer generated sounds. The results of preference judgements made using computer auralizations are in agreement with preference judgements based on recorded music at matching seats. The low subjective ratings for seats in Hall A are in agreement with musician-assessed ratings of the actual halls [19] and even with anecdotal evidence by concert-goers in Australia.

The indirect subjective comparisons of computer generated auralizations with recorded sounds for the evaluation of the acoustics of the two halls were carried out because of the limitation of using different types of dummy head. The preference judgements based on computer generated auralizations give similar rank ordering of seats and halls as the judgements made using recorded sounds. There is evidence [21] to suggest that even though there are errors in computational techniques, it may well be possible to use such techniques to make judgements about the acoustics of concert halls.

5. CONCLUSION

With the development of computer modelling techniques, especially as a result of the feedback of three international round robin evaluations, it is now possible to use them as a tool in room acoustics design. However there are still several uncertainties associated with this technique and there is a need for any user to gain practical experience in assigning suitable input values for surface materials.

Something that the computer modelling cannot do on its own, even with auralization techniques, is to predict the overall acoustic quality of a space, unless subjective judgements are carried out. If the computer modelling is to be reliable, i.e. if it is to give good agreement with measurements or even just give the same rank ordering of subjective assessments as in actual halls modelled, then some other technique, such as neural network analysis [20], could be used in conjunction with the computer modelling to obtain predictions of concert hall acoustic quality.

ACKNOWLEDGMENTS

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MEASUREMENT OF THE EFFECT ON VIOLINS OF AGEING AND PLAYING

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ABSTRACT. This is a report on the first three years of a long-term experiment designed to measure how two very similar violins change with time. After being constructed 'in parallel,' one is stored under controlled conditions in a museum and is played infrequently, while the other is played regularly by a professional musician. Vibro-acoustic measurements were performed on the instruments and parts thereof during and after construction. Playing and listening tests by a panel of experienced violinists were conducted at completion, after three years with no adjustment, and then after minor adjustments were made to the played violin only. Panels of players and listeners rated the two violins at all stages, and all results are consistent with the null hypothesis: at present there is no significant preference for either instrument over a range of categories.

1. INTRODUCTION

There is widespread belief among players of stringed musical instruments, and experienced listeners, that these instruments improve with age and/or playing. A previous study has reported some measurable changes associated with regular playing of a violin [1]. There is at least one commercial enterprise selling treatments that expose the instrument to vibration [2]. However, testing this belief is complicated by other possible factors. For example, for a given player and instrument, these 'improvements' could arise from increased experience in overcoming the deficiencies and exploiting the advantages of that particular instrument [3].

Several reasons may be proposed to explain how improvements to the instrument might occur:

(i) Evolution in parameter space

Players will have made a number of changes and adjustments to an old, regularly played instrument. These could include changes of bridge, type of string and adjustment of the sound-post. In each case the player is likely to reverse the change unless it is perceived to improve the instrument. Thus a violin might gradually evolve towards a preferred region in its possible parameter space. There will also possibly be a different selection pressure here: instruments that are unsatisfactory or that don't improve will, in general, have a lower market value and will often be played by less experienced players. Those instruments that acquire a better reputation and market value will in general be sought and played by more experienced players. These improvements will occur independently of any change in the intrinsic mechanical properties of the instrument.

(ii) Age-related mechanical changes

The intrinsic mechanical properties could change with age or with exposure to different environments. Woods used in string instruments often have a high ratio of longitudinal Young's modulus to density, and drying of wood over time would lower the density. However, there is no simple reason to expect that age-related changes in general would necessarily improve an instrument.

(iii) Playing-related mechanical changes

A violin (and its components) undergoes considerable mechanical vibration during playing and this could alter the intrinsic mechanical properties. There is usually a strong correlation between the age of a violin and the total amount of excitation it has undergone. A study has shown a decrease in internal damping as a consequence of mechanical excitation in isolated samples of violin wood [4]. Extended mechanical vibration of violins has produced improvements as judged by listeners and players [5, 6] as well as measurable changes in the vibro-acoustic properties that are associated with improved tone and playing qualities [5, 7]. However, not all studies have shown a measurable mechanical change of violin wood upon extensive mechanical excitation [8], and there is again no simple *a priori* reason to suggest that these changes will improve the instrument. However it might be argued that mechanisms that produce mechanical loss could be affected by sufficiently vigorous excitation.

A major difficulty with studying the effects of ageing and playing, and separating the relative contribution of each, has been the lack of suitable controls. It is, of course, notoriously difficult to manipulate time as a variable, particularly in the reverse direction. In this study we attempt to tackle the problem of establishing a control from the very start.

The important step was to commission a pair of violins that were as similar as possible. To study ageing we have started a series of measurements of their vibro-acoustic properties and a series of playing and listening tests. To study the effects of playing, one instrument was kept under environmentally controlled conditions in a museum, whilst the other was played regularly by a professional musician. It should thus be possible to distinguish the separate effects of playing and ageing.

No two violins are exactly identical. Even if the process of making instruments were completely standardised, the variation in the mechanical properties of wood would give rise to vibro-acoustic differences. Nevertheless, the aim of this study is to compare two very similar violins as they age, under very different playing and storage conditions.

2. The 'POWERHOUSE TWINS'

This study was conceived when Michael Lea (curator of musical instruments at the Powerhouse Museum, Sydney' s museum of science, technology and applied arts) and Romano Crivici (a prominent Sydney musician) both sought to acquire instruments from Sydney luthier, Harry Vatiliotis. Vatiliotis was a student of Arthur Edward Smith, one of Australia' s first renowned luthiers, and has a reputation for being able to make fine instruments reproducibly.

Although a study involving a larger set of ' identical' instruments, or even pairs of ' identical' instruments, would certainly improve the statistics, it would have required specific funding. It would also prove increasingly difficult to find very closely matched blocks of wood as the number of instruments increased. Finally, the idea of keeping a statistically significant number of similar, fine, hand-made instruments that would not be played regularly would be hard to defend to the musicians who might otherwise have acquired them.

The violins were made from wood that had originally been intended for a violoncello. Hence it was possible to make both top-plates from the same block of wood (quarter-sawn European/Alpine Spruce, *Picea excelsa*), and likewise the back-plates (German/European Maple, *Acer pseudoplatanus*). The wood had been seasoned for over 80 years. This does not give identical plates, of course, because of the spatial inhomogeneity of the wood. This was investigated by measuring important bulk material properties of samples taken of the wood directly surrounding the plates. These include the spatial distribution of Young' s moduli (using resonance techniques [9, 10]) along the grain and transverse directions, the mass densities, growth-ring densities and moisture contents.

A summary of values measured is presented in Table 1. Over 12 samples of various size (100 mm or less in length, 20 mm or less in width and all roughly 5 mm thick) were taken in the direction of the grain and two across the grain were obtained from the wood immediately surrounding the top-plates. The variation in longitudinal Young' s modulus for the top-plates is largely the result of a single sample having an anomalous value. Nevertheless, these variations show the difficulty confronting a luthier who might set out to make an instrument similar to an instrument s/he had previously made, and which was highly appreciated.

The results are consistent with what we would expect to find in good quality Spruce at equilibrium with the Sydney atmosphere [10].

These samples will provide a useful control for future studies on wood ageing, distinct from those of the violin itself, and are stored with their respective violins. Several measurement techniques were applied at six stages of construction:

- When the top and back plates had been carved to shape,
- When the f-holes had been cut and bass-bar installed,
- When the violins had been finished,
- Three years later and then
- A further four days later, after the played violin had been adjusted by its maker, in a session with the owner, for the first time.

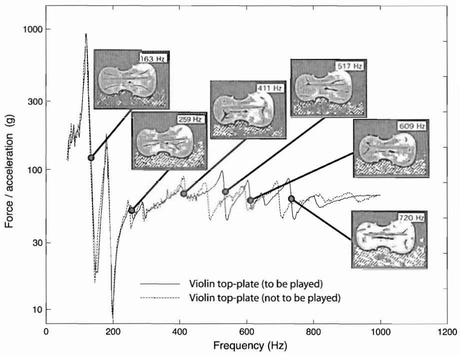

Fig 1. The ratio of the force applied by the shaker to the acceleration measured at the point of application for the two top-plates with f-holes (before assembly) as a function of frequency.

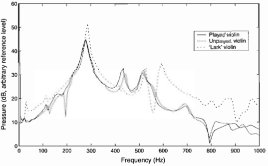

Figure 2. Near field pressure spectra of the violins excited by controlled impulses at the bridge. The third violin is an inexpensive mass produced model (' Lark' brand) included for comparison. Measurements were made after 3 years and adjustment of the played violin.

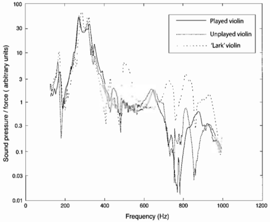

Figure 3: The ratio of near-field sound pressure to the applied force upon application of broad-band vibration to the bridge.

	Played violin	Unplayed violin
E_L (GPa)	10 ± 2 (7)	10 ± 1 (6)
E_T (GPa)	0.9 ± 0.1 (2)	0.7 ± 0.1 (2)
ρ (kg m^{-3})	473 ± 9 (22)	447 ± 13 (12)

Table 1. Measured properties (mean ± standard error (number of samples)) of wood samples from material surrounding the violin plates. Here, E_L and E_T denote the Young's modulus in the longitudinal (grain) direction and the transverse direction respectively, and ρ denotes the mass density.

3. MECHANICAL MEASUREMENTS

Before the violins were assembled, vibro-mechanical measurements and Chladni patterns were made on the carved plates, before and after the cutting of f-holes and adding the bass bar. An impedance head was mounted axially on a shaker and coupled via a magnetic clamp system to the plate, which was excited with a synthesised broad-band signal over the frequency range 50-1000Hz [11]. The results are shown in Fig 1. Note that there are clear differences in resonances between 500 and 800 Hz, as one might have expected from the measured inhomogeneities in the wood (Table 1). On the other hand, the low frequency responses are similar, and there are some similarities in the envelope of these plots. The inset photographs show Chladni patterns and the frequencies at which they were most strongly detected.

After assembly and finishing of the violins, the impulse response was measured using the method described by Jansson [12]: an impact hammer was positioned at the tip of a pendulum to impart reproducible mechanical impulses at the bridge, and a microphone was placed at the bass f-hole to measure the resulting pressure response in the near field of the violin. These measurements were also performed after one year, after three years and after subsequent adjustment of the played instrument. The pressure responses of the two instruments are given in Fig 2. The acoustic pressure in the near field of the violin was also measured while the bridge was driven with broad band excitation. The transfer functions of this measured pressure to the force applied to the bridge of the two instruments, is given in Fig 3. Although there are differences between the two instruments, they are small in comparison to the differences between either instrument and an inexpensive, mass-produced instrument (' Lark' brand).

4. PLAYING AND LISTENING TESTS

Listening and playing tests were conducted three times: First, when the two violins were new, the second was three years later (before any changes or adjustments had been made to either) and the third time was four days after this, following the installation of a new bridge and strings and a minor adjustment of the position of the sound-post of the played violin only. All tests were conducted ' live' in a concert hall (the Clancy Auditorium, at the University of New South Wales), which is regularly used for chamber, orchestral and choral music concerts. The playing and listening panel in each experiment were recruited from the most able members of the violin section of the University of New South Wales Orchestra. Their minimum formal qualifications varied from 7th grade to Licentiate in the Australian Music Examinations Board system. Each member of the listening panel in turn became a player. A few days before the first experiment, members of the panel were asked to fill a questionnaire in which they listed categories and qualities they would use in evaluating a violin for purchase. The more common words were retained for use in the questions given to players and listeners, as listed below. (Although there are published lists of terms that listeners and players might use for their assessment [13], these terms do not have universal acceptance and we preferred to use a list of terms that were judged relevant to our particular group of subjects.)

The same bow was used in all trials. Each player played three consecutive tests. In the first test, a player was given an instrument and played a G major scale over three octaves,

Listening tests	New		3 years		3 years, with adjustments	
	Played	Unplayed	Played	Unplayed	Played	Unplayed
Evenness	6.7±0.1(113)	6.9±0.1(121)	6.1±0.2(56)	6.0±0.2(52)	6.5±0.2(78)	6.6±0.2(99)
Clarity	7.0±0.2(79)	7.0±0.1(119)	5.7±0.3(56)	5.6±0.3(52)	6.4±0.2(78)	6.4±0.1(99)
Projection	7.0±0.1(79)	7.1±0.1(121)	6.0±0.2(56)	5.8±0.3(52)	6.4±0.2(78)	6.6±0.2(99)
Character	6.2±0.2(79)	6.2±0.1(119)	5.4±0.3(56)	5.4±0.3(52)	6.1±0.2(79)	6.2±0.2(99)
Warmth	6.6±0.2(79)	6.7±0.1(120)	5.3±0.3(56)	5.4±0.3(52)	6.4±0.2(79)	6.2±0.2(98)
Preference	1.0±0.1(107)	1.1±0.1(118)	1.2±0.2(56)	1.0±0.2(52)	0.9±0.1(75)	1.1±0.1(93)

Playing tests	New		3 years		3 years, with adjustments	
	Played	Unplayed	Played	Unplayed	Played	Unplayed
Warmth	6.4±0.4(20)	6.2±0.3(22)	5.6±0.5(23)	5.1±0.5(22)	5.8±0.5(17)	6.2±0.4(22)
Evenness	7.0±0.2(18)	6.4±0.3(21)	5.7±0.5(23)	5.5±0.5(22)	5.9±0.6(17)	6.2±0.4(22)
Brightness	7.0±0.2(20)	6.5±0.2(22)	5.8±0.4(23)	5.3±0.5(22)	6.2±0.4(17)	6.5±0.3(22)
Speaking ability	7.2*±0.3(20)	6.3*±0.3(22)	5.6±0.4(23)	5.1±0.6(22)	5.9±0.6(17)	6.5±0.3(22)
Playability	7.2±0.3(20)	7.0±0.2(22)	5.8±0.5(23)	5.2±0.6(22)	6.1±0.5(17)	6.2±0.4(22)
Responsiveness	7.3±0.3(20)	6.7±0.3(22)	5.6±0.5(23)	5.6±0.5(22)	6.1±0.5(17)	6.2±0.4(22)
Character	6.2±0.3(20)	5.9±0.3(22)	5.4±0.5(23)	5.3±0.6(22)	5.7±0.5(17)	6.1±0.5(22)
Dynamic range	7.0±0.3(20)	6.3±0.3(22)	5.4±0.4(23)	5.2±0.6(22)	6.1±0.3(17)	6.2±0.4(22)
Sound preference	0.8±0.2(16)	1.2±0.2(20)	0.8±0.2(23)	1.2±0.2(22)	0.9±0.2(17)	1.1±0.2(22)
Playing preference	1.1±0.2(16)	1.0±0.2(20)	0.8±0.2(23)	1.2±0.2(22)	0.9±0.2(17)	1.1±0.2(22)

Table 2. Combined results of comparisons from the listening and playing tests. Listed are the mean values of each category. The pair that significantly differs at the 95% level is marked with an asterisk.

from G3, ascending and descending, followed by a short piece chosen by that performer (the same for each test by that performer). After each test, the violin was taken from the player and placed behind a screen on the auditorium stage. According to a predetermined sequence, the player was given either the same instrument, or the other member of the pair being compared. A test was then conducted and the violin was again returned behind the screen. For a third time, the player was given an instrument and asked to play the scale and the test piece. Behind the screen, the neck and chin rest of the instrument not being played were kept warm by being held in the hands of one of the investigators. The sequence of presenting one or other of the violins was arranged in pseudorandom order, with the constraint that all possible arrangements of two violins in trial sets of three were completed with each group of 8 sets of tests. The participants were not told of the aim of the experiment. (One performer asked if he had been given the same violin each time, while many who actually had been given the same instrument each time did not comment on this.) Each player rated the instruments in the three tests on a scale from 1 (poor) to 10 (excellent) in 8 categories: 'evenness', 'playability', 'speaking ability', 'distinctive character', 'warmth', 'brightness', 'responsiveness' and 'dynamic range'. They were also asked to rate their preference for 'sound', and the overall 'playability' of each test they performed.

The listeners rated 5 categories for each test, also from 1 (poor) to 10 (excellent): 'evenness', 'clarity', 'projection', 'distinctive character' and 'warmth.' They were asked to rank each set of 3 tests in order of preference for the sound of the instrument. They were told to evaluate the sound only, as opposed to the performance quality, and were asked to use their own definitions for each of the terms listed.

In the first experiment, the new violins looked very similar and the players and listeners were not blindfolded. After playing, however, the two instruments could be readily distinguished upon close inspection: the bridge on the played instrument was noticeably darker in colour, and its varnish had a different texture. Consequently, for the later tests, players (but not listeners) were blindfolded. From the designated seats in the auditorium, the owner of the played violin could not distinguish them visually.

The results of the comparisons are given in table 2. Does playing make a violin 'warmer', more 'even', 'brighter' (and the rest of the categories), as determined by players and listeners? The choice of confidence level for tests of this nature is a compromise. If one chooses a level of 99% or 98%, it might be argued that the demands are too stringent: positive differences will only be noted if the panels could very confidently distinguish between the instruments. Conversely, if one were to choose a level of 95%, we would expect false positives in approximately 5% of comparisons: about one in twenty results would yield false positives. In each set of tests, we compared responses in 16 different categories, so, at the 95% confidence level, the probability of no false positives in a single experiment is $(0.95)^{16}$=44%. In other words, it is more probable to have one or more false positives than none at all. The chance of false positives increases with the number of comparisons. Over the years we conducted 3 sets of comparisons in each of sixteen categories, ie a total of 48 comparisons. Hence, even at the 98% confidence level, the chance of no false positives is $(0.98)^{48}$=38%. Again, one or more false positives is more likely than none.

In the 48 comparisons, no difference between the violins was significant at the 98% confidence level. In just one of the comparisons, there was one comparison that, on its own, would have been significant at the 95% confidence level. At the first trial, the violin that was to become the played violin was judged to 'speak' better (a mean of 7.2 compared to 6.3 for 'speaking ability'). However, in 48 tests, it would have been very surprising to have no false positives at the 95% level: 0.95^{48} is 9%, so, ten times out of eleven, 48 tests would yield at least one false positive at this level.

These results suggest that three years of regular playing, and the adding of new bridge, new strings and a slight adjustment of the sound-post, has not made a statistically significant difference to the performance of one of the pair of violins, as determined by playing and listening panels of experienced violinists who were unfamiliar with either instrument.

What of someone who is familiar with at least one of the violins? In a separate, blind playing trial conducted after the last comparison experiment, Romano Crivici, the owner of the played violin, was asked to play a scale and a short piece on the instruments as they were presented to him in random order, and to identify each instrument by saying "mine" or "museum's". He was correct in 20 out of 24 trials, which is significant at the 99% level.

It is not known to what extent he may have used tactile cues, which obviously are an important part of the playing sensation [14]. Further, his test was arguably a simpler one than that faced by the panels: he gave a binary choice rather than a ranking or rating.

Can we extract the effects of age alone from these experiments? In principle, listening tests could be conducted using the recordings made during these experiments. These experiments have not been conducted yet, in part because they would be expensive and this project has no formal funding. There is little point in using the data in Table 2 for this purpose: the playing and listening panels were recruited from a student orchestra and there is no overlap in members between the first two tests. Even if there had been common members, it is possible that the playing skills and musical tastes of a musician might change more rapidly than those of the instrument.

5. CONCLUSIONS

Mechanical measurements show noticeable differences between the two violins built from the same wood samples. Although the frequency envelopes are similar, there are differences in detail. Nevertheless, rankings of the instruments by experienced playing and listening panels showed no statistically significant differences in the finished instruments. This implies that measured changes in mechanical properties alone are not enough to suggest that an instrument has 'improved.' Three years after they were finished, with one instrument having been played and the other having been kept in museum conditions, the results still showed no statistically significant differences.

This suggests that the effects of playing are small after only 3 years.

Three years is not considered a long time for an instrument of which there are examples still being played after hundreds of years. The investigators hope that this study will continue, with this pair of instruments, for a time comparable with the age of these older violins.

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A CODE OF ETHICS FOR THE AUSTRALIAN ACOUSTICAL SOCIETY

Fergus Fricke,
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The Australian Acoustical Society, like most professional institutions, has a code of ethics. While there are considerable limitations on the value of such codes, they do provide a broad vision of an ideal that members of a profession share and aspire to even though there is often a large gap between the ideal and the practice.

Like the Ten Commandments, the Code of Ethics is open to interpretation. Just as the commandment that you shall not kill can be ignored if the right person tells you to kill, the ethic that the welfare of the community should be paramount is also open to various interpretations. For instance when noise is an issue, is the " community" the immediate neighbours of an airport, say, or is it the population of Australia? Over what period should the welfare be considered? How does one define the welfare of the community?

I suggest that we need to discuss and debate and feel passionate about such issues. We need to give examples of what is acceptable and what isn' t. We need, on occasions, to be able to excommunicate heretics and occasionally, in a vibrant organization, we must accept that there will be insurmountable doctrinal differences which end in splits and splinters, and that this is probably for the greater good. Life is full of contradictions and the need for both unity and diversity is just one of them. A conscious consideration of issues may lead to contradictions but it is difficult to argue that consciousness is not fundamental to human existence.

Attitudes and ideologies evolve over time and if a code of ethics is to be relevant it should evolve also. While I don' t see a need to alter the six items in the present code I would like to see a seventh item added to it. At present the code of ethics is only concerned with the responsibilities of members to the community, other members and the acoustical profession. I suggest that members of the Acoustical Society should also have responsibilities concerning the acoustical and physical environment.

Under the existing code of ethics welfare, health and safety of the community shall at all times take precedence over sectional, professional and private interests. Animals too are affected by some of the actions we take as professionals. One the most notable of these is the effect of sonar signals on whales and other marine life but bird and animal behaviour is also influenced by noisy activities.

Another " environmental" issue concerns our cultural heritage. For instance, should we support the construction of roads, with or without noise barriers, where the road will visually, aurally or physically produce a significant degradation of the built environment or the natural environment?

While it may seem unrealistic to consider environmental issues in the daily need to turn a dollar an environmental clause in the code of ethics seems to be as reasonable as other clauses in the code of ethics. It might even focus attention, in the Society, on the six existing Code of Ethics clauses. Also, given the mysticism involved in some aspects of acoustics it would seem appropriate to have a mystical seventh clause in the Code of Ethics.

Obituary

PAUL DUBOUT

10 October 1928 – 10 February 2005

Paul was born in Melbourne where he spent all his childhood and attended Haileybury College of which he was dux in his final two years. He graduated from Melbourne University with a Bachelor of Science in physics and electronics in 1950. He started work in the acoustic and thermal investigation section of the CSIRO Division of Building Research at Highett in Melbourne in April 1951, where work on acoustics had started three years earlier. One of the researchers worked on sound transmission in ducts: the rest of the team worked on auditorium acoustics. The auditorium research initially involved the scale modelling of auditoria. Paul began CSIRO' s work on subjective acoustics and studied the perception of echoes. Haas in Germany had worked with speech and a single artificial music. CSIRO extended this to music and ultimately showed that similar underlying parameters applied to all sounds.

Paul' s wife Val also graduated from Melbourne University after studying physics and mathematics. Val commenced working at CSIRO at Highett in the concrete section just before Paul. They kept their relationship a secret at CSIRO. However later in 1951 there was a budgetary crisis. There was even talk of a merger with the Experimental Building Station in Sydney which did not actually occur until July 1988 after Paul had retired. Instead there was an internal reshuffle and Val was transferred to the same section as Paul. At this stage they announced their relationship at CSIRO and shortly afterwards were formally engaged. Val left CSIRO in 1954 to raise a family of four.

The research on auditoria and subjective acoustics was wound up in 1959. After a short period working on thermal conductivity and air change rate, Paul commenced working on community noise and transmission acoustics.

Roy Muncey left in January 1966 to become chief of the CSIRO Division of Forest Products and Werner Lippert became leader of the acoustics team. Unfortunately Werner became ill a year later in January 1967 and never fully recovered. Although he did not retire until 1970, he went through a difficult period and died in 1971. Arthur Nickson took ill during 1967 and died in January 1968.

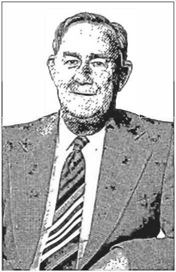
CSIRO' s acoustic chambers at Highett were constructed in 1966. Paul had to run the acoustics section and manage the fit out and commissioning of the new acoustics chambers. During this time Paul also measured rain noise and worked on the damping of steel roofs to reduce rain noise. Paul commenced his work on standards committees at this time by being invited to join one committee and inheriting his fellow researchers' positions on other committees. Paul remained very active on these standards committees until his retirement in 1986.

Paul was a foundation member of the Victoria Division of the Australian Acoustical Society. The first meeting to set up the Victoria Division was held in November 1964. Paul was elected to the provisional committee which first met in December 1964. Paul was secretary of this committee in 1966. The federal society was incorporated in 1971. Paul was the one-man federal membership grading committee until 1982 and the society' s archivist until about 1995. He was honoured for his work in acoustics and for the society by being elected a Fellow of the society.

Paul was an assessor for the National Association of Testing Authorities, Australia (NATA) since about 1970 and served on NATA' s Acoustics and Vibration Registration Advisory Committee for five years. Paul was also the Australian Acoustical Society' s representative on the National Committee for Physics of the Australian Academy of Sciences for a number of years.

Arising out of the commissioning of the acoustics chambers, Paul managed an Australian and New Zealand " round robin" on the measurement of sound absorption coefficients in reverberation chambers. The final report on this research was published in 1985. A project to evaluate a method of measuring the noise of plumbing appliances was commenced in 1972. Paul also completed the write up of this project in 1985 after the original researcher retired in 1977 due to ill health. During the 1970s, Paul supervised Ken Cook' s research on the sound insulation of typical Australian roofing systems.

In late 1986, CSIRO had an early separation incentive scheme. Having already suffered a heart attack, Paul applied. Paul' s application was unsuccessful in the first round in December 1986. In the second round in May 1987, Paul' s application was successful and Paul decided to retire after 36 years with CSIRO.



Paul Dubout

Paul was a great reader of the acoustics literature. Appropriately, one of the items that he had selected to read, just before his death, was the just published issue of Acoustics Australia. Further information on Paul' s career is contained in the April 1986 issue of Acoustics Australia.

John Davey

Book Review

Engineering Acoustics

An Introduction to Noise Control

Michael Moser

Springer-Verlag, Berlin, 2004, 289 pp (hard cover), ISBN 3 540 20236 6. DA

Information Services, www.dadirect.com Price A$120 approx.

This is the English translation by S Zimmermann of the authors 2003 book "Technische Akustik" which was the complete revision of Lothar Cremer's well respected book "Vorlesungen uber Technische Akustik". The first five chapters deal with the perception of sound and fundamentals of propagation, radiation, structure borne sound and vibration isolation. The second half of the book comprises six chapters covering topics related to sound within spaces such as sound absorbers, room acoustics, diffraction, microphones and loudspeakers.

The author suggests that the book can be used as a text for self learning or for lecture courses and that no highly specific knowledge is vital except for the " usual skills -like taking derivatives and solving simple integrals". However the extent of the mathematics in the book may make it rather challenging for such a reader. The theory of sound wave propagation and the effects within spaces are thoroughly dealt with. For example, in the chapter on sound absorbers, over 10 pages are devoted to the various aspects of the theory of sound absorption in impedance tube. In contrast less than two pages on measurement of sound absorption coefficient in a reverberation room are included in the chapter on room acoustics.

This book is certainly comprehensive in the coverage of the theory and, as such, provides a very good reference text. The equations are set out well and the diagrams clear. The translation is well executed so that it is easy to read and there are only the occasional "quaint" words. Each chapter has a brief section for further reading but the majority of these recommended documents are in German. Of the 29 references for the book about half are in German.

The use of the words 'Engineering' and 'Noise Control' in the title could be a little misleading as we have come to expect books with such words to have practical examples. There certainly are some examples but the emphasis in this book is on the fundamental theory. I suspect that it would require a dedicated self learner to work through this book. As a reference or text book it would be most valuable. Anyone seeking the fundamental theory to a particular aspect of acoustics would be likely to find that topic concisely covered within this book.

Marion Burgess

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ICA 2010

Winning the bid

This is the first in what will be a regular item in the lead up to ICA in Sydney in 2010.

In late 2003 the AAS received an invitation to submit a bid in April 2004 to hold the International Congress on Acoustics in Australia in 2010. Noting that encouraging International Conferences to Australia scored a high rating in the member survey the AAS Council agreed to accept this invitation and to provide financial support. Ken Mikl, President of AAS at that time, undertook the task with his usual enthusiastic zeal and asked me to help with the preparation and presentation of the bid. The AAS agreed that Sydney should be the location. Ken quickly obtained the support of the Sydney Visitors and Convention Bureau (SCVB) plus other government agencies and we worked with them on the preparation of the bid document and the associated audio visual presentation. The Sydney Convention Centre became the obvious choice for a venue. We were grateful for the enthusiastic support from those working in the key areas of acoustics who, when approached, unhesitatingly agreed to provide support to attract the ICA to Australia. We headed to Japan with a very professionally produced bid document but knew we were against strong competition from China and Korea. Ken did an excellent presentation, and competently overcame the AV hitch. We must have given satisfactory answers to the questions as we returned from Japan with the good news that Australia had won the bid to host ICA in 2010 in Sydney.

Then the realization hit that AAS was now given the responsibility to host an international acoustics conference in Sydney with anticipated attendance between 900 and 1500. While Australia is a popular international destination there is the disadvantage of the long travel for those from Europe and US and we began to think about other ways to ensure the high attendance. It was obvious that there was overlap of interests between the annual Internoise conferences and the ICA, held only every 3 years. So, with the tacit support from ICA board, we planned an approach to I-INCE to consider combining Internoise 2010 with ICA 2010 in Australia. This would involve a small shuffle in the schedule for the distribution of the Internoise around the world for which there was plenty of time as they had still not selected the location for Internoise 2008. To overcome not having a member on the I-INCE board and hence being unable to present the submission in person, we gathered support from a number of board members and Bernard Berry from UK agreed to present on our behalf. The SCVB again provided the professional support in the documents to present our case at the board meeting in August.

Unfortunately this time we were unsuccessful. The Board agreed that the concept of a combined conference was certainly worthy and would counter the concern that there are too many conferences. But it considered the shuffle in the schedule would require one global area to have to wait one more year for the chance to host an Internoise. One positive outcome from this approach was that the I-INCE board did agree to hold the Internoise at a time and place that would not conflict with ICA.

Since August we have been working with other Australian Societies to encourage them to hold their annual conference as part of the ICA. This will be important to ensure a good core of Australian registrants to achieve a viable conference.

Unfortunately, due to personal reasons, Ken Mikl has found it necessary to resign recently from the leadership positions he has held in the AAS including Chair of ICA 2010. His vision and enthusiasm which encourage others to aim 'for the top' coupled with his diligence which ensures that the job gets done will be greatly missed.

The next in this series will focus on what constitutes an ICA Congress

Marion Burgess

News

AAS Educational Grant, 2005

The AAS Education Grant is awarded annually and aimed at promoting research and education in acoustics in Australia. The grant of up to $5,000 can be for scholarships, research projects, educational purposes or other worthwhile use related to acoustics. Details for the submissions are available from www.acoustics.asn.au and are due by 30 July 2005.

Excellence in Acoustics Awards, 2005

The Excellence in Acoustics award, sponsored by CSR Bradford Insulation, will be presented at the Annual Conference of the Australian Acoustical Society in November 2005. The winner will be presented with a trophy and a gift to the value of $2,500, and the runner up will receive a certificate and gift to the value of $500. This award aims to foster and reward excellence in acoustics and entries will be judged on demonstrated innovation from within any field of acoustics. Any professional, student or layperson involved, or interested in, any area within the field of acoustics, with a body of work no older than 3 years, is eligible and encouraged to enter. Details are available from www.acoustics.asn.au and close 30 July 2005.

Australia Day Honour

Louis Challis, a NSW Member, received a 2006 Australian Day Honour - a Member in the general division of the Order of Australia - for service to engineering as a pioneer in environmental and architectural acoustic engineering. It is wonderful to see that the outstanding contribution to acoustics in Australia that has been made by Louis has been recognised nationally.

New Occupational noise Standard

Standards Australia has issued a revised version of **AS/NZS 1269**, the five part standard on Occupational Noise Management. This new version does not introduce any major changes in the procedures for occupational noise management but it does include some small changes and important additional material while maintaining the five part structure. Note that there are some typographical errors so check for an erratum. The five parts of the revised standard are:

AS/NZS 1269.0:2005 Occupational noise management - Overview and general requirements

AS/NZS 1269.1:2005 Occupational noise management - Measurement and assessment of noise immission and exposure

AS/NZS 1269.2:2005 Occupational noise management - Noise control management

AS/NZS 1269.3:2005 Occupational noise management - Hearing protector program

AS/NZS 1269.4:2005 Occupational noise management - Auditory assessment

I-INCE

Report on Global Approach to Noise Policy

AAS has the opportunity to comment on the draft report from I-INCE Technical Study Group (TSG) 5. The AAS member of this TSG was Les Huson. The group has been working on aspects of a Global Approach to Noise Policy and one aspect of the task has been to:

study the manner in which global policies were developed in the past and to make recommendations for improving current procedures so that future policies may provide more effective control of the emission and immission of noise. The roles of international bodies, national governments and local authorities should be clearly identified and, if necessary, clarified.

The draft report comprises four parts: General Global Approach to Noise Policy, Occupational Noise, Community Noise and Consumer Product Noise. Each part examines in depth the international situation and has recommendations. The draft report can be accessed from www.i-ince.org. The AAS is in a position to consider such documents with a different view to those from either the US or European and so its comments are valuable. In its final form this report will achieve International standing so it is important that the views of all the member countries are adequately represented.

The AAS is seeking input from the membership as a whole to comment on the report and so to assist Council in its voting. Comments should be sent to General.Secretary@acoustics.asn.au by 1 June 2005.

European Good Practice Award for Noise

While nominations are only open to EU states, it is of note that the European Agency for Safety and Health at Work has identified prevention of risks from noise at work as the central theme for their 2005 safety and health awareness campaign. The entries should show good management, particularly the effective use of risk assessment and implementation of its findings, and be focused on successful prevention of risks to workers. The Director of the European Agency, Hans-Horst Konkolewsky, said 'Noise at workplace is still too often viewed as a necessary evil, and, as its effects are not instantaneous, it is not considered a priority. The truth is noise does have a devastating impact on our health and it affects not only workers at steelworks or construction sites, but also millions of people employed in the service sector, e.g. in education, entertainment, or call centres. It can be a causal factor in accidents, contribute to work-related stress, and may act together with other workplace hazards to cause ill health. With the European directive on noise to be implemented early next year, it is high time to take more decisive measures to "stop that noise". We hope the good practice awards will demonstrate, by example, that work-related noise can be effectively controlled." Further information about the awards from http://ew2005.osha.eu.int/ .

Letters

Acoustic Provisions in the Building Code of Australia

The Australian Building Codes Board, responsible for preparing and issuing the Building Code of Australia (BCA), has recently issued a revision to Part F5 - Sound Transmission and Insulation. The Board has made significant progress and what most of us would consider to be positive improvements in the section of the BCA that deals with the airborne sound insulation ratings, for the division walls between apartments (that are classified as Class 2 or Class 3 buildings).

Notwithstanding, I am less than satisfied with some of the other most recent revisions. I hold the view that they have failed to appreciate the magnitude of the problems created by the revised section of the BCA that encompasses the " Determination of impact sound insulation ratings" .

Accordingly, I seek co-signatories on a letter incorporating the following text that I will soon be forwarding to the Australian Building Codes Board. If readers are prepared to be a co-signatory, please forward an email louis@challis.com.au, or fax to 02 9357 3684 indicating your support.

Sincerely,
Louis Challis
louis@challis.com.au

To ABCB

RE: BCA Part F5 Sound Transmission and Insulation

We the undersigned, have reviewed the HEALTH AND AMENITY objectives, FUNCTIONAL STATEMENTS and PERFORMANCE REQUIREMENTS embodied in the revised Sound Insulation Rating of Floors section, contained in PART 5 - SOUND TRANSMISSION AND INSULATION, recently revised in the BCA.

The Board has made significant progress and what most of us would consider to be positive improvements in the section of the BCA that deals with the airborne sound insulation ratings, for the division walls between apartments.

However, we hold the view that the impact criteria expressed as $L'_{n,w}+C_i$ (impact) that is currently specified as a figure of not more than 62 for a floor that separates it from:

(i) Sole-occupancy units, or

(ii) A sole-occupancy unit from a plant room, lift shaft, stairway, public corridor, public lobby or the like, or parts of a different classification, is inappropriate and has failed to address the Health and Amenity requirements of new residential buildings that would be constructed in accordance with that criterion in Australia.

We request that the ABCB should urgently revise the $L'_{n,w}+C_i$ (impact) criterion that it has adopted, in order to ensure that the problems that have been, and/or are currently being created as a result of the adoption of that promulgated criterion, may be promptly resolved through the promulgation of a more appropriate criterion.

Retiring Editors.

It was a pleasure to be associated with the former New South Wales editors of this Journal from the early 1980's until the December 2004 Issue. Firstly Howard Pollard and Marion Burgess from 1982, then Neville Fletcher, Joseph Lai, and Marion Burgess from 1993. I have appreciated their encouragement and help proffered in publishing articles and news items, and look forward to working with the new editors.

The retiring editors have indeed achieved the balance mentioned in "From the Editor" in the December 2004 Issue, and propagated a tradition, whence endorsing an aim of the Society "to promote the science and practice of acoustics in all its branches". Also, with the countless news items and technical information, have created and sustained interest in the breadth of acoustics, as well as advised of happenings among our members.

Yours faithfully,
Donald Woolford MAAS.

FASTS

Science Meets Parliament 2005

Science Meets Parliament (SMP) is organized by the Federation of Australian Scientific and Technological Societies (FASTS). The AAS is a member of FASTS which works to " influence the formulation of science and technology policy to the economic, environmental and social benefit of our nation" .

For the second time, the AAS participated in this event and I joined over 200 scientists on March 8 for the first day at the National Press Club. This comprised the introductory sessions explaining the aims of SMP, suggestions on how to get maximum benefit from the meeting with the politicians and the main issues. These included research infrastructure, productivity and balance of trade and national water initiative. The Hon Dr Brendon Nelson, Minister for Education Science and Training was the speaker at the televised Press Club Luncheon. Excerpts from this address were on the national news bulletins. I chose to opt out of attending the evening dinner, with guest speaker Dr Caroline Kovac from IBM Healthcare and Life Services.

On March 9, groups of three SMP participants were allocated interviews with politicians. It is the ' luck of the draw' which two politicians each SMP participant is allocated to. My first interview was with Laurie Ferguson, Shadow Minister for Immigration. The 20 minute interview went well, he was interested and each of us explained the area of science we were representing. There was some discussion on the impact of, and needs for, skilled migration in the sciences. We did spend some time talking on acoustics but this was on a motor sports noise problem in his electorate! We also discussed government policies on research infrastructure and in particular its effects on acoustics.

My second interview was to be with Aiden Ridgeway, a Democrat Senator who lost his seat at the last election and is due to leave Parliament soon. Unfortunately he was called to the Senate as a bill he had been working on was going through the last stages of voting. We then talked with one of his aids who was polite and interested.

During the day there were a number of other events in the meeting rooms including a forum on climate change and a Hypothetical hosted by Dr Normal Swan (ABC) on a Viral Pandemic.

I come away from SMP2005 with similar thoughts to those after SMP2003 [' Science Meets Parliament' , Burgess and Wolfe, Acoustics Australia 31, (2), p109-110]. The organization of a day in Parliament allows scientists to meet with politicians and both groups can gain more understanding of each other. The various activities and the large number of participants provide a strong message to the politicians that there is a need to consider carefully the policies which have implications for the future of science and technology in Australia. However participation in SMP is only one small step on the way to achieving actions on the concerns of the AAS. Even if the interview is with a politician who has some power in the relevant area there is limited chance, in a short interview with two other scientists from vastly different area, to raise specific issues.

On the one hand it is important to support the FASTS activity but on the other participation in SMP is unlikely to achieve progress on the current concerns for acoustics. Opportunities for direct actions are considered by AAS Council but all of the membership can contribute by taking all possible opportunities to air the concerns with their local member, other politicians and their advisors.

Marion Burgess

Meeting Reports

Australian Institute of Physics Congress

This Biennial Congress was held in Canberra at the beginning of February and attracted a record attendance of 950 people. The Congress was a really major event and was planned to mark the opening of the UN-designated "International Year of Physics", which celebrates the centenary of Einstein's three major 1905 publications on Brownian motion, the photoelectric effect (for which he later received the Nobel Prize), and the special theory of relativity. Altogether there were 9 plenary lectures, mostly from invited overseas speakers including two Nobel Prize winners, 300 contributed papers presented orally, and a large number of posters, so that it was necessary to hold 6 parallel sessions on each of the 5 days of the Congress. Joe Wolfe, for the AAS, was responsible for organising two sessions on the topic "Acoustics and music". Both sessions were very well attended — one had an overflow crowd — and the questions after each talk indicated a high level of interest. There were also acoustics posters in the evening poster session.

The venue in the Manning Clark Centre at the Australian National University was excellent for the purpose, since it has 6 lecture theatres of varying sizes and is close to Melville Hall, where morning and afternoon teas, industrial exhibits, and the poster sessions were all held. The only problem was with the plenary lectures, since the main theatre could not accommodate all who wanted to attend — those who got there well before the 8.30AM commencement were lucky, but a video link to an adjoining theatre allowed later comers to hear and see the whole thing as well. The Conference Dinner in the Great Hall of Parliament House was also very well attended — every available ticket was sold, so the hall was full — and it was a very pleasant occasion.

With so many parallel sessions over the five days of the conference, three major symposia on the Sunday before the Congress opening, a Luncheon Address at the National Press Club, a Questacon Public Lecture, and an afternoon of "outreach" activities involving high school students as well as Congress participants, it was a very full and varied week. In addition to all the talks and posters, the 40-minute morning and afternoon tea breaks were long enough for one to be able to meet old friends and make new acquaintances. Our Society should be proud to have been associated with such a notable event.

Neville Fletcher

Winds of Music

The fifth and final 2004 Victoria Division technical meeting on 1 Dec was end-of-year dinner enjoyed by 36 members, partners and friends. Professor Neville Fletcher was the invited speaker and there were 36 present.

First the grade of FAAS was the conferring on Graeme Clark, Laureate Professorial Fellow at Melbourne University, and Director of the Bionic Ear Institute. The FAAS certificate was presented on behalf of the AAS Council by Norm Broner, the Victoria Division chairman

Neville Fletcher gave a talk on "The Winds of Music -- from the bullroarer to the bassoon". He began by referring to Pythagoras (fl. 532BC) and his musical scale. In c.1000AD, a person's education was considered incomplete without music.

Drums produce musical rhythms, but wind instruments produce musical notes of definite pitch, and generally require some kind of hollow tube, which may be a tapered conch shell, a bamboo cane (as in the panpipes), a small tree trunk (the didgeridoo), or a wood or metal tube fitted with keys and levers (as in modern flutes, oboes, clarinets and bassoons). Wind instruments may consist of a single pipe, such as the didgeridoo (c. 1,5m long) in which the tone is produced from buzzing lips as with brass instruments, and in which the tone quality is varied by vocal tract changes; or, as with flutes, etc, in which the various notes are produced by covering different finger holes. Panpipes require numerous pipes, each one producing its own individual note. Pipe organs employ many pipes, in order to cover a variety of instrumental tone colors over the range of one or more 4- to 5-octave keyboards and a two to two-and-a-half octave pedal board, with the Sydney Opera House organ having 10 000. Among the instruments Neville demonstrated were a simple bamboo pipe, panpipes, an organ pipe and a modern flute. At the conclusion, Norm Broner's thanks to Neville for his interesting talk and demonstrations were carried with acclamation.

Louis Fouvy

New Products

Brigade

BBS-TEK™ BACKALARMS®

Brigade Electronics, the European leader in reversing safety systems, has introduced yet another industry first with the launch of its BBS-TEK™ BACKALARM®.

Designed to combat the two major problems with conventional beepers, location and noise pollution, these alarms are quickly finding acceptance in a wide range of industries throughout Australia. "The sound it makes is directional and quickly dissipates, enabling those nearby to accurately gauge which vehicle is reversing in a noisy work environment, without disturbing residents in built up areas", says the Australian distributor Total Source.

Further information: Total Source, tel 1800724690.

Kingdom

NVH Dream Machine

Building on the success of Abacus, Kingdom Pty Ltd has released "Quattro" from Data Physics, the latest ultra portable DSP engine, bringing a high performance and cost effective solution to small channel count systems.

Ultra portable and rugged, it provides USB 2.0 connectivity to a host PC or laptop and is completely bus powered. With up to 4 inputs, 2 outputs and 1 tachometer channel, it is the complete solution for small channel count applications. With realtime analysis capability from the 24 bit processor providing from DC to 40 kHz or 93 kHz (204.8 kHz sample rate), it is an NVH engineer's dream machine.

The high dynamic range of greater than 110 dB in a hand sized analyser which sources its power from a Notebook computer makes it ideal for laboratory or field work in vibration and acoustics analysis and measurement. Simply load the software, connect the USB cable between Quattro and the PC and it is ready to begin measurement.

Quattro interfaces to the universally popular SignalCalc software environment currently used in ACE and Mobilyzer-I & II. User configurable control and measurement panels, unlimited display layouts and intelligent data management combine to make any PC a powerful and intuitive Dynamic Signal Analyzer.

Information: Kingdom Pty Ltd 02 9975 3272, www.kingdom.com.au

AirCheck

Noise Reducing Pouch

Noise reducing pouches, ideal for Indoor Air Quality applications, are now available for the AirChek 52 and AirChek 2000 sample pumps. The results of the noise reduction test using the black noise-reducing pouch on an AirChek 52 pump (running at 2 L/Min with a 37mm 0.8μm MCE filter cassette showed a reduction from 62.5dBA. to 55.0dBA.

Information: Air Met Scientific tel 1800 000 744 or sales@airmet.com.au.

Future Meetings

Acoustics 2005

The national conference of the Australian Acoustical Society, Acoustics 2005, will be held at Abbey Beach Resort, Busselton, Western Australia from 9 to 11 November 2005. The theme of the conference is "Acoustics in a Changing Environment". This conference will offer the opportunity to consider how well the acoustics profession is serving the community in applying the best available science and technology in our ever changing environment.

The emphasis will be on practical applications of acoustical science and technology and practical solutions to acoustic problems. Topics will include but are not restricted to:

- Underwater - communications, bio-acoustics, propagation, sonar, environmental impact
- Architectural acoustics
- Environmental noise - transport, industrial
- Occupational health
- Engineering noise control

Parallel paper sessions will run on Thursday 10th November. The Conference Dinner will be held on the Thursday evening. Further papers session and Workshop will be held on the Friday, and there will be trade displays both days. The conference will include a special session and/or workshop on underwater acoustic communications and we are fortunate in having Joe Rice, an expert in underwater acoustic communications from the Naval Postgraduate School in the USA attending as a plenary speaker. In addition, a workshop on active noise control will be held in Perth on the Wednesday morning immediately prior to the conference. A short course on transportation noise is also being planned.

Abstracts are requested by 29th April. Late abstracts may be accepted at the discretion of the organising committee. Busselton is located in the scenic southwest of Western Australia close to the region's famous wineries, beautiful coastal scenery, and magnificent forests. It is a great place for a holiday if you can spare a little extra time. Transport by coach between Perth and Busselton will be arranged and can be booked at the time of registration. For further details, latest news, abstract submission guidelines etc go to www.acoustics.asn.au and follow the links to the conference.

Environmental Noise Symposium

The South Australian Division of the Australian Acoustical Society (AAS) will be holding a symposium on environmental noise issues on Friday June 17 2005 at the University of Adelaide, North Terrace Campus. The symposium is being held to bring together the broad range of professions who regularly deal with noise issues such as planners, lawyers, health professionals and Members of the AAS. The range of speakers and topics will reflect this. The course will broadly cover the principles and practice of environmental noise assessment, control and planning.

Registration fees for the full day will be $440 including GST and covers lunch, morning and afternoon teas, drinks and light snacks. Further details: http://www.acoustics.asn.au/general/divisional-notices.shtml

ACTIVE 2006

The South Australian division is pleased to announce that we will be organising Active 2006, an international conference covering all aspects of active noise and vibration control. The conference will be held at the University of Adelaide 18-20 September 2006. For more details: http://www.active2006.com

International Conferences

1st International Symposium on Advanced Technology of Vibration and Sound, Hiroshima, Japan, June 1-3, 2005 dezima.ike.tottori-u.ac.jp/vstech2005

International Conference on Underwater Acoustic Measurements: Technologies and Results.Heraklion, Crete, Greece, June 28 - July 1, 2005. UAmeasurements2005.iacm.forth.gr

12th International Congress on Sound and Vibration (ICSV12), Lisbon, Portugal, July 11 - 14. (2005) www.icsv12.ist.utl.pt

17th International Symposium on Nonlinear Acoustics (ISNA 17) Pennsylvania State University, July 18 - 21 (2005). outreach.psu.edu/c&i/isna17

Inter-Noise 2005, Rio de Janeiro, Brazil, August, 6 - 10. www.inter-noise2005.ufsc.br

World Congress on Ultrasonics Merged with Ultrasonic International (WCU/UI'05), Beijing, China, September, 28 August - 01, (2005). www.ioa.ac.cn/wcu-ui-05

Forum Acusticum (EAA Meeting), Budapest, Hungary, September 28 August - 02, 2005. www.fa2005.org

IEEE International Ultrasonics Symposium, Rotterdam, The Netherlands, September 18 - 21, 2005. www.ieee-uffc.org

Advanced Techniques in Applied and Numerical Acoustics. Leuven, Belgium, September 20-21, 2005 in Leuven www.isma-isaac.be

Modal Analysis, Theory and Practice (ISMA30) Leuven, Belgium, September 20-21, 2005 www.isma-isaac.be

International Symposium on Environmental Vibrations, Okayama, Japan, September 20 - 22, 2005. isev2005.civil.okayana-u.ac.jp

Autumn Meeting of the Acoustical Society of Japan, Sendai, Japan, September 27 - 29, 2005. www.asj.gr.jp/index-en.html

Acoustical Society of America ,150th Meeting: Minneapolis, Minnesota, 17--21 October 2005. asa.aip.org/minneapolis/minneapolis.html

Acoustical Society of America, 151st Meeting, Providence, Rhode Island, June 2006

Western Pacific Acoustics Conference (WESPAC 9), Seoul, Korea, June 26 - 28, 2006. www.wespac9.org

13th International Congress on Sound and Vibration (ICSV13), Vienna, Austria, July 3 - 7. info.tuwien.ac.at/icsv13

International Conference on Noise and Vibration Engineering (ISMA2006), Leuven, Belgium, September 18-20, 2006 www.isma-isaac.be

Acoustical Society of America, 152nd Meeting (4th joint meeting with the Acoustical Society of Japan), Honolulu, Hawaii, 28 November--2 December 2006

Inter-Noise 2006, Honolulu, Hawaii, December 3-6, 2006. www.inceusa.org

14th International Congress on Sound and Vibration (ICSV14), Cairns, Australia, July 9 - 12, 2007 n.kessissoglou@unsw.edu.au

Diary

2005

01 - 03 June, Hiroshima
1st Int Symp on Advanced Technology of Vibration and Sound.
dezima.ike.tottori-u.ac.jp/vstech2005

20 - 23 June, Brest
IEEE Oceans05 Europe.
http://www.oceans05europe.org

27-29 June, Le Mans
Managing Uncertainties in Noise Measurement and Prediction
www.uncertainty-noise.org

28 June - 1 July, Heraklion
Int Conf Underwater Acoustic Measurements: Technologies and Results
http://UAmeasurements2005.iacm.forth.gr

11-14 July Lisbon
ICSV12
www.icsv12.ist.utl.pt, icsv12@ist.utl.pt.

18-21 July, PenState
Int Symp Non Linear Acoustics.
atchley@eng.psu.edu

7-10 August, Rio de Janeiro
Inter-Noise 2005.
www.internoise2005.ufsc.br, support@internoise2005.org.br

05 - 09 September, Bath
Boundary Influences in High Frequency, Shallow Water Acoustics.
http://acoustics2005.bath.ac.uk

11 - 15 September, Beijing
6th World Cong Ultrasonics (WCU 2005).
www.ioa.ac.cn/wcu2005

17 - 21 September, Pittsburgh
Interspeech 2006 - ICSLP
www.interspeech2006.org

20 - 22 September, Okayama
Int Symp on Environmental Vibrations.
http://isev2005.civil.okayana-u.ac.jp

9-11 November, Busselton
Acoustics 2005
Acoustics in a Changing Environment
www.acoustics.asn.au

2006

15 - 19 May, Toulouse
IEEE International Conference on Acoustics, Speech, and Signal Processing
(IEEE ICASSP 2006).
http://icassp2006.org

26-28 June, Seoul
WESPAC9
www.wespac9.org

03 - 07 July, Vienna
13th International Congress on Sound and Vibration (ICSV13)
http://info.tuwien.ac.at/icsv13

17 -19 July, Southampton.
9th Int Conf on Recent Advances in Structural Dynamics
www.isvr.soton.ac.uk/sd2006/index.htm

18 - 20 September, Adelaide
ACTIVE 2006
http://www.active2006.com

18 - 21 September, Pittsburgh
INTERSPEECH 2006 - ICSLP.
www.interspeech2006.org

28 November - 02 December, Honolulu
Acoustical Soc of America & Acoustical Soc of Japan Fourth Joint Meeting.
http://asa.aip.org

3-6 December, Honolulu
Inter-Noise 2006.
www.i-ince.org

2007

9-12 July, Cairns
ICSV14
n.kessissoglou@unsw.edu.au

27 - 31 August, Antwerp
INTERSPEECH 2007.
conf@isca-speech.org

2-7 September, Madrid
ICA2007
www.ica2007madrid.org

9 - 12 September, Barcelona.
Symposium on Musical Acoustics (ISMA2007)
www.ica2007madrid.org

2008

28 July - 1 August, Mashantucket
ICBEN 9 Int Cong Noise as a Public Health Problem.
www.icben.org

2010

23-27 August, Sydney
ICA2010
www.acoustics.asn.au

Meeting dates can change so please ensure you check the www pages.
Meeting Calendars are available on www.icacommission.org/calendar.html and www.i-ince.org.

New Members

Following membership application the AAS welcomes

Member	Eric Le Page (NSW),
	Jacqueline Munn (NSW),
	Tracey Rogers (NSW),
	John Smith (NSW),
	Matthew Petterson (NSW),
	Shane Harris (NSW)
Graduate	Jeremy Cook (Qld),
	Eric Huang (Qld),
	Kenneth Fairbairn (NSW)

Following registration at Acoustics 2004 the AAS welcomes:

NSW Subscriber: Ian Bedwell, Norman Bowen, Steve Brown, Geoff Colin-Thome, Greg Collins, Graeme Dunk, Colin Ellis, Jonathan Firth, Robyn Ford, Ian Grambower, Robin Grant, Mark Hallett, Bruce Hermes, Carl Holden, Paul Isaks, Chris King, Tim Kirkness, Nicholas McGloin, John Tate, John Trenerry, Katie Weekes, Erwin Wegner **Student**: Andrew Barrett, I-Shau Chen, Jason Middelberg, James Neale,

Qld Subscriber Arne Berndt, Sunghoon Choi, Keng Tak Chui, Glen Copelin, Melissa Darke, Parijat Deshpande, Philip Dickinson, Tyson Dodd, Geoff Doyle, Sally Evans, Arthur Hall, Rob Hallows, Jocelyn Handley, Roger Hawkins, Michael Hayne, Frank Henry, Allan Hickey, Philip Huber, Jin Yong Jeon, Ryan Kathage, Martin Lawrence, Andrew Makinson, West Marrin, Kenneth McGunnigle, Geoff McPherson, Paul Meehan, Jasper Milligan, Martin Mollee, Alan Mullins, Daniel Naish, Michael Noad, Justin Overton, Julie Peters, Cedric Roberts, Tim Roberts, Mike Rogers, Jody Rossner, George Rumjahn, Kylie Soegaard, Aaron Thode, Saso Tomazic, Hans-Georg Wagner, Graham Warren, George Wilson, **Student** Michael Kingan

SA Subscriber Ley Chen, Colin Andrew, Jarrad Exelby, Chris Gillard, Ashley Larsson, Sergey Simakov, Michael Sowden, **Student** Richard Morgans

Vic Subscriber Keith Adams, Li Chen, Philip Douglas, Chris Norwood, Antti Papinniemi, Michael Plumb, Daniel Stanef, **Student** Sanjay Kumar

WA Subscriber Chaoying Bao, Rob McCauley, **Student** Yao-Ting Tseng

Following registration at the 2005 AIP Congress the AAS welcomes:

Qld Subscriber Neil Boucher,

NSW Subscriber: Geoffrey Poulton.

AUSTRALIAN ACOUSTICAL SOCIETY ENQUIRIES

NATIONAL MATTERS

* Notification of change of address
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* Proceedings of annual conferences

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www.acoustics.asn.au

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DIVISIONAL MATTERS

Enquiries regarding membership and sustaining membership should be directed to the appropriate State Division Secretary

AAS - NSW Division
Noise and Sound Services
Spectrum House
1 Elegans Avenue
ST IVES NSW 2075
Sec: Ken Scannell
Tel: (02) 9449 6499
Fax: (02) 9402 5849
noiseandsound@optusnet.com.au

AAS - Queensland Division
PO Box 760
Spring Hill Qld 4004
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rdevereux@acran.com.au

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Sec: Jim Antonopoulos
Tel (03) 9526 8450
Fax (03) 9526 8472
jim.antonopoulos@heggies.com.au

AAS–WA Division
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SOUTH PERTH 6151
Sec: Norbert Gabriels
Tel (08) 9316 3881
Fax (08) 9364 6665
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