Case Study: Design and Acoustic Performance of a Drum Practice Music Studio

by

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Design and Acoustic Performance of a Drum Practice Music Studio

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ABSTRACT
Minimising the impact of music practice and "Garage Band" performances upon neighbours in a residential area is challenging in terms of noise emissions from musical instruments, but particularly so when drums and percussion instruments are involved. Normal residential building façades and roofing designs offer limited low frequency noise attenuation and domestic building construction methods can severely compromise the performance of seemingly adequate partition construction details. This paper presents the results of design, construction and testing activities for a private drum studio that was required to meet stringent boundary noise emission targets in order to comply with local council Development Application requirements. High transmission loss lightweight partition test data is provided for the as-built final installation, along with details of cavity absorption, panel damping and vibration isolation treatments that contributed to maximising façade sound reduction performance. A range of room internal absorption treatments, including low frequency "tube traps", corner traps and diffusers were successfully employed to achieve compliance with BBC recommended reverberation times for small recording studios

INTRODUCTION
This private drum studio project began life not to appease irate neighbours, rather to maintain the sanity of family members exposed to regular loud drumming practice. An open stairwell together with an unenclosed 9 piece drum kit upstairs resulted in noise levels of 80 to 100dBA in upstairs rooms and 70 to 80dBA in living areas downstairs. After 4 years of disruption it was decided to demolish the existing single garage and build a new extended double garage with a music studio constructed inside the rear half of the extension.

Despite excellent relations with adjacent neighbours and no formal or informal complaints of noise nuisance from drumming practice, the local council Development Application proved to be a difficult and demanding process.

MUSIC NOISE ANNOYANCE CRITERIA

The NSW Department of Environment and Climate Change (DECC) provide guidelines for domestic noise emissions [1]. These guidelines recognise the wide range in sensitivity of humans to noise annoyance situations and hence, rather than be prescriptive by specifying details of noise metrics, acceptance criteria or target noise limits; they define time restrictions where noise from various activities must not be audible inside neighbouring properties. For musical instruments these restrictions apply between midnight and 8.00am everyday. Rather than utilise these DECC guidelines, the local council sought to specify a condition requiring:

- "….measurement of background noise levels at the nearest neighbouring boundary, measured when the background noise is expected to be lowest."
- "A noise goal of <5dBA over that background level."

BACKGROUND NOISE MEASUREMENTS

Background noise measurements were recorded using a Larson Davis LD700 Precision Sound Level Meter at two measurement positions on the boundary fence-line adjoining the nearest neighbour, on the western side of the property (**Figure 1**). MP1 was located at the fenceline closest to the front façade of the neighbour's dwelling that was exposed to the highest noise levels from drumming practice inside the house. MP 2 was located on the boundary fenceline immediately adjacent to the existing garage structure and closest to the rear deck of the neighbour's property.

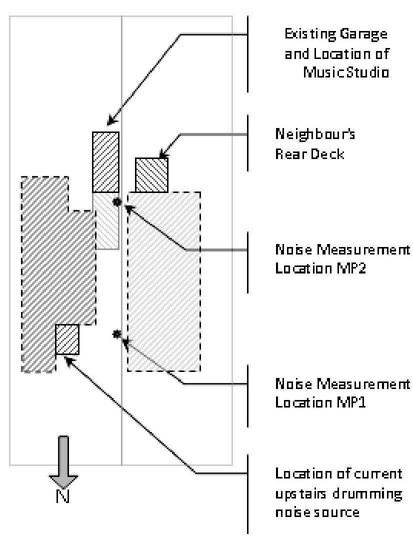

Figure 1. Studio Location and Noise Measurement Positions

Noise measurement statistics (L_{A1}, L_{A10}, L_{A50} and L_{A90}) over 30 minute periods for both background ambient noise and also noise due to drumming practice are presented in **Figure 2**.

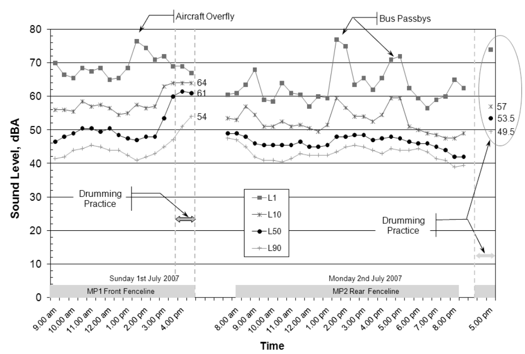

Figure 2. Boundary Noise Levels With and Without Drumming Practice

Table 1: Measured Boundary Noise Levels

Location	Background, L_{A90}	Drumming, L_{A10}
MP1 Front Fence-line	41	64
MP2 Rear Fence-line	39	57

The following conclusions may be drawn from the measured data:

- Typical minimum daytime and evening background (L_{A90}) noise levels were in the vicinity of 39 – 41dBA. A nominal 40dBA background noise level was deemed appropriate.
- Existing boundary noise levels during drumming (L_{A10}) ranged between 57 to 64dBA with the highest levels occurring immediately opposite the first floor practice room and reducing (due to screening effects) towards the rear of the property.
- Design target maximum noise level based on the background + 5dBA criterion should therefore not exceed 40 + 5 = 45dBA.
- Drumming noise emissions exceeded the 45dBA target by 12 to 19dBA for the current 4.5m setback distance from the boundary.

STUDIO ROOM DESIGN

The sizing of the studio was highly constrained in terms of the available space envelope. The exterior length and width were determined by the existing slab dimensions (6.2m x 3.1m) and the height was limited by council bylaws, however, the roof pitch height was raised by nominally 600mm to 6.35m. The Studio was designed as a completely vibration isolated and free standing structure within the double garage, such that it could be demolished at a future date (a D A condition required by Council). It was essential to select façade materials that provided a high transmission loss in addition to minimising the wall/floor/ceiling thicknesses such that the usable space inside the studio was maximised. The final interior dimensions were as follows:

Length = 5.76m

Width = 2.48m

Height = 2.46m

Table 2 presents these dimensions in a form that compares the Height:Width:Length ratio with those recommended by various researchers in Cox [2]. It is apparent that the site constraints give a sub-optimal space which invariably results in poor room modal separation. **Figure 3** presents a comparison of the Studio Length/Width ratio assuming a height of unity for all ratios. These ratios may be visualised in **Figure 4** and it is clear that the Drum Studio is too narrow for the given length and height.

Table 2: Recommended Room Dimensions From Various Researchers

Researcher	Height	Width	Length	Legend[1]
Bolt	1.0	1.25	1.60	Blue ·–·–·–·
Louden	1.0	1.40	1.90	Green ······
BSI/IEC - Old	1.0	1.50	1.59	Brown - - - -
BSI/IEC - New	1.0	1.96	2.59	Purple ··–··–··–
Drum Studio	1.0	1.01	2.34	Red ------

[1]Colour referred to **Figure 4** room ratios

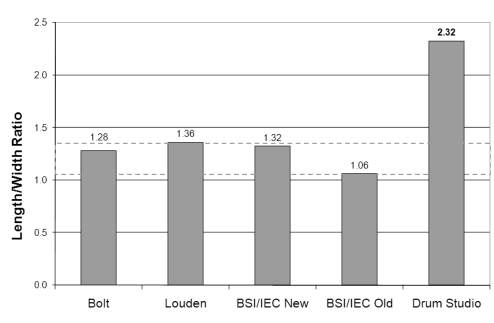

Figure 3. Comparison of Recommended Room Length:Width Ratios With Drum Studio

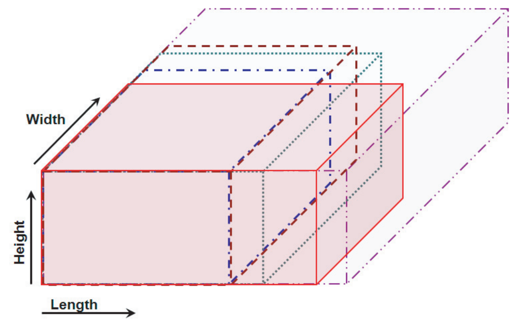

Figure 4. Comparison of Room Aspect Ratios By Various Researchers

The "ideal" room dimensions recommended by various researchers have been found to give good modal separation and a balanced modal density throughout the hearing range for critical listening environments. Deviation from these room ratios can give an uneven frequency response and extended sound decays or "booming" at low frequencies where several modes are very closely spaced. The potential for "booming" was examined by calculating the room modes for the Studio (**Figure 5**). To examine the Studio modal frequency response, an arbitrary source strength of 100dB was assigned to each axial mode. As tangential and oblique modes have correspondingly lower energy levels that are ½ (i.e. -3dB) and ¼ (i.e. -6dB) that of an axial mode, these modes were assigned 97dB and 94dB respectively. A plot of the 1/3 octave energy for the room was calculated based on the number of modes of each type in each 1/3 octave band. The results of this calculation are presented in **Figure 6** and the following trends are noted:

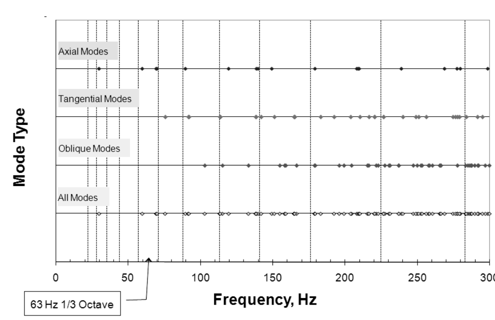

Figure 5. Calculated Drum Studio Room Modes

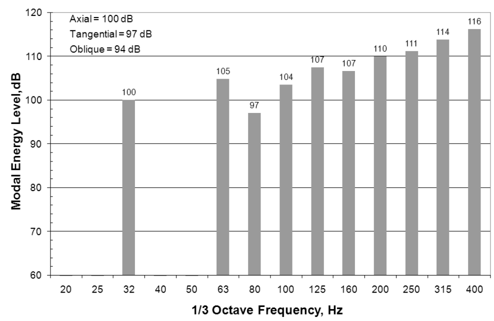

Figure 6. Modal Energy Distribution of the Studio Space

- There is a large "notch" in the modal distribution between the 31.5 Hz and 63 Hz 1/3 octave bands.
- The presence of two axial modes in the 63 Hz 1/3 octave results in a large energy peak with an 8 dB drop to the upper band (80 Hz) which contains a single oblique mode and an absence of any modes in the lower 2 bands (40 & 50 Hz). This result indicates that there is potential for "booming" in the 63 Hz frequency region should the drum spectrum have significant energy in this frequency regime.
- Above 80 Hz the 1/3 octave band energy levels approach the theoretical optimum and as expected exhibit less fluctuation as the modal density increases.

DESIGN PRINCIPLES FOR STUDIO

The original concept involved the use of a 180mm thick block work external garage façade (171 kg/m^2) with an independent, vibration isolated inner studio gyprock partition system. A high surface mass block work wall with concrete cavity infill was a logical choice to maximise low frequency performance using common building materials. This approach was abandoned following concerns raised by the Structural Engineer over the poor bearing capacity of the existing concrete slab and the mass loading imposed by the concrete block work wall.

A revised wall system was developed utilising a double skin outer wall comprising Hebel lightweight Powerpanels (50 kg/m^2) and a gyprock inner wall mounted to timber studs.

The loss of the mass block work wall placed an increased emphasis on maximising transmission loss of all remaining façade elements and to control reverberant build-up within the space.

The principal noise control features of the building are summarised below with an engineering sketch illustrating the general layout presented in **Figure 7** and details of various material elements presented in **Figure 8**:

- Vibration Isolated Inner Studio
- Wall/Ceiling Cavity Absorption

- Constrained Layer Damping
- Triple Glazing
- Pair of Communicating Doors
- Silenced Ventilation Air Supply
- Low Frequency Absorption "Tube Traps"
- Sound Acoustics RK1 Room Absorption Kit
- Gap Filling and Caulking

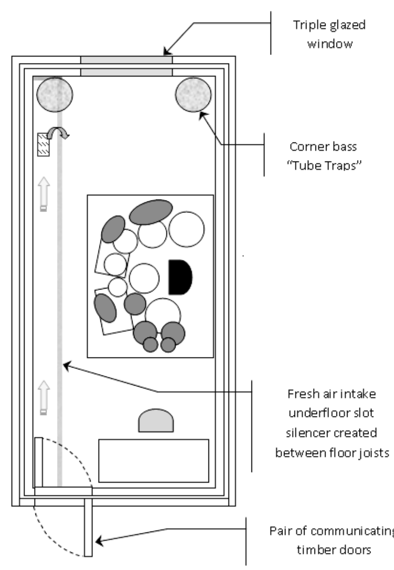

Figure 7. Layout Sketch of Drum Studio

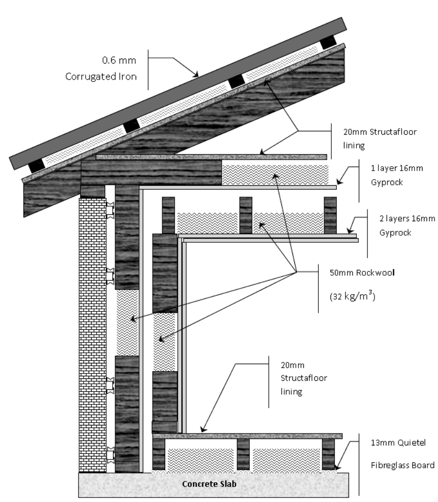

Figure 8. Schematic of Studio Construction Details

VIBRATION ISOLATED INNER STUDIO

The inner Studio structure was isolated from the concrete slab using 13mm thick Bradford Quietel™ high density (130 kg/m^3) compressed fibreglass. 100mm wide strips of material were placed under all floor bearers, with a small amount of adhesive used to fix these batts to the concrete to prevent movement of the batts over time. A 20mm thick Structafloor timber sheet was fixed to the bearers to create a platform to construct the inner walls and ceiling. A 20mm gap was maintained between the wall studs and roof bearers to the outer garage structure, such that no direct structure borne noise path existed between inner and outer structures.

WALL/CEILING CAVITY ABSORPTION

Research work in Narang [3] has shown the benefit of cavity absorption diminishes when the density of the infill material exceeds 16 to 20 kg/m^3. This is particularly the case when there is direct fixing between studs and both inner and outer panels. As several of the wall/ceiling components for the Studio were isolated and there was a need to maximise low frequency transmission loss, it was decided to utilise a heavier grade (32 kg/m^3) of insulation as a standard cavity infill.

CONSTRAINED LAYER DAMPING

An internet search revealed a constrained layer damping (CLD) treatment specifically developed for domestic and commercial building elements called GreenGlue™. The recommended coverage is between 1 to 3 tubes per 1.2m x 2.4m sheet of gyprock. In small quantities, at $50 per 860 ml tube, this equates to $17 to $52/$m^2$ which is an expensive "add-on" cost for a domestic project. The published test results in [4] for sandwich gyprock panels were impressive, with a nominal 8 to 18 dB improvement in wall TL between 250 Hz to 5kHz. A modest experiment was attempted with 4 tubes being applied to the 2x16mm gyprock inner Studio walls on the most critical N and W sides of the building. This coverage yielded a frugal 0.18 mm Green Glue™ thickness compared to the recommended 0.6 to 0.9 mm thickness. Site restrictions precluded a meaningful TL test to be performed, so an impact impedance test was undertaken using a PCB Model 086D50 hammer with firm plastic head to determine if the CLD material provided any measurable benefit. **Figure 9** presents the measured transfer Accelerance between two mid-height points (2.7m apart on the W and E walls) with and without the Green Glue™. Despite the very thin layer of damping material used, some benefit has been realised with 5 to 12 dB Accelerance reduction achieved above 500 Hz. This CLD product would appear to live up to the claims by the manufacturer and represent a very effective means of increasing partition TL across a wide frequency band.

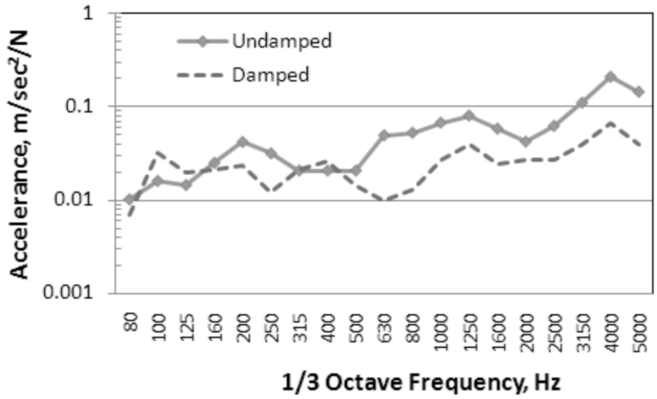

Figure 9. Measured Transfer Accelerance of Inner Studio Wall With and Without Green Glue™ CLD

TRIPLE GLAZING

To ensure that the window contained in the southern wall was matched in TL performance to both the wall and roof structures, a triple glazed window was utilised comprising 12.4mm/205mm air/6.8mm/65mm air/12.4mm. The 6.8mm/65mm air/12.4mm double glazed unit was mounted to the inner Studio wall with a 10mm mastic filled gap used on the window transom to ensure complete vibration isolation from the Hebel/gyprock outer wall.

PAIR OF COMMUNICATING DOORS

Access to the Studio was via a pair of communicating doors comprising 35mm thick solid core timber doors mounted in timber frames that were fitted to the northern end walls. The two end walls were independent stud walls with 2 x16mm gyprock outer panels. A 6mm gap between the two door frames was mastic filled to ensure vibration isolation was maintained and a set of Raven RP47 acoustic seals were installed on the outer door perimeter. The initial design intent was to include 50mm of absorption material on one of the inner door surfaces, however, the performance of the two doors plus Raven seals was such that the noise path into the garage and then to the outside was sufficiently matched to the wall/roof TL, that this was deemed unnecessary.

SILENCED VENTILATION AIR SUPPLY

Whilst a split system air conditioner was provided for temperature control inside the Studio, it was necessary to include a fresh air make-up supply. This was provided using a heavy duty domestic exhaust fan with ceiling and under-floor silenced duct slots. A 5.2m long, 13mm thick fibreglass (Quietel) lined slot provided effective underfloor attenuation of studio noise within the supply duct (see **Figure 7**) and a similar 4.4m long "switch back" duct lined with 50 mm Rockwool (32kg/m^3) in the ceiling space (see **Figure 10**), provided excellent attenuation of the exhaust air.

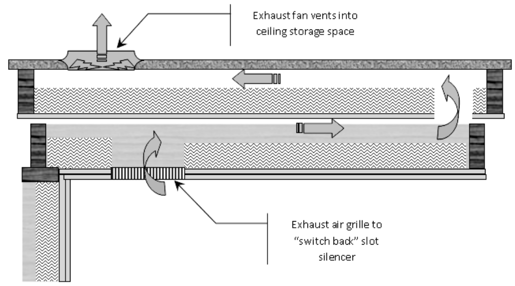

Figure 10. Schematic of "Switchback" Lined Slot Discharge Air Silencer

LOW FREQUENCY ABSORPTION "TUBE TRAPS"

To control possible "booming" from widely spaced low frequency resonant modes of the space, it was considered necessary to provide bass traps to be located in the corners of the room for maximum efficiency and to minimise encroachment on the limited width available for the room. There are several proprietary bass traps available from a range of vendors, however, budgetary constraints demanded construction of several customised cylindrical bass traps or "Tube Traps". Corner bass traps are particularly effective for suppression of tangential and oblique room modes, where two or three adjacent walls participate in the modes, respectively. A deep layer of absorption located near the room corners (with an air gap) can generate near anechoic conditions with consequent high apparent absorption coefficients being recorded. The Tube Traps utilised for the Drum Studio comprised the following:

- 500mm diameter x 1.2m high
- 20mm thick chipboard top and bottom end plates and central diaphragm
- 50mm x 20mm timber longitudinal stringers
- 3mm perforated plywood to ½ the circumference (19% open area)
- Infill of 32kg/m^3 Bradford Rockwool
- 25mm x 25mm bird wire to rear ½ of circumference
- 6mm open cell foam front padding
- Lightweight fabric front face liner
- Four of these Tube Traps were constructed as shown in **Figure 11**.

Figure 11. Construction Details of Tube Traps; Plywood Frame (upper left); With Rockwool Infill (upper right); Corner Installation in Studio (bottom)

The measured reverberation times before and after the insertion of four off Tube Traps were used to establish the absorption coefficient using the standard Sabine Absorption Coefficient formula (Equation 1),

$$RT_{60} = 0.161.\frac{V}{S\alpha} \qquad (1)$$

The absorption coefficient for the bare Studio and the four Tube Traps are presented in **Figure 12**.

- The bare room absorption coefficient is essentially constant at $\alpha = 0.05$ for all frequencies >100Hz, which is typical for acoustically "hard" surfaces such as, plaster rendered masonry walls. The measured absorption is lower than expected for residential plasterboard on stud framing systems, where membrane absorption mechanisms generally provide useful reductions of low frequency sound (<125Hz).

  For comparative purposes, test data for 9.5mm thick plasterboard mounted to 120mm timber framing with cavity absorption [5] is also presented in Figure 12. Enhanced low frequency absorption is observed with $\alpha = 0.23$ at 125Hz and if data were available for 63Hz even higher coefficients could be expected, as the mass-air resonance for this configuration will occur in the vicinity of 70 to 80Hz.

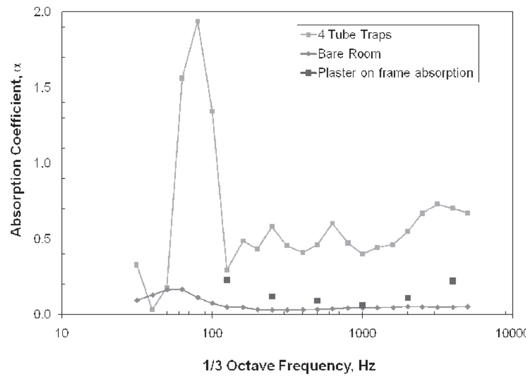

Figure 12. Measured Sabine Absorption Coefficient of Bare Studio and with 4 off Tube Traps

- To explore the reasons for the low membrane absorption of the studio walls, a driving point accelerance measurement mid-span between two studs (see **Figure 13**) shows minimal response at the calculated resonance frequency of 38Hz for the 2 x 16mm gyprock panel. The low response is due to the high bending stiffness that is created from the thick double layer of gyprock and the short (500mm) stud spacing. This combination will have a bending stiffness that is at least 10 times higher than that associated with single leaf domestic gyprock that is 10mm to 13mm thick. Interestingly the fundamental global wall panel modes in the 12 to 15Hz region exhibit strong resonant response and hence would likely provide reasonable membrane absorption, however, there is minimal drum noise at these low frequencies which are below the accepted audible range for humans.

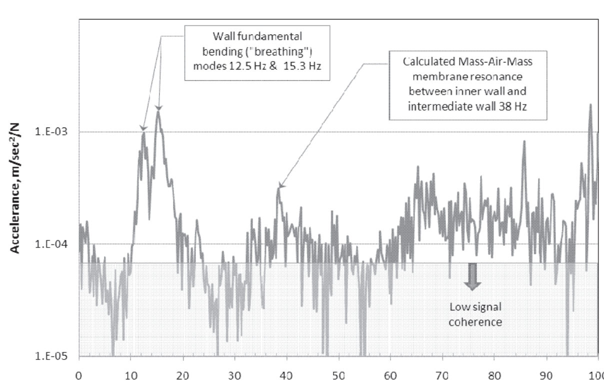

Figure 13. Measured Driving Point Accelerance of Studio Wall (mid height, between studs)

- The Tube Traps exhibited an absorption coefficient of between 1.3 and 1.95 over a narrow frequency range covering three 1/3 octave bands between 63Hz and 100Hz. This abnormally high absorption performance of > 1.0 was due to a combination of the small frontal surface area of the cylindrical Tube Traps (½ circumference x height assumed) and the high efficiency that corner absorption provides for the widely spaced modes (1 to 3 modes per 1/3 octave band). This result is entirely consistent with published data for low/mid frequency flat panel corner traps available from Fonic Acoustics [6].

SOUND ACOUSTICS RK1 ROOM ABSORPTION KIT

Mid and high frequency absorption was provided using a Sound Acoustics RK1 room kit [7]. This kit comprised 12 off SA600/75 Broadband Absorbers which are 600mm square x 75mm thick flat panels of acoustic foam and 4 off BT600/270 Pressure Zone Absorbers being 600mm long x 270mm leg length wedge shaped acoustic foam "Corner Traps" (see **Figure 14**).

Figure 14. Photo of Sound Acoustics RK1 Acoustic Foam for Mid & High Frequency Absorption

GAP FILLING AND CAULKING

One aspect of acoustic detailing that should not be underestimated when embarking on a high performance residential noise control project is the importance of eliminating air gaps in all joints of all façade elements. Few builders and tradesman appreciate the massive reduction in TL performance that can occur through minor air gaps of ≤1% of surface area. During this Studio project approximately 65 tubes of gap filler and mastic caulking compound were used by the author "after hours" to fill gaps of 1 to 5mm in timber and gyprock panels. Critical areas which need to be closely supervised include:

- Top and bottom plate junctions for all walls
- Ceiling and roof-to-wall junctions

- Gaps between walls and door & window frames
- Electrical cable penetrations for lights and power points

Daily inspections were essential to ensure that unintended gaps and structure borne sound bridging were detected and rectified before being hidden by subsequent construction activities.

Other acoustic design features that needed to be closely supervised included;

- All aspects of vibration isolation to ensure structure borne sound bridges were avoided
- Door seals
- Penetrations for fresh air supply and discharge

STUDIO TRANSMISSON LOSS PERFORMANCE

The façade sound transmission loss performance was determined using vigorous drum and cymbal practice as a sound source (see **Figure 15**), with all sound absorption material removed from the room. Simultaneous external noise measurements close to the façade surface elements were used to establish noise reduction to a free field and from this the Transmission Loss (TL) was derived using the Equation (2) as found in [8]:

$$TL = SPL_{inside} - SPL_{outside} - 6 \qquad (2)$$

A plot of the transmission loss performance of the studio side wall, roof and triple glazed window are presented in **Figure 16**. Test results indicate the following:

- The sound spectrum created by a combination of drums and cymbals produces an essentially flat A-weighted spectrum inside the Studio with a reverberant overall level of 103dBA.
- Noise reduction performance is well matched throughout the spectrum, but particularly in the critical 50Hz to 500Hz frequency regime.
- The eastern wall TL has a consistently higher performance compared to the window and roof and this is undoubtedly linked to the higher surface mass associated with the Hebel concrete panels and isolated gyprock panelling (88kg/m^2) compared to the mass of the roof (83kg/m^2) and glazing (79kg/m^2).
- Interestingly, a higher wall TL would be expected if the block wall outer façade construction had been utilised, which has almost twice the surface mass (i.e. 171kg/m^2) of the Hebel + 16mm gyprock stud system. The full potential of such a heavier construction would, however, not likely be fully recognised due to the limitations of the current roof structure selected for this application.
- The roof construction is clearly the limiting façade element with notable “dips” in TL performance in the 40Hz, 125Hz and 200Hz 1/3 octave bands. Based on test data of various corrugated roof sheeting reported in [9] the relatively low performance at these frequencies is believed to be due to the orthotropic properties of the roof sheeting when screwed to 20mm battens mounted to the 20mm Structafloor roof lining.

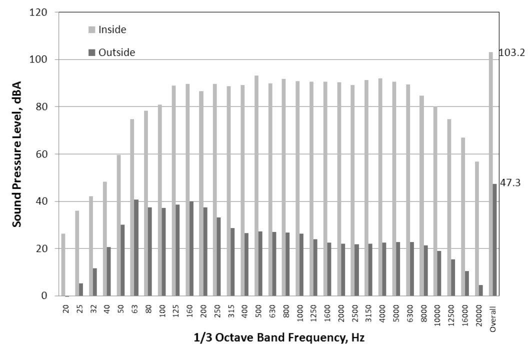

Figure 15. Typical A-Weighted Spectrum of Studio Internal Drumming Noise and Exterior Noise at 3.0m from Wall

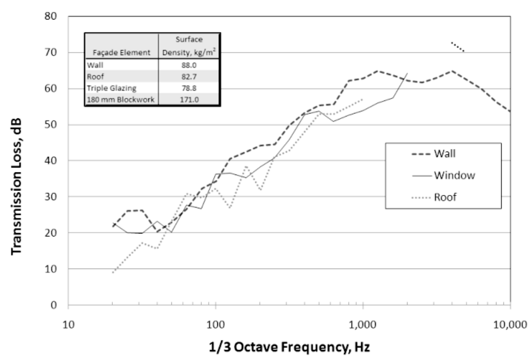

Figure 16. Measured Transmission Loss of Studio Façade Elements

STUDIO REVERBERATION TIME PERFORMANCE

The Reverberation Time for recording and control studios recommended by Walker [10] of the British Broadcasting Corporation (BBC) were used as the design target for the Studio interior. These BBC design criteria aim to produce an acoustic environment without coloration from low frequencies whilst not providing an acoustically "dead" space. An upper and lower tolerance band is specified around the average RT (T_m) between 200Hz and 3.15kHz. The BBC specification recommends an average RT for control rooms in the range 0.2 to 0.3 seconds. Reverberation Times (RT) were recorded using a Bruel & Kjaer Pulse analyser which has a standard analysis set-up for impulse testing and uses the reverse integration method of the room impulse response for each 1/3 octave band. The average RT of 3 samples for each absorption configuration has been used. The impulse source was an inflated balloon burst. This sound source provides acceptable sound energy levels for mid to high frequencies (100 to 5kHz), but lacks significant acoustic power at low frequencies <100Hz. Despite the low energy levels associated with these balloon burst tests, significant reductions in RT (≈50%)

were achieved in the 63Hz to 125Hz 1/3 octave bands to provide a confident estimate of absorption performance in this low frequency regime.

It is important to recognise that for small rooms such as rehearsal studios, there are limitations in the application of standard reverberation time tests using Sabine and Eyring theory. These theories rely on a high modal density in a given band such that individual modes are indistinguishable (due to overlap) and the noise levels in the room can be treated statistically. Under these conditions the room geometry or spatial distribution of absorption material does not affect the reverberant noise level distribution in the space. The frequency which determines the cross over from the high frequency (statistical) to low frequency (individual mode) behaviour is the Schroeder Frequency (f_s) as defined in [11];

$$f_s = 2100\sqrt{\frac{RT_{60}}{V}} \tag{3}$$

The various absorption treatments were introduced in a staged manner to quantify the incremental reduction in RT achieved. This approach enabled the Studio to be "tuned" progressively such that the target RTs were achieved within the desired range without creating "dead" frequency bands. The results of RT tests are presented in **Figure 17** with each stage of absorption described below;

Bare - All walls and floor were bare of treatments (i.e. acoustically "hard")

4 TTs - Installation of 4 Bass Tube Traps installed in the S end of the room (i.e. stacked 2 high in a column at each corner)

Car - 1.4m x 2.0m x 30mm thick carpet (rug) located on the floor centrally in the room

D - Mobile diffuser 1.2m high x 1.0m wide x 120mm thick located 1.0m from the N end of the room

4CT - Four Sound Acoustics BT270/600C Corner Traps located at the wall ceiling junction opposite the drum kit (E wall)

4A or 12A - Four or twelve 600mm x 600mm x 75mm thick Sound Acoustics SA600/75C acoustic foam panels attached to the E wall

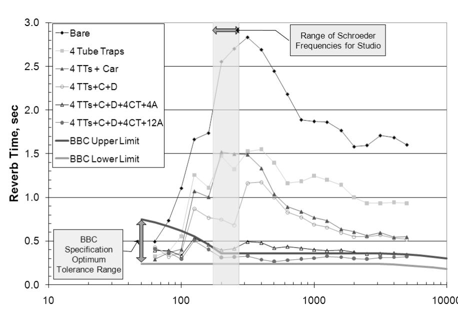

Figure 17. Measured Reverberation Times During Successive Installation of Absorption Treatments

- The Schroeder frequency (f_s) lies between 174 to 272Hz for the range of studio RTs, indicating that absorption derived from RT measurements is no longer accurate below this frequency regime. This is borne out by the very high apparent Sabine absorption coefficient recorded for the Tube Traps (Figure 12), which effectively eliminate the first tangential mode of the space (1,1,0). As indicated in Figure 5, only this single mode f1,1,0 = 76Hz lies within the 80Hz 1/3 octave, so the Tube Traps located in the corners are highly efficient at suppressing this mode shape (see Figure 18) resulting in a statistical absorption coefficient significantly > 1.0.
- The 4 Tube Traps provide excellent low frequency absorption performance (63Hz to 125Hz) and reasonable absorption at mid to high frequencies with $\alpha = 0.5$ to 0.7 for frequencies 160Hz to 5kHz.
- The 30mm thick woollen rug provides useful absorption of frequencies ≥400Hz.
- The mobile Diffuser panel comprising 19% open area plywood facia with 100mm thick 32kg/m^3 density Rockwool infill with an open back provides excellent "tuned" absorption performance in the mid-frequency regime between 125Hz and 400Hz.
- The Sound Acoustics Corner Traps and 75mm thick acoustic foam panels provide further absorption over a wide frequency band between 125Hz to 5kHz.
- Figure 17 illustrates that with all of the absorption treatments installed; the average RT lies on the upper limit recommended by the BBC for control rooms (Tm = 0.3 seconds). RT is reduced over a wide frequency band to be compliant with the British Broadcasting Corporation recommended levels for sound recording studios.

Several recordings of both drums and guitars have been made for CD album compilations with reported excellent results and the absence of "booming" and flutter echoes and a well balanced spectral response.

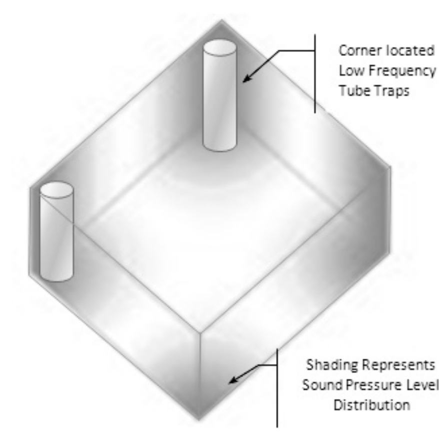

Figure 18. Sound Pressure Level Distribution of f 1,1,0 Tangential Room Mode and Optimal Location of Tube Traps

STUDIO BOUNDARY NOISE LEVELS DURING DRUMMING PRACTICE

Noise levels were recorded during a staged test with all room absorption treatments in place and vigorous drumming using an 8-piece drum kit and cymbals. Tests were conducted late at night with low background noise levels (L_{A90} = 34.5dBA) to provide maximum signal-to-noise ratio.

Typical noise levels at 3.0 metres from the wall of the Studio during the "on-time" for vigorous drumming were L_{A10} = 47.5dBA.

This level exceeds the design target of L_{A10} = 45dBA by 2.5dB but is considered an excellent result given the necessity to use a lightweight partition system for the outer façade of the garage in lieu of the original design intent for a 180mm thick concrete block wall structure. A reduction of drumming noise levels from an L_{A10} = 64dBA at the front boundary to nominally 47.5dBA at the elevated deck at the rear of the neighbour's property has realised 16.5dBA attenuation. Given the daytime L_{A10} from background traffic typically lies in the range 50 to 60dBA at neighbouring properties, the measured L_{A10} level from normal drumming practice will only be audible during low levels of traffic activity.

Another major benefit from the construction of the detached Drum Studio is the substantial reduction inside the family residence. Living room noise levels during drum practice are now barely audible with typical L_{A10} noise levels $\leq$40dBA.

CONCLUSIONS

A high performance private Drum Studio has been successfully designed to meet stringent neighbourhood noise criteria using a combination of noise control treatments to maximise the transmission loss of a lightweight partition structure. A well matched roof, wall and window construction has achieved better than mass law behaviour with 8dB/octave transmission loss between 50Hz and 1.6kHz. Noise emission levels at the nearest neighbour have been reduced by at least 16dBA to improve the amenity of the area. In order to achieve this high TL performance, extreme vigilance was required during the construction phase to ensure that leakage and structure borne noise bridging paths were eliminated. This can only be achieved with detailed daily inspection of completed work and frequent communication with tradespeople to ensure the acoustic detailing issues are closely followed.

An excellent sound recording space has been created through the use of low frequency bass corner traps, sound diffusers and floor and wall absorption treatments. **Figure 19** presents a photograph of the interior of the Studio that identifies the principal sound absorbing components that have successfully achieved an acoustically balanced space. Distribution of these absorption treatments has been crafted to control the low frequency, widely spaced modes of the room and thereby circumvent "booming" and colouration of the sound spectrum within the space. Reverberation times have been achieved that fall in the middle of the design target range recommended by the British Broadcasting Corporation for small studios.

Figure 19. Photograph of Drum Studio Interior Demonstrating Key Absorption Treatments

REFERENCES

[1] NSW Department of Environment and Climate Change, February 2006, *Dealing With Neighbourhood Noise*

[2] Cox T. J., D'Antonio J., 2000, *Determining Optimum Room Dimensions for Critical Listening Environments: A New Methodology*, Proc 110th Convention AES. Paper 5353

[3] Narang P., 1993, Effect of Fibreglass Density and Flow Resistance on Sound Transmission Loss of Cavity Plasterboard Walls, Journal of Noise Control Engineering, Vol 40/No 3

[4] Test data for GreenGlue™ constrained layer damping: www.ultrafonic.com.au/Green%20Glue%20Transmission%20Loss%20Tests.htm

[5] Test data for plasterboard absorption: www.acoustics-engineering.com/sabin/absdatabases.htm

[6] Test data for bass corner traps: www.fonic.com/realbasstraps.htm

[7] http://www.soundacoustics.com.au/roomkits.htm

[8] Australian Standard AS 2253—1979 Methods for Field Measurement of the Reduction of Airborne Sound Transmission in Buildings

[9] Hansen C. H., March-April 1993, Sound Transmission Loss of Corrugated Panels, Journal of Noise Control Engineering, Vol 40/No 2

[10] Walker R, 2002, Acoustic Criteria and Specification, British Broadcasting Corporation R& D White Paper WHP 021

[11] Lam Y., 1995, *Acoustics of Enclosed Spaces*, The University of Salford, Lecture Notes AEOF3/AEOF4