Noise Reduction through Facades with Open Windows

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ABSTRACT

The topic of noise attenuation through a façade with an open window has received little attention, especially within Australia. The objective of this study was to obtain field measured noise reduction data for facades with open windows at Queensland style residences, specifically those with timber, brick veneer and double brick facade constructions. This investigation targeted the L_{eq} and L_{max} noise descriptors, using road traffic noise and car door slams as the noise sources. To investigate this topic, a simultaneous multiple microphone method was developed using adapted testing procedures outlined in both AS 2702 "Acoustics – Methods for the measurement of road traffic noise" and ISO 140-5 "Acoustics – Measurement of sound insulation in buildings and of building elements".This study has obtained noise reduction results which can be compared to the 5 dB(A) open window attenuation correction presented by the Queensland Government's "Planning for Noise Control Guideline" (PNCG) and the Brisbane City Councils "Noise Impact Assessment Planning Scheme Policy" (NIAPSP). The results of this investigation were also compared with internal noise prediction methods currently available to be used by acoustic consultants.

INTRODUCTION

As population levels increase within Queensland and specifically within the South East Queensland (SEQ) region, so too will the demand increase for residential dwellings and infrastructure to service this growing population. As a result of this trend, new residential dwellings will be developed in close proximity to noise sources whilst established dwellings will have new noise sources forced upon them (Waters-Fuller and Lurcock, 2007). As noise is both a serious environmental and public health issue, the effectiveness of dwellings and in particular exposed facades in attenuating noise is an important issue (BCC, 2001). Furthermore, due to the warm climate of Queensland and the financial costs of installing and operating mechanical ventilation, the windows of residences are commonly left open to supply natural ventilation, decreasing the noise attenuation properties of the exposed residential facade (De Salis *et al*, 2002).

Despite its real world relevance, the reduction of noise through a façade with an open window is an issue which has previously received little attention in published literature within Queensland and Australia. To the author's knowledge no Australian or international standard exists which focuses on measuring or analyzing the noise reduction achieved by a facade with an open window. Within Australia, published works exist by Carter *et al* (1992) and Lawrence and Burgess (1982-83) however these investigations possessed different objectives to this study, with the Carter *et al* (1992) focusing on sleep disturbance and Lawrence and Burgess's (1982-83) numerous works investigating a single purpose built two room construction focusing on the L_{10} noise descriptor.

Despite the lack of published literature, government publications within Queensland namely the State Government's "Planning for Noise Control Guideline" (PNCG) and Brisbane City Councils "Noise Impact Assessment Planning Scheme Policy" (NIAPSP) present allowable corrections for noise reduction through open windows. The correction advised by both these regulations is a noise reduction of 5 dB(A) for open windows, whilst the state guideline also allows a 10 dB(A) reduction for partially open windows. However, it must be noted that these allowed corrections for noise attenuation are not limited to specific noise types or sources and are therefore able to be applied to any incident noise source affecting residential dwellings, ranging from steady state mechanical plant noise through to impulsive industrial noise sources (e.g. hammering).

The absence of previously published research in an area which is of considerable value to practical acoustics and to residents of dwellings affected by noise, was the main reason for the undertaking of this investigation. Furthermore, this study also presents an opportunity to compare field measured data with current internal noise prediction methods, as presented in AS 3671 (1989) and EN 12354.3 (2000).

METHODOLOGY

Due to the uncommon nature of this investigation, no Australian standard exists that dictates a complete method to measure or analyse the transmission loss achieved by facades with open windows. For this reason, a testing methodology was created using aspects of both Australian Standard AS 2702 (1984) "Acoustics – Methods for the measurement of road traffic noise" and International Standard ISO 140-5 (1998) "Acoustics – Measurement of sound insulation in buildings and of building elements". The inclusion of both these standards was deliberate to ensure that the data could be considered rigorously obtained.

Field Monitoring

The noise monitoring methodology created for this investigation was tailored to suit the capabilities of the Sinus Soundbook, an advanced multi-channel acoustic measuring system which has the capacity to simultaneously monitor noise levels using 4 channels (microphones). The main measurement descriptors of concern for the noise monitoring were the L_{eq}, the average A-weighted sound level and the L_{max}, the maximum A-weighted noise level. All noise monitoring tests were undertaken with windows open and closed to ensure that the internal noise level measured with an open window was 10 dB greater than the background internal noise level with closed windows, ensuring that the noise reduction measured did not require correction as per ISO 140-5 (1998).

In regards to the location of the testing microphones, at least three microphone positions were used in monitoring at all residences. In the event that the lot boundary and height above ground of the receiving room allowed for an equivalent “free field” position, a total of four microphones monitored the noise levels. The external and internal locations and set-up of these microphones are illustrated in Figure 1.

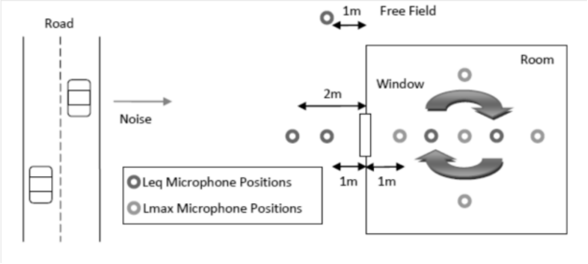

Figure 1: Site Locations for Monitoring Microphones

External microphones for monitoring were located at distances 1m ± 0.1m from the facade (AS 2702, 1984) and 2m ± 0.2m from the facade (ISO 140-5, 1998) in line with the centre of the window. A free field position, being a location greater than 3.5m from a reflective surface (excluding the ground) and at least 5m from the source of the noise, was also implemented at four residences where the site conditions allowed (AS 2702, 1984). This free field microphone was placed in line with the 1.0m position and monitored the incident noise levels without measuring noise reflected from the building façade or other reflective surface. This microphone position was employed to test the façade reflection component of the 1.0m microphone position, with typically a correction of +2.5 dB(A) for a microphone 1.0m outside a complete façade employed (AS 2702, 1984. CoRTN, 1998). In regards to height, both the 1.0m and 2.0m microphones were set up at the same height as the internal microphone, 1.5m from the height of the floor of the receiving room. Due to equipment restrictions the free-field microphone could only be set at 1.5m from the level of the ground and was therefore only able to be used at one-storey residences where the free field microphone could be positioned at the same height as the external positions.

Inside the receiving room, a microphone measured the receiving noise levels in a variety of positions depending on the noise descriptor of concern. For L_{eq} parameter readings, the microphone was moved around the room, not staying in any location longer than another. This microphone was moved at an average height of 1.5m, therefore obtaining the room averaged noise level (ISO140-5, 1998). Additional L_{eq} parameter testing was also undertaken with a stationary microphone located 1m inside the centre of the window at a height of 1.5m. This location was an additional test to investigate the noise level difference from 1m outside to 1m inside the window; however the results of this additional testing were not investigated in depth. Alternatively, for the L_{max} parameter readings, the microphone was placed at 4 or 5 different locations within the receiving room at a height of 1.5m (ISO 140-5, 1998). Although ISO 140-5 (1998) states that 5 positions should be used, the size and position restrictions meant that for two residences, only 4 positions were used.

The data obtained from field monitoring was in one-third octave band frequencies in the range of 20 Hz - 20 kHz. However, not all data from the entire 20 Hz - 20 kHz frequency spectrum was included in analysis due to the dominant noise source for the L_{eq} measurements being road traffic. Due to this noise source, the frequency range of interest was reduced to between 63 Hz - 10 kHz whilst the L_{max} results were presented across a frequency range of 50 Hz – 5 kHz.

Reverberation Testing & Internal Room Analysis

In addition to the field noise monitoring, to allow for comparison between residences, internal reverberation time testing and the measurement of room dimensions was undertaken at all subject receiving rooms. The measurement of reverberation time was undertaken using the Sinus Soundbook’s interrupted signal setting using white noise played through a powered portable speaker following the method presented in ISO 140-5 (1998). For each receiving room a total of 12 tests were undertaken for both open and closed window situations. These 12 tests were comprised of 3 noise decay measurements for each of the 4 noise source positions spread evenly throughout the test room. Each noise decay measurement was carried out by playing the white noise at a sound level of approximately 80 dB(A), then stopping the white noise, allowing the Soundbook to measure the noise decay for that particular source and receiver position. The reverberation time (T) is the time it takes for the sound level to decay by 60 dB calculated as an extrapolation of the decay over 20 dB, due to its ease of measurement and compliance with the recommendations of AS/NZS 2460 (2002) “Acoustics – Measurement of the reverberation time in rooms”. Attenuation performance testing of the facade with speaker generated noise was not undertaken due to interests regarding the disturbance of neighbourhood amenity.

Noise Prediction Calculations

With regards to internal noise level prediction methods the primary method of interest was the EN 12354.3 (2000) “Airborne sound insulation against outdoor sound” formula, used in the Marshall Day Insul software program. This formula predicts internal noise levels from external noise levels and building element specifications. Although a separate acoustic standard, the EN 12354.3 (2000) method is almost identical to the formula which can be derived from the Required Traffic Noise Attenuation method presented in AS 3671 (1989). Though these formulas are structured differently, they both essentially utilise the same parameters including element area, reverberation time and volume. Comparitively, the EN 12354.3 (2000) formula is also slightly more comprehensive as it allows a correction for the position of the receiving facade relative to the noise source. The EN 12354.3 (2000) formula is presented as equation 1.

In addition to the predictions done using the EN 12354.3 (2000) method, internal noise level calculations were undertaken using a theory presented in Australian Standard AS 3671 (1989), regarding the total open space percentage of the exposed building elements. This prediction formula uses a logarithmic scale such that if openings total 1% of the facade, the facade will attenuate of 20 dB(A) whilst for a facade with a 0.1% opening, 30dB(A) of noise will be attenuated (AS 3671, 1989). The AS 3671 (1989) formula is presented as equation 2.

$$Lp_{in} = Lp_{out} - TL - F + 10LOG(A) \qquad (1)$$

$$- 10LOG(V) + 10LOG(T) + 14$$

Where: Lp_{in} is Internal Noise Level

Lp_{out} is External Noise Level

TL is Spectral Transmission Loss of Element

F is Façade Shape Level Difference

A is Element Area

V is Room Volume

T is Reverberation Time

Note: the +14 component is a combination of the +6 dB reverb – free field correction and the +8 resulting from -10log (0.161) from the rearranged Sabines formula.

$$NR = 10LOG(A/100) \qquad (2)$$

Where : NR is Noise Reduction dB(A)

A is Open Area % of Building Envelope

RESULTS

Noise Reduction Measurements

Prior to analysing the results obtained through noise monitoring it is necessary to acknowledge the differences between the monitored residences receiving rooms. Although it was the aim of this investigation to test similar types of rooms and determine a formula or expected reduction range, a shortage of available residences required the investigation of all residences despite variations. These variations with regards to room type, room dimensions and distance to the noise source are presented in Table 1 and Table 2.

Table 1. Facade and Room Types of Monitored Residences

Street Name	Facade	Room Type
Gloucester Street (A)	Timber	Living Room
Gladstone Street	Timber	Empty Room
Gloucester Street (B)	Timber	Games Room
Raymont Street	Timber	Bathroom
Moola Street	Timber/Concrete	Living Room
Edinburgh Drive	Brick Veneer	Living Room
Thirteenth Avenue	Brick Veneer	Bedroom
Lynelle Street	Brick Veneer	Bedroom
Central Street	Double Brick	Living Room
Kenmore Road	Double Brick	Nursery
Kessels Road	Double Brick	Living Room

Table 2. Residence Dimensions and Distance to Noise Source

	Open Window Area (m^2)	Exposed Façade Area (m^2)	Volume (m^3)	Window Height (base) (m)	Distance to Noise (m)
Gloucester A	1.6	4.1	60.0	2	8
Gladstone	1.5	12.2	45.2	3.4	60
Gloucester B	0.5	6.9	21.2	3.5	12
Raymont	0.9	6.1	22.0	4	12
Moola	1.5	7.1	66.0	0.5	13
Edinburgh	1.0	9.4	31.8	1	12
Thirteenth	0.2	15.0	39.00	1.5	12
Lynelle	0.7	9.1	33.7	1	12
Central	0.9	12.8	89.8	1	13
Kenmore	0.3	8.2	24.7	1.6	12
Kessels	0.7	13.8	65.6	1	12

From noise monitoring at these 11 residences, overall and frequency spectrum based noise reduction results were obtained for the L_{eq} descriptor. The overall noise level differences measured can be viewed in Table 3, whilst the noise reductions achieved across the spectrum by timber, brick veneer and double brick facades with an open window are presented in Figures 2, 3 and 4. The 1m position measurements only were used for analysis as it is the Australian Standard's recommendation and because the reductions calculated for both external microphone positions (1m and 2m outside the facade) were very similar.

Table 3. Overall L_{eq} Noise Reductions

Residence	Facade	Reduction Leq dB(A)
Gloucester A	Timber	8.0
Gladstone	Timber	5.4
Gloucester B	Timber	12.2
Raymont	Timber	7.5
Moola	Timer/Concrete	13.8
Edinburgh	Brick Veneer	6.1
Thirteenth	Brick Veneer	14.7
Lynelle	Brick Veneer	10.8
Central	Double Brick	14.7
Kenmore	Double Brick	12.3
Kessels	Double Brick	12.4

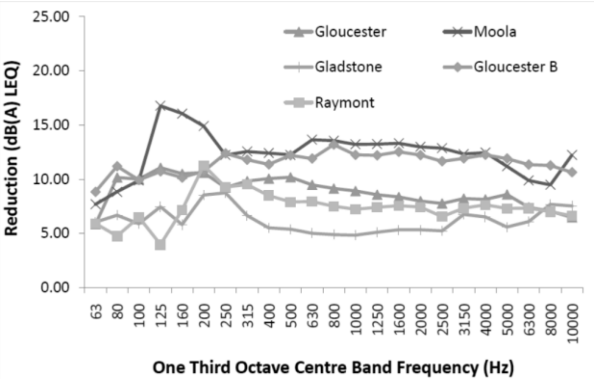

Figure 2. Frequency Spectrum Noise Reductions for Timber Facades

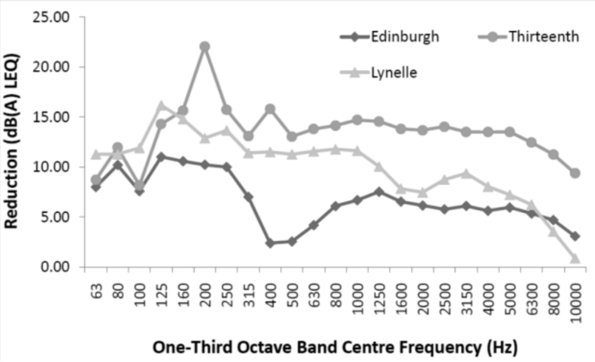

Figure 3. Frequency Spectrum Noise Reductions for Brick Veneer Facades

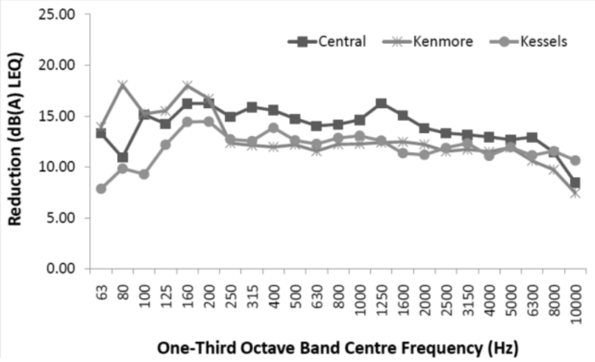

Figure 4 Frequency Spectrum Noise Reductions for Double Brick Facades

With regards to the L_{max} testing, frequency spectrum reduction results were obtained for the four residences subject to incident noise from repeated car door slams. Due to the nature of the noise source the results for this testing were not as defined as the L_{eq} results. The results of the L_{max} tests can be viewed in Figure 5.

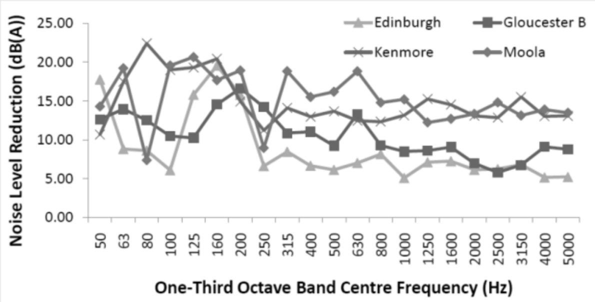

Figure 5. L_{Max} Noise Reductions

Noise Prediction Methods

Using the EN 12354.3 (2000) and AS 3671 (1989) formulas, internal noise levels were predicted for all houses monitored with the exception of the Moola residence for the EN 12354.3 (2000) method. This exception of the Moola residence was due to the mixed material composition of its external façade such that an accurate internal noise prediction was considered unlikely. A selection of the EN 12354.3 (2000) calculated internal noise levels and field measured noise levels for each of the timber, brick veneer and double brick residences can be viewed in Figures 6-11. Similar to the EN 12354.3 (2000) method, the AS 3671 (1989) method was also used to predict the noise reduction expected for each residence. These results can be analysed in Table 4, which also includes the reverberation time corrected noise reduction, calculated using the level difference standardisation method presented in ISO 140-5 (1998), using 0.35s as the reference time, calculated to compare the reductions achieved by residence corrected for internal reverberation variations.

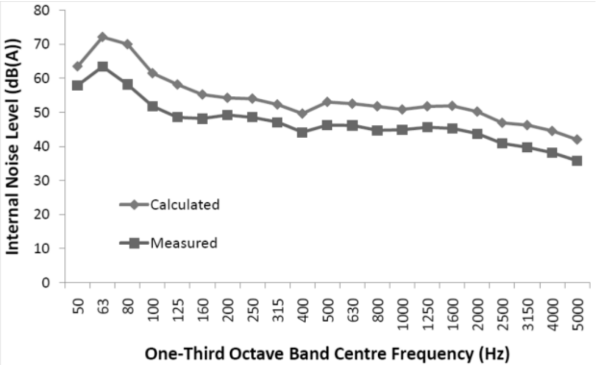

Figure 6. EN 12354.3 Calculated and Measured Internal Noise Levels for the Gloucester B (timber) Residence

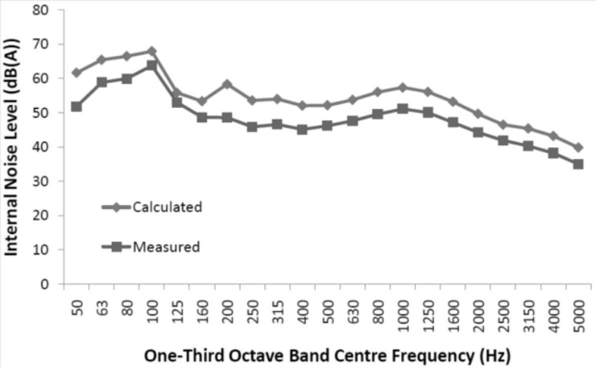

Figure 7. EN 12354.3 Calculated and Measured Internal Noise Levels for the Raymont (timber) Residence

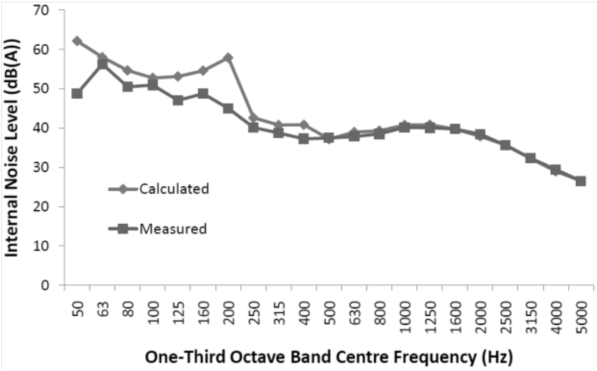

Figure 8. EN 12354.3 Calculated and Measured Internal Noise Levels for the Thirteenth (brick veneer) Residence

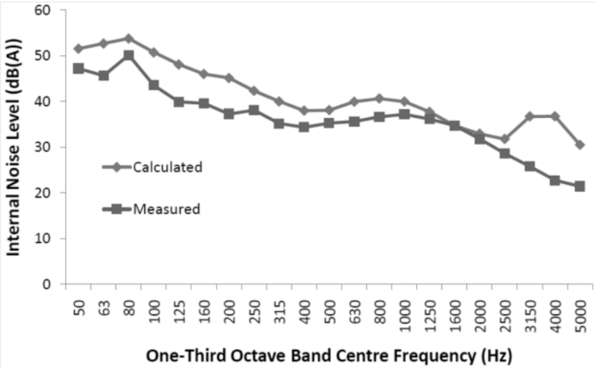

Figure 9. EN 12354.3 Calculated and Measured Internal Noise Levels for the Lynelle (brick veneer) Residence

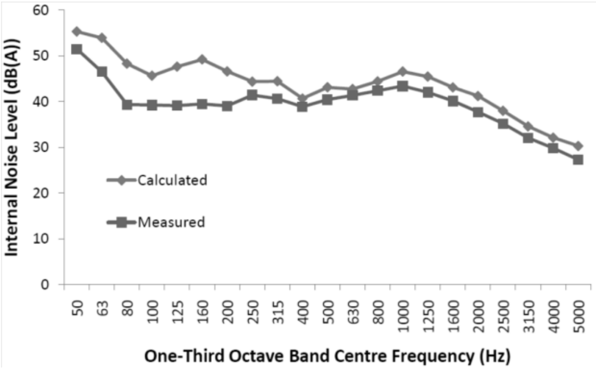

Figure 10. EN 12354.3 Calculated and Measured Internal Noise Levels for the Kenmore (double brick) Residence

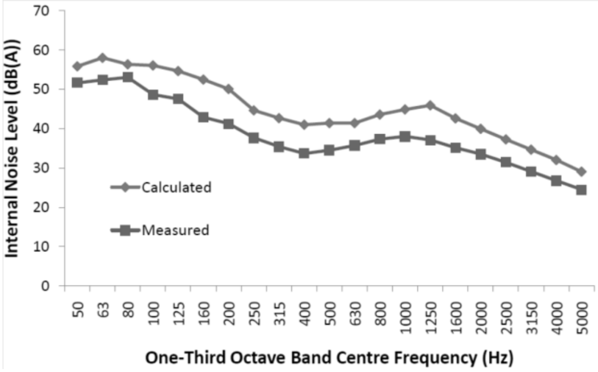

Figure 11. EN 12354.3 Calculated and Measured Internal Noise Levels for the Central (double brick) Residence

Table 4. Table of AS 3671 Predicted and Measured Noise Reductions

		Measured Noise Reduction (dB(A))	
Residence	**AS3671 Calculated**	**Field**	**T-Corrected**
Gloucester A	4.1	8.0	7.2
Gladstone	9.1	5.8	8.8
Gloucester B	11.1	12.2	10.4
Raymont	8.2	7.5	9.4
Moola	6.7	13.8	14.6
Edinburgh	9.7	6.1	5.8
Thirteenth	18.1	14.8	14.1
Lynelle	11.2	10.8	9.0
Central	11.5	14.8	16.6
Kenmore	14.0	12.3	12.0
Kessels	13.2	12.4	13.0

DISCUSSION

The main objective of this project was to measure the outdoor-to-indoor Leq noise level reductions for Queensland residences and define the expected reductions for timber, brick veneer and double brick facades with an open window. Due to the complex nature of the topic however and the limited timeframe available to obtain measurements, the results obtained are unable to fulfil this objective. Despite this though, the results obtained help explain the factors that influence the achievable noise reductions and illustrate the complexity of the subject.

Leq Noise Reductions

Viewing the overall Leq noise reductions for each residence, the noise reductions achieved did not strictly follow the initial hypothesis that double brick, brick veneer and timber residences would achieve the highest to lowest reductions in that order. Though the double brick residences did achieve the highest reductions, the brick veneer sites measured one of the lowest and highest noise reductions whilst the reductions achieved by timber residences were also scattered. Due to the small sample size for testing however, this variation is not substantial enough to disprove the theory entirely and the variation of the results from the initial hypothesis can be justified in most cases. The reasons for this variation are most commonly due to building characteristics and the reverberation time of the room whilst factors involving the external noise source are also notable.

Timber Residences

In the case of the Raymont and Gladstone residences it is likely that the high reverberation time of the receiving rooms were the main reason behind the low reduction measured. Although the highly reverberant nature of the test rooms in these residents was the result of the rooms being a bathroom (Raymont) and unfurnished (Gladstone), due to the floors of Queenslander style dwellings generally being timber boards, a higher reverberation would not be uncommon for this type of residence and as such a lower reduction may be common for this type of dwelling.

Another insight into the factors which influence the noise reduction was also provided by the Gloucester A and Gloucester B residences. Considering the physical similarities and acoustic characteristics and the fact that they were both located on the same street (although different ends), it is interesting to observe the difference between the noise reductions measured. Although all the other timber residence windows folded out so that the pane was perpendicular to the façade when opened, both the Gloucester A and B residences windows did not open completely, with the window pane unable to be opened past 45°. In the case of the Gloucester A windows, these all folded out the same way, such that when open all the window panes slanted the same direction away from the façade. However, in the case of the Gloucester B window, both panes opened from the middle out, therefore still opening but providing a better barrier to the intrusion of external noise. As the Gloucester B residence was the only site monitored which had this style of window, the effect of this opening style on noise attenuation is not entirely known, however this is a probable reason for the higher level of attenuation.

Less definitive than window opening style, deterioration and build quality is mentioned by Carter *et al* (1992) as a reason for inaccuracy between lab and field tested results, however it may also have been a factor in this investigation between residences. Although the Gloucester A and B residences were of identical construction, the deterioration and current build quality of each of the residences were quite different. The B residence having been recently refurbished and repaired whilst the A residence had noticeably deteriorated and had not yet been restored. This decay of old timber Queenslander residences will ultimately affect the acoustic strength of these styles of properties and will become an increasing issue as the age of timber residences increase.

Evaluating the timber residences measured data in terms of the frequency spectrum reduction trends it is evident that these lightweight residences follow a more stable pattern than the brick constructions. With the exception of some low frequency outlying results due to acoustic reasons, the slopes of the reduction lines as they approach the 10 kHz frequency are relatively flat and illustrate a gradual decline in attenuation towards the higher frequencies. The reason for this may be the presence of a spike in noise at the higher frequencies, resulting in a higher noise level relative to background noise and a resulting higher measured attenuation (i.e. a clearer signal-to-noise measurement). Although the definitive reason for this sudden increase is unknown, it may be due to small gaps in the building envolpe due to deterioration of the façade. This possible explanation is supported by the absence of this high frequency increase for the other masonry style residences, more resistant to deterioration.

Brick Veneer Residences

Similar to the measured reductions at timber residences, the variations between the brick veneer residences have resulted in the measured noise reductions showing substantial variation from each other. Expected to achieve reductions slightly higher than the timber residences, the brick veneer monitoring sites achieved reductions of above, below and similar to those measured at the timber and double brick residences. Different to the timber residences though, this variation is most likely due to variations in room volume and window size rather than internal reverberation, which was similar between all dwellings of this style.

With regards to the low overall reductions measured at Edinburgh and Lynelle at the lower frequencies, these lower reductions may be explained by the low incident noise levels externally. In the case of Edinburgh, the local road carried little traffic during testing and the external level overall was the lowest of all test sites. Although the Lynelle residence's incident noise source was supplied by both a local and secondary major roadway, the distance of the receiving room from the major roadway was roughly double the distance of the local road and the distance that most other residences were from the source. This increased distance may have had an effect on the reductions measured at the Lynelle residence in the higher frequencies (1600Hz – 10kHz), as high frequency sounds are more readily attenuated than low frequency sounds and as a result less high frequency sound was incident on the façade and available to be attenuated (Long, 2006). These low reductions may also be due to the incident noise behaving more like an impulse or moving point noise, rather than a continuous noise incident on residences beside busier roadways.

In regards to the relatively high attenuation achieved by the Thirteenth residence, this was most likely due to the small size of the window in relation to the exposed façade, resulting in a smaller open area for noise to penetrate into the room. The shape of the room, being a slim rectangle also increased the room average noise reduction as the window was located at one end of the room. Although the room average method is necessary to determine the average internal noise level and overall room reduction, the layout of the tested room will have an effect on the reduction. This room shape is important to note as depending on the location were the occupant spends the most time within the room, the actual internal noise level experienced will differ from the room averaged noise level measured.

Double Brick Residences

Viewing the presented results it is obvious that in terms of the actual measured reductions the double brick residences showed the best correlation in noise reduction and achieved high transmission loss values in agreement with the initial hypothesis. Although in accordance with the expected outcome, the relatedness of these reductions is interesting given the variation between the Central, Kenmore and Kessels residences with respect to incident noise, reverberation time, room volume and window size. In knowledge of how these parameters affect the noise reduction measured, it appears that for the double brick residences the differences between the residences has coincidently resulted in measured reductions showing a similar frequency trend. This result is a product of chance however it is still an accurate measure of the actual noise level difference from outdoor to indoor. It is also important to point out though that in the real world the physical and acoustical parameters of most rooms of different residences will vary considerably from one another, a feature which makes this noise attenuation issue inherently complex.

L_{max} Noise Reductions

Slightly different to the L_{eq} results due to the very small amount of tested residences, the L_{max} results provide limited insight into the noise reduction through open windows issue. In direct comparison to the L_{eq} results across the same frequency range, the reductions achieved at the peak frequency are higher than the reduction achieved at the same frequency for the steady-state noise measurements. The results of the L_{max} tests however are also less consistent in comparison to the L_{eq} results, most probably because the L_{eq} results are averaged over a time period whereas the L_{max} results are only averaged on the number of samples at each residence. The L_{max} reductions however do still exceed the predicted 5 dB(A) noise reduction for a facade with an open window.

Comparison with Published Corrections

Prior to completion of this investigation the accuracy of the noise corrections presented within the Brisbane City Plan's "NIAPSP" (2000) and the Queensland Government's "PFNC" (2004) guideline was unknown and un-verifiable due to a lack of field measured data. However, evaluating the results presented by this report against these corrections it can be concluded that the allowed noise corrections published are below the measured reductions. At all residences monitored the window tested was opened as much as possible and in all cases the noise level difference externally to internally was greater than 5 dB(A) and as much as 15 dB(A) in some cases. However, given the limited criteria used to define these reductions it is not surprising that in some cases the actual measured noise level difference is very different to the prescribed reductions for some residences. However, this deiscrepancy is not surprising considering the corrections assumed by "NIAPSP" (2000) and "PFNC" (2004) are able to be applied to numerous noise types, such as mechanical plant or mining noise, not just steady-state or quasi-steady road traffic noise. It must also be mentioned that in the acoustics field the tendency with regards to predicting noise levels is to model conservatively in an effort to protect residents of the potential affected party in case of error. Acknowledging this tendency it is accurate to say that the Queensland based noise reduction assumptions are conservative in all cases but inaccurate in regards to the specific residences affected by road traffic noise monitored during this investigation.

Accuracy of Internal Prediction Methods

Due to the lack of knowledge regarding the transmission of noise through an open window, the accuracy of the prediction methods included in this study were not expected to perform exceedingly accurate with respect to the measured data. This is mainly due to the simple nature of the AS 3671(1989) open area method and the Insul software program assumption that an open window will provide 0 dB(A) attenuation. Although not expected to achieve accurate results, the evaluation of these methods was still important as currently these methods are implemented by acoustical consultants to provide advice to clients and residents regarding internal noise levels and noise transmission loss.

In regards to prediction accuracy, it can be concluded that the EN 12354.3 (2000) method as used in the Insul software program shows some precision with respect to the actual measured internal noise levels. In some instances the predicted noise level matches the actual recorded level and in the case of the Gloucester A and Edinburgh residences (not shown) the EN 12354.3 (2000) method actually under predicts the internal noise level at some frequencies. However, in general the calculated level internally was above the levels that the field measurement achieved. The reason for this difference between actual and measured levels is understandable though due to the assumption that an open window will attenuate 0 dB. It must also be noted that as the residences materials were not able to be dissected, the element ratings used in prediction may be slightly different to the ratings of the actual building elements. For most residences this prediction method projects internal noise just above the measured level which can be considered a conservative means of providing noise exposure advice to residents.

Similar to the EN 12354.3 (2000) method, the basic open area method taken from AS 3671 (1989) also had limited success with respect to the accuracy of its noise level reduction predictions. Although for some residences the open area method is able to predict a noise reduction quite similar to the reduction measured, this accuracy may be a result of luck rather than technique due to the limited input and information required to predict the reduction. Due to the simple nature of the method, the accuracy achieved in prediction is not surprising. However, the results of this investigation do illustrate that it is unadvisable to use this simple method to determine the noise reduction achieved by a facade with an open window subject to road traffic noise.

CONCLUSION

This study has concluded that the tested residences despite variations in construction and incident noise have all achieved reductions exceeding 5 dB(A) for road traffic noise and limited impulse point noise sources. It has also determined that whilst theoretically slightly weaker acoustically than the masonry residences, the traditional Queenslander style timber facade dwellings measured in this test are still capable of providing noise attenuation at a level comparable to those measured at the more solid double brick and brick veneer residences.

This project has determined that no overall noise reduction can be estimated based only on façade construction type and that the noise level difference from outdoors to inside is a result of numerous incident noise and individual room characteristics. This investigation has ultimately determined that whilst two separate residential dwellings may have the same material construction, they may in fact achieve significantly different noise reductions based on the volume and layout of the room in addition the size of the window in relation to the façade.

REFERENCES

Brisbane City Council (BCC). 2001. “Environmental Themes – Noise.” In 3111ENV Readings in Environmental Noise. Brisbane: Griffith University.

“Brisbane City Plan Vol. 2: Noise Impact Assessment Planning Scheme Policy” (NIAPSP). 2000. Brisbane City Council (BCC). Accessed March 7, 2011. http://www.brisbane.qld.gov.au/bccwr/lib181/appendix2_noiseimpact_psp.pdf.

Carter, N.L., Ingham, I. Tran, K. 1992. “Overnight Traffic Noise Measurements In Bedrooms and Outdoors, Pennant Hills Road, Sydney – Comparisons with Criteria for Sleep.” *Acoustics Australia*: vol. 20 (2) 49-55.

Department of Transport, Welsh Office. 1998. “Calculation of Road Traffic Noise (CoRTN).” HMSO Publication Centre. Accessed on May 25, 2011. http://www.noiseni.co.uk/calculation_of_road_traffic_noise.pdf.

De Salis, M.H.F. Oldham, D.J. Sharples, S. 2002. “Noise control strategies for naturally ventilated buildings”, *Building and Environment* vol. 37: 471 – 484.

International Organization for Standardization (ISO). 1998. “Acoustics – Measurement of sound insulation in buildings and of building elements. ISO 140 – 5.” Genève: International Organization for Standardization.

Lawrence, A. Burgess, M. 1983. Reduction of traffic noise by facades containing windows. In *The Economics of Noise Control: Proceedings of the Annual Australian Acoustical Society Conference, Barossa Valley, South Australia, February 1983*, 16.1-16.8.

Long, M. 2006. *Architectural Acoustics*. Sydney: Elsevier Academic Press.

National Standards Authority of Ireland (NSAI). 2000. “*Building Acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 3: Airborne sound insulation against outdoor sound.* EN 12354.3.” Dublin: National Standards Authority of Ireland.

“Planning for Noise Control Guideline (Qld)” (PNCG). 2004. Queensland Government, Environmental Protection Agency. Accessed March 3, 2011.http://www.derm.qld.gov.au/register/p01369aa.pdf.

Standards Association of Australia. 1984. “*Acoustics – Methods for the measurement of road traffic noise*. AS 2702.” Homebush: Standards Association of Australia.

Standards Association of Australia. 1989. “*Acoustics – Road traffic noise intrusion – Building siting and construction.* AS 3671.” Homebush: Standards Association of Australia.

Waters-Fuller, T. Lurcock, D. 2007. “NANR116: Open Closed Window Research”. Napier University, School of the Built Environment. Accessed on March 8, 2011. http://researchrepository.napier.ac.uk/

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