GABRIELS HEARNE FARRELL

REPORT: 19-030

ACOUSTIC REPORT
NORTHBRIDGE ENTERTAINMENT PRECINCT
Evaluation of Residential Building Attenuation

28 OCTOBER 2019

For

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EXECUTIVE SUMMARY

Northbridge is the predominant night life / music venue precinct for Perth and is characterised by a large number of night clubs, taverns, bars and restaurants. The bars and restaurants are often open to the street. The music and patron noise emission into the street is considered desirable, as it defines a vibrant entertainment district.

Over time there has been an increase in the number of residential developments within the Northbridge area. However, the encroachment of residential buildings into the Northbridge entertainment district is becoming a concern. The level of music entertainment noise intrusion into residential apartment is causing significant resident annoyance. On the other side, there is the associated concern of the music entertainment industry that venues will be closed down as they are unable to meet regulatory criteria established to control environmental noise emissions. There is also the concern that any controls to reduce noise emission from entertainment venues will stifle the vibe which is considered to be of high importance in a vibrant night life entertainment area.

The specific concern is that many music entertainment venues incorporate amplified music with significant low frequency noise content. It is this low frequency noise transmission into apartments characterised by regular repetitive bursts of sound, with negligible frequency modulation commonly referred to as “doof-doof” noise. In itself, this sound has no musical character and is in fact not unlike many industrial noise sources.

Typical external noise levels(2) at night time between 11:00pm and 1:00am on Friday and Saturday nights are in the region L_{eq} 57 to 65 dB(A), & 70 to 80 dB(C). The external noise levels used in this assessment of façade acoustic performance for Northbridge Residential Development are 65dB(A) and 80dB(C).

There are no clear design standards for low frequency noise in Australia. Based on a review of various Australian examples including Fortitude Valley, the implied requirements of the Environmental Protection (Noise) Regulations, and the approach taken Internationally, a design objective for the 63Hz and 125 Hz octave bands was selected based on the DEFRA curve. In this assessment, the design objective for internal noise levels due to music entertainment noise intrusion are set at:

63 Hz Octave Band : L_{eq} 47dB 125 Hz Octave Band: L_{eq} 41 dB

As reliable Sound Reduction test data is not available in the 63Hz octave band, mathematical predictions were carried out using INSUL Version 9, Sound Insulation Prediction software. Based on this data, the level of noise intrusion in the 63Hz and 125Hz octave bands was determined. Issues considered in the calculation procedure included:

- The design external noise is taken as 65 dB(A),and 79 dB(C), based on the noise spectrum provided by DWER (i.e. ‘composite venue spectrum’.)
- Façade acoustic insulation values were determined in accordance with ISO 12354.
- Acoustic absorption within the room was based on the acoustic absorption properties of typical internal room finishes and furniture.

The current stock of more recent Apartment constructions in the Northbridge area have facades constructed of:

- High mass external walls being concrete or cavity brick
- Upgraded glazing typically 10.38mm glass
- Typical light frame roof ceiling construction with double layer plaster sheeting to ceiling.

This construction addresses the general environmental noise in the Northbridge area associated with traffic and street noise. It does not address the low frequency noise associated with the music entertainment industry. As noted, the purpose of this study was to focus on the low frequency noise intrusion and determine a practical approach to acoustic upgrades. The focus was therefore on the performance of the façade and the roof. The major conclusions of the study are:

- Typical constructions standard for external walls being high mass > 300kg/m2 surface density (concrete) provides high sound reduction performance in the low frequencies.
- Standard 10.38mm laminated glass generally used in Apartment buildings to effectively address normal environmental noise intrusion e.g. traffic and street noise, results in low frequency noise levels 12dB above the design objective of 47 dB at 63 Hz
- Upgrading the façade glazing to high performance glass e.g. 12.5 VLam Hush glass reduces internal noise intrusion by 2 dB but is still 10 dB above the design objective of 47 dB at 63 Hz
- Acoustic double glazing with a 75mm air cavity is in fact is less effective than heavy single glass because the mass-air-mass resonant frequency of the double glazing system occurs in the 63 Hz octave band, seriously reducing the sound reduction performance in this critical octave band.
- A very large cavity (minimum 1 metre) is required in the double glazing format to provide good sound reduction performance in the 63 Hz octave band. This is achievable by fully glazing the balcony perimeter. This involves constructing a normal balcony and installing openable windows , e.g. multi slider above the normal balustrade height.
- *Balcony Glazing* utilising 6mm glass at the balcony and minimum 10.38mm glass to the habitable rooms meets the low Frequency Noise criteria established in the DEFRA Low frequency noise criteria.
- The Balcony Glazing provides significant low frequency noise reduction but provides very significant noise reduction in the mid and high frequencies. Internal masking noise form general environmental noise within the apartments will therefore be extremely low. Provision of *Acoustic Masking* within the apartments will therefore need to be considered. This is outside the scope of this study, although discussion is provided in 7.3 of this report.
- Noise intrusion via the roof for penthouse constructions (top floors) has been considered. The typical light frame roof ceiling construction used in apartment construction has been shown to be ineffective in controlling low frequency noise transmission. The most cost effective acoustic upgrade is to provide high mass concrete slab with insulated metal roofing over.
- Costing of designs options have been presented. The cost of upgrading in terms of the % increase to building cost for upgraded acoustic single glazing are relatively small at ≈ 0.6 % of building cost. However this only marginally improves performance in the low frequencies, being well below relevant design targets.
- *Balcony Glazing* with acoustic absorbent ceiling to the balcony does represent a significant cost as it is in fact a second façade. It represents an approximate 8% increase in overall building cost.

This report identifies that low frequency noise intrusion into Residential Building in the Northbridge Precinct can be controlled to meet Low Frequency Noise design targets where external noise levels are up to 65 dB(A) and 79 dB(C). Where the external noise levels as set out above are exceeded, it is expected that the noise emission from the venue will need to be addressed at source, as further increase in ‘receiver building’ construction standards are not likely to be viable.

The sound reduction of these high acoustic performance constructions is based on mathematical predictions. It is therefore recommended that these systems be field tested to confirm the predicted performance.

It has been noted that the use of such high sound reduction performance façade and roof construction will result in extremely low internal ambient noise with an unbalanced internal background noise spectrum. Inter apartment noise sources will be significantly more audible due to the lack of acoustic masking. We advise that the use of electronic masking within the apartments should be further investigated.

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Rev No.	Rev Date	Revision Description	Prepared by	Reviewed By
DRAFT_02	9 July 2019	Draft for Client Review	N. Gabriels	K. Hearne
Revision_01	28 October 2019	Includes Client comment on Draft	N. Gabriels	K. Hearne

1. INTRODUCTION

Northbridge is the predominant night life / music venue precinct for Perth and is characterised by a large number of night clubs, taverns, bars and restaurants. The bars and restaurants are often open to the street. The music and patron noise emission into the street is considered desirable, as it is one of the elements that defines a vibrant entertainment district.

Over time there has been an increase in the number of residential developments within the Northbridge area. There are current issues associated with the encroachment of residential buildings into the Northbridge Area. At this point the level of officially reported annoyance seems limited. However, with the increase in residential encroachment into the Northbridge entertainment district, there is the potential for increased resident annoyance. On the other side, there is the associated concern of the entertainment industry that venues will be closed down, as they are unable to meet regulatory criteria established to control environmental noise emissions. There is also the concern that any controls to reduce noise emission from entertainment venues will stifle the vibe which is considered to be of high importance in a vibrant night life entertainment area.

Of particular concern is the fact that many entertainment venues incorporate amplified music with significant low frequency noise content. Low Frequency noise is normally associated with industrial noise and the noise emission from foundries etc. This sort of low frequency noise is not normally associated with residential areas. This report considers the potential for residential apartment buildings to attenuate entertainment noise and particularly the invasive low frequency noise that is characteristic of this area.

This report identifies some physical limitations of building construction systems when it comes to control of low frequency intrusion, and provides recommendations and suggestions regarding construction options to address the low frequency sound reduction performance of buildings. Where acoustic requirements impact on planning, building and/or engineering requirements, the matter must be referred to an appropriate professional person.

This report also provides basic cost implications of the recommended acoustic upgrade options.

2. NORTHBRIDGE ENTERTAINMENT PRECINCT

2.1 Northbridge Entertainment Precinct

The Northbridge entertainment precinct in Perth is generally considered to be the area confined by Newcastle, Fitzgerald, Wellington and Stirling Streets in Perth. This is the night life / music venue area for Perth and is characterised by a large number of night clubs, taverns, bars and restaurants. The bars and restaurants are often open to the street. Music and patron noise emission into the street is considered desirable as it part of the 'Vibe' of a lively entertainment area. Noise emission from music entertainment venues is a particular concern, in that noise sensitive residential premises are located throughout the area, often very close to these night clubs and bars.

The allowable noise emission from these venues is currently regulated by the Environmental Protection (Noise) Regulations, 1997 (as amended). However, as residential development is encroaching on these venues which may have existed for many years, compliance with the Regulations is difficult and involves significant cost. On the other hand the noise intrusion into the residential apartments generates annoyance.

2.2 Existing Regulations

2.2.1 Environmental Protection (Noise) Regulations, 1997 (as amended)

The allowable noise emission from any premises within Western Australia is controlled by the Environmental Protection (Noise) Regulations(1) (EPNR). The Regulations establishes a procedure to determine the 'Assigned Level' criteria for any specific site. The Assigned Levels are the maximum permissible sound levels at any premises resultant from noise emission from surrounding sites.

2.2.2 Assigned Levels

The Assigned Levels vary depending on type of receiver, time of day, duration of noise source, and are calculated based on an "Influencing Factor" that is added to a set of baseline Assigned Levels. The Influencing Factor is determined by taking into account the receiver premise's proximity to busy traffic routes and land zoning of the surrounding land.

2.2.3 Typical Assigned Levels in Northbridge

The Influencing Factor is separately determined and varies for different sites. In the Northbridge area the Influencing Factor for specific sites will likely vary between 6 and 16 dB(A) with a typical value being 10 dB (2). As the Influencing Factor ranges from 6 to 16dB, the Assigned Levels as set out in Table 2.1will vary by up to +6dB and -4 dB. The Assigned Levels based on a typical Influencing Factor of 10 dB for a Noise Sensitive <u>residential</u> receiver at various times of the day would then be as set out in Table 2.1.

Part of premises receiving noise	Time of day	Assigned Level (dB)		
		L_{A10}	L_{A1}	L_{Amax}
Noise Sensitive Premises: highly sensitive area (i.e. Locations within 15 metres of a building directly associated with a noise sensitive use)	0700 to 1900 hours Monday to Saturday	55	65	75
	0900 to 1900 hours Sunday and public holidays	50	60	75
	1900 to 2200 hours all days	50	60	65
	2200 hours on any day to 0700 hours Monday to Saturday and 0900 hours Sunday and public holidays	45	55	65

TABLE 2.1 - ASSIGNED LEVELS

The sound level parameters used to describe the noise environment are defined as:

L_{A10} is the 'A' weighted noise level which is not to be exceeded for more than 10% of the representative assessment period (e.g. for more than 10 minutes in 100 minutes).

LA1 is the 'A' weighted noise level which is not to be exceeded for more than 1% of the representative assessment period, (e.g. for more than 1 minutes in 100 minutes).

L_{Amax} is the 'A' weighted noise level which is not to be exceeded at any time.

Considering the type and duration of entertainment venue noise emissions, it is the L_{A10} parameter that applies to music noise received outside a residential premises.

2.2.4 Measurement of Compliance with EPNR

Characteristics of the Sound: In assessing the measured noise level to check compliance with the Assigned Level, the Regulations identify that sound with tonal, modulating or impulsive characteristics increases the annoyance of the audible noise and therefore requires adjustment of +5 dB to the measured level for tonal and modulating characteristics, and +10dB for impulsive characteristics. The maximum adjustment is +15dB.

Generally audible music is considered to be tonal and modulating attracting this +10dB adjustment to the measured level. To assess if a noise is impulsive an analysis of the noise of a specific event must be carried out in accordance with the definition of impulsiveness as defined in Regulation 7 of the Environmental Protection (Noise) Regulations which is:

> *"variation in the emission of a noise where the difference between the $L_{A\ peak}$ and $L_{A\ Max\ slow}$ is more than 15 dB when determined for a single representative event"*

In practice, impulsiveness in strict accordance with the definition above is rarely determined in situations where noise with a prominent beat, emitted from a music venue is audible. Hence it is common to apply the noise character adjustment for tonality and modulation of +10dB to the measured level and not include an adjustment for impulsiveness unless specifically tested.

Measurements Indoors: Under the Noise Regulations an adjustment for indoor assessments with windows and doors closed is 15 dB or 10 dB if the windows or doors are open .

2.2.5 Compliance with Regulations

Outside Criteria: Measurement of compliance where music is audible requires an adjustment for noise character of +10 dB to the measured dB(A) level. Based on an Influencing Factor of 10 dB, to achieve the Assigned Levels as set out in Table 2.1 the allowable outside measured noise level at the Residential premises, if music is audible, is then:

Daytime:	7 am to 7 pm	L_{10} 45 dB(A)	+6/-4 dB
Evenings:	7 pm to 10 pm	L_{10}40 dB(A)	+6/-4 dB
Night Time:	10 pm to 7 am	L_{10}35 dB(A)	+6/-4 dB

Indoor Criteria: Where measurements are taken indoors, the allowable level where music is audible is reduced by a further 15 dB. The allowable Inside measured noise level within the Residential premises, based on an Influencing Factor of 10 dB, is then:

Daytime:	7 am to 7 pm	L_{10} 30 dB(A)	+6/-4 dB
Evenings:	7 pm to 10 pm	L_{10}25 dB(A)	+6/-4 dB
Night Time:	10 pm to 7 am	L_{10}20 dB(A).	+6/-4 dB

Given the current Regulations, the onus is entirely on the noise emitting venue to achieve the Assigned Levels. This can be difficult to achieve, and is complicated by the fact that there may be multiple emitters, all contributing to the noise received at a single receiver premises. It is noted that if there are a number of emitters (noise sources) contributing to an exceedance of the Assigned Level at a specific receiver location, in accordance with the Regulations, the group of emitters are all required to meet a level of 5dB less than the Assigned Level.

There is currently no obligation on the receiver premises to implement any form of noise mitigation.

3. NORTHBRIDGE AMBIENT NOISE

3.1 Ambient Noise

The ambient noise in Northbridge can vary significantly depending on the measurement location and the proximity to entertainment venues. Also, the noise level can vary significantly from one moment to the next.

Based on DWER measurements daytime Leq levels in Northbridge are in the region of 60 dB(A) and 68 dB(c)

DWER has also provided an indication of the levels that can be expected in the vicinity of music venues in Northbridge, based on measurements made by DWER in 2010. The measurements were made on Friday and Saturday nights between 11pm and 1am the next day, this is within the time periods when venues were busiest. The measurements indicate that over distance from 5m to ≈ 65m the levels range from 62 dB(A) to 83 dB(A) and on the C-weighted scale from 79dB(C) to 102 dB(C).

It is evident that the general ambient noise levels adjacent to Northbridge residential facades exceeds the Assigned Levels at night. (See Table 2.1 and clause 2.2.5) The environmental noise is a combination of pedestrian activity, traffic noise and breakout from entertainment venues.

3.2 Low Frequency Noise Intrusion

It is the noise level on Friday and Saturday nights that needs to be addressed in the acoustic design of Northbridge residential buildings. An indication of the amount of low frequency noise present within the general ambient noise can be gained by determining the dB(C) minus dB(A) levels for any specific measurement. DWER Data indicates that in close proximity to the venues, the C-A levels range from 10 to 23 dB. For more distant venues, the C-A levels range from 9 to 20 dB

Generally, the ambient noise throughout the week is a result of traffic, pedestrian and normal city noises. On Friday and Saturday nights, the sound level of the low frequency component within the general ambient noise increases significantly. This is associated with music from entertainment venues and is evidenced by only a small increase in the overall dB(A) level. This is because the “A” weighting significantly reduces the contribution of the low frequencies to the overall sound. The “A” weighting follows the sensitivity of human hearing which is significantly reduced at these low frequencies. The potential effect of the low frequency is more clearly evidenced in the dB(C) or the Linear weighting where the weighting of the sound across the frequency range is virtually flat.

In terms of the acoustic design of Northbridge building facades, it is the low frequency sound reduction performance of the building element that must be assessed, based on noise levels measured during the Friday and Saturday night entertainment modes. Typical external noise levels(2) at night time between 11:00PM and 1:00AM on Friday and Saturday nights are in the region L_{eq} 57 to 65 dB(A), & 70 to 80 dB(C). The noise level used as the representative external noise source in this assessment of facades in the Northbridge Precinct are: 65 dB(A) and 79 dB(C)

3.3 External Noise Frequency Spectrum

A 1/3 octave band frequency spectrum of ambient noise in the Northbridge area has been provided by the Department of Water and Environmental Regulation. The DWER ‘composite venue spectrum’ is derived from outdoors noise level measurements in the vicinity of live music entertainment venues. The frequency spectrum is dominated by bass and kick drum in the low frequencies with a slight vocal peak in the mid frequencies (~630 Hz). The spectrum as provided has an overall level of 76 dB(A), and 89 dB(C). The sound level in each of the 1/3 octave bands from 25 to 5kHz are set out below in Table 3.1.

Northbridge Ambient Noise Spectrum 1/3 Octave Band (Linear)								
Frequency (Hz)	32	63	125	250	500	1k	2k	4k
1/3 octave Sound Levels dB	62.8	86.5	76.9	70.2	66.5	66.6	62.2	56.3
	67.6	85.1	74.3	68.6	68.0	64.4	60.2	53.5
	78.4	81.5	71.1	67.1	68.1	63.1	58.7	49.4

Table 3.1 – Northbridge ambient noise spectrum (DWER Northbridge Spectrum*)*

Generally acoustic calculations relevant to the assessment of noise intrusion into buildings are carried out in octave bands. The octave band sound levels based on the above data is:

Northbridge Ambient Noise Spectrum Octave Band (Linear)								
Frequency (Hz)	32	63	125	250	500	1k	2k	4k
Octave Band Sound Levels dB	78.8	89.1	79.5	73.6	72.4	69.7	65.4	58.7

Table 3.2– Northbridge ambient noise - Octave band 'composite venue spectrum'

For the purposes of this assessment, the spectrum set out above is taken to represent the frequency characteristics of entertainment venue noise likely to be received at the façade of a neighbouring building, although the relative levels will change depending on actual proximity.

When considering the sound reduction performance of typical façade materials over the full frequency spectrum, they all provide good performance in the mid to high frequencies of 500Hz to 4kHz but relatively poor acoustic performance in the low frequencies 32 to 125Hz octave bands . Based on the octave band levels in the Northbridge Ambient Noise Spectrum as per Table 3.2, the overall LAeq level of the intruding noise will be determined by the sound energy in the low frequency 63Hz and 125 Hz octave bands. This assessment therefore concentrates on the performance of various materials and construction options in the 63 and 125 Hz octave bands. It is the sound energy in these bands that dominates the ambient spectrum and determines the resultant dB(A) and dB(C) sound levels inside residential premises.

4 INTERNAL DESIGN SOUND LEVELS FOR LOW FREQUENCY NOISE

4.1 Design Internal Levels for Low Frequencies

When considering the noise intrusion of music entertainment noise into residential premises the major impact will be in the low frequency 63 Hz and 125 Hz octave bands. Unfortunately acoustic predictions and measurements indoors at these low frequencies have a degree of uncertainty greater than the usual mid to high frequency range of 250 to 4,000Hz.

For this reason most standards that address low frequency noise provide assessment procedures for the evaluation of low frequency noise measured <u>externally</u>. From an architectural acoustics perspective it is the design standard for low frequency noise <u>inside</u> the residence that is important; this then provides the design objective.

4.2 Australian Standards

The Australian Standard[3] AS/NZS 2107:2016 *Acoustics – Recommended Design Sound levels and Reverberation Times for Building Interiors* sets the indoors Design Sound Level range for houses and apartments located in urban areas / entertainment districts at:

	Lower Limit	*Upper Limit* ($L_{eq,t}$)
• Living Areas	35 dB(A)	45 dB(A)
• Sleeping Areas	35 dB(A)	40 dB(A)

Note: This standard is applicable to steady state and quasi steady state sound. So whilst these criteria may be considered relevant to the general "Buzz" within the Northbridge area, they do not apply to noise of individual events, or the low frequency beat associated with music entertainment noise intrusion.

Low Frequency Noise: The Australian Standard AS/NZS 2107 specifically states (Clause 2.2(k)) that the standard is **not** intended for spaces with high levels of low frequency noise.

Low Background Noise Levels: The Australian Standard also advises that where acoustic isolation from adjacent spaces is important, that sound levels below the lower level of the recommended design range increases the risk of inadequate acoustic masking. Where this occurs, noise intrusion from adjoining apartments can become a significant concern. In these situations acoustic masking can be introduced into the space, to raise the sound level to within the recommended design sound level range as per above. (See also Section 7).

4.3 Environmental Protection (Noise) Regulations

The Environmental Protection (Noise) Regulations can be used to establish an indoor design standard for Low Frequency noise. The night time Assigned Level for Northbridge as set out in Table 2.1 is 45 dB(A). With adjustments to this level for the "modulating and tonal" content of + 10 dB, plus the adjustment for internal noise level measurement of +15 dB, the allowable noise level inside a Noise Sensitive building at night is typically L_{10} of 20 dB(A), with a range of -4dB to +6dB. The allowable indoor level adjusted for music and measured indoors is then L_{10} of 20 dB(A). This is based on an Influencing Factor of 10dB. The allowable levels in the overall Northbridge Precinct may therefore range from L_{10} 16 to 26 dB(A), depending on site location.

We note that environmental design standards for internal noise are often established in term of the L_{eq} level. To enable comparison with standards that are L_{eq} based, DWER[4] has advised that the mathematical relationship between the WA statistical L_{A10} Assigned Levels and L_{Aeq} for Low Frequency entertainment noise is:

$L_{Aeq,\,8hr} = L_{A10,8hr} + 4.5$ dB (i.e. $L_{A10,8hr}$ 20 = $L_{Aeq,\,8hr}$ 24.5 dB)

Based on the above L_{Aeq} sound level, DWER established one third octave frequency sound levels based on an assessment method where:

- the overall energy in the L_{Aeq} spectrum is distributed evenly over the low frequency bands of 31.5 Hz to 125 Hz, and
- the LAeq spectrum is provided of the single band maximum level where the overall energy is concentrated in just one third octave band.

These 1/3 octave band criterion curves are set out in Table 4.1.

However, DWER[4] advises that there is insufficient measurement data of music received from venues to confirm the actual relationship between L_{A10} and L_{Aeq}, and in reality live music does not use the extra energy afforded by the higher statistical levels; and whilst the + 4.5 dB relationship is mathematically correct, the L_{A10} Assigned Level as it stands may actually be the best value to compare to criteria defined in L_{Aeq}.

4.4 Fortitude Valley - Brisbane

Fortitude Valley in Queensland is Brisbane's Entertainment District. The Brisbane City Council[(6)] regulates entertainment noise and provides criteria for allowable noise levels measured at 1 metre from the venue. The level varies according to the location of the venue within the Zone, and each venue is given an Amplified Music Venue Permit that sets out the maximum internal noise limits that are determined for the specific premise to ensure it meets the external noise criteria as measured externally at 1 metre from the venue.

In terms of addressing the internal noise levels within residential apartments the Brisbane City Council has determined noise reduction requirements to achieve an Amplified Music Level of L_{eq} 43 dB at 63 Hz (1/3 octave) in bedrooms and 45 dB at 63 Hz (1/3 octave) in Living Areas. (See Ref: 6 Table 4) Typically they are:

Special Entertainment Area- Core and Buffer Area A:
Noise reduction of **25dB** at 63 Hz where noise at façade is:
>68dB at 63 Hz in bedroom, and
> 70dB at 63 Hz in Living Room

Special Entertainment Area- Core and Buffer Area B:
Noise reduction of **20dB** at 63 Hz where noise at façade is:
>63dB at 63 Hz in bedroom, and
> 65dB at 63 Hz in Living Room

Short Term Accommodation in Core Areas A and B:
Noise reduction of **18dB** at 63 Hz where noise at façade is:
>61dB at 63 Hz in bedroom, and
> 63dB at 63 Hz in Living Room

Where an entertainment venue is located within the same building as the residential area, requirements is for an amplified music level of not > 43 dB in any one-third octave band between and including 31.5Hz and 125 Hz in Bedrooms and 45 dB in Living areas.

The Fortitude Valley criteria is to a large extent focused on the noise reduction through the façade in the 63 Hz 1/3 octave band. This is reasonable in that the higher frequencies will generally have increased sound reduction performance. The possible exception is at the mass-air-mass resonance frequency.

For venues with residential facilities within the same building, the sound pressure level criteria within the space of 43dB applies through the full low frequency range of 31.5 Hz to 125 Hz. We note that at the lower end of this frequency range, the 43 dB criterion in the 31.5 Hz 1/3 octave band is significantly below the 59.5 dB ISO threshold of hearing. In the upper low frequency 1/3 octave band of 125Hz the criteria of 43 dB is significantly above the 22.1 dB ISO threshold of hearing. In that regard, this criteria appears a little arbitrary.

4.5 Australian Criteria

Table 4.1 sets out Low frequency Design Criteria in one-third octave bands for noise measured internally as used in Fortitude Valley and as determined to meet the Environmental Protection (Noise) Regulation requirements . It is worthwhile noting that the broadband dB(A) level relates poorly with the low frequency energy allowed by the criteria. This can be seen by comparing the frequencies at and below 63 Hertz for the EPNR and Fortitude Valley criteria.

Criterion Curve for Low Frequency Assessment									
		One third octave Frequency (Hz)							
Criteria	Broadband dB(A)	31.5	40	50	63	80	100	125	160
EPNR As advised by DWER(5) Evenly distributed across bands	**24.5**	55.4	50.6	46.2	42.2	38.5	35.1	32.1	
EPNR As advised by DWER(5) Maximum Single Band	**24.5**	63.9	59.1	54.7	50.7	47.0	43.6	40.6	
Fortitude Valley (6)	**30**	43	43	43	43	43	43	43	
ISO 389-7 Threshold of hearing		59.5	51.1	44.0	37.5	31.5	26.5	22.1	17.9

Table 4.1 Un-weighted one third octave criterion curve for Low Frequency Noise Assessment

4.6 International Approach

There is no consensus at an international level on a criterion for low frequency noise within habitable spaces. Presumably the design aim should be to design to the ”inaudible”. This will involve high sound reduction facades resulting in lower background noise levels within the habitable space, making it more difficult to achieve this “inaudible” status. The aim is therefore to provide a design standard for residential buildings where the intruding noise is considered “acceptable” to the majority of people.

United Kingdom: Moorhouse et al(8) in his report prepared for the Department for Environment, Food & Rural Affairs (DEFRA) *Procedure for the Assessment of Low Frequency Noise Complaints* Revision 1, December 2011 (4) Provides a Low Frequency Criterion Curve to be used for the frequency range 10Hz to 160 Hz. Table 3.3.

Criterion Curve for Low Frequency Assessment													
One third octave Frequency (Hz)	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
Sound Levels dB	92	87	83	74	64	56	49	43	42	40	38	36	34

Table 4.2 Un-weighted one third octave criterion curve for Low Frequency Assessment

For acoustic design purposes it is practicable to use octave bands. The octave band levels are determined by the (Log) summation of the three 1/3 octave bands that define the octave band. The criterion in the one octave 63Hz and 125 Hz octave bands are then:

63 Hz Octave Band : L_{eq} 47dB 125 Hz Octave Band: L_{eq} 41 dB

Although the Moorhouse curve does not specifically relate to music entertainment noise (as per the specific exclusion in this revised edition), these levels provide a good practical basis to assess low frequency music noise intrusion. It is noted that the music entertainment noise intrusion addressed in this report is in fact the “doof-doof” noise. It is low frequency noise with regular repetitive bursts of sound, with negligible frequency modulation. While in itself it has no musical character, and is in fact not unlike many other industrial noise sources, the receiver is well aware that the source is music.

Denmark: Low frequency noise in Denmark is measured in one third octave bands over the frequency range of 10 to 160 Hertz and then A-weighted over this frequency range[8] The maximum acceptable level are:

Dwellings:	Night 18:00h to 07:00h	20 dB(A)
	Day 07:00h to 18:00 h	25 dB(A)

There is no reference curve in the Danish method , but it can be compared with other criteria by assuming the overall energy is concentrated in a single one third octave band. The value set out in Table 4.3 represents this value for the night time criteria of 20 dB(A). The Danish method also includes a 5 dB adjustment added to the measured level for impulsive noise but provides no objective indication as to when it should be applied. The criterion in the one octave 63Hz and 125 Hz octave bands are then:

63 Hz Octave Band : L_{eq} 52 dB 125 Hz Octave Band: L_{eq} 42 dB

Sweden: Sweden guidelines[8] state that low frequency noise should not exceed any one third octave band in the range of 31.5 to 200 Hz as set out in Table 4.3. It should be noted that they are identical to the DEFRA Criteria set out in Table 4.2. The criterion in the one octave 63Hz and 125 Hz octave bands are then

63 Hz Octave Band : L_{eq} 47dB 125 Hz Octave Band: L_{eq} 41 dB

Netherlands: This method is intended to determine whether a suspected Low Frequency Noise is audible or not rather than whether it should be classed as a nuisance. The criterion curve[8] is therefore below the ISO Threshold for audibility. Criteria is set out in Table 4.3. The criterion in the one octave 63Hz octave bands is then 40 dB. This is very stringent criteria.

Criterion Curve for Low Frequency Assessment									
		One third octave Frequency (Hz)							
Criteria	Broadband dB(A)	31.5	40	50	63	80	100	125	160
UK- Defra Criteria		56	49	43	42	40	38	36	34
Denmark Based on 20 dB(A) criterion	**20**	59.4	54.6	50.2	46.2	42.5	39.1	36.1	33.4
Sweden		56	49	43	41.5	40	38	36	34
Netherlands		55	46	39	33	27	22		
ISO 389-7 Threshold of hearing		59.5	51.1	44.0	37.5	31.5	26.5	22.1	17.9

Table 4.3 Un-weighted one third octave criterion curve for Low Frequency Assessment

Overview: In this study. the Evaluation of Residential Building Attenuation for the Northbridge Precinct we are focussing on the low frequency sound reduction performance of the residential building façade and specifically the 63Hz and 125 Hz octave bands. In this frequency range the DEFRA Criteria represents a reasonable average which sits close to many of the criteria identified in Tables 4.1 and 4.3. For acoustic design purposes it is practicable to use octave bands. The acoustic design objective for residential apartments is for internal noise levels due to music entertainment noise intrusion to achieve:

63 Hz Octave Band : L_{eq} 47dB 125 Hz Octave Band: L_{eq} 41 dB

5. ACOUSTIC PERFORMANCE – RESIDENTIAL BUILDING CONSTRUCTION SYSTEMS

5.1 Types of Residential Developments

Residential buildings in Northbridge include Apartments, Hotels, Hostels, Short Stay / Youth Hostel accommodation and also some single / small group residential developments. This report specifically targets Residential Apartment type developments. Guests in Hotels and Hostels are short stay occupants, they are more likely to be accepting of some noise intrusion as being part of the Vibe of the area. On the other hand, apartment dwellers may have been originally attracted to the area because of the Vibe or close proximity to places of work in the CBD, but when exposed to the noise over time tend to be more seriously affected and annoyed by noise intrusion.

Although this report targets Apartment type Buildings, the principles of construction may be applicable to small scale residential developments and to a lesser extent short stay type developments.

Specific attention is given to the performance of the building enclosure in the low frequencies being 63 Hz and 125 Hz octave bands. This is targeting the "doof-doof" noise intrusion that infiltrates residential buildings in the Northbridge Precinct.

5.2 Construction of Residential Facades

5.2.1 Common Forms of Construction

Wall Types: The most common forms of construction for apartment buildings include:

- AFS/Ritek concrete wall systems and Pre Cast Concrete walls
- Cavity Brick / Masonry – 2 to 3 storey construction (includes concrete block)
- Concrete or steel Frame Construction with light weight framed wall systems

Windows: Glazing in Apartment buildings represents a significant proportion of façade area. The typical glazing systems currently used include:

- Normal and Laminated glass
- Thermal double glazing with small air gaps
- Some Secondary Glazing systems to provide increased sound reduction performance.

5.2.2 Improving Sound Reduction Performance

Increasing the overall sound reduction performance of the façade will correspondingly reduce the ambient noise level within the apartment. As the Sound Reduction of building elements is consistently more effective in the high frequency region, the high frequencies are attenuated to a greater level than the low frequencies. Hence the intrusion of low frequency 63Hz and 125Hz octave bands can be more prominent within the general ambient noise within the apartment, albeit at a lower background noise level.

5.3 Sound Reduction of Wall Systems

When addressing low frequency noise intrusion in the 63 Hz and 125 Hz octave bands, it is very difficult to obtain Sound Reduction data. Australian and International Standards for laboratory testing of the Sound Reduction of building elements limit the reporting of Sound Reduction to the 100Hz to 5,000Hz frequency range. Measurements below 100Hz are outside the scope of the Standards. The reason being is that to achieve diffuse sound fields in frequencies below this range requires test chambers with extremely large volumes, which then makes the test chambers unsuitable for normal testing. The Australian Standard AS1191-2002 (Cl.5.2.2) provides the minimum volume for a test chamber to achieve sufficient number of room modes to achieve diffuse field conditions suitable for a laboratory testing of low frequencies at:

- 125 Hertz octave band Room Volume of 160 m3
- 63 Hertz octave band Room Volume of 1,200 m3
- 32 Hertz octave band Room Volume of 10,000 m3

5.3.1 Prediction of Low Frequency Performance

Acoustic Laboratories designed to test the Sound Reduction performance of building materials to Australian or International Standard are required to have volumes between 100 and 200m^3. This is adequate for testing the normal test range of 125 to 4,000 Hz octave bands. Where Laboratory results are provided for the 63 Hz octave band, this is not part of the normal reporting requirement of the Standards and published results should only be considered as indicative. In reality, the data will be volume controlled and the reported Sound Reduction performance in the 63 Hertz octave band are likely to be higher than would normally be achieved in the field.

A method that provides an improved indication of performance that can realistically be expected in the 63 Hertz octave band is mathematical prediction techniques. In this assessment the current version of the industry standard prediction method “INSUL” (V9.0.17) has been utilised. However, it must be acknowledged that the lowest 1/3 octave frequency band included in this prediction method is at 50 Hz. This is worth noting, as DWER has advised that some recent measurements (2019) indicate some Venues have dominant levels in the 40 Hz 1/3 octave band. However no sound reduction data is available for this very low frequency 1/3 octave band

Limitations: For mathematical predictions of the Sound Reduction of standard construction systems, where various layers and arrangement of materials can be readily input into the model, the INSUL predicted performance generally provides good correlation with Laboratory tested data. However where systems are complex such as glazing systems with aluminium frames, operable panels, seals and damped interlayers, the modelling is complex. In this assessment the glazing in the façade is modelled as the glass only. Laminated glazing is modelled by selecting a glass/interlayer system that best matches the reported laboratory Weighted Sound Reduction Index (Rw) data for the laminated glass element.

It is assumed the aluminium frames will be commercial quality frames with minimum 1.2mm wall thickness. For these window systems, we expect that the framing system will not significantly affect the low frequency performance of the window system. More likely is that the performance of the window system will be reduced in the mid to high frequencies due to the performance of the seals etc.

The real value of prediction models is that they provides a method to view the performance of unusual construction systems e.g. the effect of large cavity in a construction. The Sound Reduction performance of these systems are difficult to test in a laboratory. The predictions provides answers but the margin of error is unknown. For this reason the recommendations in this report should be tested to verify the predicted sound reduction performance is achievable in the field.

The “INSUL” Sound Insulation Prediction method has a reported “margin of error” of ± 3dB. In reality the prediction method rarely under-predicts. So where calculations in this report are based on INSUL predictions, the sound reduction value used in the calculation is the INSUL Prediction minus 3dB.

The Low Frequency Sound Reduction Values used in calculations for the various materials / constructions are set out in Tables 5.1 to 5.11 and summarised in Table 5.12.

5.3.2 High Mass Wall Systems

Concrete Wall Systems: Building materials with high surface mass provide good sound reduction performance in the low frequencies. External wall systems commonly used in multi storey residential construction are the permanent formwork concrete walls systems such as AFS and Ritek, and Precast concrete systems. The concrete is generally 150mm thick. These wall systems have been extensively tested and are a 'Deemed-to-Satisfy' wall in the Building Code of Australia (BCA) rated at a sound reduction performance of Weighted Sound Reduction Index R_W+C_{tr} of 50.

In practice, these wall systems need to be insulated in order to achieve the thermal performance required by the National Construction Code - Building Code of Australia. This can be achieved by installing a discontinuous stud frame with insulation on the inside of the concrete panel.

It should be noted that whilst adding insulation and a light weight sheet lining to a stud frame wall will increase the overall Weighted Sound Reduction Index (Rw) performance of the wall, it will actually reduce the sound reduction performance of the wall at the low frequencies where optimised performance is required. Care must therefore be taken in the design of the mass wall / thermal insulation systems, to ensure that as far as is practical the high sound reduction performance of the wall is maintained in the low frequencies.

The predicted sound reduction performance of the 150mm concrete wall with discontinuous stud frame with glasswool insulation and plasterboard lining is:

Sound Reduction Performance – Concrete Walls						
High Mass Wall System	**Insulated Concrete wall** ▪ 150 concrete ▪ 15mm discontinuity ▪ 75mm stud frame + 75mm glasswool Insulation ▪ 13mm Plasterboard					
Weighted Sound Reduction Index		**R_W 72**		**R_W+C_{tr} 61**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	35	32	36	43	48	52
Octave Band		34			46	

Table 5.1 – Sound Reduction Performance - Concrete Wall Systems

The low frequency performance of the wall can be increased by adding a second layer of plasterboard to the internal lining. This increases the low frequency octave band performance to 37dB at 63 Hz and 55 dB at 125Hz.

Cavity Brick Walls: Cavity brick construction is commonly used for low rise residential apartments of 2 to 3 floors. To achieve the required thermal rating, the standard practice has been to locate a thermal insulation board in the cavity.

However, with very recent changes to the fire safety provisions of the BCA, rigid insulation products which may be considered 'combustible' are no longer acceptable for use in façade cavities of multi-story residential developments. At this stage it appears most likely that where reflective foil in the cavity is inadequate, the only remedy in this regard is to utilise Rockwool or other 'non-combustible' mineral wool fibre batt insulation products, rather than the traditional rigid board types. Before and after Laboratory Acoustic tests of insertion of mineral wool in the cavity of a cavity brick wall indicates that the mineral wool neither increases nor decreases the sound reduction performance of the cavity wall. The predicted sound reduction performance of this wall construction is tabulated below:

Sound Reduction Performance – Cavity Brick Wall						
High Mass Wall System	**Cavity Brick Wall** ▪ 90 Cavity Brick construction ▪ 50mm cavity ▪ Butterfly ties in cavity					
Weighted Sound Reduction Index		**R_W 49**		**R_W+C_{tr} 46**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	31	35	38	41	43	44
Octave Band		33			42	

Table 5.2 – Sound Reduction Performance Cavity Brick Wall Systems

The sound reduction of 33 dB at 63Hz and 42dB at 125Hz is not quite as good as concrete walls but represents very creditable acoustic performance.

5.3.3 <u>Stud frame- wall systems</u>

Typical stud frame constructions to address 'general environmental' low frequency noise (e.g. traffic), consists of an insulated dual stud wall systems. The system provides increased cavity depth and increased surface mass on both sides of the wall. A typical construction designed to achieve high performance suited to traffic noise is:

- 9mm fibre cement external sheeting (non-ventilated)
- Dual stud frame, insulated with fibre batt or building blanket, and
- 2 layer 13mm plasterboard internally

The predicted sound reduction performance of this wall construction is:

Sound Reduction Performance – Stud Framed Walls						
Stud Frame Wall System	**Light Frame – Dual Stud Wall** ▪ 9mm Fibre Cement - External ▪ Dual Stud insulated frame System ▪ 2 layers 13mm Plasterboard - internal					
Weighted Sound Reduction Index		**R_W 61**		**R_W+C_{tr} 49**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	9	17	24	31	37	42
Octave Band		13			34	

Table 5.3 – Sound Reduction Performance - Stud Frame Wall Systems

Although the overall Rw rating is high, the low frequency Sound Reduction performance of this light weight wall system is significantly below the performance of the mass wall systems. Also, the current trend towards externally ventilated cavities will further degrade the sound reduction performance. This construction is not suited to the Northbridge precinct as low frequency sound reduction performs very poorly. This demonstrates that use of the Rw and Rw + Ctr ratings are not suited to the evaluation of low frequency music intrusion.

5.3.4 Overview of External Wall Construction for the Northbridge Precinct

It is evident that stud frame construction provides limited sound reduction performance in the 63 Hertz octave band compared to the performance of high mass wall constructions and is therefore not suited for use in residential buildings subject to music entertainment noise within the Northbridge Precinct.

To address music noise emission from entertainment venues, the external wall construction to Residential buildings within the Northbridge Precinct must provide high level of sound reduction performance in the 63Hz and 125Hz octave bands. This can be achieved using high mass constructions such as concrete and cavity brick. These wall systems generally have a surface mass ≈ 400 kg/m^2.

5.4 Sound Reduction of Window Systems

In apartment buildings glazed doors and windows are often the major elements of the façade. The type of glazing systems will therefore have a significant effect on the overall Sound Reduction performance of these facade. Factors that influence the performance of glazed systems include:

- Type of window system – awning window / sliding window / sliding door etc;
- The quality of the frame – thickness of the aluminium;
- Type and quality of the seals; and
- The performance of the glass used in the system.
- Cavity size in double glazed systems

This report specifically addresses building constructions for the Northbridge Entertainment Precinct where the dominant and concerning noise is the low frequency noise specifically the 63 and 125 Hertz octave bands.

As previously noted reliable Laboratory test data of the sound reduction performance of window systems in the 63 Hertz octave band is not generally available. For this reason this reports provides sound reduction performance data based on predictions using INSUL (V9.0.17).

The predictions used in this assessment are based on the glass type and do not consider the performance of the frame and/or seals. The acoustic influence of the frame and seal is usually evident in the mid and high frequency region of the sound spectrum. These frequencies are of reduced acoustic importance when considering music entertainment noise intrusion. It is assumed that windows with glazing systems to address low frequency noise will be commercial quality frames with appropriate seals. Laboratory test data for the normal acoustic test range of 100 to 5,000 Hertz must be available.

5.4.1 Single Glazing Systems – Northbridge New Construction

The glazing commonly used in new Northbridge projects is 10.38mm laminated glass to living areas and bedrooms. This is generally considered to be the default approach to deal with general urban environmental and traffic noise.

More recently with the concern over low frequency noise intrusion, some new projects are proposing 12.38 mm laminated glass in bedrooms. However, increasing the thickness of glass by 20% provides minimal change in performance. For this study we have therefore selected an acoustic upgrade to the higher acoustic performance 12.5mm Viridian VLam Hush glass.

Table 5.4 below sets out the predicted Weighted Sound Reduction Index (Rw) for standard 6mm glass and the 2 acoustic glass options of 10.38mm laminated and 12.5mm Viridian VLam Hush glass . The sound reduction in the low frequency 63 Hz and 125Hz Octave bands for these glass systems is also provided.

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Sound Reduction Performance – Single Glazing						
Glazing Type	**Single Glazing** ▪ 6mm Glass					
Weighted Sound Reduction Index		**R_W 28**		**R_W+C_{tr} 26**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	15	15	16	17	18	19
Octave Band		15			18	
Glazing Type	**Single Glazing** ▪ 10.38mm Laminated Glass					
Weighted Sound Reduction Index		**R_W 33**		**R_W+C_{tr} 30**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	19	20	20	21	22	24
Octave Band		20			22	
Glazing Type	**Upgraded - Single Glazing** ▪ 12.5mm Viridian V-Lam Hush					
Weighted Sound Reduction Index		**R_W 35**		**R_W+C_{tr} 33**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	23	24	24	25	26	28
Octave Band		23			26	

Table 5.4 – Sound Reduction Performance – Single Glazing systems in new construction – Northbridge Area

The increase of 3 to 4 dB in sound reduction in the 63Hz and 125 Hz octave bands to achieve a sound reduction of 23dB at 63 Hz and 26 dB at 125Hz using the 12.5mm VLam Hush glass is a worthwhile improvement. However it is still well below the sound reduction of 34dB at 63 Hz achieved by the high mass wall systems.

5.4.2 Thermal Double Glazing

Double glazing systems with small air cavities are referred to as thermal double glazing systems. The performance of standard 6/12/6 thermal double glazing with a small air cavity provides significant improvement in thermal performance but negligible improvement in sound reduction performance compared to single 10.38 mm laminated glass systems.

Use of thicker 10.38 mm laminated glass to one side of the 6/12/10 thermal double glazing improves the 63 and 125Hz octave band data to be comparable to the 12.5 V-Lam Hush glass. However, its mass air mass resonant frequency is in the 250 Hertz octave band and significantly drops the performance in this Low /mid frequency region. This is a concern. The overall low frequency sound reduction performance is still well below the sound reduction of 34dB at 63 Hz and 46 dB at 125 Hz achieved by the high mass wall systems.

The overall sound reduction performance in terms of the Weighted Sound Reduction Index (Rw) and R_W+C_{tr} of these systems are set out in Table 5.5. The sound reduction in the low frequency 63 Hz and 125Hz Octave bands for these glass systems is also provided.

Sound Reduction Performance - Thermal Double Glazing						
Thermal Double Glazing Overall Thickness: 24mm	**Standard Thermal Double Glazing** ▪ 6mm glass ▪ 12mm air cavity ▪ 6mm glass					
Weighted Sound Reduction Index		**R_W 32**		**R_W+C_{tr} 27**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	19	20	21	22	22	21
Octave Band		20			22	
Thermal Double Glazing Overall Thickness: 25mm	**Upgraded Thermal Double Glazing** ▪ 6mm glass ▪ 12mm air cavity ▪ 10mm Laminated glass					
Weighted Sound Reduction Index		**R_W 39**		**R_W+C_{tr} 33**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	24	24	25	25	25	24
Octave Band		24			25	

Table 5.5 – Sound Reduction Performance – Thermal Double Glazing in new construction – Northbridge Area

5.4.3 Acoustic Double Glazing

Acoustic double glazing is characterised by the use of a large air cavity compared to thermal double glazed systems. To achieve improved acoustic performance, air cavities greater than 50mm are required. To address the dominant frequencies associated with general environmental noise (predominantly traffic noise), the air cavity is usually in the order of 75mm. A typical construction is:

- External glazing: 10.38mm laminated glass
- 75mm air cavity
- 6mm internal glass as an internal secondary window or sliding door

This construction is normally constructed using a secondary glazing system. The building is provided with a normal 10.38mm glass window system in the façade. A second window frame is then installed with 6mm glass internal from the normal external window. The overall sound reduction performance in terms of the Weighted Sound Reduction Index (Rw) and R_W+C_{tr} of this construction systems is set out in Table 5.6. The sound reduction in the low frequency 63 Hz and 125Hz Octave bands for these glass systems is also provided.

Sound Reduction Performance – Acoustic Double Glazing						
Acoustic Double Glazing Type	**Acoustic Secondary Glazing** ▪ 10.38mm Laminated Glass in building facade ▪ 75mm air cavity ▪ 6mm glass in internal secondary window					
Weighted Sound Reduction Index		**R_w 44**		**R_w+C_{tr} 37**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	23	18	15	20	25	29
Octave Band		17			23	

Table 5.6 – Sound Reduction Performance – Acoustic Double Glazing Systems

With increased cavity width the overall sound reduction performance in terms of the Weighted Sound Reduction Index (Rw) performance increases significantly, by 5dB compared to upgraded 10/12/6 Thermal Double Glazing. Also the Rw+Ctr performance which is an indicator of its lower frequency sound reduction performance increase by creditable 4 dB, but this is due to the superior performance in the mid to high frequencies from 250 Hz upwards, rather than low frequencies of 50 to 125 Hz.

It is of significant interest to note the very low frequency sound reduction performance in the 63Hz octave bands actually drops to below the performance of the 10mm single glass, and also below the performance of the 6/12/6/ thermal double glazing units. This is because the mass-air-mass resonant frequency for the acoustic double glazing system occurs at approximately 70 Hertz – that is within the upper portion of the 63Hertz octave band. There is a significant dip in the Sound Reduction performance at this mass-air-mass resonant frequency. So although the acoustic double glazing provides significant reduction in the overall noise intrusion as indicated by the Weighted Sound Reduction Index (Rw) performance, the very low frequency noise associated with music entertainment venues is less attenuated. This form of glazing is therefore not suited to those locations where low frequency external noise associated with music entertainment venues is involved.

5.4.4 Balcony Glazing

The Sound Reduction performance of the glazing systems discussed above have significantly reduced low frequency performance compared to the Sound Reduction performance of high mass masonry wall systems. In effect the Sound Reduction performance of a building façade with single glazing or even thermal or acoustic double glazing is totally controlled by the performance of the window system.

To achieve any significant improvement in the low frequency performance of the façade, the Sound Reduction performance of glazing needs to achieve similar performance to the mass wall. To achieve this a very large cavity within the glass system is required – minimum 1 metre wide. This can be achieved by means of fully glazing the apartment balcony. The construction is then:

- A fully glazed balcony with openable windows – 6mm glass
- Minimum 1 metre wide balcony
- 100mm Glasswool insulation at 24 kg/m3 density applied to underside of balcony soffit with perforated metal face; (Minimum Weighted Absorption Coefficient (α) of 0.8)
- Glazing to habitable rooms to be comprised of minimum 10.38mm laminated glass

The acoustic absorption within the balcony void between the two glass systems is important as it provides a significant increase in performance. The INSUL prediction indicates an increase in sound reduction performance in the balcony window system by providing acoustic absorption to the balcony ceiling of:

63Hz octave Band: 7dB 125 Hz Octave band 10 dB.

This is represents a very significant increase in performance.

The acoustic absorption can be installed as an acoustic ceiling to the balcony. Clearly low frequency absorption is important. An example of a preferred acoustic ceiling treatment to the balcony is a perforated metal sheet with 100mm thick glass wool insulation at a density of ≈ 14 kg/m3.

This is in effect a two window system. The *Balcony Glazing* will consist of fixed glazing to 1m height to comply with design codes for a balcony. Above this level the windows may be 2 sets of multi sliders to allow the windows to be moved to the each side of the balcony to provide a wide unobstructed opening as per a normal balcony. The glazing to the living area or bedroom will be openable glazing as per a normal apartment, with glazing designed to address the normal environmental noise intrusion with the balcony windows open. The glass should be not less than 10.38mm laminated glazing or equivalent.

With the large air gap (minimum 1 metre), the mass-air-mass resonant frequency is moved down the frequency range to 18 Hertz. This is well below the lowest frequency of concern which is the 40 Hertz 1/3 octave band.

Glazing Formats: The sound reduction of two glazing formats have been considered.

Balcony Glazing System

Balcony Glazing: 6mm Glass
Balcony depth: minimum 1 metre
Balcony Acoustic Ceiling:
Acoustic Absorption α = 0.95
Habitable room Glazing: 10.38mm Lam Glass

Upgraded Balcony Glazing

Balcony Glazing: 6.38mm Lam Glass
Balcony depth: minimum 1 metre
Balcony Acoustic Ceiling:
Acoustic Absorption α = 0.95
Habitable room Glazing: 12.5 VLam Hush

The predicted sound reduction performance of the Balcony Glazing systems as above are set out in Table 5.7 and 5.8.

Sound Reduction Performance – Balcony Glazing System						
Balcony Glazing	**Balcony Glazing -2 window system** ▪ 6mm Glass to balcony (openable for ventilation) ▪ 1m wide Balcony (minimum) ▪ Balcony ceiling insulated α = 0.95 ▪ 10mm glass to habitable room					
Weighted Sound Reduction Index		**R_W 64**		**Rw+C_{tr} 56**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	33	35	37	40	44	47
Octave Band		35			43	

Table 5.7 – Sound Reduction Performance - Balcony window system with acoustic absorbent ceiling

Installing Balcony Glazing system with a minimum 1 metre width balcony / air gap significantly increases the low frequency Sound Reduction performance through the window system, to match the performance provided by a high mass wall system. The high mass wall system provides a low frequency sound reduction of:

63Hz octave Band 34 dB 125 Hz Octave band 46 dB

This then represents a very significant improvement in the Sound Reduction performance of the façade and provides a practical limit in terms of Sound Reduction performance of the façade. It specifically targets the low frequency sound reduction performance requirements for residential buildings subject to music entertainment noise.

Upgraded Balcony Glazing System: The Balcony system can be upgraded by installing specialist high performance acoustic glazing in the windows to habitable rooms. The INSUL prediction for this Upgraded Balcony Glazing System is set out in Table 5.8

Sound Reduction Performance – Upgraded Balcony Glazing						
Upgraded Balcony Glazing	**Balcony Glazing -2 window system** ▪ 6.38mm Lam. Glass to balcony (openable for ventilation) ▪ 1m wide Balcony (minimum) ▪ Balcony ceiling insulated α = 0.95 ▪ 12.5mm Viridian VLAm Hush glass to habitable room					
Weighted Sound Reduction Index		**R_w 66**		**$Rw+C_{tr}$ 60**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	37	39	41	44	48	51
Octave Band		39			47	

Table 5.8 – Sound Reduction Performance Upgraded Balcony window system with acoustic absorbent ceiling

In this scenario the sound reduction performance of the glazing system exceed the performance of the mass concrete wall system. If this system is to be used it must be accompanied by an upgraded wall system to match the balcony glazing performance. As the cost of this upgrade is in the cost of the high acoustic performance glass in the habitable space, it may be a consideration in just the bedroom.

Utilisation of Balcony Glazing systems: Balcony Glazing systems are intended to address the low frequency noise intrusion associated with the Northbridge Entertainment Industry which occurs around the 11 pm to 1 am time slot, on typically Friday and Saturday nights. With <u>minimum</u> 10.38mm laminated glass to the façade wall of the Living area and Bedrooms, the general environmental daytime noise in the region of 60 dB(A) and 68 dB(C)[2] is adequately attenuated. The balcony windows can be left open during the day and evenings and then closed at night to control the low frequency noise intrusion.

Design Implications: All new apartment designs would have to include balconies adjacent to all Bedroom and Living Areas windows, to enable the Balcony Glazing approach to be applied. How enclosing of the balcony:

a) Impacts on various planning requirements in terms of plot ratios and area calculations,
b) Affects natural ventilation requirements,
c) Impacts on the location and costs of precluding air-conditioning equipment from balconies,

are not addressed in this report. In this acoustic assessment, it suffices to say that Balcony Glazing is extremely effective in increasing low frequency Sound Reduction performance of the façade. The large cavity (> 1m) provided by the Balcony Glazing system and ceiling insulation provides a level of sound reduction performance comparable to the 150mm Concrete wall system.

5.4.5 <u>Overview of window systems</u>

Single and Thermal Double Glazing Systems: Current standards for glazing in the Northbridge Precinct are for single glazed system generally using 10.38mm laminated glass. An alternative glazing system is the thermal double glazing using small air cavities. The low frequency (63 Hertz octave band) performance of these glass systems achieve a sound reduction of ≈22 dB. Although this performance addresses general environmental noise it does not address the low frequency “doof-doof” noise intrusion associated with music entertainment noise. The sound reduction performance of these glazing systems are well below the sound reduction performance of masonry walls that achieve sound reduction in the 63 Hz octave band of ≈ 34 dB.

Increasing the thickness of glass in these single glazed and thermal double glazed units provides a marginal improvement in low frequency sound reduction performance, but is still well below the performance of the high mass wall systems. As such these systems are considered inadequate to address entertainment noise in the Northbridge Precinct.

Acoustic Double Glazing: Interestingly, acoustic double glazing with the larger 75mm air cavity provides improvement in the overall sound reduction performance compared to single 10.38mm laminated glass as evident in the Weighted Sound Reduction Index (Rw) and the Rw+Ctr performance. However, its performance in the 63 Hz octave band is less than single glass. This is due to the mass-air-mass resonant frequency, which for this system falls within the 63 Hertz octave band. This type of glazing system is therefore not suitable for use in locations near music entertainment venues.

Balcony Glazing: To significantly increase the sound reduction performance in the 63 Hz octave band requires a very large cavity, greater than 1 metre. Glazing the balcony and having all living and bedroom areas open onto the balcony achieves the large air cavity requirement between the two window system. This, plus acoustic absorption to the balcony ceiling is required to achieve a mass-air-mass resonant frequency below 40 Hz.

With 6 mm glass to the balcony window system, and a 10.38mm glazing system designed to address the general ambient environmental noise, the combined effect of these two window systems provides a significant increase in the low frequency sound reduction performance to address the entertainment, “doof-doof” music noise intrusion.

5.5 Sound Reduction of Roof Ceiling Systems

With the acoustic upgrading of the façade using balcony glazing a significant increase in the low frequency sound reduction performance of the façade is achieved. To ensure that the top floor apartments achieve similar acoustic performance, the roof ceiling construction for these apartments will need to be upgraded to also address the low frequency sound transmission.

Normal light weight framed roof ceiling construction provides limited sound reduction performance, particularly in the low frequencies. The performance can be improved by increasing cavity width and adding sheets of fibre cement / plasterboard at both the roof and ceiling levels. Alternatively, a mass construction such as concrete slab can be considered.

The overall sound reduction of the roof ceiling system should be designed to achieve similar low frequency sound reduction performance to that achieved through the building façade. Depending on the roof type, and the height of the building there may be some acoustic screening effect achieved by the massing of the building, although this would have to be reviewed on a case by case basis.

5.5.1 Light Frame Roof Ceiling Construction

Standard Roof Ceiling Construction: The common roof ceiling construction specified for Apartments in urban environments where traffic noise is the primary consideration consists of:

- Metal roof sheeting 0.42 BMT
- Anticon insulation supported on mesh
- 400 ceiling void with Light steel grid suspension and R3 insulation
- 1 sheets 13 mm plasterboard to living areas

The predicted sound reduction performance of this roof ceiling constructions provides limited sound reduction performance in the low frequencies.

Sound Reduction Performance – Metal Roof						
Roof Ceiling Construction	**Light Frame Construction** ▪ Metal roof over Anticon ▪ 400mm void with R3 insulation ▪ **1** layer 13mm Plasterboard					
Weighted Sound Reduction Index		**Rw 44**		**Rw+Ctr 37**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	3	8	15	20	26	29
Octave Band		6			24	

Table 5.9 – Sound Reduction Performance in 1/3 Octave Bands

It is evident from above that this 'standard' construction provides very limited control of low frequency intrusion.

5.5.2 Upgraded Light Frame Roof Ceiling Construction

The light frame roof ceiling construction provides poor sound reduction performance in the low frequency. To upgrade the light frame roof ceiling construction to achieve a significant improvement in low frequency region requires a large ceiling void plus some mass at both roof and ceiling level. An example of an upgraded construction is:

- Metal roof sheeting 0.6 BMT over
- Anticon insulation
- 9mm fibre cement sheeting fixed at roof level
- 900 ceiling void with light steel grid suspension
- R3.0 insulation
- 2 sheets 13mm plasterboard

The predicted sound reduction performance of this roof ceiling construction is with 2 sheets of 13mm Plasterboard to the ceiling is set out in Table 5.10:

Roof Ceiling Construction	**Upgraded Light Frame Construction** ▪ Metal roof over Anticon ▪ 9 mm Fibre cement fixed at roof level ▪ 900 void with R3 insulation ▪ 2 layers 13mm Plasterboard					
Weighted Sound Reduction Index		**Rw 59**		**Rw+Ctr 51**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	29	32	34	36	37	41
Octave Band		31			37	

Table 5.1 0 – Sound Reduction Performance in 1/3 Octave Bands

Overview: Increasing the surface mass at roof and ceiling level and increasing the size of the ceiling void depth provides a significant improvement in low frequency performance compared to standard construction systems but still is still lower than the low frequency sound reduction performance of façade wall systems with mass wall and Balcony Glazing. Possibly with tall buildings or buildings with large parapets adequate barrier / screening effect can be can be achieved. This would need to be reviewed on a case by case basis.

5.5.3 Concrete roof

The alternative option to light frame roof ceiling construction is a high mass roof such as concrete. Concrete roofs are normally installed with an insulated metal roof over. Typically the ceiling is then similar to all floors below being a skim coat ceiling direct to the concrete in all living areas. The construction is then:

- Metal roof sheeting 0.42 BMT over
- Thermal insulation -R3
- 150 concrete
- Skim coat ceiling to habitable area

The predicted sound reduction performance of this roof ceiling construction is set out in Table 5.11:

Sound Reduction Performance						
Roof Ceiling Construction	**High Mass Construction** ▪ Metal Roofing 0.6 BMT ▪ 145 cavity with R 3.5 insulation ▪ 150mm Concrete with skim coat ceiling					
		R_W 60		**$Rw+C_{tr}$ 56**		
Frequency (Hz)	**50**	**63**	**80**	**100**	**125**	**160**
1/3 octave band	35	33	37	44	50	55
Octave Band		35			48	

Table 5.11 – Sound Reduction Performance of Concrete Roof construction

This concrete roof construction matches the sound reduction performance of the walls and Balcony Glazing system.

5.5.4 Recommended Roof Ceiling Construction

The preferred roof construction is a high mass roof being a concrete slab. This requires an insulated metal roof over the concrete but allows for a skim coat ceiling.

If light frame roof construction is required, then to achieve worthwhile improvement in Sound Reduction performance in the 63 and 125Hz octave bands requires a minimum 1 metre ceiling void. In addition increased surface mass is required at both roof level to increase low frequency sound reduction performance via the roof. The adequacy of this construction would need to be checked for the specific site situation.

5.6 Summary

5.6.1 Sound Reduction Performance

Laboratory test data of the Sound Reduction Performance of building materials or construction is not available for the low frequency region below the 125 Hz octave band. For this reason the sound reduction performance for the various wall systems considered in this report have been determined utilising the Sound Insulation Prediction model INSUL (V9.0.17).

5.6.2 Stud Frame Walls

External stud framed wall systems provide limited sound reduction performance in the 63 Hertz octave band. Stud frame walls are not suitable for facade wall construction in areas subject to music entertainment noise.

5.6.3 High Mass Wall Constructions

High mass walls constructed of concrete, brick or blockwork have high surface density. These wall systems can provide significant sound reduction performance in the low frequency region being 63Hz and 125 Hz octave bands. It is recommended that all residential buildings in the Northbridge Precinct be required to use high mass wall systems. That is a construction with a surface density > 300kg/m^2.

5.6.4 Glazing Performance

Predictions of the Sound Reduction performance for glazing systems have been carried out using INSUL Sound Insulation Prediction (v9.0.17) software. To address the low frequencies requires a very large air cavity, to ensure the mass-air-mass resonance falls below 40 Hertz. This cannot be achieved by acoustic double glazing or secondary glazing options. In fact, this can only be achieved by glazing the outer perimeter of the balcony and using the balcony itself as the large cavity, of minimum 1m width.

Where Balcony Glazing cannot be provided, high performance single glazing, minimum 12.5mm VLam Hush glass or glazing of similar laboratory tested performance may be considered. Upgraded thermal double glazing of the 10.38/12/6 format may also be considered. Glazed areas should then be minimised, to limit window areas to the minimum area requirements of the Building Code of Australia (BCA) - Part F4 (i.e. 10% equivalent of a habitable space Floor Area - must be 'light transmitting area'). However, this approach is unlikely to be suited to locations close to entertainment venues, as it still well below the potential of the overall façade system given the high performance of concrete mass walls. In addition, a large reduction in glass area will impact on daylight and view, which may not be palatable to developers / purchasers.

5.6.5 Roof Ceiling Constructions

The preferred construction is a high mass roof being a concrete slab. This requires an insulated roof over, but allows for a skim coat ceiling common in modern apartments.

If light frame roof construction is required, then to achieve improved sound reduction performance in the 63 and 125Hz octave bands requires additional mass at roof and ceiling levels and a minimum 1 metre ceiling void.

5.7 Synopsis

A synopsis of the Sound Reduction provided by the various constructions is set out in Table 5.12. It provides a quick view of the sound reduction performance of the various systems. The intent is that a glazing system is selected that matches the low frequency 63Hz and 125Hz Octave Bands the sound reduction performance achieved by the High Mass Concrete Wall System; i.e.

63 Hz 34 dB and 125 Hz octave Band 46 dB

The costs provided in the Table below are the costs in dollar / sq. metre for each particular option as provided by the Quantity Surveyor - see Section 8, Table 8.1.

Low Frequency Sound Reduction of Construction Formats					
Construction	**Rw**	**Rw+Ctr**	**Octave Band dB(Lin) 63 Hz**	**125 Hz**	**Cost $ / m2**
WALL CONSTRUCTION					
High Mass Wall System - Concrete	72	61	**34**	**46**	**$ 330**
Cavity Brick Wall	49	46	**33**	**42**	
Light Frame Dual Stud	61	49	13	34	
GLAZING SYSTEMS					
Single Glazing Systems					
6mm glass	28	26	15	18	$ 40
10.38mm Laminated	33	30	20	22	$ 83
12.5mm V-Lam Hush	37	34	23	26	$ 86
Thermal Double Glazing					
6mm glass - 12mm Air - 6mm Glass	32	27	20	22	$ 138
6mm glass - 12mm Air – 10.38 Lam Glass	39	33	24	25	$ 182
Secondary Glazing					
10.38 lam Glass-75 Air-6mm glass	44	37	17	23	$ 550
Balcony Glazing					
6mm glass 1m cavity 10.38 mm glass	64	56	**35**	**43**	**$ 771**
6.38mm Lam / 1m cavity / 12.5mm Viridan VLam Hush	69	63	**39**	**47**	**$ 788**
Acoustic Ceiling to Balcony					$ 165
ROOF-CEILING CONSTRUCTION					
Light Frame Construction	44	37	6	24	$ 370
Upgraded Frame Construction	59	51	31	37	$ 540
Concrete Roof Construction	60	56	**35**	**48**	**$480**

Table 5.12 Synopsis – Sound reduction of constructions

6. ACOUSTIC PERFORMANCE OF NORTHBRIDGE RESIDENTIAL BUILDINGS

6.1 Requirements to Address Northbridge Noise Environment

6.1.1 Ambient Noise in Northbridge

The ambient noise in the Northbridge area is high. Daytime noise levels are in the region 60dB(A) and 68dB(C) Night time noise levels including entertainment noise are generally over 65 dB(A).

The ambient noise is generally associated with the buzz of the Northbridge area and is a result of traffic, pedestrian and general activity within Northbridge. However after 10pm the music entertainment industry kicks in and there is a significant increase in the low frequency energy within the general ambient noise, characterised by the intruding 'doof-doof' noise.

Generally, the ambient noise level throughout the day significantly exceeds the Assigned Level as established in the Environmental Protection (Noise) Regulations.

The Façade of Northbridge residential buildings must therefore address the general ambient noise level, as well as the low frequency noise intrusion.

6.1.2 Calculations of Internal Noise Levels

The purpose of the following calculations is to determine the indoor ambient noise level within an apartment to compare to internal background noise criteria. Issues considered in the calculation procedure included:

- For calculation purposes the design external noise is taken as 65 dB(A),and 79 dB(C) and based on the noise spectrum provided by DWER (See Section 3.3)
- Façade acoustic insulation values determined in accordance with ISO 12354
- Acoustic absorption within the room based on the acoustic absorption properties of internal room finishes and furniture.

6.1.3 Construction to Address Low Frequency Noise Intrusion

Section 4 of this reports identifies the constructions that can be used to maximise sound reduction performance through the façade of multi storey residential buildings to address the low frequencies being the 63 and 125 Hertz octave bands. Generally the requirements are:

- Utilise constructions with high surface mass (masonry / concrete)
- Where materials with low surface mass are used, incorporate large cavities to address the 63 and 125 Hertz octave bands
- Design apartments to enable the use of glazed balconies to maximise the sound reduction through the window system.
- Roof ceiling constructions for top floor apartments require high surface mass constructions.
- Where light frame roof/ceilings are used they require increased mass at both roof and ceiling level and minimum 1m ceiling void.

6.2 Practical Design Approach to Northbridge Residential Development

The realities of Apartment design are that bedroom and living areas are located on the façade to access daylight and view. Non-habitable spaces that do not require an external windows are located internally away from the façade. Living areas normally incorporate the kitchen facility as part of the open main living area.

Once a site within the Northbridge precinct is identified for development as residential or mixed use, there are generally limited opportunities to address generic 'quiet house' design guidelines such as:

- Orientation and layout to take into account location of nearby noise emitting sources

- Location of bedrooms and living areas in the floor plate design to screen these rooms from the noise sources, or
- Use of building massing to provide effective acoustic buffers or screening effect

As the above issues cannot be addressed on confined sites typical of inner city building, to take into account multiple existing (or future) venue noise sources, it is then a requirement that the façade of the building be constructed to address the intrusion of low frequency noise associated with music noise intrusion.

6.2.1 Typical Apartment Design

Plan and elevation of the Reference apartment used for assessment purposes are set out in :

Figure 6.1: One Bed Apartment plus Living
Figure 6.2: Two Bed Apartment plus Living

As can be seen, the bedroom or living area in these Apartments have very similar façade sizes and overall area dimensions. In this assessment we have based calculations on a bedroom and living area in the single bed unit with large balcony. The dimensions are:

Living Area

- Dimensions: 4.2m wide; Depth 7.2m; Height 2.7m
- Overall floor area: 30.2 m^2
- Overall front façade area: 11.1 m^2
- Glazing to Living area Width 4.1m glazing to 2.1 metres high, area of **8.6m^2**
  *Represents **28% of floor area** and 77% of the relevant Living façade area*

Bedroom:

- Dimensions: 3.1m wide; Depth 3.8m; Height 2.7m
- Overall floor area: 11.8 m^2
- Overall front façade area: 8.4 m^2
- Glazing to bedroom – Full width 3.1m glazing to 2.1 metres high, area of **6.5m^2**
  *Represents **55% of floor area** and 77% of the relevant Bedroom façade area*

Surface finishes used in the assessment are:

- Floor: Carpet to Bedroom, Timber to Living Area
- External walls: Insulated concrete wall
- Internal Walls: Stud frame
- Ceiling: Skim coat to concrete
- Typical furnishings in a modern apartment

The design provides a balcony that can accommodate Balcony Glazing to all bedrooms and living areas.

The design of two bedroom units are similar to the above, except that a second bedroom is located on the façade, with continuous balcony along the front of both the bedrooms and living area.

In terms of the acoustic performance of various plan formats, the overall performance of the façade is determined by the glazing format. The performance is determined by glass area as a percentage of the floor area, with various construction options being assessed in the following parts of this report.

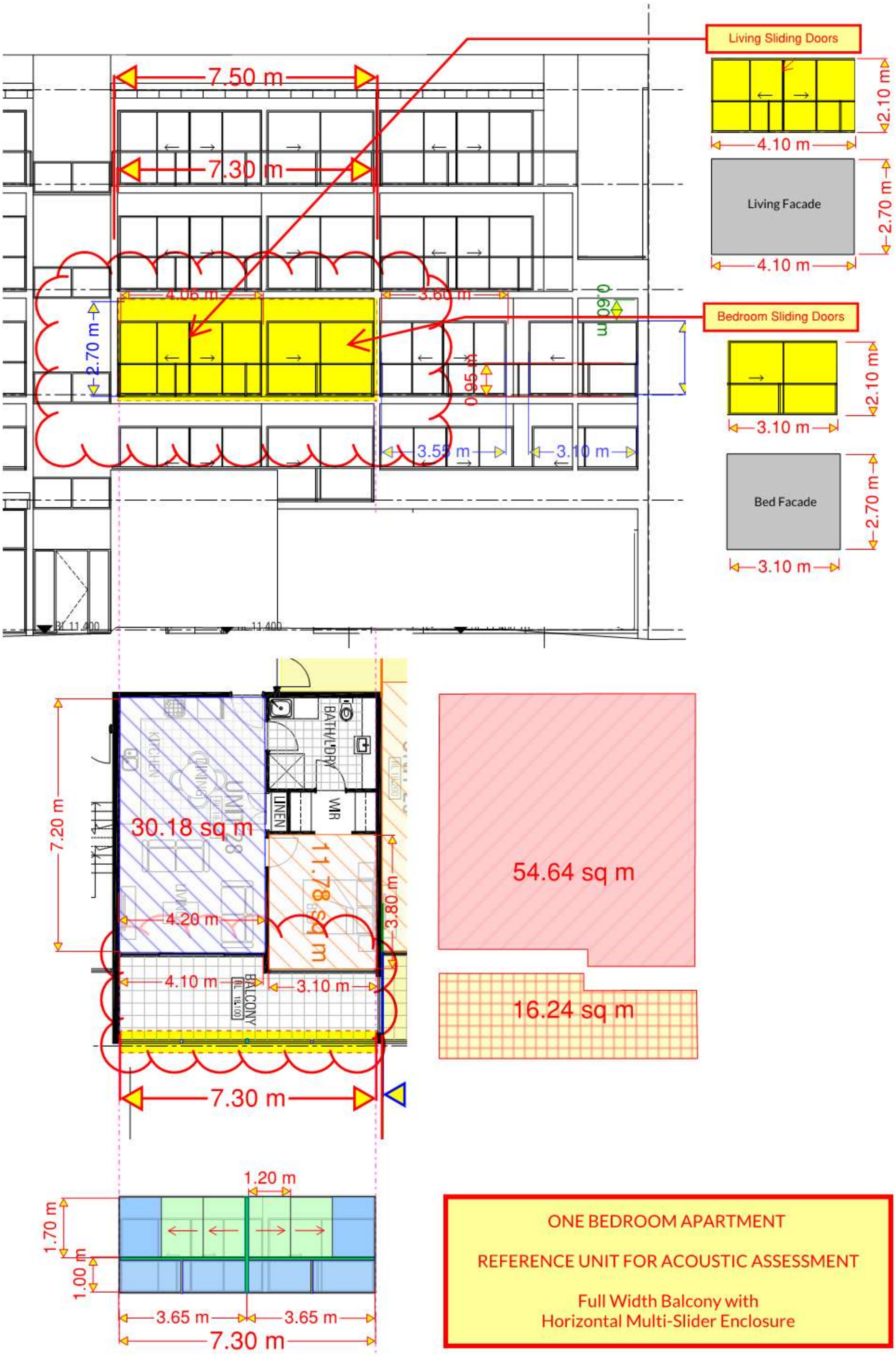
Living Sliding Doors
7.50 m
7.30 m
2.10 m
4.10 m
Living Facade
2.70 m
4.10 m
4.06 m
3.60 m
0.60 m
Bedroom Sliding Doors
2.70 m
0.95 m
2.10 m
3.10 m
3.55 m
3.10 m
Bed Facade
2.70 m
3.10 m
7.20 m
30.18 sq m
11.78 sq m
3.80 m
4.20 m
54.64 sq m
4.10 m
BALCONY
3.10 m
16.24 sq m
7.30 m
1.20 m
1.70 m
1.00 m
3.65 m
3.65 m
7.30 m
ONE BEDROOM APARTMENT
REFERENCE UNIT FOR ACOUSTIC ASSESSMENT
Full Width Balcony with
Horizontal Multi-Slider Enclosure

FIG 6.1

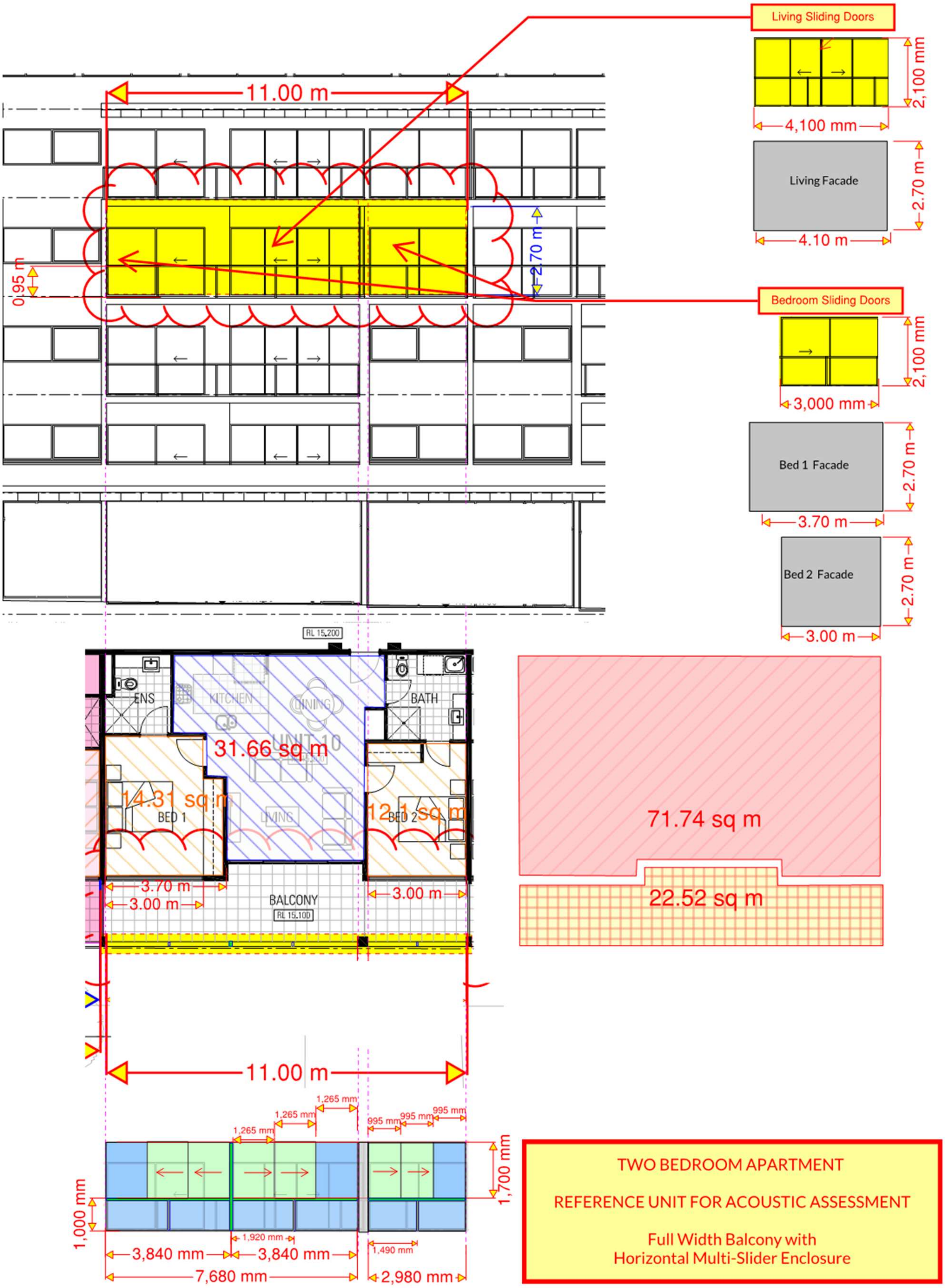
Living Sliding Doors
2,100 mm
4,100 mm
Living Facade
2.70 m
4.10 m
11.00 m
0.95 m
2.70 m
Bedroom Sliding Doors
2,100 mm
3,000 mm
Bed 1 Facade
2.70 m
3.70 m
Bed 2 Facade
2.70 m
3.00 m
ENS
KITCHEN
DINING
BATH
UNIT 10
31.66 sq m
14.31 sq m
BED 1
LIVING
12.1 sq m
BED 2
3.70 m
3.00 m
BALCONY
3.00 m
71.74 sq m
22.52 sq m
11.00 m
1,265 mm
1,265 mm
1,265 mm
995 mm
995 mm
995 mm
1,000 mm
1,700 mm
1,920 mm
3,840 mm
3,840 mm
1,490 mm
7,680 mm
2,980 mm
TWO BEDROOM APARTMENT
REFERENCE UNIT FOR ACOUSTIC ASSESSMENT
Full Width Balcony with
Horizontal Multi-Slider Enclosure

FIG 6.2

6.3 Current Construction Standard

6.3.1 Construction

Façade: Multi storey apartment projects constructed in the Northbridge area over the past years have mainly used AFS or Pre Cast Concrete construction. Currently the common standard for glazing of the façade is 10.38mm laminated glass to both Bedrooms and Living Area.

Also common in Northbridge residential apartments is standard thermal double glazing with 6mm glass and 12mm air gap and 6mm glass. As noted in 5.4.2, this has very similar performance to 10.38mm laminated glass and is therefore not separately considered.

Roof: For top floor apartments the standard roof/ceiling construction is a light steel frame roof ceiling as described in 5.5.1. The effect of the additional sound transmission through this roof ceiling construction is also considered.

The sound incident on the roof will be screened to some extent by the height of the building. However it is noted that the Northbridge music entertainment sound is somewhat omnipresent in that it is non directional and a result of many surrounding sources. There will be some screening effects at high frequencies and less in the lower frequencies. For the purposes of this study we have assumed a screening effect for sound incident on the roof of:

- 2 dB for the low 63 and 125 Hertz octave bands
- 3 dB for the mid frequency 250 and 500 octave bands, and
- 5 dB for the high frequency 1,000 to 4,000 octave bands

We note that depending on location within the Northbridge Precinct and the height of the building this scenario may significantly change, and much higher levels may apply for screening effect

6.3.2 Noise Source: The frequency spectrum used as the noise source in the following calculations to determine the performance of various façade systems is the spectrum provided by DWER, as set out in Table 3.2. Based on 2010 measurements, DWER provided a sound level of L_{Aeq} 2hr of 65 dB(A)as a nominal ambient level near residences. **For the purposes of calculation, the DWER 'composite venue spectrum' has therefore been adjusted to provide an overall sound level of 65 dB(A).** This spectrum is a composite of external noise measurements taken in the Northbridge area, to represent conditions adjacent to residential buildings, where the low frequency noise associated with music entertainment venues is clearly audible.

The L_{Aeq} of 65 dB(A) is an energy average over a 2 hour period. There will of course be a variation about this mean.

6.3.3 Living Area Façade with Single Glazing - 10.38mm Laminated Glass

The predicted Level of Noise Intrusion into the Living Area with dimensions and finishes as per 5.2.1 have been determined at:

Predicted Level of Noise Intrusion		
Typical Living Area **Single Glazing – 10.38mm** **Glazing 28% of floor Area**	**Construction:** ▪ Insulated concrete external wall-Façade ▪ 10.38mm Single Glazing (7.5m^2) – 77% of Façade Area ▪ Concrete Floor slab with skim coat ceiling	
External Noise Level L_{eq}:	**65 dB(A)**	**79 dB(C)**
Predicted Internal Level L_{eq}:	**37dB(A)**	**58 dB(C)**
Assigned Level - adjusted for music and indoor measurement L_{10} 20dB(A) + 6dB/-4dB	**20 dB(A)**	
Frequency (Hz)	**63 Hz**	**125 Hz**
Predicted Octave Band Lp (Lin)	59 dB	47 dB
DEFRA Criteria dB (Lin)	47 dB	41 dB

Table 6.1 – Predicted Performance – Living Area with Balcony Performance

6.3.4 Bedroom Façade with Single Glazing - 10.38mm Glass -

The predicted Level of Noise Intrusion into the bedroom with dimensions and finishes as per 5.2.1 have been determined at:

Predicted Level of Noise Intrusion		
Typical Bedroom **Single Glazing – 10.38mm** **Glazing 55% of floor Area**	**Construction:** ▪ Insulated concrete external wall-Façade and Side wall ▪ 10.38mm Lami. Glass (6.5m^2) – 77% of Facade Area ▪ 150mm Concrete with skim coat ceiling	
External Noise Level L_{eq}:	**65 dB(A)**	**79 dB(C)**
Predicted Internal Level L_{eq}:	**37 dB(A)**	**59 dB(C)**
Assigned Level -adjusted for music and indoor measurement L_{10} 20dB(A) + 6dB/-4dB	**20 dB(A)**	
Frequency (Hz)	**63 Hz**	**125 Hz**
Predicted Octave Band Lp (Lin)	59 dB	47 dB
DEFRA Criteria	47 dB	41 dB

Table 6.2 – Predicted Performance – Bedroom with Single Glazing – 10.38 mm laminated glass

The resultant level of Leq 36 to 37 dB(A) significantly exceeds Assigned Level adjusted for music and indoor measurement of L_{10} 20 dB(A) in both the living area and Bedroom; (See section 4.3). In addition, there is significant Low Frequency Noise (LFN) sound transmission in the 63 Hz and 125 Hz octave bands associated with the Northbridge music entertainment noise which exceed the DEFRA Criteria.

6.3.5 Penthouse Living Area with Single Glass Façade plus **Light Frame Roof**

The top floor apartments are subject to noise intrusion through the façade plus the roof. The predicted Level of Noise Intrusion into the Penthouse Living Area based on the roof construction as per 5.5.1 with dimensions and finishes as per 5.2.1 is:

Predicted Level of Noise Intrusion		
Penthouse Living Area **Light Frame Roof Ceiling** **Plus 10.38 glazing in Facade**	**Construction:** ▪ Metal roof plus Anticon ▪ Insulated 400mm ceiling void ▪ Light steel hangers with 13 Plasterboard ceiling	
External Noise Level L_{eq}:	**65 dB(A)**	**79 dB(C)**
Predicted Internal Level L_{eq}:	**50 dB(A)**	**75 dB(C)**
Assigned Level -adjusted for music and indoor measurement L_{10} 20dB(A) + 6dB/-4dB	**20 dB(A)**	
Frequency (Hz)	**63 Hz**	**125 Hz**
Predicted Octave Band Lp (Lin)	76 dB	51 dB
DEFRA Criteria dB (Lin)	47 dB	41 dB

Table 6.3 – Predicted Performance – Living Area with Light Frame Roof with 10.38 Glazing in Mass Wall facade

The resultant increased sound level is due to the very poor sound reduction performance of the roof ceiling system in the 63 Hertz octave band. It is evident that this Roof/Ceiling construction is inadequate for the Northbridge Precinct.

6.3.6 Overview – 10.38mm glass

Façade Performance: The resultant L_{eq} 36 to 37 dB(A) noise level in bedroom and living area with 10.38mm glass meets the requirement- of Australian standard AS2107:2016 *Acoustics - Recommended Design Sound levels and Reverberation Times for Building Interiors* of 35 to 45 dB(A) for intrusion of general environmental noise. However the Standard states that is not applicable for LFN Intrusion.

This level of L_{eq} 36 to 37 dB(A) significantly exceeds the Assigned Level adjusted for music and indoor measurement of L_{10} 20 dB(A). It is also significantly exceeds the DEFRA low frequency Noise Criteria in the 63 and 125 Hz octave bands.

The level of the noise intrusion into the bedroom can be improved by reducing the area of the window. Currently the window area in the Bedroom is set at 53% of the floor area. If the window area is reduced to 25% of the floor area this will provide a 3 dB reduction in noise level. This 3 dB reduction will not address the overall acoustic concerns and therefore is not helpful.

Similarly, reducing the area of the Living room window by 50% will not be very effective as it currently represents 25% of the floor area. A 3 dB reduction in noise intrusion is a noticeable improvement but it is still well above the Low Frequency Noise (LFN) Criteria. It should also be noted that a 50% reduction in glass areas impacts on daylight and view, which may not be palatable to developers / purchasers.

Penthouse Performance: The current standard of construction for a Penthouse in Northbridge area is masonry façade, 10.38mm laminated glazing and light framed insulated plasterboard ceiling, The ambient noise levels within the penthouse is totally controlled by the sound transmission via the roof/ceiling. The roof ceiling construction with 400mm air cavity has a mass-air-mass resonance in the 63Hz octave band. Noise transmission into the penthouse is dominated by this 63 Hz octave band, providing negligible sound reduction performance in this frequency. This ceiling system is not suited to the Northbridge area.

6.4 Acoustic Performance using High Performance Single Glazing Systems

Upgrading of glazing systems is difficult in that a significant increase in glass thickness is required to achieve a noticeable reduction in noise intrusion. In this assessment we consider the option of upgrading the glass to a high performance single glass being 12.5mm Viridian V-Lam Hush glass achieving an Weighted Sound Reduction Index of Rw 40 and Rw+Ctr 37.

6.4.1 Living Area with 12.5mm Viridian V-Lam Hush glass

The predicted Level of Noise Intrusion into the bedroom with dimensions and finishes as per 5.2.1 have been determined at:

Predicted Level of Noise Intrusion			
Typical Living Area **Single Glazing – 12.5mm** **Glazing 28% of floor Area**	**Construction:** ▪ Insulated concrete external wall-Façade ▪ 12.5 V-Lam Hush Glass (6.5m^2) – 77% of Facade Area ▪ Concrete Floor slab with skim coat ceiling		
External Noise Level L_{eq}:	**65 dB(A)**	**79 dB(C)**	
Predicted Internal Level L_{eq}	**34 dB(A)**	**55 dB(C)**	
Assigned Level -adjusted for music and indoor measurement L_{10} 20dB(A) + 6dB/-4dB	**20 dB(A)**		
Frequency (Hz)	**63 Hz**	**125 Hz**	
Predicted Octave Band Lp (Lin)	56dB	43 dB	
DEFRA Criteria	47 dB	41 dB	

Table 6.4– Predicted Performance – Living Area with 12.5 VLam Hush glass

6.4.2 Bedroom with 12.5mm Viridian V-Lam Hush glass

The predicted Level of Noise Intrusion into the Bedroom with dimensions and finishes as per 5.2.1 have been determined at:

Predicted Level of Noise Intrusion				
Typical Bedroom **Single Glazing – 12.5mm** **Glazing 55% of floor Area**	**Construction:** ▪ Insulated concrete external wall-Façade and Side wall ▪ 12.5 V-Lam Hush Glass (6.5m^2) 77% of Facade Area ▪ 150mm Concrete with skim coat ceiling			
External Noise Level L_{eq}:		**65 dB(A)**	**79 dB(C)**	
Predicted Internal Level L_{eq}		**34 dB(A)**	**56 dB(C)**	
Assigned Level -adjusted for music and indoor measurement L_{10} 20dB(A) + 6dB/-4dB		**20 dB(A)**		
Frequency (Hz)		**63 Hz**	**125 Hz**	
Predicted Octave Band Lp (Lin)		57 dB	43 dB	
DEFRA Criteria		47 dB	41 dB	

Table 6.5– Predicted Performance – Bedroom with12.5 VLam Hush glass

The resultant L_{eq} 33 to 34 dB(A) noise level in bedroom and living area with 12.5 VLam Hush glass meets the requirement of Australian standard AS2107:2016 *Acoustics - Recommended Design Sound levels and Reverberation Times for Building Interiors* of 35 to 45 dB(A) for intrusion of general environmental noise. However the Standard states that is not applicable for LFN Intrusion.

This level of L_{eq} 33 to 34 dB(A) significantly exceeds the Assigned Level adjusted for music and indoor measurement of L_{10} 20 dB(A). It is also significantly exceeds the DEFRA Criteria for LFN in the 63Hz octave band.

6.4.3 Overview – High Performance Glazing:
Upgrading glazing to the high performance 12.5mm Viridian V-Lam Hush glass reduces the level of general ambient noise intrusion by 3 to 4 dB(A). Whilst this appears to be a worthwhile improvement it still exceeds the Assigned Level adjusted for music and indoor measurement of L_{10} 20 dB(A). Also it is well outside the DEFRA design target for the noise level in the 63 Hz octave bands.

Secondary glazing was not assessed as its performance is no better than single and thermal glazing systems.

6.5 Balcony Glazing Systems

The Balcony Glazing system consists of :
- 6mm Glazed window to balcony
- Minimum Balcony width of 1 metre
- Acoustic Absorbent Ceiling to the Balcony - Weighted Absorption Coefficient (α)of 0.95
- 10.38mm laminated glass to Habitable room

6.5.1 Living Area with Balcony Glazing
The predicted Level of Noise Intrusion into the Living area with dimensions and finishes as per 5.2.1 have been determined at:

Predicted Level of Noise Intrusion			
Typical Living Area **Balcony Glazing** **Glazing 28% of floor Area**	**Construction:** ▪ Insulated concrete external wall-Façade ▪ Balcony Glazing 6mm and 10.38mm glass ▪ Acoustic absorbent ceiling ▪ Concrete Floor slab with skim coat ceiling		
External Noise Level L_{eq}:	**65 dB(A)**	**79 dB(C)**	
Predicted Internal Level L_{eq}	**20 dB(A)**	**44 dB(C)**	
Assigned Level -adjusted for music and indoor measurement L_{10} 20dB(A) + 6dB/-4dB	**20 dB(A)**		
Frequency (Hz)	**63 Hz**	**125 Hz**	
Predicted Octave Band Lp (Lin)	45dB	27 dB	
DEFRA Criteria	47 dB	41 dB	

Table 6.6 – Predicted Performance – Living Area with perimeter Balcony Glazing

This meets the DEFRA Criteria and represents high quality acoustic performance.

6.5.2 Bedroom with Balcony Glazing

The predicted Level of Noise Intrusion into the bedroom with dimensions and finishes as per 5.2.1 have been determined at:

Predicted Level of Noise Intrusion			
Typical Bedroom **Balcony Glazing** **Glazing 55% of floor Area**	**Construction:** ▪ Insulated concrete external wall-Façade ▪ Balcony Glazing 6mm and 10.38mm glass ▪ Acoustic absorbent ceiling ▪ Concrete Floor slab with skim coat ceiling floor slab with skim coat ceiling		
External Noise Level L_{eq}:	**65 dB(A)**	**79 dB(C)**	
Predicted Internal Level L_{eq}	**20 dB(A)**	**45 dB(C)**	
Assigned Level -adjusted for music and indoor measurement L_{10} 20dB(A) + 6dB/-4dB	**20 dB(A)**		
Frequency (Hz)	**63 Hz**	**125 Hz**	
Predicted Octave Band Lp (Lin)	46 dB	27 dB	
DEFRA Criteria	47 dB	41 dB	

Table 6.7 – Predicted Performance – Bedroom with Balcony Glazing.

This represents high quality acoustic performance.

6.5.3 Living Area with Upgraded Balcony Glazing

Predicted Level of Noise Intrusion			
Typical Living Area Upgraded Balcony Glazing **Glazing 28% of floor Area**	**Construction:** ▪ Insulated concrete external wall-Façade ▪ Balcony Glazing 6mm and 10.38mm glass ▪ Acoustic absorbent ceiling ▪ Concrete Floor slab with skim coat ceiling		
External Noise Level L_{eq}:	**65 dB(A)**	**79 dB(C)**	
Predicted Internal Level L_{eq}	**20 dB(A)**	**44 dB(C)**	
Assigned Level -adjusted for music and indoor measurement L_{10} 20dB(A) + 6dB/-4dB	**20 dB(A)**		
Frequency (Hz)	**63 Hz**	**125 Hz**	
Predicted Octave Band Lp (Lin)	41dB	22 dB	
DEFRA Criteria	47 dB	41 dB	

Table 6.8 – Predicted Performance – Living Area with Upgraded Balcony Glazing

Interesting, the predicted overall dB(A) and dB(C) levels with the upgraded glazing are the same as for the normal balcony glass as proposed in Table 6.7. However the level in the 63 Hertz octave band is reduced by 5dB, and therefore fully complies with the DEFRA Criteria.

6.5.4 Living Area with Balcony Glazing plus Upgraded **Light Frame Roof**

The top floor apartments are subject to noise intrusion through the façade plus the roof. The predicted Level of Noise Intrusion into the Penthouse Living Area with dimensions and finishes as per 5.2.1 is:

Predicted Level of Noise Intrusion			
Penthouse Living Area **Upgraded Frame Roof/Ceil** **Plus Balcony Glazing**	**Construction:** ▪ Metal roof plus Anticon ▪ Insulated 1 metre ceiling void ▪ Light frame steel hangers, 2x 13 Plasterboard ceiling		
External Noise Level L_{eq}:	**65 dB(A)**	**79 dB(C)**	
Predicted Internal Level L_{eq}:	**27 dB(A)**	**51 dB(C)**	
Assigned Level -adjusted for music and indoor measurement L_{10} 20dB(A) + 6dB/-4dB	**20 dB(A)**		
Frequency (Hz)	**63 Hz**	**125 Hz**	
Predicted Octave Band Lp (Lin)	52 dB	36 dB	
DEFRA Criteria dB (Lin)	47 dB	41 dB	

Table 6.9 – Predicted Performance – Living Area with Light Frame Roof with Balcony Glazing in Mass Wall facade

The upgraded roof ceiling construction provides a reasonable level of sound reduction but exceeds the criteria by 6 to 7 dB.

6.5.5 Living Area with Balcony Glazing plus **Concrete Roof**

The top floor apartments are subject to noise intrusion through the façade plus the roof. The predicted Level of Noise Intrusion into the Penthouse Living Area with dimensions and finishes as per 5.2.1 is:

Predicted Level of Noise Intrusion			
Penthouse Living Area **Concrete Roof Ceiling** **Plus Balcony Glazing**	**Construction:** ▪ Metal Roofing 0.6 BMT ▪ 145 cavity with R 3.5 insulation ▪ 150mm Concrete with skim coat ceiling		
External Noise Level L_{eq}:	**65 dB(A)**	**79 dB(C)**	
Predicted Internal Level L_{eq}:	**24 dB(A)**	**49 dB(C)**	
Assigned Level -adjusted for music and indoor measurement L_{10} 20dB(A) + 6dB/-4dB	**20 dB(A)**		
Frequency (Hz)	**63 Hz**	**125 Hz**	
Predicted Octave Band Lp (Lin)	49 dB	28 dB	
DEFRA Criteria dB (Lin)	47 dB	41 dB	

Table 6.10– Predicted Performance – Living Area with Concrete Roof with Balcony Glazing in Mass Wall facade

The Concrete roof ceiling construction provides a reasonable level of sound reduction but marginally exceeds the criteria.

6.5.6 Overview – Balcony Glazing System:

Façade: Providing a very large cavity with acoustic absorption between 2 separate window systems significantly increases the low frequency sound reduction performance of the Balcony Glazing system.

Based on a representative external noise level at the façade of 65 dB(A), with significant energy in the 63Hz and 125 Hz octave bands, the Balcony Glazing system reduces the noise intrusion to meet the Assigned Level adjusted for music and indoor measurement of L_{10} 20 dB(A) and also meets the DEFRA criteria of octave band sound levels of < 47 dB and < 42 dB in the 63Hz and 125 Hz octave band respectively.

As the predicted sound reduction performance for the Balcony Glazing system is similar to the sound reduction performance of the Mass walling system, the window area of the glazing as a percentage of the floor area is not important.

Penthouse Performance: The acoustic performance of a penthouse constructed with Balcony glazing and an upgraded light frame roof/ceiling has been calculated. With a 1m cavity void in the ceiling and extra mass added at both to both the roof and ceiling levels, a good sound reduction performance can be achieved. The result achieved is that the intruding noise exceeds the design standards by 6 to 7 dB. This is a creditable performance. We note that the 1 metre ceiling void will have planning implications, but this is not a part of this acoustic study.

If the roof ceiling construction is changed to a concrete roof, then the intruding noise is reduced by 3 to 4 dB, and only marginally exceeds the criteria established in this report.

6.6 Summary – Construction Standards

Current Construction Standard: The current acoustic construction for Northbridge residential developments is to use high mass walls (Concrete) and 10.38mm glazing in commercial quality frames. Thermal double glazing systems are also used and have similar acoustic performance to 10mm single glazing.

This construction provides basic performance, generally adequate to address daytime Leq levels in the region of 60 dB(A) and 68 dB(C) (typical of an urban environment including traffic noise), to meet the recommended design sound levels of < 45 dB(A) for Living Areas and < 40 dB(A) in Bedrooms, as set out in Australian Standard AS/NZS 2107:2016.

However at times when the music entertainment industry ramps up, which is Friday to Saturday between the hours of 10pm to 2am the next day, the noise takes on a different character, with a significant increase in low frequency sound energy, specifically the 63Hz octave band. Although it does not increase the overall sound level as measured terms of the dB(A) frequency weighted scale; the level when measured on the dB(C) frequency weighted scale increases. With this construction the predicted level of Low Frequency Noise (LFN) intrusion is high. The resulting level of LFN intrusion significantly exceed the Low Frequency Noise levels established in the DEFRA Criteria

Although this construction controls the ‘general’ ambient noise in Northbridge, the low frequency noise intrusion associated with Music Entertainment industry can result in significant annoyance.

Upgraded Single Glazing: In order to reduce the intrusion of low frequency noise, an assessment has been carried out to consider the benefit in the use of high acoustic performance glazing. An assessment has been carried out using Viridian 12.5mm VLAM Hush glass that achieves a Weighted Sound Reduction Index of (Rw) 40 and Rw+Ctr 37.

This high performance glazing reduces the level of general ambient noise intrusion by approximately 3 dB(A). The low frequency noise intrusion is still significantly above the DEFRA Criteria and is therefore not acceptable.

Balcony Glazing: The balcony glazing approach provides high Sound Reduction performance, reducing the ambient noise at a representative residential premises from 65 dB(A) (DWER ‘composite venue spectrum’) down to a predicted indoors noise level of 20dB(A). In this option the LFN transmission is reduced to meet the DEFRA Criteria.

The Balcony Glazing system provides low frequency Sound Reduction performance comparable to a 150mm concrete wall, insulated internally with fibre insulation and a single sheet of plasterboard. Based on this construction, the normal requirement to control / minimise the area of windows no longer exists, as the wall and window construction have similar low frequency performance. Based on the calculations, this construction system meets the DEFRA design standards for low frequency noise intrusion (based on external composite venue spectrum at 65 dB(A).

It is noted that the difference between the predicted dB(A) and dB(C) levels is over 20 dB. This indicates a significant imbalance across the frequencies. The result may be perceived as an uncomfortable acoustic environment.

Upgraded Balcony Glazing: The upgraded balcony glazing involves the use of specialist acoustic glazing. It provides no improvement in the overall dB(A) or dB(C) results but does reduce the sound level in the troublesome 63 Hertz octave band by 5 dB. This may be worthwhile in some high noise areas within the Northbridge Precincts.

Balcony Glazing Implications: How enclosing of the balcony affects various planning requirements in terms of plot ratios and area calculation and limitations on location of air-conditioning condensing units etc is not addressed in this report. In this acoustic assessment, it suffices to say that Balcony Glazing is extremely effective in increasing low frequency Sound Reduction performance of the façade. The large cavity (> 1m) provided by the Balcony Glazing system is all important to achieving this level of performance

Penthouse Apartments: Penthouse Apartments have additional sound energy transmitting into the room via the roof ceiling. The standard roof construction of a light steel roof with 400mm ceiling void and single sheet plasterboard provides minimal sound reduction performance in the 63 Hz octave band. This is the result of the mas-air-mass resonance occurring within this octave band. As a result this ceiling system is not suitable for the Northbridge area where the noise source is characterised by music entertainment noise.

An upgraded light frame roof ceiling system with a 900mm ceiling void and additional mass added at both roof and ceiling levels by means of additional sheets of plasterboard and fibre cement sheets, can provide a high standard of performance. Based on an external noise level of 65 dB(A), 79 dB(C) (DWER 'composite venue spectrum'), the resultant noise level for a Penthouse living room exceeds the DEFRA Criteria in the 63 and 125 Hz octave bands by 5 to 6 dB.

If the roof ceiling construction is changed to a concrete roof, then the intruding noise is reduced but still marginally exceeds the DEFRA criteria in the 63 Hz octave band by 2 dB.

Practical Maximum Performance: The construction described in this report with high mass masonry walls, balcony glazing and concrete roof represents the practical maximum performance that can be provided to address the music entertainment Northbridge noise environment.

Spectral Balance: The spectrum shape of the intruding noise is characterised by high levels of sound energy in the low frequencies and negligible sound energy in the mid to high frequencies. The sound reduction performance of building materials is poor in the low frequencies and good in the high frequencies. The resulting noise intrusion therefore has significant spectral imbalance resulting in a uncomfortable acoustic environment. In addition, as the ambient sound in the mid to high frequencies within the apartment will be low, there is negligible acoustic masking for noise intrusion from adjoining apartments. To address these concerns consideration will need to be given to introducing electronic acoustic masking. See Section 7 of this report

Ventilation: The assessment of the various construction options assumes that the openable windows in the various systems are closed. It is possible for the windows to be opened for ventilation, but internal noise levels will then exceed acceptable sound levels. It is noted that this report is an acoustic report and does not address mechanical ventilation issues. It suffices to say that any mechanical system utilising external air inlet systems will require significant acoustic attenuation in the ductwork so as not to degrade the low frequency performance of the building envelope.

6.7 Synopsis

A synopsis of the Predicted Noise Levels in Living and Bedroom Areas based on various façade treatments and roof constructions for Penthouse units has been set out in Table 6.11. It clearly indicates that the DEFRA criteria for Low Frequency Noise can only be addressed by using Balcony Glazing. It also indicates that Penthouse Units will receive higher levels of levels of Music Entertainment Noise intrusion due to the additional surface area exposed to noise; i.e. the roof.

Predicted Level of Noise Intrusion

Construction	Space	Overall Levels dB(A)	Overall Levels dB(C)	Octave Band dB(Lin) 63 Hz Predicted	63 Hz Criteria	125 Hz Predicted	125 Hz Criteria	Cost Per Living Room	% Increase to building cost %
Single Glazing Systems		Not Assessed							
6mm glass Base Design	Living							$ 340	Base
10.38mm Laminated Glass	Living	37	58	59	47	47	42	$ 710	0.28%
10.38mm Laminated Glass	Bedroom	37	59	59	47	47	42	$ 540	0.28%
10.38 glazing; Stnd Light frame roof	Penthouse Living	50	75	76	47	51	42		
12.5 VLam Hush Glazing	Living	34	55	56	47	43	42	$1,510	0.89%
12.5 VLam Hush Glazing	Bedroom	34	56	57	47	43	42	$1,140	0.89%
Balcony Glazing Systems									
6mm and 10.38mm Laminated glass	Living	**20**	44	**45**	47	**27**	42	$8,250	6.22% ++
6mm and 10.38mm Laminated glass	Bedroom	**20**	45	**46**	47	**27**	42	$5,760	6.22% ++
6mm and 12.5mm VLam Hush glass	Living	**17**	42	**43**	47	**23**	42	$9,140	6.90% ++
Balcony Acoustic Ceiling	Bedroom	Must be included	integral part of balcony glazing system					$1,098	1.15%
Balcony Acoustic Ceiling	Living	Must be included	integral part of balcony glazing system					$1,072	1.15%
Penthouse Living – Roof								**Cost per 1 bed Unit**	
Standard Roof ceiling construction		Not Assessed						$24,420	Base
6mm& 10.38mm glass upgraded frame roof construction	Living	29	53	54	47	**38**	42	$35,640	1.31%
6mm& 10.38mm glass Concrete roof construction	Living	25	50	50	47	**29**	42	$31,680	0.85%

Table 6.11 - Synopsis - Predicted Levels of Noise Intrusion

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7. LOW BACKGROUND NOISE LEVELS WITHIN APARTMENTS

7.1 Low Background Noise in Apartments

Reducing the level of external noise intrusion into an apartment buildings by upgrading the sound reduction performance of the building façade will result in low background noise levels within the apartments. This reduces acoustic masking within the apartment. The result is that noise intrusion from adjoining apartments becomes more audible in terms of both airborne and stuctureborne (impact) noise intrusion.

The audibility of noise intrusion from adjoining apartments due to low background noise is already a concern in the general community. Background noise levels as low as 20 dB(A) are often measured with octave band noise levels in the mid frequency being <20 dB and in the high frequencies being <15 dB. With the requirement for upgraded acoustic performance of the façade to address music entertainment noise intrusion in the Northbridge precinct, the resultant background noise levels in these Apartments may be further reduced to extra low background noise levels.

With the use of very high sound reduction performance glazing systems such as the Balcony Glazing discussed in this report, the concern for the audibility of intruding noise from adjoining apartments is raised and needs to be addressed.

7.2 Reducing Noise intrusion from Adjoining Apartments

To reduce the noise intrusion from adjoining apartments requires attention to both Airborne and Structureborne noise transmission paths:

Airborne noise: Current construction standards are that the wall and floor systems are designed to meet the requirements of the Building Code of Australia (BCA). Basically, separating walls and floors to adjoining apartments are required to meet an Rw + Ctr of 50 performance. To achieve this the BCA provides a number of 'Deemed-to-Satisfy' constructions. To increase the sound reduction performance of these 'Deemed-to-Satisfy' wall and floor constructions by further 5-10 dB will result in significant increase in the construction. It will also require increased depth of construction to achieve the higher acoustic performance requirements. This additional area requirement may reduce the available area for apartments. The number of apartments available in any specific development envelope may then also reduced.

Structure-borne Noise: The main structure-borne noise sources that result in annoyance in Apartments include:

- Floor impact noise
- Toilet noise including Flushing and Urination
- Kitchen bench impact noise

These issues are addressed in the BCA but are still often problematic in the current stock of Apartments particularly where background noise is low. With the a further reduction in the background noise, the floor/ceiling construction will need to be upgraded to reduce the audibility of noise intrusion . This will result in increased cost and depth of the Floor/Ceiling zone

The impact on the construction cost and the planning of the development may make this difficult for marketable residential development.

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7.3 Acoustic Masking

An alternative to upgrading wall and floor construction is to provide an electronic acoustic masking system. Electronic Acoustic Masking systems are extensively used in Commercial Offices but the use in residential accommodation is rare. The principle is that the electronic masking system raises the level of background noise within the apartment with a noise spectrum designed to be non-intrusive and to cover the frequency range from 63 Hz to 8 kHz octave bands. Simply put, it raises the background noise level so that the intruding noise is less audible.

Often people use fans or air conditioners as masking system. Small electronic "sleep sound masking systems" are also used to address a specific concern for people who have a sleep disorders and for those with problematic tinnitus. These systems are effective, but for a complex noise environments such as living within an entertainment precinct where façade control systems are significantly reducing the mid and high frequency noise ,a more comprehensive acoustic masking system is required. The acoustic masking level required during the day can be at a relatively low level but once the low frequency noise intrusion starts, the masking noise level may need to be increased to help cover the intrusion of the low frequency sound associated with music entertainment noise intrusion.

Acoustic masking systems in offices are normally installed in either:

- the air conditioning duct system so that the sound is perceived to be part of the air conditioning system, or
- the ceiling void over a suspended office ceiling, such that the location of the speakers is not obvious.

In apartments where the normal ceiling is a skim coat finish to the underside of the slab with no suspended ceiling, neither of the above options are possible. Speakers mounted on walls or ceilings are perceived as too directional and not well suited to sound masking systems. It is essential that the sound masking system provide a diffuse sound where the direction of the sound source is not noticeable.

The alternative is the use sound masking vibration exciters where the unit is attached to a stud framed wall. The vibration exciter then converts the plasterboard to a large speaker, providing a diffuse sound suitable for acoustic masking.

How this works in practice and the effectiveness of the system would need to be trialled. The system can be programmed to be at a relatively low level for general use during the day and evening. Mainly to increase the background noise in the mid to high frequencies. Then when the low frequency noise intrusion from the music entertainment noise starts, the level of the acoustic masking system can be raised to provide more effective masking of the low frequency noise intrusion. Trialling of a system is essential to establish the efficacy of the system.

The issue of requirement of electronic acoustic masking is raised, but is outside the scope of this study and requires separate consideration.

8 COST OF CONSTRUCTION

8.1 Cost Implications

The intent of including costing information is to provide an overview of the cost implications associated with upgrading the sound reduction performance of an Apartment Facade to address the specific low frequency noise concerns associated with Music entertainment noise such as exists in the Northbridge Precinct.
It should be noted that there is a practical limit to the sound reduction performance that can be achieved through a Building façade. The constructions considered in this study with the Balcony

glazing systems and high mass concrete walls and roof constructions represent practical limits to acoustic sound reduction performance for apartment buildings. Further increases in sound reduction performance are possible but will generally involve significant increases in the overall depth of the construction. This then increases the construction area of each apartment and has significant effect not only on the cost but potentially the number of Apartment that can be constructed on any specific site. This impacts on Project viability.

8.2 Apartment Design

In Apartment design, bedroom and living areas are located on the façade to access daylight and view. Non-habitable spaces that do not require an external windows are located internally away from the façade. Kitchens are normally designed as part of the living area, and located at the far end of the Living room away from the windows and daylight source.

A typical single bed unit has been selected as the focus of the study. The rooms sizes are based on an existing Apartment building in Northbridge and are representative of the typical construction. The room and window sizes have been identified as set out in in Figure 6.1 and 6.2.

8.3 Costing

A cost estimate of the construction options discussed in this report is provided by **Owen Consulting** quantity surveyors and construction consultants. The Indicative Cost Estimate is provided at Table 8.1.

Cost per Square Metre (sqm): The Cost per sqm of the various construction element options is set out in Column 1 in Table 8.1. It provides the costs of the various constructions options priced on a $/m2 basis. This allows the costs of the various construction element be compared; e.g. the various types of Façade Glazing. The costs are based on a new construction, where the acoustic upgrade can be considered an option in the design and documentation phase of the project.

Cost per Room: Table 8.1 in columns 2 and 3 sets out the cost of a specific construction element when incorporated into a standard living area or bedroom. This cost is based on dimensions of the room and glazing element as set out in clause 6.2.1 and depicted on Figure 6.1.

Cost per 1 Bed or 2 Bed Unit: Table 8.1 in columns 4 and 5 sets out the cost of a specific construction element when incorporated into a standard 1 bed or 2 bedroom Unit. This cost is based on dimensions of the room and glazing element as set out in clause 6.2.1 and depicted on Figure 6.1 and 6.2.

% Increase to Building Cost: The last column in Table 8, column 6, sets out the percentage increase if that specific construction element option is incorporated into a whole apartment building. This is based on a 4 storey building with a 2 to 1 ratio of 1 bed and 2 bed apartments and an overall budget for the building of $15.0m. The % increase is over base/standard construction.

Balcony Glazing: The costs for the balcony glazing is based on the balcony being glazed up to balustrade height and complying with normal design codes. Above the balcony are horizontal multi sliders to maximise the openness of the space. It has been assumed that vertical steel structure will be required mid span on the wide balconies, and also horizontal steel structure will be required at the balustrade level to meet normal design codes including wind codes.

owenconsulting
quantity surveyors + construction consultants

8 July 2019

NORTHBRIDGE ENTERTAINMENT PRECINCT
Residential Building Attenuation Options

Indicative cost estimate

	Cost per sqm	Cost per bedroom	Cost per living room	Cost per 1 bed unit	Cost per 2 bed unit	% increase to building cost
GLAZING						
Single glazing						
Base - 6mm	$ 40.00	$ 260.00	$ 340.00	$ 600.00	$ 860.00	
10.38 lam	$ 83.00	$ 540.00	$ 710.00	$ 1,250.00	$ 1,790.00	0.28%
12.5 vlam hush	$ 176.00	$ 1,140.00	$ 1,510.00	$ 2,660.00	$ 3,800.00	0.89%
Double glazing						
Thermal 6mm-12-6mm	$ 138.00	$ 900.00	$ 1,190.00	$ 2,080.00	$ 2,980.00	0.64%
Upgraded thermal 6mm-8-10.38 lam	$ 182.00	$ 1,180.00	$ 1,570.00	$ 2,750.00	$ 3,930.00	0.93%
Secondary glazing						
10mm - 75 cavity - 6mm	$ 550.00	$ 3,580.00	$ 4,730.00	$ 8,310.00	$ 11,880.00	3.61%
Balcony glazing (full height)						
6mm balcony - 10.38 lam room	$ 711.00	$ 5,760.00	$ 8,250.00	$ 14,010.00	$ 21,120.00	6.22%
6.38 lam balcony - 12.5 vlam room	$ 788.00	$ 6,380.00	$ 9,140.00	$ 15,520.00	$ 23,400.00	6.90%
Acoustic soffit lining to balcony	$ 165.00			$ 2,670.00	$ 3,710.00	*1.15%*
WALL CONSTRUCTION						
150 AFS / internal lining + insulation	$ 330.00					
ROOF CONSTRUCTION						
Standard roof construction (+ ceiling)	$ 370.00			$ 24,420.00	$ 31,970.00	
Additional 13 thick p/board ceiling layer	*$ 40.00*			*$ 2,640.00*	*$ 3,460.00*	*0.31%*
Additonal roof void + barrier ceiling	*$ 170.00*			*$ 11,220.00*	*$ 14,690.00*	*1.31%*
Concrete roof construction (+ skim coat)	$ 480.00			$ 31,680.00	$ 41,470.00	0.85%
ACOUSTIC MASKING						
Costs not available						

Notes

* Refer to Gabriels Hearne Farrell's report for details of the 1 bed and 2 bed templates used as the basis for this cost report
* Excludes cost escalation past 2019
* Rates reflect new build (not retrofit to existing buildings)
* Rates include for builders preliminaries, overheads and profit
* 'Roof construction' costs are based on:
  - area based on unit internal floor area +20% for external/party walls and common circulation space
  - only applicable to top storey units
  - excludes balcony area
* The '% increase to building costs' are based on:
  - 4 storey building with a 2:1 ratio of 1 bed and 2 bed units (budget $15.0m)
  - represents the % increase over base/standard construction
* Additional roof void option excludes any loss of apartments due to exceeding maximum building heights
* Glazing and window costs are based on information provided AWS Aluminium Innovations

Table 8.1 Cost estimate provided by Owen Consulting

8.4 Overview

As indicated in Table 6.11 upgrading of single glass options results in a small improvements in acoustic performance but fall very short of the Criteria for internal noise levels. Percentage increase in costs as indicated are small but a 2 to 3 dB improvement in Low Frequency noise intrusion still falls 9 to 10 dB short of the criteria. If this is the proposed standard of residential construction in the Northbridge Precinct, then to meet the low frequency criteria will require a substantial reduction in the existing low frequency noise emission from venues.

With Balcony Glazing the sound reduction through the facade is significantly improved such that the Criteria established in Section 6 of this report is achieved. However this involved the additional of a structurally designed full glazing system over the full façade. There is a small reduction in cost due to the deletion of a normal balustrade system. However the cost impact is significant with a 8% increase to the overall building cost.

9. CONCLUSIONS

In this Evaluation of Residential Building Attenuation for the Northbridge Entertainment District, the purpose has been to define the potential and practical limits in terms of building constructions to attenuate music entertainment noise intrusion.

The music entertainment noise intrusion is the Low Frequency Noise (LFN) associated with the bass and drums and is described as the "doof-doof" noise. Although the receiver is well aware that the source is music, the noise itself has no musical character, and is in fact not unlike many other industrial noise sources. As such, criteria for low frequency noise intrusion - specifically the DEFRA criteria - was used to provide targets for low frequency noise intrusion into the residential Apartments. The representative external noise source used for calculation purposes was provided by DWER at 65 dB(A) and 79 dB(C), being based on the DWER 'composite venue spectrum'. All reference to compliance with LFN design objectives are therefore relevant to this 'reference' external noise condition.

The current stock of more recent Apartment constructions in the Northbridge area have facades constructed of:

- High mass external walls being concrete or cavity brick.
- Upgraded glazing typically 10.38mm glass.
- Typical light frame roof ceiling construction with double layer plaster sheeting to ceiling.

This construction addresses the general environmental noise in the Northbridge area associated with traffic and street noise. It does not address the LFN associated with the music entertainment industry. As noted, the purpose of this study was to focus on the low frequency noise intrusion and determine a practical acoustic upgrade. The focus was therefore on the performance of the façade and the roof.

The major conclusions of the study are:

- Typical constructions standard for external walls being high mass > 300kg/m2 surface density (concrete) provides high sound reduction performance in the low frequencies.
- Standard 10.38mm laminated glass generally used in Apartment buildings to effectively address normal environmental noise intrusion e.g. traffic and street noise, results in low frequency noise levels 12dB above the design objective of 47 dB at 63 Hz
- Upgrading the façade glazing to high performance glass e.g. 12.5 VLam Hush glass reduces internal noise intrusion by 2 dB but is still 10 dB above the design objective of 47 dB at 63 Hz
- Acoustic double glazing with a 75mm air cavity is in fact is less effective than heavy single glass because the mass-air-mass resonant frequency of the double glazing system occurs in the 63 Hz octave band, seriously reducing the sound reduction performance in this critical octave band.

- A very large cavity (minimum 1 metre) is required in the double glazing format to provide good sound reduction performance in the 63 Hz octave band. This is achievable by fully glazing the balcony perimeter. This involves constructing a normal balcony and installing openable windows , e.g. multi slider above the normal balustrade height.
- *Balcony Glazing* utilising 6mm glass at the balcony and minimum 10.38mm glass to the habitable rooms meets the low Frequency Noise criteria established in the DEFRA Low frequency noise criteria.
- The Balcony Glazing provides significant low frequency noise reduction but provides very significant noise reduction in the mid and high frequencies. Internal masking noise form general environmental noise within the apartments will therefore be extremely low. Provision of *Acoustic Masking* within the apartments will therefore need to be considered. This is outside the scope of this study, although discussion is provided in 7.3 of this report.
- Noise intrusion via the roof for penthouse constructions (top floors) has been considered. The typical light frame roof ceiling construction used in apartment construction has been shown to be ineffective in controlling low frequency noise transmission. The most cost effective acoustic upgrade is to provide high mass concrete slab with insulated metal roofing over.
- Costing of designs options have been presented. The cost of upgrading in terms of the % increase to building cost for upgraded acoustic single glazing are relatively small at ≈ 0.6 % of building cost. However this only marginally improves performance in the low frequencies, being well below relevant design targets.
- *Balcony Glazing* with acoustic absorbent ceiling to the balcony does represent a significant cost as it is in fact a second façade. It represents an approximate 8% increase in overall building cost.

This report identifies that low frequency noise intrusion into Residential Building in the Northbridge Precinct can be controlled to meet Low Frequency Noise design targets, where external noise levels are at 65 dB(A) and 79 dB(C). It will require a change in the construction standards for apartments. The major impact is the requirement for 'Balcony Glazing' and the use of high mass concrete roof construction. Where the external noise levels as set out above are exceeded, it is expected that the noise emission from the venue will need to be addressed at source, as further increase in construction standards are likely to make the residential development uneconomic.

As reliable laboratory test data for the low frequency performance of the construction used in this study are not available, the assessment carried out in this study is based on the sound reduction performance of constructions as predicted by the Sound insulation Program INSUL Version 9. Confirmation of the acoustic performance as predicted in this study should be confirmed by field measurements.

It has been noted that the use of such high sound reduction performance façade and roof systems will result in extremely low internal ambient noise, with an unbalanced internal background noise spectrum. Consequently, inter apartment noise sources will become significantly more audible, due to the lack of acoustic masking. We advise that the use of electronic acoustic masking within the apartments should be further investigated.

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