Construction Noise Impact Statement

Shore Graythwaite Development

North Sydney

Report Number 610.8964-R3

23 November 2010

Shore School
c/- Mayoh Architects
60 Strathallen Avenue
NORTHBRIDGE NSW 2063

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Construction Noise Impact Statement

Shore Graythwaite Development

North Sydney

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1 INTRODUCTION

SLR Heggies Pty Ltd (SLR) has been engaged by Mayoh Architects on behalf of Sydney Church of England Grammar School (Shore) to assess the potential noise and vibration emission levels from the construction works associated with the staged expansion of the School in North Sydney.

This report is in addition to the operational noise assessment conducted by Heggies for the development (refer Heggies Report *10-8964 R1R1*). Specific acoustic terminology is used within this report. An explanation of common terms is included as **Appendix A**.

2 DESCRIPTION OF THE PROPOSED WORKS

This Construction Noise Impact Statement (CNIS) provides a site specific assessment of the construction works associated with the staged alterations and additions to the School.

The Project involves the staged construction of buildings to the west of the existing school site as outlined below.

Stage 1

- Demolition of Graythwaite House roof
- Demolition of minor buildings associated with Graythwaite House
- Construction and refurbishment to
  - Graythwaite House
  - The Coach House
  - Tom O'Neill Centre
- Installation of drainage pipes from Graythwaite House to Union Street with some drainage pipes in the terraces

Stage 2

- Demolition of Ward building
- Construction of East buildings adjoining eastern boundary of Graythwaite and School

Stage 3

- Demolition of Tom O'Neill building
- Construction of West buildings
- Construction of North building

This site specific assessment has focussed on the first stage of works (Stage 1), however, it is anticipated that the findings and recommendations provided in this report will be applied during the detailed design phase and prior to release of Construction Certificates for future stages (Stage 2 and 3).

This CNIS has been prepared to satisfy Key Issue 15 of the Director-General's Requirements.

> ***15. Noise and Vibration***
>
> *Provide a quantitative assessment of the potential demolition, construction, operation and traffic noise impacts of the project.*

Construction often requires the use of heavy machinery which can generate significant noise and vibration emissions at nearby buildings and receivers. For some equipment, there is limited opportunity to mitigate the noise and vibration levels in a cost-effective manner and hence the potential impacts should be minimised by using feasible and reasonable management techniques.

At any particular location, the potential noise and vibration impacts can vary greatly depending on factors such as the relative proximity of sensitive receivers, the overall duration of the construction works, the intensity of the noise and vibration emissions, the time at which the construction works are undertaken and the character of the noise or vibration emissions.

Offsite traffic access will remain unchanged during the proposed construction works and there would be negligible changes to traffic on the surrounding local road. Accordingly, traffic noise emissions are not considered any further in this CNIS.

3 NEAREST SENSITIVE RECEIVERS

The Shore School is the nearest and most sensitive receiver to the proposed works and will be the most significant constraint for the noise and vibration emissions from the project. However, the purpose of this CNIS is to determine the potential noise and vibration impacts on the nearest non-associated properties. Accordingly, the three nearest non-project associated sensitive receiver locations have been identified as Noise Catchment (NC) areas and are shown in **Figure 1**.

Figure 1 Location of the Nearest Sensitive Receivers

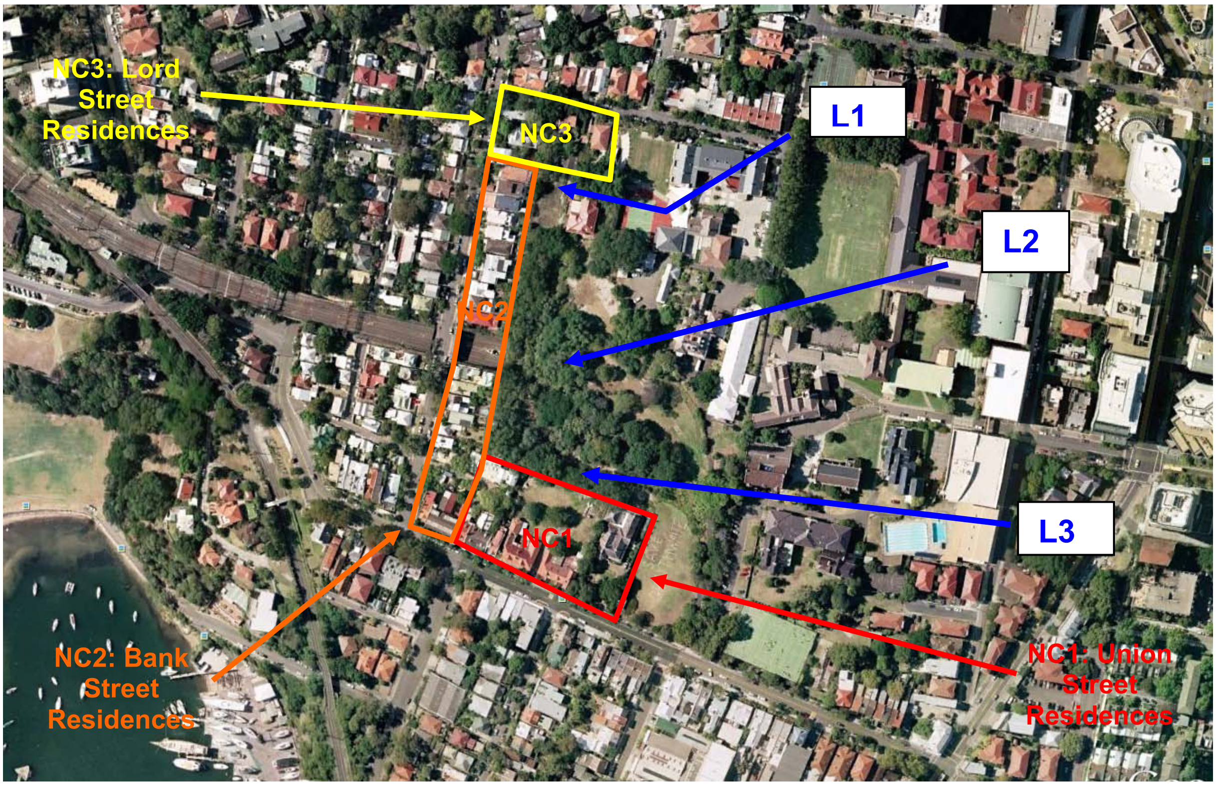


Image courtesy of Google Earth

4 CONSTRUCTION NOISE AND VIBRATION GOALS

4.1 Noise Goals

In accordance with the DECCW's Interim Construction Noise Guideline (ICNG), **Table 1** presents the specific criteria as "$L_{Aeq(15minute)}$ Noise Management Levels (NMLs)" that have been adopted for noise sensitive residential receivers.

Table 1 Specific $L_{Aeq(15minute)}$ NMLs for Residential Receivers

Time of Day	Management Level, $L_{Aeq(15minute)}$[1]	How to apply
Recommended standard hours: Monday to Friday 7 am to 6 pm Saturday 8 am to 1 pm No work on Sundays or public holidays	Noise affected RBL + 10 dB	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured $L_{Aeq(15\ min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75 dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: 1. Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences 2. If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.

Note 1: Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.

In addition, the ICNG presents the NMLs for noise at other sensitive land uses based on the principle that the characteristic activities for each of these land uses should not be unduly disturbed, as shown in **Table 2**.

Table 2 Noise at sensitive land uses (other than residences) using quantitative assessment

Land use	Noise Management level, LAeq (15 min) (applies when properties are being used)
Classrooms at schools and other educational institutions	Internal noise level 45 dB(A)
Hospital wards and operating theatres	Internal noise level 45 dB(A)
Places of worship	Internal noise level 45 dB(A)
Active recreation areas (characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion)	External noise level 65 dB(A)
Passive recreation areas (characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, for example, reading, meditation)	External noise level 60 dB(A)
Community centres	Depends on the intended use of the centre. Refer to the recommended 'maximum' internal levels in AS2107 for specific uses.

With regard to internal noise criteria presented (i.e. for Schools), the typical outdoor to indoor noise reductions provided by most standard building construction (ie without special acoustical treatment) is generally accepted as being 10 dBA with windows open (allowing for natural ventilation) and 20 dBA with windows closed. The corresponding external noise criteria for those spaces with an internal criterion of 45 dBA therefore becomes 55 dBA allowing for natural ventilation via an open window and 65 dBA with windows closed.

4.1.1 Continuous Unattended Noise Monitoring

Unattended noise logging was conducted at three locations throughout the development site. The locations of the noise loggers are contained in **Table 3** and shown in **Figure 1**.

Table 3 Logger Locations

Description	Location	Logger Type	Serial Number
Location 1 (L1)	NW end of development site	ARL EL215	194447
Location 2 (L2)	W end of development site	ARL EL215	194603
Location 3 (L3)	S development site to rear of building at 44 Union St.	ARL EL215	194637

Weather data for the subject area during the noise monitoring period was obtained from the Bureau of Meteorology's automatic weather station at Sydney Airport. Noise data during periods of any rainfall and/or wind speeds in excess of 5 m/s (approximately 9 knots) were discarded in accordance with INP weather affected data exclusion methodology.

Measurement Results

A summary of the continuous unattended noise monitoring results is contained in **Table 4**.

Table 4 Continuous unattended noise monitoring results – 01 to 09 September 2010.

Location	Period	LA1	LA10	LA90	LAeq
L1	Daytime	65	55	42	58
	Evening	56	49	38	47
	Night	54	43	34	48
L2	Daytime	61	52	40	53
	Evening	57	47	36	46
	Night	51	43	34	48
L3	Daytime	61	54	42	52
	Evening	49	44	36	43
	Night	46	42	34	45

Review of the information contained in **Table 4** indicates the following:

- Measured background LA90 sound pressure levels are similar (within 2 dB) at each noise logger location.
- Measured daytime background LA90 sound pressure levels were 42 dBA, 40 dBA and 42 dBA at noise logger locations L1, L2 and L3 respectively.
- Measured daytime LAeq(period) sound pressure levels were 58 dBA, 53 dBA and 52 dBA at noise logger locations L1, L2 and L3 respectively.

4.1.2 Project Specific Noise Management Levels

Having defined the area type, the processed results of the unattended noise monitoring have been used to generate project specific noise criteria summarised in **Table 5**. Continuous unattended noise logger data as presented in **Table 4** (refer to **Figure 1**) adjacent to the relevant NC areas have been used to specify the project specific noise criteria shown in **Table 5**.

Table 5 Background Noise Levels and Construction Noise Management Levels

Receiver	LA90 Background Noise Levels (RBL) - Daytime	Construction NMLs[1] - LAeq (15 minute)	
		Noise Affected	Highly Noise Affected
NC1: Union Street Residences	42 dBA	52[2] dBA	75[3] dBA
NC2: Bank Street Residences	40 dBA	50[2] dBA	75[3] dBA
NC3: Lord Street Residences	42 dBA	52[2] dBA	75[3] dBA

Note 1: The construction NMLs are based on DECCW's Interim Construction Noise Guideline (ICNG).
Note 2: Based on RBL + 10 dBA for residential receivers.
Note 3: For the "highly noise affected" residential receivers

4.1.3 Scope for Exceedances

Where predicted or measured noise levels exceed the NMLs, the ICNG recommends that the proponent apply all “feasible and reasonable” work practices in order to minimise noise.

Where $L_{Aeq(15minute)}$ construction noise levels are predicted to be in the “highly noise affected” category (ie above 75 dBA) the relevant authority (consent, determining or regulatory) may require respite periods to be observed. This may include restricting the hours that the very noisy activities can occur, taking into account:

1. Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences).
2. If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.

The implementation of an effective community consultation and liaison programme is emphasised as being a critical tool in successfully handling adverse noise impacts from construction works.

The guideline provides comprehensive guidance for work practices which aim to achieve *“desired environmental outcomes - there are no prescribed noise controls for construction works.”*

4.2 Vibration Damage Goals - Surface Structures

Most commonly specified “safe” structural vibration limits are designed to minimise the risk of threshold or cosmetic surface cracks, and are set well below the levels that have potential to cause damage to the main structure.

4.2.1 British Standard 7385: Part 2 - 1993 Guidelines

In terms of the most recent relevant vibration damage goals, Australian Standard AS 2187: Part 2-2006 *‘Explosives - Storage and Use - Part 2: Use of Explosives’* recommends the frequency dependent guideline values and assessment methods given in BS 7385 Part 2-1993 *‘Evaluation and measurement for vibration in buildings Part 2’* as they “are applicable to Australian conditions”.

The Standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk for a named effect is usually taken as a 95% probability of no effect.

Sources of vibration that are considered in the standard include demolition, blasting (carried out during mineral extraction or construction excavation), piling, ground treatments (eg compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

The recommended limits (guide values) for transient vibration to ensure minimal risk of cosmetic damage to residential and industrial buildings are presented numerically in **Table 6** and graphically in **Figure 2**.

Table 6 Transient Vibration Guide Values - Minimal Risk of Cosmetic Damage

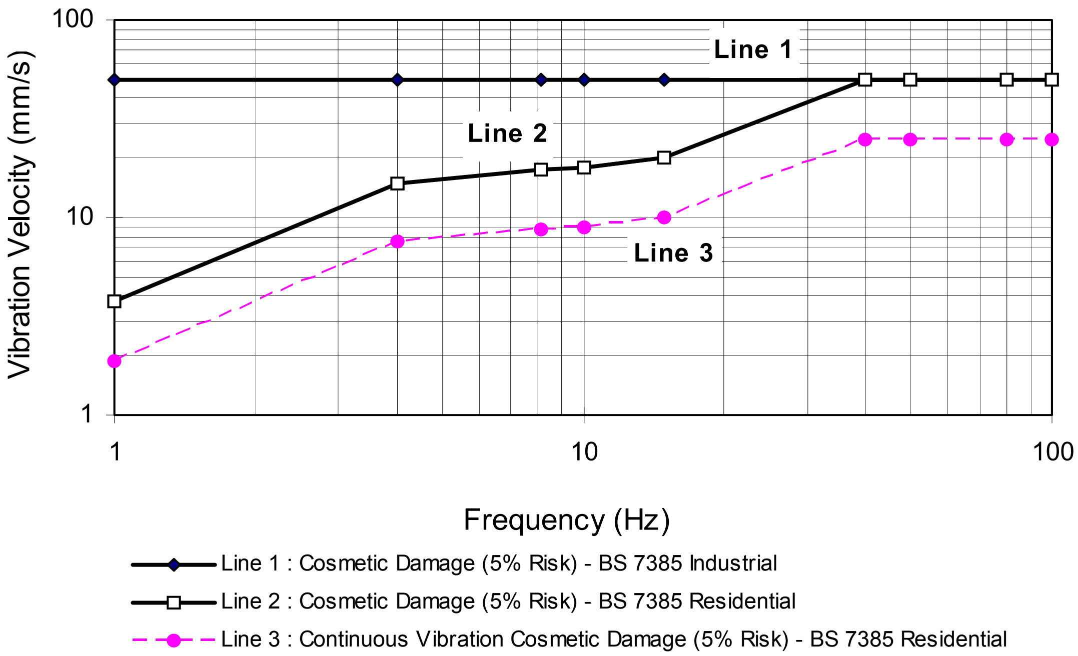
Line	Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
		4 Hz to 15 Hz	15 Hz and Above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

The Standard states that the guide values in **Table 6** relate predominantly to transient vibration which does not give rise to resonant responses in structures and low-rise buildings.

Where the dynamic loading caused by continuous vibration may give rise to dynamic magnification due to resonance, especially at the lower frequencies where lower guide values apply, then the guide values in **Table 6** may need to be reduced by up to 50%.

Note: rockbreaking/hammering and sheet piling activities are considered to have the potential to cause dynamic loading in some structures (eg residences) and it may therefore be appropriate to reduce the transient values by 50%.

Figure 2 Graph of Transient Vibration Guide Values for Cosmetic Damage



In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for building types corresponding to 'Line 2' are reduced. Below a frequency of 4 Hz where a high displacement is associated with the relatively low peak component particle velocity value, a maximum displacement of 0.6 mm (zero to peak) is recommended. This displacement is equivalent to a vibration velocity of 3.7 mm/s at 1 Hz.

The Standard goes on to state that minor damage is possible at vibration magnitudes which are greater than twice those given in **Table 6**, and major damage to a building structure may occur at values greater than four times the tabulated values.

Fatigue considerations are also addressed in the Standard and it is concluded that unless calculation indicates that the magnitude and number of load reversals is significant (in respect of the fatigue life of building materials) then the guide values in **Table 6** should not be reduced for fatigue considerations.

In order to assess the likelihood of cosmetic damage due to vibration, AS2187 specifies that vibration measured should be undertaken at the base of the building and the highest of the orthogonal vibration components (transverse, longitudinal and vertical directions) should be compared with the guidance curves presented in **Figure 2**.

It is noteworthy that extra to the guide values nominated in **Table 6**, the standard states that:

> *"Some data suggests that the probability of damage tends towards zero at 12.5 mm/s peak component particle velocity. This is not inconsistent with an extensive review of the case history information available in the UK."*

Also that:

> *"A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive."*

For most construction activities involving intermittent vibration sources such as rockbreakers, piling rigs, vibratory rollers, excavators and the like, the predominant vibration energy occurs at frequencies greater than 4 Hz (and usually in the 10 Hz to 100 Hz range). On this basis, a conservative vibration damage screening level of 7.5 mm/s has been adopted for preliminary assessment purposes.

At locations where the predicted and/or measured vibration levels are greater than 7.5 mm/s, a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure would be required to determine the applicable safe vibration level.

4.2.2 Human Comfort Vibration Goals

Humans are far more sensitive to vibration than is commonly realised. They can detect vibration levels which are well below those causing any risk of damage to a building or its contents.

The actual perception of motion or vibration may not, in itself, be disturbing or annoying. An individual's response to that perception, and whether the vibration is 'normal' or 'abnormal', depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as 'normal' in a shop, office or dwelling.

Human tactile perception of random motion, as distinct from human comfort considerations, was investigated by Diekmann and subsequently updated in German Standard DIN 4150 Part 2-1975. On this basis, the resulting degrees of perception for humans are suggested by the vibration level categories given in **Table 7**.

Table 7 Peak Vibration Levels and Human Perception of Motion

Approximate Vibration Level		Degree of Perception
Peak Vibration Level	**RMS Vibration Level**	
0.10 mm/s	**0.07 mm/s**	**Not felt**
0.15 mm/s	**0.1 mm/s**	**Threshold of perception**
0.35 mm/s	**0.25 mm/s**	**Barely noticeable**
1 mm/s	**0.7 mm/s**	**Noticeable**
2 mm/s	**1.4 mm/s**	**Easily noticeable**
6 mm/s	**4.2 mm/s**	**Strongly noticeable**
14 mm/s	**10 mm/s**	**Very strongly noticeable**

Note: These approximate vibration levels (in floors of building) are for vibration having a frequency content in the range of 8 Hz to 80 Hz. The RMS vibration levels assume a crest factor of 1.4 for sinusoidal vibration.

Table 7 suggests that people will just be able to feel floor vibration at levels of about 0.1 mm/s (RMS) and that the motion becomes 'noticeable' at a level of approximately 0.7 mm/s (RMS).

The DECCW's *"Assessing Vibration: a technical guideline"* notes that *"vibration in buildings can be caused by many different external sources, including industrial, construction and transportation activities. The vibration may be continuous (with magnitudes varying or remaining constant with time), impulsive (such as in shocks) or intermittent (with the magnitude of each event being either constant or varying with time)."*

Construction activities typically generate building vibrations that are intermittent or impulsive in nature, however vibration levels may sometimes be constant from sources such as generators or ventilation fans.

Examples of intermittent vibration events include the vibration generated by rockbreakers, vibratory rollers, drilling/piling and excavators. Examples of impulsive vibration events include the vibration generated by demolition activities, blasting or the dropping of heavy equipment.

Where vibration is intermittent or impulsive in character, the DECCW's vibration guideline (and other similar guidelines) recognise that higher vibration levels are tolerable to building occupants than for continuous vibration. As such, higher vibration goals are usually applicable for short term, intermittent and impulsive vibration activities than for continuous vibration sources.

The following sections describe the applicable continuous and intermittent vibration goals for the construction activities.

4.3 Human Comfort Goals for Continuous and Impulsive Vibration

The DECCW's *'Assessing Vibration: a technical guideline'* is applicable for the construction work and is based on the guidelines contained in British Standard BS 6472-1992 '*Evaluation of Human Exposure to Vibration in Buildings (1 Hz to 80 Hz)'*. The DECCW guideline refers only to human comfort considerations and nominates preferred and maximum vibration goals for critical areas, residences and other sensitive receivers.

The criteria in the DECCW's guideline are non-mandatory, *"they are goals that should be sought to be achieved through the application of all feasible and reasonable mitigation measures. Where all feasible and reasonable measures have been applied and vibration values are still beyond the maximum value, the operator would need to negotiate directly with the affected community"*.

Construction vibration can be continuous, intermittent or impulsive and the DECCW's vibration guideline provides different goals for each category. The continuous vibration goals are most stringent and higher vibration levels are acceptable for intermittent and impulsive vibration on the basis of the shorter exposure times. Examples of typical vibration sources are provided in **Figure 3**.

Figure 3 Examples of Vibration (DECCW Vibration Guideline)

Examples of types of vibration

Continuous vibration	Impulsive vibration	Intermittent vibration
Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).	Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, e.g. occasional dropping of heavy equipment, occasional loading and unloading. Blasting is assessed using ANZECC (1990).	Trains, nearby intermittent construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer this would be assessed against impulsive vibration criteria.

The applicable human comfort vibration goals for continuous, intermittent and impulsive vibration sources are provided in **Table 8**, **Table 9** and **Table 10** respectively. In all cases, the vibration goals are expressed in terms of the RMS vibration velocity level in mm/s, measured in the most sensitive direction (z-axis).

The DECCW's vibration guideline notes the following in relation to the preferred and maximum vibration levels:

> *"There is a low probability of adverse comment or disturbance to building occupants at vibration values below the preferred values. Activities should be designed to meet the preferred values where an area is not already exposed to vibration. Where all feasible and reasonable measures have been applied, values up to the maximum value may be used if they can be justified. For values beyond the maximum value, the operator should negotiate directly with the affected community. Situations exist where vibration above the preferred values can be acceptable, particularly for temporary disturbances and infrequent events of short term duration. An example is a construction or excavation project.*
>
> *In circumstances where work is short term, feasible and reasonable mitigation measures have been applied, and the project has a demonstrated high level of social worth and broad community benefits, then higher vibration values (above the maximum) may apply. In such cases, best management practices should be used to reduce values as far as practicable, and a comprehensive community consultation program should be instituted."*

Table 8 Preferred and Maximum Vibration Levels for Continuous Vibration

Building Type	Preferred Vibration Level RMS Velocity (mm/s)	Maximum Vibration Level RMS Velocity (mm/s)
Critical Woking Areas (eg hospital operating theatres, precision laboratories)	**0.10**	**0.20**
Residential Daytime	**0.2**	**0,4**
Residential Night-time	**0.14**	**0.28**
Offices, schools, educational institutions and places of worship	**0.4**	**0.8**
Workshops	**0.8**	**1.6**

Note: Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

Table 9 Preferred and Maximum Vibration Levels for Intermittent Vibration (Vibration Dose Values)

Building Type	Preferred Vibration Dose Value ($m/s^{1.75}$)	Maximum Vibration Dose Value ($m/s^{1.75}$)
Critical Woking Areas (eg hospital operating theatres, precision laboratories)	0.10	0.20
Residential Daytime	0.2	0,4
Residential Night-time	0.13	0.26
Offices, schools, educational institutions and places of worship	0.4	0.8
Workshops	0.8	1.6

Note: For the definition of the Vibration Dose Value refer to the discussion in the following section. Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

Table 10 Preferred and Maximum Vibration Levels for Impulsive Vibration

Building Type	Preferred Vibration Level RMS Velocity (mm/s)	Maximum Vibration Level RMS Velocity (mm/s)
Critical Working Areas (eg hospital operating theatres, precision laboratories)	0.10	0.20
Residential Daytime	6.0	12.0
Residential Night-time	2.0	4.0
Offices, schools, educational institutions and places of worship	13.0	26.0
Workshops	13.0	26.0

Note: Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

4.4 Intermittent Vibration (Vibration Dose Values)

For most construction activities that generate perceptible vibration in nearby buildings, the character of the vibration emissions is intermittent. This includes equipment such as rockbreakers, excavators, piling rigs, rock drills, vibratory rollers and heavy vehicle movements.

Intermittent vibration is defined in the DECCW's vibration guideline as follows:

> *"**Intermittent vibration** can be defined as interrupted periods of continuous (e.g. a drill) or repeated periods of impulsive vibration (e.g. a pile driver), or continuous vibration that varies significantly in magnitude. It may originate from impulse sources (e.g. pile drivers and forging presses) or repetitive sources (e.g. pavement breakers), or sources which operate intermittently, but which would produce continuous vibration if operated continuously (for example, intermittent machinery, railway trains and traffic passing by). This type of vibration is assessed on the basis of vibration dose values".*

Where vibration comprises a number of events, a Vibration Dose (Dv) may be estimated for each event by the following formula using vibration measured in velocity:

$$Dv = 0.07\ V\ (rms) \times t^{0.25}\ m/s^{1.75}$$

Where, V (rms) = rms particle velocity (mm/s)
t = Total cumulative time (seconds) of the vibration event or period of vibration

The total vibration dose is then calculated using the following formula:

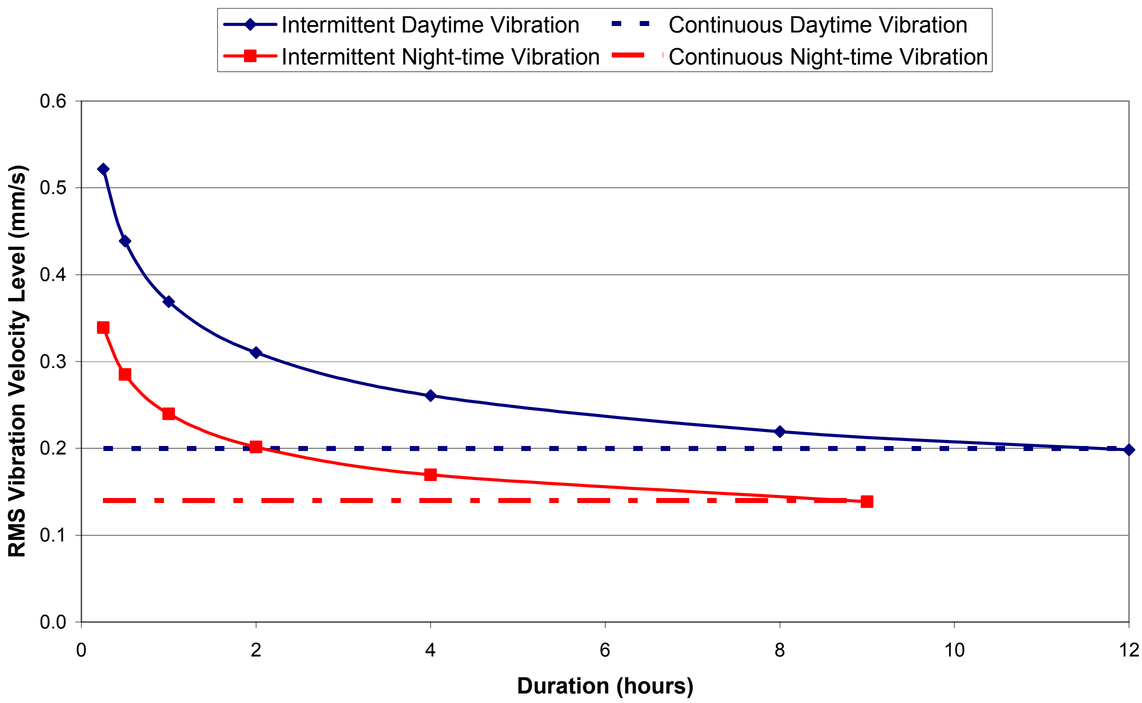
$$Dv = \left(\sum_{n=1}^{n=N} Dv_n^4 \right)^{0.25}$$

Where, Dv = Total vibration dose value for the day or night
Dvn = Vibration dose value for each vibration dose event
N = Total number of vibration dose events

The permissible vibration level corresponding to the vibration dose value varies according to the duration of exposure. For example, higher vibration levels are permitted if the total duration of the vibration event(s) is small and lower vibration levels are permitted with if the total duration of the vibration event(s) is large.

This concept is illustrated graphically in **Figure 4**, where the intermittent vibration curves for the daytime and night-time periods correspond to the preferred Vibration Dose Values in **Table 9**. As the total duration of the intermittent vibration sources during the daytime and night-time periods get larger, the intermittent vibration goals approach the preferred continuous vibration goals in **Table 8**.

Figure 4 Vibration Levels Corresponding to "Low Probability of Adverse Comment" for Residential Receivers - Continuous and Intermittent Vibration



5 CONSTRUCTION NOISE PREDICTIONS

5.1 Methodology and Assumptions

The noise levels at the nearest sensitive receiver have been calculated based on the maximum sound power levels from the equipment and the distance between the construction site and the nearest sensitive receivers. Furthermore, the calculated noise levels will inevitably depend on the number of plant items and equipment operating at any one time and their precise location relative to the receiver of interest.

In practice, the noise levels will vary due to the fact that plant and equipment will move about the work sites and will not all be operating concurrently. In some cases, reductions in noise levels will occur when plant are located in cuttings or behind embankments or buildings.

Maximum sound power levels for equipment assumed in the modelling are presented in **Table 11**.

Table 11 Summary of Sound Power Levels used for Construction Equipment

Plant Item	L_{Amax} Sound Power Level (dBA)
Truck (approx 12-15 tonne)	108
Dump Truck	108
Excavator (approx 20T)	105
Mobile Crane	110
Generator	104
Jack Hammer	113
Concrete Pump	106
Concrete Mixer	112
Concrete Vibrator	105
Hand Tools	100

The sound power levels given in **Table 11** are maximum noise emission levels for plant that will, or may, be used on this project in typical operation. To assess the impact of the likely noise emissions, it is necessary to convert these levels to equivalent $L_{Aeq(15minute)}$ noise emissions. From numerous field studies on large construction projects, the measured difference values between the L_{Amax} and $L_{Aeq(15minute)}$ noise levels have been found to be up to 10 dBA depending on the mixture of the plant, intensity of operation and location of the plant relative to the receiver.

The proposed equipment used at the station sites will be a subset of that presented in **Table 11**, with the noise model using sound power levels (SWLs) per activity and plant operating loads and cycles, based on the maximum noise levels presented in **Table 11**.

5.2 Construction Noise Modelling

A summary of the predicted $L_{Aeq(15minute)}$ noise levels at the nearest affected receivers adjacent to the construction works are provided in **Table 12**.

Table 12 Construction Noise Predictions

Receiver	Type of Building	Distance from the Site (m)	Predicted LAeq(15 minute) Noise Level (dBA)		Noise Criteria LAeq(15 minute) (dBA)	
			Demolition and Earthworks	Building Construction	Noise Affected	Highly Noise Affected
NC1: Union Street Residences	Residential	76-100	61-66	60-61	52	75
NC2: Bank Street Residences	Residential	20-100	60-74	63-72	50	75
NC3: Lord Street Residences	Residential	50-120	58-66	60-65	52	75
Shore School	School	5-20	76-88	76-82	65[1]	

Note 1: External noise criterion assuming windows closed as discussed in Section 4.1.

5.2.1 Discussion

Stage 1 Works

This phase of work involves only minor demolition at the rear of the House and minor excavation for new drainage pipes. Further, the renovations works are effectively equivalent to a typical house renovation/repair. As a result, noise impacts during this stage are expected to be at the lower levels indicated in **Table 12**.

Stage 2 and 3 Works

With reference to **Section 4.1.2**, the noise predictions indicate that $L_{Aeq(15minute)}$ construction noise levels in the range of 60 dBA to 74 dBA are expected at the nearest noise affected residential receivers for typical demolition and earthworks. The NMLs are predicted to be exceeded by up to 24 dBA at the nearest noise affected residential receivers.

In addition, with reference to **Section 4.1.2**, the noise predictions indicate that $L_{Aeq(15minute)}$ construction noise levels in the range of 60 dBA to 72 dBA are expected at the nearest noise affected residential receivers for typical building construction works. The NMLs are predicted to be exceeded by up to 22 dBA at the nearest noise affected residential receivers.

Further, significant exceedances are predicted to occur within the Shore School grounds in the vicinity of the proposed works. Accordingly, it is likely that the a construction Noise Management Plan will need to be implemented in order to manage and mitigate the noise emissions from the works to sensitive receivers associated with the school which will consequently result in a benefit to the surrounding residential receivers.

6 VIBRATION ASSESSMENT

As a guide, indicative safe working distances for typical items of vibration intensive plant are listed in **Table 13**. The safe working distances are quoted for both "cosmetic" damage (refer BS 7385) and human comfort (refer BS 6472).

Table 13 Indicative Safe Working Distances for Vibration Intensive Plant

Plant Item	Rating/Description	Indicative Working Distance	
		Cosmetic Damage (BS 7385)	Human Response (BS 6472)
Vibratory Roller	< 50 kN (Typically 1-2 tonnes)	5 m	15 m to 20 m
	< 100 kN (Typically 2-4 tonnes)	6 m	20 m
	< 200 kN (Typically 4-6 tonnes)	12 m	40 m
	< 300 kN (Typically 7-13 tonnes)	15 m	100 m
	> 300 kN (Typically 13-18 tonnes)	20 m	100 m
	> 300 kN (> 18 tonnes)	25 m	100 m
Small Hydraulic Hammer	(300 kg - 5 to 12t excavator)	2 m	7 m
Medium Hydraulic Hammer	(900 kg - 12 to 18t excavator)	7 m	23 m
Large Hydraulic Hammer	(1600 kg - 18 to 34t excavator)	22 m	73 m
Vibratory Pile Driver	Sheet piles	2 m to 20 m	20 m
Pile Boring	≤ 800 mm	2 m (nominal)	N/A
Jackhammer	Hand held	1 m (nominal)	Avoid contact with structure

Note: More stringent conditions may apply to sensitive structures.

The safe working distances presented in **Table 13** are indicative and will vary depending on the particular item of plant and local geotechnical conditions. They apply to cosmetic damage of typical buildings under typical geotechnical conditions. Vibration monitoring is recommended to confirm the safe working distances at specific sites and for specific plant items.

In relation to human comfort (response), the indicative safe working distances in **Table 13** relate to continuous vibration. For most construction activities, vibration emissions are intermittent in nature and for this reason, higher vibration levels, occurring over shorter periods may be allowed.

7 NOISE AND VIBRATION MONITORING

7.1 Vibration Monitoring

Where it is anticipated that an item of plant will operate within the safe working distance for cosmetic damage nominated in **Table 13**, vibration monitoring would be required on the potentially nearest affected receiver. Where it is anticipated that an item of plant will operate within the safe working distance for human response and concerns have been raised regarding vibration, vibration monitoring would also be required at the receiver(s) under question.

The distances to the nearest receivers (refer **Table 12**) indicate that the Graythwaite construction works will not result in any cosmetic damage (refer **Table 13**). Human responses will only be observed if large vibratory rollers or hydraulic hammers are used.

8 NOISE AND VIBRATION MANAGEMENT PLAN

Where noise and/or vibration issues have been identified after all feasible and reasonable mitigation measures have been implemented, the construction contractor would produce a noise and vibration management plan. The noise and vibration management plan is to be project specific and will cover all aspects of the works. A copy of the noise management plan would be kept on site in order to provide guidance to the construction contractor relating to the management of noise and vibration issues. The noise and vibration management plan would include:

- A recommendation for noise monitoring should be considered during the development of a Noise Management Plan.
- Where it is anticipated that an item of plant will operate within the safe working distance for cosmetic damage nominated in **Table 13**, vibration monitoring would be required on the potentially nearest affected receiver. Where it is anticipated that an item of plant will operate within the safe working distance for human response, vibration monitoring would also be recommended at the receiver(s) under question.
- Identification of the specific activities that will be carried out and associated noise and vibration sources.
- Identification of all potentially affected sensitive receivers (both Project associated and private), including residences, churches, commercial premises, schools and properties containing noise and/or vibration sensitive equipment.
- The construction noise objectives based on the existing background noise levels in accordance with the conditions of consent.
- The construction vibration criteria specified in the conditions of consent.
- Determination of appropriate noise and vibration objectives for each identified sensitive receiver in accordance with the conditions of consent.
- Noise and vibration monitoring, reporting and response procedures assessment of potential noise and vibration from the proposed demolition, excavation and construction activities, including noise from construction vehicles and any traffic diversions.
- Description of specific mitigation treatments, management methods and procedures that will be implemented to control noise and vibration during construction.
- Construction timetabling to minimise noise impacts including time and duration restrictions, respite periods and frequency.
- Construction timetabling to minimise noise impacts including time and duration restrictions, respite periods and frequency.
- Procedures for notifying residents of construction activities which are likely to affect their amenity through noise and vibration.
- Contingency plans to be implemented in the event of non-compliances and/or noise complaints.

9 CONCLUSION

The noise predictions indicate that both the proposed demolition and construction activities are likely to exceed the construction noise goals by clear margins for the Stage 2 and 3 works, resulting in anticipated moderate noise impacts at the nearest noise affected residential receivers and high noise impact at the adjoining school.

Accordingly, a noise and vibration management plan will be produced identifying reasonable and feasible noise mitigation measures to reduce the noise emissions from the Project to acceptable levels, and where this is not achievable, identify noise management practices to reduce the potential impacts.

It is recommended that noise and vibration monitoring take place for the Stage 2 and 3 works for assessment against the noise levels and safe working distance predicted in this report at the nearest and most impacted noise and vibration sensitive receivers during construction works.

10 REFERENCED DOCUMENTS AND GUIDELINES

- Director-General's Requirements (Application Number: MP 10_0149 and MP 10_0150)
- British Standard 6472:1992 - *Guide to evaluation of human exposure to vibration in buildings.*
- British Standard 7385-1:1990 *Evaluation and measurement for vibration in buildings. Guide for measurement of vibrations and evaluation of their effects on buildings*.
- DECCW's Assessing Vibration: *A Technical Guideline* (MCoA 2.6).
- DIN 4150 Part 3:1999 Structural Vibration in Buildings - Effects on Structures (MCoA 2.6).

11 CLOSURE

This report has been prepared by Heggies Pty Ltd with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of Shore School. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from Heggies.

Heggies disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

Acoustic Terminology

1 Sound Level or Noise Level

The terms "sound" and "noise" are almost interchangeable, except that in common usage "noise" is often used to refer to unwanted sound.

Sound (or noise) consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. The human ear responds to changes in sound pressure over a very wide range. The loudest sound pressure to which the human ear responds is ten million times greater than the softest. The decibel (abbreviated as dB) scale reduces this ratio to a more manageable size by the use of logarithms.

The symbols SPL, L or L_P are commonly used to represent Sound Pressure Level. The symbol L_A represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Levels expressed in decibels is 2 x 10^{-5} Pa.

2 "A" Weighted Sound Pressure Level

The overall level of a sound is usually expressed in terms of dBA, which is measured using a sound level meter with an "A-weighting" filter. This is an electronic filter having a frequency response corresponding approximately to that of human hearing.

People's hearing is most sensitive to sounds at mid frequencies (500 Hz to 4000 Hz), and less sensitive at lower and higher frequencies. Thus, the level of a sound in dBA is a good measure of the loudness of that sound. Different sources having the same dBA level generally sound about equally loud.

A change of 1 dBA or 2 dBA in the level of a sound is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness. The table below lists examples of typical noise levels

Sound Pressure Level (dBA)	Typical Source	Subjective Evaluation
130	Threshold of pain	Intolerable
120	Heavy rock concert	Extremely noisy
110	Grinding on steel	
100	Loud car horn at 3 m	Very noisy
90	Construction site with pneumatic hammering	
80	Kerbside of busy street	Loud
70	Loud radio or television	
60	Department store	Moderate to quiet
50	General Office	
40	Inside private office	Quiet to very quiet
30	Inside bedroom	
20	Recording studio	Almost silent

Other weightings (eg B, C and D) are less commonly used than A-weighting. Sound Levels measured without any weighting are referred to as "linear", and the units are expressed as dB(lin) or dB.

3 Sound Power Level

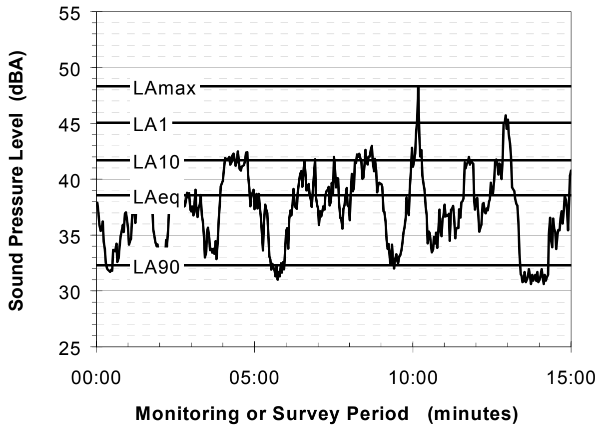
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or L_W, or by the reference unit 10^{-12} W.

The relationship between Sound Power and Sound Pressure may be likened to an electric radiator, which is characterised by a power rating, but has an effect on the surrounding environment that can be measured in terms of a different parameter, temperature.

4 Statistical Noise Levels

Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels L_{AN}, where L_{AN} is the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the L_{A1} is the noise level exceeded for 1% of the time, L_{A10} the noise exceeded for 10% of the time, and so on.

The following figure presents a hypothetical 15 minute noise survey, illustrating various common statistical indices of interest.



Of particular relevance, are:

L_{A1} The noise level exceeded for 1% of the 15 minute interval.

L_{A10} The noise level exceed for 10% of the 15 minute interval. This is commonly referred to as the average maximum noise level.

L_{A90} The noise level exceeded for 90% of the sample period. This noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level.

L_{Aeq} The A-weighted equivalent noise level (basically the average noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

When dealing with numerous days of statistical noise data, it is sometimes necessary to define the typical noise levels at a given monitoring location for a particular time of day. A standardised method is available for determining these representative levels.

This method produces a level representing the "repeatable minimum" L_{A90} noise level over the daytime and night-time measurement periods, as required by the EPA. In addition the method produces mean or "average" levels representative of the other descriptors (L_{Aeq}, L_{A10}, etc).

5 Tonality

Tonal noise contains one or more prominent tones (ie distinct frequency components), and is normally regarded as more offensive than "broad band" noise.

6 Impulsiveness

An impulsive noise is characterised by one or more short sharp peaks in the time domain, such as occurs during hammering.

7 Frequency Analysis

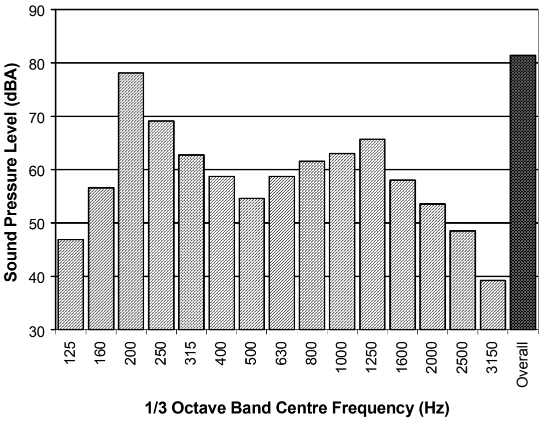
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

The units for frequency are Hertz (Hz), which represent the number of cycles per second.

Frequency analysis can be in:

- Octave bands (where the centre frequency and width of each band is double the previous band)
- 1/3 octave bands (3 bands in each octave band)
- Narrow band (where the spectrum is divided into 400 or more bands of equal width)

The following figure shows a 1/3 octave band frequency analysis where the noise is dominated by the 200 Hz band. Note that the indicated level of each individual band is less than the overall level, which is the logarithmic sum of the bands.



8 Vibration

Vibration may be defined as cyclic or transient motion. This motion can be measured in terms of its displacement, velocity or acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of “peak” velocity or “rms” velocity.

The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as “peak particle velocity”, or PPV. The latter incorporates “root mean squared” averaging over some defined time period.

Vibration measurements may be carried out in a single axis or alternatively as triaxial measurements. Where triaxial measurements are used, the axes are commonly designated vertical, longitudinal (aligned toward the source) and transverse.

The common units for velocity are millimetres per second (mm/s). As with noise, decibel units can also be used, in which case the reference level should always be stated. A vibration level V, expressed in mm/s can be converted to decibels by the formula 20 log (V/V_o), where V_o is the reference level (10^{-9} m/s). Care is required in this regard, as other reference levels may be used by some organizations.

9 Human Perception of Vibration

People are able to “feel” vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building (even though they may not be disturbed by the motion). An individual's perception of motion or response to vibration depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as “normal” in a car, bus or train is considerably higher than what is perceived as “normal” in a shop, office or dwelling.

10 Over-Pressure

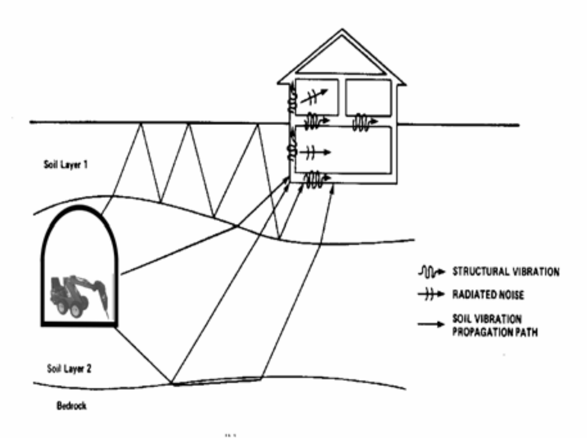
The term “over-pressure” is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

11 Ground-borne Noise, Structure-borne Noise and Regenerated Noise

Noise that propagates through a structure as vibration and is radiated by vibrating wall and floor surfaces is termed “structure-borne noise”, “ground-borne noise” or “regenerated noise”. This noise originates as vibration and propagates between the source and receiver through the ground and/or building structural elements, rather than through the air.

Typical sources of ground-borne or structure-borne noise include tunnelling works, underground railways, excavation plant (eg rockbreakers), and building services plant (eg fans, compressors and generators).

The following figure presents the various paths by which vibration and ground-borne noise may be transmitted between a source and receiver for construction activities occurring within a tunnel.



The term “regenerated noise” is also used in other instances where energy is converted to noise away from the primary source. One example would be a fan blowing air through a discharge grill. The fan is the energy source and primary noise source. Additional noise may be created by the aerodynamic effect of the discharge grill in the airstream. This secondary noise is referred to as regenerated noise