Manual

Transport Noise Management Code of Practice: Volume 2 – Construction Noise and Vibration

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Queensland Government

Feedback: Please send your feedback regarding this document to: tmr.techdocs@tmr.qld.gov.au

Amendment Register

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1	–	First Edition	CE (E&T)	September 2014
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1 Overview

1.1 Framework behind the Code of Practice

The *Transport Noise Management Code of Practice* is structured into volumes. Initially there are two:

- Volume 1: Road Traffic Noise
- Volume 2: Construction Noise and Vibration.

Transport Noise Management Code of Practice Volume 1 is primarily used to address operational road traffic noise, while Volume 2 (this Code) is primarily used to address transport infrastructure construction noise and vibration.

This document has been developed by the Queensland Department of Transport and Main Roads and endorsed by the Queensland Department of Environment and Heritage Protection. Unless otherwise noted, all references to 'the department', 'departmental' and so on refer to the Queensland Department of Transport and Main Roads.

All the following refers to Volume 2 unless noted otherwise.

1.2 Aim of the Code

This Code aims to demonstrate compliance of the Queensland Department of Transport and Main Roads (the department) with its general environmental duty defined in the *Environmental Protection Act 1994* with respect to environmental harm and nuisance. Overall, the department's obligation to meet its general environmental duty associated with construction activities requires all reasonable and practicable measures to be implemented to prevent or minimise environmental harm (which includes environmental nuisance) from construction noise and vibration.

This Code is a published standard (Section 9(b) of the *Transport Infrastructure Act 1994*) that provides a framework for assessment and management of the potential impact of construction noise and vibration on public amenity and safety.

This Code is gazetted under s318E of the *Environmental Protection Act 1994*. The effect of this gazettal is that projects complying with this Code, including compliance with a Noise and Vibration Management Plan prepared under this Code, are deemed to comply with the general environmental duty (s493A *Environmental Protection Act 1994*).

Compliance with this Code is not mandatory. However where a transport infrastructure project chooses not to follow this Code, the project will need to be able to demonstrate compliance with its general environmental duty defined in the *Environmental Protection Act 1994* with respect to environmental harm and nuisance by other means and cannot rely on the provisions of this Code.

1.3 Objectives of the Code

This Code aims to achieve the following objectives:

- Provide a consistent framework for the identification and assessment of noise and vibration impacts from transport infrastructure construction. Community amenity and building damage impacts are considered.
- Provide guidance regarding reasonable and practicable control measures to minimise noise and vibration impacts from transport infrastructure construction.

- Provide guidance on how a construction entity meets its general environmental duty by mitigating noise and vibration impacts. This includes when a noise and vibration management plan should be developed and what it should contain.

1.4 Principles of the Code

Construction noise and vibration, like other environmental impacts, must be managed to minimise potential adverse impacts. As the construction of infrastructure is temporary and provides a benefit to the community, it should be recognised as an essential part of urban and rural development and not be restricted by unreasonable mitigation measures.

This Code has been developed to focus on balancing the noise and vibration impact management of construction projects with community expectations by considering all 'Practicable' and 'Reasonable' mitigation and management measures.

The terms 'Practicable' and 'Reasonable' are the guiding principle for the application of this Code and they frame the intent of the Code when considering the management of noise and vibration impacts, particularly mitigation measures.

A noise and vibration mitigation measure, being of administrative or engineering nature, is considered practicable if it is capable of being implemented or engineered. The practicality of the mitigation measure should consider the bounds of the project, technical feasibility, environmental impacts, maintenance aspects and implications in relation to safety.

To determine whether a mitigation measure is reasonable relies upon common sense and good judgement to arrive at a decision. Overall, the reasonableness of the noise and vibration measures should be weighed with community expectations, cost effectiveness and other environmental implications. The following (and other relevant issues) should be considered when determining reasonableness:

- noise and vibration measure effectiveness (for example, absolute level, duration of exposure, post construction benefits, potential for damage)
- community/stakeholder expectations (for example, community support and input from local and public agencies)
- cost effectiveness (for example, attenuation benefits, costs and life cycle of attenuation treatments, disruption to infrastructure and utilities/services, potential cost of repairs/rehabilitation without mitigation)
- environmental impacts (for example, impacts of mitigation on drainage/overland flow paths, disturbance of contaminated land, light spillage, impacts on air quality, streetscape and scenic/visual amenity)
- risk to safety.

1.5 Legislative framework

Legislation having potential to affect the environmental assessment and approval processes for the department from a maintenance and construction perspective includes:

- *Environmental Protection Act 1994* (Qld)
- *Transport Infrastructure Act 1994* (Qld)
- *Professional Engineers Act 2002* (Qld).

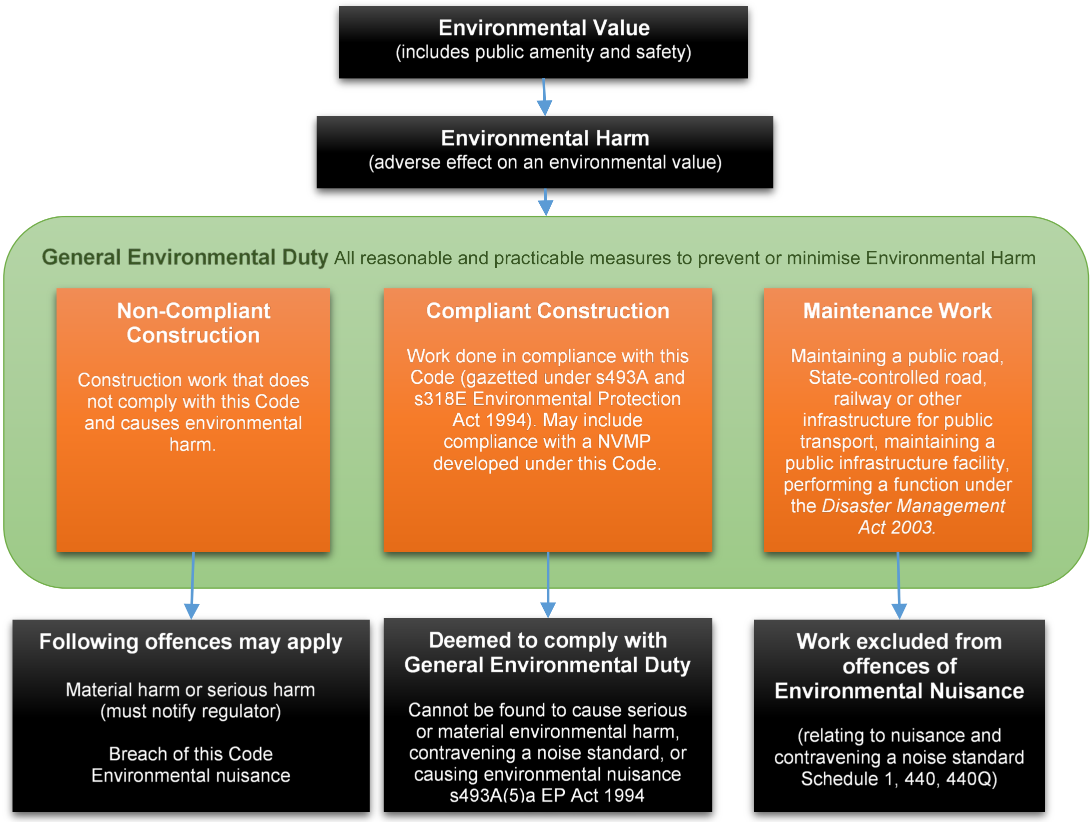
The *Environmental Protection Act 1994* is the legislative instrument which seeks to protect environmental values. Environmental harm, which includes environmental nuisance, is the adverse or potential adverse impact on an environmental value. Maintenance of transport infrastructure is excluded from offences relating to nuisance and contravening a noise standard (Schedule 1).

The *Environmental Protection Act 1994* also defines the general environmental duty, that is, '*A person must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practicable measures to prevent or minimise the harm*'. This gazetted Code of Practice under s318E of the *Environmental Protection Act 1994* provides a framework for a transport infrastructure construction project to comply with its general environmental duty requirements.

The *Environmental Protection (Noise) Policy 2008* is subordinate legislation to the *Environmental Protection Act 1994* and is used to provide nuisance criteria for environmental noise emissions with a long-term focus. It is noted that nuisance from maintenance and ordinary use of transport infrastructure is excluded from offences relating to nuisance and contravening a noise standard (see Schedule 1, Part 1 item 1 and 2, *Environmental Protection Act 1994*).

Figure 1.5 presents the relationship of terms relating to a general environmental duty regarding construction and maintenance of transport infrastructure, which requires all reasonable and practicable measures to prevent or minimise environmental harm.

Figure 1.5: Relationship between Environmental Protection Act 1994 terminology and the general environmental duty



The *Transport Infrastructure Act 1994* requires the construction, maintenance and operation of all government supported infrastructure to be carried out with the following objectives:

- take into account best practice and national benchmarks

- reduce adverse environmental impacts.

Under the *Transport Infrastructure Act 1994*, the Chief Executive is authorised to publish standards if necessary. Standards published by the Chief Executive should be designed to consider the transport objectives, namelyefficiency, affordable quality and cost effectiveness. This Code is a published standard and is authorised by the Chief Executive. In addition to being a published standard, the Code is gazetted under s318E of the *Environmental Protection Act 1994*.

1.6 Departmental policies

1.6.1 Environmental management process

Transport infrastructure projects are classified based on levels of potential environmental risk, as explained in the department's *Environmental Processes Manual*, and are required to address relevant departmental technical standards and implement appropriate mitigation measures. This Code is one of a series of technical standards published by the department. Other documents that provide guidance on good environmental management practices associated with transport infrastructure projects address topics including but not limited to:

- road landscape
- cultural heritage
- roads in the wet tropics
- fauna sensitive road design.

1.6.2 Specifications

Transport and Main Roads Specifications (including Technical Specifications (MRTS) and Specifications (MRS)) apply to all construction and maintenance activities conducted by or on behalf of the department.

The following specifications include specific requirements and conditions particularly relating to noise and vibration associated with transport construction and maintenance works:

General environment

MRS/MRTS51	Environmental Management

Ground vibration and airblast tech note

TN03	Measurement of Ground Vibration and Airblast

Subject matter from TN03 forms part of this Code.

Blasting

MRS/MRTS55	Use of Explosives in Roadworks

Piling works

MRS/MRTS63	Cast-In-Place Piles
MRS/MRTS63A	Piles for Ancillary Structures
MRS/MRTS65	Precast Prestressed Concrete Piles
MRS/MRTS66	Driven Steel Piles

Noise fences

MRS/MRTS15	Noise Fences

In some cases a practical and reasonable option to mitigate noise from road works is by the use of fences. In construction, noise fences may be temporary or permanent structures. Permanent noise fences, whether or not they would be required to meet operational traffic noise mitigation requirements, must be designed and constructed in accordance with the requirements of MRTS15.

Other specifications

MRS/MRTS03	Drainage, Retaining Structures and Protective Treatments
MRS/MRTS04	General Earthworks
MRS/MRTS06	Reinforced Soil Structures
MRS/MRTS16	Landscape and Revegetation Works
MRS/MRTS28	Contractor's Site Facilities and Camp

Those specifications specify particular construction methods and work practices and may also be of direct relevance to noise and vibration management for road works.

1.7 Matters covered by the Code

This Code is applicable to noise and vibration impacts associated with:

- construction or demolition associated with transport infrastructure (including earthworks)
- construction or demolition associated with public utilities related to transport infrastructure (including earthworks)
- mobile or temporary fixed facilities associated with a construction project (transport infrastructure/utilities) and established on a short-term or semi-permanent basis to meet the specific requirements of the construction project – this does not include facilities which are located outside the project area
- traffic generated by construction projects (transport infrastructure/utilities) including construction traffic on public roads
- blasting associated with construction projects (transport infrastructure/utilities) within the project area.

This Code is not applicable to noise and vibration which may result from maintenance of transport infrastructure or from works conducted in relation to emergency repairs to infrastructure or to public utilities located in the reserve performed as a function under the *Disaster Management Act 2003*. Environmental management for road maintenance is generally considered within a separate contractual arrangement by the department.

1.8 Other related matters

The following matters are not the focus of this Code, but generally addressed by other legislation, policies or standards:

- Operational noise emissions from different transport modes, which are covered by various government policies including:

  - Road traffic – *Transport Noise Management Code of Practice Volume 1: Road Traffic Noise,* 2013 (Transport and Main Roads).
  - Road traffic – *Policy for Development on Land Affected by Environmental Emissions from Transport and Transport Infrastructure* Version 2, 10 May 2013 (Transport and Main Roads).
  - Airports – *Airports Act 1996* (Commonwealth).
  - Airports – *Airport Environmental Protection Regulation 1997* (Commonwealth).
- Operational vibration emissions from different transport modes, which are technically not the subject of this Code. However it is expected that the vibration limits for human comfort should generally be met. The following standards can be referenced:
  - Australian Standard AS 2670.2-1990 [ISO 2631-2: 1989]: *Evaluation of human exposure to whole-body vibration* – Part 2: *Continuous and shock induced vibration in buildings (1 Hz to 80 Hz)*. Standards Australia, Sydney.
  - British Standard BS 6472-1:2008 *Guide to evaluation of human exposure to vibration in buildings – Vibration sources other than blasting*. British Standards Institution, London.
  - *Policy for Development on Land Affected by Environmental Emissions from Transport and Transport Infrastructure* Version 2, 10 May 2013 (Transport and Main Roads).
- Occupational noise and vibration requirements associated with construction and maintenance, which are covered by:
  - *Work Health and Safety Act 2011* (Qld).
  - *Work Health and Safety Regulation 2011* (Qld).
  - *Work Health and Safety and Another Regulation Amendment Regulation (No. 1) 2013* (Qld).
- Industry noise and vibration requirements (including Environmentally Relevant Activities (ERA) within the construction area), which are addressed in Queensland Department of Environment and Heritage Protection (DEHP) guidelines:
  - DEHP Guideline – *Planning for noise control* (2004).
  - DEHP Guideline – *Noise and vibration from blasting* (2016).
  - DEHP Manual – *Noise measurement manual* (2013).
- Local government planning schemes, which address the noise and vibration impact management from a Council perspective.
- Operator environmental guidelines, which address the noise and vibration impact management from an operator perspective.

1.9 Structure of the Code

The management of transport construction noise and vibration is outlined in this Code within the following chapters.

Chapters 3, 4, and 7 are written primarily for:

- departmental regional officers

- project managers
- acoustical consultants.

Chapters 5 and 6 are written primarily for:

- departmental regional officers
- acoustical consultants.

Chapters 5 and 6 requirements should also be generally understood by project managers.

Chapter 2 *Description of construction noise and vibration* defines construction noise and vibration including:

- factors contributing to the generation and propagation of noise and vibration
- a set of noise and vibration descriptors relevant to this Code.

Chapter 3 *Criteria* provides guidance on construction noise and vibration criteria for human comfort and structural damage.

Chapter 4 *Assessment* outlines the type and specific requirements of a construction noise and vibration assessment. It specifies:

- the assessment process to ensure compliance with this Code
- methods for construction noise and vibration attenuation
- construction noise and vibration assessment requirements.

Chapter 5 *Measurements* outlines the requirements for noise and vibration measurement. This chapter provides advice of the following:

- location and mounting of sensors
- minimum specification for monitoring equipment
- relevant standards to consider.

Chapter 6 *Prediction* provides guidance on recommended prediction methods for noise and vibration. It provides various levels of prediction and recommends available methods and algorithms.

Chapter 7 *Mitigation and management* provides guiding principles for the management of noise and vibration impacts. This chapter also sets requirements for a Noise and Vibration Management Plan (NVMP).

Chapter 8 *Glossary of terms* provides definitions of important technical terms and abbreviations.

Chapter 9 *References* provides a list of documentation considered in the formulation of this Code.

2 Description of construction noise and vibration

Environmental noise (or community noise) is unwanted or harmful sound, usually generated by human activities including road traffic, railways, air transport, industry, recreation and construction, that is perceived in areas frequented by the general community. Environmental noise typically excludes noise exposure within the workplace.

Construction noise is a component of environmental noise associated with construction activities. While most construction machinery and equipment can generate airborne noise, heavy construction equipment and trains can also generate groundborne noise (noise radiated from building structures as a result of groundborne vibration).

Construction activities involving blasting, pile-driving, tunnelling equipment and large compressors, as well as heavy transportation such as trucks and trains, can create significant levels of vibration.

Construction can occur in close proximity to sensitive receptors including residential properties, educational facilities, hospitals and community facilities. The effects from exposure to excessive levels of noise and vibration may include:

- sleep disturbance
- annoyance (impacts on recreation, including relaxation/conversation)
- inhibited concentration, leading to difficulties in studying or learning
- building damage (including impacts on sensitive equipment/utilities/activities).

2.1 Construction noise

2.1.1 What is noise

2.1.1.1 Definition of noise

The *Environmental Protection Act 1994* defines noise as '*vibration of any frequency, whether emitted through air or another medium*'. For the purpose of this Code, noise is defined as 'unwanted sound' (that is, vibration of the air).

Noise may be described as sound power (unit of W) at the source or as sound pressure (unit of Pa) at a specified distance from a source. It is more commonly presented as sound power level (L_w, unit of dB referenced to 10^{-12} W) or sound pressure level (L_p, unit of dB referenced to 20 μPa). Sound power level is an absolute that does not vary with distance or acoustic environment. The formula following gives the sound pressure level in relation to the root mean square (RMS) of a given sound pressure to the reference sound pressure (ρ_{ref}) of 20 μPa.

$$L_\rho = 20log_{10}\left(\frac{\rho_{rms}}{\rho_{ref}}\right)dB$$

The conversion between sound pressure level and sound power level should consider geometrical spreading (K), directivity (Directivity Index, DI_M) of the source as well as other propagation effects (excess attenuation, A_E) (see Section 2.1.1.2 of this Code). The formula is as follows:

$$L_p = L_w - K + DI_M - A_E$$

If directivity and excess attenuation are set to zero the relationship between sound pressure level and sound power level may be described as:

$L_p = L_w - 10log_{10}(4\pi r^2)$ *(spherical spreading)*

$L_p = L_w - 10log_{10}(2\pi r^2)$ *(hemispherical spreading for example, location on the ground)*

where r is the radius from a noise source.

Noise is often measured by a sound level meter. The measured noise data is generally time-weighted as exponential averaging in RMS measurements. By convention these time-weightings include:

- 0.125 s for time-weighting F (Fast)
- 1 s for time-weighting S (Slow).

This temporally time-weighted data is then analysed to produce various noise descriptors required for a specified time period (for example, 15 minutes). Noise levels in this Code are assumed to be 'Fast' response unless otherwise stated.

Shorter term descriptors may also be used, for example, the peak sound levels (< 30 µsec) measured or calculated from the greatest absolute instantaneous sound pressure level during a specified time interval for airblast.

The frequency contribution of noise to the overall noise level can also be analysed. This is typically conducted by the use of constant percentage bandwidth filters (1/1, 1/3 octave or Fast Fourier Transform (FFT)) in which the noise signal is converted to a discrete frequency spectrum. For environmental acoustics, the audible frequency for humans with unimpaired hearing perception is typically within the range of 20 to 20 000 Hz. The octave bands are generally in accordance with IEC 61260 (for example, 1/1 octave bands within the audible spectrum include 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, 16000 Hz).

It should be noted that human ears do not perceive all frequencies equally. To compensate for this, the frequency content of noise is weighted to account for human perception. A-weighting is commonly used to approximate the frequency response of the human hearing system. It weights the lower frequencies as less perceptible than the middle and higher frequencies. Noise levels in this Code are assumed to be A-weighted unless stated otherwise.

2.1.1.2 Noise propagation

Construction noise emanates from the source and propagates through the atmosphere. There are numerous factors influencing the noise level received at a sensitive receptor including:

- directivity of the source, DI_M (source may be noisier in a particular direction for example, exhaust outlet)
- separation distance from the source, K (attenuation associated with geometrical spreading)
- excess attenuation, A_E:
  - atmospheric absorption (attenuation is a function of temperature, humidity and frequency within the atmosphere)
  - meteorological influences (attenuation or enhancement due to surface temperature and humidity, vertical temperature profile, wind speed and direction)
  - ground absorption (influence of hard or soft ground types on propagation)

- topography and structures (attenuation due to intervening buildings and terrain features. It should be noted that under certain meteorological conditions such as temperature inversions, attenuation provided by obstacles can be degraded).

2.1.2 Noise category

Noise emissions for the purpose of this Code are categorised as:

- airborne noise (general construction and construction traffic)
- groundborne noise (construction)
- airblast (blasting).

Blasting (explosions) can cause groundborne vibration and airblast (also known as blast overpressure) which is the pressure wave (or pulse) transmitted through the air as the result of an explosion. Airblast may have both acoustic effects in terms of overpressure and vibration effects in terms of airborne and groundborne vibration. The acoustic and vibration effects of airblast are discussed separately in this chapter.

The types of noise emissions and transmission paths are illustrated in Figure 2.1.2.

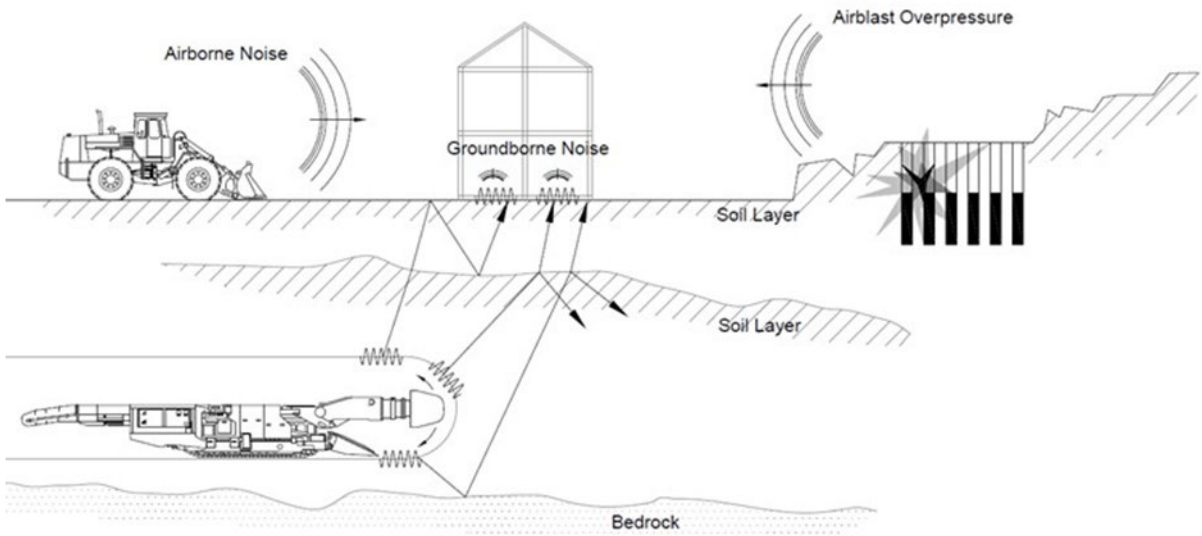


Figure 2.1.2: Noise emissions and transmission paths

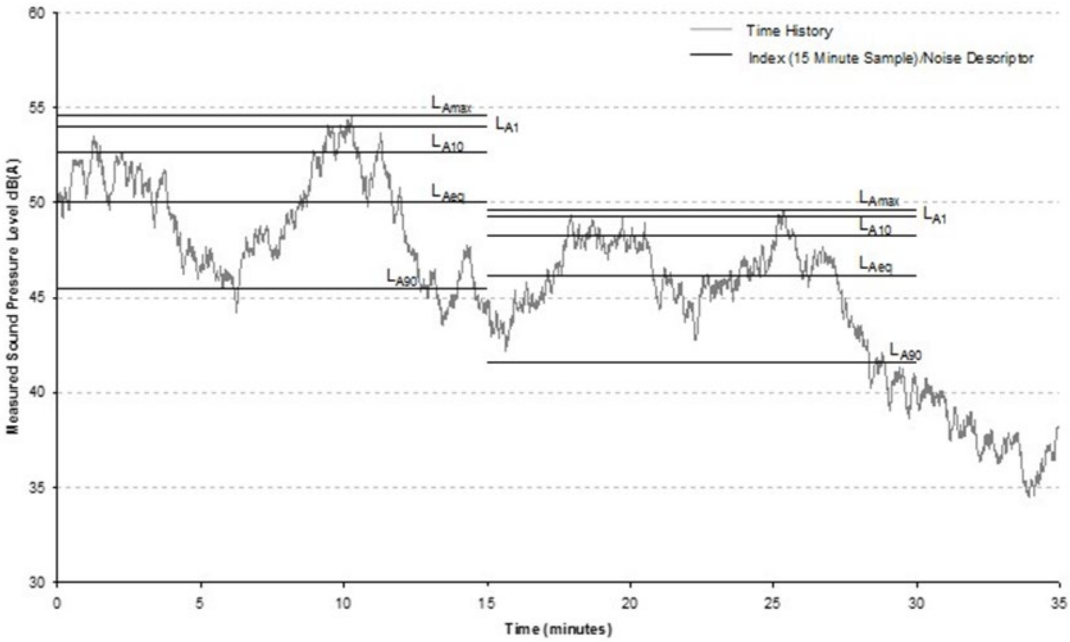
2.1.2.1 Airborne noise

When considering construction airborne noise the following noise descriptors may be used:

- $L_{Amax,T}$ – the maximum A-weighted noise level in a given time period T.
- $L_{A\%,T}$ – the A-weighted noise level which is exceeded for a percentage (for example, 1, 10, 90%) of a given time period T.
- $L_{Aeq,T}$ – the continuous steady A-weighted noise level that has the same mean square sound energy as a noise under consideration whose level varies within that time period T.

These descriptors are generally considered for discrete 15 minute (or hourly) periods as presented in Figure 2.1.2.1 and then further evaluated for different time periods of a day. The time periods may form part of the descriptors.

Figure 2.1.2.1: Example of sound pressure level time history and descriptors



Airborne construction noise typically fluctuates. This fluctuation is due to discrete activities of work being conducted for discrete durations at different points within the construction area, utilising various processes and machinery. Noise from certain items (for example, generators, pumps, idling machinery) of fixed mechanical plant may be considered as steady state or quasi-steady state in nature. Noise from some machinery/activities may be considered as non-steady state and its characteristics may cause greater annoyance. The types of construction noise and their characteristics are described in Table 2.1.2.1(a) with examples of construction activities.

Table 2.1.2.1(a): Construction noise type

Type	Description	Typical Construction Activity
Continuous	Noise that gives fluctuations over a range of not more than 3 dB	Generators, pumps, idling machinery, tunnel boring
Intermittent	Noise that gives fluctuations greater than 5 dB	Vehicle manoeuvring, hammering.
Tonal	A sound producing in a listener a definite pitch sensation	Air compressor, grinding
Impulsive	Sound characterised by brief excursions of sound pressure level (acoustic impulses) that significantly exceed the background sound pressure level. The duration of a single impulsive sound is usually less than one second.	Air release, piling, hammering, metal falling on metal
Dominant low frequency	Where the noise is dominated by sound in the frequency range 10 Hz to 200 Hz	Vibrating roller, burners

Adjustments may be required to account for distinct noise characteristics when assessing potential annoyance. The requirement for the use of adjustment factors is denoted by ‘adj’, for example, $L_{Aeq,adj,T}$. Adjustment factors for different noise characteristics are presented in Table 2.1.2.1(b).

Table 2.1.2.1(b): Adjustment factors

Factor	Assessment/ measurement	When to apply	Correction	Comments
Tonal Noise	1/3 octave or narrow band analysis	Level of 1/3 octave band exceeds the level of the adjacent bands on both sides by: • 5 dB or more if the centre frequency of the band containing the tone is above 400 Hz • 8 dB or more if the centre frequency of the band containing the tone is 160 to 400 Hz inclusive • 15 dB or more if the centre frequency of the band containing the tone is below 160 Hz	5 dB	Narrow-band frequency analysis may be required to precisely detect presence of tonality.
Low frequency Noise	Measurement of C-weighted and A-weighted level	Measure/assess C and A frequency weighted levels over same time period. Correction to be applied if the difference between the two levels is 15 dB or more	5 dB	C-weighting is designed to be more responsive to low-frequency noise. All noise energy down to 10 Hz should be considered.
Impulsive Noise	A-weighted fast response and impulse (I) response or C-weighted for low frequency noise	If difference in A-weighted maximum noise levels between fast response and impulse response is greater than 2 dB If difference in C-weighted maximum noise levels between fast response and impulse response is greater than 2 dB for low frequency noise.	Apply difference in measured levels as the correction, up to a maximum of 5 dB	Impulse response is defined by a short rise time of 35 milliseconds (ms) and decay time of 1.5 s.
Intermittent / Modulating Noise	Measurement of difference between L_{A10} and L_{A90}, average difference between short term samples, or subjectively assessed	• Difference between L_{A10} and L_{A90} exceeds 5 dB repeatedly for a characteristic averaging period (for example, 10 seconds) for intermittent sources. • Average difference between measured LA_{eq} levels exceeds 5 dB for a characteristic sampling frequency (for example, 10 Hz) for rapidly varying source. • Subjectively annoying for a combination not easily characterised.	5 dB	Adjustment to be applied for night-time only.
Maximum Adjustment	Refer to individual modifying factors	Where two or more adjustment factors are indicated	Maximum correction of 10 dB(A)	

While sources may have characteristics that require adjustments to be applied, the magnitude of the factors will depend on the age/type of technology/machinery, whether sources are enclosed/shielded, and the distance from the source to receptor. For example, older equipment designs may be less silenced or exhibit more tonal characteristics. Poor maintenance and general deterioration may introduce whines or rattles. Enclosure may selectively reduce particular frequencies. Distance will attenuate some frequencies more than others and their level in relation to background. These factors will affect the final adjustment applied.

2.1.2.2 Groundborne noise

Groundborne noise (also known as structureborne noise or regenerated noise) is a separate issue to airborne noise. Groundborne noise is generated by vibration transmitted through the ground into a structure. The vibration of structures causes noise to be radiated into a room.

Groundborne noise may be caused by underground works such as road headers and tunnel boring machines (TBM), as well as construction traffic, conveyors and ventilation fans within tunnels. Works located above ground are typically dominated by airborne noise which masks the groundborne component. However, this may not always be the case if the sensitive receptor is well shielded from the airborne noise component and groundborne noise becomes dominant.

Groundborne noise from construction is typically measured using A-weighting and slow response (L_{ASMax} or L_{ASeq}), generally within the frequency range of 16 Hz to 250 Hz as described in ISO 14837 *Mechanical vibration – ground-borne noise and vibration arising from rail systems*.

Groundborne noise tends to be more noticeable than airborne noise at the same A-weighted level due to the large portion of energy at low frequencies. If groundborne noise is dominated by very low frequencies then the use of A-weighted sound pressure levels may underestimate the subjective response.

2.1.2.3 Airblast

Airblasts (overpressure due to blasting) contain significant airborne energy at frequencies in or below the audible range of the human ear.

Airblasts are typically measured as L_{peak} dB(L), which is the flat (Z-weighting) peak noise level (derived from the peak pressure and measured with a meter equipped with a peak detector). It should not be confused with the maximum level, such as L_{max} and L_{Amax} which refers to the maximum RMS sound pressure level.

2.2 Construction vibration

2.2.1 What is vibration

2.2.1.1 Definition of vibration

Vibration is an oscillatory motion of particles that propagates in the form of characteristic waves (for example, compression, shear and surface waves). Vibration may be described by:

- Displacement – the distance that an element moves away from its static position.
- Velocity – the instantaneous speed of an element.
- Acceleration – the rate of change of the speed of an element.

Velocity and acceleration are often used to characterise the expected response of humans, structures and equipment to vibration levels. They are normally described in units of metre per second (m/s) and metre per second squared (m/s^2) respectively. Decibel notation, while not common, is sometimes utilised to express vibration levels (for example, VdB). It is important that if vibration is expressed in decibels, the reference value needs be included as a notation (usually $5x10^{-8}$ m/s international, $1x10^{-6}$ in/s United States of America).

The frequency range of interest for construction vibration is typically from 0.5 to 500 Hz. However, most building damage from man-made sources occurs in the frequency range of 1 Hz to 150 Hz (ISO 14837-1:2005).

2.2.1.2 Frequency and weightings

Human perception of vibration depends on various factors, including the vibration frequency and direction. Human perception of building vibration is mainly related to the frequency range of 0.5 Hz to 80 Hz for the three translational axes: x, y and z. Generally different frequency ratings are required for different axes of motion. Once weighted, the overall vibration level may be used to assess the potential for impacts relating to perception, comfort or adverse comment for whole-body vibration.

British Standard BS 6472-1:2008 *Guide to evaluation of human exposure to vibration in buildings – Vibration sources other than blasting* revises the weighting values for RMS acceleration from previous versions and fixes the axes (z axis is always vertical to the ground, geocentric earth based coordinate system) so that they no longer relate to human orientation (head to foot). This standard utilises the weighting W_b in the z axis and W_d in the x and y axes. W_b and W_d are defined in British Standard BS 6841:1987 '*Guide to measurement and evaluation of human exposure to whole-body mechanical vibration and repeated shock'*. The weightings demonstrate maximum sensitivity to vertical acceleration in the frequency range 4 Hz to 12.5 Hz and to horizontal acceleration in the range 1 Hz to 2 Hz.

British Standard BS 6472-1:2008 has sought to simplify the assessment methodology and descriptors from the previous 1992 version and the methodologies contained within ISO 2631-1:1997 '*Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration* – Part 1: *General requirements'*. It utilises vibration dose value (VDV) for all vibration types. VDV is a cumulative measurement of the vibration level received over an 8-hour or 16-hour period. It is calculated by the fourth root of the integral with respect to time of the fourth power of the acceleration after it is weighted. Previous methods relied on a combination of approaches including acceleration and VDV for evaluation of human perception.

2.2.1.3 Vibration propagation

Construction activities transfer energy to the ground from the machinery, which results in elastic and inelastic deformation of the surrounding materials. Part of this energy travels in the form of elastic waves and results in ground and structure vibration.

The most common waves due to vibration are compression, shear and Rayleigh (or surface) waves. These waves travel at different speeds and attenuate at different rates as a function of the physical properties of the ground.

Compression and shear waves travel in the body of the material and attenuate as they travel from the source. Rayleigh waves and other boundary waves are constrained to propagate in the plane of a surface and attenuate less rapidly. The effect of such differences in propagation speed is sometimes observed with blast monitoring where the ground motion changes as each wave type passes the receptor position.

For surface construction activities, Rayleigh waves which occur at the surface of the ground are very common and are dominant at some distance from the site due to their lower rate of attenuation. Closer to the source the situation will be more complicated, where constructive and/or destructive interference of wave forms can occur as a result of wave type interactions.

For underground construction activities and operations, vibration propagation is mainly via compression and shear waves. However, surface waves may become dominant and this depends on the depth of the underground operations and the separation distance to the point of interest.

The magnitude of the vibration transferred from ground to a structure is directly linked to its effects such as structure damage or disturbance to people. Generally, adverse comment from occupants of buildings may be expected when vibration levels are only slightly above thresholds of perception.

For groundborne vibration, the magnitude of the vibratory disturbance at a receptor structure is determined by factors such as:

- the energy input to the ground
- the distance between source and receptor
- the ground conditions at the site (soil or rock, height of water table and so on)
- the efficiency of the coupling between the ground and the receptor structures
- the manner in which the receptor structure responds to the vibration input (with resulting amplification or attenuation of the input).

Due to complicated ground conditions and other variables associated with construction vibration, an exact vibration assessment result is generally not to be expected by use of available prediction methods. Rather, regular monitoring of vibration levels at adjacent sensitive receptors is often required to help understand the vibration effect. This is particularly the case with activities such as pile driving and operation of heavy vibratory compaction plant, where avoidance of damage or other disruption is critical.

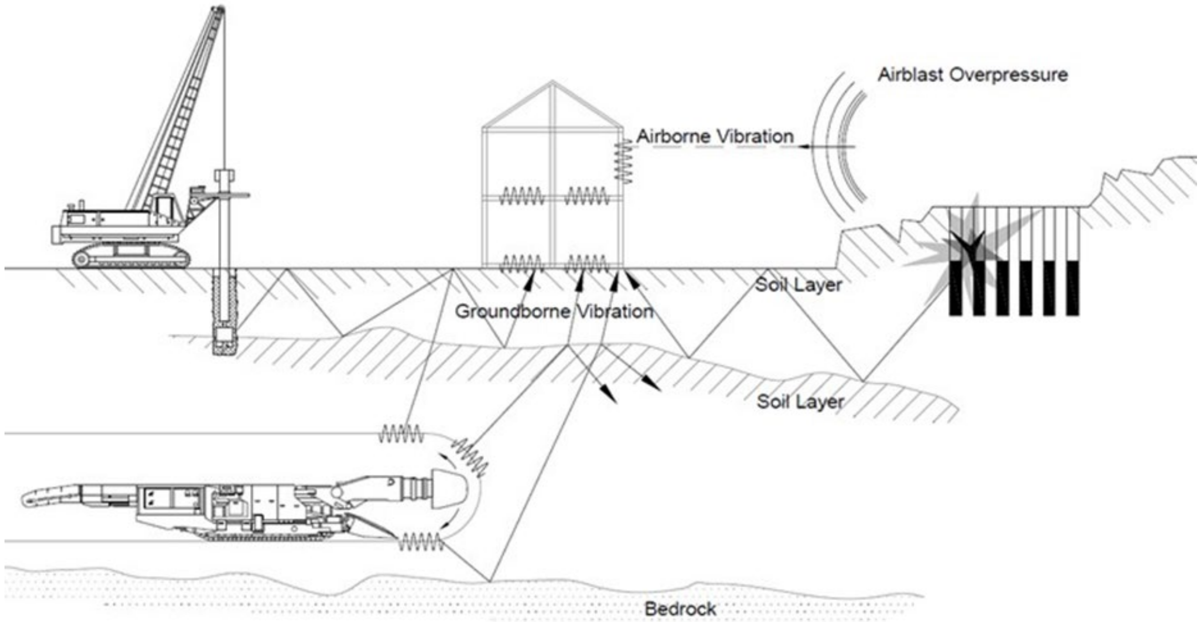
2.2.2 Vibration categories

Vibration emissions for the purpose of this Code are categorised as:

- groundborne vibration (construction)
- airborne vibration (construction).

The types of vibration emissions and transmission paths are illustrated in Figure 2.2.2.

Figure 2.2.2: Vibration emissions and transmission paths



2.2.2.1 Groundborne vibration

Groundborne vibration may be caused by various sources including construction activities, infrastructure and industry operations. Groundborne construction vibration typically fluctuates with the type of equipment utilised and it can be classified as different vibration types as shown in Table 2.2.2.1.

Table 2.2.2.1: Construction vibration type

Vibration types	Description	Typical Construction Activity
Continuous	A vibration source that is continuous in nature during an assessment period (may be constant or variable).	Tunnel boring, vibratory pile driving.
Impulsive	A vibration source (continuous or intermittent) which has a rapid build up to a peak followed by a damped decay that may or may not involve several cycles of oscillation (depending on frequency and damping).	Blasting, dropping of heavy equipment, pile driving.
Intermittent	Intermittent vibration can be defined as interrupted periods of continuous (for example, a drill) or repeated periods of impulsive vibration (for example, a pile driver), or continuous vibration that varies significantly in magnitude.	Heavy vehicle movements, pile driving, jack hammering.

Several vibration descriptors are used to assess the likelihood of vibration impacts based on the velocity and acceleration.

Peak particle velocity (PPV or v_p) is a commonly used vibration descriptor for building/structural damage. It can also be used for human perception. It is defined as the maximum peak of the instantaneous fluctuating vibration velocity signal. The overall maximum instantaneous velocity of particle motion is defined as the resultant PPV, which is the vector sum of the three orthogonal component particle velocities (component PV) as follows:

$$v_p = \sqrt{v_T^2 + v_L^2 + v_V^2}$$

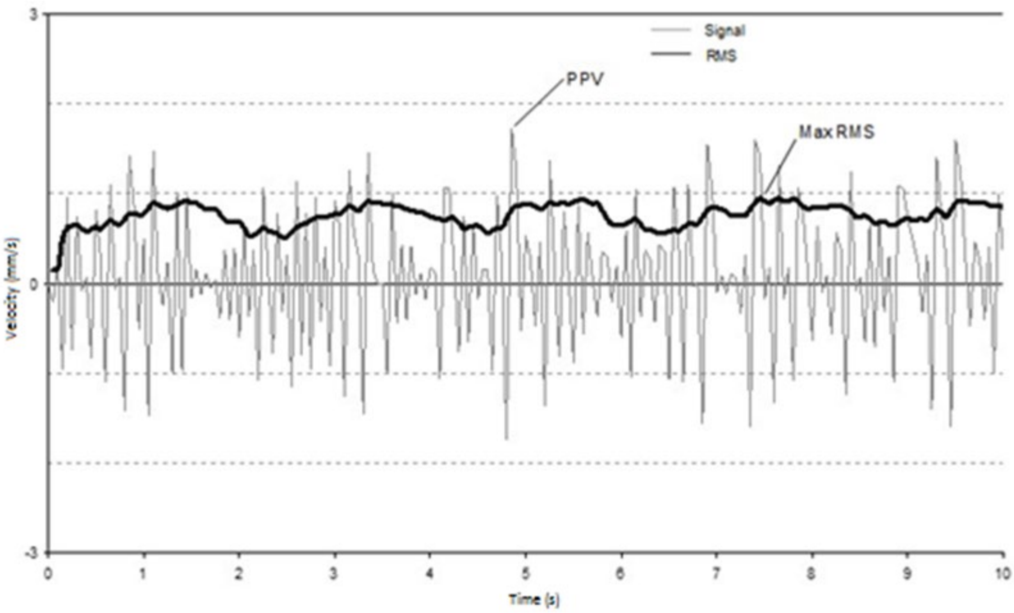
Where:

v_p is the resultant PPV of the particle velocity at a particular time

v_T, v_L and v_V are the respective transverse, longitudinal and vertical component PV of the particle velocity at a particular time.

Vibration may also be described as an average value and used to gauge human perception. The RMS is utilised to average the vibration signal as the net arithmetic average would result in zero. The RMS of the raw signal is the square root of the average of the squared amplitude of the signal. The RMS average is typically defined over a one-second period. Figure 2.2.2.1 presents an example of the relationship between the signal, PPV and RMS vibration velocity.

Figure 2.2.2.1: Vibration signal and descriptors



While weighted RMS acceleration was historically used in evaluating vibration impacts on human comfort and perception, vibration dose value (VDV) has become a focus in more recent years with the exception of blasting. The VDV (in $m/s^{1.75}$) is given by the fourth root of the integral with respect to time of the fourth power of the acceleration after it is weighted (see British Standard BS 6472-1:2008).

VDV is a cumulative measure which increases as the exposure duration increases. It is much more strongly influenced by vibration magnitude than by duration. A doubling (or halving) in the vibration magnitude results in a sixteen-fold decrease (or increase) in the exposure duration for a VDV with the same magnitude.

British Standard BS 5228-2:2009 *Code of practice for noise and vibration control on construction and open sites* – Part 2: *Vibration* recommends an alternative approach to VDV when considering human response to vibration from construction activities. This alternative approach utilises PPV which is more commonly used to gauge potential building damage as well as impacts from blasting. The PPV descriptor is also commonly used in vibration prediction methods. Therefore it may be beneficial that both human perception and building damage are evaluated against PPV in the context of construction vibration assessment.

2.2.2.2 Airborne vibration

Airborne vibration is structural vibration induced by low frequency sound. Sources of airborne vibration may include airblast (overpressure from blasting), pile driving (both impact and vibratory driving) and vibratory compaction plant. Large vibratory screens used with crushing and screening operations are sometimes also the source of airborne vibration. Mechanically driven plant with poor quality, defective or missing mufflers can also cause airborne vibration.

Depending on the frequency and level of airborne vibration, persons exposed may hear the disturbance as sound or experience it via other sensations such as a feeling of vibration or pulsation in the chest or abdomen. Alternatively, the sound and accompanying vibration may not be noticed as a direct sensation, but may be noticed in terms of ‘rattles’ or other similar high frequency noise associated with the induced vibration of a lightweight building element such as a window or door.

While nuisance effects may occur, it is rarely necessary to specify particular limits (with the exception of blasting) for airborne vibration for plant or equipment used in construction activities. When investigating vibration related complaints, airborne vibration should be considered on a case-by-case basis.

2.3 Construction noise and vibration descriptors

2.3.1 Noise descriptors

The following noise descriptors are used in this Code as the basis to determine airborne construction noise criteria:

- background noise level
- rating background level (RBL).

Definition of these descriptors can be found in the Glossary.

The preferred noise descriptors in this Code for construction noise measurement and assessment are as follows:

- Airborne noise – $L_{Aeq,adj,15\ minute}$, the adjusted A-weighted equivalent continuous sound pressure level considering adjustment factors (see Table 2.1.2.1(b)), measured over a 15-minute time period. This descriptor is used to gauge the impact of general construction noise levels and can be measured inside or outside of a building. It is used along with RBL when measured externally.
- Groundborne noise – L_{ASMax}, the A-weighted maximum sound pressure level with slow response.
- Airblast – L_{peak} dB(L), the peak noise level (derived from the peak pressure) using the linear frequency weighting and Peak Hold time weighting.

2.3.2 Vibration descriptors

The preferred vibration descriptors in this Code for construction vibration measurement and assessment to determine human perception and structure damage are as follows:

- Component Particle Velocity (component PV) – the instantaneous particle velocity of a particle at each orthogonal component axis.
- Peak Component Particle Velocity (PCPV) – the maximum instantaneous velocity of a particle in any one of the three orthogonal component axis directions during a given time interval. Also represented by the notation v_i in DIN 4150-3.
- Peak Particle Velocity (Resultant PPV) – the maximum instantaneous velocity of a particle at a point during a given time interval being the vector sum of component velocities in three orthogonal directions.

3 Criteria

This chapter defines working hours, sensitive/critical receptors and criteria/limits that should be considered when assessing noise and vibration impacts from construction of transport infrastructure.

3.1 Sensitive receptors, work hours and activities

3.1.1 Sensitive land uses

Sensitive land uses have the potential to be impacted by construction noise and vibration. Sensitive land uses/receptors considered in this Code include:

- a dwelling (detached or attached) including house, townhouse, unit, reformatory institution, caravan park or retirement village
- a library, child care centre, kindergarten, school, school playground, college, university, museum, art gallery or other educational institution, hospital, respite care facility, nursing home, aged care facility, surgery or other medical centre
- a community building including a place of public worship
- a court of law
- a hotel, motel or other premises which provides accommodation for the public
- a commercial (office) or retail facility
- a protected area, or an area identified under a conservation plan as a critical habitat or an area of major interest under the *Nature Conservation Act 1992*
- an outdoor recreational area (such as public park or gardens open to the public, whether or not on payment of a fee, for passive recreation other than for sport or organised entertainment) or a private open space.

While outdoor recreational areas are considered to be noise and vibration sensitive sites, for the durations involved in construction activities, it is not considered necessary or justified for mitigation measures to be required, but they may be included on a case-by-case or project-specific basis.

Other receptors which may at times be sensitive to construction noise and vibration include industrial premises, other infrastructure and utilities/services.

3.1.2 Critical facilities, infrastructure and utilities

This Code defines critical facilities, infrastructure and utilities (critical receptor) as those buildings, infrastructure and utilities which, by their nature or by the nature of the activities conducted therein, are particularly sensitive to disruption due to construction noise and vibration effects, or where the consequences of such disruption would be severe. Critical facilities, infrastructure and utilities are a subset of sensitive receptors and include the following:

- Critical facilities include medical/health buildings, educational/research facilities, courts of law and community buildings. The latter three are only considered when in use. Critical facilities are usually sensitive to both construction noise and vibration.
- Critical infrastructure and utilities include dams, electrical and telecommunications facilities (including railway signalling systems), oil and gas pipelines and other petrochemical installations and utilities such as water mains and sewers. Critical infrastructure and utilities are typically sensitive to construction vibration.

- Other facilities, infrastructure or utilities (for example bridges) which may be deemed to be of critical importance on a project-specific basis.

Ordinary residential sites and other noise and vibration sensitive sites are not considered to be critical facilities or infrastructure. Similarly, heritage listed sites are not automatically included in the definition of critical facilities and infrastructure, but may be included as such on a project-specific basis.

Where critical facilities, infrastructure or utilities are likely to be affected by construction activity, specific assessment to determine appropriate construction noise and vibration controls are required in all cases.

3.1.3 Construction activities and work periods

For this Code, construction activities are those occurring within the project area, which include the following:

- general construction (for example, pile driving and compaction, work sites, earthworks)
- construction traffic
- blasting.

Table 3.1.3 defines different work periods of the day used in this Code for construction activities.

Table 3.1.3: Work periods for construction activities

<table>
<tr><th>Work Period</th><th>General Construction & Construction Traffic</th><th>Blasting</th></tr>
<tr><td>Standard hours</td><td>Monday – Friday 7:00 am to 6:00 pm
Saturday 8:00 am to 1:00 pm</td><td>Monday – Friday 9:00 am to 5:00 pm
Saturday 9:00 am to 1:00 pm</td></tr>
<tr><td>Non-Standard hours – day/evening</td><td>Monday – Friday 6:00 pm to 10:00 pm
Saturday 1:00 pm to 10:00 pm
Sunday 7:00 am to 10:00 pm</td><td rowspan="2">Generally, blasting is not to be conducted outside standard hours.
Any blasting outside of standard hours must be approved by the department prior to blasting. It is noted that reduced limits may be required to be achieved.</td></tr>
<tr><td>Non-Standard hours – night time</td><td>Monday – Sunday 10:00 pm to 7:00 am</td></tr>
</table>

Note: Public holiday periods are taken to be the same periods as defined for Sunday.

Construction activities (including blasting) should be generally undertaken within the Standard hours. Construction activities with the potential for significant impacts should be discouraged if possible in the night time. The use of high impact machinery such as pile driving, vibratory rollers and impact devices (rock breakers and jackhammers) should be avoided where possible for night work construction in residential or other noise and vibration sensitive areas. Where night work is required in the vicinity of residential or other sensitive sites, careful planning is required and a higher level of control is recommended, to mitigate potential complaints of sleep disturbance.

If the use of high impact machinery is unavoidable, the level of vibration, groundborne and airborne noise from activities involving the use of the machinery must be properly assessed before approval for any activities outside Standard working hours is given.

Construction activities associated with major arterial roads are typically associated with high ambient traffic noise levels due to high traffic volumes, which (with appropriate traffic control) usually continue through the project period. The high traffic volume may commence before 5:00 am and continue to around 9:00 pm or later. Where this is the case, the 'Standard hours' may be extended into the 'Non-Standard hours' periods with essentially no increase in the overall level of impact. This may also lead to a reduction in the overall level of disruption to the local community, due to shorter project durations.

3.2 Construction noise criteria

Noise criteria in this Code are considered primarily to be aimed at dealing with nuisance. All reasonable and practicable control measures are still required to meet the criteria as part of best practice. If all reasonable and practicable control measures are applied and noise levels are still greater than the nominated criterion values, the contractor will need to negotiate directly with the affected person or community for further mitigation measures (for example, respite periods or alternative mitigation).

Noise criteria are defined for the following noise emissions categories:

- airborne noise (general construction and construction traffic)
- groundborne noise
- airblast.

The determination of noise criteria for this Code is based on the review of Queensland state legislation as well as Australian and international standards and guidelines.

3.2.1 Airborne noise

3.2.1.1 General construction criteria

For dwellings (including hotels and motels), noise emissions associated with general construction activities, such as pile driving and compaction, should be assessed using the criteria in Table 3.2.1.1(a). These criteria are further presented graphically in Figure 3.2.1.1(a) and Figure 3.2.1.1(b) for Standard hours and Non-Standard hours respectively. It should be noted that these limits are for the noise contribution from construction only (component limit).

The noise criterion levels for general construction activities are defined as external and facade corrected with lower and upper limits. The noise criteria should be used to manage construction noise as follows:

- Standard hours – work within Standard hours should be encouraged where possible. All reasonable and practicable measures should be implemented to achieve the lower limit. Exceedance of the upper limit requires immediate action and community consultation to determine further mitigation measures.
- Non-Standard hours – all reasonable and practicable measures should be implemented to achieve the lower limit. If exceeded, community consultation should be conducted for further mitigation measures.

Table 3.2.1.1(a): External construction noise criteria

Work Period		**External Noise level $L_{Aeq,adj,15\ minute}$[4, 5], dB(A)**	
		Lower Limit	**Upper Limit [6]**
Standard hours		RBL + 10 [1][2][3]	75 Where: RBL > 55
			70 Where: 40 < RBL ≤ 55
			65 Where: RBL ≤ 40
Non Standard hours	Evening	RBL + 5 [3]	RBL + 5
	Night time		

Notes:

[1] RBL + 5 dB(A) should be considered where a facility, equipment and long-term earthworks are required in an area for greater than six months.

[2] Where the lower limit value exceeds the upper limit value, the lower limit is taken to equal the upper limit value.

[3] Minimum lower limit is 50 dB(A) for Standard hours and 45 dB(A) for Non-Standard hours. A maximum lower limit of 75 dB(A) applies to Non-Standard hours.

[4] Noise contribution from construction activity determined as the component level.

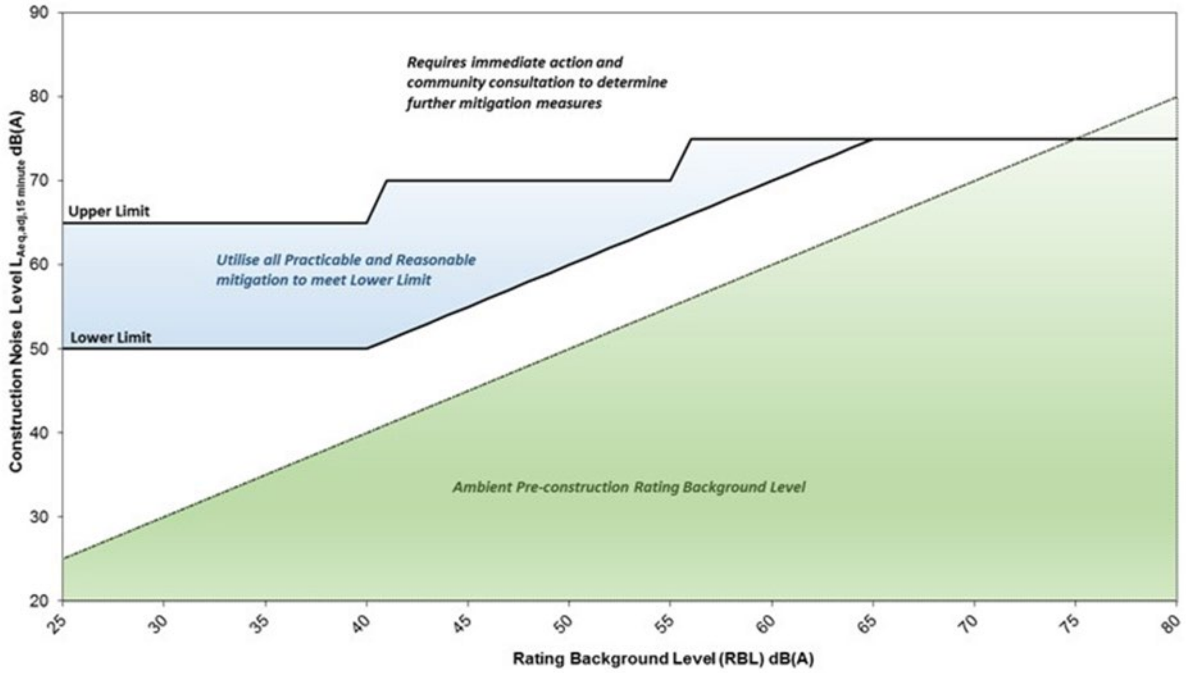
[5] The noise level from construction includes adjustment factors in Table 2.1.2.1(b) (for example, low frequency noise, impulsivity, tonality, intermittency and modulation).

[6] For a single short event in a 24-hour period, the upper limit may be increased by:

- for Standard hours
  - 2 dB(A) for event of 6 minutes to 15 minutes
  - 10 dB(A) for event of 1.5 minutes to 6 minutes
  - 15 dB(A) for event of less than 1.5 minutes.
- for Non-Standard hours
  - 5 dB(A) for event of less than 1.5 minutes.

This single short event adjustment is designed to account for unusual and one-off events, and does not apply to regular high-noise levels that occur more frequently than once per day.

Figure 3.2.1.1(a): Construction noise criteria – Standard hours



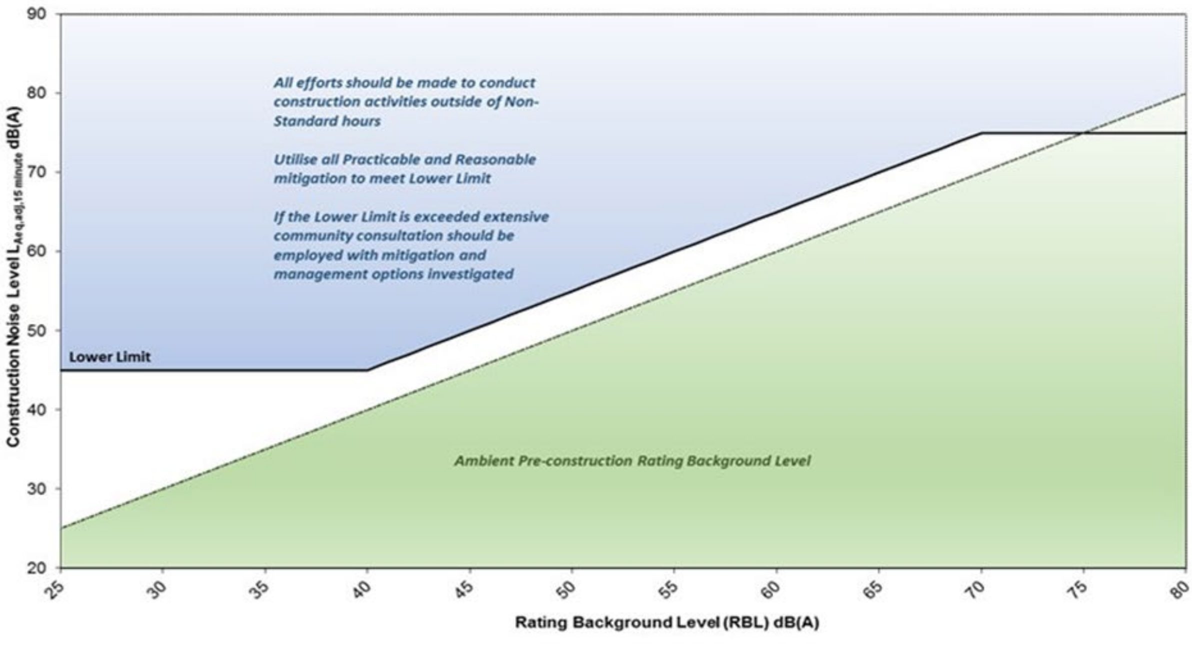


Figure 3.2.1.1(b): Construction noise criteria – Non-Standard hours

For commercial and retail facilities when required to be assessed in the construction project, the upper limit values may be utilised. Where these premises include an external component such as outdoor dining/sports venue, it may be reasonable to minimise construction activity during the time that the majority of trade is conducted (for example, lunchtime, sporting games).

In addition, critical facilities require the internal criteria as presented in Table 3.2.1.1(b) to be met where reasonable and practicable. The criteria shall be considered for the operational hours of the facility.

Table 3.2.1.1(b): Internal construction noise criteria for critical facility

Type of Occupancy/Activity	Internal Noise level $L_{Aeq,adj,15\ minute}$, dB(A)
Medical/health buildings (wards, surgeries, operating theatres, consulting rooms)	40
Educational/research facilities (rooms designated for teaching/research purposes)	45
Court of law (court rooms)	35
Court of law (court reporting and transcript areas, Judges' chambers)	40
Community buildings (libraries, places of worship)	45

3.2.1.2 Construction traffic

Haulage/transportation associated with construction activities on public roads within the project area or beyond has the potential to create traffic noise issues for existing sensitive receptors. The following criteria shall be used to limit traffic noise caused by construction traffic:

- Construction traffic should not increase the pre-construction traffic noise level $L_{A10,1\ hour}$ by more than 3 dB(A).

The increase due to construction traffic should be considered against the median minimum $L_{A10,1\ hour}$ noise levels for each of the relevant hours within each work period. If measurements are unavailable, the increase should be considered against the predicted pre-construction $L_{A10,1\ hour}$ noise level.

The construction traffic should be generally assessed out to a minimum of 500 m beyond the project area boundary. This distance may be increased where it is reasonable to assume that the community would perceive the construction traffic as being associated with the project.

3.2.2 Groundborne noise

Groundborne noise (structureborne noise or regenerated noise) is the noise radiated into a room caused by structural vibration, due to, for example, underground works using road headers and tunnel boring machines. Groundborne noise has significant low frequency components and tends to be more noticeable compared with airborne noise at the same A-weighted level. Where this is observed the internal noise limits presented in Table 3.2.2 shall be used to determine whether additional reasonable and practicable mitigation options should be investigated.

Table 3.2.2: Construction groundborne noise investigation limits

Building	Groundborne Noise Limit	
	Work Period	**L_{ASMax}, dB(A)**
Dwellings (including hotels and motels)	Standard hours	40
	Non Standard hours – evening	35
	Non-Standard hours – night time	
Medical/health buildings (wards, surgeries, operating theatres, consulting rooms)	All	35
Educational/research facilities (rooms designated for teaching/research purposes)	While in use	35
Court of law (court rooms)		30
Court of law (court reporting and transcript areas, Judges' chambers)		35
Community buildings (libraries, places of worship)		40
Commercial (offices)		40
Retail areas		45

Some institutions/facilities, such as concert halls, TV studios, recording studios, auditoriums and theatres, may require specific acoustic performance in order to operate successfully. If these facilities are potentially affected by groundborne noise then consultation with the affected parties should be conducted to determine a reasonable and practicable approach to mitigation.

3.2.3 Blasting – Airblast

The following documents contain criteria for human comfort and building/structural damage for airblast overpressure (airblast):

- Australian Standard AS 2187.2:2006
- ANZEC '*Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration'*, 1990
- *Environmental Protection Act 1994* Section 440ZB
- DEHP Guideline - *Noise and Vibration from Blasting* (DEHP, 2016).

Table 3.2.3 presents the human comfort criteria taken from DEHP Guideline - '*Noise and Vibration from Blasting* to minimise annoyance from airblast. The criteria in Table 3.2.3 shall be used to assess annoyance from airblast.

Table 3.2.3: Human comfort criteria to minimise annoyance from airblast

Location	Airblast Limit L_{peak}
Sensitive land uses	Not more than 115 dB(L) for 9 out of any 10 consecutive blasts, and not more than 120 dB(L) for any blast
Occupied non-sensitive sites, such as factories and commercial premises	See Australian Standard AS 2187.2:2006, Table J5.4(A)

Limits in Table 3.2.3 may need to be lowered in individual circumstances, such as in close proximity to historical buildings and hospitals, or in the presence of sensitive machinery/instruments.

Structural/building damage airblast limits are to be taken from Table J5.4(B) within Australian Standard AS 2187.2:2006. It should be noted that the structural/building damage airblast limits within AS 2187.2:2006 may need to be lowered where facades contain large sections of glazing.

For groundborne vibration due to blasting, the criteria in Section 3.3.1.2 of this Code concerning building damage and in Section 3.3.1.3 of this Code concerning building contents and services are to be used.

3.3 Construction vibration criteria

Vibration criteria in this Code relate to both human comfort and structural/building damage. All reasonable and practicable control measures are still required to meet the criteria as part of best practice. If all reasonable and practicable control measures are applied and vibration levels exceed the nominated criterion values, the contractor will need to negotiate directly with the affected person or community for further mitigation measures (for example, respite periods or alternative mitigation/work method).

Vibration criteria are defined for the following vibration emissions categories:

- groundborne vibration (general construction and blasting).
- airborne vibration.

The determination of vibration criteria for this Code is based on the review of Queensland state legislation as well as Australian and international standards and guidelines.

3.3.1 Groundborne vibration

Vibration criteria for both human comfort and building damage due to groundborne vibration caused by construction activities (for example, pile driving, compaction and blasting) are provided in this section. It should be noted that in most cases compliance with the human comfort criteria would also achieve the building damage criteria.

3.3.1.1 Human comfort

General construction and construction traffic

British Standard BS 5228-2:2009 provides an alternative approach to that historically used to assess human comfort presented in British Standard BS 6472-1:2008. While BS 6472-1 provides guidance on human response to vibration in buildings in terms of VDV, BS 5228-2 Table B.1 provides guidance on the use of PPV which is typically measured to determine potential building damage.

For human comfort, to minimise annoyance due to groundborne construction vibration, this Code adopts vibration levels with lower and upper limits as presented in Table 3.3.1.1(a). The lower limits are generally considered to be just perceptible. The upper limits are considered to cause significant annoyance if exceeded.

All reasonable and practicable measures should be implemented to achieve the lower limit. Exceedance of the upper limit requires immediate action and extensive community consultation to determine further mitigation measures.

Table 3.3.1.1(a): Human comfort vibration limits to minimise annoyance

<table>
<tr><th rowspan="2">Building</th><th rowspan="2">Work Period</th><th colspan="2">Resultant PPV, mm/s</th></tr>
<tr><th>Lower limit</th><th>Upper limit</th></tr>
<tr><td rowspan="3">Dwellings (including hotels and motels)</td><td>Standard hours</td><td>1.0</td><td>2.0</td></tr>
<tr><td>Non-Standard hours – evening</td><td rowspan="2">0.3</td><td rowspan="2">1.0</td></tr>
<tr><td>Non-Standard hours – night time</td></tr>
<tr><td>Medical/health buildings (wards, surgeries, operating theatres, consulting rooms)</td><td>All</td><td rowspan="4">0.3</td><td rowspan="4">1.0</td></tr>
<tr><td>Educational facilities (rooms designated for teaching purposes)</td><td rowspan="3">While in use</td></tr>
<tr><td>Court of Law (Court rooms)</td></tr>
<tr><td>Court of Law (Court reporting and transcript areas, Judges' chambers)</td></tr>
<tr><td>Community buildings (libraries, places of worship)</td><td rowspan="2">While in use</td><td rowspan="2">1.0</td><td rowspan="2">2.0</td></tr>
<tr><td>Commercial (offices) and retail areas</td></tr>
</table>

Blasting

Blasting causes groundborne vibration and it may also cause the secondary effect of airborne vibration due to airblast.

The following documents contain blasting vibration criteria for human comfort:

- Australian Standard AS 2187.2:2006
- ANZEC '*Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration*', 1990
- *Environmental Protection Act 1994* Section 440ZB
- EHP Guideline *'Noise and Vibration from Blasting'* (DEHP, 2016).

The Code sets human comfort criteria for vibration from blasting as presented in Table 3.3.1.1(b).

Table 3.3.1.1(b): Human comfort vibration limits to minimise annoyance from blasting

Location	Blasting Limit Resultant PPV
Buildings of special value or significance (may include historical buildings, monuments)	2 mm/s
Sensitive land uses	Not more than 5 mm/s for 9 out of any 10 consecutive blasts and not more than 10 mm/s for any blast
Occupied non-sensitive sites, such as factories and commercial premises	See Australian Standard AS 2187.2:2006, Table J4.5(A)

If works are in close proximity to sensitive buildings/equipment or critical facilities, the limits in Table 3.3.1.1(b) shall be reassessed. Direct consultation should occur with the operators/owners of the sensitive receivers/equipment and where the operators/owners of the sensitive receivers/equipment nominate a limit lower than those contained in 3.3.1.1(b) all reasonable and practicable measures should be implemented to achieve it.

3.3.1.2 Building damage

The vibration criteria for building damage due to blasting is considered the same as that induced by transient groundborne vibration due to general construction activities.

Vibration levels for potential building damage contained in British Standard BS 7385-2:1993 *Evaluation and measurement for vibration in buildings* – Part 2: *Guide to damage levels from groundborne vibration* are referenced in British Standard BS 5228-2:2009 and Australian Standard AS 2187.2:2006. The vibration levels in BS 7385-2:1993 are adopted as building damage criteria from construction activities in this Code. It should be noted that the vibration values are related predominantly to transient vibration (for example, blasting, heavy vehicles, pile driving), which does not give rise to resonant responses in structures and to low-rise buildings. Dynamic loading caused by continuous vibration (for example, vibratory piling, tunnel boring, rock breaking, rock hammering and sheet piling) may give rise to dynamic magnification due to resonance, in this case BS 7385-2:1993 recommends a reduction of the transient vibration levels.

German Standard DIN 4150-3:1999 '*Structural vibration – Effects of vibration on structures*' provides building damage criteria for short-term or long-term vibration. DIN 4150-3 provides guidance on an additional type of structure that is of intrinsic value, which is a category not specifically covered within British Standard BS 7385-2:1993.

The department recommends both British Standard BS 7385-2:1993 and German Standard DIN 4150-3:1999 be used for construction projects to determine the likely building/structural damage impacts. The results of the assessment should be used to inform the need for conditions surveys as presented in Section 4.5.

3.3.1.3 Building contents, services and structural impacts

For building contents including sensitive instruments and electronics, vibration criteria should be established through discussion with the manufacturer, supplier or operator. Reference may also be made to previous experience or if appropriate other published sources such as '*Vibration control design of high technology facilities*' (Ungar et al, 1990).

Where third party utilities and facilities (for example, bridges, cables, pipes, and so on) are in the vicinity of the project the owners should be consulted to determine their specific requirements in relation to vibration exposure. In the absence of third party advice, guidance may be taken from British Standard BS 5228-2:2009 or German Standard DIN 4150-3:1999 which provide information on the vulnerability of ground-related services and structures to vibration.

It should be noted that these British and German standards do not consider effects of vibration on soil settlement. Vibration-induced soil settlement may still occur at vibration levels below structural damage limits. Settlement may affect structural foundations and services as well as slopes and temporary excavations. Expert advice is to be sought if soil settlement is a potential issue.

3.3.2 Airborne vibration

Airborne vibration is structural vibration induced by low frequency sound. Sources of airborne vibration may include airblast (overpressure due to blasting), pile driving (both impact and vibratory driving) and vibratory compaction plant.

This Code does not provide specific limits for impacts associated with airborne vibration due to construction activities other than blasting as they are typically rare and should be considered on a case-by-case basis.

For blasting, the airborne vibration effects are indirectly considered by limiting blast overpressure (see Section 3.2.3 of this Code).

4 Assessment

During the pre-construction phase of planning and design, typically it is the responsibility of the department and its representatives to identify and assess noise and vibration impacts for construction activities. This may be in the form of a pre-construction construction noise and vibration assessment report.

Unless otherwise specified by the department, it is the responsibility of the construction entity and its representatives to ensure that a Noise and Vibration Management Plan (NVMP) and a construction noise and vibration assessment report have been prepared prior to any construction works.

The department is responsible for the review of a construction noise and vibration assessment report and acceptance of an adequate NVMP. The department's project manager will consider the scale of works and likely impacts and be responsible for acceptance of the plan, based on advice from regional environmental staff and Engineering and Technology Branch where appropriate. Key issues for construction noise and vibration assessments are covered in Chapters 3, 4, 5 and 6 of this Code. NVMP requirements are discussed in Chapter 7.

During construction it is the responsibility of the construction entity and its representatives to implement the accepted NVMP and conduct assessments where required to support its function. Regular reporting to the department during construction is required for compliance monitoring purposes.

The requirements of the *Professional Engineers Act 2002* need to be satisfied in the design and implementation of management plans by ensuring that a suitably qualified person (Registered Professional Engineer of Queensland (RPEQ)) from or on behalf of the construction entity and its representatives is involved when addressing noise and vibration matters from infrastructure construction and signing off on any assessment reporting.

4.1 Type of assessments

Construction noise and vibration assessments are generally conducted at two stages of a project:

- pre-construction stage
- construction stage.

The type of construction noise and vibration assessments required is dependent on a number of factors such as the purpose of the assessment, the scale and type of works, and the separation distance to sensitive and critical receptors. Screening assessments and detailed assessments are normally required during the pre-construction stage, while planned assessments, complaint assessments and trial assessments may be required during the construction stage. Table 4.1 provides a brief description of the types of assessments.

Table 4.1: Noise and vibration assessment types

Stage	Assessment Type	Description
Pre-construction	Screening Assessment	A simplified assessment which gives a robust set of mitigation and management measures for inclusion in a NVMP. Typically a screening assessment does not include measurement or detailed computer modelling.
	Detailed Assessment	A detailed assessment which gives a robust set of mitigation and management measures for inclusion in a NVMP. A detailed assessment requires measurement and detailed computer modelling to determine impacts.
Construction	Planned Assessment	Assessment and reporting as a result of planned monitoring triggered by a specific requirement within a NVMP. If adverse impacts are determined then any changes to mitigation and management should be incorporated into the NVMP.
	Complaint Assessment	Assessment and reporting typically as a result of monitoring in response to a complaint. If adverse impacts are determined then any changes to mitigation and management should be incorporated into the NVMP.
	Trial Assessment	Assessment and reporting as a result of monitoring in response to a trial of a particular work activity. Trial Assessments may be required where there is insufficient knowledge available to predict the resulting impacts with a reasonable level of confidence. If the impacts are considered to be acceptable, the description of works, impacts and mitigation and management should be incorporated into the NVMP.

For each type of assessment, the following two tasks are generally required:

- identification of construction works

  This is required to identify each type of work conducted within the project area. Descriptions should include tabulations of type and number of machines used, time periods of use and where the works are to be conducted within the project area.

- identification of sensitive and critical receptors

  This is required to identify sensitive and critical receptors including critical facilities. The identification may need to consider surrounding services and utilities which may be impacted by works. Once the identification is completed, the sensitive and critical receptors should be represented graphically in relationship to the project area.

Pre-construction assessment aims to identify potential noise and vibration impacts and propose necessary mitigation measures. The types of assessment and reporting will be determined by the level of risk. The construction entity and its representatives will be expected to nominate in writing to the department the project's noise and vibration risk level. Suitable justification in the form of an adequate screening assessment should be provided with the risk application. Where the department accepts that the project's risk level is low, then reduced NVMP requirements may apply, as presented in Chapter 7. The risk level of the project must be reassessed in response to a justifiable complaint or in the event of structural/building damage caused by the project's activities, or when changes in the equipment/work method, intensity, location, duration or timing of impacts are expected to increase noise and vibration impacts. Where the noise and vibration risk level is increased it is the responsibility of the construction entity to conduct additional assessments and revise the NVMP. Any revision to the

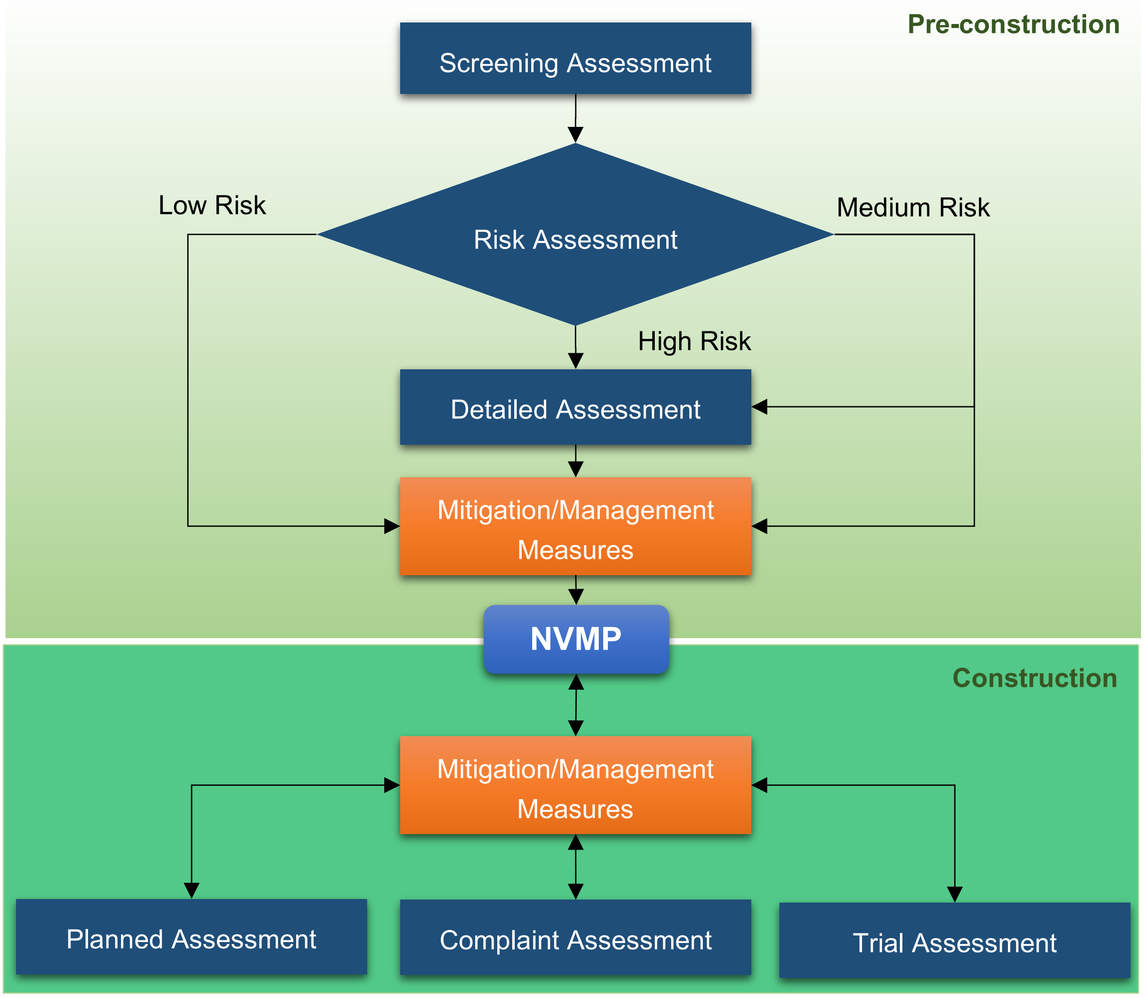
NVMP should be accepted by the department. It is at the discretion of the department (i.e. project manager) whether construction continues prior to the acceptance of a revised NVMP.

Where this noise and vibration risk level is accepted to be medium to high, further assessment to inform the NVMP may be required in the form of a detailed assessment.

The pre-construction assessment and resulting NVMP may need to be supported by periodic monitoring conducted during the construction stage in response to planned actions, complaints and trial works. It should be noted that a complaint assessment may only be required where preliminary investigations cannot quickly resolve the issue and the complaint is justifiable.

The interaction of assessment types and the NVMP is presented in Figure 4.1.

Figure 4.1: Assessment types and NVMP



4.2 Assessment during pre-construction stage

At the pre-construction stage a screening and/or detailed assessment may be conducted for projects. Screening assessments may be conducted to:

- determine noise and vibration risks and necessary mitigation/management requirements
- inform the need for a detailed assessment.

If the screening assessment results for noise and vibration are below the criteria in Chapter 3 and the noise and vibration impacts are accepted by the department to be low risk, then the screening assessment results can be used to prepare a basic NVMP by incorporating necessary mitigation and management requirements. Where the screening assessment results show that the criteria might be exceeded and the noise and vibration impacts are considered significant, a detailed assessment may be required to determine mitigation/management requirements of a more detailed NVMP.

A further detailed assessment should only be conducted where:

- screening results show that the criteria might be exceeded, and/or
- measurements are likely to change the criteria, and/or
- the differences between screening and detailed predictions are significant.

4.2.1 Screening assessment

A screening assessment may be used to initially assess the impacts and understand suitable mitigation and management requirements. Whilst simpler than a detailed assessment, a screening assessment should result in a robust set of mitigation and management measures.

The screening assessment should include the following as presented in Table 4.2.1.

Table 4.2.1: Screening assessment requirements

Item	Requirements
Identification of all relevant work practices and equipment	Review all stages of the construction project to identify all noise and vibration generating construction works and activities including (but not limited to): • work sites • construction traffic • excavation and blasting • underground works.
Identification of sensitive and critical receptors and services/structures	Identify all sensitive receptors and critical facilities within and in the vicinity of the project area. Included should be any services, structure and utilities which may be sensitive to noise and/or vibration impacts.
Identification of the relevant noise and vibration issues	Based on the above, identify whether the following issues are to be included within the assessment: • airborne noise • groundborne noise • groundborne vibration (including blasting) • airborne vibration (including airblast overpressure).
Measurement requirements	Measurements are not typically required for a screening assessment. If conducted they may be used to: • justify the construction noise criteria • provide a benchmark for existing vibration exposure. Chapter 5 provides methods for noise and vibration measurement, if required.
Prediction requirements	Predictions for a screening assessment may rely on spreadsheet calculations and may not require the use of detailed computer models. Predictions should consider worst case operations for each of the identified work practices during the various phases of a given construction project. Chapter 6 provides requirements for conducting noise and vibration screening predictions. Predictions should be made for construction, construction traffic and blasting.
Reporting requirement	In addition to the reporting requirements within Section 4.4 of this Code, the following should be included: • justification for the use of a screening assessment as opposed to a detailed assessment.

4.2.2 Detailed assessment

A detailed assessment requires a greater level of information than that required for a screening assessment. It results in a better understanding of the noise and vibration impacts and the necessary mitigation and management requirements. A detailed assessment would normally be required for high risk and some medium risk construction projects.

The general assessment method is similar to that required for a screening assessment. However it is supported by measurements and detailed computer modelling to determine impacts, mitigation and management.

The detailed assessment should include the following as presented in Table 4.2.2.

Table 4.2.2: Detailed assessment requirements

Item	Requirements

Item	Requirements
Identify all relevant work practices and equipment	Review all stages of the construction project to identify all relevant noise and vibration generating construction works and activities including (but not limited to): • work sites • construction traffic • excavation and blasting • underground works.
Identify sensitive and critical receptors and services/structures	Identify all sensitive receptors and critical facilities within and in the vicinity of the project area. Included should be any services, structures and utilities which may be sensitive to noise and/or vibration impacts.
Identify the relevant noise and vibration issues	Based on the above, identify whether the following issues are to be included within the assessment: • airborne noise • groundborne noise • groundborne vibration (including blasting) • airborne vibration (including airblast overpressure).
Measurement requirements	Measurements are a requirement of a detailed assessment: **Noise** Conduct ambient pre-construction noise monitoring. Sensitive receptors should be grouped by location and a representative location selected for each group. This data is used to determine the general construction noise criteria. **Vibration** If relevant, conduct ambient pre-construction vibration monitoring. Sensitive receptors should be grouped by location and a representative location selected for each group. This data is used to provide an existing benchmark for comparison to construction vibration exposure. Chapter 5 provides methods for noise and vibration measurements. While requirements for geo-technical investigations are not within the scope of this Code, it is noted that the results of such investigations are highly relevant to the choice of construction method and also to the understanding of ground propagation conditions and ground related vibration susceptibilities at the site.
Prediction requirements	Predictions for a detailed assessment require the use of specific algorithms or detailed computer models. Typically a greater level of detail is required to conduct the assessment (for example, structural foundations, ground characteristics, water table, topography, meteorology, external facade construction/orientation of critical facilities). Predictions should consider worst case operations for each of the identified work practices during the various phases of a given construction project. Chapter 6 provides requirements for conducting detailed noise and vibration predictions. Where screening assessments for vibration show that impacts from vibration are unlikely, detailed vibration predictions may not be required. Predictions should be made for construction, construction traffic and blasting.
Reporting requirements	In addition to the reporting requirements within Section 4.4 of this Code, the following should be included: • construction scheduling/timelines.

4.3 Assessment during construction stage

Noise and vibration assessments during construction stage may be proactive or reactive. Proactive assessments are in the form of planned measurements conducted as a requirement of a NVMP. Proactive assessments may also be conducted where the impacts from a work activity are unknown or difficult to predict. Thus, a trial assessment may be required to determine the likely impacts.

Reactive assessments are typically conducted in response to complaints received during construction. A complaint assessment should determine whether the construction impact creates a justifiable concern and is typically managed under the community consultation provisions within the NVMP.

4.3.1 Planned assessment

A planned assessment is conducted in response to planned measurement as a requirement of a NVMP. A planned assessment requires the activity to be routinely monitored and reported to determine compliance with NVMP requirements.

The planned assessment should include the following as presented in Table 4.3.1.

Table 4.3.1: Planned assessment requirements

Item	Requirements
Identification of all relevant work practices and equipment	Identify all relevant work practices and equipment for which the planned monitoring relates.
Identification of sensitive and critical receptors and services/structures	Identify all sensitive receptors, critical facilities, services, structure and utilities within and in the vicinity of the project area to which the planned monitoring relates.
Identification of the relevant noise and vibration issues	Based on the above, identify whether the following issues are to be included within the assessment: • airborne noise • groundborne noise • groundborne vibration (including blasting) • airborne vibration (including airblast overpressure).
Measurement requirements	Justify the selection of monitoring locations. Locations should be selected to adequately represent all identified sensitive and critical receptors and services/structures/utilities. Chapter 5 provides methods for noise and vibration measurements. The duration of the measurements will be specified by the NVMP. Alternatively the duration of the measurements may be agreed with the affected parties.
Reporting requirements	In addition to the reporting requirements within Section 4.4 of this Code, the following should be included: • NVMP requirement which triggers a planned assessment; if it is based on an agreement outside a NVMP then state the details of the agreement. • any consultation conducted with affected parties.

4.3.2 Complaint assessment

A complaint assessment typically involves measurement of particular work activities which are perceived by sensitive and critical receptors as being annoying. A complaint assessment requires the impact of the activity to be measured, predicted or a combination of both, to determine likely impacts during worst case construction and environmental conditions.

A complaint assessment should be conducted for a justifiable complaint only when preliminary investigations and communication cannot quickly resolve the issue.

The complaint assessment should include the following as presented in Table 4.3.2.

Table 4.3.2: Complaint assessment requirements

Item	Requirements
Identification of all relevant work practices and equipment	Identify all work practices and equipment to which the complaint monitoring relates.
Identification of sensitive and critical receptors and services/structures	Identify all sensitive receptors, critical facilities, services, structures and utilities within and in the vicinity of the project area to which the complaint monitoring relates.
Identification of the relevant noise and vibration issues	Based on the above, identify whether the following issues are to be included within the assessment: • airborne noise • groundborne noise • groundborne vibration (including blasting) • airborne vibration (including airblast overpressure).
Measurement requirements	Justify the selection of monitoring locations. Locations should be selected to adequate represent all identified sensitive and critical receptors and services/structures/utilities. Chapter 5 provides methods for noise and vibration measurements. The duration of the measurements will be specified within the NVMP. Alternatively the duration of the measurements may be agreed with the affected parties. As a minimum, monitoring should cover noise and/or vibration worst case operations.
Reporting requirements	In addition to the reporting requirements within Section 4.4 of this Code, the following should be included: • justification of the duration of measurements and how worst case construction impacts were included within the assessment. Where the complaint is in regard to construction noise and the RBL at the complainant's premises is measured to be below 30 dB(A), the assessment should investigate practicable and reasonable noise mitigation further to those required to meet thresholds nominated in Table 3.2.1.1(a).

4.3.3 Trial assessment

A trial assessment may be required for a particular work activity where there is insufficient knowledge available to predict the resulting noise and vibration impacts with a reasonable level of confidence. A trial assessment may be required during the construction of a project.

Any trial assessments should be negotiated with the department and consulted with the surrounding affected community prior to any trial works being conducted. Trial works should only cover a discrete period of work to allow measurement. They should not be considered as a means to emit noise and vibration from works which may exceed the criteria in this Code.

The assessment requirements would be the same as those required for complaints response, with the exception that monitoring may be conducted for the entire duration of the trial works.

4.4 Assessment reporting requirements

All assessment reports should be prepared by or supervised by an RPEQ with relevant experience.

General reporting requirements for each of the assessment types include:

- Description of construction works (see Section 4.1 of this Code).
- Review of sensitive and critical receptors (see Section 4.1 of this Code). Typically a pre-construction survey or surveys are used to ensure that all buildings, building contents, services and utilities and ground and landform elements susceptible to noise and vibration induced disruption or damage are identified prior to commencement of any construction activity at the site.
- Identification of issues for consideration – airborne noise, groundborne noise, groundborne vibration (including blasting), and airborne vibration (including airblast overpressure) from all construction activities including work sites, construction traffic, excavation and blasting and underground works.
- Description of measurements conducted – reporting requirements as presented in Chapter 5.
- Determination of noise and vibration criteria as per Chapter 3.
- Details of source data used in the determination of noise and vibration emissions – reporting requirements as presented in Chapter 6.
- Details of noise and vibration prediction methods including formulae or algorithms used to determine exposure at sensitive and critical receptors – reporting requirements as presented in Chapter 6.
- Results of noise and vibration predictions – reporting requirements as presented in Chapter 6.
- Assessment of construction noise and vibration predictions and/or measurements against construction noise and vibration criteria.
- Review of mitigation and management options considering practicality and reasonableness – guidance on mitigation and management is presented in Chapter 7.
- Identify areas where building/structure/utilities condition surveys are required. These condition surveys should be conducted based on guidance presented in Section 4.5 of this Code.
- Provision of a conclusion with a summary of requirements to be incorporated into a NVMP. Details of the requirements of NVMPs are contained in Chapter 7. Sufficient detail should be contained within the assessment report to either prepare a NVMP during pre-construction assessment (Section 4.2 of this Code) or support the NVMP following construction assessments (Section 4.3 of this Code).

4.5 Condition surveys

Building condition surveys are required for all buildings and structures in the vicinity of the construction activity which would be subject to airblast and vibration impacts at levels that could cause building damage. Building contents investigations are required on a more limited basis, but are needed in all cases where vibration sensitive critical facilities (such as hospitals and research institutions) are involved. Additional detailed site investigations may be required where sensitive infrastructure, services and utilities are located in the vicinity of the proposed works.

In some cases building condition surveys may result in the identification of particularly vibration sensitive building structures or contents that were previously unknown to the project team. The condition survey information obtained could then be used to develop appropriate vibration mitigation measures and limits for inclusion in specifications and in the project NVMP.

4.5.1 Building condition

The building condition survey program provides the mechanism by which the prior condition of buildings and other structures in an area likely to be affected at a significant level by construction vibration can be documented.

This is essential for purposes of ensuring that:

- building condition (or ‘state of repair’) is known prior to the onset of any construction vibration effects, and
- the proper degree of vibration control can be exercised during the period of construction.

Properly conducted, the building condition survey process also provides an effective means of establishing necessary contacts with the affected community well before commencement of any vibration related disruption.

Requirements for condition surveys should normally be determined on the basis of the results and recommendations of a noise and vibration assessment.

All condition surveys and subsequent reporting should be conducted by or supervised by an RPEQ with relevant experience (that is, Structural Engineer RPEQ).

Building condition survey reports should be submitted to the department prior to commencement of construction. Subsequent to completion of the works, post-construction condition surveys should be conducted. Post-construction condition survey reports detailing the results of the inspections shall be submitted to the department following completion of the relevant activity.

Timeframes for provision of condition surveys will be set by the department.

4.5.2 Building contents

Where vibration sensitive building contents are identified as likely to be present in buildings or other structures, a building contents investigation should be conducted to ensure that the relevant items and their particular vibration susceptibilities are properly described and considered.

4.5.3 Infrastructure, services and utilities

Similar detailed site investigations may be needed where buried services or other critical infrastructure that may be susceptible to vibration induced disruption are present. While such services and infrastructure are usually substantially more robust than is the case with equipment which would be classed as ‘vibration sensitive’, site investigation is often necessary. In particular with such services and infrastructure, it may be very important to establish the actual condition of the item to be protected prior to construction vibration specifications being finalised.

5 Measurement

This chapter describes the methods and standards required by the Code when conducting noise and vibration measurements of construction activities. The measurements are assessed using the required noise descriptors for the corresponding noise and vibration modes. If alternative measurement methods are proposed they should be approved by the department.

It is important to note that for any measurement, the instrumentation must be properly protected from unintended vibration or electromagnetic interference. As a general rule when conducting noise measurements in the vicinity of vibratory plant or other sources of vibration, it is essential to ensure that the equipment is located in a stable position and properly isolated from obvious sources of vibration. Non-shielded cabling should not be used for the purpose of noise measurement.

The measurement results need be analysed against the work periods (for example, Standard hours, Non-Standard hours for evening/night) as defined in Chapter 3.

Typically measurements are conducted for selected locations which are representative of the identified relevant receptors (including buildings and structures). This limits measurements to a smaller group of representative receptors.

5.1 Noise measurement

5.1.1 Instrumentation

Sound level meters used for the purposes of noise assessment or noise compliance must be Type 1 or Type 2, complying with the requirements of Australian Standard AS 1259.2-1990 or Australian Standard AS IEC 61672.1-2004. Measurement conducted using octave and third octave band filters should comply with the requirements of IEC 61260.

Other measurement equipment, such as data recorders, analogue tape recorders, chart recorders or statistical analysers, may be used in conjunction with the sound level meter, provided that the overall accuracy of the measurement system is not less than that which would be acceptable for a Type 2 sound level meter.

5.1.2 Calibration

Calibration of sound level meters, or sound level meters in conjunction with other measurement equipment, should be conducted by a NATA certified calibration laboratory at intervals of preferably 12 months, but in any event not exceeding two years.

Calibrated reference sound sources used to check calibration in the field (‘sound level calibrators’) should be recalibrated at least once a year.

A field check of instrument calibration (including any attached measurement equipment) should be made before and after each set of measurements, using a calibrated reference sound source with accuracy of ± 1 dB.

Notwithstanding this, where instrumentation will be unattended and used for an extended period at the same site (for example, ’noise logging’), care should be taken to ensure that field checks of calibration are made at appropriate intervals by considering the reliability and stability of the measurement instrument or system.

If during a field check of instrument calibration, the sound level meter reading differs from the calibrated reference level, the difference must be noted. Any measurements taken in the interval since calibration was last checked should be adjusted accordingly.

In all cases, where a difference in field calibration of more than 1 dB is noted between consecutive checks, measurement data obtained during the previous interval should be discarded.

5.1.3 Airborne noise measurement

Noise measurement and reporting should be conducted generally in accordance with the following provisions:

- construction and ambient noise
  - Australian Standard AS 1055: Part 1-1997 *Acoustics – Description and Measurement of Environmental Noise* – Part 1: *General Procedures*.
- road traffic noise
  - Australian Standard AS 2702-1984 *Acoustics – Methods for the Measurement of Road Traffic Noise*
  - Queensland Department of Transport and Main Roads – *Transport Noise Management Code of Practice* Volume 1 – *Road Traffic Noise*.

Noise measurements should be conducted generally with the sound level meter set to A-weighting and fast response and with an approved windscreen fitted to the sound level meter microphone. Unless specified, noise level measurements should be presented to a single decimal place with the appropriate units specified (for example, 61.2 dB(A)).

A portable weather station should be collocated with noise measurements where meteorological influences may affect the measured noise levels. The portable weather station should be well placed to limit the effects of obstructions and capable of measuring the following:

- temperature
- humidity
- rainfall
- wind speed and direction (anemometer should be located 2.0 m ± 0.2 m above ground).

5.1.3.1 Rating background level

Rating background level (RBL) is the overall single-figure background level representing each work period as defined in Chapter 3. It is derived from the measured ambient background levels at noise sensitive receptors. Specifically, RBL is derived from the following:

- Determining the background noise level for each work period using the tenth percentile method of measured $L_{A90,15\ minute}$. Noise levels measured in each work period of each day are ranked from the lowest to highest with the lowest tenth per cent position taken by multiplying 0.1 by the number of samples within each work period. The tenth percentile position is rounded up if not a whole number with the value at that position taken to be the background level for that work period. If the site has been selected to measure road traffic noise and the time interval has been set to one hour, the background noise level may be taken to be the minimum $L_{A90,1\ hour}$ within each work period.

- Taking the median background levels over all days for each work period as RBL. The values should be rounded to the nearest whole number.
- A plot should also be provided showing the L_{A1}, L_{A10}, L_{A90} and L_{Aeq} values for the measurements period.

The measurement of ambient background levels used to determine RBL should be conducted prior to any disruption in traffic that may accompany the commencement of the project (including disruptions due to activities in other parts of the project area). It should meet the following requirements:

- The microphone should be placed in free-field and be at least 3.5 m from any building or other vertical reflecting surface. Measurements may also be conducted 1 m from a facade. While the selection of locations is site specific, any influences from surrounding facades should be noted.
- The microphone height should be at least 1.5 m above ground level, but may be at a higher level if the noise sensitive building is multistorey.
- Measurements should be made for 15 minute intervals conducted over a seven day period (shorter periods may be approved by the department).
- Measurements are analysed for each work period.

If the measurement location is affected by noise from the construction activities or other extraneous sources, then:

- the background level may be measured at an equivalent position not subject to the effects of the construction and/or extraneous noise, or
- if possible, the background ambient noise is measured during a scheduled break in the construction activity.

5.1.3.2 Road traffic noise

Road traffic noise measurements may be required to determine the pre-construction noise level on public roads intended to be used by construction traffic. The measurement locations should be selected to be representative of the most exposed facades of noise sensitive buildings.

Road traffic noise measurements should meet the following requirements:

- Unattended measurements need to include two days of representative weekday traffic (and two days of representative weekend traffic if activities occur on weekends) (shorter periods may be approved by the department).
- The requirement for attended measurements is at the discretion of the department.
- The hourly time interval measurements in each work period should be analysed with the minimum L_{A10} (1h) values within each work period tabulated. A plot should also be provided showing the L_{A1}, L_{A10}, L_{A90} and L_{Aeq} values for the measurement period.
- The median minimum L_{A10} values over all days for each work period should be used for assessment purposes.

5.1.3.3 Construction noise

Measurement for gauging the impact of construction noise levels should be conducted at a time which is relevant to the particular noise source of interest. Where practicable, measurements should coincide with the time at which disruption due to noise from an activity would be considered 'worst case'.

Measurements should document any influence from background or extraneous noise levels. Any corrections for background or extraneous noise contribution should be clearly stated.

The $L_{Aeq,adj,15\ minute}$ is normally used to measure general construction noise. The measurement can be conducted externally or internally of the noise sensitive buildings. Adjustment factors as defined in Chapter 2 may need to be applied. To determine the suitable adjustment factors, measurement should provide results for the following:

- non-frequency weighted one-third octave band levels
- L_{Aeq} measured using A and C frequency weighting
- impulse response and fast response maximum noise levels for specific construction activities, both conducted using A and C frequency weighting.

External

The $L_{Aeq,adj,15\ minute}$ measured externally can be used for comparison with external criteria or in conjunction with the calculated facade noise attenuation to determine internal noise impacts. The external measurement should meet the following requirements:

- The microphone should be placed in free-field and at least 3.5 m from any building or other vertical reflecting surface or 1 m from the most exposed facade. If measurement is made in front of a window, the window should be closed.
- The microphone height should be at least 1.5 m above ground level, but may be at a higher level if the noise sensitive building is multistorey. The position may be selected to be the centre of the most exposed window on the highest floor.
- Measurements should be made for 15 minute intervals. Duration would be dependent on the activity with a minimum of 15 minutes of activity measured.
- The measurement results should be analysed for each work period.

Internal

The $L_{Aeq,adj,15\ minute}$ may also be measured inside a building to determine pre-construction internal noise environments for sensitive or critical receptors as well as the impact of general construction noise exposure. The measurement should meet the following requirements:

- The microphone should be placed at least 1 m from walls or other major reflecting surfaces and 1.5 m from windows. The presence of furnishings or other reflective surfaces, which may result in shielding or scattering of the noise, should also be considered.
- The microphone should be 1.2 m to 1.5 m above the floor.
- Measurements should be made for 15 minute intervals.
  - During construction – overall duration would be dependent on the activity with a minimum of one interval (15 minutes of activity) measured. Construction measurements should

document any influence from background or extraneous noise levels. Any corrections for background contribution should be clearly stated.

  - Pre-construction – unattended measurements should include two days of representative weekday traffic (and two days of representative weekend traffic if weekend activities are planned) (shorter periods may be approved by the department)

- The measurement results should be analysed for the work periods defined in Chapter 3.

Pre-construction noise measurement inside buildings may be warranted as part of detailed assessments where:

- critical facilities are involved
- external measurement is not possible due to site constraints
- external criteria cannot be met and more detailed internal investigation is required.

5.1.4 Groundborne noise measurement

Groundborne noise measurement and reporting should be conducted using methodologies in general accordance with the provisions of ISO 14837-1.

The L_{ASMax} is the groundborne noise assessment descriptor. It should be measured inside a building to determine the internal noise impacts.

A type 1 sound level meter set to A-weighting and slow response should be generally used. Measurement should be conducted at a time which is relevant to the particular noise source of interest. Where practicable, measurements should coincide with the time at which disruption due to noise from an activity would be considered 'worst case'.

The measurement for this purpose should meet the following requirements:

- The microphone should be placed at least 1 m from walls or other major reflecting surfaces and 1.5 m from windows. The presence of furnishings or other reflective surfaces, which may result in shielding or scattering of the noise, should also be considered.
- The microphone should be 1.2 m to 1.5 m above the floor.
- All windows, doors and other openings to the room should be closed.
- Measurements should be made for 15 minute intervals. Duration should be dependent on the activity with a minimum of one interval (15 minutes of activity) measured.
- Measurements should document any influence from background or extraneous noise levels. Any corrections for background contribution should be clearly stated.
- The measurement results should be analysed for each work period.

5.1.5 Airblast measurement

Airblast measurement and reporting should be conducted using methodologies in accordance with the provisions of Australian Standard AS 2187.2-1993 Appendix J.

Airblast measurements should be conducted with an appropriate sound level meter capable of measuring L_{peak} dB(L). Measurement should be conducted during blasting activity and located away from structures that may produce reflections and cause spurious readings. The measurement should meet the following requirements:

- The microphone should be placed at least 1 m above ground level unless a specific investigation shows that measurements taken at a lower height are valid.
- The microphone should be oriented in a direction of maximum sensitivity to the incident sound and a windshield fitted in accordance with the manufacturer's recommendations.

5.2 Vibration measurement

This section describes vibration measurements for groundborne vibration only. It does not prescribe any methods to measure airborne vibration with the exception of airblast (see Section 5.1.5 of this Code). Any methods to measure airborne vibration except for airblast should be discussed with the department to determine acceptability.

Instrumentation and methodologies required for vibration measurement will depend on the type of vibration and whether human comfort or structures/contents are being considered. Requirements may also vary based on the types of ground, buildings or structures on which measurement is undertaken.

Instrumentation utilised for vibration monitoring should be of sufficient sensitivity to allow comparison with the criteria specified in Chapter 3. Instrumentation should also comply with the minimum requirements contained in:

- for human perception and blasting – Australian Standard AS 2187.2-1993 Appendix J, or
- the relevant standard under which those limits were developed (for example, British Standard BS 7385-2 and German Standard DIN 4150-3).

While standards may state additional requirements the following three sections provide general requirements for calibration, instrumentation performance and coupling to substrate.

5.2.1 Instrumentation

Vibration measurement may be conducted using either geophones (seismic velocity transducers) or accelerometers, in a triaxial transducer arrangement (that is, either triaxial geophones or accelerometers) with the transducers arranged orthogonally, so that each of the three component vibration velocities or accelerations can be measured. In all cases the particular transducer orientation should be properly recorded and documented. This should specifically include the transducer orientation with respect to the source and to the surface on which it is fixed.

The instrumentation selected should have a frequency range meeting the particular assessment requirements.

5.2.2 Calibration

Testing and recalibration of geophones, accelerometers and other vibration measurement instrumentation should be conducted by a NATA certified calibration laboratory at intervals of 12 months.

5.2.3 Coupling to substrate

To ensure the vibration measurement accuracy, it is critical to maintain effective and secure coupling of the transducers to the ground, building foundations, other structural elements or substrates on which measurement is undertaken.

The following guidelines should be followed:

- for geophones – the guidance given in the ISEE *Field Practice Guidelines for Blasting Seismographs*
- for accelerometers – the guidance given in Australian Standard AS 2775-2004.

The preferred coupling method depends on site conditions. Where there is a rigid surface (for example, concrete or rock), adhesive or mechanical bonding can be used. Where the surface is soil, the transducer can be embedded or fixed to an embedded mount (for example, 200 mm concrete cube or similarly sized cylinder). If measurements are repeated at the same location, an embedded mount is particularly justified for consistency of results.

Coupling with soil spikes in soft conditions may lead to exaggerated measurements and is not recommended.

5.2.4 Human perception

Measurements for gauging human perception should be conducted to determine the Resultant PPV and meet the following requirements:

- Measurements on the ground should be representative of ground motions at the subject building or structure, but at sufficient distance from the building or structure to avoid undue interference from that structure.
- Measurements within a structure should be located on the floor of the room where any complaint originates or where the greatest adverse impact is predicted.
  One or two measurement points in a suitable available area, preferably in the central part of the room, will typically be sufficient in most cases.
- Measurement should be conducted during construction activity for a representative two day period to determine vibration exposures (shorter periods may be approved by the department).

5.2.5 Structural damage/building contents

Measurement of PCPV (or v_i) and Resultant PPV for assessing structural damage and building contents should be:

- located at the base/foundation of the structure as required by the standard
- also located at the horizontal plane of the highest floor of a structure, if required
- located to be representative of sensitive building contents
- conducted during construction/blasting activity or for a representative two day period to determine pre-construction exposure (shorter periods may be approved by the department).

6 Prediction

Noise and vibration prediction forms part of the construction noise and vibration assessment. Generally there are two levels of prediction:

- screening prediction
- detailed prediction.

Both prediction methods rely on a similar process. However, detailed predictions may be supported by measurements and involve detailed computer modelling to determine impacts.

This chapter provides guidance on the requirements, reference sources and methodologies for construction noise and vibration prediction.

6.1 Noise prediction

6.1.1 Airborne construction noise

Noise predictions require consideration of:

- locations of all noise receptors that may be affected by construction works
- plant and machinery required during each stage and their activity (that is, running times and location)
- potential noise emissions in the form of sound power levels (L_w) (or sound pressure (L_p) at a reference distance (m)) from construction activities
- noise attenuation due to distance, ground and air absorption, screening effects by topography, buildings, temporary or permanent noise barriers
- enhancements in the noise level due to the effects of sound reflection and situations such as propagation over water
- meteorological effects including wind speed and direction as well as atmospheric stability.

Noise emission data for construction plant and equipment may be measured, obtained from manufacturers or estimated based on available databases. There are numerous databases of plant and equipment noise emission data. Whilst a useful resource, care should be taken when using this data to ensure that it is representative of local equipment selections.

Available databases include:

- British Standard BS 5228-1:2009 including the 2014 Amendment where Annex C and Annex D contain current and historical noise emission data respectively
- The European Commission issued Directive 2000/14/EC (amended by Directive 2005/88/EC) on equipment sound power levels http://ec.europa.eu/enterprise/sectors/mechanical/noise-outdoor-equipment/database/.
- The United Kingdom Department of Environment, Food and Rural Affairs (DEFRA) document entitled '*Update on noise database for prediction of noise on construction and open sites*'
- The Department of Planning, Transport and Infrastructure in South Australia document entitled '*Infrastructure Works at Night – Operational Instruction 21.7*'

- Australian Standard AS 2436-1981 Appendix D which contains sound power levels for construction equipment
- Australian Standard AS 2436-2010 Appendix A which contains typical sound levels for construction equipment and which is derived from Australian Standard AS 2436-1981, British Standard BS 5228-1 and DEFRA database noted previously.

The preferred external receptor position, for purposes of prediction, is at 1 m from the most exposed facade of the relevant noise receptor and 1.5 m above floor level. Where internal noise levels are required, guidance from Australian Standard AS 3671-1989 may be used to estimate transmission loss through the facade. Where details are unknown, a 5 dB facade reduction allowance may be used to estimate transmission loss from outside to inside with an open window.

6.1.1.1 Screening prediction

Screening predictions require less detail in relation to topography and meteorology and may typically be conducted in a computer based 'spreadsheet' using an overall A-weighted noise level approach. The preferred methodology for screening assessments is presented in:

- British Standard BS 5228-1:2008 Annex F '*Estimating Noise from Sites*'
- Australian Standard AS 2436:2010 Appendix B '*Estimating Noise from Sites*'.

These standards provide a methodology for the prediction of $L_{Aeq,T}$ from stationary and quasi-stationary activities. Character adjustment ($L_{Aeq,adj,T}$) to these predictions should be considered based on the factors described in Chapter 2 (for example, tonality, impulsivity, and so on).

6.1.1.2 Detailed prediction

Detailed predictions require octave band noise level emissions, digitised topography and the inclusion of intervening barriers, air absorption and meteorology. This requires the use of computer noise modelling packages and relies on various algorithms developed to predict environmental noise.

The use of a computer noise model enables the consideration of multiple noise sources, receptors and propagation conditions. The methods in the following documents are recommended and supported in many suitable computer noise modelling packages:

- ISO 9613-2:1996 '*Acoustics - Attenuation of sound during propagation outdoors* – Part 2: *General method of calculation*'
- CONCAWE '*Report no.4/81 the propagation of noise from petroleum and petrochemical complexes to neighbouring communities*'.

All predictions should consider the relevant character adjustment ($L_{Aeq,adj,T}$) to predictions and should be based on the factors described in Chapter 2 (for example, tonality, impulsivity, and so on).

Meteorological variables should be considered where appropriate for the given methods. Variables relating to temperature, wind characteristics and relative humidity may be based on long-term climatic average data applicable to the particular hours of work and to the geographical area or region in which the works will be conducted. In the absence of site specific information the following default meteorological conditions may be utilised as presented in Table 6.1.1.2.

Table 6.1.1.2: Default meteorological values for use in modelling

Time of Day	Temperature	Humidity	Wind speed	Wind direction	Temperature Lapse Rate
Daytime (7:00 am to 6:00 pm)	20°C	70%	3 m/s	All	0°C/100 m
Evening/Night time (6:00 pm to 7:00 am)	15°C	70%	2 m/s	Drainage-flow (where receptor is downhill from source)	3°C/100 m
			None	None	3°C/100 m

6.1.1.3 Reporting

Reporting of construction noise prediction should include the following as a minimum:

- Adopted prediction methods and their general assumptions.
- Details of noise sources included in the predictions.
  - The source of estimated noise emission should be documented including all assumptions in relation to position, adjustment for tonality, impulsivity, and so on, activity, control measures (including estimated mitigation efficiency) and adjustments when based on a similar source. Predictions of $L_{Aeq,adj,15\ minute}$ should be conducted with and without all reasonable and practicable controls, with residual exceedances noted.
  - The estimated sound power level for all items of plant and equipment should be included in the report including any octave band level data utilised and the relevant operating conditions, location and height to which the sound power level data applies.
- Details of all noise sensitive receptors, including specifically the receptors' height in relation to local ground level. Assumptions made regarding façade reflections and reflections from other surfaces in the immediate vicinity of the receptors should also be stated. In some situations it may be acceptable to limit predictions to a smaller group of representative receptors.
- Details of all terrain data used in the modelling.
- Details of any buildings, structures, walls, bunds or noise barriers considered to be significant and included in the modelling process. This should include specifically height relative to local ground level.
- Assumptions made in relation to ground cover (hard ground, soft ground, and so on). This should include specifically any areas where propagation over water would occur for significant distances.
- Meteorological data used in the modelling.
- Noise prediction results should be tabulated and presented graphically as contours for sensitive receptors and compared against the criteria as defined in Chapter 3.

6.1.2 Construction road traffic

Predictions of $L_{A10,1\ hour}$ are required for pre-construction traffic and traffic during construction (includes construction traffic). The requirements in the *Transport Noise Management Code of Practice* Volume 1 should be generally followed. Modelling of road traffic noise should be conducted using the algorithms contained in the United Kingdom's Department of Transport (Welsh Office) '*Calculation of Road Traffic Noise*' (CoRTN). Specifically the following are required by CoRTN to predict road traffic noise:

- hourly traffic volume
- hourly percentage of commercial vehicles
- traffic speed
- road surface pavement types and gradient
- intervening ground type (hard or soft)
- distance to point of interest (for example, sensitive receptor).

The preferred noise receptor position, for purposes of prediction, is at 1 m from the most exposed facade. Where prediction of pre-construction and construction traffic is conducted in the free field, a facade correction allowance of + 2.5 dB(A) should be considered.

6.1.3 Groundborne noise

Prediction of groundborne noise is typically based on the groundborne vibration levels or empirically derived formulae. In order to predict groundborne noise the following methods may be relied on:

- British Standard BS 5228-2:2009 and the 2014 Amendment, including:
  - Annex E – which contains empirical formulae for the prediction of groundborne noise for a range of construction activities. These formulae are based on work conducted by Hiller and Crabb '*Groundborne vibration caused by mechanised construction works TRL report 429*'.
- Prediction of groundborne vibration is as per model development and evaluation presented in Section 6.2 of this Code. These groundborne vibration predictions may be used to estimate groundborne noise using the following methodology.

  In order to estimate groundborne noise, RMS velocities may be derived from predicted Peak Particle Velocity (PPV) using 'crest factor' considerations. Where this approach is used, care should be taken to ensure that the crest factors utilised are appropriate to the particular vibration characteristics of the construction plant and equipment being assessed.

  RMS velocities may then be used to calculate groundborne noise levels as per the procedure set out in the FTA, 2006 document '*Transit noise and vibration impact assessment manual*'. The procedure involves the following:

  - prediction of the unweighted vibration velocity profile referenced to $1x10^{-6}$ in/s
  - adjustments to vibration propagation (coupling loss, floor-to-floor attenuation and amplification due to resonances of floors, walls and ceilings)
  - application of an A-weighting to the unweighted velocity profile referenced to $1x10^{-6}$ in/s

  This procedure provides an estimate of the levels of radiated noise given the average vibration amplitude of the room surfaces. It assumes that the unweighted sound pressure level is approximately equal to the vibration velocity level when the velocity level is referenced to $1x10^{-6}$ in/s. FTA, 2006 states that the A-weighting adjustment be applied to the measured 1/3 octave frequency bands to estimate the A-weighted noise level within the room.

6.1.4 Airblast

Predictions of airblast and reporting shall be conducted using methodologies in accordance with the provisions of Australian Standard AS 2187.2-1993 Appendix J.

Predictions of airblast L_{peak} dB(L) should be at the preferred location which is typically 1 m from the most exposed facade of the relevant receptor.

Other methodologies may also be used and should be confirmed with the department for acceptability.

6.2 Vibration prediction

This section focuses on vibration prediction for groundborne vibration only. It does not prescribe any methods to predict airborne vibration, with the exception of airblast for which the airborne vibration effects are considered by limiting blast overpressure (see Section 6.1.4 of this Code).

Any methods to predict airborne vibration except for airblast should be discussed with the department to determine acceptability.

As a preliminary to all ground vibration predictions, available details relating to the project proposal should be reviewed. This should include, for example, geotechnical reports and ground vibration records from previous works if relevant.

Prediction of groundborne vibration should consider:

- source (location, depth, soil structure interaction, and so on)
- propagation path (geological profile and properties, water table, obstructions, and so on)
- receptors (soil-structure interaction, foundation type, building/floor type, and so on).

Predictions should be at the preferred location which is typically the most exposed location of the relevant receptor.

Typically during the early stages of a project when limited information is available to allow detailed prediction, screening prediction may be performed.

6.2.1 Screening prediction

Screening predictions may rely on the following methods for predicting PCPV and Resultant PPV:

- empirical formulae (may include a combination of parametric and empirical methods)
- measured vibration level combined with propagation estimates.

Information to support these methods may be sourced from but not limited to the following documents:

- Australian Standard AS 2187.2-1993 Appendix J – contains a method for the prediction of Resultant PPV from blasting
- British Standard BS 5228-2:2009 and the 2014 Amendment, including:
  - Annex C and Annex D – they contain current and historical piling vibration emission data respectively

  - Annex E – it contains empirical formulae for the prediction of vibration for a range of construction activities. These formulae are based on work conducted by Hiller and Crabb '*Groundborne vibration caused by mechanised construction works TRL report 429*'

- California Department of Transportation document entitled '*Transportation and Construction Induced Vibration Guidance Manual, 2013*'

  Other methodologies may also be used but should be confirmed with the department for acceptability.

Predictions of free field vibration using these methods may be corrected to account for the attenuation/amplification of a building structure. This allows predictions to be made at a point of interest within a structure. The following documents provide guidance on the estimation of coupling losses and amplification of structures that may be applied to free field predictions:

- US Federal Transit Administration (FTA) document entitled '*Transit noise and vibration impact assessment manual, 2006*'
- US Department of Transport – Transportation Systems Center, '*Handbook of Urban Rail Noise and Vibration Control Report UMTAMA-06-0099-82-2, 1982*'.

The conditions which form the basis for parametric/empirical formulae may not represent the particular conditions of the project area. Therefore, it is important to account for these differences by considering predictions over a range of possible values and note any uncertainty which would be expected. Predictions should be conducted within the ranges against which the model is validated. If extrapolation of the method is required, it should be clearly noted with the expected uncertainty.

Screening methodologies and other parameterisations based on measurements at unrelated sites, while sufficient for many purposes, are in general limited in accuracy. Where the consequences of an under-prediction of a result would be critical in terms of structural damage, or where the predictions imply major modification to the proposed work method (particularly where experience would suggest such modification is unlikely to be necessary), further and more detailed investigations may be warranted to remove as far as is practicable the uncertainties involved in the prediction process.

6.2.2 Detailed prediction

Detailed predictions generally require site specific vibration propagation data or additional information to be obtained during later stages of a project.

It is important with model development that appropriate measurements be conducted so that the uncertainty of the model results may be reviewed. ISO 14837-1-2005 provides useful information on the development and refinement of model methods.

Detailed predictions may consider:

- Prediction supported by additional measurements of vibration levels associated with particular plants or construction equipment/activities in conditions similar to those at the relevant site.
- Measurement of site specific soil attenuation properties for use in model predictions. The measurement of transfer mobility may be used to characterise the propagation of vibration from the source to the receptors. The results may provide confirmation of scoping vibration prediction assumptions relating to soil attenuation and transfer functions. Guidance relating to measurement of transfer mobility (and force density) for at grade and underground operations

is contained in the FTA's document '*Transit noise and vibration impact assessment manual, 2006*'.

- Detailed numerical solutions which may be required in complex situations where measurements are impractical. A detailed model may be developed and may include numerical solutions based on:
  - finite element method (FEM).
  - finite difference method (FDM).
  - boundary element method (BEM).

In some cases the uncertainty of predictions may be such that it is necessary to conduct continuous vibration monitoring during works adjacent to the relevant site. Where this is done, the vibration data may be used to adjust work procedures so that appropriate levels are not exceeded. Refer to Chapter 5 for measurement methodologies.

6.2.3 Reporting

Reporting of construction vibration prediction should include the following as a minimum:

- Information relied on for predictions including:
  - topographical and geotechnical data used in the assessment
  - measured data and modification methods for that data.
- Construction plant and equipment details included in the project assessment including:
  - description of the relevant work requirements
  - size of the plant
  - specific requirements relating to the size of the plant, where relevant (for example, MRTS66 *Driven Steel Piles*, MRTS66.1 Clause 1 and 2 which specify the hammer type and minimum energy input per blow)
  - location of the plant
  - duration of the activity.
- Prediction methodologies and inputs to the predictions. The following details should be provided:
  - relevant standard or other document, in which the method is given
  - source vibration levels, reference distance, input energy and any assumptions made in relation to ground conditions
  - the particular prediction relationships used
  - their range of applicability
  - the expected accuracy of the methodology
  - assumptions made adapting the methodology to the requirements of the project assessment
  - details of the measurements used in parameterisation, including a description of plant (including parameters relevant to their vibratory source strength for example, vibratory

rollers, the drum module weight and nominal drum amplitude), measured levels and ground conditions.

- Relevant buildings or other sensitive structures. The following actions should be undertaken:
  - Document assumptions relating to the relevant structural details and vibration transmission between the ground and the building or structure.
  - Identify relevant receptors (including buildings and structures). In some situations it may be acceptable to limit predictions to a smaller group of representative receptors.
  - Identify areas to be included in the preconstruction survey or other site inspections. A conservative approach should be adopted when selecting required calculation inputs. In these assessments, it is essential that all facilities which could be affected by the works are identified. This may mean that some areas which will not ultimately be affected by construction vibration will be included in the survey area.
  - Estimate safe working distances for purposes of operational control of particular plant and equipment.
- Assumptions made regarding vibration control techniques with the following information included:
  - A description of the methods expected to be used and their location (for example, with driven piles, pre-boring/drilling, jetting with dynamic compaction or other high energy ground improvement techniques, cut-off trenches). The description should be specific as to details. For example, for a cut-off trench, its position relative to the source area and to adjoining sensitive sites, the depth of the excavation required and requirements for support of the trench walls should be stated.
  - The required effect. Where the use of a vibration control technique is critical to the predicted result, but site specific assessment is needed for detailed prediction, the report should provide indicative calculations for an example situation, to demonstrate the potential of the method. Details of results achieved with previous applications of the technique may also be relevant. Recommendations for further assessments necessary for the operational implementation of the technique should be provided where necessary.
- Results of the assessment with the following included:
  - All predictions for human comfort, structural damage and safe working distances should be tabulated. In some circumstances a map(s) should be provided, showing those areas or ‘vibration effect zones’ where ground vibration would be expected to exceed specific levels. The areas or zones should be annotated with respect to potential construction vibration effects (for example, vibration perceptibility, groundborne noise).
  - A map showing preliminary safe working distances for particular activities or types of equipment should be provided where necessary (uncertainty and grid spacing used in the contours should also be noted on the map).

7 Mitigation and management

Control of noise and vibration from transport construction projects shall rely on effective mitigation and management measures implemented through the use of a Noise and Vibration Management Plan (NVMP).

The objective of a NVMP is to ensure that all reasonable and practicable measures are taken to minimise noise and vibration impacts on the community and that the affected community is well informed and consulted through the construction process. In order to maintain positive community relations, the public should be kept informed about the construction plans and efforts to minimise noise and vibration. Procedures should be established as part of a NVMP for prompt response and corrective action with regard to noise and vibration complaints during construction.

A NVMP should be developed and maintained based on mitigation and management measures informed by assessments conducted in Chapter 4. While a NVMP should be prepared as a standalone document, noise and vibration impacts are normally addressed in a separate noise and vibration assessment report. A NVMP and a supporting noise and vibration assessment report normally form part of the overall Environmental Management Plan for Construction (EMP(C)).

It is the responsibility of the construction entity to develop, implement and maintain a NVMP. A NVMP including any revision is required to be accepted by the department prior to use.

7.1 Noise and Vibration Management Plan

A NVMP should provide accessible and consistent documentation of noise and vibration goals, limits and control mechanisms which apply to the subject activity or project. In order for the NVMP to be effective, sufficient investigation should be conducted in the pre-construction phase to permit early identification of all relevant noise and vibration constraints and enable appropriate control measures to be determined and implemented in the NVMP.

A NVMP should be prepared as a standalone document but may incorporate sub-plans where required for a specific activity or project phase. It should be noted that large construction projects would usually require greater emphasis on particular work practices, controls and monitoring requirements, than would be required for projects of a smaller scale.

A NVMP should include (but not limited to) the following:

- A statement in the introductory section which states the intent of the NVMP

  This NVMP has been prepared in accordance with the Transport Noise Management Code of Practice: Volume 2 – Construction Noise and Vibration (Code). All reasonable and practicable mitigation will be implemented to achieve the noise and vibration criteria nominated in the Code. This NVMP will be reviewed and additional reasonable and practicable measures implemented where:

  - *directed by the department, or*
  - *in response to a justifiable complaint or in the event of structural/building damage caused by the project's activities, or*
  - *when changes in the equipment/work method, intensity, location, duration or timing of impacts that are expected to increase noise and vibration impacts are foreseen.*

The wording of the statement is at the discretion of the department and may be altered from the above.

- Construction activities (plant and equipment) to be utilised on the project.
- The time periods of construction activities, including where relevant consideration of:
  - particular requirements for impact pile-driving or blasting
  - activities conducted inside and outside of Standard hours
  - time periods in the vicinity of particular critical facilities or other nominated sensitive sites where these differ from general project areas
  - activity time periods and mitigation where these differ from the general case (for example, where plant or equipment is permitted to operate on a project specific basis with specific noise mitigation)
  - time period requirements for site access, construction traffic routes or facilities/plant insofar as these influence general operations.
- The location of:
  - site access points and construction traffic routes to and from the site
  - construction traffic routes within the site (where these are relevant to the management of construction noise and vibration impacts)
  - facilities associated with the project and the access arrangements to and from such facilities
  - proposed noise and vibration generating activities
  - adjoining residential or other noise or vibration sensitive facilities (this should include separate identification of all critical or heritage listed structures). Their location should be presented on a map.
  - particular infrastructure, utilities or landforms for which specific vibration (or other) protection is required.
- Noise and vibration limits applicable to the construction including, where relevant limits applicable to:
  - specific work activities
  - particular items of plant
  - facilities
  - all buildings, building contents, structures and utilities requiring particular protection
  - safe working distances (provide a table of safe working distances from specific activities) to prevent damage to structures (buildings, bridges, and so on), services (pipes, cables, and so on), utilities and critical sites.

- Reasonable and practicable mitigation and management measures adopted to minimise disruption due to noise and vibration from construction activities. This would include particular noise and vibration control practices that apply:
  - inside and outside of Standard hours
  - during designated stages within the overall project duration
  - for operation of specific types of equipment (for example, impact breakers or vibratory rollers)
  - for specific types of operation (for example, blasting within defined proximity of a particular building or structure)
  - in the vicinity of a particular noise and vibration sensitive site
  - with alternative mitigation procedures (respite, alternative accommodation).
- Dilapidation/building/structural condition survey and reporting requirements (or if these have been conducted separately, reference to the relevant completed pre-construction surveys).
- Monitoring procedures to verify compliance with noise and vibration limits including, where relevant, nominated monitoring positions and designated reporting intervals.
- Reference to any associated documents such as relevant assessment reports used in plan preparation and associated documents and management plans.
- Community liaison requirements and complaint procedures (including all contact details). The central point of contact should have the authority to alter mitigation and construction activities onsite.
- Reporting procedures to provide the department and other relevant authorities with evidence of compliance when requested.
- Reporting procedures to notify the department (i.e. project manager) within 24 hours of any complaints occurring or within 24 hours of becoming aware of any damage caused by construction activities.
- Reporting procedures to notify the EHP within 24 hours of any material environmental harm or serious environmental harm caused by construction activities.

Where the department accepts that the project's noise and vibration risk level is low, a less detailed NVMP may be accepted. While the above information would be required, the NVMP would not be expected to be voluminous, given the limited noise and vibration impacts expected from a low risk project.

7.2 Control options

Mitigation and management measures which may be used to control noise and vibration from construction are provided in this section, as well as the community consultation procedures.

In addition to the information provided, qualitative guidance on engineering noise and vibration controls applicable to construction is given in:

- Australian Standard AS 2436-1981, Appendices A and E
- Australian Standard AS 2436-2010, Appendices C and D

- British Standard BS 5228: Part 1:2008, Section 8
- British Standard BS 5528: Part 2:2008, Section 8.

It is important to note that any mitigation and management should be determined on a project specific basis and should be reasonable and practicable.

7.2.1 Administrative procedures

Administrative procedures for the general management of a site relate to general measures which may be used to reduce noise and vibration impacts.

Administrative procedures shall:

- Provide an induction to site personnel (including subcontractors) addressing the requirements of the NVMP and their responsibilities with regard to noise and vibration management ensuring:
  - work occurs within approved hours
  - appropriate mitigation and management measures are being utilised.
- Provide ongoing education of supervisors, operators and sub-contractors on the need to minimise noise and vibration through toolbox meetings and on-site training.
- Include clauses that require minimisation of noise and vibration in subcontractor agreements.
- Provide a protocol for handling noise and vibration complaints that includes recording, reporting and acting on complaints.
- Organise work to be undertaken during the Standard hours where reasonable and practical and safe to do so.
- Include an outside Standard hours works procedure to minimise the impact of any significant noise and vibration works outside Standard hours.
- Avoid the use of radios or stereos outdoors where neighbours may be affected.
- Avoid the overuse of external public address systems or link these systems to the telephone system where neighbours may be affected.
- Avoid shouting, and minimise talking loudly and slamming vehicle doors.
- Avoid the use of horns within the construction area, except in the case of emergency or a requirement for safety.
- Where noise assessment indicates reverse beepers/warning signals are likely to result in adverse impacts on amenity, minimise mobile equipment reversing/movement or use alternative beepers, such as ‘broadband noise beepers’ or warning systems. All warning signals should meet the relevant occupational safety requirements. This should be implemented for plant operating during night-time hours where reasonable and practicable.
- Where significant impacts are unavoidable, particularly at night, ensure that respite measures are implemented (see Section 7.2.6 of this Code).
- Where respite measures are implemented and significant noise and vibration impacts still occur, consider alternative mitigation measures as a last resort (see Section 7.2.7 of this Code).

7.2.2 Construction traffic and deliveries

Construction traffic and deliveries mitigation and management procedures may include:

- Setting the site entry and egress points as far from sensitive and critical receptors as practical. If sensitive sites surround the construction area, the entry and egress points should be designed to distribute the movements rather than directing all movements through a single entry/exit point.
- Providing on-site parking for staff and on-site truck waiting areas away from residences and other sensitive land uses.
- Avoiding unnecessary revving of engines and switching off equipment when not required.
- Positioning loading and unloading points away from sensitive and critical receptors.
- Avoiding traffic calming devices which may cause loads to shift or securing loads to limit shifting.
- Ensuring traffic movement is kept to a minimum (for example, ensuring trucks are fully loaded so that the volume of each delivery is maximised) and night time construction traffic is redirected away from sensitive and critical receptors where possible.
- Regularly grading unsealed areas or fill potholes in sealed access roads and hardstand areas to reduce noise and vibration from vehicles.
- Refilling aggregate bins prior to the bins being completely empty.

7.2.3 Plant and equipment

Plant and equipment mitigation and management procedures may include:

- Selecting plant and equipment based on noise and vibration emission levels.
- Turning off plant and equipment or throttling them down to a minimum when not in use.
- Selecting appropriately sized equipment for the task, such as vibratory compactors and rock excavation equipment.
- Avoiding use of plant and equipment simultaneously adjacent to sensitive receptors where possible.
- Using alternative construction methods to minimise noise and vibration levels (for example, during clearing, excavators with grabs and rake attachments may be used instead of chainsaws, for piling, an alternative piling method may be selected, refer to Section 7.2.3.1 of this Code).
- Using mufflers and engine covers/screens where appropriate.
- Ensuring equipment is operated in the correct manner and correctly maintained including replacement of engine covers, repair of defective silencing equipment, tightening of rattling components, repair of leakages in compressed air lines and shutting down of equipment not in use.
- Avoiding where possible the night time use of equipment which generates impulsive noise:
  - impact piling
  - dropping materials from a height

  - metal-to-metal contact on equipment.
- Lining aggregate bins and chutes with a rubber material, to dampen the vibration of the structure.
- Minimising drop height of materials when transferring (for example, loading and unloading vehicles and storage areas).
- Using damped tips on rockbreakers where appropriate.
- Replacing noisy fatigued sealed bearings on conveyor rollers.
- Silencing dust extraction fan exhausts and orienting them away from sensitive receptors.
- Enclosing standby generators or fitting them with an effective muffler.
- Isolating stationary plant located near sensitive receptors with resilient mounts.

7.2.3.1 Piling and compaction

The selected piling technique should minimise noise and vibration impacts but still allow work to proceed without placing unreasonable restriction on the activity.

It should be noted that the selection of a quieter method may prolong the piling operation, and therefore the overall disturbance to the community may not necessarily be reduced.

Piling and compaction mitigation and management procedures may include the following:

- Avoiding impact pile driving where possible near noise and vibration sensitive receptors. Continuous flight auger injected piles, pressed-in preformed piles, auger bored piles, impact bored piles or vibratory piles may be an alternative. However, some alternative methods (for example, vibratory piles) provide continuous fixed frequency characteristics that may give rise to resonance responses in structures and potentially be more perceptible at lower vibration levels. So the substitution should be carefully considered and trial assessments may be used to gauge the potential impacts (all impacts, for example, soil stability, should be reviewed including change in vibration levels). In some instances, a combination of approaches may be necessary as distance to sensitive locations varies across the site.
- Avoiding dynamic compaction using large tamping weights near sensitive and critical receptors.
- Providing acoustic screens to hammer head and top of pile.
- Providing acoustic damping to sheet steel piles to reduce vibration and resonance.
- Using resilient pad between pile and hammerhead. Care should be taken when selecting a resilient pad as energy is transferred to the pad in the form of heat. Refer to Australian Standard AS 2436-2010 for further details.
- Providing careful alignment of pile and rig.
- Minimising cable slap and chain clink.
- Providing mufflers and engine covers/screens where appropriate.
- Removing obstructions which may exacerbate vibration transmission (for example, old foundations) where appropriate, prior to piling operations.

- Providing cut-off trenches to interrupt the direct transmission path of vibrations between source and receptors where reasonable and safe to do so. Refer to British Standard BS 5228 Part 2:2008 for further details.
- Reducing energy per blow when piling (consider first whether this may result in prolonged exposure with no realised reduction in community disturbance).

7.2.3.2 Blasting

Blasting mitigation and management procedures may include:

- Reducing the maximum instantaneous charge (MIC) by use of delays, reduced hole diameter, and/or deck loading.
- Ensuring adequate stemming and eliminating exposed detonating cord.
- Avoiding secondary blasting where possible; the use of rock breakers or drop hammers may be an acceptable alternative.
- Avoiding toe shots where appropriate.
- Avoiding blasting during heavy cloud cover or temperature inversions where possible.
- Avoiding blasting during strong winds blowing towards sensitive receptors.
- Establishing a blasting timetable through community consultation for example, blasts times negotiated with surrounding sensitive receptors.

7.2.4 Transmission path

Transmission path mitigation and management procedures may include:

- Locating construction equipment in a position that provides the most acoustic shielding from buildings and topography.
- Scheduling construction of permanent acoustic barriers as early as possible (for example, mitigation provided by operational noise barriers may be of use during construction phase).
- Locating temporary noise barriers between the construction site and sensitive receptors. Temporary barriers may be constructed using soil stockpiles, shipping containers and temporary site offices. The barriers should be positioned to limit gaps.
- Constructing temporary enclosures/screens around especially noisy activities, or clusters of noisy equipment (for example, loaded vinyl or plywood temporary acoustic barriers). Further guidance may be obtained in Australian Standard AS 2436-2010.
- Constructing an enclosure around significant points of construction activity (for example, tunnel portals) for construction activities greater than 12 months, if appropriate.

It should be noted that temporary acoustic barriers are not subject to MRTS15 requirements. If the acoustic barriers are to be permanent then this specification would apply.

7.2.5 Facility layout

Facility site layouts should be planned and include the following:

- Maximising acoustic shielding from existing topography and buildings and from structures and buildings associated with the facility (for example, storage units and temporary offices may be grouped together to form an effective acoustic barrier), for the nearest adjacent sensitive sites.

- Planning site entry and egress locations as per Section 7.2.2 of this Code.
- Mitigating plant and equipment as per Section 7.2.3 of this Code.
- Minimising reversing movements (and use of audible reversing alarms). For example, sites should be designed so that delivery vehicles can drive through the site and not be required to reverse. With asphalt plants and batch-plants, use drive-through loading bays, rather than backup loading.
- Considering the layout and orientation of individual items of plant and equipment to ensure that, where at all practicable, intake and exhaust vents from fans, blowers and other items of powered mechanical plant are orientated away from noise sensitive sites (that is, maximise use of 'directivity' effects).
- Avoiding onsite fabrication work where possible. The use of enclosures (for example, well-sealed shed) may be an alternative, but ventilation should be adequate and not degrade the acoustic performance of the enclosure.

7.2.6 Respite

Where all reasonable and practicable measures are implemented and noise and vibration impacts are unavoidable and significant, respite measures may be used. The provision of respite periods involves scheduling work during periods when people are least affected to minimise exposure. Provision of respite periods should follow consultation with the affected community and may include:

- Scheduling work when premises are not in operation (for example, commercial and educational facilities may not operate outside typical business hours).
- Restricting the number of nights per week that the works are undertaken near residences.

7.2.7 Alternative mitigation and management

Where noise and vibration impacts are unavoidable and significant after all reasonable and practicable measures and respite periods are implemented, alternative mitigation measures may be used. Currently alternative mitigation is limited to temporary relocation and the provision of architectural treatments.

Temporary relocation involves the relocation of affected occupants for short periods of time where all reasonable and practicable measures and respite periods are implemented and further mitigation is impractical. Examples of temporary relocation may involve the offer of an alternative activity or accommodation.

Architectural treatments may involve the provision of alternative ventilation where the windows are to remain closed. However, the performance of the building envelope may be limited by specific elements (for example, windows and doors) and architectural treatments should primarily focus on those elements.

7.2.8 Community consultation

Good community consultation practices are a key component for the management of disruption from construction activities. Prior to construction commencing, clear communication channels must be established between the project team and those persons and organisations in the community potentially most affected by project related activities. This is particularly important where activities with potential for high levels of disruption, such as blasting, pile driving or night work will be required. It is important that information is provided in a transparent and consistent manner in relation to exposure, duration, mitigation and management measures.

Community consultation should maintain a working relationship with the community by implementing the following:

- Disseminating information regarding the project schedule and potential impacts to the surrounding sensitive locations. The following may be used:
  - letterbox drops
  - community meetings
  - newsletters
  - website
  - a point of contact for information (dedicated phone line).
- Initiating a procedure for complaints response including a dedicated phone line for Standard and Non-Standard hours.

7.2.8.1 Notification

Notification regarding specific construction activities should be provided to adjacent residents and property owners likely to be affected by noise and vibration from the activity. Such notification should be provided prior to the activity commencing (typically one week notice) and should provide the following details:

- the reason for the activity
- types of equipment required
- the expected hours of operation, including any permitted site preparation works which will occur outside Standard hours
- the likely duration and impact of operation at the site and any requirement for subsequent additional works
- contact details for further information and complaints.

Where changes are made to any of these items, including particularly to hours of operation or to likely duration of the operation, affected residents and property owners should be notified.

These requirements are additional to any general community engagement procedures adopted at project level.

7.2.8.2 Complaints

The project should establish an effective documented complaints handling procedure which provides a fair and quick response to valid complaints. A complaints handling procedure should consider the following:

- A dedicated phone line should be provided to enable the community to contact a central project representative.
- A central point of contact should have the authority to alter mitigation, management and construction activities onsite.

- A register of complaints should be maintained, including time, date, location, persons contact details and any details regarding construction activities which are the focus of the complaint. In addition, the actions taken as well as alterations to the NVMP should be recorded. The timeframe for response as well as likely actions should be provided immediately to the complainant by the recipient of the complaint.
- Reporting procedures to notify the department (i.e. project manager) within 24 hours of any complaints occurring or within 24 hours of becoming aware of any damage caused by construction activities.
- Reporting procedures to notify the EHP within 24 hours of any material environmental harm or serious environmental harm caused by construction activities.

Where possible the complaint should be resolved quickly using all reasonable and practicable mitigation and management measures.

Reporting procedures contained within this code do not override the project's legislative obligations with respect to notification presented in the *Environmental Protection Act 1994*.

8 Glossary of terms

8.1 General definitions

Term	Definition
Assessment	A procedure designed to identify whether noise and vibration issues are likely to be significant and to ensure all reasonable and practicable mitigation management measures are implemented. Chapter 4 defines the requirements for different assessment types.
Blasting	The practice of the use of explosions for the purpose of loosening or breaking up rock or other material.
Building condition survey	A survey of a building or structure conducted for the purpose of providing documentation and record of the buildings 'state of repair' at a particular time. Building condition surveys are sometimes also referred to as 'dilapidation surveys'.
Building contents investigation	A survey or investigation carried out for the purposes of documentation of particular vibration sensitive building contents or equipment located in a specific building or group of such buildings. It also means the subsequent investigations and assessments necessary to establish the particular sensitivities of identified vibration sensitive contents or equipment.
Building envelope	Those building components (comprising the external walls, floors and roofs/ceilings) which separate habitable internal spaces of a building from the external environment and particularly from sources of external noise.
Community engagement	The process of ensuring good communication with those members of the community likely to be affected by project related activities and effects (see Chapter 7).
Construction	All construction activities which include blasting, impact pile driving, construction traffic and temporary facilities and plant.
Construction traffic	All traffic associated with construction (including haul routes) when using a public road.
Critical receptor	See Chapter 3.
Descriptor (of sound or vibration)	A measure or index used to describe the fluctuating amplitude or level of a sound or vibration signal (or a subset of those amplitudes or levels), derived from the actual fluctuating signal values by statistical or other methods.
Dynamic compaction	The process whereby ground compaction is achieved by repeatedly lifting and dropping a large mass (or tamping weight) onto the substrate. Typically masses of 10 to 20 tonnes and heights of 15 to 20 m are used.
Frequency	For a periodic, oscillatory or vibratory phenomena, the 'frequency' means the number of times the phenomena repeats itself in a unit time interval. Frequency is measured in Hertz (Hz); 1 Hz being one cycle per second.

Term	Definition
Frequency analysis	The process used to discriminate between the various frequency components (or tones) which together comprise the overall sound or vibration signal. Sound varies in both level and frequency (subjectively, loudness and pitch). For many purposes to assess acoustic (or vibration) effects and control requirements, it is necessary to have information regarding both the overall level of the sound (or with vibration, the displacement, velocity or acceleration amplitudes) and also the various frequency components comprising the overall signal. Conventionally, the frequency spectrum is divided into standard 'octave bands' where the centre frequency of each band is double that of the previous band. Each octave band may be further subdivided into 'third-octave bands'. Frequency analysis may also be conducted using smaller fractions of an octave band or by a 'narrow band' process, where the frequency spectrum is divided into a large number of bands of equal width.
General construction	Construction with the exclusion of blasting and construction traffic.
Habitable room	Any room which is used for purposes of work, relaxation or sleeping and which is not a bathroom, laundry, toilet or room used primarily for storage purposes.
Haul route	A road or group of such roads used to transport materials and equipment to and from a construction site. It also means a road or track within a construction site used by heavy vehicles (trucks and scrapers and so on) for purposes of transportation of materials within the site.
Heritage listed	A place, building, tree, natural formation or other structure of cultural heritage significance which is listed on the Queensland Heritage Register under the provisions of the *Queensland Heritage Act 1992*.
Hertz (Hz)	Cycles per second.
Impact pile driving	Pile driving by sinking or driving a pile by direct or indirect hammering or impact. It includes pile driving by the use of a drop hammer, internal drop hammer, diesel hammer, double-acting hammer, single-acting hammer, air, steam or hydraulic hammer or other mechanical impact device excluding hand held devices.
Impact roller	A 'square roller' or 'lobed roller' which achieves soil compaction as a result of the impacts imparted to the soil as the roller rotates and the mass of each face or lobe of the roller impacts the ground surface.
Justifiable Complaint	A complaint that is not considered to be vexatious or frivolous by the department.
Non-Standard hours – evening	See Chapter 3.
Non-Standard hours – night time	See Chapter 3.
NVMP	Noise and Vibration Management Plan (see Chapter 7).
Pile	Any sheet, column, post, tube or caisson driven or formed in the ground and includes any pile referred to as a 'bored pile', 'jacked pile', 'screw pile', 'cast-in-place pile', 'caisson pile', 'composite pile', 'sand pile', 'sheet pile' and any other form of pile.

Term	Definition
Piling	Works in connection with or for the installation or forming of a pile in the ground by hammering, jacking, screwing, augering, boring, jetting, vibrating, casting; or by any other means. It includes the driving or sinking of any casing or tube into the ground to form a well or caisson for foundation purposes, whether or not the pile casing or tube is later withdrawn.
Piling and related ground improvement methods (short form, piling and related activities)	Piling, dynamic compaction, vibroflotation and impact placement of stone columns or other ground stabilisation by use of equipment normally or typically used for impact pile driving. It also includes insertion of wick drains (band drains) by vibratory or other means.
Piling system for impact and vibratory pile driving	The particular combination of pile driver and the type of pile.
Pneumatic tyred roller	A roller equipped with pneumatic tyres. The majority of such rollers are static rollers and achieve compaction of the substrate by a combination of the static weight of the roller and the kneading action of the roller tyres on the substrate. Such rollers typically incorporate mechanisms to increase the applied mass by use of ballast. To enhance tyre kneading effects, pneumatic rollers may incorporate systems to automatically vary tyre pressure and to pivot or oscillate individual wheel sets.
Pneumatic tyred vibratory roller	A pneumatic tyred roller with the tyres mounted from a common axle which incorporates a vibratory mechanism (similar to a steel drum vibratory roller).
Pre-construction survey	A survey or investigation conducted in the vicinity of a proposed construction site (or group of such sites), carried out for the purposes of identifying all buildings, building contents, services and utilities, ground and landform elements susceptible to vibration induced disruption or damage for which protection must be provided. The pre-construction survey, by definition, must be conducted prior to commencement of any construction activity at the construction site.
Public road	A road that is open to the public, whether or not on payment of money.
RMS	Root mean square.
Safe working distance	The minimum distance from vibration sensitive buildings, structures or other items, at which a particular class or type of activity may be carried out under a defined level of operational vibration control.
Sensitive receptor	See Chapter 3.
Standard hours	See Chapter 3.
Static roller	A roller which achieves compaction of the substrate soil primarily as a result of application of the weight of the roller drum to the substrate, as it advances over the area to be compacted. The term static roller includes vibratory rollers when these are operated in non-vibratory mode.
Temporary facility	Includes sites such as depots, plant maintenance and layover areas, batch plants, asphalt plants, crushing and screening equipment, stockpile sites and all other materials processing and handling sites established on a short-term or semi-permanent basis, to service the specific requirements of a particular road construction or maintenance project. This does not include activities which are classed as Environmentally Relevant Activities (ERA).

Term	Definition
Temporary plant	Particular items of mechanical plant or equipment (such as pumps, stationary generators and compressors and so on) which are not associated with a temporary facility, but which will be required to operate at the one site more or less continuously over an extended period. This does not include plant activities which are associated with an Environmentally Relevant Activity (ERA).
Vibroflotation	Ground improvement techniques (vibrocompaction and vibroreplacement) which use a large vibrating probe or 'poker' (in some cases, an H-pile driven at resonance by a vibratory pile driver) to penetrate the ground and use vibration to compact the surrounding materials. Once the probe has reached a predetermined depth, additional material is introduced into the hole and is compacted as the probe is gradually withdrawn, to form a dense column of sand or stone ('stone-columns').
Vibratory pile driving	The process of pile driving by application of vibration to the pile shaft, whereby vibration of the pile causes soil fluidisation in the immediate vicinity of the pile during part of each vibratory cycle. The consequent loss of frictional soil support allows the advance of the pile into the substrate due to the combined weight of pile and pile driver.
Vibratory roller (also vibratory roller compactor)	A roller which achieves compaction of the substrate by a combination of static weight and vibration of the roller drum. Typically the vibration results from the rotation of an eccentric (unbalanced) mass or masses located within the roller drum.
Wick drains (also band drains)	Vertical drainage conduits installed in soft sediments to provide drainage of excess water. These comprise a central plastic conduit and a porous jacket which filters soil water entering the drain. They are installed using a mandrel or lance, which protects the drain as it is forced into the ground. Once the mandrel reaches the required depth, it is withdrawn, leaving the drain in place. The mandrel and drain is typically inserted using plant which is similar to a small vibratory pile driver. Alternatively hydraulic jacking may be used to push the mandrel into the ground. Other systems use a combination of vibratory and hydraulic means.

8.2 Noise related definitions

Term	Definition
A-weighting	A standard electronic weighting network within a sound level meter, designed to approximate the loudness response of the average ear to sounds of different frequency at moderate sound pressure levels.
A-weighted equivalent continuous sound pressure level (denoted L_{Aeq})	The equivalent continuous sound pressure level measured using an A-weighted network.
Adjusted measured noise level (denoted $L_{Aeq,adj}$)	The measured noise level from a noise source, with adjustments applied to correct for background ambient sound level and particular audible characteristics. The adjusted measured noise level is also referred to as the assessed noise level.
Airblasts (overpressure due to blasting)	The pressure wave transmitted through the air, caused by an explosion and which contains significant airborne energy at frequencies in or below the audible range of the human ear.

Term	Definition
Ambient noise	The totally encompassing sound in a given situation at a given time, composed of sound from all sources near and far, measured by the totally encompassing time average A-weighted sound pressure level in a given situation at a given time.
Background noise	The underlying level of noise present in the ambient noise, excluding the noise source under investigation, when extraneous noise is removed. This is described using the L_{A90} descriptor.
Background noise level	The minimum ambient level, in the absence of the noise source under investigation. It may be defined as the A-weighted sound pressure level that is equalled or exceeded for 90 per cent of that part of the interval in which the investigated noise is absent (L_{A90}).
C-weighting	A standard electronic weighting network within a sound level meter which is designed to approximate the loudness response of the average ear to sounds of different frequency at high sound pressure levels.
C-weighted equivalent continuous sound pressure level (denoted L_{Ceq})	The equivalent continuous sound pressure level measured using a C-weighted network.
Continuous noise (steady state noise)	Noise that gives fluctuations over a range of not more than three dB.
Dominant low frequency noise	Where the noise is dominated by sound in the frequency range 10 Hz to 200 Hz.
Engineering noise control	Measures which provide a reduction in the noise level at the receiver by physical means (excluding personal hearing protection).
Equivalent continuous sound pressure level (denoted L_{eq})	That level, which, if present as a steady signal, would in any particular time period have the same sound energy as the actual fluctuating sound pressure level in the same period.
Fast response	An instrument time weighting (125 ms) within the sound level meter.
Frequency weighting	The practice of modifying the level of the various components of an incoming signal in a standardised manner which varies with the frequency or spectral composition of the signal. With sound level meters or other sound measurement instrumentation, this is done to provide an instrument response which approximates the (non-linear) response of the human perception of hearing to sounds of different frequency and level. The two weightings in most common use are the A and C frequency weightings. Z-weighting is now being used in blast noise assessment and low frequency noise evaluation.
Groundborne noise (also structureborne noise or regenerated noise)	A separate issue to airborne noise, groundborne noise is generated by vibration transmitted through the ground into a structure. The vibration of structures causes noise to be radiated into a room.
Impulsivity	Sound characterised by brief excursions of sound pressure level (acoustic impulses) that significantly exceed the background sound pressure level. The duration of a single impulsive sound is usually less than one second.
Infrasound	Very low frequency sound below the normal range of human hearing (that is, less than around 20 Hz).

Term	Definition
Intermittent noise (also transient, variable noise)	Noise that gives fluctuations greater than five dB.
L_{A1}	The A-weighted sound pressure level, which in any particular time period is exceeded one per cent of the time by the actual fluctuating sound pressure level.
L_{A10}	The A-weighted sound pressure level, which in any particular time period is exceeded 10 per cent of the time by the actual fluctuating sound pressure level. The L_{A10} is the standard noise descriptor for assessment of traffic noise.
L_{A90}	The A-weighted sound pressure level, which in any particular time period is exceeded 90 per cent of the time by the actual fluctuating sound pressure level. In the absence of the noise source under consideration, the L_{A90} is commonly utilised as a measure of the background or average minimum ambient sound pressure level.
$L_{A\%,T}$	The A-weighted sound pressure level that is exceeded for the per cent exceedance under consideration for the time interval (T) considered.
$L_{Aeq,T}$	The A-weighted, equivalent continuous sound pressure level within a measuring period (T).
$L_{Aeq,adj,T}$	An A-weighted sound pressure level of a continuous steady sound, adjusted for characteristics (see Chapter 2, Table 2.1.2.1(b) *Adjustment factors*), that within a measuring period (T) has the same mean square sound pressure level as a sound pressure level that varies with time.
$L_{Aeq,adj,15\ minute}$	The adjusted A-weighted equivalent continuous sound pressure level considering adjustment factors (see Table 2.1.2.1(b)), measured over a 15-minute time period.
L_{Amax}	The maximum A-weighted sound pressure level in any particular time period. L_{Amax} is an RMS parameter and should not be confused with the peak level (or non-RMS instantaneous maximum level).
L_{ASMax}	The A-weighted maximum sound pressure level with slow response.
L_{Ceq}	The C-weighted, equivalent continuous sound pressure level.
Noise	Defined by the *Environmental Protection Act 1994* as 'vibration of any frequency, whether emitted through air or another medium'. For the purposes of this Code, noise is used in the more limited sense of 'unwanted sound' (that is, vibration of the air).
Peak sound pressure level	The peak sound pressure level (L_{peak}) or 'peak level' and is 20 times the logarithm to the base 10 of the ratio of the peak sound pressure to the reference sound pressure (20 µPa). For purposes of blast monitoring, peak level is synonymous with 'overpressure level' or 'airblast level'. Peak level is a non-RMS level. It should not be confused with the maximum level (L_{max} or L_{Amax}) which refers to the maximum, RMS, sound pressure level.
Peak noise level	The peak sound pressure level.
Rating background level (RBL)	The overall single-figure background level representing each assessment period (for example, Standard hours, Non-Standard hours). The RBL is the level as derived and presented in Chapter 5.

Term	Definition
Slow response	An instrument time weighting (1 second) within the sound level meter.
Sound pressure	The instantaneous difference between the actual pressure and the average or barometric pressure at any particular location. Sound pressure is measured in Pascals (Pa). The 'effective sound pressure' is the RMS sound pressure. The 'maximum sound pressure' is the maximum RMS sound pressure. The 'peak sound pressure' is the instantaneous amplitude (non-RMS or 'peak') of the (positive or negative) fluctuation in pressure during the passage of a sound wave.
Sound pressure level (Lp)	The level of the RMS sound pressure level in decibels given by $L_p = 10\log_{10}(p/p_o)^2$ (where p is the RMS sound pressure in Pascals. The reference sound pressure p_o is 20 μPa).
Sound power level (L_w) for the noise source	An absolute that does not vary with distance or differing acoustic environments. It is 10 times the common logarithm of the ratio of the sound power of the source to a reference sound power (usually 1 pW).
Sound absorption	That property of a material or surface which allows it to absorb and dissipate sound.
Sound absorption coefficient	The ratio of sound energy absorbed (that is, not reflected) by a material (or surface) to the total sound energy incident upon it.
Sound level meter	An instrument which is designed and calibrated for measurement of sound pressure level.
Time response (also time weighting) of a sound level meter	The dynamic response of the instrument (refer Australian Standard AS 1259.2-1990 or Australian Standard AS IEC 61672.1-2004). Time weightings in common use include 'Fast', 'Slow', 'Impulse' and 'Peak' (see also **fast response**, **slow response**).
Tonality	A sound producing in a listener a definite pitch sensation.

8.3 Vibration related definitions

Term	Definition
Airborne vibration	Structural vibration induced by low frequency sound.
Amplification factor for ground vibration	The ratio of the vibration amplitude at a particular point on a building or structure to the vibration amplitude measured at the base or on the foundation of the building or structure.
Component particle velocity (component PV)	The instantaneous velocity of a particle at each orthogonal component axis (transverse, longitudinal and vertical).
Continuous vibration	A source of vibration that is continuous in nature during an assessment period (may be constant or variable).
Crest factor	The ratio between the peak amplitude and the maximum RMS amplitude of a signal.
Groundborne vibration	Vibration transmitted from a source to a receiver via the ground (see also **Structureborne vibration**).
Intermittent vibration	Interrupted periods of continuous (for example, a drill) or repeated periods of impulsive vibration (for example, a pile driver), or continuous vibration that varies significantly in magnitude.

Term	Definition
Impulse vibration	A source of vibration (continuous or intermittent) which has a rapid build up to a peak followed by a damped decay that may or may not involve several cycles of vibration (depending on frequency and damping).
Particle displacement, velocity and acceleration	Can be characterised by measurement of the displacement, velocity or acceleration of a representative point (a 'particle') of the ground or structure affected by the disturbance. For measurements of ground motion (or for other surfaces) the particle displacement is defined as the distance that the ground (or other surface) is displaced from its mean (or static) position during the course of a vibration. The particle velocity is simply rate of change of displacement of the ground or floor, and the particle acceleration the rate of change of that velocity.
Peak component particle velocity (PCPV)	The maximum instantaneous velocity of a particle at any one of the three orthogonal component axes during a given time interval. Also represented by the notation v_i in DIN 4150-3.
Peak particle velocity (Resultant PPV, PPV or v_P)	The maximum instantaneous velocity of a particle at a point during a given time interval. The Resultant PPV is the vector sum of the three orthogonal component particle velocities (component PV) as follows: $v_p = \sqrt{v_T^2 + v_L^2 + v_V^2}$ where: v_P is the Resultant PPV of the particle velocity at a particular time v_T, v_L and v_V are the respective transverse, longitudinal and vertical component PV of the particle velocity at a particular time.
Propagation velocity for vibration	The speed with which the vibratory disturbance (a wave) propagates within the medium in which it travels. For vibrations of the air (sound), the propagation velocity is the 'speed of sound'.
RMS particle acceleration	The root mean square particle acceleration.
RMS particle velocity	The root mean square particle velocity, commonly used (with the RMS particle acceleration) to assess human response to vibration. Unless otherwise specified, RMS particle velocity (denoted v_{RMS}) refers to the overall vector sum RMS particle velocity rather than to any particular component of the RMS particle velocity.
Short-term and long-term vibration	As defined in DIN 4150: Part 3:1999 *Structural Vibration – Effects of Vibration on Structures*.
Structureborne vibration	Vibration transmitted from a source to a receiver via intervening structure(s) (see also **Groundborne vibration**).
Transient vibration	Vibration in which the oscillatory displacement of the ground or structure reaches a peak and then decays rapidly towards zero.
Vibration	Vibration of the ground or of structures and buildings; that is, the oscillatory displacement of the ground or of structures and buildings.

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