

**Technical Note 03**

# **Guidelines for construction-induced ground vibration on structures**

**May 2026**

## Copyright

© The State of Queensland (Department of Transport and Main Roads) 2026.

## Licence



This work is licensed by the State of Queensland (Department of Transport and Main Roads) under a Creative Commons Attribution (CC BY) 4.0 International licence.

### CC BY licence summary statement

In essence, you are free to copy, communicate and adapt this work, as long as you attribute the work to the State of Queensland (Department of Transport and Main Roads). To view a copy of this licence, visit: <https://creativecommons.org/licenses/by/4.0/>

### Translating and interpreting assistance



The Queensland Government is committed to providing accessible services to Queenslanders from all cultural and linguistic backgrounds. If you have difficulty understanding this publication and need a translator, please call the Translating and Interpreting Service (TIS National) on 13 14 50 and ask them to telephone the Queensland Department of Transport and Main Roads on 13 74 68.

### Disclaimer

While every care has been taken in preparing this publication, the State of Queensland accepts no responsibility for decisions or actions taken as a result of any data, information, statement or advice, expressed or implied, contained within. To the best of our knowledge, the content was correct at the time of publishing.

### Feedback

Please send your feedback regarding this document to: [tmr.techdocs@tmr.qld.gov.au](mailto:tmr.techdocs@tmr.qld.gov.au)

## 1 Scope

This document provides safe vibration limits and minimum working distances for rollers and general plants. These guidelines apply to Queensland Department of Transport and Main Roads projects, as well as third-party development projects adjacent to departmental structures, to prevent structural damage from construction-related ground vibration. These guidelines become mandatory when this document is referenced in a specification.

Transport and Main Roads structures may include buildings, bridges, culverts, retaining walls and tunnels located on or adjacent to construction sites. Construction-related vibration may be caused by activities such as compacting rollers, hydraulic hammers, excavation, pile driving or boring and blasting. Vibration on bridge decks due to operational traffic and non-construction related vibrations such as long-term vibration of plant and machinery in factories falls outside the scope of this document.

The aim of this document is to provide limits and minimum working distances to manage the risk of structure damage in a practical way, resulting in effective and economical construction practices while reducing the risk of damage to acceptable levels without imposing overly conservative constraints on the construction process. Vibration-induced structure damage is a complex topic with many variables, and therefore, this document should be used to aid engineering judgement and not replace it, especially for vibration sensitive structures.

## 2 Construction vibration

Civil construction and maintenance typically involve activities such as pile driving, excavating, soil compaction, drilling, movement of heavy vehicles and blasting. These activities typically generate ground vibrations as well as noise. Ground vibrations may produce direct vibration effects on structures, trigger resonant structural vibrations of adjacent and remote structures and be the cause of dynamic settlement [1].

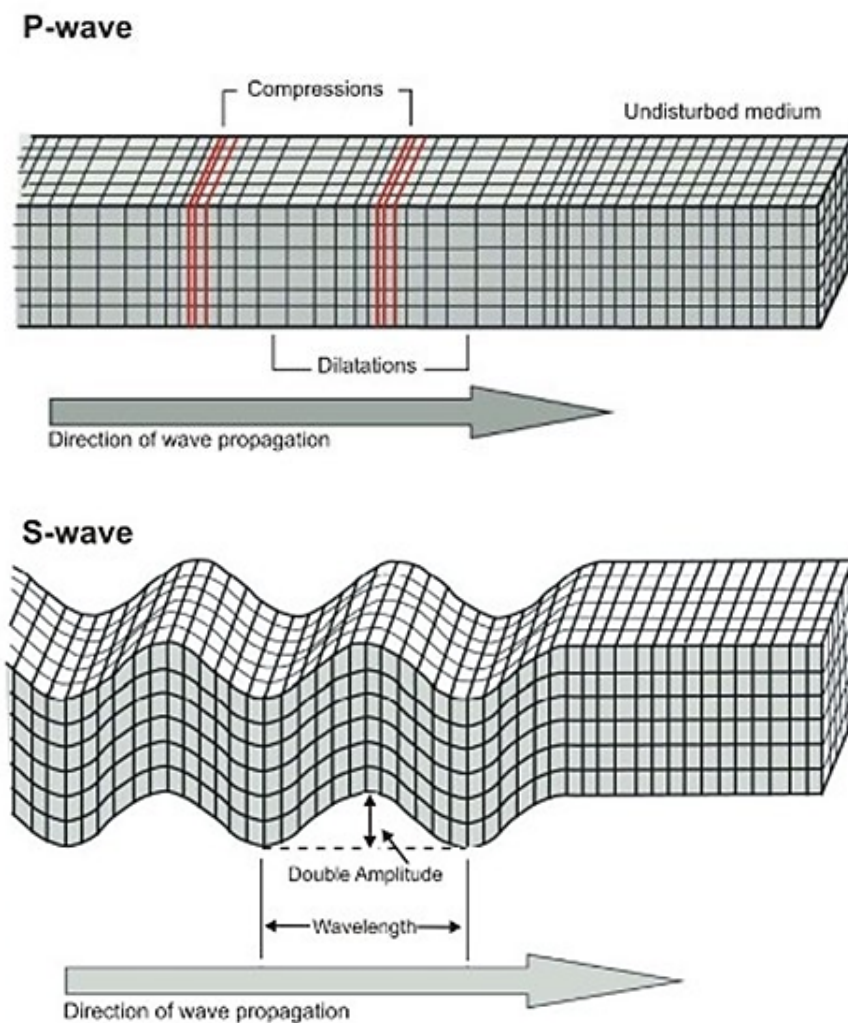
The intensity of motion at a distance from the source depends on the amount of energy transmitted into the ground, the way the ground responds and the internal damping within the ground as vibration waves travel through it.

Vibration waves may be categorised into body waves and surface waves. Body waves travel through the interior of rock and soil, while surface waves move along a surface, usually the ground surface. Due to their high amount of energy and lower rate of decay, the most significant surface wave type is Rayleigh waves, which move in a rolling motion as indicated in Figure 2.

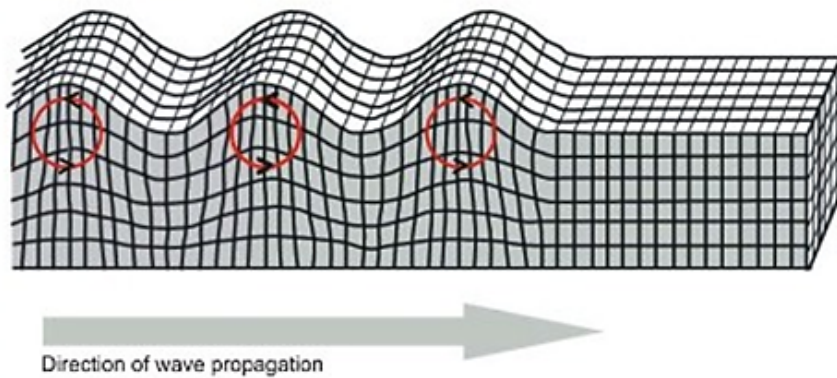
Body waves may be subdivided into compressive waves, denoted as P (Primary or Pressure waves), and distortional or shear waves, denoted as S (Secondary or Shear waves) as indicated in Figure 2.

Surface waves contain two-thirds of the total vibration energy, and their peak particle velocity is dominant on velocity records. They also decay significantly slower than P and S waves. These factors are primary concern for foundations or near surface sources or receivers.

**Figure 2 – Basic deformation characteristics of P, S and Rayleigh waves adopted from *Ground Vibration from Road Construction* [2]**



## Rayleigh wave



Local geology has a significant effect on how the waves propagate through the ground. When the waves reach a structure, the dynamic response of the structure to ground motion is dependent upon the unique structure, site and geological characteristics.

## 3 Parameters of vibration

### 3.1 Duration of vibration

Vibrations may be categorised as continuous, transient, or intermittent based on the duration and repetitive pattern as illustrated in Figure 3.1.

Continuous vibrations occur uninterrupted over a defined period. Vibratory rollers, plate compactors and vibratory pile drivers may generate continuous vibrations.

Transient vibrations involve a rapid build up to a peak amplitude followed by a damped decay that may or may not involve several cycles of vibration. Blasting, dynamic soil compaction by dropping a weight, wrecking balls strike and occasional dropping of heavy machinery may generate transient vibrations.

Intermittent vibration may be defined as continuous vibrations with periods of interruption or continuous vibrations that vary significantly in magnitude. Trains, passing heavy vehicles, impact pile driving, jack hammers and pavement breakers may generate intermittent vibrations.

In practice, distinguishing between intermittent and continuous vibrations can be challenging. For clarity and due to their similar behaviour, this guideline treats intermittent and continuous vibrations as a single category. In contrast, transient vibrations have a clear dissipation of vibrations before the next cycle of vibration, refer to Table 3.1.

In Table 3.1, the machinery that commonly generate the 3 vibration categories are shown.

**Table 3.1 – Types of vibration sources**

<b>Continuous (C) / Intermittent (I) Vibration</b>	<b>Transient (T) Vibration</b>
Vibratory Pile Drivers / Extractors (installing or extracting steel H-section piles and temporary or permanent steel casing for bored pile) (C) Rotary bored piling (C)	Start up and shut down of vibratory compaction plant/vibratory rollers (T)
Vibratory compaction plant/Vibratory rollers (C)	Clamshell grabs (T)
Resonant pile drivers (C)	Blasting (T)
Plate compactors (C)	Dynamic soil compaction by drop weight (T)
Continuous flight auger injected piling and pressed-in-piling (C)	
Tunnel Boring Machine (TBM) (C)	
Double acting air stream hammer (C) Single acting hammer (I)	
Hydraulic Impact Piling (I)	
Jack hammer and pavement breakers (I)	
Passing trains and heavy vehicles (I)	

**Figure 3.1 – Continuous, transient and intermittent vibration from Groundborne vibration caused by mechanised construction works [3]**

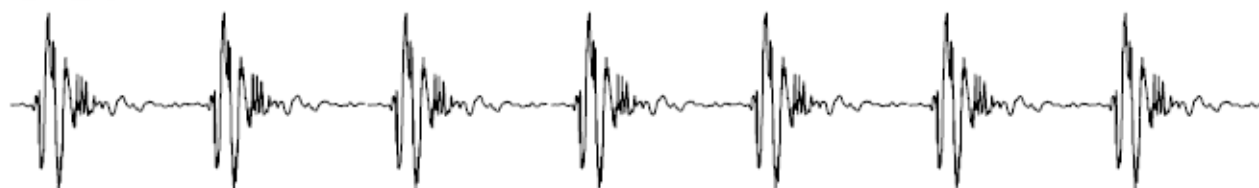
Continuous



Transient



Intermittent



### 3.2 Peak Particle Velocity (PPV)

Vibrations can be characterised by parameters such as amplitude, frequency, particle acceleration, and particle velocity over time. Of these, particle velocity is commonly used to assess the potential of a wave to cause damage. Geophones measure particle velocity along 3 primary axes (X, Y, Z). The resultant particle velocity is derived from these 3 axial components. Various definitions are used to describe peak velocity values. For this guideline peak particle velocity (PPV) is used and defined as the resultant particle velocity ( $V_r(t)$ ) at a given instant. PPV can be calculated as the vector sum of the velocities measured along 3 mutually perpendicular axes by geophones, giving the resultant particle velocity at a specific time (t):

$$PPV = V_r(t) = \sqrt{V_x(t)^2 + V_y(t)^2 + V_z(t)^2} \quad \text{Eq.1}$$

### 3.3 Frequency

A natural frequency is the frequency at which an object (for example a structure) naturally vibrates when subjected to free vibration with no damping. Structures may have multiple natural frequencies, which is dependent on several aspects including but not limited to structure's mass, stiffness, geometry, boundary conditions, and material properties.

When the frequency of ground vibrations (typically equal to or lower than the source frequency) matches or comes close to the natural frequency of the structure, resonance occurs. Resonance can lead to dynamic amplification which increases Peak Particle Velocities (PPVs) and potentially causes significant structural damage. This is particularly relevant for continuous vibration.

Frequencies may have a significant impact on vibrations. However, frequency-dependent criteria may not be readily implemented for all parties in a construction projects. Due to this, frequency-based limit recommendations are not made within this document. Refer Table 5.3(a).

## 4 Vibration receivers

There are 3 primary types of receivers that may be adversely affected by ground vibration: humans, structures, and equipment.

Structural vibration in buildings can be detected by the occupants and can affect them in many ways; their quality of life can be reduced, as can be their working efficiency. The vibration limits that affect human comfort are typically well below the levels at which damage to structures occurs.

Vibration guidelines for humans' exposure should consider the subjective nature of human comfort. *Transport Noise Management Code of Practice: Volume 2 Construction Noise and Vibration* provides guidance on this topic [4].

## 5 Vibration-related damage

### 5.1 Damage to structures

Vibration in structures can cause both direct damage to the structure itself and indirect damage due to vibration-induced ground settlement. Uneven settlement under a building can lead to extensive damage. The following factors affect the vibration impact on a structure: frequency of vibration, magnitude of vibration, stiffness of the structure and its elements, damping characteristics, type of construction, type of foundation, duration of vibration, wave form and condition of the structure [5]. Besides structural harm, vibration can also interfere with the operation of vibration-sensitive equipment, such as scanning electron microscopes and Magnetic Resonance Imaging (MRI) machines, commonly found in advanced research centres.

Damage can be classified as cosmetic cracking, minor / architectural damage or major / structural damage as per British Standard BS 7385 [6]. Refer to Table 5.1 for descriptions of the different damage levels.

**Table 5.1 – Structure damage – cosmetic, minor and major descriptions**

<b>Cosmetic cracking threshold</b>	<b>Minor or architectural damage</b>	<b>Major or structural damage</b>
<ul style="list-style-type: none"> <li>• Formation of hairline cracks on plasterboard surfaces, or the growth of existing cracks in plaster or plasterboard surfaces.</li> <li>• Formation of hairline cracks in the mortar joints of brick / concrete block construction.</li> </ul>	<ul style="list-style-type: none"> <li>• The formation of large cracks or loosening and falling of plaster or plasterboard surfaces, or cracks through bricks / concrete blocks.</li> <li>• These cracks do not affect structural capacity.</li> </ul>	<ul style="list-style-type: none"> <li>• The cracks affect the structural integrity of a building or a bridge.</li> <li>• Damage to structural elements such as cracks in support columns, loosening of joints, large cracks in beams, columns or foundations, shifted foundations, splaying of masonry cracks and so on.</li> </ul>

Where vibration damage might be a concern, a pre-construction dilapidation survey is recommended to capture the existing defects.

## **5.2 Vibration Sensitive Receptors / Structures**

Historically or culturally significant structures and critical or high-value structures may warrant a very conservative approach to limit vibrational damage. Vibration sensitive structures may include, but are not limited to:

- historical structures
- cultural structures
- tunnels
- laboratories
- research structures, and/or
- advanced technology structures.

## **5.3 PPV limits for reducing structure damage**

The PPV limits in Table 5.3(a) are recommended to reduce the risk of structure damage [7]. These limits are based on PPV values at the base of the structure. For very old structures or structures in poor condition as defined by the department's *Structures Inspection Manual* (SIM) [8], the PPV limits may need to be adjusted downwards by an RPEQ, considering the Condition of the Structure as per the SIM.

The PPV limits for tunnels are addressed in the department's *Design Criteria for Bridges and Other Structures* [9].

Transient vibration does not induce resonant response in structures and low-rise buildings. In contrast, the dynamic loading caused by continuous vibration is to give rise to dynamic magnification due to resonance, especially at lower frequencies. Therefore, PPV values for transient vibration are reduced by 50% compared to continuous vibration, as shown in Table 5.3(a). The German Standard refers to short-term vibration instead of transient vibration, which does not occur often enough to cause material fatigue. Its development over time and duration is not suitable for producing a significant increase in vibration due to resonance in a particular structure [10].

**Table 5.3(a) – PPV limits for reducing structure (building, bridge, culverts and retaining walls) damage**

Category	Type of structure	Continuous and intermittent vibrations PPV limit (mm/s)	Transient vibrations PPV limit (mm/s)
1	Historical buildings and monuments, and buildings of special value or significance	3	6
2	Unreinforced or light framed structures. Houses and low-rise residential buildings; commercial buildings not included in item 3 below	7.5	15
3	Heavy commercial and industrial buildings or structures (including bridges <sup>1</sup> ) of reinforced concrete or steel construction	25	50
4	Reinforced concrete culverts and retaining walls	17	34

1: For bridges – The maximum vibration limit defined in the above table must be re-evaluated by and RPEQ based on the Condition State (as per the SIM) and age of the structure and the proposed construction activity, refer to Section 8.

## 6 Vibration measurement and Instrumentation

Ground vibration is typically measured using a transducer that generates an electrical signal proportional to a parameter of the ground motion, such as its amplitude, displacement, velocity, or acceleration depending on the design purpose of the transducer.

Seismometers and geophones are velocity transducers, which produce signals proportional to velocity. Accelerometers, in contrast, are acceleration transducers, generating signals proportional to acceleration. Vibration transducers typically measure motion along a single axis but can be combined into a triaxial array to measure vibrations in 3 orthogonal directions simultaneously. Numerical integration and differentiation can be used to convert between displacement, velocity and acceleration.

In general, a vibration measuring system usually includes the following: transducers, signal conditioning instrument and a data capturing and calibrated analysis system.

The vibration transducers must have an appropriate frequency and amplitude range for the relevant measurements and be calibrated. For guidelines on using accelerometers, refer to Australian Standard for *Mechanical Vibration and Shock—Mechanical Mounting of Accelerometers* (AS 2775–2004) [11]. The Australian Standard for *Explosives – Storage and Use* (AS 2187.2-2006) [12] also provides specifications for ground vibration monitoring equipment.

A potential alternative for preliminary assessment of ground vibration may be the use of mobile phones to measure amplitude levels through specialised apps. However, since mobile phone sensors are not calibrated, it is only recommended to use it for a preliminary assessment and not to replace calibrated geophones / accelerometers where required.

## **7 Vibration Assessment**

### **7.1 Vibration assessment by the designer**

Assessment of construction-induced vibration on departmental structures (bridges, tunnels, retaining walls, culverts and bus stations) shall be considered at the design stage of the project, as required by Clause 3.4.6.1 of the department's *Design Criteria for Bridges and Other Structures* manual. Designers must include vibration analysis in their design submission, reflecting the assumed construction methodology, particularly for piling works and impact on existing structures. The Condition State of the affected structure, as per the SIM, must be considered in the vibration analysis.

The designer's vibration assessment shall adhere to the vibration threshold stated in Table 5.3(a), ensuring predicted vibration limits are below these thresholds. If the predicted vibration exceeds thresholds stated in Table 5.3(a), redesign or alternative construction methods are required.

The designer is responsible for a Vibration Impact Assessment (VIA) Report, which must be available to the Contract Administrator and contractors prior to the commencement of construction work.

Australian Standard AS 2187.2 provides guidance on the prediction of vibration levels produced by blasting. The standard includes an empirical equation based on the charge weight and distance to calculate the free-field ground borne vibration.

## 7.2 Managing vibration impacts during construction

The contractor is responsible for the vibration assessment of non-departmental structures associated with the project and for the Vibration Impact Assessment (VIA) report.

The contractor shall review the designer’s Vibration Impact Assessment (VIA) Report and incorporate the designers report and his own VIA report and produce the Construction Vibration Management Plan (CVMP) for the entire project.

The department requires that all vibration assessment under a contract be carried out by an RPEQ with relevant experience in assessing vibration from infrastructure projects.

The CVMP shall consist of a vibration and instrumentation monitoring plan incorporating the traffic light system shown in Section 8 of this document. The vibration monitoring shall be automated, and access to the online portal shall be readily available to E&T Structures (via [ET\\_Structures\\_PlanningandDelivery@tmr.qld.gov.au](mailto:ET_Structures_PlanningandDelivery@tmr.qld.gov.au)) for the project duration. The contractor shall supply the raw data to the Manager of Engineering Delivery at E&T Structures.

## 8 Vibration Monitoring departmental Structures – Bridges

### 8.1 Bridges with Condition State 1 and 2 (CS1/CS2)

This section addresses bridge vibration monitoring and the other structures can follow similar traffic light procedure shown here. Condition State 1 (CS1) and Condition State 2 (CS2) are based on the SIM.

For construction projects adjacent to departmental bridges, the contractor shall propose a monitoring and response plan with appropriate values for vibration with target value generally not to be exceeded, and maximum value never to be exceeded under any circumstances.

Unless a lower limit is defined in the VIA report, refer to Section 7.1 of this document for Transport and Main Roads bridges, the trigger levels for automated vibration monitoring for vibration activity that causes continuous or intermittent vibrations are:

<b>Green:</b>
Where $PPV < 10 \text{ mm/s}$ – proceed at Contractor's risk.
<b>Orange:</b>
Where $10 \text{ mm/s} \leq PPV \leq 25 \text{ mm/s}$ Hold on construction activity and immediately notify the Contractor's supervising engineer, the Administrator. 1. The contractor's supervising engineer must review construction procedures to limit the PPV does not exceed 25 mm/s, inspect the structure for possible damage, and increase monitoring frequency.

2. Vibration inducing activities may resume under the direct supervision of the Contractor's supervising engineer (with agreement from the Administrator) after:
  - a. No evidence of damage to structure. (Where damage is evident, workers and traffic may be required to be removed from the structure.)
  - b. Construction procedure has been reviewed with update to further reduce vibration risks.
  - c. Monitoring frequency is increased.

**Red:**

- Where PPV > 25 mm/s  
Should the maximum value ever be exceeded:
1. Place a hold on the vibration creating activities and immediately notify the Contractor's supervising engineer, the Administrator, and Manager of Engineering Delivery at E&T Structures ([ET\\_Structures\\_PlanningandDelivery@tmr.qld.gov.au](mailto:ET_Structures_PlanningandDelivery@tmr.qld.gov.au)).
  2. Contractor's supervising engineer must undertake a bridge safety inspection including assessing any structural damage identified.
  3. Where deemed necessary, by the Contractor's supervising engineer or the Administrator give direction to remove workers and traffic from the structure.
  4. As an immediate action, the Contractor's supervising engineer must provide an RPEQ certified advice on the structural condition to the Administrator with a copy to Transport and Main Roads' Structures Directorate.
  5. Construction activities may only recommence after the Contractor's supervising engineer has reviewed and adjusted the Construction procedures to ensure that the maximum value is not exceeded again. Release for work to be provided by Director, E&T Structures.
  6. Within 5 Business Days after the exceedance, the Contractor's supervising engineer must provide an RPEQ certified report on each exceedance of the maximum value to the Administrator with a copy of the report to the Structures Directorate ([ET\\_Structures\\_PlanningandDelivery@tmr.qld.gov.au](mailto:ET_Structures_PlanningandDelivery@tmr.qld.gov.au)). The report must include:
    - a. The RPEQ certified release before traffic is permitted to continue using the structure (if any).
    - b. Details of the adjusted construction procedures, and all other relevant information.
    - c. Details of the Contractor's inspection including an addendum to the current Level 2 – Condition Rating Inspection Report for any damage identified after an exceedance event.

**8.2 Target and maximum vibration limits for project specific structures (CS3/CS4)**

Condition State 3 (CS3) and Condition State 4 (CS4) are based on the SIM.

<b>Green:</b>
Where PPV < 7.5 mm/s - proceed at Contractor's risk.
<b>Orange:</b>
Where 7.5 mm/s <= PPV <= 15 mm/s, hold on construction activity and immediately notify the Contractor's supervising engineer.

**Red:**

PPV &gt; 15 mm/s.

All other notes regarding trigger level actions shall be in accordance with Section 8.1.

## 9 Minimum working distances

This section provides the minimum working distances for category 2, 3 and 4 structures as defined in Table 5.3(a). Category 1 structures (i.e. historical buildings and monuments, and buildings of special value or significance) require special consideration and engineering judgement.

Table 9(a) provides minimum safe working distances for hydraulic hammers, piling and jack hammers (similar to the Transport for NSW (TfNSW) guideline [13]). The working distances are indicative and may vary depending on the specific item of plant and local geotechnical conditions. They apply to cosmetic damage of typical buildings under typical geotechnical conditions. If the project proposes to change the minimum working distance, an assessment is required and must be submitted to the administrator and Structures Directorate, for review and approval. Vibration monitoring is recommended to confirm the minimum working distances at specific sites.

**Table 9(a) – Vibration offset table for general plant**

Plant	Rating / description	Minimum working distance for preventing cosmetic damage in metres
Jack hammer	Handheld	1 (nominal)
Small hydraulic hammer	(300 kg – 5 to 12 t excavator)	2
Medium hydraulic hammer	(900 kg – 12 to 18 t excavator)	7
Large hydraulic hammer	(1,600 kg – 18 to 34 t excavator)	22
Pile boring	≤800 mm	2 (nominal)

Note: More stringent conditions may apply to historical, cultural or other sensitive / critical structures.

Table 9(b) provides the minimum safe working distances for vibratory rollers [7]. The roller classification is based on the centrifugal force and should be relevant to the levels of centrifugal force used on the roller (some rollers have high and low vibration settings with different centrifugal force ratings). Oscillatory rollers often produce significant lower PPVs in comparison to vibratory rollers with the same centrifugal force rating. The use of oscillatory rollers to be considered where damage risk is high, subject to PPV measurement and confirmation that adequate compaction levels will be achieved.

**Table 9(b) – Vibration offset table for rollers**

Plant	Rating Centrifugal force	Minimum working distance for preventing damage in metres	
		Category 2 structures	Category 3 & 4 structures
Vibratory roller	<100 kN	10	5
	<200 kN	15	10
	<300 kN	22	12
	>300 kN	25	15

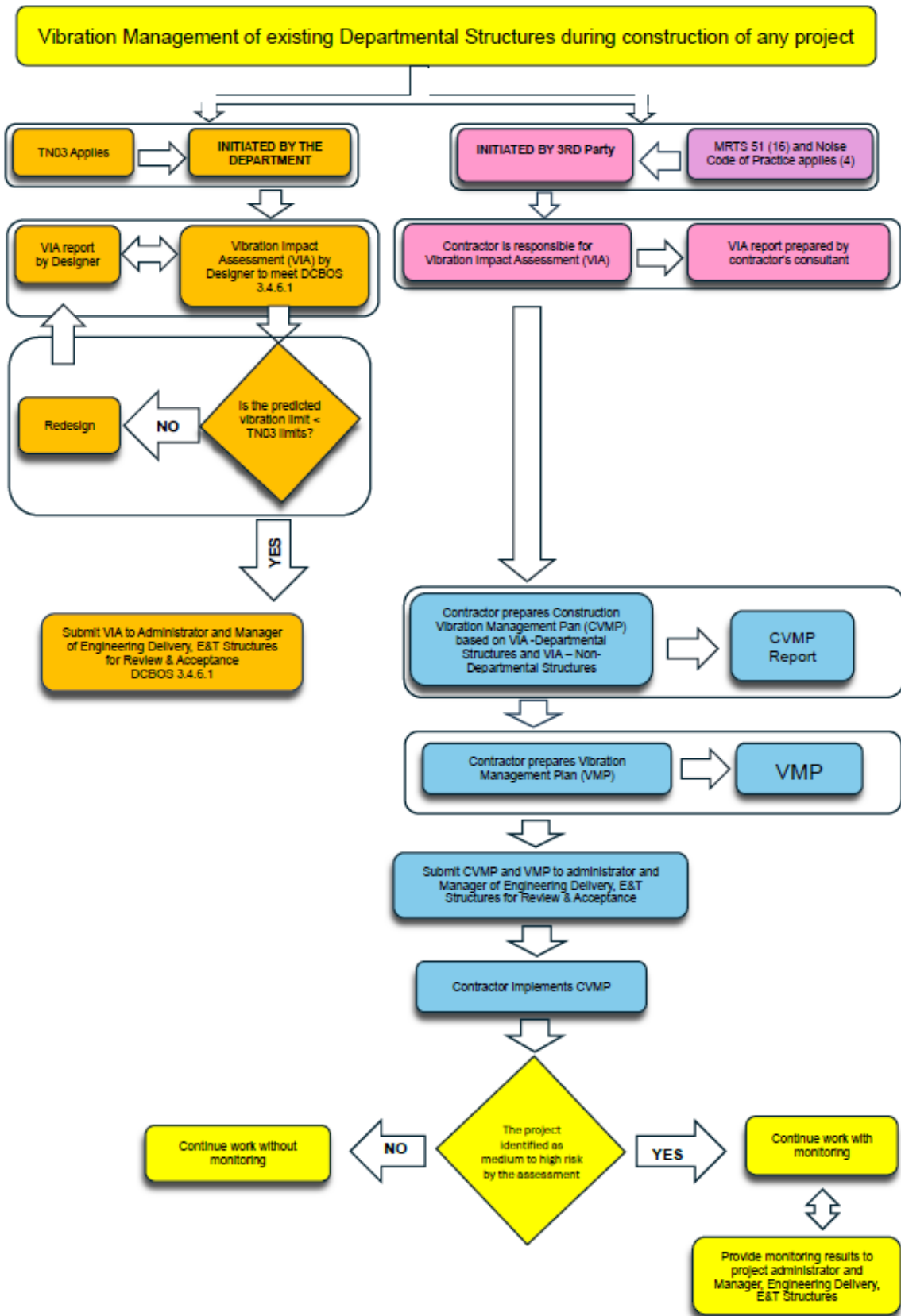
Note: More stringent conditions may apply to historical, cultural or other sensitive / critical structures.

The minimum working distance in Section 9 has been determined by reviewing related literature on vibration prediction, as well as analysing local test data and empirical evidence. Consideration has been given to the empirical equations developed by Hiller and Crabb (2000) [14] and Crabb and Hiller (2002) [15] in the UK, which predict vibrations from vibratory rollers. These equations are based on roller parameters provided by plant manufacturers, including the amplitude of the roller's vibration, the width of the vibrating drum, and the distance between the source and the receiver.

## 10 Recommended procedures

Figure 10 illustrates the vibration management process that designers and contractors should follow for existing departmental or third-party construction projects adjacent to departmental and non-departmental Structures.

**Figure 10 – Vibration management process for departmental and third party initiated projects**



## 11 References

1. Svinkin MR (2014). *Tolerable limits of construction vibrations*, Practice Periodical on Structural Design and Construction, vol. 20, no. 2, doi:10.1061/(ASCE)SC.1943-5576.0000223.
2. Cenek PD & Sutherland AJ (2012). *Ground vibration from road construction*, research report 485. New Zealand Transport Agency: Wellington, New Zealand.
3. Hiller DM & Crabb GI (2000). *Groundborne vibration caused by mechanised construction works*, TRL report 429. Transport Research Laboratory: United Kingdom.
4. Queensland Department of Transport and Main Roads. [Transport Noise Management Code of Practice: Volume 2 Construction Noise and Vibration](#). Queensland Government: Brisbane, Qld.
5. Decker, Fanny (2013). *Ground vibration due to pile and sheet pile driving – influencing factors, predictions and measurements*. Licentiate thesis, KTH. Royal Institute of Technology: Stockholm, Sweden.
6. British Standards Institution (1990). *Evaluation and measurement for vibration in buildings: Part 1: Guide for measurement of vibration and evaluation of their effects on buildings*. BS7385-1, BSI: United Kingdom.
7. NACOE (2024) Project Report Prj-23-01620-BGS-NACOE\_23\_24-S64\_Y2 NACOE S64: *Revision and Updating of TN03 – Measurement of Ground Vibration and Air Blast*.
8. Queensland Department of Transport and Main Roads. [Structures Inspection Manual](#). Queensland Government: Brisbane, Qld.
9. Queensland Department of Transport and Main Roads. [Design Criteria for Bridges and Other Structures](#). Queensland Government: Brisbane, Qld.
10. German Standards (DIN\_Normen). *Vibration in Buildings – Part 3: Effect on structures*. English translation of DIN 4150-3:2016-12, Beuth Verlag GmbH, 10772: Berlin, Germany.
11. Standards Australia AS 2775–2004. *Mechanical Vibration and Shock—Mechanical Mounting of Accelerometers*.
12. Standards Australia AS 2187.2-2006. *Explosives – Storage and use*.
13. Transport for NSW (2023). *Guideline on Construction noise and vibration guideline public transport infrastructure*. New South Wales Government: Sydney, NSW.
14. Hiller DM & Crabb GI (2000). *Groundborne vibration caused by mechanised construction works*, TRL report 429. Transport Research Laboratory: United Kingdom.

15. Crabb GI & Hiller DM (2002). *Prediction of groundborne vibration from vibrating rollers*. Proceedings of the Institution of Civil Engineers, ICE Publishing, pp. 131–40. United Kingdom.
16. Queensland Department of Transport and Main Roads. [MRTS51 Environmental Management](#). Queensland Government: Brisbane, Qld.

