

**TECHNICAL
MEMORANDUM**

Noise and Vibration No.1

To All suppliers

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Subject Construction vibration criteria

1 Introduction

Vibration from construction works (including blasting) and noise from blasting ('airblast') can cause adverse effects on humans and buildings, including:

- perception and annoyance
- loss of concentration, including effects on learning performance
- sleep disturbance
- increased risk of mental and physical health problems
- building damage

In the absence of a New Zealand Standard to address these effects, the NZTA convened a working group in 2011 to review construction vibration criteria in international standards and propose criteria for use in New Zealand. The working group consisted of:

- James Whitlock, Marshall Day Acoustics
- Peter Cenek, Opus
- Peter Millar, Tonkin and Taylor
- Stephen Chiles, NZTA

The construction vibration and airblast criteria proposed by the working group are presented in the NZTA *State highway construction and maintenance noise and vibration guide*. This technical memorandum summarises the reasoning behind the selection of the criteria. Reference should be made to the guide for an explanation of terminology used here.

2 Existing guidance

Noise from construction and maintenance works is usually managed within New Zealand in accordance with New Zealand Standard NZS 6803:1999 *Acoustics - Construction noise*. The NZTA promotes the use of NZS 6803 to manage noise from road construction and maintenance. That Standard, however, does not cover vibration and only briefly addresses airblast (section 8.1.4).

The working group made reference to the following three international Standards:

- British Standard BS 5228-2:2009 *Code of practice for noise and vibration control on construction and open sites - Part 2: Vibration*, provides source data, prediction methodologies, mitigation measures and management. Additionally, the Standard includes guidance on the levels of vibration that cause varying degrees of human response and

damage to buildings or services. These are specified in terms of a component peak particle velocity (ppv). The criteria for building damage in BS 5228-2 are taken from British Standard BS 7385-2:1993 *Evaluation and measurement for vibration in buildings – Part 2: Guide to damage levels from groundborne vibration*.

- German Standard DIN 4150-3:1999 *Structural vibration – Effects of vibration on structures*, addresses effects of vibration on buildings. As with BS 5228-2, these are presented in terms of the component ppv. The guideline values in the two Standards are similar, although the German Standard is more conservative.
- Appendix J of Australian Standard AS 2187-2 *Explosives – Storage and use – Part 2: Use of explosives* provides guidance for assessment of blasting noise and vibration. The criteria for building damage from blasting vibration are the same as those in BS 5228-2. Airblast noise values apply outside the building.

3 Proposed criteria

The proposed vibration criteria from the NZTA guide based on the above Standards are reproduced in Table 1.

Table 1 Proposed vibration and airblast criteria

Receiver	Location	Details	Category A	Category B
Occupied PPFs*	Inside the building	Night-time 2000h – 0630h	0.3 mm/s ppv	1 mm/s ppv
		Daytime 0630h – 2000h	1 mm/s ppv	5 mm/s ppv
		Blasting – vibration	5 mm/s ppv	10 mm/s ppv
	Free-field	– airblast	120 dB L _{Zpeak}	–
Other occupied buildings	Inside the building	Daytime 0630h – 2000h	2 mm/s ppv	5 mm/s ppv
All other buildings	Building foundation	Vibration – transient (including blasting)	5 mm/s ppv	BS 5228-2 Table B.2
		Vibration – continuous		BS 5228-2 50% of Table B.2 values
	Free-field	Airblast	–	133 dB L _{Zpeak}

*PPFs – definition as per NZS 6806:2010

In accordance with BS 5228-2 and DIN 4150-3, the effects caused by vibration and airblast are assessed at the point where the effect occurs.

Hence, human perception and annoyance are assessed inside a building, typically on the floor where the person is subjected to the vibration. In the case of building damage, the vibration is usually assessed on the building foundation. Under AS 2187-2, airblast is assessed outside buildings, in a 'free-field' position (i.e. away from the walls/foundations of a building which could increase the noise levels due to reflections). Measurement methods for vibration in buildings are specified in ISO 4866:2010 *Mechanical vibration and shock – Vibration of fixed structures – Guidelines for the measurement of vibrations and evaluation of their effects on structures*.

Due to the range of perception/annoyance sensitivities of people and of the propensity of buildings to damage, it is difficult to determine definitive criteria without being excessively cautious. Hence the proposed criteria are structured in two categories which are to be used within a process that proactively manages construction vibration and airblast effects.

Construction vibration and airblast should be managed to comply with the Category A criteria in Table 1 where practicable. If measured or predicted vibration and airblast levels exceed the Category A criteria then a suitably qualified expert should be engaged to assess and manage construction vibration and airblast, to comply with the Category A criteria as far as practicable. Following the expert's assessment, initial building condition surveys should be carried out for properties that might exceed Category A. If the construction vibration exceeds the Category B criteria then construction activity should only proceed if there is monitoring of vibration levels and effects on those buildings at risk of exceeding the Category B criteria, by suitably qualified experts. Final building condition surveys should be carried out for all properties exceeding Category A.

The guide suggests that additional criteria should be used in the case of historic, vibration-sensitive or multi-storey buildings. Advice on such buildings is given in BS 5228-2 and DIN 4150-3. Similarly, if there is history of foundation settlement, then expert geotechnical advice should be sought regarding specific vibration criteria.

4 Criteria – Occupied PPFs

Table 2 Criteria for occupied PPFs

Receiver	Location	Details	Category A	Category B
Occupied PPFs	Inside the building	Night-time 2000h – 0630h	0.3 mm/s ppv ^(a)	1 mm/s ppv ^(c)
		Daytime 0630h – 2000h	1 mm/s ppv ^(b)	5 mm/s ppv ^(d)
		Blasting – vibration	5 mm/s ppv	10 mm/s ppv
	Free-field	– airblast	120 dB LZpeak	–

The criteria for non-blasting sources are based on the human response guidance contained with BS 5228-2:

- (a) Table B.1 of BS 5228-2 states that vibration with a ppv of 0.3 mm/s ‘*might be just perceptible in residential environments*’. The working group considered this to be a good standard to avoid sleep disturbance, and it is therefore proposed for the Category A criterion at night.
- (b) During the day, people are generally less sensitive to vibration and a higher limit is proposed for Category A (1 mm/s). This is also obtained from BS 5228-2 which states that ‘*vibration of this level in residential environments will cause complaint, but can be tolerated if prior warning and explanation has been given to residents*’. Hence the management of the effects of construction vibration is important, including communications with affected neighbours. This is emphasised in the NZTA guide, and in the model designation conditions in that guide which together with the criteria require a management plan including processes for communications with neighbours.
- (c) As part of the management process explained above, if the Category A levels are to be exceeded, then Category B levels provide an additional threshold before more intensive monitoring is required. At night,

1 mm/s is proposed which, as above, could be tolerated if prior warning and explanation is provided.

- (d) For Category B during the day, a level of 5 mm/s is proposed. In BS 5228-2 it is stated that at 10 mm/s '*vibration is likely to be intolerable for any more than a very brief exposure to this level*'. The working group has sought to set the Category B threshold between 1 mm/s where BS 5228-2 states that vibration can be tolerated (with warning and explanation) and 10 mm/s where BS 5228-2 states that vibration is intolerable. The value selected of 5 mm/s also corresponds to the building damage criterion from DIN 4150-3.

Where blasting occurs the criteria are taken directly from AS 2187-2:

- (e) Table J5.4(A) of AS 2187-2 gives a vibration level of 5 mm/s ppv for 95% of blasting where operations last more than 12 months or have more than 20 blasts. This is proposed as the Category A criterion.
- (f) In the same table, a vibration level of 10 mm/s ppv is given for 100% of blasting and for operations lasting less than 12 months or 20 blasts. This is proposed as the Category B criterion.
- (g) For airblast table J5.4(B) of AS 2187-2 gives several levels. 120 dB L_{Zpeak} is given for 100% of blasting for long-term operations and for 95% of blasting for operations lasting less than 12 months or 20 blasts. This is proposed as the Category A criterion. This is consistent with Section 8.1.4 of NZS 6803 which references AS 2187-2 and specifies a level of 120 dB L_{Cpeak} , although it is noted that the proposed use of L_{Zpeak} is more conservative than using L_{Cpeak} from NZS 6803. The working group did not consider that AS 2187-2 provides reasonable grounds to set a higher Category B criterion in terms of human comfort for airblast.

5 Criteria selection – Other occupied buildings

Table 3 Criteria for other occupied buildings

Receiver	Location	Details	Category A	Category B
Other occupied buildings	Inside the building	Daytime 0630h – 2000h	2 mm/s ppv ^(h)	5 mm/s ppv ⁽ⁱ⁾

‘Other occupied buildings’ such as offices and factories typically are only occupied during the day and therefore no night-time criteria are specified. Occupants of these types of buildings are generally more tolerant to vibration, although there is not a standard that provides guidance on appropriate thresholds.

- (h) The working group considered that the Category A level for these types of buildings should be taken as double that proposed for occupied dwellings (based on BS 5228-2) to account for the increase in tolerance.
- (i) The Category B level has been capped at the same level as residential buildings and the building damage criterion from DIN 4150-3.

6 Criteria selection – All other buildings

Table 4 Criteria for all other buildings

Receiver	Location	Details	Category A	Category B
All other buildings	Building foundation	Vibration – transient (including blasting)	5 mm/s ppv ^(j)	BS 5228-2 Table B.2 ^(k)
		Vibration – continuous		BS 5228-2 50% of Table B.2 values ^(k)
	Free-field	Airblast	–	133 dB L _{Zpeak} ^(l)

‘All other buildings’ are those that are unoccupied and therefore only building (cosmetic) damage criteria are required. As noted above, for occupied buildings the Category B criteria are the same or less than the unoccupied Category A criterion.

- (j) As discussed above, both DIN 4150-3 and BS 5228-2 include criteria for building cosmetic damage. The lowest level for dwellings from DIN 4150-3 has been proposed for Category A as this is more conservative than the levels contained in BS 5228-2. Under DIN 4150-3 there is no differentiation between continuous and transient vibration so the same criterion has been applied to both.
- (k) For the Category B criteria, the frequency dependent guidance in Table B.2 of BS 5228-2 has been adopted. In accordance BS 5228-2, a 50% reduction is applied for continuous rather than transient vibration.
- (l) For building damage from airblast the criterion of 133 dB L_{Zpeak} has been taken from Table J5.4(B) of AS 2187-2. This is a high level of sound and has therefore been proposed as the Category B criteria so that any exceedance is required to be subject to specific assessment and appropriate monitoring.