TERROCK
CONSULTING ENGINEERS

P O Box 829
Eltham Vic 3095
Phone: (03) 9431 0033
URL: http://terrock.com.au
Email: terrock@terrock.com.au
ABN: 99 005 784 841

Alan B. Richards
Ph.D, F.I.E.Aust., F.Aus.I.M.M., F.IQA.

Andrew Brodbeck
B.E. (Min.), MBA, M. Aus I.M.M., F.IQA., M. ISEE

CASTLE HILL BLASTING GROUND VIBRATION LIMIT

1. INTRODUCTION

Mangoola Coal (Mangoola) requested Terrock Consulting Engineers conduct a review of blasting ground vibration limits for the Castle Hill site. The site contains a slab hut and, to date, access to conduct a survey of the hut's condition or determine specific ground vibration limits has not been granted.

In lieu of specific limits for blasting ground vibration being able to be determined, a review of structural damage limits presented in *Australian Standard Explosives – Storage and use Part 2: Use of explosives (AS2187.2-2006)* was conducted to determine an appropriate safe blasting ground vibration limit.

An analysis of predicted levels of blasting ground vibration and frequencies at the Castle Hill site was conducted by the Mangoola Drill and Blast team.

This analysis was compared to the guide limits from AS2187.2-2006 and a recommendation for a frequency-based blasting ground vibration limit made for the Castle Hill site.

2. AUSTRALIAN STANDARD REVIEW

A review of AS2187.2-2006 (the Standard) was conducted to determine levels of blasting ground vibration with the potential to cause damage to structures. The Standard notes, in determining potential damage criteria, both the magnitude of the blasting ground vibration and the frequency should be used.

Of interest, the Standard also suggests that cracks in buildings or building movement may be associated with ground or foundation movement due to reactive clay soils during periods of wet and dry weather. The age of the structure should also be considered when determining the cause of cracks or structural damage.

The Standard offers the frequency-dependent cosmetic damage criteria from British Standard 7385-2, reproduced as Table 2.1 below, for prevention of minor or cosmetic damage in structures. The table presents frequency-based limits for two lines in Figure 2.1 (a graphical representation of Table 2.1). Line 1 refers to reinforced industrial structures and Line 2 refers to light framed residential type structures.

Line	Type of building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structure. Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

NOTES:

1 Values referred to are at the base of the building.

2 For line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) should not be exceeded.

Table 2.1: Transient vibration guide values for cosmetic damage (BS 7385-2)

The notes to Table 2.1 suggest that for frequencies below 4 Hz the *displacement* should not exceed 0.6 mm. Analysis of recent blasts measured at Castle Hill indicated the displacement was between 0.02 mm and 0.05 mm.

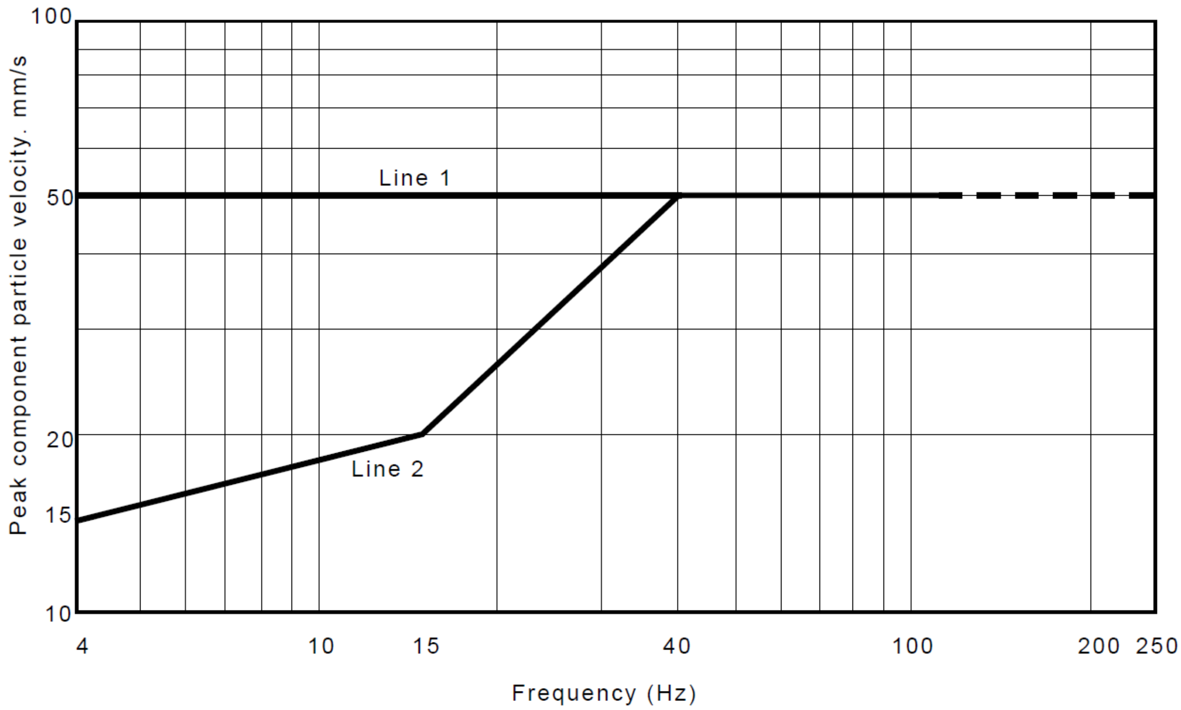

Figure 2.1: Transient vibration guide values for cosmetic damage (BS 7385-2)

The Castle Hill hut would be considered a light framed residential type structure so the frequency-based limits for Line 2 would apply. These limits are for potential cosmetic damage with the definition of 'cosmetic' given in Table 2.2 taken from the Standard which refers to British Standard 7385-1.

Damage classification	Description
Cosmetic	The formation of hairline cracks on drywall surfaces or the growth of existing cracks in plaster or drywall surfaces; in addition, the formation of hairline cracks in the mortar joints of brick/concrete block construction
Minor	The formation of cracks or loosening and falling of plaster or drywall surfaces, or cracks through bricks/concrete blocks
Major	Damage to structural elements of the building, cracks in support columns, loosening of joints, splaying of masonry cracks etc.

Table 2.2: Damage classification (BS 7385-1)

The Standard suggests the guide values discussed above are applicable to Australian conditions and recommend frequency-based blasting ground vibration limits to control damage to structures. Based on this, the limits for the Castle Hill hut would be:

- 15 mm/s at 4 Hz, increasing to
- 20 mm/s at 15 Hz, increasing to
- 50 mm/s at 40 Hz and above

These limits will now be reviewed based on the predicted levels of blasting ground vibration and frequencies in Section 3.

3. PREDICTED BLASTING GROUND VIBRATION AND FREQUENCIES

The Mangoola Drill and Blast team has completed an analysis of the predicted blasting ground vibration and frequencies for future blasting near the Castle Hill monitoring location.

The maximum blasting ground vibration prediction is 10.7 mm/s when the maximum charge weight of explosives of 1,200 kg is loaded in a single blasthole. This is unlikely to occur due to blasting ground vibration limits at other structures. The more likely scenario would be 800 kg per blasthole resulting in a predicted blasting ground vibration of 8.8 mm/s at the Castle Hill monitor. See Appendix 1 for the analysis.

The blasting ground vibration frequencies have also been predicted and range from 7.14 Hz to 16.31 Hz. The predictions are based on the timing and spacing between blastholes and the travel time of the vibration wave through the ground. See Appendix 2 for the analysis.

Comparing the predictions with the guide values in Table 2.1 and Figure 2.1 indicates the blasting ground vibrations are below 15 mm/s and above 4 Hz. That is, they are below Line 2 in Figure 2.1.

4. RECOMMENDATIONS

The frequency-based blasting ground vibration limits from AS2187.2-2006 discussed in this review should be applied to control potential damage to the Castle Hill hut. These limits are conservative as they are for potential cosmetic damage, the lowest category, as defined in the Standard.

The limit recommended for Castle Hill hut is 20 mm/s for frequencies above 15 Hz.

When designing blasts to comply with this limit, it is recommended that if the predicted blasting ground vibration is above 15 mm/s, the frequencies are reviewed to ensure levels are above 15 Hz.

Andrew Brodbeck
Principal Engineer
Terrock
Consulting Engineers
1 September 2020

Appendix 1 – Blasting Ground Vibration Predictions

A single hole, scale distance regression analysis was used to compile similar and relevant blast designs with recorded PPV results over 2mm/s on the Castle Hill vibration monitor. 19 blast data points (Table 3) have been included to develop the site law (Figure 3) used in the vibration data analysis for the PPV limit adjustment.

Date	Blast Number	Min Distance to Monitor	Charge Weight	Scaled Distance	PPV
8/02/2019	1065	1657.8	557.5	70.2	2.5
15/02/2019	1099	1538.6	467.6	71.2	2.1
29/03/2019	1061	1978.8	962.4	63.8	2.2
9/04/2019	1056	1802.4	1111.7	54.1	2.1
31/05/2019	1082	1912.8	818.5	66.9	2.5
13/06/2019	1098	1862.5	856.5	63.6	3.3
15/07/2019	1062	1657.8	552.4	70.5	2.7
26/07/2019	1112	1829.2	1056.5	56.3	2.4
26/07/2019	1123	1675.3	221.7	112.5	2.4
1/08/2019	1103	1673.6	709.7	62.8	2.1
2/09/2019	1110	1737.0	709.7	65.2	2.4
12/09/2019	1111	1665.7	941.7	54.3	3.1
20/11/2019	1140	1819.7	864.5	61.9	2.3
6/12/2019	1141	1725.6	1037.9	53.6	2.8
6/12/2019	1122	1725.6	1037.9	53.6	2.8
19/03/2020	1181	1605.1	1015.8	50.4	3.8
29/04/2020	1173	1690.7	896.1	56.5	2.8
30/04/2020	1161	1274.2	702.2	48.1	2.9
16/07/2020	1248	1339.6	977.1	42.9	5.2

Table 3: Blast data used to develop single hole regression site law.

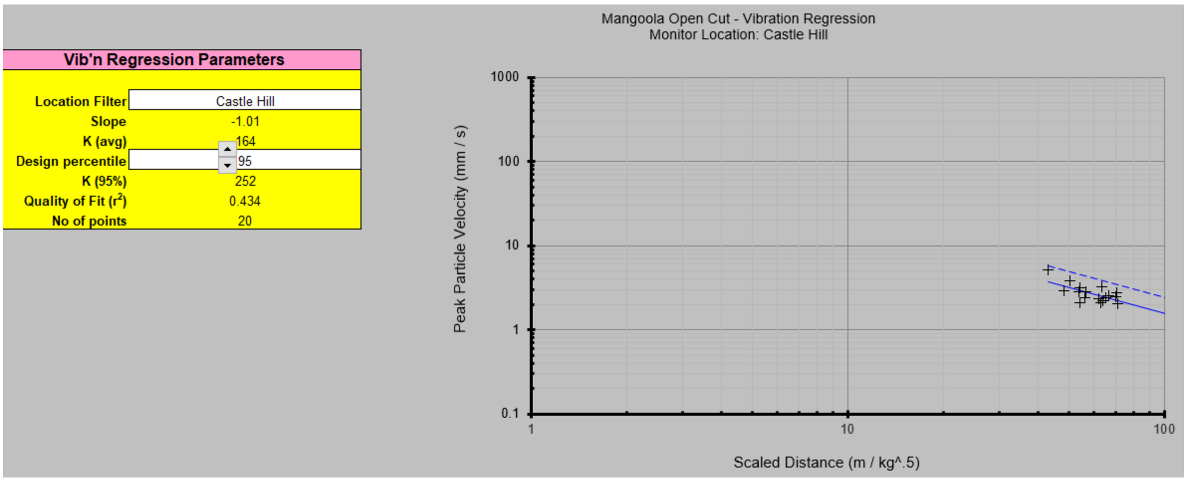

Figure 3: Blast data used to develop single hole regression site law.

Coordinates from future blast locations from Strip 15-20 and typical single hole charge weights corresponding to planned blast hole depths were entered into the vibration analysis spread sheet. Average expected and 95% confidence interval PPV predictions for varied charge weights were generated and are presented in Table 4.

					Monitor			Monitor			Monitor		
						20m / 800kg			15m / 550kg			10m / 300kg	
		X	Y	Z	Distance	K ave	K95	Distance	K ave	K95	Distance	K ave	K95
Strip 15	1	280362.8	6425068	132.069	1294	3.6	5.8	1294	3	4.8	1294	2.2	3.5
	2	280228.7	6425079	124.327	1200	3.9	6.2	1200	3.2	5.2	1200	2.4	3.8
	3	280095.3	6425145	116.111	1151	4.1	6.5	1151	3.4	5.4	1151	2.5	4
Strip 16	1	280371.2	6424893	131.4	1201	3.9	6.2	1201	3.2	5.2	1201	2.4	3.8
	2	280238.6	6424901	127.085	1096	4.3	6.8	1096	3.5	5.7	1096	2.6	4.2
	3	280102.8	6424971	117.733	1029	4.5	7.2	1029	3.8	6	1029	2.8	4.4
Strip 17	1	280378.8	6424700	133.534	1118	4.2	6.7	1118	3.5	5.5	1118	2.6	4.1
	2	280264.5	6424710	130.409	1019	4.6	7.3	1019	3.8	6.1	1019	2.8	4.5
	3	280117.8	6424792	124.676	927	5	8	927	4.2	6.6	927	3.1	4.9
Strip 18	1	280400.2	6424514	135.384	1080	4.3	6.9	1080	3.6	5.7	1080	2.7	4.2
	2	280302.2	6424518	132.76	987	4.8	7.6	987	3.9	6.3	987	2.9	4.6
	3	280153.9	6424611	128.183	871	5.4	8.5	871	4.4	7.1	871	3.3	5.2
Strip 19	1	280431.5	6424315	137.107	1083	4.3	6.9	1083	3.6	5.7	1083	2.7	4.2
	2	280334.6	6424326	134.516	988	4.8	7.6	988	3.9	6.3	988	2.9	4.6
	3	280192.1	6424417	129.94	851	5.5	8.8	851	4.6	7.3	851	3.4	5.4
Strip 20	1	280450.6	6424192	137.95	861	4.3	6.8	861	3.5	5.6	861	2.6	4.2
	2	280346	6424225	135.522	992	4.7	7.5	992	3.9	6.2	992	2.9	4.6
	3	280214.6	6424326	130.811	1098	5.4	8.7	1098	4.5	7.2	1098	3.3	5.3
Strip 19	1	280431.5	6424315	137.107	1083	5.3	8.5						
1200kg	2	280334.6	6424326	134.516	988	5.8	9.3						
	3	280192.1	6424417	129.94	851	6.7	10.7						

Table 4: PPV prediction by charge weight using single hole scale distance regression analysis (August 2020).

Appendix 2 – Blasting Frequency Predictions

Frequency predictions have been generated using a typical P-wave velocity of 3800m/s, typical hole spacing and timing delay designs suitable for a range of different blast depths. P-wave frequencies have been generated for comparison to AS2187.2-2006 (the Standard) and are shown in Figure 4.

	Burden relief ms/m					
Spacing m	12	13	14	15	16	
5	60	65	70	75	80	Time

Scenario 1												
Spacing (m)	5		**Anti-initiation direction**				**Perpendicular**			**Initiation direction**		
Time between Holes	60											
P wave (m/s)	3800		Frequency	16.31	Hz		Frequency	16.67		Frequency	17.04	Hz
Echelon 1 (m)	5											
Time between Holes	65											
P wave (m/s)	3800		Frequency	15.08	Hz		Frequency	15.38		Frequency	15.70	Hz
Echelon 2 (m)	5											
Time between Holes	70											
P wave (m/s)	3800		Frequency	14.02	Hz		Frequency	14.29		Frequency	14.56	Hz
Spacing (m)	5											
Time between Holes	75											
P wave (m/s)	3800		Frequency	13.10	Hz		Frequency	13.33		Frequency	13.57	Hz
Echelon 1 (m)	5											
Time between Holes	80											
P wave (m/s)	3800		Frequency	12.30	Hz		Frequency	12.50		Frequency	12.71	Hz

	Burden relief ms/m					
Spacing m	12	13	14	15	16	
6	72	78	84	90	96	Time

Scenario 2												
Spacing (m)	6		**Anti-initiation direction**				**Perpendicular**			**Initiation direction**		
Time between Holes	72											
P wave (m/s)	3800		Frequency	16.31	Hz		Frequency	13.89		Frequency	14.20	Hz
Echelon 1 (m)	6											
Time between Holes	78											
P wave (m/s)	3800		Frequency	15.08	Hz		Frequency	12.82		Frequency	13.09	Hz
Echelon 2 (m)	6											
Time between Holes	84											
P wave (m/s)	3800		Frequency	14.02	Hz		Frequency	11.90		Frequency	12.13	Hz
Spacing (m)	6											
Time between Holes	90											
P wave (m/s)	3800		Frequency	13.10	Hz		Frequency	11.11		Frequency	11.31	Hz
Echelon 1 (m)	6											
Time between Holes	96											
P wave (m/s)	3800		Frequency	12.30	Hz		Frequency	10.42		Frequency	10.59	Hz

	Burden relief ms/m					
Spacing m	12	14	16	18	20	
7	84	98	112	126	140	Time

Scenario 3												
Spacing (m)	7		Anti-initiation direction				Perpendicular			Initiation direction		
Time between Holes	84											
P wave (m/s)	3800		Frequency	16.31	Hz		Frequency	11.90		Frequency	12.17	Hz
Echelon 1 (m)	7											
Time between Holes	98											
P wave (m/s)	3800		Frequency	15.08	Hz		Frequency	10.20		Frequency	10.40	Hz
Echelon 2 (m)	7											
Time between Holes	112											
P wave (m/s)	3800		Frequency	14.02	Hz		Frequency	8.93		Frequency	9.08	Hz
Spacing (m)	7											
Time between Holes	126											
P wave (m/s)	3800		Frequency	13.10	Hz		Frequency	7.94		Frequency	8.05	Hz
Echelon 1 (m)	7											
Time between Holes	140											
P wave (m/s)	3800		Frequency	12.30	Hz		Frequency	7.14		Frequency	7.24	Hz

Figure 4: P wave frequency predictions for typical blast designs where hole spacing and timing delays are a function of blast depth.