Adelaide Brighton Cement - Acoustic Consultancy

Ground Vibration Monitoring Survey

Report Date: Tuesday, 12 July 16
Reference: A15623RP3, Revision C

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Document Information

Project	Adelaide Brighton Cement - Acoustic Consultancy	
Client	Adelaide Brighton Cement	
Report title	Ground Vibration Monitoring Survey	
Project Number	A15623	
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Revision Table

Report revision	Date	Comments
0	10 June 2016	Initial release
A	23 June 2016	Clarifications and additional graphs
B	1 July 2016	Graph title changes
C	12 July 2016	Revised post correspondence with EPA

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Executive Summary

Ground vibration monitoring was undertaken in and around the Adelaide Brighton Cement (ABC) Birkenhead plant whilst the plant was fully operational and whilst plant was shut down to determine the impact and extent of ground vibrations caused by the plant (if any). Monitoring was undertaken from the 7th March until the 4th May 2016 at four different locations for a minimum period of 1 week during both the shut-down and fully operational plant conditions.

Measured ground-borne peak particle velocity (PPV) in and surrounding the ABC Birkenhead plant whilst the plant was fully operational and during shut-down periods show that there is a small increase in the background vibration level when comparing both sets of measurement data. However, these background PPV levels are low, and vibrations from traffic on nearby roads and other activities are generally higher than the vibrations likely attributable to ABC. Vibration levels of these transient events, such as traffic etc. are likely to have a higher impact when they occur than the baseline vibration levels which are attributable to ABC plant. These transient vibrations typically occur on weekdays during the day time. This indicates that activities independent of the ABC plant have a potential to have a greater impact on nearby residences than the plant itself. Additionally, it is likely that vibration levels within residences are lower than the measured levels due to coupling losses between the ground and the house foundations.

Further investigation is therefore warranted within a selection of nearby residential properties to determine the full extent and impact from vibrations in the area, especially during early morning or late evening periods. We expect that the vibration levels within nearby residential buildings to be below whole body vibration standards (such as AS2670), however it is recommended that this be confirmed with further detailed investigation.

Glossary

Peak Particle Velocity (PPV)	The peak (or highest amplitude) speed a mass reaches during its vibratory cycle. Typically measured in mm/s.
RMS	Meaning root mean square is the square root of the arithmetic mean of the squares of a set of numbers. Typically, this gives an average value for energy of vibrations which oscillate in both a positive and negative direction (where a standard arithmetic average will give a result of zero, or near zero).
Frequency (Hz)	The number of times a vibrating object oscillates (moves back and forth) in one second. Fast movements produce high frequency sound (high pitch/tone), but slow movements mean the frequency (pitch/tone) is low. 1 Hz is equal to 1 cycle per second.
Triaxial geophone	A set of three velocity transducers arranged orthogonally from each other to measure vibration velocity in three axes (vertical, transverse and longitudinal)

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1 Introduction

Ground vibration monitoring in and around the Adelaide Brighton Cement (ABC) Birkenhead plant whilst the plant was fully operational and whilst plant was shut down to determine the impact and extent of ground vibrations caused by the plant (if any).

Monitoring was undertaken from the 7th March until the 4th May 2016 at the following locations:

- Location 1 – Tower 4A Base
- Location 2 – ABC Boundary 1 – Community park
- Location 3 – ABC Boundary 2 – Reclaimer shed
- Location 4 – ABC Social Club.

Figure 1 shows the physical locations of the measurement points.

Figure 1: ABC Birkenhead and Measurement Points

Ground vibration monitors were installed whilst the ABC Birkenhead plant was shutdown, and the plant was fully operational from the 23rd March 2016.

The triaxial geophones were installed either directly into the ground via ground spikes, or where there was no friable ground present, the sensor was attached via beeswax, with a sandbag on top of the sensor to ensure good coupling between the ground and the sensor.

Where the instruments were moved between shutdown and operational measurements, the sensors were placed in the same general location (± 1m). The same instrument and sensor was used for both before and after measurements for each location to ensure a direct comparison of data.

2 Criteria

AS2670.2-1990 outlines criteria and limits for the evaluation of human exposure to whole-body vibration from continuous and shock-induced vibration in buildings. It gives guidelines as to thresholds of human comfort, and if thresholds are exceeded, likely annoyance and/or complaints about vibration inducing activities. The vibration limits are provided in both acceleration and velocity RMS levels, and vary with the vibration frequency. Table 1 outlines these RMS Velocity vibration levels, taken from AS2670.

Table 1 RMS vibration velocity criteria for human comfort

	Human comfort RMS Vibration Limits (mm/s)		
Third octave band center frequency (Hz)	**Z-Axis**	**X and Y Axis**	**Variable orientation of human occupants**
1	1.59	0.57	0.57
1.25	1.13	0.458	0.45
1.6	0.796	0.358	0.35
2	0.557	0.287	0.28
2.5	0.401	0.287	0.23
3.15	0.288	0.287	0.195
4	0.199	0.287	0.162
5	0.159	0.287	0.136
6.3	0.126	0.287	0.116
8	0.0995	0.287	0.0995
10	0.0995	0.287	0.0995
12.5	0.0995	0.287	0.0995
16	0.0995	0.287	0.0995
20	0.0995	0.287	0.0995
25	0.0995	0.287	0.0995
31.5	0.0995	0.287	0.0995
40	0.0995	0.287	0.0995
50	0.0995	0.287	0.0995
63	0.0995	0.287	0.0995
80	0.0995	0.287	0.0995

Additionally, AS2670.2 outlines that for residential properties, these criteria are to have a multiplication factor of 2 to 4 for residential areas in the day-time, and 1.4 during night time periods.

The initial ground vibration survey undertaken in and around the ABC Birkenhead plant used ground vibration logging equipment, which broadly measured peak particle velocity (PPV) with no frequency, and not RMS velocity levels. However, a conservative estimation of the PPV from the RMS velocity is to multiply by 1.414 ($\sqrt{2}$).

Therefore, a worst-case criterion within a residential zone at night time, will have an RMS vibration criterion of 0.14mm/s (0.0995 x 1.4), which gives an approximate PPV criterion of 0.19mm/s (0.14 x 1.414).

3 Instrumentation

The noise measurements were taken with calibrated AvaTrace M1 Ground vibration loggers, with triaxial geophones (velocity transducers). The installation of the measuring instrumentation is outlined in Table 2 below. Copies of the calibration certificates are available on request. Peak particle velocities were measured in three axes (vertical, transverse and longitudinal).

Table 2: Instrument Placement Details

Location	Measurement Dates		AvaTrace Serial number
Location 1 – Tower 4A Base	Shutdown	16/03/2016 – 23/03/2016	8867
	Plant Fully Operational	23/03/2016 – 11/04/2016	
Location 2 – ABC Boundary in line with Community Park	Shutdown	7/03/2016 – 16/03/2016	8875
	Plant Fully Operational	26/04/2016 – 04/05/2016	
Location 3 – ABC Boundary Reclaimer	Shutdown	N/A	8875
	Plant Fully Operational	11/04/2016 – 26/04/2016	
Location 4 – ABC Social Club	Shutdown	7/03/2016 – 23/03/2016	8875
	Plant Fully Operational	23/03/2016 – 04/05/2016	

4 Results

Where there were data for both the plant operating and whilst shut down, a histogram of the measured data during each period has been generated. Figures 2, 3 and 4 show histograms of the measured peak particle velocity (PPV) in the vertical axis for three measurement locations before and after the shutdown period. We have shown the vertical axis as we consider that this is the most significant in this case.

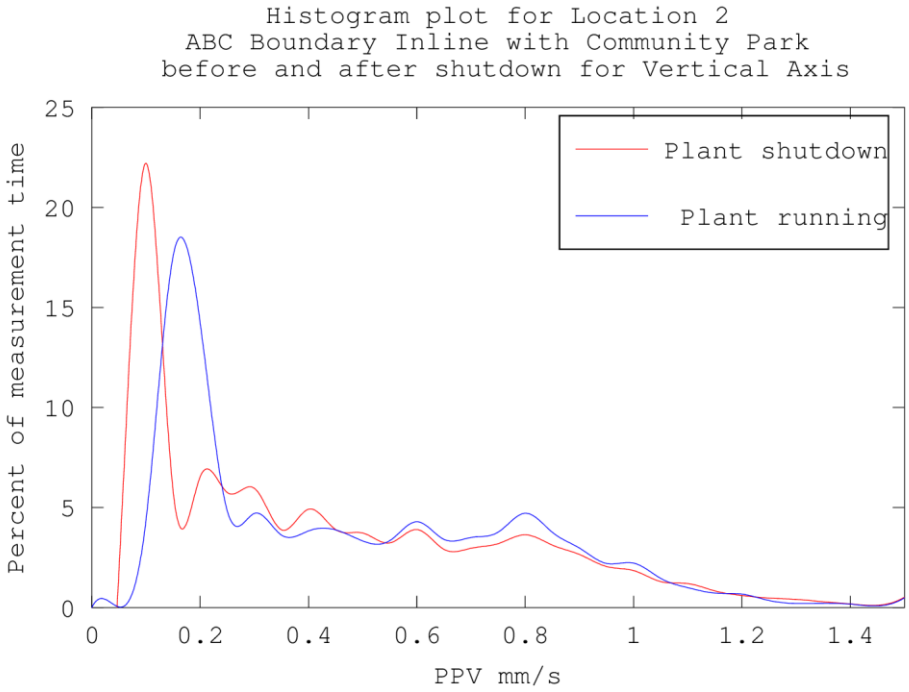

Figure 2: Location 2 vibration level histogram during and after plant shutdown

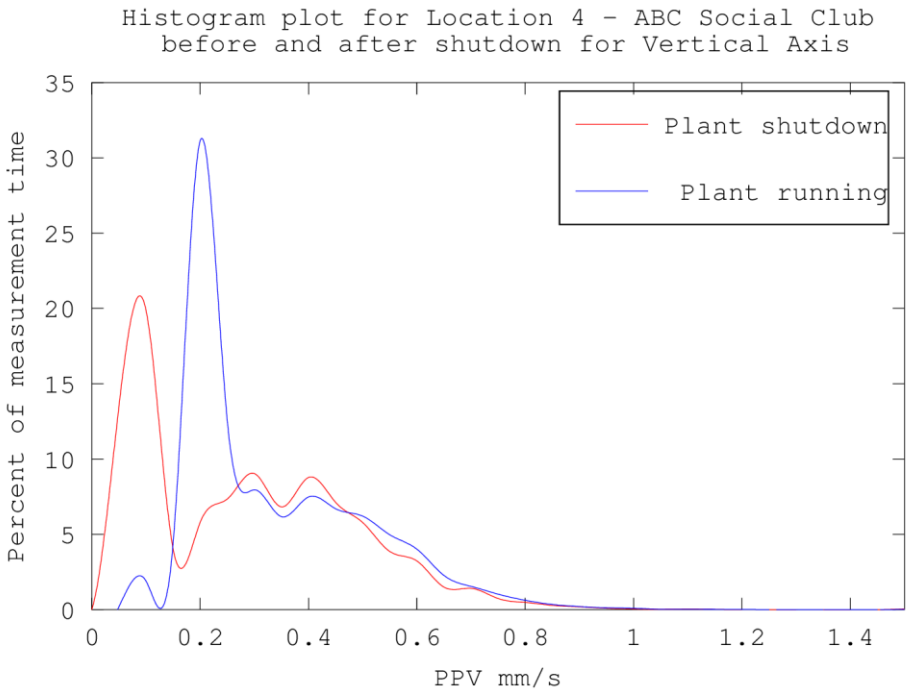

Figure 3: Location 4 ABC Social Club vibration level histogram during and after plant shutdown

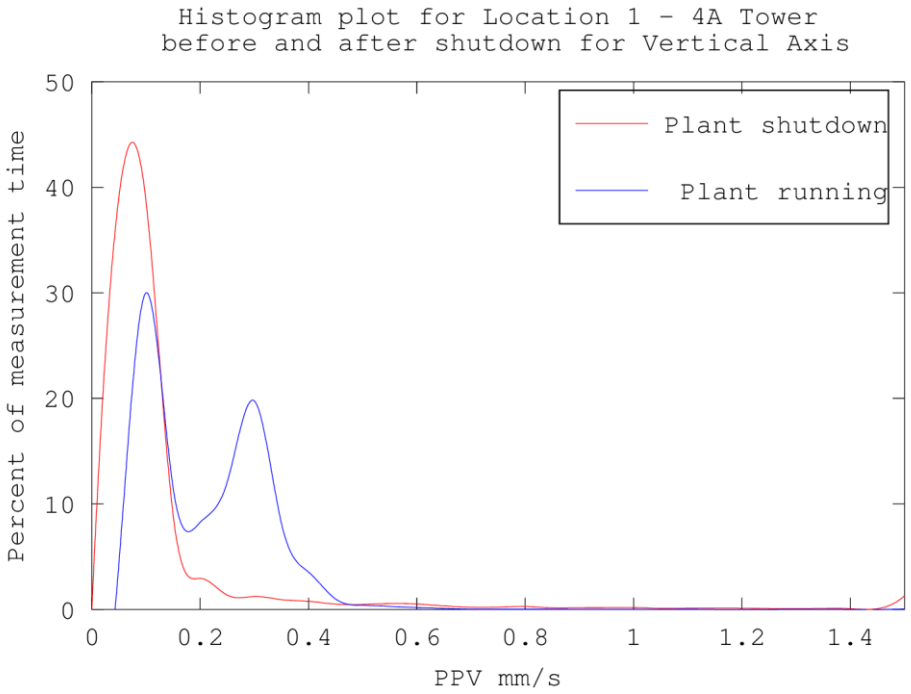

Figure 4: 4A Location 1 Tower vibration level histogram during and after plant shutdown

The histogram plots show that there is a general increase in the background peak particle velocity vibration level when the plant is turned on compared to whilst it was shut down. The measurements taken at the ABC Social club (shown in Figure 3) were also taken back-to-back, where the sensor was not moved or measurements stopped between the plant being shut-down and fully operational.

Vibrations from the ABC plant are present and detectable within the nearby community.

The majority/mode of the measured peak particle velocities measured at the boundary and the social club were in the order of 0.15 mm/s and 0.2 mm/s respectively, which are considered to be very low in regards to ground-borne vibrations. We note however that for a large proportion of the time, these vibration levels were measured during quiet night time periods. Typically, on weekdays during the day-time, vibration levels were higher than these background levels, which are likely due to increased traffic movements along Victoria Road, or other activities. These increased levels are both present when the plant was offline as well as online, indicating that it is likely not due to ABC operations. See Figure 5, which outlines this occurrence on a typical weekday during and after the shutdown. The results show that whether the plant is shut down or running, vibration levels during the day are typically much higher than the baseline levels and independent of plant activity. This indicates that the measured background vibration levels, which are likely caused by the ABC plant, are much lower than other transient vibration events such as vehicle traffic on Victoria Road, train movement and other activities. This means that activities independent of the ABC plant have the potential to be of greater impact on nearby residences than the plant itself.

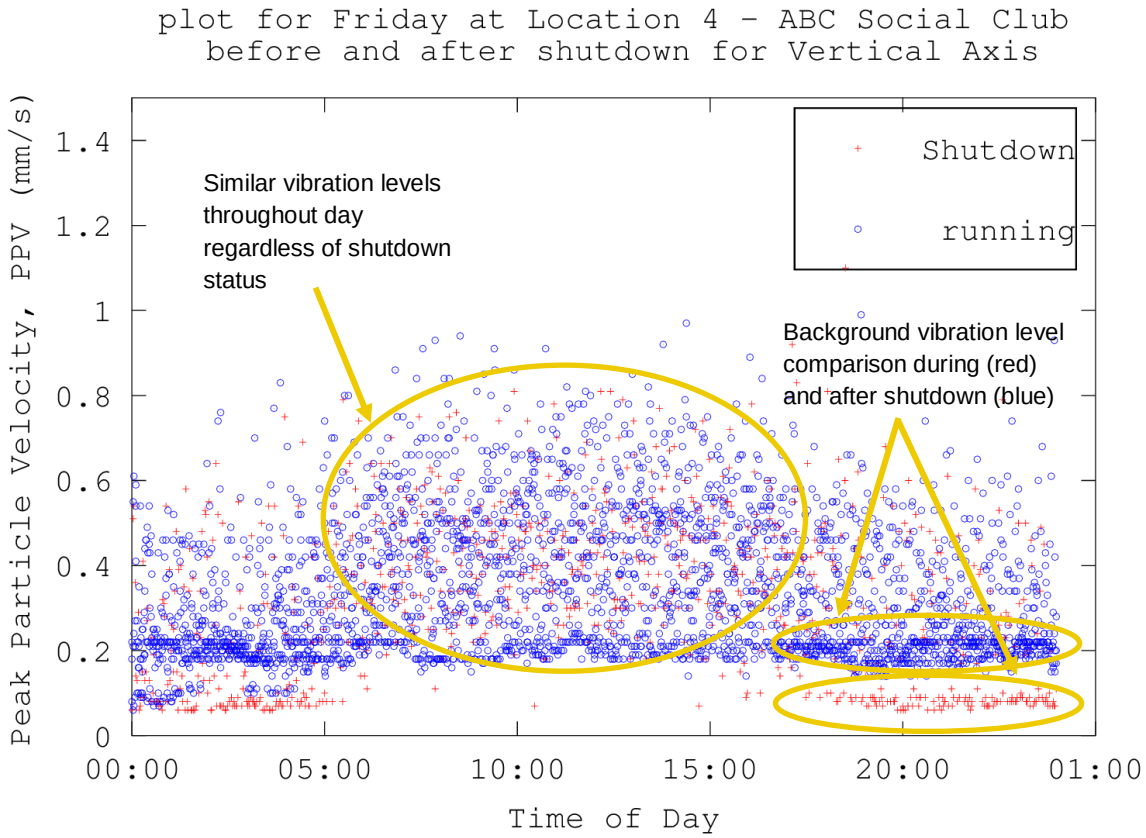

Figure 5: Vibration levels throughout typical week day at Location 4 during and after shutdown

We would expect that vibrations from the ground into residential foundations/properties would generally experience some coupling loss, therefore the measured vibration on the ground directly is likely to be lower than when measured within a residential building. Currently, the vibration levels measured are on the threshold of the human comfort criterion given by AS2670.2. However, our conversion of the RMS criterion to a PPV criterion level is conservative. Furthermore, we have also adopted the most stringent frequency specific criterion, given that spectral measurements have not been undertaken at this stage. Therefore from our conservative assessment approach, combined with the expected coupling losses between the ground and building foundations (and also between furniture and building floors), we expect the vibration levels from the ABC plant to be below the AS2670.2 guidelines.

Further detailed investigation is therefore warranted within a selection of nearby residential properties to confirm the measured vibration levels and foundation coupling loss.

Figure 6, below shows the peak particle velocity histogram for the measurements taken at the reclaimer. We note that measurements couldn't be taken at the reclaimer during the shutdown period and therefore no direct comparison can be made to determine if the measured vibrations are operational or not. However, the majority of the measured vibration levels are at the noise floor of the measurement instrument (0.1 mm/s) and therefore show that there is minimal vibration levels present from the plant at this location.

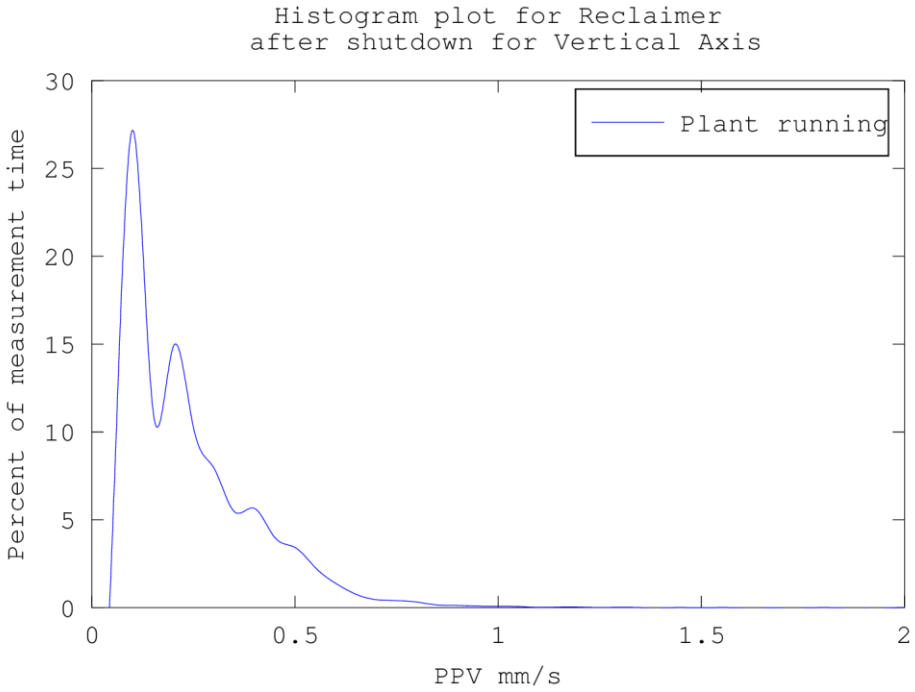

Figure 6: Reclaimer (Location 6) boundary vibration level histogram during and after plant shutdown

5 Conclusion

Measured ground-borne peak particle velocity (PPV) in and surrounding the ABC Birkenhead plant whilst the plant was fully operational and during shut-down periods show that there is a small increase in the background vibration level when comparing the two sets of measurement data. However, these background PPV levels are low, and vibrations from traffic on nearby roads and other activities are generally higher than the vibrations likely attributable to ABC. Vibration levels of these transient events, such as traffic etc. are likely to have a higher impact when they occur than the baseline vibration levels which are attributable to ABC plant. These transient vibrations typically occur on weekdays during the day time.

It is concluded from this study that activities independent of the ABC plant have the potential to be of greater impact on nearby residences than the plant itself. Additionally it is likely that vibration levels within residences are lower than the measured levels due to coupling losses between the ground and the house foundations. Further investigation is therefore warranted within a selection of nearby residential properties to confirm the measured vibration levels and foundation coupling loss. However, we expect that the vibration levels within nearby residential buildings to be below whole body vibration standards (such as AS2670).