

Revision history

1	23/01/2019	Minor grammar corrections and commentary added to Section 4.3 on selection of trigger level values
0	18/01/2019	Report issued for Heritage Manager

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Attention:

Dear Chloe

Windsor Bridge - Heritage Brick Barrel Drain Stage 2 - Test Piles Vibration Monitoring Results 17 January 2019

1 Introduction

VMS Australia Pty Ltd (VMS) was engaged by Georgiou Group to undertake vibration measurements during the excavation of Test Piles 71 and 72 on 17 January 2019.

The purpose of the monitoring was to measure the vibration levels directly on the Heritage Brick Barrel Drain during pile excavation activities being conducted directly adjacent to the drain.

2 Site Description and Work Operations

Pile excavation works was undertaken using an Enteco E300 Drilling Rig. The nominated test piles, Piles 71 and 72, were located approximately 8m and 4m, respectively, north of the exposed Heritage Brick Barrel Drain monitoring location.

Vibration measurements were carried out directly on the roof of the Heritage Brick Barrel Drain on section previously exposed and approved by the Heritage Manager. A second vibration monitor was also utilised for part of the piling excavation of Pile 71 to determine the vibration levels on the surface of the ground adjacent to the drain.

A photograph showing the setup of the vibration monitoring survey is shown in **Figure 1**.

Figure 1 Test Pile Monitoring



3 Vibration Monitoring Results

Table 2 and Table 3 present a summary of the measured maximum vibration velocity levels (in any orthogonal direction) for the two test piles.

Table 1 Summary of Maximum Vibration Levels – Test Pile 72 – 4m offset

Auger Depth from Surface	Monitor One – on Roof of Exposed Drain	
	Measured Maximum Vibration Level	Frequency
0m-1.0m	0.3 mm/s	36 Hz
1.0m-2.0m	0.4 mm/s	25 Hz
2.0m-2.5m	0.4 mm/s	25 Hz
2.5m-3.0m	0.5 mm/s	42 Hz
3.0m-3.5m	0.9 mm/s	28 Hz
3.5m-4.0m	0.8 mm/s	31 Hz
4.0m-4.5m	0.5 mm/s	25 Hz
4.5m-5.5m	0.5 mm/s	19 Hz
5.5m-6.0m	0.4 mm/s	25 Hz
6.0m-6.5m	0.4 mm/s	42 Hz
6.5m-7.0m	0.2 mm/s	31 Hz

Table 2 Summary of Maximum Vibration Levels – Test Pile 71 – 8m Offset

Auger Depth from Surface	Monitor One – on Roof of Drain		Monitor Two – on Surface of Ground	
	Measured Maximum Vibration Level	Frequency	Measured Maximum Vibration Level	Frequency
0m-0.5m	0.2 mm/s	18 Hz	Not monitored	
0.5m-1.0m	0.2 mm/s	14 Hz		
1.0m-1.5m	0.2 mm/s	11 Hz		
1.5m-2.0m	0.2 mm/s	9 Hz		
2.0m-2.5m	0.2 mm/s	4 Hz		
2.5m-3.0m	0.2 mm/s	7 Hz	0.5 mm/s	31 Hz
3.0m-3.5m	0.2 mm/s	9 Hz	0.8 mm/s	28 Hz
3.5m-4.0m	0.2 mm/s	9 Hz	1.5 mm/s	28 Hz
4.0m-4.5m	0.2 mm/s	7 Hz	0.9 mm/s	15 Hz
4.5m-5.0m	0.2 mm/s	5 Hz	0.7 mm/s	63 Hz
5.0m-5.5m	0.2 mm/s	5 Hz	0.4 mm/s	36 Hz
5.5m-6.0m	0.2 mm/s	7 Hz	0.7 mm/s	21 Hz
6.0m-6.5m	0.2 mm/s	13 Hz	0.4 mm/s	28 Hz
6.5m-7.0m	0.2 mm/s	10 Hz	0.5 mm/s	28 Hz

4 Comments and Recommendations

4.1 Discussion of Results

The maximum recorded vibration level which can be attributed directly to the drilling works was 0.9 mm/s, measured directly on the roof of the Heritage Brick Barrel Drain at an offset distance of 4m from the piling excavation of Pile 72. When the excavation was occurring at Pile 71, at an offset distance of 8m from the drain, the maximum vibration level recorded on the drain was 0.2 mm/s.

During the excavation of Pile 71, the vibration levels reached 1.5 mm/s on the surface of the ground measured directly above the Heritage Brick Barrel Drain at an offset distance of 8m from the pile.

It is concluded that piling conducted in close proximity (less than, say, 6m) to the drain induces vibration excitation of the drain proportional to the force of drilling effort. Further away (i.e greater than 6m from the piling), the vibration energy within the ground has mostly been converted into ground surface waves, resulting in only a small fraction of the vibration generated by the piling reaching the Heritage Brick Barrel Drain. Consequently, the ground surface vibration levels are at least 2 times higher than that measured on the drain.

4.2 Comparison Against Vibration Damage Criteria

The Stage 1 testing report identified German Standard DIN4150 as containing the most stringent, applicable and recent vibration criteria which may be adopted for the protection of the Heritage Brick Barrel Drain from potential vibration induced damage associated with the piling activities. An extract of the relevant frequency dependent vibration limits for heritage structures is presented in **Table 3**.

Table 3 DIN 4150 Safe Vibration Limits for Heritage Structures

Group	Type of Structure	Peak Particle Velocity (mm/s)		
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz ¹
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Lines 1 or 2 and have intrinsic value (eg buildings that are under a preservation order)	3	3 at 10 Hz increasing to 8 at 50 Hz	8 at 50 Hz increasing to 10 at 100 Hz and above

Review of the vibration limits presented in **Table 3** shows that the vibration criteria are more stringent at lower frequencies, with a minimum (most stringent) vibration limit of 3 mm/s for frequencies below 10 Hz. A comparison of the maximum measured vibration level (0.9 mm/s) from the Stage 2 test piles against the DIN4150 vibration limits has found that the vibration levels induced on the Heritage Brick Barrel Drain from the test piles was well below even the most stringent vibration limit of 3 mm/s.

4.3 Recommend Vibration Limits for Heritage Brick Barrel Drain

For all subsequent attended monitoring, if required, particularly for any piles being drilled closer than 2 m to the Heritage Brick Barrel Drain, the DIN4150 frequency dependent vibration criteria for heritage structures (**Table 3** above) will continue to be adopted for the drain.

For the remaining piles, Stage 3 piles (Abutment A piles P27, P28, P32 and P33 and the Western Retaining Wall), vibration monitoring would be undertaken using unattended vibration monitors with local alarm notification (flashing lights and siren). For all unattended monitoring, two control limits are recommended:

- “Operator Warning Level” of 6 mm/s
- “Operator Halt Level” of 8 mm/s

The nominated control limits would apply to vibration monitoring conducted on the ground surface directly above the Heritage Brick Barrel Drain and at the near point to the piling works. The control limits have been nominated based on the typical ground surface vibration frequency range of 30 Hz to 50 Hz, a minimum vibration attenuation from the ground surface to the drain of 50 % (which also increases with increasing surface vibration level) and a predicted maximum vibration level on the Heritage Brick Barrel Drain of 3 mm/s corresponding to the 8 mm/s “Operator Halt Level” applied to the ground surface above the drain.

4.4 Recommended Drilling Controls

The following operational controls are recommended in order to minimise the ground vibration when working adjacent to the Heritage Brick Barrel Drain:

- Maintain constant auger rotational velocity during drilling
- Ensure that the end of the drill hole is not rammed by the auger when reinserting into the hole
- Run the auger at the lowest constant speed when drilling through the top layer of engineered rocky fill
- Minimise aggressive manoeuvring of the drill rig, repeated raising and lowering of the auger and changes in rotation velocity (particularly rapid direction reversal) of the auger
- Progressively relocate the vibration monitor to the nearest ground surface point above the Heritage Brick Barrel Drain for each piling area

I trust the above meets your current requirements. Please feel free to contact me if you require any additional information.

Regards,



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