11 August 2022

22044 Tunkers Vibration Resullts 20220811

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Attention: **Mr David Hopkins**

Dear David

Summary of Results
Tünkers Shock Absorber
Vibration Isolation Testing

1 Introduction

VMS Australia Pty Ltd (VMS) were engaged by Pilequip Australia Pty Limited to undertake in-situ vibration monitoring trials to determine the effectiveness of the Tünkers Shock Absorbers. The Tünkers Shock Absorbers are designed to isolate the vibration between the vibratory pile driving equipment and the carrier unit (such as a crane or excavator).

Two Tünkers Shock Absorbers model types were tested: SD70 and SD130. The specification for each shock absorber is shown in **Table 1**.

Table 1 Tünkers Shock Absorber Specifications

Shock absorber	Typ	SD 20	SD 30	SD 70	SD 130	SD 180
Max. admissible prestressing	kN	120	160	250	500	800
Height	mm	1070	1090	1550	2100	2370
Width	mm	670	730	840	1060	1170
Weight approx.	kg	155	200	325	750	900

Source: Tünkers Shock Absorbers product brochure (Id.-Nr. 1255211 05/2018). Mark-up by VMS.

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2 Testing Setup and Instrumentation

2.1 Vibration Testing Overview

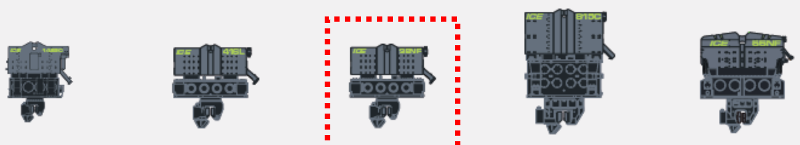
VMS have conducted a series of simultaneous vibration measurements at an array of locations on the vibratory pile driver, support structure and operator's position locations. The test plan was developed by Pilequip with the main aim of quantifying the vibration isolation performance of the Tünkers SD130 and SD70 shock absorbers. Testing was conducted using both static moment and variable moment vibratory pile drivers.

A 80 tonne crawler crane was used as the carrier unit to suspend the shock absorber and pile driver.

An ICE 32NF 1650 rpm normal frequency (28 Hz) static moment vibratory hammer with an ICE 400 series Power Pack and a PVE 28VM 2300 rpm high frequency (38 Hz) variable moment Vibro Hammer with a PVE 600 series Power Pack were used during the testing. The equipment specifications are shown in **Figure 1** and **Figure 2**, respectively.

Figure 1 Static Moment Vibratory Hammer Specification - ICE 32NF

NORMAL FREQUENCY VIBRATORY HAMMERS



		1423C	416L	32NF	815C	55NF
Eccentric moment	kgm	14.0	23.0	32.0	46.0	54.0
Max. centrifugal force	kN	812	647	955	1250	1711
Max. frequency	rpm	2300	1600	1650	1570	1700
Max. amplitude *)	mm	16.5	19.6	27.2	23.3	30.1
Max. static line pull	kN	240	400	400	400	800
Max. oil flow	L/min	370	359	370	610	617
Dynamic weight *)	kg	1700	2350	2350	3950	3580
Total weight *)	kg	2750	3550	4600	7450	5700
L x W x H *)	mm	1919 x 738 x 1620	2548 x 495 x 1567	2548 x 495 x 1567	2658 x 840 x 2595	2642 x 678 x 1939
Recommended power pack		400 series	400 series	400 series	600 series	600 series
Recommended sheet pile clamp		100TU	100TU	130TU	160TU	200TU
Recommended tube clamp set		55TC	81TC	81TC	81TC	100TC
Recommended pile clamp		120TP	120TP	120TP	180TP	180TP

Source: ICE equipment catalogue. Mark-up by VMS.

Figure 2 Variable Moment Vibratory Hammer Specification - PVE 28VM

Specifications :			PVE 28VM		
Eccentric moment	0-28	kgm	**Clamps:**		
Max. centrifugal force	0-1600	kN	Sheet pile clamp	200TU-P	
Max. frequency	2300	rpm	Transport weight per piece	2000	kg
Max. amplitude excl. 200TU-P	14	mm	Double clamps	100TC	
Max. amplitude incl. 200TU-P	10,8	mm	Transport weight per piece	690	kg
Max. static line-pull	400	kN			
Max. operating pressure	350	bar	**Powerpack:**		
Max. oil flow	590	l/min	Model	600 series	
Forced lubrication	yes				
Dynamic weight excl. 200TU-P	3500	kg	**Hose set:**		
Dynamic weight incl. 200TU-P	5500	kg	Length	45	m
Total weight excl. 200TU-P & hoses	5900	kg	Transport weight (±)	1121	kg

Source: PVE equipment catalogue.

5.5m length double Z sheet piles, pre-embedded in stiff clay ground, were used in the testing (refer to **Figure 3**).

Figure 3 Photo of Double Z Sheet Piles Used in the Testing

The testing was conducted on Wednesday 13 July 2022 at Pilequip Australia Pty Limited's Yard located at 39 Chapman Road VINEYARD NSW 2765.

2.2 Vibration Measurement Locations

The vibration measurement locations on the crane structure were:

- On the top of the Crane hook, vertical direction
- At the extreme end of the Crane jib, perpendicular to the long axis of the jib in a vertical plane
- At the mid-point of the Crane jib, perpendicular to the long axis of the jib in a vertical plane
- In the Crane operator's cabin, vertical direction

Figure 4 to **Figure 6** show photographs of the Crane used in the tests with sensor locations marked.

Figure 4 Photo of Crane Used in Testing with Vibration Measurement Locations Shown

Figure 5 Photographs of Accelerometers at Hook and Jib Measurement Locations

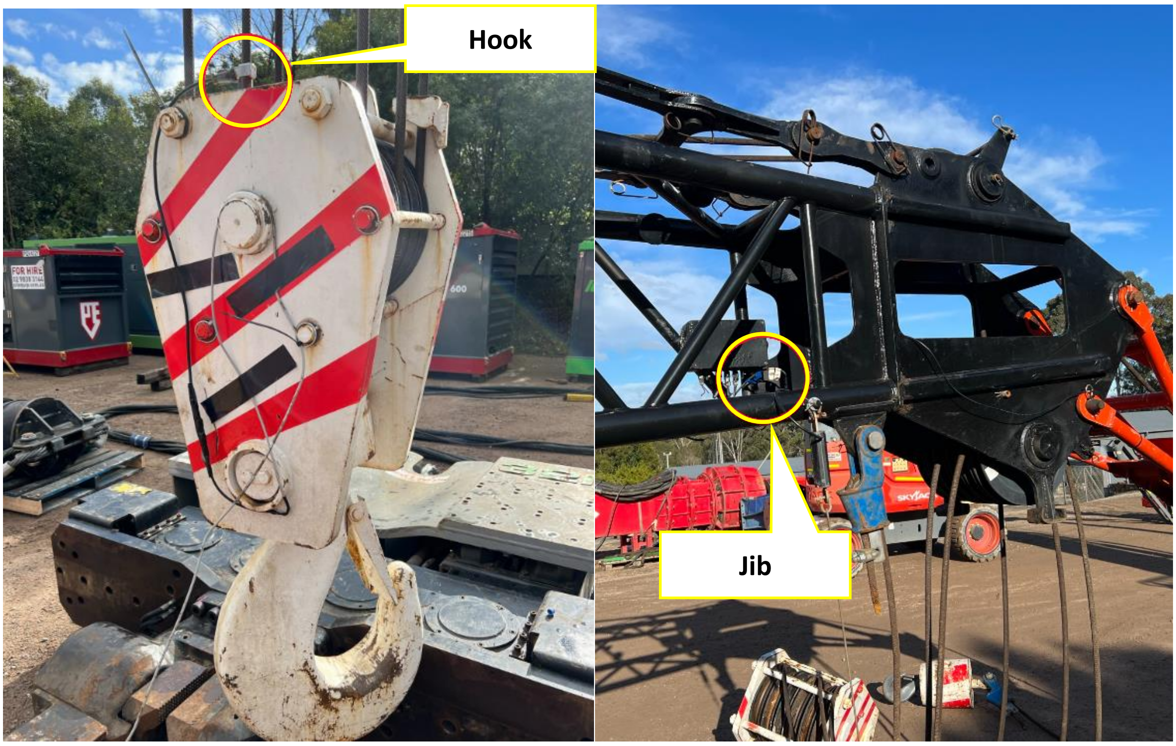


Figure 6 Photographs of Accelerometers at Mid Jib and Cabin Measurement Locations

2.3 Instrumentation

The following instrumentation was used in this study:

- Accelerometers, 4 off, Wilcoxon model 786A, nominal sensitivity 100mv/g
- Data acquisition, Data Translation DT9834, 4 channel FFT analyser
- Data storage Dell laptop
- DAQ software Quick DAQ

3 Results

3.1 General

The results for each test are presented in detail in **Appendix A**.

Table 2 presents a summary of the results for each test cycle and **Table 3** presents an average of the results for each test.

Table 2 Summary of Results for Each Test Cycle

Test No.	Vibration Hammer	Pile Load Condition	Vibro Type	Shock Absorber	Vibration results Above Hook			Vibration results at jib head			Vibration results on Jib - midway			Vibration results in Cabin		
					g RMS			g RMS			g RMS			g RMS		
					1	2	3	1	2	3	1	2	3	1	2	3
1	ICE 32NF	No Pile			1.520	2.020	1.980	0.350	0.400	0.400	0.350	0.600	0.700	0.150	0.160	0.150
2	ICE 32NF	Sit on Pile (Pile Install)	Static	None	1.410	0.350	0.150	0.310	0.080	0.020	0.320	0.080	0.020	0.110	0.020	0.020
3	ICE 32NF	Pile Extract / Lift			1.520	1.480	1.510	0.350	0.320	0.310	0.350	0.320	0.330	0.120	0.110	0.100
5	PVE 28VM	No Pile			1.030	1.010	1.020	0.180	0.220	0.210	0.250	0.250	0.250	0.070	0.070	0.070
6	PVE 28VM	Sit on Pile (Pile Install)	Variable	None	0.060	0.060	0.060	0.015	0.015	0.015	0.030	0.025	0.025	0.030	0.030	0.030
7	PVE 28VM	Pile Extract / Lift			1.020	1.010	1.180	0.210	0.220	0.200	0.250	0.210	0.230	0.120	0.110	0.100
9	ICE 32NF	No Pile			0.090	0.110	0.110	0.060	0.055	0.056	0.040	0.035	0.038	0.015	0.018	0.016
10	ICE 32NF	Sit on Pile (Pile Install)	Static	SD130	0.035	0.020	0.020	0.015	0.015	0.015	0.030	0.028	0.020	0.015	0.015	0.018
11	ICE 32NF	Pile Extract / Lift			0.100	0.100	0.100	0.030	0.030	0.030	0.050	0.050	0.050	0.020	0.025	0.025
13	PVE 28VM	No Pile			0.190	0.170	0.190	0.025	0.022	0.025	0.035	0.032	0.032	0.028	0.025	0.027
14	PVE 28VM	Sit on Pile (Pile Install)	Variable	SD130	0.025	0.013	0.013	0.013	0.015	0.015	0.025	0.020	0.020	0.035	0.033	0.033
15	PVE 28VM	Pile Extract / Lift			0.160	0.170	0.170	0.030	0.030	0.030	0.035	0.030	0.032	0.035	0.030	0.030
17	ICE 32NF	No Pile			0.500	0.600	0.500	0.150	0.160	0.150	0.250	0.280	0.250	0.090	0.110	0.100
18	ICE 32NF	Sit on Pile (Pile Install)	Static	SD70	0.050	0.050	0.040	0.015	0.015	0.015	0.030	0.030	0.030	0.014	0.014	0.015
19	ICE 32NF	Pile Extract / Lift			0.180	0.180	0.170	0.050	0.055	0.060	0.045	0.046	0.048	0.015	0.018	0.017
21	PVE 28VM	No Pile			0.120	0.110	0.121	0.015	0.016	0.013	0.035	0.035	0.020	0.021	0.022	0.023
22	PVE 28VM	Sit on Pile (Pile Install)	Variable	SD70	0.015	0.017	0.016	0.020	0.025	0.023	0.038	0.040	0.040	0.025	0.028	0.028
23	PVE 28VM	Pile Extract / Lift			0.130	0.120	0.130	0.025	0.023	0.025	0.035	0.025	0.030	0.030	0.025	0.025

Table 3 Average of Test Cycle Results

Test No.	Vibration Hammer	Pile Load Condition	Vibro Type	Shock Absorber	Crane Hook g RMS AV	Jib g RMS AV	Mid Jib g RMS AV	Cabin g RMS AV
1	ICE 32NF	No Pile	Static	None	1.840	0.383	0.550	0.153
2	ICE 32NF	Sit on Pile (Pile Install)			0.637	0.137	0.140	0.050
3	ICE 32NF	Pile Extract / Lift			1.503	0.327	0.333	0.110
5	PVE 28VM	No Pile	Variable	None	1.020	0.203	0.250	0.070
6	PVE 28VM	Sit on Pile (Pile Install)			0.060	0.015	0.027	0.030
7	PVE 28VM	Pile Extract / Lift			1.070	0.210	0.230	0.110
9	ICE 32NF	No Pile	Static	SD130	0.103	0.057	0.038	0.016
10	ICE 32NF	Sit on Pile (Pile Install)			0.025	0.015	0.026	0.016
11	ICE 32NF	Pile Extract / Lift			0.100	0.030	0.050	0.023
13	PVE 28VM	No Pile	Variable	SD130	0.183	0.024	0.033	0.027
14	PVE 28VM	Sit on Pile (Pile Install)			0.017	0.014	0.022	0.034
15	PVE 28VM	Pile Extract / Lift			0.167	0.030	0.032	0.032
17	ICE 32NF	No Pile	Static	SD70	0.533	0.153	0.260	0.100
18	ICE 32NF	Sit on Pile (Pile Install)			0.047	0.015	0.030	0.014
19	ICE 32NF	Pile Extract / Lift			0.177	0.055	0.046	0.017
21	PVE 28VM	No Pile	Variable	SD70	0.117	0.015	0.030	0.022
22	PVE 28VM	Sit on Pile (Pile Install)			0.016	0.023	0.039	0.027
23	PVE 28VM	Pile Extract / Lift			0.127	0.024	0.030	0.027

3.2 Discussion

The results presented in **Appendix A** consist of three pages per test.

Page 1 presents the acceleration time history of all three cycles of the particular test. **Figure 7** shows a sample acceleration time history plot for test 9 showing each test cycle.

Page 2 presents cycle 1 only. **Figure 8** present a sample acceleration time history plot from page 2, cycle 1, showing the distinct phases of the test cycle, including run up, mid cycle (running), and run down.

Page 3 shows a zoomed acceleration time history plot of mid cycle 1.

Note that on all three pages of the test result Appendices, the upper plot is an acceleration time history and the lower plot is a 1 second RMS acceleration time history.

It is noted that, of the three load conditions (No Pile, Sit on Pile (Pile Install) and Pile Extract / Lift) that the Pile Extract load condition corresponds to the load condition that the crane operators typically express concern for the level of vibration transmission into the structure of the crane. The Sit on Pile (Pile Install) load condition would typically result in the vibration travelling via the ground into the crane structure, i.e. not via the cables into the jib. The No Pile load condition was primarily undertaken as an academic exercise and does not represent a typical operating mode of a vibration hammer.

Figure 7 Sample Acceleration Time History Plot Page 1 of Each Test Appendix

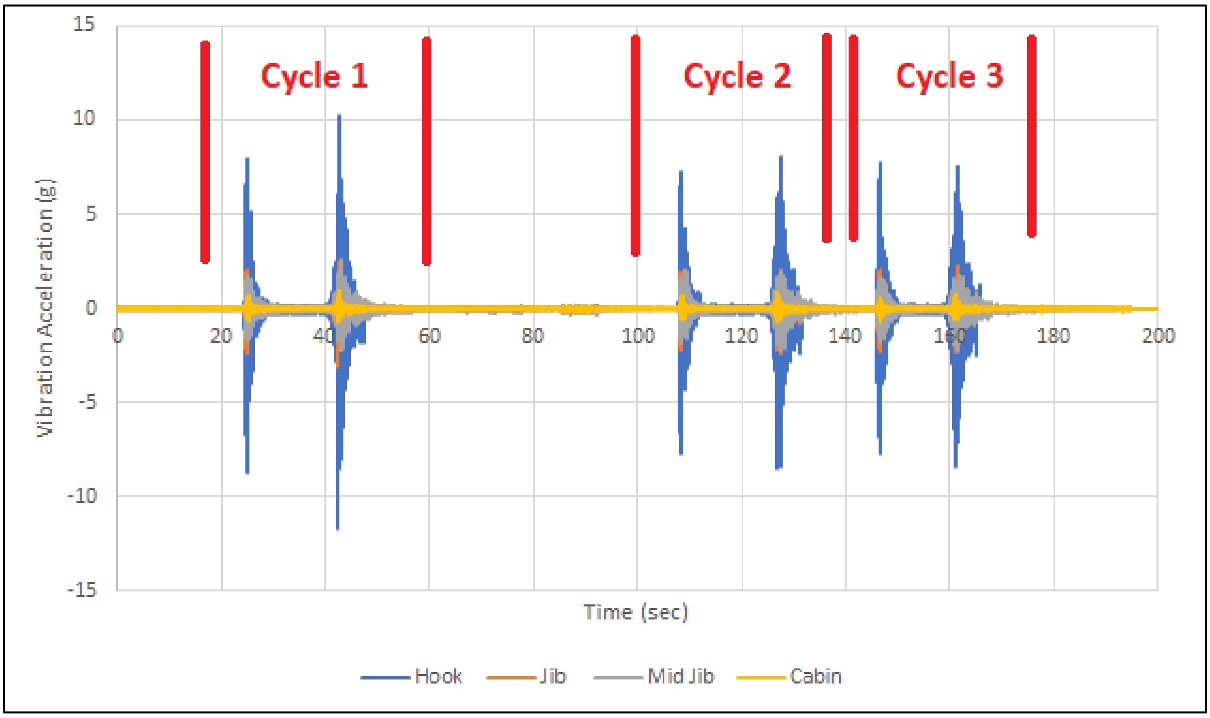
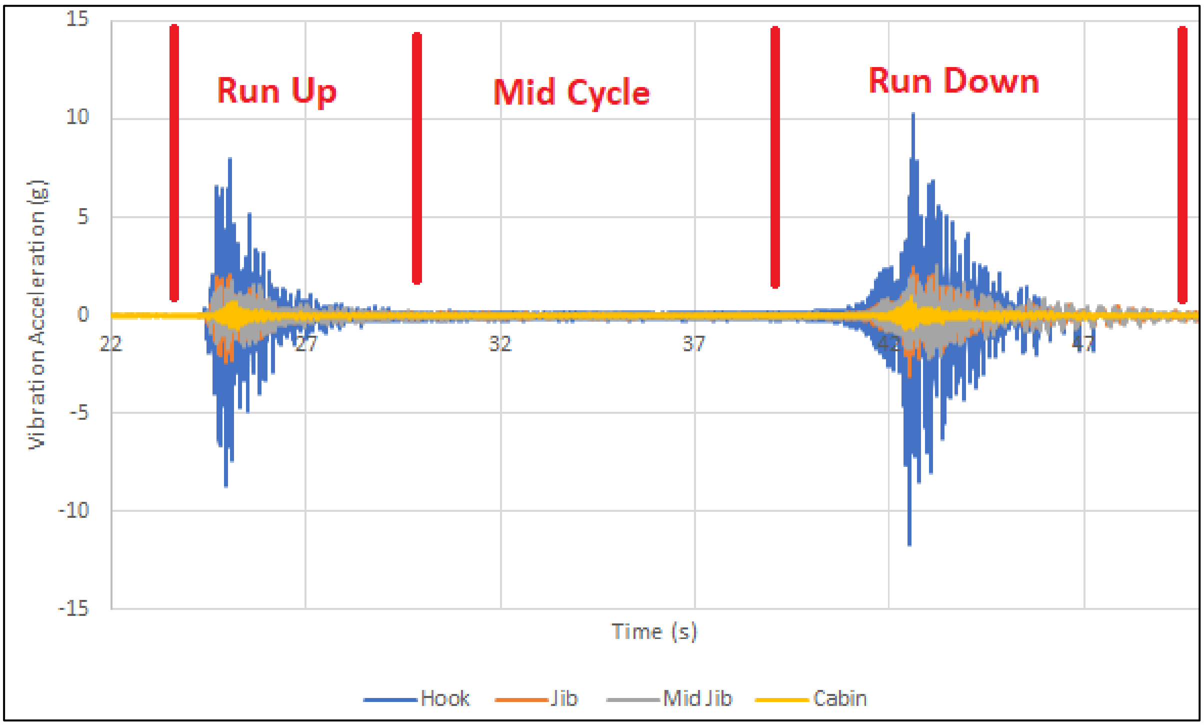


Figure 8 Sample Acceleration Time History Plot for One Test Cycle



3.3 Performance Assessment

VMS have used the nominal measured one second RMS acceleration levels (for mid cycle operation), in order to make direct comparisons between the vibration responses, with and without shock absorbers in line.

The average RMS vibration responses for each test were used to calculate the vibration isolation efficiency expressed as a percentage reduction. The results are summarised in **Table 4** and **Table 5**.

Figure 9 and **Figure 10** show summary plots of the measured average RMS vibration levels for each measurement location for the ICE 32NF and PVE 28VM drive heads, respectively.

Table 4 Summary of Vibration Isolation Performance for ICE 32NF Tests

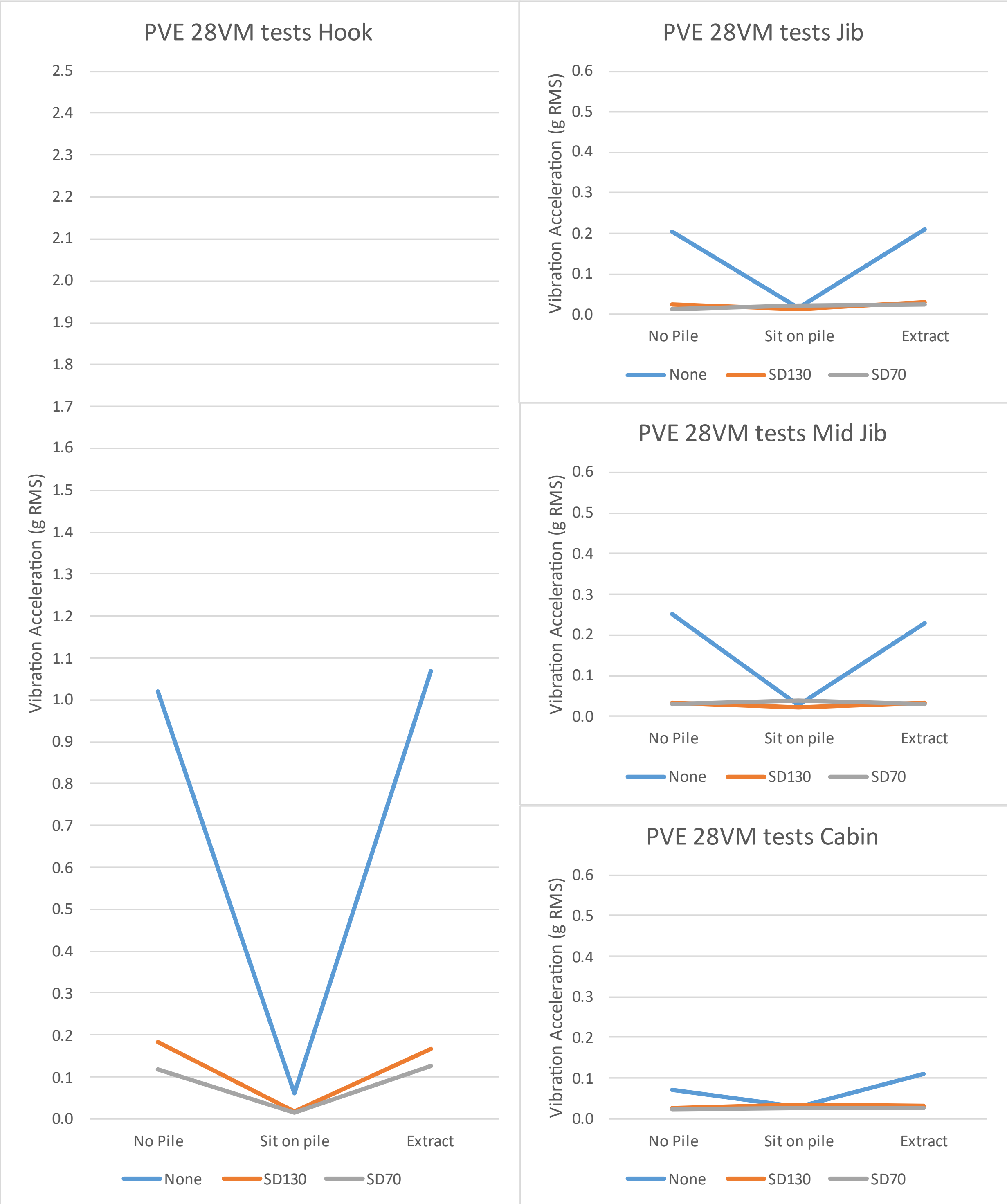
	Crane Hook			Jib			Mid Jib			Cabin		
	No Pile	Sit on pile	Extract	No Pile	Sit on pile	Extract	No Pile	Sit on pile	Extract	No Pile	Sit on pile	Extract
SD130	94%	96%	93%	85%	89%	91%	93%	81%	85%	89%	68%	79%
SD70	71%	93%	88%	60%	83%	83%	53%	72%	91%	86%	46%	76%

Table 5 Summary of Vibration Isolation Performance for PVE 28VM Tests

	Crane Hook			Jib			Mid Jib			Cabin		
	No Pile	Sit on pile	Extract	No Pile	Sit on pile	Extract	No Pile	Sit on pile	Extract	No Pile	Sit on pile	Extract
SD130	82%	72%	84%	88%	4%	86%	87%	19%	86%	62%	-12%	71%
SD70	89%	73%	88%	93%	-51%	88%	88%	-48%	87%	69%	10%	76%

Figure 9 Summary Plots Showing Average RMS Operating Levels for Comparative Tests on the ICE 32NF Drive Head

Figure 10 Summary Plots Showing Average RMS Operating Levels for Comparative Tests on the PVE 28VM Drive Head



4 Discussion and Conclusion

VMS Australia Pty Ltd (VMS) were engaged by Pilequip Australia Pty Limited to undertake in-situ vibration monitoring trials to determine the effectiveness of the Tünkers Shock Absorbers. SD70 and SD130 Tünkers Shock Absorber model types were tested.

The pile extraction load condition corresponds to the load condition that crane operator's typically express concern for the level of vibration transmission into the structure of the crane. During the pile extraction load condition, the maximum vibration load is transferred via the cable into the carrier unit. Testing found that both the SD70 and SD130 Tünkers Shock Absorber model types were both effective at reducing the vibration transmitted into the crane, showing reductions in structural vibration levels of up to 91% and 93%, respectively.

When sitting on the pile load condition, there is no tension on the crane line other than the load from the crane hook and shock absorber. Accordingly, under this load condition the shock absorber is not engaged and therefore the structural vibration levels are primarily due to a combination of self-generated vibration from the engine and vibration transmitted from the pile, via the ground, into the crane. Consequently, changes in the engine load condition or ground vibration levels would result in changes in the structural vibration levels. Hence, it is noted in **Table 5** that there are 3 anomalies in the results with both the SD130 and SD70 Tünkers Shock Absorber whilst using the PVE 28VM drive head, due to the very low vibration levels (an order of magnitude lower than during pile extraction load condition) and consequent influence of the self-generated engine vibration and transmitted ground vibration into the crane.

Regards,

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