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ASSESSMENT OF NOISE FROM "QUIET" PILE DRIVERS

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1. Introduction

A pile must be driven into the ground in such a manner that it will satisfactorily resist the forces imposed upon it by the completed structure. The use of impact devices in creating this situation almost inevitably gives rise to high noise levels, thus making it one of the most significant sources of noise annoyance.

The Control of Pollution Act 1974 (1) and an accompanying Code of Practice (2) on the control of noise from construction and demolition sites gave local authorities the powers to limit noise from construction and demolition sites by the imposition of a noise notice specifying noise limits, use of specific types of plant, or hours of working. Because of this recent act, manufacturers of construction and demolition equipment have been researching into methods of quietening their equipment without unacceptable loss of efficiency.

This paper summarises the results of a study of noise levels, spectra and waveform shapes from a range of pile driving devices which were either adapted or designed specifically to produce noise levels below those normally expected.

2. Basic Characteristics of Impact Pile Drivers

Impact piling applies the force created by the deceleration of a massive weight or free piston to force the pile into the ground and some of the basic characteristics of these pile drivers are discussed below.

2.1 Waveforms

The 'A' weighted pressure time waveforms of noise from pile drivers were examined with the aid of the ISVR Data Analysis Centre facilities. One example of such a waveform sampled at 1000 samples per second is shown in Figure 1. The conclusion drawn was that, in all cases where impact was taking place above the ground, noise produced by hammer impact and exhaust of working fluid was dominant over noise from other sources such as ancillary equipment. From examination of these data it appeared that the characteristic waveform shape was that of a decaying exponential impulse except where a significant exhaust pulse was present or where a high impact rate rendered the noise effectively continuous.

2.2 Sound Pressure Level Time Histories

Pressure-time (p(t)) data were integrated digitally to produce representations of sound pressure level time (SPL(t)) histories. Integration times of 10, 35, 200 and 500 ms were employed in certain cases to encompass the range of integration times found on sound level meters. Figure 2 shows an example of such an SPL(t) trace. The use of the shortest practicable integration time (10 ms) has allowed the rapid rise of the main impulse and the secondary peak caused by exhaust emission to be observed. An exponential p(t) pulse should normally exhibit a linear decay of SPL(t) on the trailing edge of the pulse. This was not readily observable in raw SPL(t) traces so in each case the cumulative distribution function of sound pressure level (CDF(L)) was derived. This is shown in Figure 3. The tendency to linearity of the low probability sections of the CDF(L) curves indicates that even in the presence of exhaust noise the predominant characteristic of the pulses is exponential where the repetition rate allows the separation of adjacent impacts.

This conclusion allows an examination of the mathematics and statistics of such pulses which throws light on various practical situations. This is discussed in the next section.

3. Theoretical Analysis of Impact Pulses

The principal parameters of an exponential impulse are the peak pressure (P_{pk}), decay constant (C; defined as the time taken for P_{pk} values to decay to 1/e of its peak value) and repetition rate (N). An analysis (3,4) has shown that equivalent sound level (L_{eq}) may be related to these parameters in the following manner where $C < 1/N$ and SPL_{pk} is the absolute peak sound pressure calculated from P_{pk}.

$$L_{eq} = SPL_{pk} + 10 \log_{10} CN/2.$$

It can also be shown that L_{eq} is related to the probability distribution of sound pressure levels:

$$L_{eq} = SPL_{pk} + 10 \log_{10} \left(4.3 \times \frac{\Delta CDF(L)}{\Delta SPL(t)}\right)$$

The fraction in the logarithmic term represents the (constant) slope of the ideal distribution curve. Both of the above expressions have been found to apply within ± 5dB where repetition rates are not so high as to render the sound effectively continuous.

It has also proved instructive to examine the relationship between absolute peak sound pressure level and that indicated by a sound level meter. If the sound level meter integration function is assumed to be rectangular (rather than the actual RC function) it is possible to derive the following expressions (3):

$$SPL_{max.SLM} = SPL_{pk} + 10 \log_{10} \left(C/2\tau \left(1 - e^{-2\tau/C}\right)\right)$$

where τ is the SLM integration time.

4. Measurement Procedures and Results from 'Quiet' pile drivers

4.1 Measurement Procedures and Analysis

A set of recordings were made of noise from six 'quiet' and one conventional pile driver at Bircham Newton. In all cases data was gathered with precision grade instruments at a distance of 15 metres from the base of sheet pile and at a height of 1.5 metres. Additional data was also collected, under similar conditions, from DMD 'Noise Abated Piling System' and 'SH-SH-Shelbourne's Piling Rig'.

The recorded analogue data were analysed digitally upon the ISVR Data Analysis computer which allowed close examination of pressure waveforms and sound pressure level time histories.

In all cases equivalent sound level (Leq) and peak sound pressure levels were determined. The effect of different integration times upon the peak levels was also examined.

Though the exact determination of the frequency spectrum of impulse noise requires careful manipulation and interpretation it was thought worthwhile to derive spectra which would allow comparison with those generated by other construction noise sources. The data were therefore analysed by means of the Bruel and Kjaer Type 3347 Real Time Analyser. A response time encompassing several pulses was used to generate third octave spectra.

4.2 Results and Discussions

The results from the 'quiet' piling demonstration in terms of equivalent sound level (Leq) and the maximum peak sound pressure levels are presented in

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Table 1. These results are shown with relation to three separate days of demonstration. The results from a BSP '700 N' pneumatic conventional hammer are included in Table 1 as a comparison. Table 1 also shows the results from DMD 'Noise Abated Piling System' and 'SH-SH-Shelbourne's Piling Rig'.

The pile driving rigs in Table 1 have been divided into three categories, according to noise levels emitted, namely - 'quiet', 'semi-quiet' and 'conventional' rigs. The range of equivalent sound level values measured within each category are 62.3 - 72.0 dB(A) for 'quiet', 78.8 - 88.3 dB(A) for 'semi-quiet' and 104.7 - 105.9 dB(A) for conventional untreated rigs. These results indicate that the equivalent sound levels generated by extensively treated machines (i.e. Hush, Pilemaster, DMD and Dawson rigs) are approximately 30-40 dB(A) lower than those generated by untreated machines at equivalent distances. These noise levels being equal to or less than that produced by other construction site noise sources. Generally, the expected Leq levels emitted by medium size piling rigs at similar distances are in the range 90 - 100 dB(A) and for large capacity piling rigs from 100 dB(A) upwards (2,3).

Table 1 shows the range of peak sound pressure levels on an 'A' weighted scale for different averaging (i.e. integration) periods and it indicates, as mentioned earlier in Section 3, the need for specifying the response settings where this type of measurement is required.

References

1. Control of Pollution Act. HMSO, London 1974
2. British Standard Code of Practice for Noise Control on Construction and Demolition Sites. BS5228, 1975.
3. J.E. LUDLOW 1976. ISVR Memorandum 541, University of Southampton. Noise from impact pile drivers.
4. A.M. MARTIN & G. ATHERLEY 1973. Anal. Occ. Hygiene 16. A method for the assessment of impact noise with respect to hearing damage.

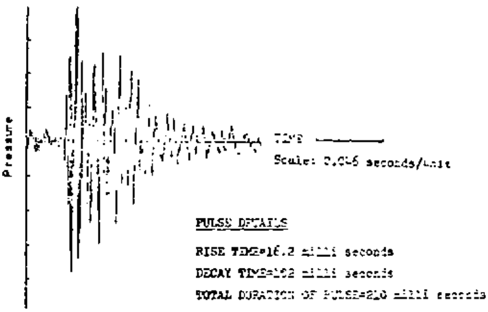

Fig.1 - 'A' weighted pressure time waveform of DMD 'Noise Abated Piling System'

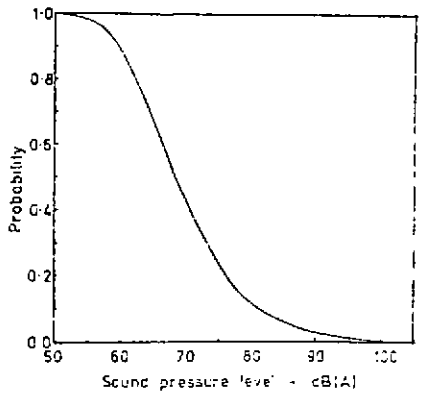

Fig.3 - Probability of exceeding a particular sound pressure level for Evans 'Stealth Hammer'.

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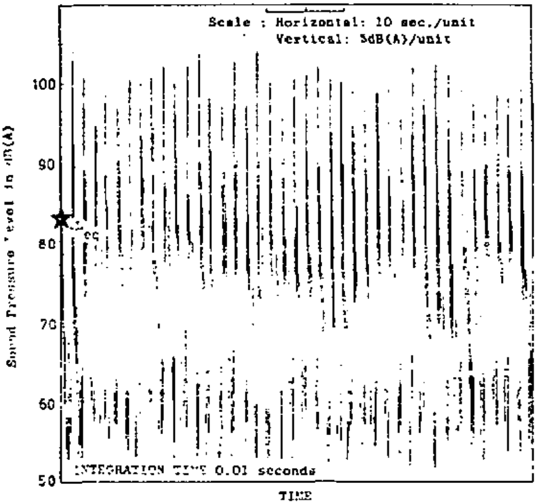

FIGURE 2 - Sound pressure level time history (SPL(t)) for Evans 'Stealth Hammer'. (Driving sheet piles).

TABLE 1. Showing the measured equivalent sound levels (L_{eq}) and the maximum sound pressure levels.

MEASURED SOUND LEVELS AT 'QUIET' PILING DEMONSTRATION											
	L_{eq} -dB(A)*			RANGE OF MAXIMUM dB(A)*							
DEMONSTRATION DAY	1	2	3	1				2		3	
				AVERAGING PERIOD MILLISECONDS							
MACHINE TYPE				500	200	35	10	500	200	500	200
SPC 'Hush Rig' (Q)	62.8	63.1	62.3	65.1 - 70.2	66.8 - 73.8	71.8 - 78.7	74.8 - 81.3	64.4 - 70.1	66.2 - 72.5	[illegible]	[illegible]
Taywood 'Pilemaster'** (Q)	65.9	60.5	65.0	64.[illegible] - 70.0	65.2 - 70.8	65.9 - 72.0	66.0 - 74.0	63.0 - 68.1	[illegible] - 64.4	[illegible] - 70.6	[illegible]
Dawson 'Quiet Piling Rig' (Q)	70.4	72.0	70.9	73.0 - 80.8	76.4 - 84.3	81.2 - 88.5	83.0 - 89.5	77.1 - [illegible]	60.1 - 67.8	77.2 - 81.6	76.4 - [illegible]
Evans 'Stealth Hammer' (SQ)	82.8	81.1	82.5	85.4 - 92.6	89.4 - 96.6	93.8 - 103.0	95.6 - 104.1	86.0 - 92.2	92.6 - 98.1	[illegible]	[illegible]
Evans 'Tonne/vibro VR2/5000'** (SQ)	-	80.6	85.2	-	-	-	-	77.0 - 83.0	-	82.5 - 92.7	82.0 - 91.1
BSP 'Impulse Pile Driver' (SQ)	88.3	88.1	87.4	87.8 - 90.7	90.7 - 97.6	-	-	87.4 - 93.0	90.6 - 97.5	87.5 - [illegible]	87.6 - [illegible]
BSP '700 N' Pneumatic Hammer (C)	-	104.7	105.9	-	-	-	-	104.5 - 107.9	104.6 - 109.2	[illegible]	[illegible]

ADDITIONAL MEASURED DATA		
MACHINE TYPE	RANGE OF L_{eq} - dB(A)***	RANGE OF MAXIMUM dB(A)*** (Averaging period of 500 milli seconds)
[illegible] 'Noise Abated Piling System' (Q)	67.7 - 70.5	70.0 - 84.0
'SF-SC-Shelbourne's Piling Rig' (SQ)	78.8 - 70.5	72.0 - 83.0

Q = Quiet; SQ = Semi-quiet; C = Conventional Machine
* Measured at a height of 1.5 m and at a distance of 15 m from base of sheet pile.
** Extraction and driving operations analysed together.
*** Measured over long periods while rig was driving different pairs of piles.