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MONITORING QUARRY BLAST NOISE - A STUDY OF TECHNIQUES

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Introduction

Quarrying, by its very nature, is likely to present environmental problems. For example, noise, dust and visual intrusion. To assess the impact on the environment of new works or the extension of existing works, it is essential that all these factors can be quantified and related to community response. One potential source of considerable annoyance is the high level impulsive noise from the explosions used in certain quarrying operations. Although much information exists on community reaction to sonic bang type impulsive noise, there is much less information relating to quarry type situations. Thus an investigation was initiated to study all aspects of quarrying explosive noise including its form, propagation and reception. This paper describes the initial measurements made, comments on the type of instrumentation required and presents typical wave forms and spectra.

Types of quarry explosion

(i) Primary Blasts: Typically a primary blast consists of 10-30 150mm diameter holes drilled about 6m apart and 5-7m behind the quarry face. Each hole contains explosive (130-670 kg per hole) and is sealed with specified quantities of small stone. The explosive in each hole is fired using explosive fuse chord and there is a delay (typically 17ms) between the firing of each hole. Primary blasts can produce from 10,000 to 100,000 tonnes of fragmented rock.

(ii) Face Dressing Blasts: Any unsafe rock left on the quarry face, after the primary blast, which cannot be removed manually is removed using small explosive charges. This is called face-dressing blasting. The explosive is attached to a length of fuse chord and lowered over the quarry face. The weight of explosive used for an uncontained blast of this type is limited to about 4 kgs.

(iii) Stumping Blasts: When a primary blast fails to make a clean break at quarry floor level, a stump results. This is removed with a stumping blast. Holes are drilled horizontally into the stump and charged as for primary blasts. The total amount of explosive vary between 45 kg and 1150 kg and delays are used between the firing of each hole.

In the particular quarry under study there are on average 2 primary blasts per week, about 50 face dressing shots per week while stumping shots are quite infrequent.

Acoustic measurements and analysis

In order to measure accurately down to very low frequencies, a frequency modulated (FM) carrier system was used with a standard 25mm capacitor microphone which had had its pressure equalisation vent closed. The demodulated signal after passing through a stepped gain low frequency amplifier was recorded on a 4 track FM instrumentation tape recorder. By cascading three of the channels of the tape recorder with a fixed attenuation of 10 dB or 20 dB between channels it was possible to cover a wide dynamic range and be sure of capturing the signal at an adequate level. The total dynamic range of the system was from 80 dB to 150 dB and the frequency range (-3 dB points) was from 0.3 Hz to 10 kHz. On site monitoring of the blast noise was achieved using an impulse precision sound level meter which was set to either peak hold or impulse B hold. The output of this meter was also fed to the fourth channel of the recorder. This fourth channel was also used to record the signal from a high gain hydrophone B & K type 8101

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to assess the use of this type of transducer as a permanent outdoor monitor.

The recorded signals were replayed through the low frequency amplifier and captured in a B & K Digital Event Recorder. The input sampling rate of the DER was chosen so that the lowest frequency of interest could be analysed (5ks/s or 10 ks/s for face dressings, 2 ks/s for primary blasts or stumps). Obviously the choice of input sampling rate limits the upper analysis frequency possible but in all cases it was found that the majority of energy fell within the available frequency range. The stored signal was played back at an increased speed (usually X10) to increase the effective low frequency capability of the analyser. (B & K R.T.A. type 2131). This gave a lowest $\frac{1}{3}$ octave band with center frequency 0.16 Hz. A single impulse was replayed from the DER into the R.T.A. which was used with a 4 sec linear averaging time. A pistonphone calibration on the tape allowed the analysis system to be calibrated. The signal from the DER was also fed to a precision sound level meter to measure the dB(B) value and peak hold value (the signal was played back on a real time scale for this). However, as the sound level meter was found to be unrealiable for recording the peak level of signals with a large low frequency content,the peak level was also monitored on an oscilloscope and a voltmeter with an extended low frequency range. (0.5 Hz).

The signal from the DER could also be fed to a tape punch to provide data for computation. This digitised information was used in an F.F.T algarithm to calculate $\frac{1}{3}$ octave band levels.

Discussion

Typical waveforms for primary blasts and face dressing blasts are shown in Figs 1 and 2. Usually primary blasts and stumping shots are of 2 to 3 secs duration while face dressing shots last for only 100x200 millisecs. There are small variations in the signal depending on whether one is in front or behind the quarry face and the distance from the face at which the measurement is made. From figs 3 and 4 it can be seen that the primary blast contains significant amounts of energy at frequencies below 1 Hz and the majority of signals analysed show a peak in the frequency spectra between 0.5 and 1 Hz. Similar results are indicated for stumping blasts but so far very few stumping shots have been recorded. Face dressing blasts all show a peak in the frequency spectrum between 16 and 40 Hz. Figs 3 and 4 show the effect on the measured spectra produced by recording the original signal using a system with a lower frequency limit of 2 Hz (B & K precision SLM 2209). This indicates that for true reproduction of the signal and a reliable frequency spectra a system with a low frequency capability well below 1 Hz is required. Even for the sample monitoring of peak levels it is recommended that the system used have a similar low frequency capability.

Although all the results obtained using the hydrophone have not been analysed, it does appear that it is very suitable for recording blast noise provided the level is high enough. (in excess of 86 dB SPL).

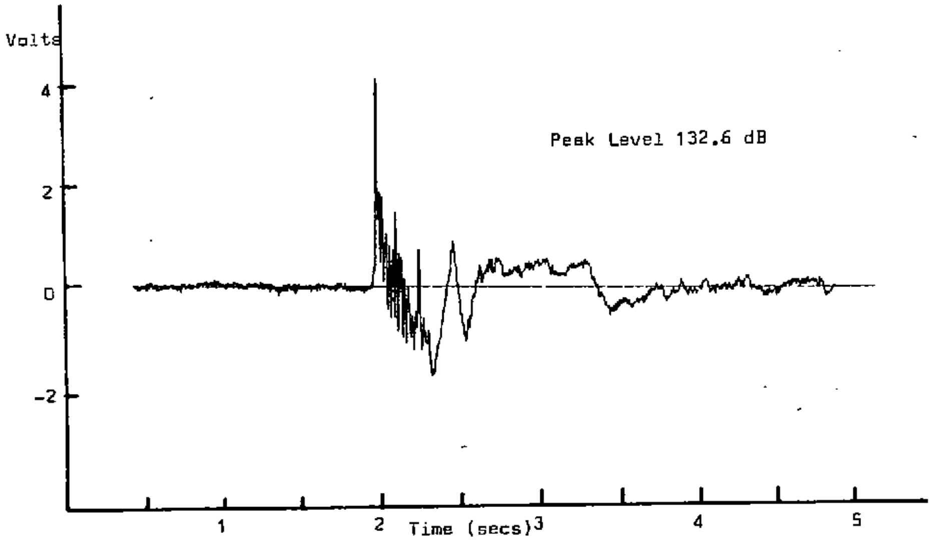

Fig. 1 Waveform of typical primary blast

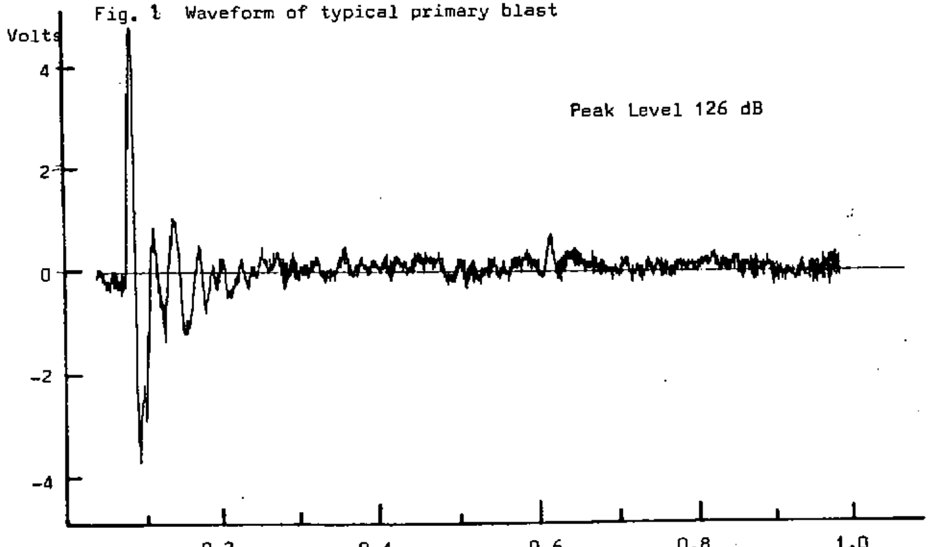

Fig. 2.Waveform of typical face dressing blast

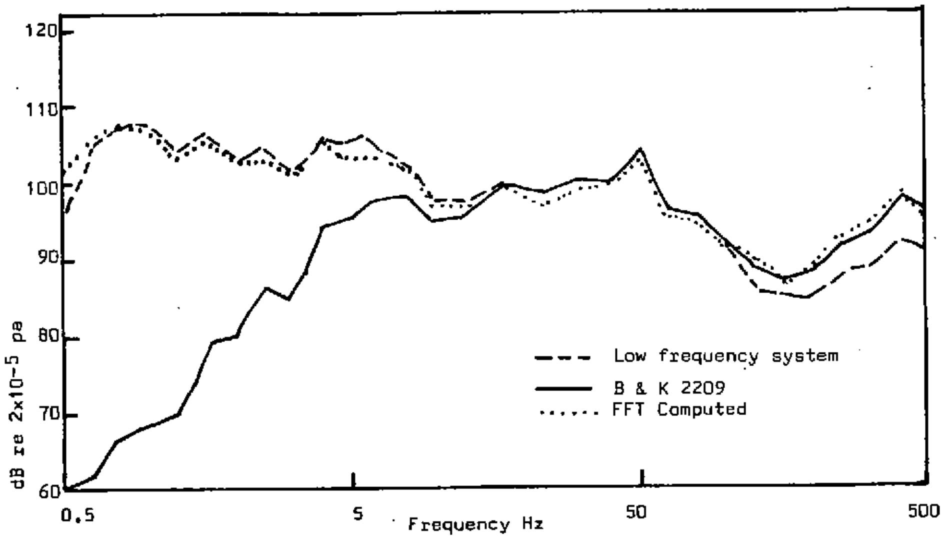

Fig. 3 Typical spectra of primary blast

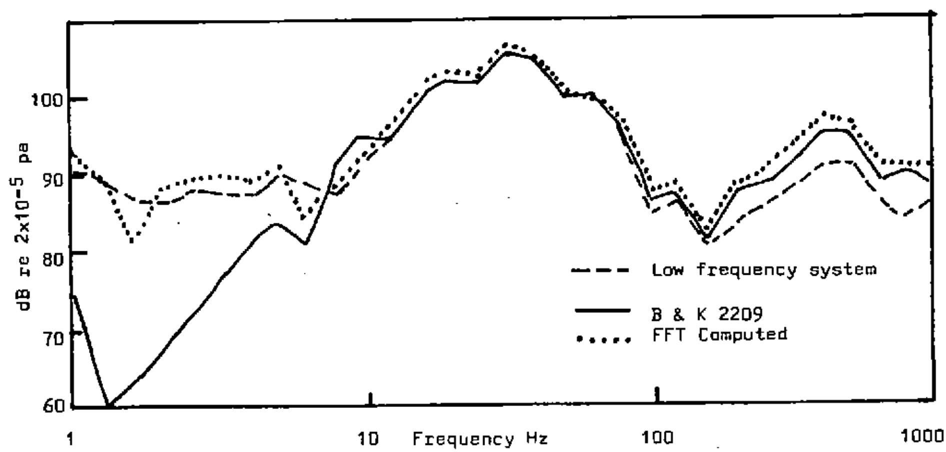

Fig. 4 Typical spectra of face dressing blasts

TRAFFIC NOISE LEVELS IN THE REGION OF ROUNDABOUTS

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One area where the U.K. prediction method for L_{10} 18 hr, given in "Calculation of Road Traffic Noise" requires further investigation is in situations where flow is restricted at junctions. This paper considers the behaviour of noise levels at roundabouts by means of direct measurements, and a digital computer simulation.

The site plan for the roundabout is shown in Figure 1. This lies on a trunk road with a 97km/hr limit. 18 hr vehicle flows were approximately 18,000 on the N and S arms and 6,500 on the E arm with 43% heavies. At distances of 6m from the kerb 18 hrs noise levels were measured simultaneously on both sides of the road at various distances from the roundabout on the N arm at the positions shown. The differences between the measured L_{10} 18 hrs levels and those predicted using the suggested DOE method, are shown in Figure 2.

(a) A difference of upto + 4 dB(A) at 100m adjacent to the departing stream and a difference of -4.5 dB(A) at 25m adjacent to the approaching stream are observed.

(b) The erratic nature of the approaching side curve is probably indicative of some fairly complicated manoeuvering behaviour in approaching vehicles (queuing).

(c) As expected the curves tend to the predicted L_{10} 18 hr level beyond 350m.

This experiment leads to the general conclusion that measurements of L_{10} 18 hr adjacent to accelerating streams from roundabouts exceed the DOE prediction and those adjacent to decelerating streams are exceeded by the DOE predictions.

While measurements give the magnitude and extent of these deviations for particular cases and an indication of general trends, the wide range of factors affecting not only noise production, but also propagation, makes the derivation of predictive techniques from a small number of empirical results very difficult A possible prediction method, which can be adapted to individual sites and which allows sufficient control over all variables for the noise production mechanisms at junctions to be effectively studied, is by the use of computer simulation models. Within a digital computer a traffic flow model is developed for particular flow patterns and particular junction geometry. Each vehicle in the simulation has a noise level associated with it as a function of its instantaneous manoeuvering parameters (velocity and acceleration). Thus the total noise level at an observation position can be calculated at increments of time and a temporal noise level distribution function constructed. Hence L_{10}, L_{eq} and any other noise index based on this function. We are developing such models of priority junctions, traffic signal controlled intersections and roundabouts. Figure 3 illustrates the basic functions used in the simulation for noise levels from light and heavy vehicles in terms of velocity and acceleration. These functions were derived from measurements of instantaneous SPL, velocity and acceleration of over 1000 vehicles at roadside sites and over a range of manoeuvering conditions. Of the total number of measurements about 200 were of heavy vehicles.

The first runs of this roundabout simulation model were carried out recently. The junction geometry and traffic characteristics encountered at the roundabout were used to enable a comparison between measured and simulated results to be made. Table 1 shows that at this stage agreement is poor at several positions. This can probably be attributed to two main causes. First of all the inverse square law was used to calculate the attenuation of sound with distance from vehicles within the simulation, i.e. 6dB/doubling. This is a realistic value for hard ground conditions. However, at the measuring site it was obvious that for vehicles in certain areas of the junction the sound propagation was mainly over grassland so that a higher attenuation rate for vehicles in these areas would be more appropriate. Secondly, the SPL curves for heavies shown on Figure 3 were derived using proportions of heavies normally encountered in urban conditions. At the roundabout site a high proportion of very heavy

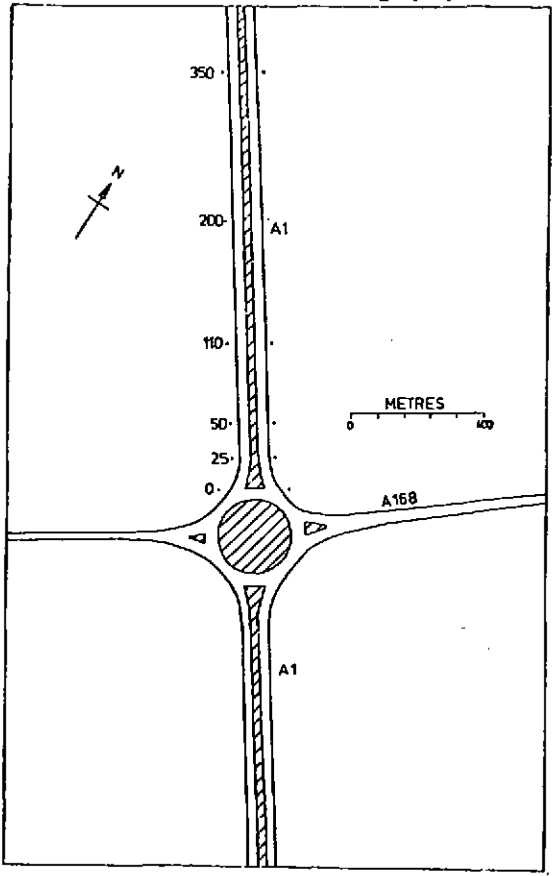


Figure 1. Measurement site.

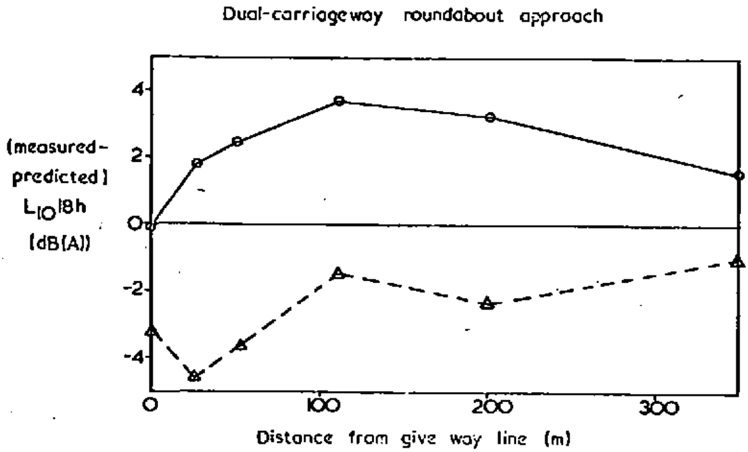
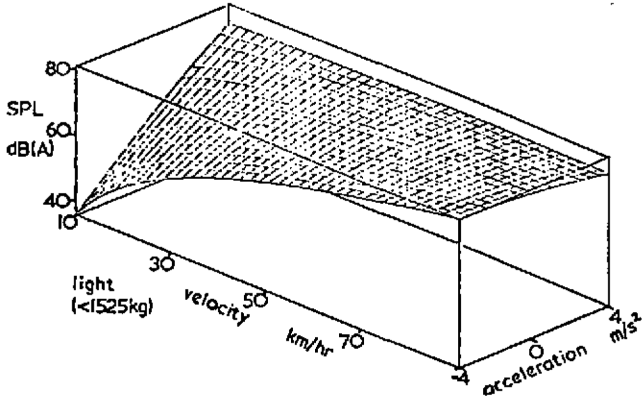
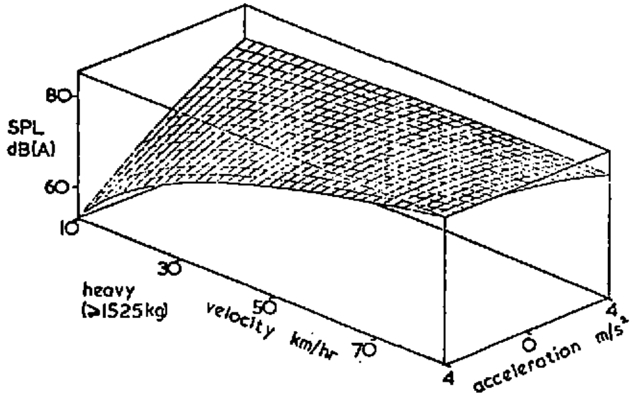


Figure 2. Comparison between L_{10} 18 hr measured and predicted.

Observation Position (W arm)	N - S		E		L_{10} dB(A)	
	Veh/hr	% heavies	Veh/hr	% heavies	Measured	Simulated
0m approach	1008	21.4	324	18.5	74.2	72.3
0m departure					70.1	72.1
25m approach	1356	21.2	336	14.3	78.9	76.1
25m departure					71.9	73.0
50m approach	1032	22.1	398	12.1	80.1	75.8
50m departure					73.9	74.1
110m approach	1176	25.5	660	25.5	77.6	77.6
110m departure					75.2	76.1
200m approach	1577	37.4	312	38.5	81.0	77.9
200m departure					75.9	77.7

Table 1. Roundabout simulation results.





mean, peak SPL at 7.5m from vehicle centre line

Figure 3. S.P.L. functions used in computer simulation.

vehicles occurred. This suggests that a greater number of vehicle classes would probably improve the simulated results in this particular case.

The analysis of a large amount of empirical data would enable prediction methods for noise levels at junctions to be refined beyond their present level in terms of simple corrections using parameters such as junction geometry, observer position, traffic composition, speed limit value etc. Computer modelling can usefully add to the data required for this type of prediction method. However, with further development computer modelling may enable traffic noise levels in the region of junctions to be predicted with increased accuracy when directly applied to individual cases.