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ASSESSMENT OF NOISE FROM PRIMARY BLASTING IN QUARRIES

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INTRODUCTION

Much of the stone output from quarries is used in the building and road construction industries. In the United Kingdom, quarries are usually sited on the sides of hills. The rock is extracted in steps or benches which may be up to 40 m deep. When quarry blasting, vertical holes of 100-175 mm diameter are drilled 3 to 6 m from the edge of the bench and the same distance approximately from each other. They are then filled with dynamite to a distance from the top about equal to the spacing and finally packed with quarry dust. The dynamite in each hole is then fired consecutively at 17 or 25 ms time intervals so that the rock peels away from the bench. The stone debris is subsequently collected for processing to size.

There appears to be a correlation between the environmental acceptability of the noise produced by the explosion and the peak overpressure level. Siskind and Summers (1) have indicated that a peak linear overpressure of 128 dB should be regarded as a caution threshold with 136 dB as the maximum allowable. They also report the linear relationship between the peak overpressure and log $(L/M^{1/3})$. Term $L/M^{1/3}$ is called the scaled distance where L is the distance between the source of the blast and the receiver and M the maximum instantaneous charge of explosive being fired. This relationship does not allow for the effects of topography or surface covering in the vicinity of the quarry or the effects of geological faults in the rock. Other factors ignored are the variations in wind direction and velocity, temperature lapses and inversions and humidity, etc.

OBJECT OF THE INVESTIGATION

In this preliminary investigation it is shown that an allowance can be made for the barrier effect of topography so that a more accurate assessment can be made of the peak overpressure induced at any location in the area.

THE BARRIER ATTENUATION

Normally, because of the topography, the source of the explosion is hidden from the observer by the interposing land mass which acts as a sound barrier causing attenuation in excess of that anticipated from the inverse square law. For a point source, it has been shown (2) that the excess attenuation (A_b) for a continuous barrier is given by

$$A_b = 20 \log \frac{\sqrt{2\pi N}}{\tanh\sqrt{2\pi N}} + 5 \text{ dB} \quad \text{for } N \geq -0.2 \qquad \ldots . (1)$$
$$= 0 \quad \text{for } N < -0.2$$

where $N = \pm \frac{2}{\lambda}(A + B - d)$

λ = wavelength of the sound wave

d = straight-line distance between source and receiver

A + B = path length of wave travelling over barrier between source and receiver

A + B - d = path difference (see fig.4)

+/- sign = receiver in the shadow/bright zones respectively

The excess barrier attenuation has an upper limit of 24 dB (2).

ANALYSIS OF TEST RESULTS

In fig.1 (before correction) is shown a plot of peak overpressure to a base of log ($L/M^{1/3}$) for quarry B. The rate of attenuation of the line of best fit in units of dB per D.D. (doubling of distance) and the estimated population standard deviation of the test results from this line are given in Table 1, columns 1 and 2. Also included in the table are the results from eight other limestone quarries.

In fig.2 are shown typical octave band frequency spectra down to 31.5 Hz of peak overpressure recordings where there has been a frontal view of the firing. As a first approximation, the irregular pattern of each spectra has been replaced by its straight line of best fit. For 7 tests analysed, these lines decrease at a rate ranging between 1.0 and 4.4 dB per octave frequency with a mean value of 2.5 dB per octave. It was found that the line of best fit of the spectrum down to 8 Hz frequency approximated to the peak overpressure as measured on the sound level meter.

It is assumed that the initial overall noise level is the acoustic sum of the octave band noise levels as given by the above mean line of best fit down to 8 Hz frequency. The overall noise level after the barrier would then be the acoustic sum of the above octave band noise levels less their corresponding barrier attenuations as derived from equations 1. The overall barrier attenuation is the difference between the initial and final overall noise levels. In fig.3 is shown the theoretical relationship between the overall barrier attenuation and path difference based on an octave band spectrum decreasing at the mean rate of 2.5 dB per octave. The error in barrier attenuation introduced by this assumption should not exceed 2 dB.

When calculating the barrier attenuation, an elevation of the ground between the source of the explosion and the receiver is drawn to scale, the path difference measured and the attenuation determined from fig.3. Typical elevations are shown in fig.4. It is assumed that the noise source is located at the top of the explosive charge and the barrier is continuous. The barrier attenuation has been calculated for each test made in the quarry and added to its corresponding measured peak overpressure level to obtain the noise level assuming that the interposing land mass had been removed. These 'clear view' peak overpressure levels have now been plotted to a base of log scaled distance ($d/M^{1/3}$) as shown in fig.1 (after correction). In Table 1, columns 3 and 4, are indicated the attenuation rates of the lines of best fit and the estimated population standard deviations for the nine quarries investigated. The table shows that the maximum standard deviation of the 'clear view' peak overpressure has reduced from 8.19 to 4.66 dB. It would appear that the considerable excess attenuation that could have been caused by wind velocity and temperature variations with altitude (3) has not occurred in these tests.

Table 1. Summary of results for all quarries

Quarry	Number of Tests	Before correction dB/DD	Before correction $\hat{\sigma}$	After correction Best fit dB/DD	After correction Best fit $\hat{\sigma}$	After correction 6dB/DD $\hat{\sigma}$
A	6	5.29	1.85	6.17	2.78	2.79
B	14	8.92	8.19	5.15	2.72	2.81
C	8	2.76	4.42	6.57	4.29	4.32
D	7	8.41	3.01	5.35	4.53	4.57
E	5	2.47	6.78	4.83	3.46	4.37
F	9	3.56	5.47	4.51	3.20	3.30
G	8	-1.15	3.76	3.06	4.66	5.00
H	7	6.55	3.54	8.67	4.17	4.48
J	7	4.60	5.55	5.55	3.35	3.36
Column		1	2	3	4	5

It will be noted from Table 1, column 3, that the attenuation per D.D. varies between 3.06 and 8.67 dB. It is difficult to explain values below 6.0 dB although higher values could be attributed to environmental factors (3) and ground absorption. When there is no excess attenuation the theoretical value of 6 dB per D.D. should apply. In Table 1, column 5, is shown the standard deviation for the corrected test results assuming a modified line of best fit reducing at 6 dB per D.D. It will be noted that these standard deviations are of similar magnitude to those for the lines of best fit given in column 4. This modified line is also shown in fig.1. The peak overpressure at a particular location will vary from one explosion to the next. For practical application it is therefore necessary to determine the 'safe' line below which, for a given value of the scaled distance, the peak overpressure will not be exceeded on say 90% of all explosions. This 90% confidence limit will lie on a line parallel to the modified line and distance $\hat{\sigma}t_{0.9}$ above it where $t_{0.9}$ is the 90% confidence coefficient for the Student t-distribution. The 'safe' line is shown in fig.1 superimposed on the results obtained for quarry B.

CONCLUSIONS

It has been shown that the barrier attenuation due to the interposing land mass may be determined for a given source/receiver situation. This barrier attenuation can be added to the measured peak overpressure to obtain a 'free view' overpressure level. The 'free view' overpressure levels can be plotted against the logarithm of the scaled distance and a modified best fit line obtained decreasing at the rate of 6 dB per D.D. The corresponding population standard deviation of the test data from this line is then calculated. This information can then be applied to produce a 'safe' modified line of best fit parallel to the first and below which the peak overpressure will be expected to occur for a given percentage of firings. From this line can be deducted the barrier attenuation for a particular location to derive the safe peak overpressure at that point for a particular value of the scaled distance.

ACKNOWLEDGEMENTS

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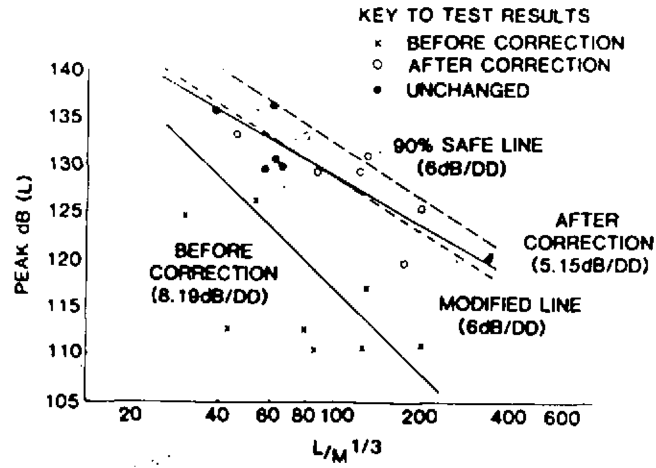

FIG 1 VARIATION OF PEAK OVERPRESSURE WITH SCALED DISTANCE FOR QUARRY B

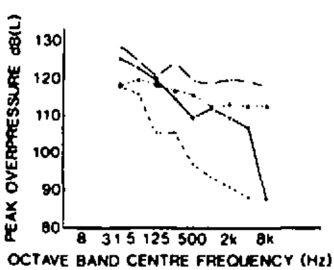

FIG 2 OCTAVE BAND SPECTRA FOR TESTS INSIDE QUARRY B

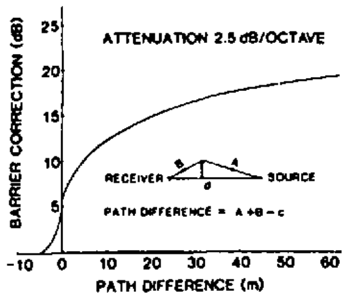

FIG 3 BARRIER CORRECTION CURVE

(a) DIRECT VIEW OF EXPLOSION

(b) EXPLOSION HIDDEN FROM RECEIVER

(c) RECEIVER BEHIND EXPLOSION

FIG 4 TYPICAL SOURCE/ RECEIVER ELEVATIONS