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AIRBORNE BLAST WAVES AND STRUCTURAL VIBRATION IN BUILDINGS

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Introduction

Buildings situated close to quarries, open-cast mines or any building operation which regularly uses explosives are subject to vibration. This vibration causes concern to the occupiers of the buildings, mainly because they associate it with possible damage to the building but also because it disturbs and annoys them. There are two sources of vibration input to a structure - a ground-borne wave and an airborne wave each of which is capable of exciting structural resonances.

During an investigation of explosive noise from quarrying operations, a disused farmhouse became available for use. This was instrumented to investigate the response of the building structure to both types of excitation over an extended period of time. In this paper the initial results of the investigation are presented.

Description of Property

The farm lies approximately 750 metres behind the quarry face and is built of stone in the traditional Derbyshire manner. A ground-floor room and a first floor room were used in the investigation. The intervening floor between the two rooms was replaced with a structure built to current Building Regulations. One half comprised a floor/ceiling section of 12mm T & G boarding 230mm x 50mm joists at 400 mm centres with a 12mm plasterboard ceiling with skimmed joints and a 5mm skim coat and the other a ceiling section with 75mm x 50mm joists and 12mm skimmed plasterboard. Additional timber hangers tied this section to the original roof joists which, together with the slates, were revealed following the removal of the first-floor ceiling.

Measuring Positions

The outside sound pressure was monitored by means of a hydrophone fixed on a pole exactly one metre from the east wall and at eaves height.

Internal sound pressures were monitored in each room, as appropriate, by suspending a microphone on the end of a cord 1.4 metres above the respective floor and in the centre of each room.

The vibration levels (vertical axis) were monitored in the centre of the solid ground floor; in the centre of the first-floor; in the centre of the ceiling section on a joist, and at the edge of the ceiling on a joist 100mm from the wall. Additional measurements were made in the horizontal axis on the east, west and north walls at a height of 300 mm above first-floor level and also on the slates and rafters on an axis normal to the plane of the roof.

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Instrumentation

To overcome the problems associated with outdoor noise monitoring, a B & K type 8101 hydrophone was used. Although obviously designed for underwater use, the sensitivity (approximately 630 mV/µPa) is sufficiently great to allow its use in air for sound levels above 100 dB. The low frequency response extends to below 1 Hz but there is an upper limit of approximately 4 kHz. Although it is not possible, using this device, to meet the International Standards requiring uniform high frequency response and omnidirectional characteristics, the response is adequate for quarry-blast monitoring. The dynamic range extends from 172 dB (re 20 µPa) to below 100 dB dependent upon the lower frequency required. The unit will operate over a temperature range from -10°C to +65 °C, and with a temperature sensitivity of 0.04 dB/°C the usual variation in outdoor temperature will affect the output by less than 1 dB. Low frequency signals due to wind noise were reduced by means of a 15 mm diameter foam windshield.

The internal sound pressure was detected on a conventional capacitor microphone system with a lower frequency limit of 2 Hz, and the vibration levels by means of various accelerometers. Of the four tracks available on the FM tape recorder, one was used to monitor the external sound pressure and the other three to monitor various combinations of internal vibration and noise.

The recording system was programmed to operate automatically twice a day for a 20-minute period covering the normal blasting schedule of the quarry. Accordingly a slow recording speed has been used and this sets the upper frequency limit at 600 Hz. However, it has been shown (ref 1) that this will be good enough for recording quarry blasts.

Analysis has been restricted, in the main, to measuring peak levels from a recorder trace either directly or via an electronic integrator to obtain velocity levels. Some records have been selected for analysis using a linear average $\frac{1}{3}$-octave band real time analyser (B & K type 2131) using the technique described in ref 1.

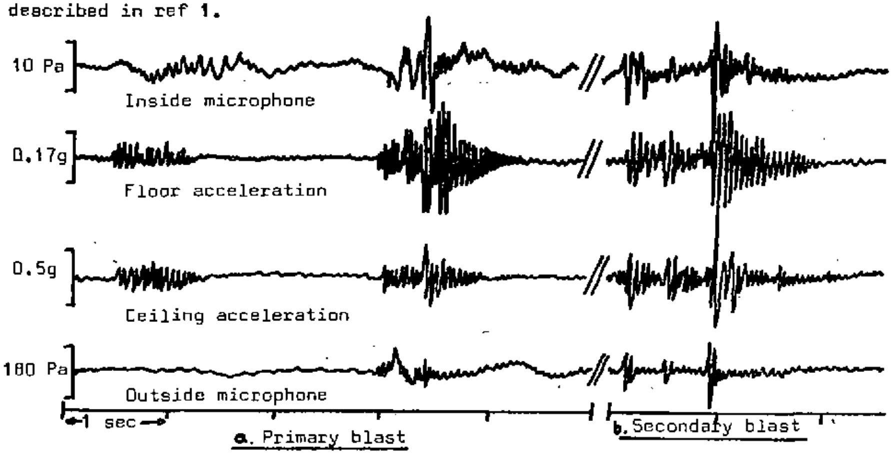

Figure 1

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Results

Responses of certain building elements to the ground wave and air wave are shown in figure 1. This indicates a typical pattern of events with the suspended floor and ceiling elements being excited to a greater extent by the air wave. It was also found that the external walls were excited by both the ground and air wave to a similar extent. The ground floor, which is solid and directly linked to the ground, reacted to a much greater extent to the ground wave.

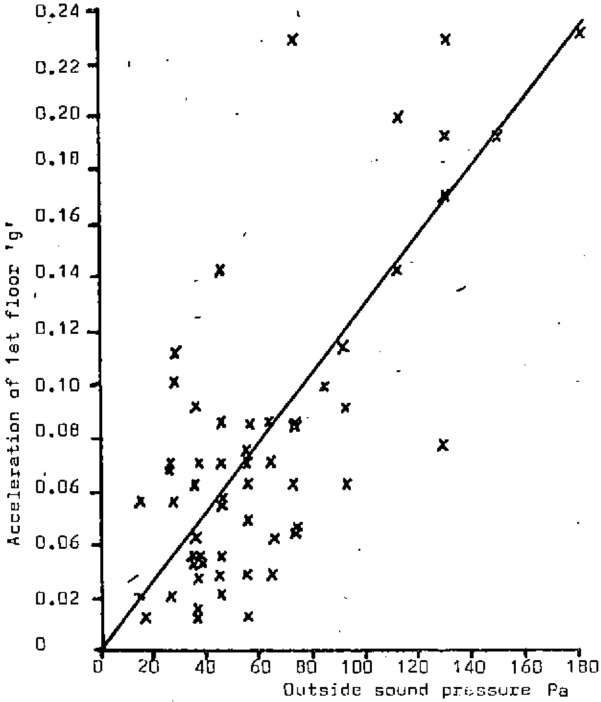
Figures 2 to 4 show the response of the suspended floor, suspended ceiling and front wall as a function of the outside pressure level.

Conclusions

1. The particle velocity levels in all the structural elements were below the currently accepted limit for damage of 50mm/s and no damage was observed.

2. The vibration levels in the wall and suspended floor are frequently above the acceptable levels suggested in the draft addendum to ISO2631 "Guide to the evaluation of human exposure to vibration and shock in buildings". The levels were compared with the day time impulsive limits given in the document.

Figure 2



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3. The air wave can be as important as the ground wave in exciting resonances in building elements. It is common practice to assess the effect of quarry blast induced vibrations by monitoring levels at ground level. The initial results of this work confirm earlier work (ref 2) that this may not indicate the total extent of the problem because of air wave excitation. Hence it is suggested that when assessing the subjective acceptability of vibrations levels should be monitored on other structural elements, such as floors.

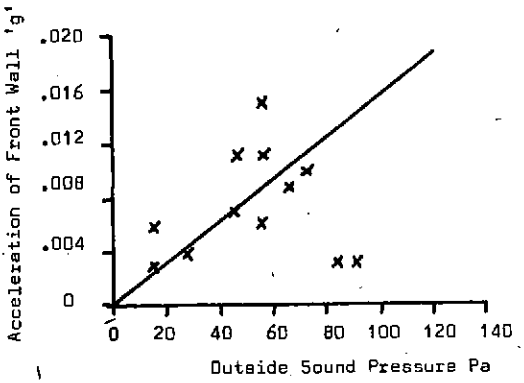

Figure 3

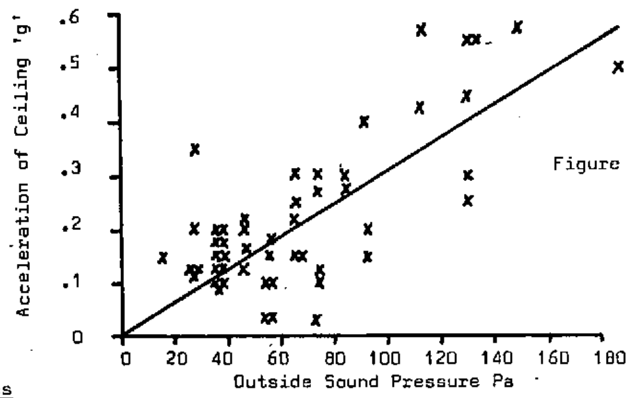

Figure 4

References

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   Kerry and Saunders. Proc IOA 1978

2. Noise and Vibrations in Residential Structures from Quarry Production Blasting
   Siskind et al. US Bu Mines R18168 1976