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ENVIRONMENTAL LOW FREQUENCY NOISE

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Over the past few years a number of complaints have arisen about environmental low frequency noise. Although inaudible to the casual listener, it appears to be the real cause of severe annoyance to the sufferers. Several common characteristics of these complaints and annoyance situations can be identified as follows:-

(a) The problem seems to arise most frequently in quiet rural or suburban environments. Complaints have been particularly prevalent by people in the 50-70 years age group, although younger people are also affected.

(b) The intrusive noise is often, apparently, so close to inaudibility in level that most people are not able to hear it.

(c) The noise is of a "throbbing" character and is typically audible indoors rather than outdoors.

(d) The noise would appear to be subject to background masking, being more audible at night than during the day.

(e) The complainants have variously described the noise as a "rumbly noise", "the noise of a diesel truck with its engine at idle" and "throbbing noise".

The source of the problem, therefore, would appear to have a low frequency character. This study particularly deals with the frequency range 2 - 200 Hz.

The work can be split into two parts. (1) A long-term survey and (2) Field measurements.

(1) Survey In order to understand the nature of this mysterious noise problem a random selection of 40 sufferers from Southern England was included in this survey. They were requested to monitor the daily variation of the noise. They rated the noise as being quiet, mild, heavy, very heavy or violent. The survey covered two periods, (i) August-October 1977 (ii) June-October 1978. A typical result is shown in figure 1.

The X-axis represents the hour of the day, Y-axis represents the rating scale and the Z-axis represents the day of the month. The major conclusions arising from this long survey can be summarised as follows:

(i) Between persons, identical rating is not to be expected; individual differences must account for this.

(ii) However, a general trend of daily variation does exist. The noise problem is particularly annoying between late evening and early morning hours.

(iii) 60% of the subjects thought the problem was all the more serious during bad weather or winter months.

In order to distinguish between problems which are imagined or self-generated and those which have their origin in real acoustic phenomena, the complainants were invited to the College to take part in hearing tests. Only eighteen (of the above 40 people) could take part in the hearing tests. These tests form the subject matter of a companion paper by Walford (ref.1). Participants in the hearing tests also completed a questionnaire. Apart from confirming the general characteristics of the noise referred to, earlier, the following points emerged:-

(i) Most sufferers find the intensity is reduced only partially when they close their ears with ear plugs or ear muffs. The noise appears to be subject to masking when the T.V. or radio is on.

(ii) Most sufferers identify the noise as being of a low frequency character. But some thought it contained both low and high frequencies.

(2) Field Measurements Field measurements were made at several locations. A combination of Bruel and Kjaer precision sound level meter (2209) and Real Time Analyser (PARC 4512) was used all the time. In some instances, tape recordings were also made on a SE Lab Eight-Four portable FM tape recorder. These were used for more detailed analysis at a subsequent time. The analysis range was usually restricted to 2 to 200 Hz. The analysis bandwidth was 0.25 Hz. The analysis time was five minutes in each case. This ensured an accuracy of ± 1 dB with a confidence level of 98%. The system was calibrated before and after each measurement using a pistonphone. Prior to each measurement the electrical noise floor of the measuring system was established by using a dummy microphone. The measurements in every instance showed the electrical floor level to lie well below the recorded acoustic levels.

Figure 2 summarises the result of measurements made at a location in Chiswick. When the noise was heard by the complainant and rated as being heavy, the appearance of a clear peak at 48.8 Hz is noteworthy. In addition, the level itself has risen by 15 dB, bringing it close to the ISO threshold curve (ISO/R226 - 1961).

Figure 3 summarises spectra obtained in a flat in Woking. When the complainant was not troubled by the intrusive noise, outdoor levels below 50 Hz lie well below threshold. However, when the noise was clearly audible to the occupant of the house as well as the experimenter, not only does a clear peak emerge at 40 Hz but also the level rises well above threshold.

All the evidence presented so far suggests that throbbing noise nuisance can be associated with distinct pure tone components. Earlier work by Vasudevan and Gordon (ref.2) at Southampton University does present evidence for also associating throbbing noise situations with spectra which are entirely devoid of any pure tone components - but of an unbalanced spectrum shape, (fig.4). The level of the spectrum changes very substantially from time to time and on the two occasions when the throbbing noise was said to be audible, the spectrum levels lay close to or above the ISO threshold curve.

Where pure tone components have been identifiable, future work must inevitably be directed at locating the offending source. A three element microphone array system mounted on a portable frame is under construction for this purpose. With this, it is hoped that in some instances at least, the mystery behind the throbbing noise will be removed, thus alleviating the annoyance associated with it.

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(2) R. N. Vasudevan and Colin G. Gordon 1977 Applied Acoustics **10**, 57-69. Experimental study of annoyance due to low frequency environmental noise.

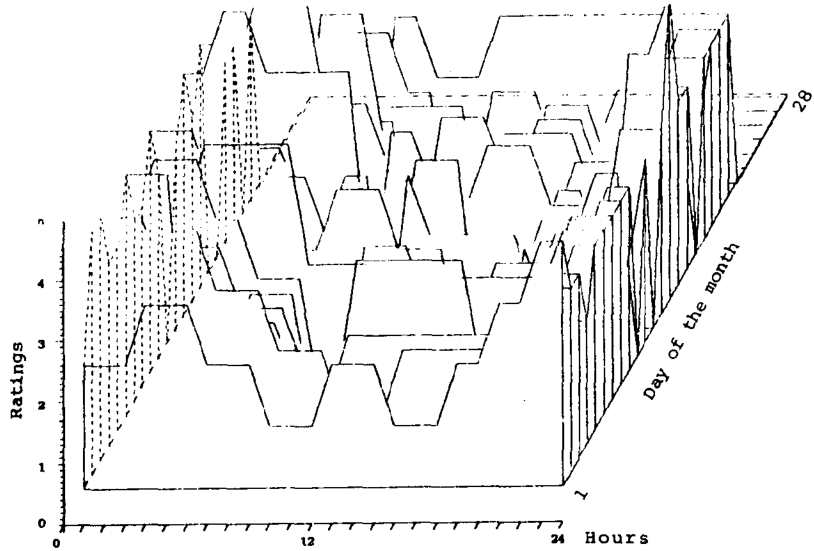

Fig. 1 Diurnal variation during August, 1977.

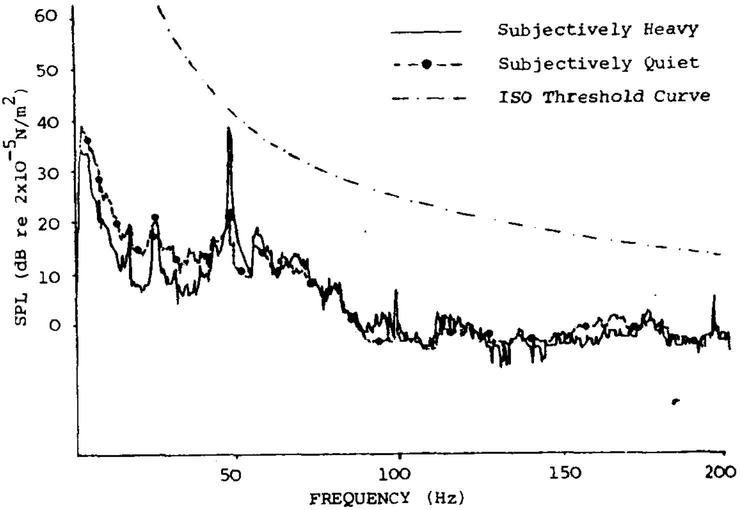

Fig.2 Indoor spectra at a location in Chiswick

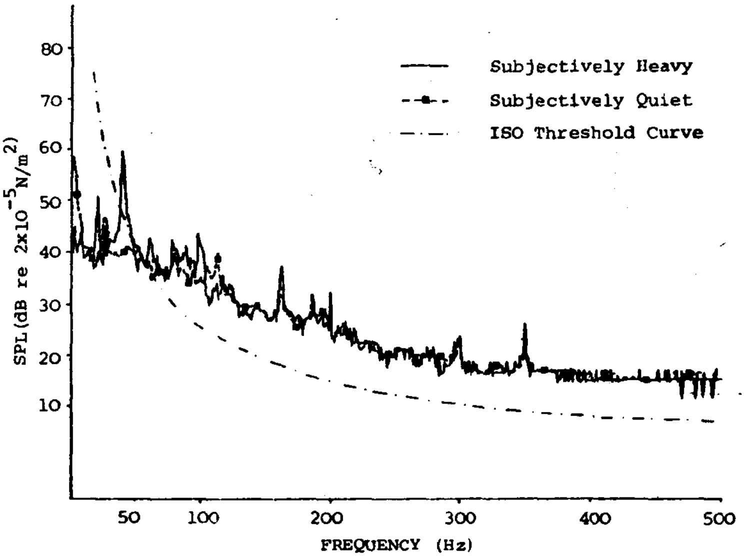

Fig.3 Outdoor spectra at a location in Woking

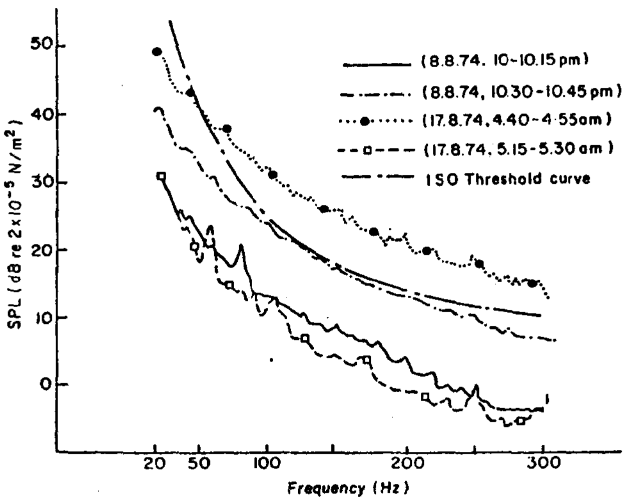

Fig.4 Indoor spectra at a location in New Forest

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THE ATTENUATION OF LOW FREQUENCY SOUND BY BUILDING FACADES

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INTRODUCTION

Much research has been done on the sound insulation of building facades in the frequency range 100 Hz to 4000 Hz. However, little information is available at frequencies below 100 Hz and therefore this project attempted to measure the low frequency sound insulation of a variety of building facades. The frequency range of measurements was chosen to be 2 Hz to 1 kHz with the results analysed in $\frac{1}{3}$ octave bands from 2 Hz and in octave bands from 125 Hz to 1 kHz.

This frequency range includes the fundamental resonant frequencies of most rooms and building facade elements and therefore it was expected that resonances would have a major effect on the measured transmission loss.

MEASUREMENT TECHNIQUE

i) Field measurements

Simultaneous recordings were made inside and outside each building facade in the presence of high levels of external ambient noise, usually due to traffic. Ambient noise had to be utilised, as a portable sound source for the frequency range of interest was not practicable. The external microphone was positioned 1m away from the building facade and opposite the centre of any window. The internal microphone was positioned in a room corner in order to respond to all room resonant modes. Due to the difficulty of measuring the acoustic absorption of room surfaces at the low frequencies under investigation no attempt was made to allow for the effect of the room and therefore the results obtained are for the complete room/window combination.

ii) Laboratory analysis

Various methods of laboratory analysis were investigated. The system which proved most satisfactory was one in which the simultaneous inside and outside tape recordings were traced sequentially onto the same section of level recorder paper, after appropriate filtering. The transmission loss was then estimated visually. This system had the following advantages.

a) Any equipment fault was immediately apparent.

b) The degree of accuracy which could be attached to the results could be observed.

c) If one or other signal fell below the noise floor of the measuring equipment this could be seen.

d) Any spurious noises, especially on the inside signal, could be seen.

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All the previous points could be checked by observing the degree of correlation between the inside and outside signal traces.

THEORY

Of the various theoretical treatments available to describe the situation under investigation the most useful was considered to be that by Guy and Bhattacharya 1973. They derived an equation for the transmission loss of a flexible panel backed by a rigid cavity, in terms of the panel and cavity acoustic impedences and a coupling co-efficient which in turn depended on the panel and cavity resonant mode numbers. This theory has been shown to give good agreement with measurements made on models constructed to be as close to the theoretical ideal as possible. However, for the present results good agreement was not obtained.

RESULTS

A typical result is shown in figure 1. The majority of transmission loss curves followed this shape. The main characteristics of all results were as follows:

i) A transmission loss of between +5 or -5 from 2 Hz to approximately 8 Hz.

ii) A rise in transmission loss at approximately 6 dB per octave to approximately 20 Hz.

iii) A room and window resonance region between 30 Hz and 100 Hz which can reduce the transmission loss to 5 to 10 dB at the resonant frequencies.

Figure 2 shows the result of a test carried out before and after double glazing was installed. The double glazing was achieved by installing an extra frame behind the existing one giving a pane separation of approximately 100mm. It can be seen that the double glazing gives inferior sound attenuation at some frequencies. This is probably due to the additional possible resonant modes introduced by the second panel. At frequencies above 100 Hz however, the double glazing gives greater attenuation than single glazing, as would be expected.

Figure 3 shows the average attenuation of all the measurements made. The shape of these curves are fairly representative of the individual results except individual results all showed resonant variations between approximately 30 and 100 Hz.

REFERENCE

R. W. Guy and M. C. Bhattacharya 1973. Journal of Sound and Vibration, Vol. 27(2), pages 207-223. The transmission of sound through a Cavity Backed Finite Plate.

Fig. 1. Typical result

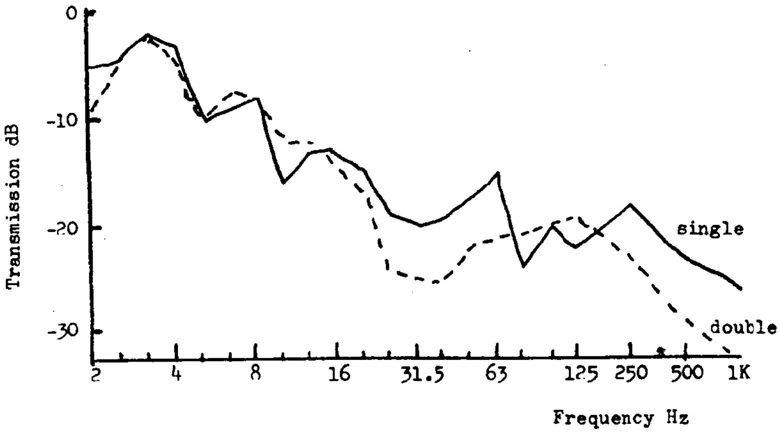

Fig. 2. Comparison of single and double glazing

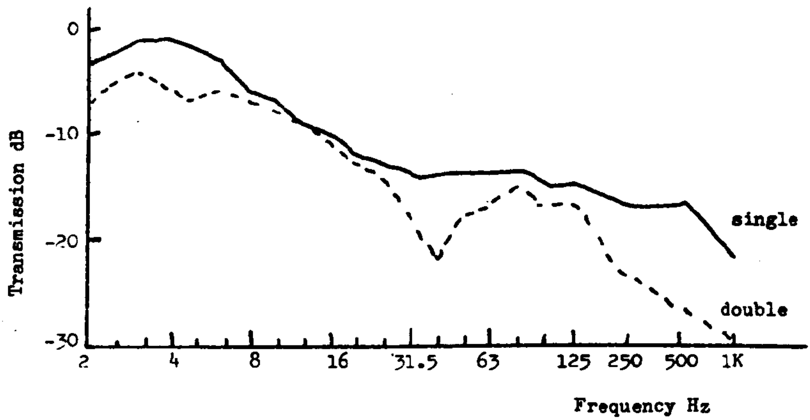

Fig. 3 Average of all results

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CRITERIA FOR THE ASSESSMENT OF LOW FREQUENCY NOISE

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Introduction

Over the last few years, it has become apparent that annoyance due to low frequency noise sources such as boilers, burners and ventilation systems is more common than originally thought (Anon, 1977; Broner 1978). In most cases, the response of the disturbed individual has been much more extreme than would be expected based on a dBA criterion (Tempest, 1973, Bryan, 1976) and some evidence indicates that this may be due to the unbalanced nature of the spectrum (Kraemer, 1973, Vasudevan and Gordon, 1977). This paper reports some of the results of a psychophysical investigation into the annoyance due to low frequency noise and indicates a superior criterion for its assessment.

Annoyance Response Measurement

The magnitude-estimation technique, in which the subject assigns numbers to quantify his perception, was used. It has been shown that subjects can successfully quantify their sensations for over two dozen continua (S.S. Stevens 1960, 1976, Marks 1974).

Subjects

20 subjects, 10 males and 10 females, participated in the experiment. They were either University staff or post-graduate students and had a mean age of 31 years and a standard deviation of 10.5 years. All reported good hearing and all had no prior experience with the magnitude estimation task.

Stimuli

The noise stimuli consisted of the seven 10 Hz bandwidths between 20-90 Hz and each was presented at an overall sound pressure level of 90, 100 and 105 dB. A sequence for the 21 stimuli thus obtained was generated randomly with the provision that no two adjacent stimuli should be of the same frequency range. The dBA range was 45.8-82.2 dB, whilst it was 68.1-96.8 dB for the dBB noise measure and 46.7-80.7 dB for the dBE measure.

Method

Each subject carried out the estimation task in the Chelsea College low frequency noise test chamber (Leventhall and Hood, 1971). The first stimulus was assigned randomly and then the sequence of 21 stimuli was completed. Each stimulus was presented for 20 seconds with a 10 second break between stimuli (during which the subject responded), resulting in an overall test session length of 10.5 minutes.

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Results

The log of the geometric mean of annoyance for the group of 20 subjects as a whole was correlated with each of ten noise measures over the three overall sound pressure levels (see the Table). Figure 1 shows the least squares regression line of best fit for the subjective annoyance against both dBA and dBB, and it can be seen that the spread about the line of best fit is larger for the dBA than for the dBB. This is reflected in the highest correlation coefficient and smaller standard error of the estimate for the dBB measure as shown in the Table. It can also be seen that except for the PNdB measure, every one of the other eight measures yields a higher correlation coefficient than that obtained against the dBA ($r = 0.926$). None of the differences are statistically significant (at $P < .05$ or better) but this may have been due to the small number of subjects employed in this study. As overall the correlation coefficients are very high, greater numbers of subjects may be required to show reliably what appears to be the case - that the PNdB* (the PNdB modified to account for low frequencies) and dBB in particular, gave the highest correlations, (see Broner and Leventhall, 1979).

Conclusion

As there is reason to believe that the dBA measure is not the best predictor for low frequency noise annoyance, it would seem valid to tentatively suggest the PNdB* or dBB as better alternatives. However, as the PNdB* calculation method is relatively laborious, the dBB noise measure, which is widely available on sound level meters, is indicated as the most suitable for general use in predicting the annoyance due to higher level low-frequency noise. The E-weighting, which was recently standardized for use in human response studies, does not seem as useful.

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