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TOWARDS THE PREDICTION OF TRAFFIC-INDUCED VIBRATION

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A report entitled 'Road Traffic and the Environment' (Ref.1) published in 1978 gives the results of a broadly based social survey designed to represent the attitudes of the adult population of England to road traffic. The questionnaire covered a wide range of topics relating to general disturbance by road traffic and other external factors. Because of the nature of the survey sample it is possible to determine the proportion of the population which is subjected to or disturbed by a particular factor. This survey has been referred to by some people as a National Environmental Survey.

One of the topics specifically studied in the above survey was the disturbance from vibration caused by traffic in the home (sic). 10% of the respondents claimed to experience vibration 'often' and a further 27% 'occasionally'. In all, 38% of this random sample of the population stated that they experience vibration from road traffic and 8% claim to be bothered 'quite a lot' or 'very much'. The responses are also broken down according to the peak hour traffic flow outside the dwelling. As would be expected the percentage of the sample who experience vibration increases as the traffic volume rises but it is interesting to note that the proportions of respondents experiencing vibration who are 'disturbed' and 'seriously disturbed' remain relatively constant for traffic flows from 6 to 1800 vehicles per hour. Although physical measurements were made of the traffic flows and noise levels in the areas where this social survey was carried out, no measurements were made of the vibration levels that gave rise to these responses. Nevertheless, from these results it is clear that traffic induced vibration greatly concerns a large number of people and should not be dismissed as a minor problem. However, if it is to be considered as part of the planning process it is essential to be able to make some kind of prediction of vibration levels at the design stage.

Over the last three years therefore, the Greater London Council and the Transport and Road Research Laboratory have collaborated in a study of vibration in dwellings caused by road traffic. The early work on this project considered the relative importance of vibration propagating through the ground and low frequency noise propagating through the air as the primary transmission paths for traffic vibration in buildings (Refs.2&3). Although ground borne vibration originating from road/wheel contact can be the major cause of problems in some situations, in the majority of cases vibration in the buildings adjoining roads was found to result from low frequency sound entering the building and subsequently exciting the structure.

The Transport and Road Research Laboratory have carried out a further social survey to obtain more detailed information on the reaction of people to the vibration in dwellings induced by a wide range of traffic volumes. Some preliminary results of this survey were presented at the 1979 Spring Conference of the Institute held at Southampton (Ref.4). At the same conference the author of this paper described the details of the physical measurements of vibration in dwellings that had been taken by the Greater London Council to support this social survey (Ref.5). That paper gave details of the measurement and analysis techniques used and presented some preliminary findings. The measurements have provided typical levels of traffic induced vibration that people are subjected to in their homes and which they are reacting to in their responses to social surveys. Further analysis has now been carried out and this paper gives some of the findings.

The measurements were made in one occupied suburban dwelling at each of the 14 social survey sites within the Greater London area. The dwellings were all two storeys high, built during the inter-war period and were mostly semi-detached. Each measurement consisted of simultaneous 20 minute FM recordings of the signals generated by external noise and internal vertical vibration in the wooden floor. The external noise was measured 1 m from the facade (generally about 10 m from the kerb) while the vibration was measured at the centre of the front ground floor room of each dwelling. Traffic counts were also taken during the measurement period. The traffic volumes at the sites produced an even distribution over the range 170 - 2800 vehicles per hour with the percentage of heavy vehicles ranging from 9 - 41%. The tape recordings were subsequently analysed in the laboratory to produce a range of percentile levels and the L_{eq} in 1/3 octave bands for frequency ranges from 3 Hz to 2000 Hz.

The external noise exhibits a very uniform spectral shape but the absolute level of the spectrum varies with the differences in the traffic flows at each of the sites. For the floor vibration, however, both the level and the spectral shape vary widely. Every site exhibits a unique spectral characteristic although the survey was designed in the belief that the buildings used were of a uniform type. It seems probable that these spectral differences are due to small variations in room dimensions, window sizes and many other factors which contribute to the resonances within the room and conditions the buildings' response to the traffic noise stimulus. Despite this variability in the vibration response at individual sites, the mean values of noise and vibration for all 14 sites together (published in Ref.5) give very similar spectral shapes although there are differences in the standard deviations. Not surprisingly, given the variability in the vibration spectra, there is a very poor correlation between external noise levels and vibration levels in the floor if all 14 sites are grouped. If anything, the correlations between the vibration levels and the traffic flows are worse.

Any variability resulting from the differences between individual sites can be excluded from the analysis by looking at the correlation between the two signals at each site separately. This has been achieved by reanalysing the tape recordings in successive periods of 0.8 minute duration and using the results for these short periods to obtain correlations between the two signals for each site in turn. The results of this analysis show much stronger relationships, correlation coefficients of .9 are not uncommon and the majority of values are highly significant. Having obtained reasonable correlations, linear regression analysis was used to provide equations for the relationships between exteranl noise and vibration at each site over the range of 1/3 octave bands from 25 to 250 Hz.

Figure 1 gives an example of the 'family' of regression equations for one of the 1/3 octave bands. It can be seen that the gradients of the regression lines are generally similar but that the absolute values vary between individual sites. The similarity in the gradients makes it reasonable to consider using a 'mean gradient' to predict changes in vibration level due to changes in the external noise level at a particular frequency. This mean gradient has not been calculated as a simple arithmetic average, but has been weighted to take account of the reliability of each of the constituent values as given by its correlation coefficient. The relationship that has been used to derive the mean gradient $\bar{m}$ is

$$\bar{m} = \frac{\sum (m_i \cdot |r_i|)}{\sum |r_i|}$$

where m_i and r_i are respectively the gradient and correlation coefficient for the i th site. The mean gradients for the peak frequencies in the noise spectra are given in Figure 2.

A relationship has thus been established which enables changes in vibration to be predicted from changes in external noise level. Because the gradients have been separated from their associated intercepts in the regression equations it is not possible to use this result to predict directly the absolute level of vibration.

Using conventional multiple regression analysis, equations have been developed which enable 1/3 octave band L_{eq} levels for traffic noise to be predicted from the total traffic flow and percentage of heavy vehicles. The form of the equation is very similar to existing techniques for predicting L_{10} dB(A) levels (Ref 6). Further work would, however, be required to include terms for speed and distance as these were effectively held constant by the design of this experiment.

Simple techniques for predicting absolute vibration levels directly from traffic parameters are not possible at present and seem unlikely in the foreseeable future. However, from the results described above it can be seen that limited predictions of future vibration levels are possible in a specific, but commonly occurring situation (suburban dwelling of conventional construction). Changes in floor vibration level can be predicted from changes in external noise level. The noise level can itself be predicted directly from traffic volumes. In this way an indirect relationship between traffic induced vibration in floors and the traffic causing it has been established.

References

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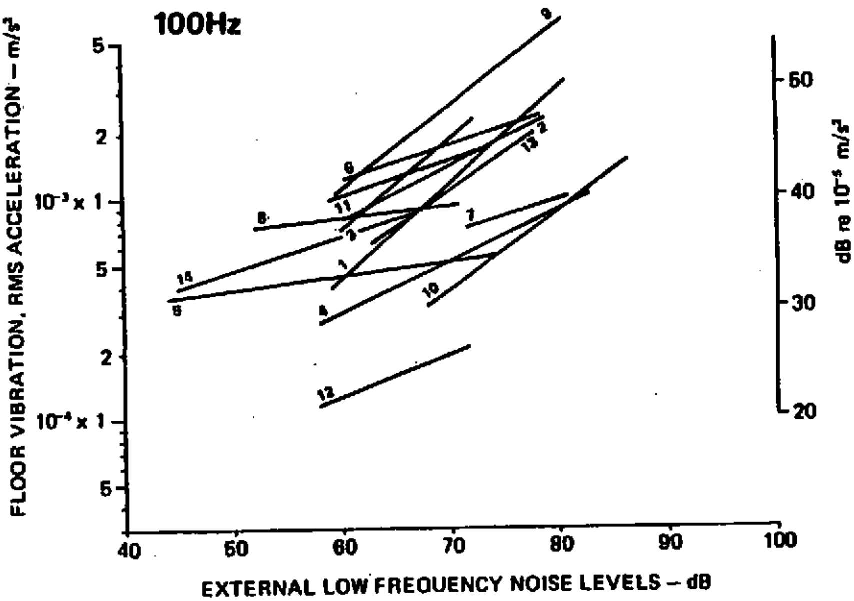

FIGURE 1 L_{eq} Regression Lines for all 14 Sites

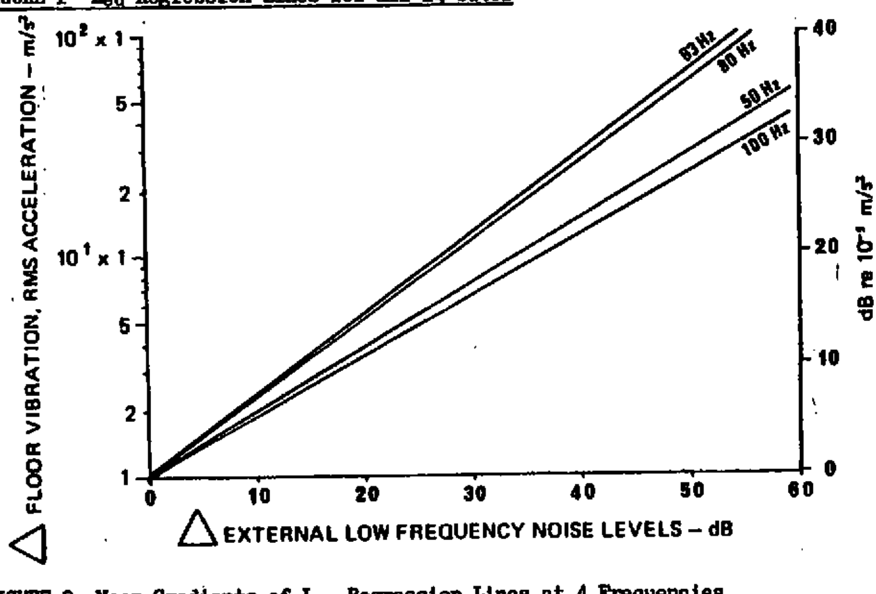

FIGURE 2 Mean Gradients of L_{eq} Regression Lines at 4 Frequencies