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FLOOR MOBILITY IN THE ESTIMATION OF STRUCTUREBORNE EMISSION FROM PLANT ROOM MACHINERY

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1. INTRODUCTION

Mechanical services in the form of plant room machinery are potential sources of airborne, ductborne, and structureborne noise. Methods for the prediction and control of airborne and ductborne sound are generally well understood, whereas the same cannot be said for structureborne sound.

The awareness of the importance of structureborne transmission and radiation in building structures has increased over the past few years, but there remains a lack of information on structureborne emission of machines including the effect of supporting floor mobility. An ISO working group [1] has been assigned this problem in order to characterise machines as sources of structureborne sound. The methods proposed, as of 1986, are outlined in reference [2].

In this paper the associated effect of floor mobility is investigated by means of a limited field survey of typical plant rooms. The power flow (P) into a floor structure of mobility (Y) due to an applied point force (F) exciting a velocity (v) is given in [3] as,

$$P = \frac{1}{2}\,\mathfrak{Re}(\underline{Y})\,\underline{F}^2 = \frac{1}{2}\,\frac{\underline{v}^2}{\mathfrak{Re}(\underline{Y})}$$

and the importance of the prediction or measurement of mobility can be clearly seen. The prediction of the mobility of a structure is relatively straightforward for simple cases, for example an infinite thin isotropic plate, but when a more complex structure is studied such as a plant room floor the theory is likely to be more complicated. The work presented here attempts to show that for all intents and purposes a plant room floor can be treated as a thin isotropic plate.

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For simplicity the results presented in this paper are for only one degree of freedom; that of translation in the z-axis.

2. PREDICTION OF MOBILITY

The prediction of the characteristic mobility of a thin isotropic plate has been well documented by many workers, see for example [3-6], and is dependent only upon the thickness of the plate (h), its density (ρ), its longitudinal wave speed (c_L), and its' Poisson ratio (υ),

$$Y_C = \frac{\sqrt{12(1-\upsilon^2)}}{8\rho c_L h^2} \approx \frac{\sqrt{3}}{4\rho c_L h^2}$$

The prediction of an upper limit, is obtained from,

$$Y_r = \frac{4}{M\omega\eta}$$

where M is the mass of the plate and η is the total loss factor composed of material and edge losses, and Craik [7] gives that $\eta \approx 1/f^{1/2}$ for frequencies above 100Hz.

At high frequencies the upper limit tends towards that of the characteristic mobility.

3. MEASUREMENT OF MOBILITY

The force mobility of a structure (Y_F) is obtained by measurement of the ratio of its velocity (v) due to a excitation force (F).

In this investigation the force mobility was measured by means of an accelerometer attached to the structure under the impact of a hammer containing a force transducer. Division of the transfer function between force and acceleration by ω yields the force mobility.

For each floor investigated a number of (typically five) measurements were performed to allow both a maximum and average mobility to be computed. The maximum mobility could thus be compared with the predicted upper limit, and the average with the predicted characteristic.

For each of five positions in each room the average accelerance (a/F) was obtained for sixteen hammer hits. Post-processing using a BBC Master microcomputer and IEEE488 interface transfer allowed division by ω and computation of mobilities in a calibrated logarithmic format of dB($10\log_{10}$) re 1 $ms^{-1}N^{-1}$

4. RESULTS

Prediction and measurement were performed on a total of ten operational plant rooms within the University precinct. Prediction was based upon information gained from plans of the building when available, or by measurement of dimensions where access allowed. Generally accepted values of material density, longitudinal wave speed, loss factor and Poisson ratio were used. Dimensions of the plant rooms studied are given in Table 1.

Room	1	2	3	4	5	6	7	8	9	10
Length	54.41	54.41	9.5	22.56	13.23	9.17	13.2	8.18	13.44	11.48
Width	6.44	4.24	8	10.36	7.95	6.05	4.16	6.77	6.77	6.77
Thickness	0.229	0.102	0.17	0.112	0.175	0.202	0.127	0.285	0.275	0.275

Table 1. Floor dimensions of the ten plant rooms studied (metres).

From Table 1 it can be seen that the thickness of plant room floors tested are in the range 0.102 to 0.285 metres, and consequently, the predicted characteristic mobilities are in the range -53 to -63 dB re 1 $ms^{-1}N^{-1}$.

A typical display of average and maximum mobilities are given in Figures 1 and 2 along with the predicted characteristic and upper limit mobilities for a frequency range 0-500Hz. Figure 1 contains measurements performed on a relatively small floor of 11.48x6.77x0.275 metres for which the upper limit bears some resemblance to the maximum mobility, although it cannot be said to exceed it. Figure 2 is is for a large room of floor dimensions 54.41x4.24x0.102 metres and it can be seen that damping effects have been overestimated. However, the average mobility gives fair agreement with characteristic above 100 Hz.

5. CONCLUSIONS

For the limited survey of plant rooms conducted:

i) The characteristic and measured average mobilities agree well in most cases
ii) For all the rooms in no case is the maximum mobility greater than 10 dB above characteristic
iii) The characteristic mobility is within the range -50 dB to -65 dB re 1 $ms^{-1}N^{-1}$ for the floors investigated
iv) Prediction of the upper limit was less successful and the estimate of total loss factor remains problematical

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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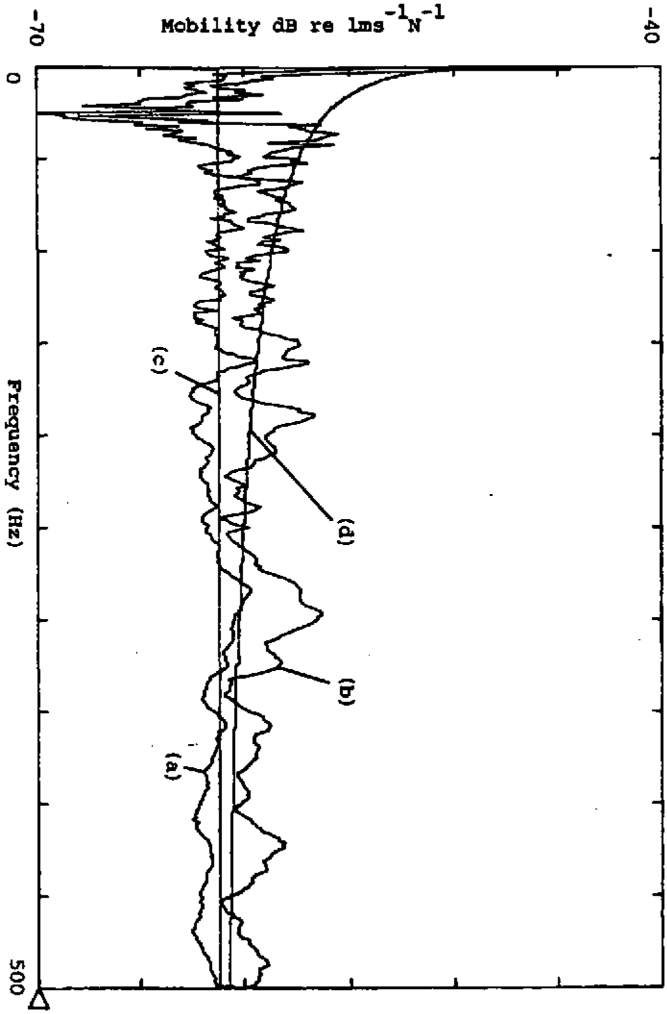

Figure 1. Mobilities (dB re 1 ms^{-1}N^{-1}) for a 11.48x6.77x0.285 m floor. (a) average, (b) maximum, (c) characteristic, (d) upper limit.

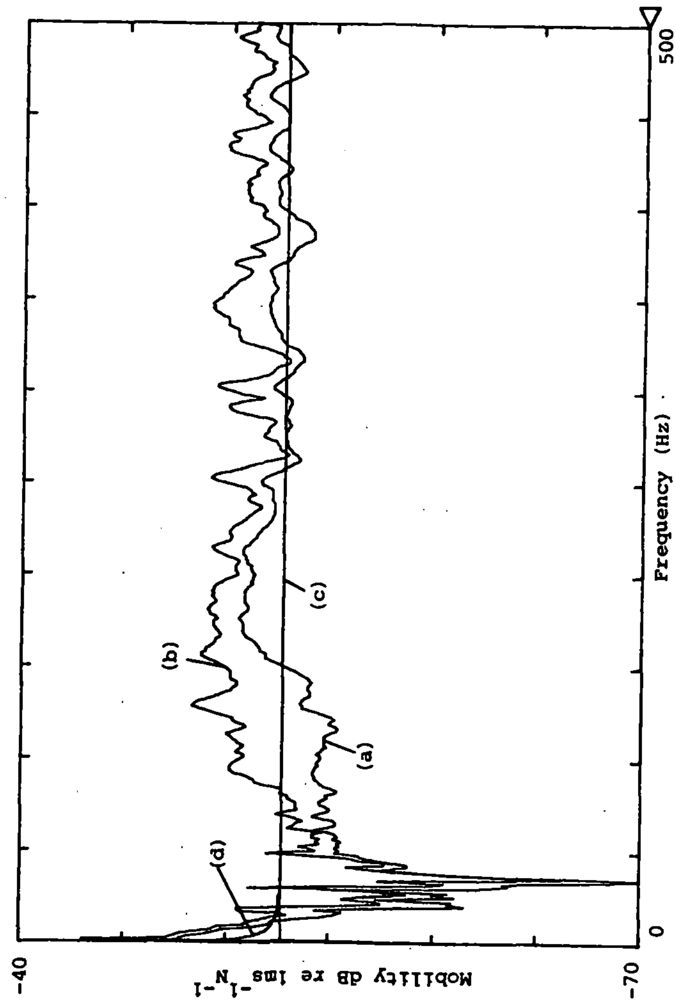

Figure 2. Mobilities (dB re 1 $ms^{-1}N^{-1}$) for a 54.41x4.24x0.102 m floor.
(a) average, (b) maximum, (c) characteristic, (d) upper limit.