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# MEASUREMENT OF BUILDING ELEMENT MOBILITY

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## INTRODUCTION

For many types of noise problem in buildings it is found that the noise originates with an external force acting on the building structure. Examples include almost all types of plant and equipment. The amount of sound (power) that enters the structure depends on the mobility (ratio of velocity to force) of the structure.

When the excitation of the structure is at mid or high frequencies then a wall or floor of a building can be considered to be a large infinite plate and the infinite plate mobility can be used to determine the structural response. However, at lower frequencies, in the region of the first few modes, it is found that there are large fluctuations in the mobility depending on whether or not the structure is excited at a resonant mode.

In this paper the magnitude of the fluctuations in the mobility are examined and some simple equations are produced which give the upper and lower limits to the mobility.

## THEORY

For the prediction of mobility estimates of resonance frequencies, mass and damping are required. The resonance frequencies, $f_{mn}$, for simply supported plates are given by [1],

$$f_{mn} = 0.45hC \left[\frac{m^2}{l_x^2} + \frac{n^2}{l_y^2}\right] \qquad (1)$$

where h is the plate thickness, C is the longitudinal wavespeed, $l_x$ and $l_y$ are the plate dimensions and m and n are integers taking values of 1,2,3,.....

The real part of the mobility, Y, of a single plate mode is given by [1].

$$Y = \frac{1}{2\pi f_i \eta m \left[1 + \left(\frac{f_i}{f} - \frac{f}{f_i}\right)^2 \frac{1}{\eta^2}\right]} \tag{2}$$

where $f_i$ is the ith resonance frequency, m is the mass and $\eta$ is the total loss factor. This can be approximated to $f^{-1/2}$ [2].

The infinite plate mobility, $Y_\infty$ is given by [1],

$$Y_\infty = \frac{1}{2.3\rho_s hC} \tag{3}$$

where $\rho_s$ is the surface density. At low frequencies the mobility fluctuates about the infinite plate value as shown in Fig 1. The maximum mobility occurs on resonance at $f=f_i$. Dividing eqn(2) by (3) gives the ratio

$$\frac{Y_{peak}}{Y_\infty} = \frac{2}{\pi f \eta n} \tag{4}$$

where n is the modal density. This is the upper limit for the mobility.

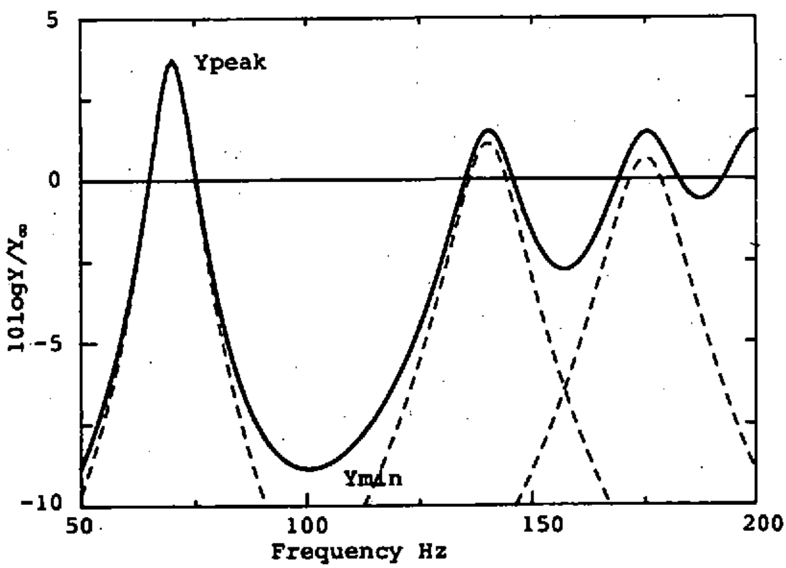


Fig 1. Typical mobility curve (real part). ———— total mobility; - - - individual modal response.

If measurements are made in 1/3 octave bands then the average mobility, <Y>, averaged over the 1/3 octave band is required. Assuming the entire modal response is contained within the measurement band and assuming that there is only one mode in that band gives the ratio of <Y>, to $Y_\infty$ as [3],

$$\frac{\langle Y \rangle}{Y_\infty} = \frac{1}{N} \tag{5}$$

where N is the statistical mode count for the frequency band. This is only valid where N < 1.

The minimum mobility occurs where the frequency band of interest lies between two modes as shown in Fig 1. Combining the responses of the nearest two modes gives the ratio of the minimum mobility to infinite plate mobility as [3]

$$\frac{Y_{min}}{Y_\infty} = \frac{4f\eta n}{\pi} \tag{6}$$

clearly this is only valid when $4f\eta n/\pi < 1$.

Therefore given the modal density and damping the upper and lower limits of the mobility curves can be determined. The upper limit is approached where there is a mode in a band and the lower limit is approached where there are no modes in a frequency band. Averaging over frequency reduces the magnitude of fluctuations above and below the mean.

## EXPERIMENT

To measure the mobility of a building element it is necessary to excite the element by a point force and measure the resulting velocity. This can be readily carried out using a hammer with a force transducer to give the applied force and an accelerometer to give the velocity. The set up is shown in Fig 2.

Measurements were made on a number of walls and floors in a building. For each wall (or floor) ten impulses were recorded at each of twenty positions. The average real part of the mobility was calculated for comparison with predictions.

The best position for the accelerometer was found to be about 50mm from the point of impact or on the opposite side of the wall from the point of impact, to avoid any effects of local stiffness on the measurements. Local stiffness only affects the imaginary part of the mobility which is not considered in this paper.

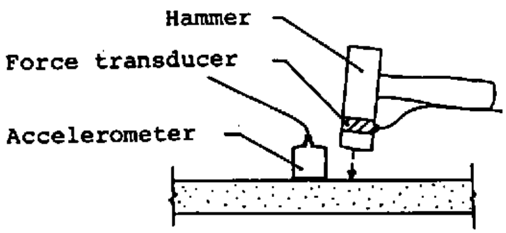


Fig 2. Typical setup for the measurement of mobility.

## RESULTS

The results of the measurements on four walls are shown in Figs 3 and 4. The data is shown as a ratio of the real part of the mobility to the predicted infinite plate mobility. In Fig 3 the results for two identical concrete block walls, 1.09 x 2.32 x 0.15m, are shown together with the predicted mobility.

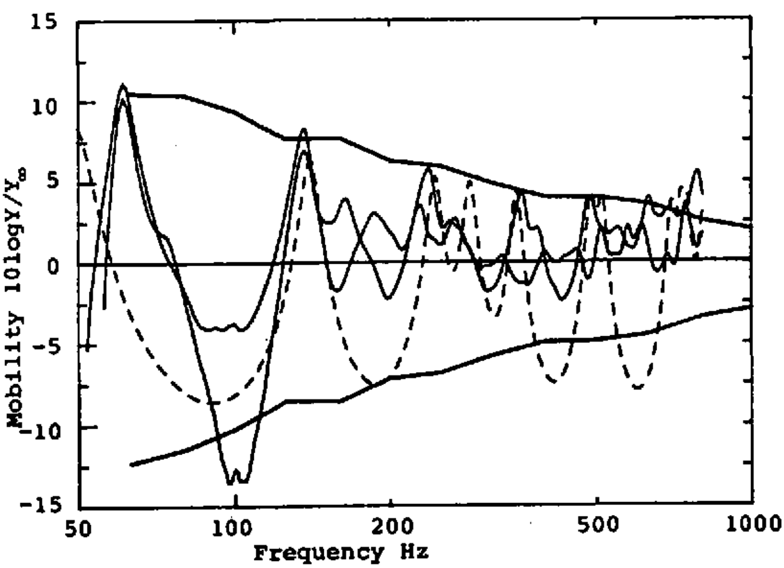


Fig 3. Measured and predicted mobility (real part) of two identical walls. ____ measured mobility; - - - predicted mobility; ——— upper and lower limits.

As can be seen the shape of the measured curves are very similar but the predicted 1st mode frequency is slightly low. The results lie inside the upper and lower limits of eqns(4) and (6).

In Fig 4 the results for another two walls, 0.659 x 2.32 x 0.15m are presented. While one measured curve is very similar to the predicted result the other is not. Although the walls have the same dimensions there is a difference between measured first modes of 26Hz. This is an indication of the variations possible in the modal frequencies of building elements. The results are contained within the upper and lower limits though the measured results do not approach the lower limit.

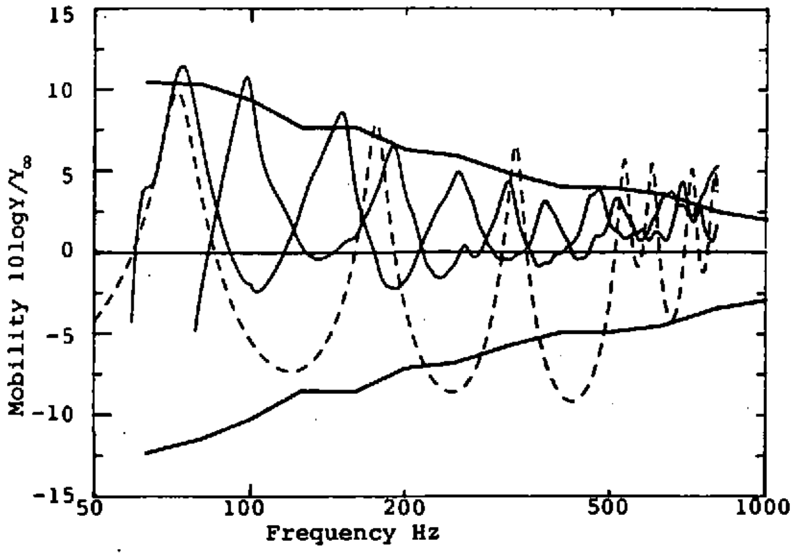


Fig 4. Measured and predicted mobility (real part) of two identical walls. _____ measured mobility; - - - predicted mobility; ——— upper and lower limits.

These results are typical for the results obtained for measurements on small and large walls, concrete floors and brick columns.

## CONCLUSIONS

Mobility predictions show reasonable agreement with measured results and both the measured and predicted results show good agreement with the predicted upper and lower limits. However it is clear that actual resonance frequencies cannot be predicted with accuracy.

When a building structure is excited at low frequencies where there are few, if any resonant modes, then the exact response of the structure will be difficult to predict due to uncertainty in the actual mode frequencies. However the upper and lower limits of the mobility can be computed which do not require a knowledge of actual resonant frequencies.

## ACKNOWLEDGEMENTS

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