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# INCLUSION OF DAMPING IN A FEM MODEL OF LOW FREQUENCY SOUND IN ROOMS

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## ABSTRACT
A Finite Element (FE) model was developed to investigate the sound insulation between dwellings at low frequencies. It has been found that for small empty rooms (smaller than 50m$^3$), the airborne sound insulation properties of the party wall depend on the structural modal characteristic of the party wall and on the acoustic modal characteristics of the two rooms. They therefore are influenced by the edge conditions of the party wall and by room configuration and size. As dwellings usually are furnished, it also is necessary to examine the effects of localized absorption on the acoustic modal characteristic. Preliminary comparisons between measurements and prediction of the frequency response and sound level difference were promising despite the fact that damping was not included in the FE model. At higher frequencies, the agreement is less good for the empty room and damping must be included in an appropriate form, before investigating the effects of furniture and fittings. Different ways of including 'room' damping are considered and comparisons between measured and predicted frequency response were carried out to validate the FE model.

## 1 - INTRODUCTION
The airborne sound insulation in dwellings at low frequencies has been investigated by developing a Finite Element (FE) model [1]. The model was validated by comparing measurements and predictions, which were promising despite the fact that damping was not included in the model. The outcomes of this investigation highlighted that the sound pressure level difference is controlled by the modal characteristics of the party wall and of the acoustic fields of the two empty rooms. However, the aim of this investigation is to recreate what is happening in dwellings. As rooms usually are furnished, it then becomes necessary to examine the effects of surface and localized absorption on the acoustic modal characteristic and level difference. Damping must therefore be included in the FE model of an empty room in a suitable form before investigating the effects of furniture and fittings. The present paper describes the adjustments to the FE model in order to obtain the most accurate predicted frequency response for empty rooms.

## 2 - MEASUREMENTS
The sound field of different room constructions have been investigated, including brickwork walls, concrete floor and concrete ceiling, and timber-frame walls and timber floors. The acoustic fields were measured using MLSSA [2] and a large speaker, located in a corner, with a flat frequency response from 30Hz to 2kHz. The room frequency response was measured from 25Hz up to 205Hz, for each room.

## 3 - ASSIGNMENT OF DAMPING TO THE ACOUSTIC F.E. MODEL
Using the same software package as in a previous investigation [1−3], different F.E. models were defined to represent the field measurements. The model was defined according to the room dimensions and to the upper frequency of interest, 205Hz. The acoustic modes were processed and a point source defined at a corner of the room. The frequency response was processed at field points identified from the selected microphone positions in the field. The power of the real speaker being unknown, the predicted frequency response was adjusted to the measurements by visual inspection.

Acoustic damping can be included in the acoustic F.E. model either by assigning a complex admittance to the six surfaces or by providing a modal damping factor to the room modes. The surface admittance, which relates to the absorption coefficient, is included as an impedance matrix C to the undamped expression of the acoustic field. The sound field is expressed as

$$\left([K] + i\omega\,[C] - \omega^2\,[M]\right)\{p\} = -i\rho_0\omega\,\{Q\} \tag{1}$$

where $K$ is the stiffness matrix and $M$ is the mass matrix; where $p$ and $Q$ are the amplitudes of nodal pressures and flows, respectively. In this model, the surface absorption must be assigned before processing the room modes and therefore does not vary with frequency.
The modal damping is equivalent to adding an extra imaginary term proportional to the eigenfrequency and can vary between 0 (i.e. no damping) to unity. The advantage of this method compared with the surface absorption is that a frequency dependent value can be assigned.

## 4 - EFFECT OF SURFACE ABSORPTION

At present, no accurate method of measurement for absorption at low frequencies is available [4,5]. Therefore, preliminary estimates were made by calculating the acoustic damping from the half-power bandwidth of the peaks of the measured room response. Half-power bandwidth can only be estimated from well separated peaks. However, despite the non-statistical acoustic field of small rooms, only one or two peaks were sufficiently separated in the frequency range of interest. Therefore, a best fit was obtained by incremental variation of input damping.
Figure 1 shows the measured and predicted frequency response of a room of plastered brick walls and concrete floor and ceiling. The room dimensions are 5.75 x 4.88 x 4.24m. Peaks and dips are displayed and show that a surface of assumed absorption coefficient of 0.02 gives a best agreement with measurement.

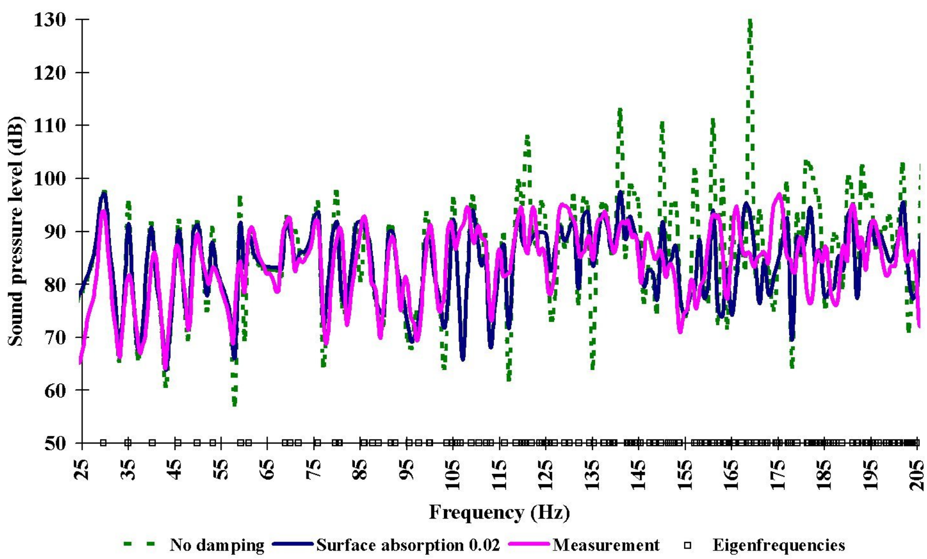


**Figure 1:** Surface absorption to model the frequency response of a room with brick walls and concrete floor and ceiling.

Figure 2 shows the measured and predicted frequency response of a room with plasterboard and timber-frame walls, floor and ceiling for a range of surface absorption coefficients. The room of dimensions 4.24 x 2.84 x 2.40m was a bedroom in a semi-detached house. The predicted curves display the same signature as the measured. Agreement is best for values of absorption coefficient around 0.15.
Figure 3 shows the predicted and measured frequency responses with a resolution of 1/12 octave band. An absorption coefficient of 0.15 seems the most appropriate to represent the sound field. However, as seen in Figures 1 and 2, agreements could be improved in some parts of the spectra by setting different values.
Adjustment of the FE model by modal damping also was considered. Figure 4 displays the predicted frequency response for different values of modal damping compared with the frequency response of the room with plastered and timber-frame walls. The room of dimensions 2.62 x 2.32 x 2.40m also was a

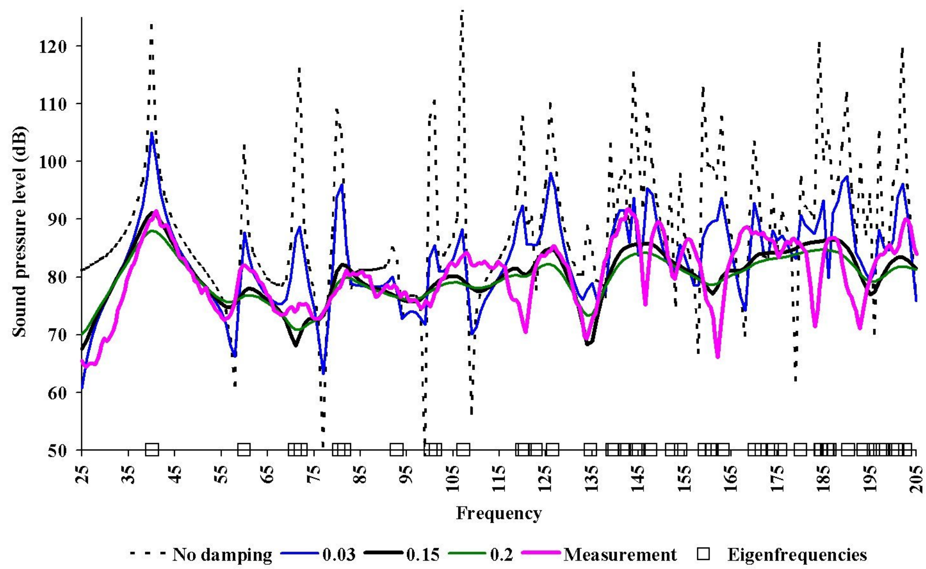


**Figure 2:** Surface absorption to model the frequency response of a room with timber-frame walls, floor and ceiling.

bedroom in a semi-detached house. It can be observed again that the predicted frequency responses have the same signature as the measured frequency response. A modal damping of 0.05 gives a predicted response that is over-damped values above 120Hz whereas a modal damping of 0.025 gives better agreement. This agreement can be improved by assigning different values of modal damping to different parts of the spectrum. For example, a value of 0.05 up to 120Hz, 0.025 up to 135Hz and 0.01 up to 175Hz.

## 5 - CONCLUDING REMARKS

Attempts were made to improve the agreement between field measurements and predictions by assigning a surface absorption or modal damping to the acoustic F.E. model. It was found that both methods provide good agreement between measurements and prediction over the frequency range of interest. Modal damping offers the advantage that the damping can be varied with frequency. However it is not suitable for investigating the effect of furniture which might introduce frequency shifts and extra peaks as well as damping to the room response. It seems therefore more appropriate to consider the surface admittance method which not only reproduces the effect of the acoustic damping on the frequency response but can also include the effect of wall vibrations. It was observed that a surface absorption coefficient of 0.02 is required to model a room made of brickwork and concrete and a surface absorption coefficient of 0.15 is required for a room of plastered timber-frame walls, floor and ceiling.

## ACKNOWLEDGEMENTS

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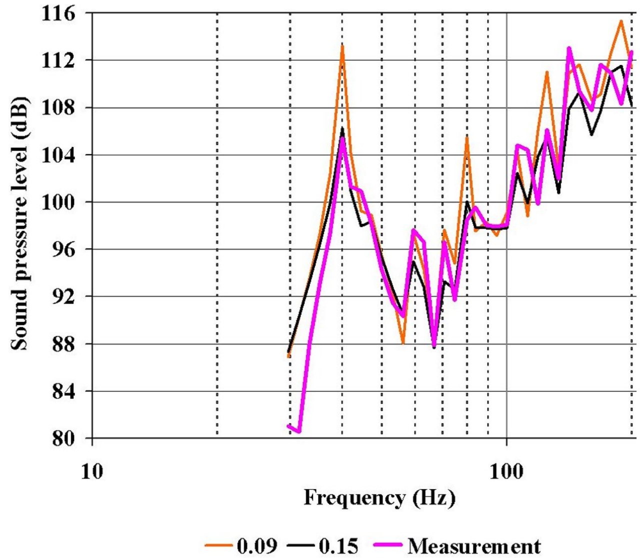


**Figure 3:** Surface absorption compared with measured with a 1/12 octave band resolution.

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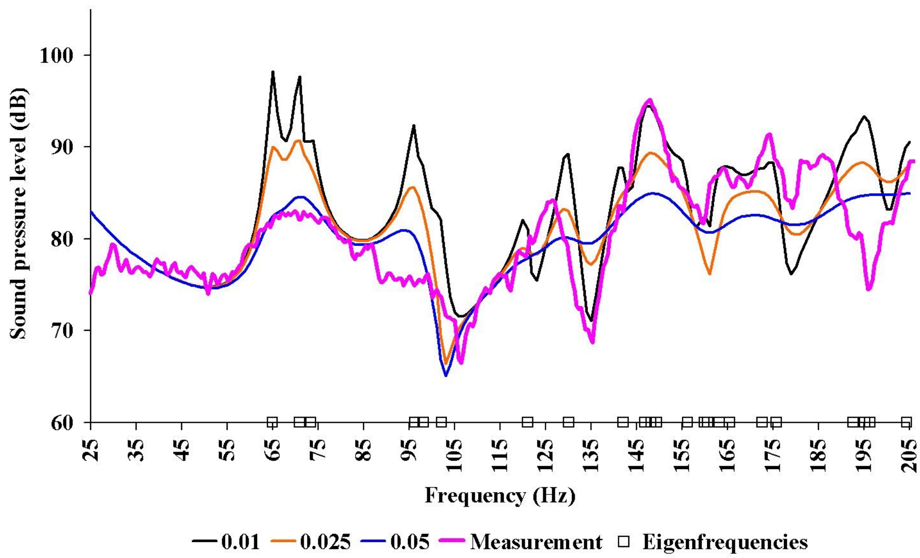


**Figure 4:** Effect of modal damping on the predicted frequency response of room with timber-frame walls.