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PREDICTION OF SOUND TRANSMISSION IN THE BRE FLANKING LABORATORY USING STATISTICAL ENERGY ANALYSIS

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INTRODUCTION

In order to provide a design tool for calculating sound insulation between and within dwellings[1], BRE is developing a computer model using Statistical Energy Analysis (SEA). Predictions from this SEA model are then being checked against measurements made in the BRE Flanking Laboratory to validate the theory used. Some results are presented in this paper, and underlying theoretical considerations for the comparison of measured and predicted data are discussed.

THEORETICAL BACKGROUND

In SEA[2,3], a building 'system' is represented by its individual subsystems of which the most common types are rooms, walls, floors and cavities. Coupling between these subsystems gives rise to a net power flow from subsystems of high modal energy to those of low modal energy. With knowledge of all the Total Loss Factors (TLFs) and Coupling Loss Factors (CLFs) in the 'system' it is possible to calculate the overall performance using matrix methods. This gives the energy levels in each of the subsystems from which Energy Level Differences (ELDs) can be calculated for comparison with measured data. However, in SEA, non-resonant (mass law) transmission is represented by a CLF between rooms/cavities and does not give rise to energy in the intervening structure. This means that it is not always appropriate to look at ELDs involving energy levels of the structure at frequencies where non-resonant transmission is significant. In these cases it may be more useful to look at the predicted power radiated by the structure for comparison with measured sound power levels (PWL). The measured energy level in the source room can be corrected for higher energy density near the wall surfaces with the Waterhouse correction and used with the predicted ELD to give energy levels in cavities and walls from which to calculate radiated power due to resonant and non-resonant paths. When resonant transmission is dominant, a combination of predicted ELDs and predicted sound power levels can be used to assess the radiation efficiency used in the SEA model.

Wall TLFs were calculated using the method described by Craik[4], with CLFs between walls calculated using bending wave transmission from Cremer et al[2]. The CLF between walls and rooms is dependent on the radiation efficiency for which two models are used, a thin plate version[3] for the chipboard and plasterboard panels, and a thick plate version[5] for the masonry walls. The wall cavity SEA parameters were based on the theory of Price and Crocker[6], with the CLF for the ties from Craik and Wilson[7].

BRE FLANKING LABORATORY

Details of the test construction which is built into the U shaped shell of the flanking laboratory are shown in Figure 1. The timber joist floor that separates the two levels supports the plasterboard ceiling and flooring grade chipboard with joists built into the separating wall leaves 5,6,7 and 8.

MEASUREMENTS

Measured data used for comparison with the predicted data in this paper were obtained using wide band noise in the chosen source room. The measurements included the sound pressure level in each room, the acceleration of all the room surfaces and the sound intensity level from those surfaces emitting sufficient sound power for reliable measurements.

The following measured data were incorporated into the SEA prediction model

a) the room reverberation times which were used to give room TLFs;

b) the reverberation time[4] of the concrete ground floor which was used to give the floor TLF;

and

c) the longitudinal wavespeed[8] of all the materials which was needed to give critical frequency values in order to determine the radiation efficiency.

RESULTS

The main transmission path between rooms 1 and 3 is through the timber joist floor. A mode count was used to give the modal density of the floor cavities between the joists because the cavities are long and narrow and there are 1/3 octaves below 125Hz without resonant modes. Predicted ELDs for individual transmission paths between source room 3 and room 1 via the timber joist floor are shown in Figure 2. Below 1kHz the dominant path is path A, with non-resonant transmission across the chipboard from room 3 into the cavities and non-resonant transmission across the plasterboard from the cavities into room 1. This makes it necessary to use PWL for comparison of measured and predicted data in this frequency range. Between 1kHz and 2kHz, path C, which includes resonant transmission from the chipboard into the cavities is dominant. Above 2kHz the dominant path is path D, this path includes resonant transmission from the plasterboard into room 1. The measured data for the timber joist floor in Figure 3 shows good agreement with the prediction except in the 1250Hz and 1600Hz 1/3 octave bands where the thin plate radiation efficiency near the chipboard critical frequency is too high. However, above 2kHz where resonant transmission from the plasterboard is dominant, there is very good agreement with the thin plate radiation efficiency at the plasterboard critical frequency.

Figure 4 shows generally good predictions for wall 7 above and well below its critical frequency which is 161Hz. In the 125Hz and 160Hz 1/3 octave bands, vibration measurements suggest an underestimate of the radiation efficiency.

The sound power radiated by wall 6 (Figure 5) is over predicted below 400Hz and under predicted above this frequency. From vibration measurements it was found that the energy level of wall 5 was correctly predicted and it was the path via the cavity where transmission was not correctly modelled. The dominant transmission path via wall 6 at low frequencies is the resonant path Room 1 - Wall 5 - Cavity - Wall 6 - Room 2 which appears to be too strong. The error probably arises because the boundary conditions make this cavity awkward to model. The top of the cavity opens directly into the roof void which affects the reverberant energy in the cavity and the coupling between the two leaves due to the stiffness of the air. The TLF of the cavity is calculated from the sum of the cavity CLFs which could be overestimated due to the open boundary, causing the underprediction of the PWL at high frequencies. It is hoped that access to the cavity will be available at a later stage in order to take measurements inside the cavity and investigate this problem further.

Figure 6 shows good agreement between measured and predicted data over the measurable frequency range except at 200Hz and 250Hz where the measured wall vibration level was lower than expected for transmission from wall 9 to wall 11 across a straight junction.

CONCLUSIONS

In SEA, non-resonant paths do not give rise to energy in the structure, which makes energy level differences at these frequencies of limited use. Therefore, when non-resonant transmission is significant, sound power levels measured using sound intensity can give more information when comparing measured data with SEA predictions. In general, data measured using this approach in the BRE flanking laboratory showed good agreement with predictions from the SEA model.

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PREDICTION OF SOUND TRANSMISSION USING SEA

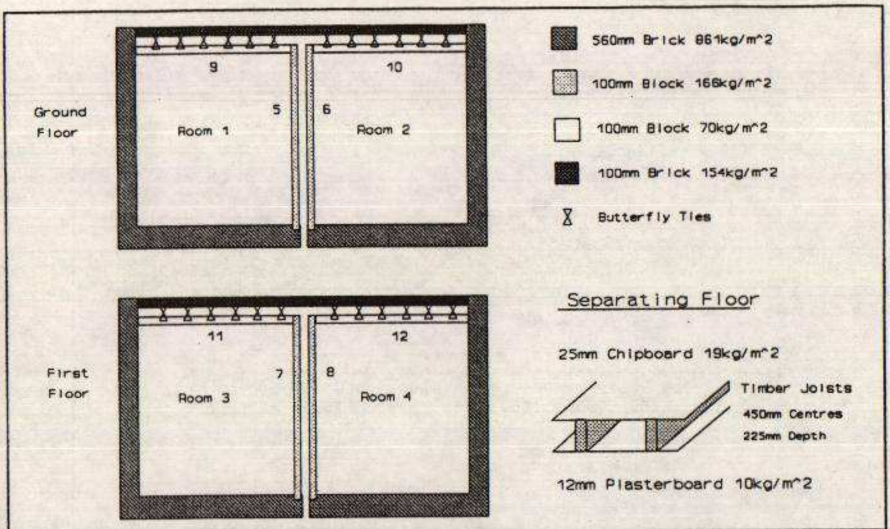

Figure 1: Flanking Laboratory

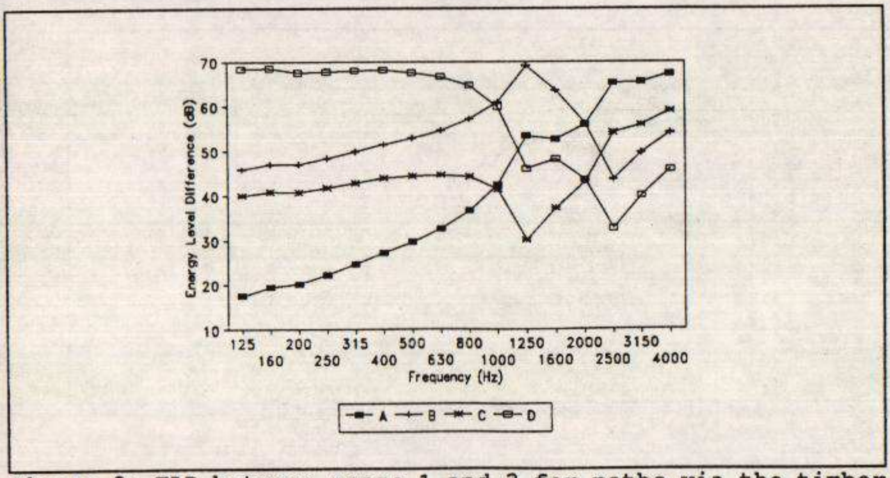

Figure 2: ELD between rooms 1 and 3 for paths via the timber joist floor.
A:Room3-Cavities-Room1
B:Room3-Cavities-Plasterboard-Room1
C:Room3-Chipboard-Cavities-Room1
D:Room3-Chipboard-Cavities-Plasterboard-Room1

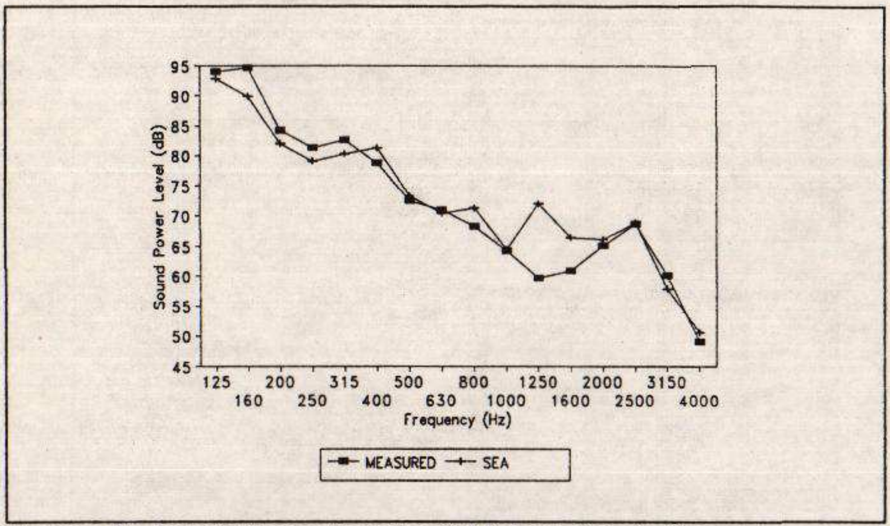

Figure 3: Sound Power Level of timber joist floor
(Source: Room 3)

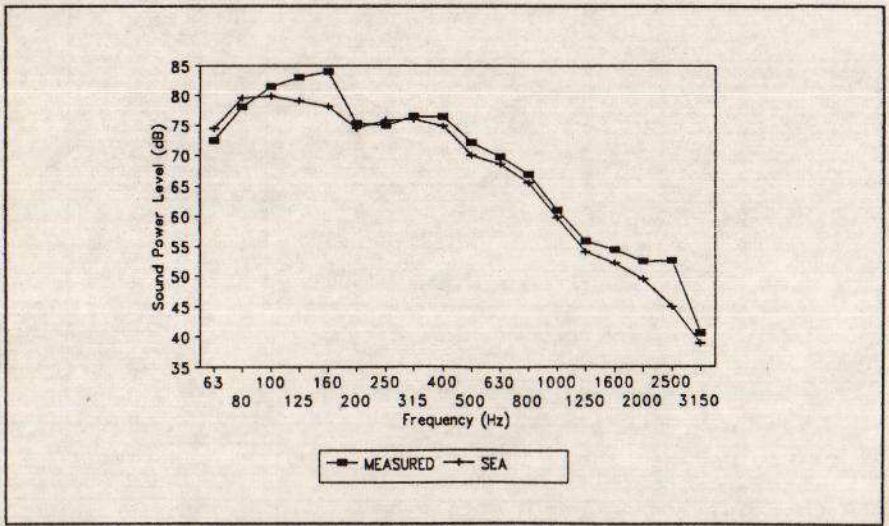

Figure 4: Sound Power Level of Wall 7
(Source: Room 1)

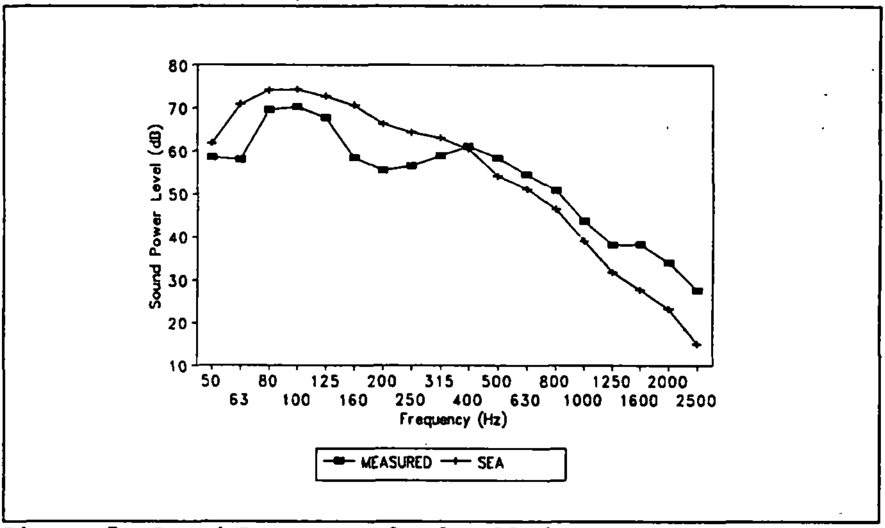

Figure 5: Sound Power Level of wall 6
(Source: Room 1)

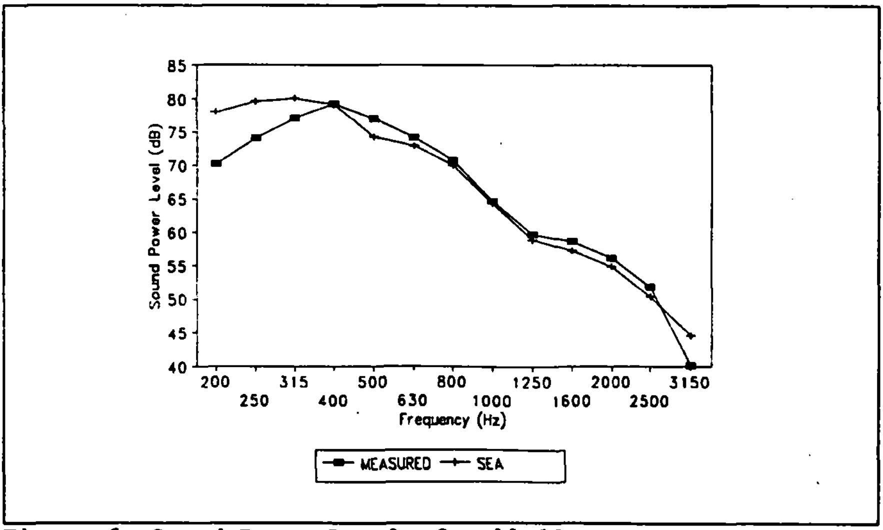

Figure 6: Sound Power Level of wall 11
(Source: Room 1)