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INVESTIGATION OF SOUND TRANSMISSION IN BUILDINGS USING THE SOUND INTENSITY TECHNIQUE

T A Carman, L C Fothergill

Building Research Establishment, Garston, Watford, Herts, WD2 7JR, England

1. INTRODUCTION

Sound can travel between two rooms in a building by many paths. These may be direct paths, for example through a separating wall or floor, or flanking paths, for example via the inner leaf of an external cavity wall. A sound insulation measurement can give an indication of the extent of sound transmission between the rooms, but cannot give any information on the relative importance of the different transmission paths.

Intensity is a vector quantity equal to power per unit area. If the sound intensity radiated by different surfaces of the receiving room (walls, ceiling etc.) is measured, the sound power radiated by each surface can be calculated and the relative importance of the main transmission paths into the room can be compared.

Sound intensity measurement has been used in the field and in the laboratory to investigate sound transmission paths in structures, and the results of these investigations are presented in this paper. The technique has some limitations in practice and these are also discussed.

2. EXPERIMENTAL DETAILS

For the investigations described in this paper, a broad band noise source was operated in the source room, and the mean sound intensity levels radiated by the surfaces of the receiving room were calculated from measurements made at discrete points using a two-microphone probe connected to a real time intensity analyser.

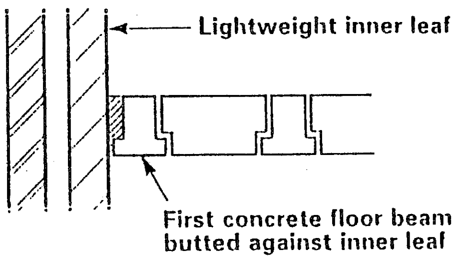
The frequency range over which the instrument can be used depends on the separation of the two microphones in the probe. For these investigations a separation of 25mm was used, allowing measurements to be made over the frequency range 100 Hz to 3150 Hz.

Each surface to be investigated was divided into equal areas of approximately $0.5m^2$ and the probe was positioned normal to the surface at the centre of each area, with the midpoint of the microphones 100mm from the surface. The validity of intensity measurements made with this system depends on the difference between the sound pressure level and the sound intensity level (called the P-I index) at the point of measurement. In practice it has been found that reliable measurements cannot be made in sound fields where the P-I index exceeds 13 dB. To reduce the P-I index at the room surfaces, the reverberent sound field was reduced by arranging blocks of acoustic foam in the receiving room, where possible forming an irregular wall in front of the surface being investigated. The sound intensity level was then measured in third octave bands at each probe position, with a minimum averaging time of 32 seconds and the mean intensity level and sound power level radiated by the surface were calculated.

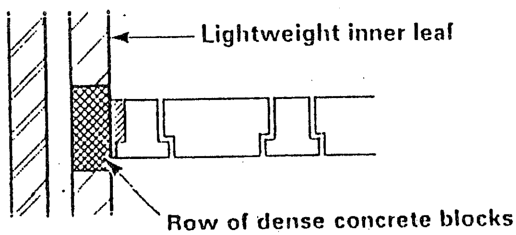
3. INVESTIGATIONS CARRIED OUT USING THE INTENSITY TECHNIQUE

3.1 Comparison of sound transmission at floor/wall junctions.
The first investigation was to compare sound transmission through three different junctions between a separating floor and the inner leaf of an external wall. The junctions to be tested were constructed in an acoustic test chamber. The chamber was two storeys high with three sides of dense reinforced concrete and a separating wall of dense concrete blocks, dividing the chamber into two. An external double leaf wall was constructed to form the fourth side of the chamber. This wall comprised a brick outer leaf, a 50 mm cavity and an inner leaf of lightweight concrete blocks. The separating floor was a pot and beam floor with a levelling screed and a floating floor. The following wall/floor junctions were constructed and tested in turn:

A. the first concrete beam of the separating floor laid parallel to and butted up against the inner leaf of the external wall;



B. as for A, with one row of dense concrete blocks replacing the lighter density blocks in the inner leaf at the level of the separating floor;



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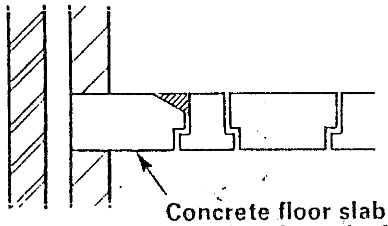
C. the first concrete beam moved away from the inner leaf by 175mm and a concrete floor slab built into the wall.



The room above the floor was used as the source room and the room directly below it as the receiving room. At each stage of the investigation, the sound intensity level radiated by the ceiling and four walls of the receiving room were measured. The sound power levels radiated by the ceiling, inner leaf, and the three solid concrete walls combined have been calculated and the results are shown in Figs 1-3.

The direct path through the separating floor was the main single transmission path at low frequencies for all three junction types, but decreased sharply above 125 Hz. For junctions A and B, the probe measured a negative intensity from the ceiling for all frequencies above 250 Hz, showing that there was more sound energy incident on the ceiling than radiated by it at these frequencies. For junction C, a positive intensity was measured at the ceiling at all frequencies, showing that the sound intensity radiated by the ceiling was now greater than the intensity incident on it. The sound transmitted directly through the floor should not have been affected by the detail of the floor/wall junction, and so the increased sound energy radiated by the ceiling must therefore have been due to increased energy being transmitted into the floor from the inner leaf through the built-in floor block.

The flanking path from the source room to the receiving room through the inner leaf was clearly the dominant sound path at 250 Hz and above, when the floor was butted up against the inner leaf (A and B). This flanking transmission was slightly reduced by introducing the row of heavier concrete blocks into the wall at the floor level to create a discontinuity in the wall (B). This gave rise to an improvement in the airborne sound insulation ($D_{nT,w}$) between the two rooms of 2 dB. When the floor was built into the inner leaf (C), sound radiated by this wall was reduced at these higher frequencies and was no longer significantly dominant. This shows that the energy transmitted into the lower half of the inner leaf is reduced in this construction. This will be partly due to the increased transmission from the inner leaf to the floor, which was indicated by the increased level of radiation from the ceiling, and partly due to the discontinuity in the wall caused by the floor slab being built into the wall. This gave a further 3 dB improvement in the airborne sound insulation between the rooms.

The sound paths via the three solid concrete walls were not important individually, but when combined, the sound power radiated by these walls was comparable with that from the ceiling at low frequencies. At higher frequencies the sound from these walls became more significant as the junction was modified and the flanking transmission via the inner leaf was reduced.

3.2 Investigation into the effect of flanking transmission on the sound insulation of a timber platform floor.

A timber platform floor was constructed in a timber framed house to form the separating floor between two rooms. In order to investigate the effect of flanking transmission down the walls, four sets of measurements were carried out: without wall linings; with independent wall linings added to the walls in the upstairs room only; both the upstairs and downstairs rooms; and the downstairs room only.

With a broad-band noise source operating in the upper room, sound intensity measurements were carried out in the room immediately below it. The sound intensity levels radiated by the ceiling and four walls were measured, and from this the sound power levels radiated by the four walls combined and the ceiling were calculated.

Fig 4 shows the sound power radiated by the ceiling at each stage. When wall linings are added upstairs the sound radiated by the ceiling above 250 Hz is reduced. As the direct transmission through the floor will not be affected by the wall linings, this shows that flanking transmission via the walls into the floor was greater than the direct transmission through the floor at these frequencies, whereas below 250 Hz, it was the direct transmission through the floor which was greater.

Fig 5 shows the sound power that could be measured from the four walls at each stage. Below 160 Hz, the measured intensity was strongly negative (not shown on the graph), indicating that transmission by the walls was insignificant compared with the sound energy coming from the ceiling. Results between 160 Hz and 250 Hz have not been included as the P-I index at these frequencies was generally above 13 dB. The results for frequencies between 250 Hz and 800 Hz are more reliable and have been plotted. It can be seen that adding wall linings upstairs is more effective for reducing flanking transmission via the walls than adding linings downstairs. Above 800 Hz the intensity levels were too low to measure accurately and were therefore lower than those radiated by the ceiling.

These intensity measurements therefore indicate that flanking transmission via the walls or floor, can most effectively be reduced by adding independent wall linings to the upstairs walls. Additional wall linings downstairs do not have much effect. This is confirmed by sound insulation measurements which showed that the airborne sound insulation ($D_{nT,w}$) between the rooms improved from

56 dB to 60 dB when the wall linings were added upstairs. There was no further improvement in the sound insulation when wall linings were added downstairs.

4. DISCUSSION

From these investigations it can be seen that the intensity technique can be used successfully to identify and compare major transmission paths in buildings and can show how changes in the construction affect sound transmission along these paths.

The technique does have some disadvantages, and these became apparent during the course of the investigations. One practical disadvantage of the technique is that it is very time-consuming compared with sound insulation measurements and this can be a problem in field investigations where time is usually limited. The time needed to carry out an investigation could be decreased by scanning the intensity probe over each surface instead of measuring at discrete points; the number of areas into which the wall is divided could then be reduced. However, if a scanning technique is used, great care must be taken that noise is not generated in the receiving room by the movement of the operator or probe.

Another practical disadvantage of the technique is the need to add acoustic absorbent to the receiving room, since this absorbent is usually bulky and difficult to transport.

Even with the additional absorbent in the receiving room, it was found that problems could arise when attempting to measure the mean intensity from weakly radiating surfaces in the presence of a strongly radiating surface, as the P-I index frequently exceeded 13 dB. This was the case in investigation 2 when we were trying the measure the intensity radiated by the flanking walls at frequencies below 250 Hz. In this situation however, it is unlikely that the sound power radiated by the surface is contributing significantly to the sound level in the room, and therefore the fact that it cannot be accurately measured is not so important as it can usually be neglected.

5. CONCLUSIONS

The sound intensity technique has been used to investigate sound transmission by different wall/floor junctions, and the effect of flanking transmission on sound insulation of a timber platform floor. In both investigations the technique identified the most important sound paths and showed how transmission by these paths was affected by changes in the construction. The technique has some practical disadvantages, particularly for field investigations, however in situations where sound insulation measurement alone is insufficient, these disadvantages are out-weighed by the advantages of the additional information about transmission paths that can be obtained using this technique.

6. ACKNOWLEDGEMENT

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FIG 1 WALL/FLOOR JUNCTION A
SOUND POWER LEVELS RADIATED INTO RECEIVING ROOM

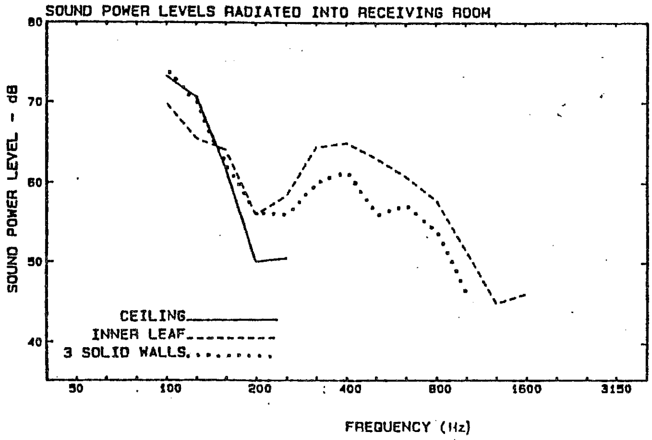

FIG 2 WALL/FLOOR JUNCTION B
SOUND POWER LEVELS RADIATED INTO RECEIVING ROOM

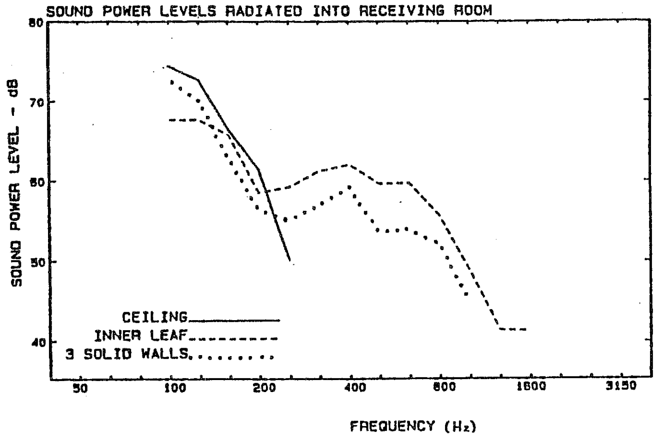

FIG 3 WALL/FLOOR JUNCTION C
SOUND POWER LEVELS RADIATED INTO RECEIVING ROOM

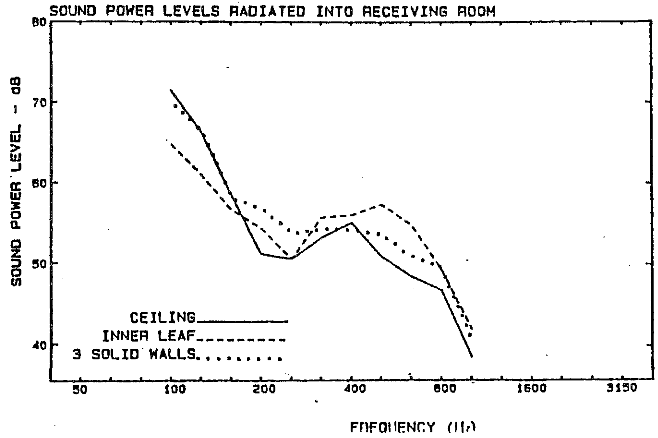

FIGURE 4 INVESTIGATION 2

SOUND POWER RADIATED BY THE CEILING IN THE RECEIVING ROOM

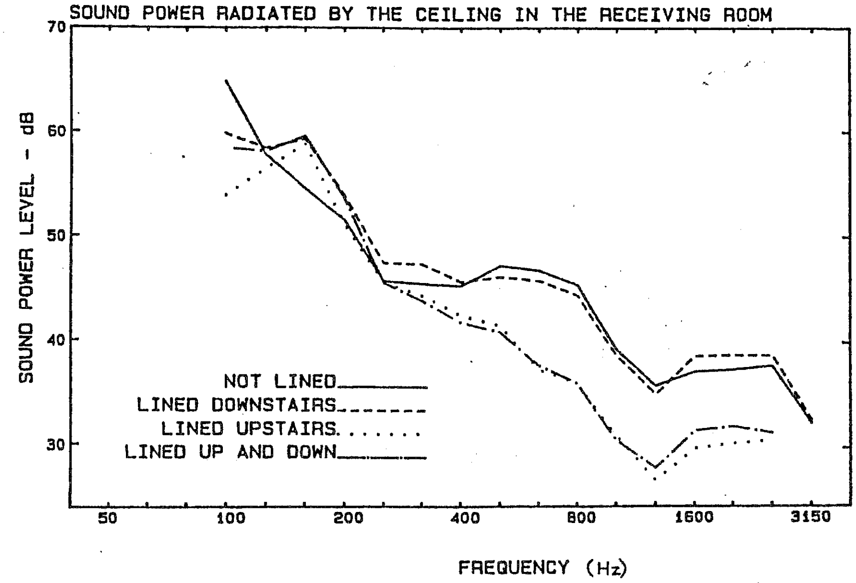

FIGURE 5 INVESTIGATION 2

TOTAL SOUND POWER RADIATED BY THE FOUR WALLS IN THE RECEIVING ROOM