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MEASUREMENT OF FLANKING TRANSMISSION PATHS

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INTRODUCTION

The poor performance of walls and floors when measured under field conditions is often attributed to flanking transmission through the structure. However, it can be very difficult to measure flanking transmission paths to establish whether or not flanking paths are important and if so which paths.

In this paper a simple method of measuring flanking paths is described which is suitable for use under field conditions.

FLANKING PATHS

A typical part of a building which has two rooms separated by a common wall (or floor) and has a possible flanking path along an external wall is shown in Fig 1. The external wall can be solid or a cavity wall or can be part of the internal structure of the building and simply be another wall.

The direct path will be from room 1 to the common wall, 2, and then to the receiving room, 3 to give the path 123. There will also be a non-resonant path but for clarity this is not included.

Flanking paths are transmission paths where the sound is transmitted by other routes. For example sound could be transmitted along the path 1453 in which sound from the source room excites the external wall, 4, passes along the external wall to wall 5 and then is radiated into the receiving room, 3.

It can be shown, using statistical energy analysis, [1] that the level difference of a path 12345...n can be given by

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$$L_1 - L_n = 10 \text{ Log } \frac{\eta_2 \eta_3 \eta_4 \cdots \eta_n V_n}{\eta_{12} \eta_{23} \eta_{34} \cdots \eta_{n-1,n} V_1} \quad (1)$$

where η_{ij} is the coupling loss factor from subsystem i to j, η_i is the total loss factor of subsystem j and V is the room volume. The sum of all the possible transmission paths will give the same answer as a complete analysis of the structure if the possible paths are defined in the following way.

A path must (obviously) begin in the source room (in this case 1) and may not include the source room for a second time. A path must (obviously) end in the receiving room but may include the receiving room any number of times. The path can include all other elements of the building (walls, floors, rooms) any number of times.

From this definition the direct path is path 123. There are three paths that cross one structural joint :- 1453, 1253 and 1423. There are also an infinite number of longer paths but these are not usually important in determining overall performance. The possible paths for a building that only has the 5 elements shown in Fig 1 are given in Table 1.

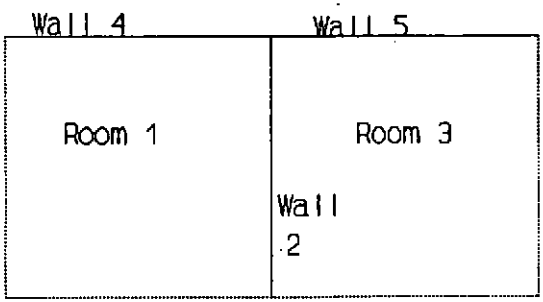

Fig 1 Layout of two rooms separated by a common wall with an external flanking wall.

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Number of elements in path	Number of paths	Paths
2	0	
3	1	123
4	3	1253, 1423, 1453
5	7	12323, 12353, 12423, 12453, 12523, 14253, 14523
6	19	123253, 123523, 124253, 124523, 125253, 125323, 125353, 125423, 125453, 142323, 142353, 142423, 142453, 142523, 145253, 145323, 145353, 145423, 145453
7	47	...
8	123	...
....		

Table 1 Sound transmission paths from room 1 to room 3.

MEASURING A FLANKING PATH

Consider the flanking path 1453. From the definition of the path the level difference of this path given in equation (1) can be rewritten as

$$L_1 - L_3 = 10\text{Log}\frac{\eta_4}{\eta_{14}} + 10\text{Log}\frac{\eta_5}{\eta_{45}} + 10\text{Log}\frac{\eta_3}{\eta_{53}} + 10\text{Log}V_3/V_1 \qquad (2)$$

From a knowledge of the material properties and the system geometry it is possible to predict the noise reduction of the individual paths [2]. However the aim of this paper is to show how the paths can be measured.

The first term in the equation is the ratio of the total loss factor to the coupling loss factor. More usefully it is approximately the ratio of the energy in the source element, 1, to the energy in the receiving element, 4, for a source in the source element, 1.

In the same way the second term is approximately the ratio of the energy in wall 4 to the energy of the wall 5 when wall 4 is excited and the third term is approximately the ratio of the energy in room 3 to the energy in wall 5 when wall 5 is excited.

The last term is a conversion term that converts the energy ratios to pressure ratios.

Although each term is an energy ratios it is pressure and acceleration that is measured. However, except for the source and receiving subsystems each element is measured twice, once as a source and once as a receiving element. Therefore all the correction terms that convert measurements of pressure and acceleration to energy cancel out and pressure and acceleration measurements can be used in place of energy. The correction term $10\text{Log } V_3/V_1$ is also not required since the measurements of the first and last rooms are already in the units of pressure.

In order to measure the flanking path 1453 the procedure is as follows. Excite the source room (with loudspeaker) and measure the average sound pressure level (SPL) and the acceleration level of wall 4. Next excite wall 4 and measure the acceleration level of wall 4 and wall 5. Finally excite wall 4 and measure the acceleration of wall 5 and the SPL in room 3.

From this data an estimate of the path level difference can be made by simply summing the difference at each stage as in the example in Table 2.

Source	SPL 1 dB	Accel 4 dB	Accel 5 dB	SPL 3 dB	Difference dB
Room 1	100	60			40
Wall 4		56	48		8
Wall 5			80	60	20
				TOTAL	68

Table 2 Typical example of measurements of a path level difference.

Measurements can be made in 1/3 octaves or octaves as appropriate.

For field measurements it is not practical to use structural shakers to excite the walls. A good practical structural source is a plastic headed hammer like those used by panel beaters. The plastic head protects the wall from damage even for reasonably hard hits.

Since all hammer hits have different "strength" the source and receiving levels must be measured at the same time. This can be done with two sound level meters or by the use of more sophisticated instruments or by recording the data for further analysis. The hammer source has the advantage that it is simple to move the source about the wall.

Care should be taken when using this method to excite a wall when measuring the SPL in a room as in measuring from wall 5 to room 3. If possible the wall should be struck on the opposite side of the wall from the room being measured since there can be some sound radiated by the action of hitting the wall. This depends on the type of wall being tested.

A typical procedure for measuring the structural attenuation would be to place two accelerometers one on each wall (4 and 5). The accelerometers are connected to some instruments which measures true average, L_{eq}, for a period of about 15 seconds. The source wall is then excited for the same time with each hit being at a different location so as to give good spacial averaging of the source. The two accelerometers are then moved to new positions and the process is repeated. This would be repeated as necessary (say 6 times).

The averaging of the instruments should begin before the first hit and should continue till all the vibrations of the wall from the last hit have died away. In practise this means stopping hitting a second or two before stopping the instrument averaging.

DISCUSSION

This method of measuring the magnitude of flanking paths is simple and reasonably accurate. It is assumed that when exciting one element (such as wall 4) that the power flow to the receiving element (say 5) is all across the structural link 4-5. In practise of course some of the power flow from 4 to 5 will be along the path 425. Thus the power flow that is measured will include other paths and so will be higher than the true power flow. This error is typically 1 dB for each section of a path and so can be a considerable error if attempts are made to measure long paths.

However if measurement are being made to measure short paths that are dominant in determining overall transmission then the errors will be small.

REFERENCES

[1] R.J.M. Craik, Sound transmission paths through a statistical energy analysis model. Accepted for publication in Applied Acoustics.

[2] R.J.M. Craik, The noise reduction of flanking paths. Applied Acoustics, 22, 163-175, 1987.