STATISTICAL ENERGY ANALYSIS APPLIED TO LIGHTWEIGHT CONSTRUCTIONS PART 3: MEASUREMENTS AND PREDICTIONS OF FLANKING TRANSMISSION

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This is the third of three papers on the application of statistical energy analysis (SEA) to a lightweight wood frame construction. This paper takes the basic model for direct transmission presented in Part 1[1] and uses the 'two corner joints sharing a common plate' model developed in Part 2[2] to describe the coupling to the load bearing party walls. The model will be used to reveal the dominant flanking paths and to investigate the potential effectiveness of two retrofits.

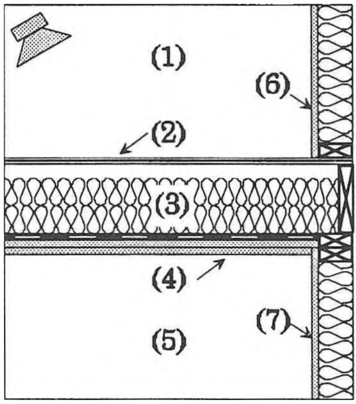

Figure 1: Sketch the floor/ceiling assembly and the load bearing party walls that are modelled. The sub-systems are (1): source room, (2): 15.9 mm OSB decking, (3): 235 mm deep cavity with two layers of 89 mm batt insulation, (4): 2 layers 12.7 mm type X gypsum board mounted on resilient channels, (5): receive room, (6) and (7): 15.9 mm type X gypsum board.

As in Part 1, the SEA model will use assumptions to keep the model as simple as possible. They are: there is no significant coupling between the floor decking and the gypsum board ceiling, the studs of the walls can be ignored, and the joists of the floor/ceiling assembly can be ignored. The SEA sub-system diagram for the complete model is shown in Figure 2.

Measured and predicted net transmission loss

Figure 3 shows the measured and predicted net transmission loss (TL) for the assembly shown in Figure 1. The predicted results indicate the correct trends in the measured transmission loss, but the SEA model tends to underestimate the transmission loss. This underestimation of the TL was also present in the SEA prediction for the floor/ceiling assembly without any flanking paths given in Part 1. This suggests that the basic model for the transmission through the floor/ceiling assembly is biased toward underestimating the transmission loss (i.e., overestimating the coupling between sub-systems).

In the low frequencies 50-200 Hz, differences may be due to incorrectly estimating the total loss factor of the floor cavity, and/or incorrectly estimating the coupling between the surfaces forming the cavity (i.e., the OSB floor decking and the gypsum board ceiling). It should also be realized that the low modal density of the small source and receive rooms (volumes, source: 50 m^3 and receive: 40 m^3) will tend to increase uncertainty in the transmission loss measurements in the low frequencies.

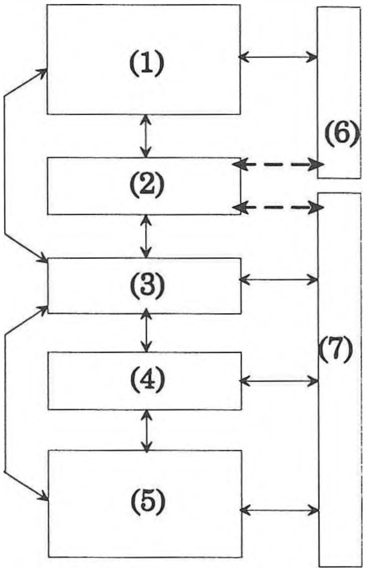

Figure 2: SEA sub-system model used to describe the direct and flanking paths for the floor/ceiling assembly. Paths via the joints are indicated by the wide dashed lines.

In the mid-frequencies, 250-1600 Hz the model has good agreement with measured results. A significant portion of this range, above 315 Hz, is controlled by flanking transmission, indicating that when both the transmission through the joint and the coupling between the room and its surfaces can be modelled accurately, there is good agreement with measured results.

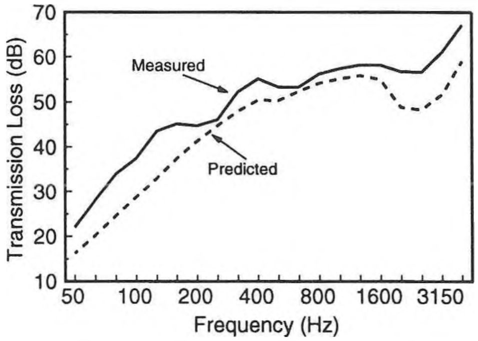

Figure 3: Measured and predicted net transmission loss (including flanking paths) for the floor ceiling assembly.

In the high frequencies 2000-4000 Hz flanking transmission completely controls the sound isolation and the SEA model underestimates the transmission loss. The underestimation is most likely due to the fact that the coupling between the flanking surfaces and the room volume is overestimated at the critical frequencies of the flanking surfaces (floor decking: 2000 Hz, party walls: 2500 Hz, and ceiling: 3000 Hz). A more exact method for computing the radiation efficiency could have been used.

Noise reduction as a function of flanking path

SEA lends itself to the prediction of noise reduction for a particular flanking path. The noise reduction for room to room transmission is given in terms of the computed counpling and total loss factors for the sub-systems in the path and, V, the volumes of the source and receive rooms,

$$NR_{1-2-3-4...n} = 10\log\left[\frac{\eta_{12}\eta_{23}\eta_{34}\cdots\eta_{n-1,n}V_n}{\eta_2\eta_3\eta_4\cdots\eta_n V_1}\right] \qquad [1]$$

Figure 4 shows the predicted noise reduction for the three most important flanking paths 1-2-7-5, 1-6-2-7-5 and 1-6-2-3-4-5.

It is clear that the path 1-2-7-5 is the dominant flanking path, controlling the net sound reduction for all frequencies greater than 315 Hz. The path 1-6-2-7-5 is the next important, but has typically 10 dB greater noise reduction than path 1-2-7-5. Of almost negligible importance is the path 1-6-2-3-4-5. From the path analysis it can be seen that the two flanking paths offering the least noise reduction are those involving the party wall (sub-system (7)) in the lower room. In both cases, because of the joint model chosen, the energy must travel through the floor decking (sub-system (2)) and the joist header (sub-system (9)) to get to the party wall of the receive room.

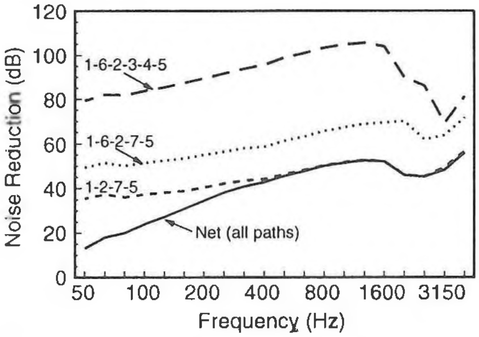

Figure 4: Predicted noise reduction (or sound pressure level difference) between the source room (sub-system (9)) and the receive room (sub-system (10)) as a function of the flanking path.

Treatments to improve the sound isolation

The path analysis indicates that the most important path is 1-2-7-5. Sound transmission along this path can only be reduced by treating sub-systems 2, 7 or redesigning the joint that connects them. If sub-system 2 is treated, then sound isolation of both the direct and flanking paths can be improved, and there is the greatest potential for improvement to the sound isolation.

A possible treatment for new or existing constructions might be to add a concrete topping to the floor decking. Figure 5 shows the predicted transmission loss for the assembly with and without a 38 mm thick concrete topping (91 kg/m^2). (In the prediction it was assumed that the bending stiffness of the topping and the OSB would be about that of the concrete topping alone.) The predictions indicate that there should be a significant increase in the sound isolation in the low frequencies where the mass of the topping helps to control the direct transmission through the floor/ceiling assembly. Differences between the bending stiffness of the concrete topping and the gypsum board of the walls tends to reduce transmission through the joints for high frequencies. With the topping, the predicted sound isolation is STC 64, a 12-point improvement from the STC 53 without the treatment.

Alternatively, one could place the gypsum board of the upper and lower party walls on resilient channels. This should effectively remove the structural coupling between the finish gypsum board surfaces and the frame work. This will remove all the flanking paths. Figure 5 shows that a significant improvement only occurs for frequencies above about 400 Hz. In terms of a single number rating, the sound isolation would be STC 58 with the treatment, a 5-point improvement.

Redesigning the joint is an option for new constructions. Further work needs to be done in this area. It was shown in Part 2 that including the joist header in the model reduced joint transmission in the high frequencies. Thus, using a double joist header may help to reduce transmission through the joint.

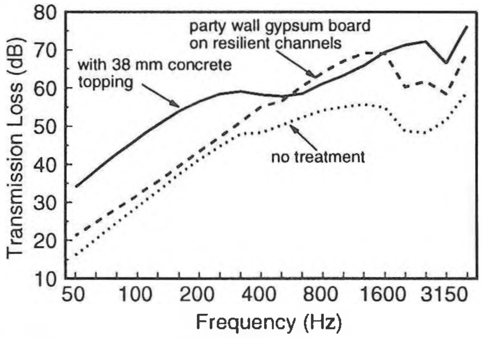

Figure 5: Predicted transmission loss for various treatments to improve the sound isolation between the two rooms. It has been assumed that the joint model developed in part 2 is still valid for the case when the OSB is covered with a concrete topping.

General conclusions Parts 1, 2, and 3

Part 1 in the series showed that the direct sound transmission through a floor/ceiling assembly can be modelled with good accuracy using the method of Price and Crocker. This method requires that the total loss factor of the cavity be accurately known. The assumption that the joists could be ignored and that resilient channel in the ceiling removed any structural paths from the decking to the ceiling was reasonable for direct transmission.

Part 2 showed that the joint between the floor/ceiling assembly and the load bearing party wall was complex, having to be treated as two corner joints sharing a common plate. Including the sole plate and joist header in the model were necessary if the joint transmission was to be accurately predicted in the high frequencies. The results suggest that greater accuracy can be attained by computing the joint transmission coefficients at each modal frequency of the sub-panels. This had the largest effect for frequencies below the first cross mode of the sub-panels.

Part 3 showed that flanking paths controlled the net transmission loss for frequencies greater than about 400 Hz. The most dominant flanking path was from the floor decking through the joist header and into the party wall below. Predictions also showed that adding a concrete topping to the floor decking would be an effective way of increasing the net sound isolation.

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[1] Nightingale, T.R.T., Craik, Robert J.M., Steel, John .A., "Statistical energy analysis applied to lightweight constructions Part 1: sound transmission through floors," Canadian Acoustics, Vol. 23, No. 3, 1995.

[2] Nightingale, T.R.T., Steel, John A., "Statistical energy analysis applied to lightweight constmctions:Part 2: joints between floors and party walls," Canadian Acoustics, Vol. 23, No. 3, 1995.