STATISTICAL ENERGY ANALYSIS APPLIED TO LIGHTWEIGHT CONSTRUCTIONS PART 2: JOINTS BETWEEN FLOORS AND PARTY WALLS

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This is the second of three papers on the application of statistical energy analysis (SEA) to a lightweight wood frame construction. This paper considers methods of modelling the joint that is formed when a load bearing party wall is added to the floor/ceiling assembly considered in Part 1[1] of this series. 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 simplified assembly and the sub-systems are shown in Figure 1.

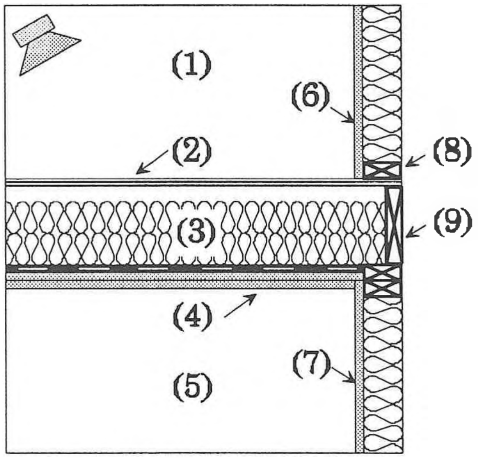

Figure 1: Section through the floor and load-bearing party walls. (1): source room, (2): 15.9 mm OSB decking, (3): 235 mm deep cavity with two layers of 89 mm batt insulation, (4): 2 layers 12.7 mm type X gypsum board mounted on resilient channels, (5): receive room, (6) and (7): 15.9 mm type X gypsum board, (8): 38x89 mm sole plate, (9): 38x235 mm joist header.

The material properties of sub-systems are given in Table 1.

Sub-system	length (m)	width (m)	height (m)	density (kg/m^3)	f_c (Hz)
2	4.5	4.6	n/a	451	2000
4	4.5	4.6	n/a	751	3000
6	4.5	n/a	2.4	751	2500
7	4.5	n/a	2.0	751	2500
8	4.5	0.089	0.038	451	n/a
9	4.5	0.038	0.235	451	n/a

Table 1: Material properties of the sub-systems.

From Figure 1, which shows the sub-systems of the simplified model SEA model, it can be seen that the load bearing party wall introduces a series of flanking paths: 1-6-7-5, 1-2-7-5, 1-2-6-7-5, etc. It is assumed that the gypsum board ceiling (sub-system (4)) is not involved in any of the flanking paths since it is mounted on resilient channels and is only very weakly connected to the head of the lower party wall.

In order to model the flanking paths, the joint between the walls and the floor/ceiling assembly must be modelled. A series of different models for the joint are now presented and their accuracy discussed.

Simple Tee Joint

A tee formed by the intersection of the gypsum board party wall (sub-systems (6) and (7)) by the OSB floor decking (sub-system (2)) is the simplest representation of the joint. It is assumed that the plates are rigidly connected and that the beams (sub-systems (8) and (9)) at the joint can be ignored. In Figures 2, 3 and 4 the predicted velocity level differences (VLD's) are shown and labeled as 'Simple "Tee"'. Measured data is also shown for comparison. The simple tee joint model completely fails to predict the VLD's (as calculated from Equation 10[1]) for the paths 2-7 shown in Figure 3 and 6-7 shown in Figure 4. The prediction for path 2-6 is perhaps the best of the three predictions; showing the general trend for frequencies greater than 400 Hz. It is clear from the measured data that the type of coupling between the floor decking (2) and the upper party wall (6) is different than that to the lower party wall (7). A more complex model is required which does not have the symmetry suggested by the simple tee joint.

Tee Joint with a Beam

The upper and lower party walls are of nominally identical construction so it is likely that the differences in the measured VLD's between the two paths 3-5 and 3-6 will be due to different coupling mechanisms for each path. Figure 1 suggests that the joist header might be involved in the coupling between the floor decking and the lower party wall. Similarly, the upper party wall might be viewed as also being connected to the joist header. In this representation the head plates of the lower party wall are taken to be an extension of the joist header thereby making an equivalent beam of dimension 38x311 mm. The model of Steel[2] was used to calculate the joint transmission coefficients and using Equation 10[1] the VLD's were computed. In Figures 2, 3 and 4 the predictions are labeled '"Tee" with Beam' and show that including a joist header did not improve the accuracy of the predictions for any of the paths. This suggests that the joint may not behave as a "Tee".

Examining the measured data, it can be seen that the VLD for the path 6-7 is close to the sum of the VLD's for the paths 2-6 and 2-7. This might suggest that the joint should be modelled as two corner joints sharing a common plate; the floor decking (sub-system (2)).

Two corner joints sharing a common plate

In this representation, the joint is modelled as being two corner joints sharing a common plate, the floor decking. The first corner joint will be between the floor decking (2) and the gypsum board of the upper party wall (6). The 38x89 mm sole plate (8) common to both (2) and (6) is included. The second corner joint will be between the floor decking (2) and the lower party wall (7). The 38x235 mm joist header (9) common to both is included. The predicted VLD's for the three paths are labeled "2 Corner

Joints" and are shown in Figures 2, 3 and 4. For all three paths there is reasonably good agreement between measured and predicted results for the frequency range 400-4000 Hz. However, below 400 Hz the predictions are quite poor. The VLD's are underestimated and in all cases the wrong trend is indicated.

Discussion

For most ribbed panels there is a transition between behaving as a single plate and a series of independent sub-panels defined by the ribs. The 400 Hz third octave marks the cut-on of cross modes in the sub-panels and a corresponding increase in modal density as shown in Table 2.

1/3 Octave Band (Hz)	Number of Modes	Angular range (degrees)
Less than 100	0	n/a
100	5	$5 \le \theta \le 23$
125	3	$27 \le \theta \le 35$
160	3	$38 \le \theta \le 44$
200	2	$46 \le \theta \le 49$
250	3	$51 \le \theta \le 54$
315	3	$56 \le \theta \le 59$
400	13	$5 \le \theta \le 62$

Table 2: Number of modes and angular range for the OSB floor decking sub-panels (0.4x4.6 m dimension).

Below about 400 Hz the floor may behave as a single plate or a series of independent sub-panels. As sub-panels, there are only a very small number of modes in any one of the third octaves below 400 Hz. The angular range of the modes within each third octave band is quite narrow. This does not satisfy the requirent of SEA that there be a diffuse field.

To investigate the behaviour of the sub-panels, all the modes were computed along with their angle of incidence on the joint. The joint transmission coefficients for each mode were computed using the "two corner joints sharing a common plate" model and band averaged to compute the VLD's in the usual way. The results are shown in the Figures and labeled as "2 Corner Joints + Modes". Improvement in the predictions for all paths are shown for frequencies above about 315 Hz. This suggests that the sub-panel model is the most accurate once the cross modes have cut-on. For paths 2-6 and 2-7 the sub-panel model apparently improved results for frequencies below 315 Hz. However, this was not the case for 6-7.

Conclusions

Measured and predicted results for sound transmission along flanking paths have been shown. Best agreement is found with predictions which allow for separate joints. The first is between floor deck and upper party wall with the sole plate included. The second is between the floor deck and lower party wall with the joist header included. Modelling the system using two joints assumes that there is no direct coupling mechanism between the sole plate and the joist header. In measured specimen, the sole plate was nailed to the floor decking and not the joist header.

The model gives very good agreement with measured results at frequencies above 400 Hz with measured and predicted transmission reducing with increasing frequency. It is in this range of very good agreement where flanking paths involving the joint may become significant. At lower frequencies where flanking via the joints will not be important, the measured transmission is much weaker than predicted.

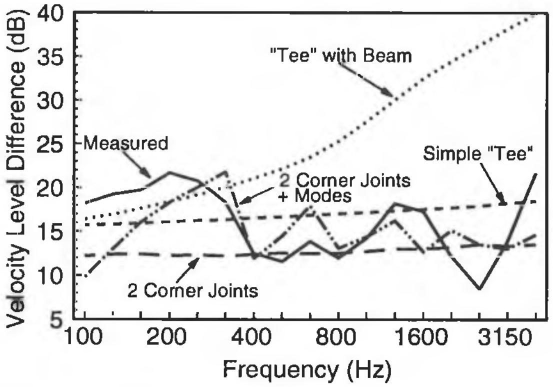

Figure 2: Measured and predicted velocity level differences for transmission from floor decking (2) to upper party wall (6).

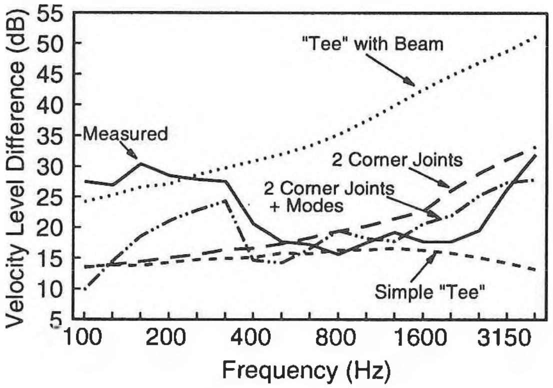

Figure 3: Measured and predicted velocity level differences for transmission from floor decking (2) to lower party wall (7).

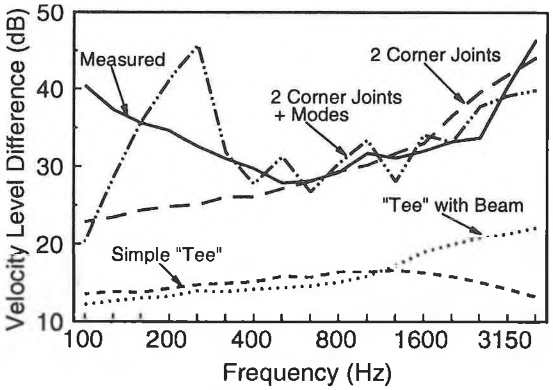

Figure 4: Measured and predicted velocity level differences for transmission from the upper party wall (6) to the lower party wall (7).

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[1] Nightingale, Craik, Steel, "Statistical energy analysis applied to lightweight constructions Part I: sound transmission through floors," Canadian Acoustics, Vol. 23, No. 3, 1995.

[2] Steel, John, A., "Sound transmission between plates in framed structures," Journal of Sound and Vibration, Vol. 178, No. 3, pp. 379-394, 1994