When more is less – the unexpected effect of lightweight timber floor finishes on the sound insulation performance of separating walls

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1 BACKGROUND

During pre-completion sound testing of two large multi-storey concrete-framed developments, we noticed unusual features in the sound insulation performance results of the separating walls, and to a lesser extent also the floors, presenting as notable dips at certain frequencies. These were centred around 315Hz on one scheme (site A) and 400-500Hz on the other (site B), and these deviate from the usual performance associated with the construction types.

The schemes both comprised Approved Document E (ADE) Type 4 walls (dry-lined twin metal stud partitions), in conjunction with ADE Type 1 floor (typically 200-300mm solid concrete slabs with bonded resilient layer on top and plasterboard ceiling below).

All tests comfortably met the Part E requirements. However, as specialists in acoustic design, we don't just accept passes as passes. We also like to know why we see unusual or distinguishing features in the results to inform future designs, and constantly strive for better performance and value-engineered solutions.

This article therefore presents the results of our analysis, investigation, and conclusions into the cause of these features, and the impact on the sound insulation performance of the walls and floors that use this type of design.

2 THE 'FEATURES'

As example of the type of 'dip' in the sound insulation performance of separating walls and floors at Site A and Site B is shown in Figure 1 and Figure 2. These show the notable reduction in the sound insulation performance centred around the 315Hz and 400-500Hz 1/3 octave bands respectively. This feature is present but less pronounced in airborne tests taken across separating floors.

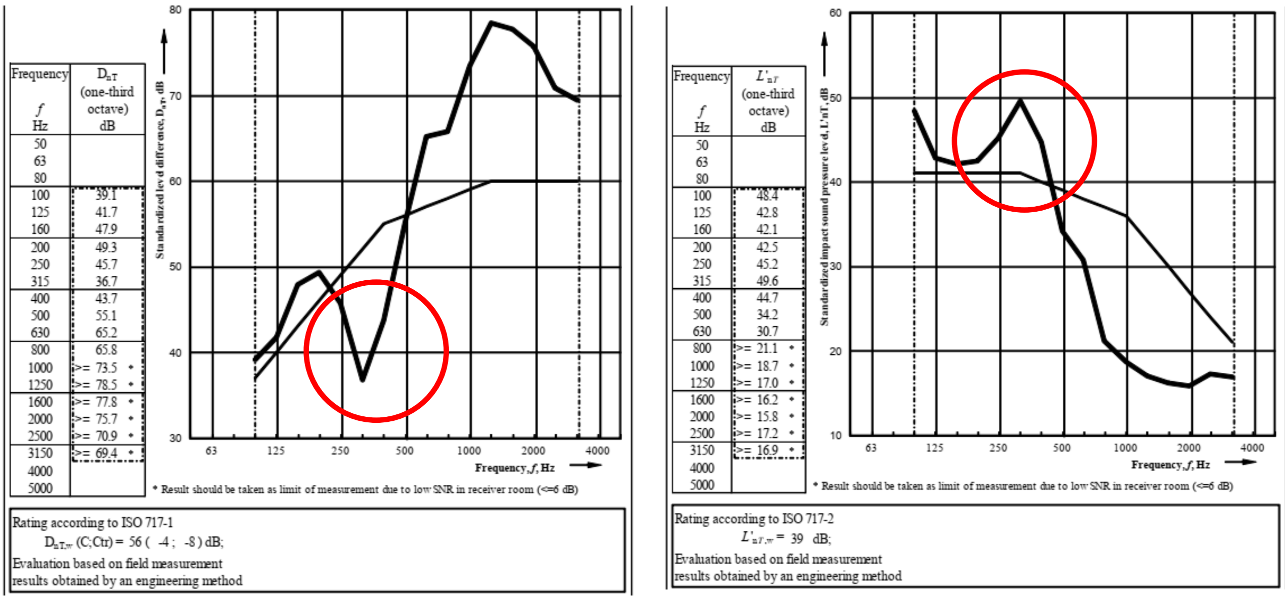


Figure 1 - Example airborne wall (left), and impact floor (right) test result at Site A

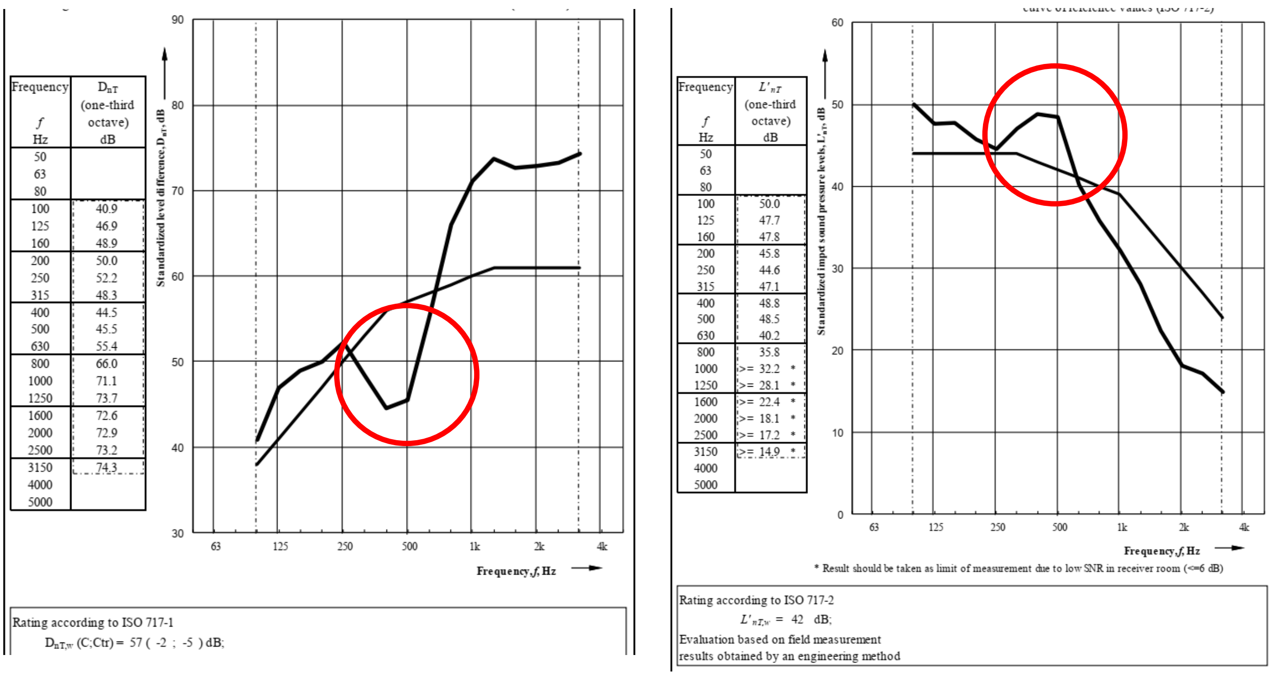


Figure 2 - Example airborne wall (left), and impact floor (right) test result at site B

3 INVESTIGATION AND CAUSES

3.1 The design

An on-site investigation into the cause of the features was carried out at Site B, where the design of the separating walls and floors is illustrated in Figure 3 and comprise:

Walls: Twin framed independent metal 'I' stud walls, with two layers of 15mm dense plasterboard on either side, and 100mm mineral wool quilt in the void.

Floors: 225mm reinforced concrete slab, with:

- 3mm rubber / cork crumb resilient layer bonded to the top of the concrete, and a nominal 8mm laminate timber floor finish loose-laid on top.
- 12.5mm standard plasterboard ceiling on MF system with 190mm void.

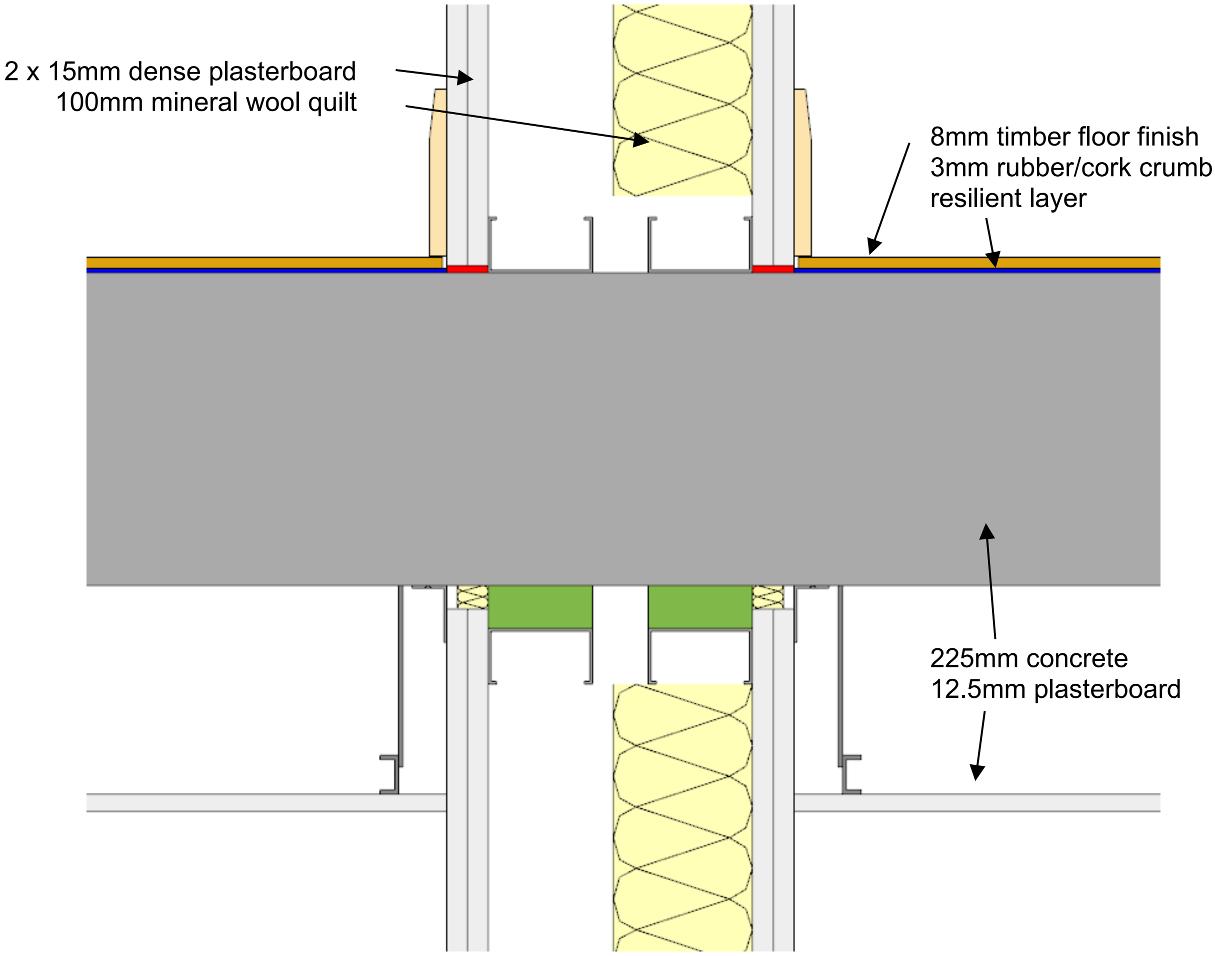


Figure 3 - SECTION: Example separating walls and floor constructions.

Due to the programming of the scheme, the sound insulation tests at Site B were taken with the timber laminate floor finishes already installed on the floors. This was accepted by Building Control on the basis that it should represent a worst case because if other finishes were subsequently installed later (such as carpet) the sound insulation across the floor should only improve.

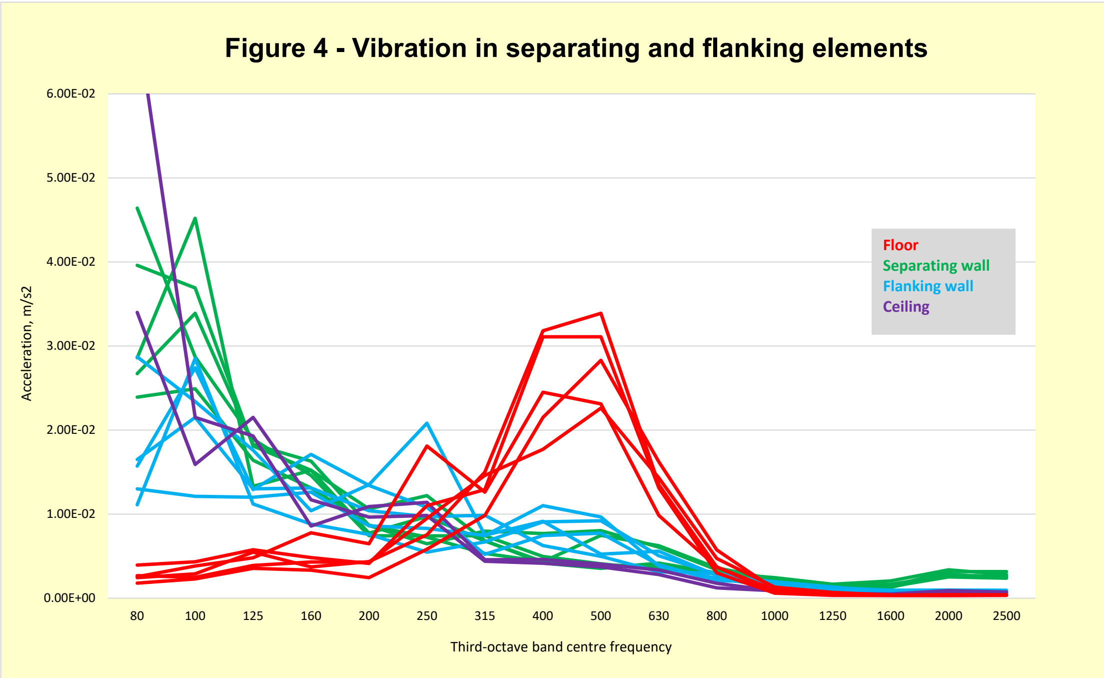
At Site A, the pre-completion tests were taken when there was a mix of some flats having had the floor finish installed and others not.

3.2 The investigation

The investigation of the separating wall performance at Site B was carried out using a combination of listening tests and vibration measurements. The transmission path for the poorer performance at the feature frequencies was difficult to localise with listening alone, but measurements with the accelerometer were far more conclusive.

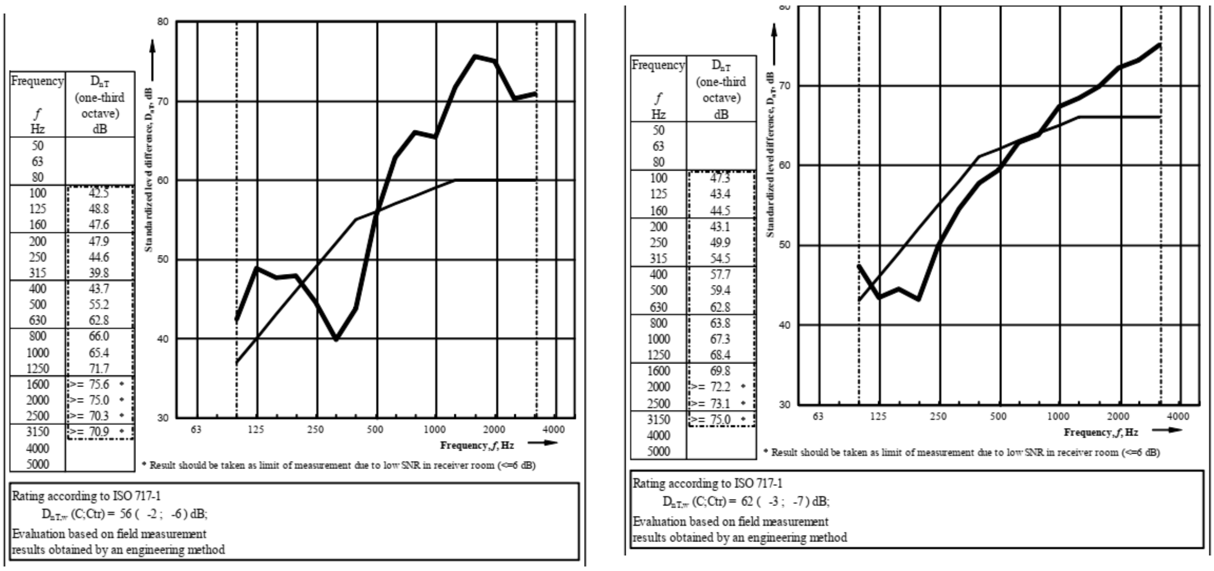
The accelerometer measurements were conducted by taking measurements at a selection of random positions on the separating wall, and on the flanking paths including the external flanking wall, ceiling, and floors. The results are summarised in Figure 4, which demonstrate significantly higher vibration levels in the floor finish than any other transmission path, even including the separating wall itself, at the exact same frequencies at which the features occur.

The investigation was therefore conclusive that the cause of poor performance in the separating walls was flanking transmission via the floors, but why was this happening?



3.3 The causes and theory

Flanking transmission via the floors is caused by resonances in the timber floor finish. This was verified by analysing the results of the measurements at Site A, of which there was a mix of tests taken in flats with and without the floor finish installed. For the tests where there were no floor finishes installed, the features shown in Figure 1 and Figure 2 are entirely absent. Figure 5 and Figure 6, show examples of typical results for airborne tests across walls and impact tests across floors, with and without the timber laminate floor.



Frequency f Hz	D_{nT} (one-third octave) dB (left)	D_{nT} (one-third octave) dB (right)
50		
63		
80		
100	42.5	47.3
125	48.8	43.4
160	47.6	44.5
200	47.9	43.1
250	44.6	49.9
315	39.8	54.5
400	43.7	57.7
500	55.2	59.4
630	62.8	62.8
800	66.0	63.8
1000	65.4	67.3
1250	71.7	68.4
1600	>= 75.6 *	69.8
2000	>= 75.0 *	>= 72.2 *
2500	>= 70.3 *	>= 73.1 *
3150	>= 70.9 *	>= 75.0 *
4000		
5000		

Figure 5 - Airborne wall tests with floor finish (left), and no floor finish (right)
***Note - not the same wall**

The impact tests are taken in the same flat, but in the Lounge /Kitchen the floor finish was installed, whereas in the bedroom it was not. Tests in the bedroom were taken directly onto the resilient layer.

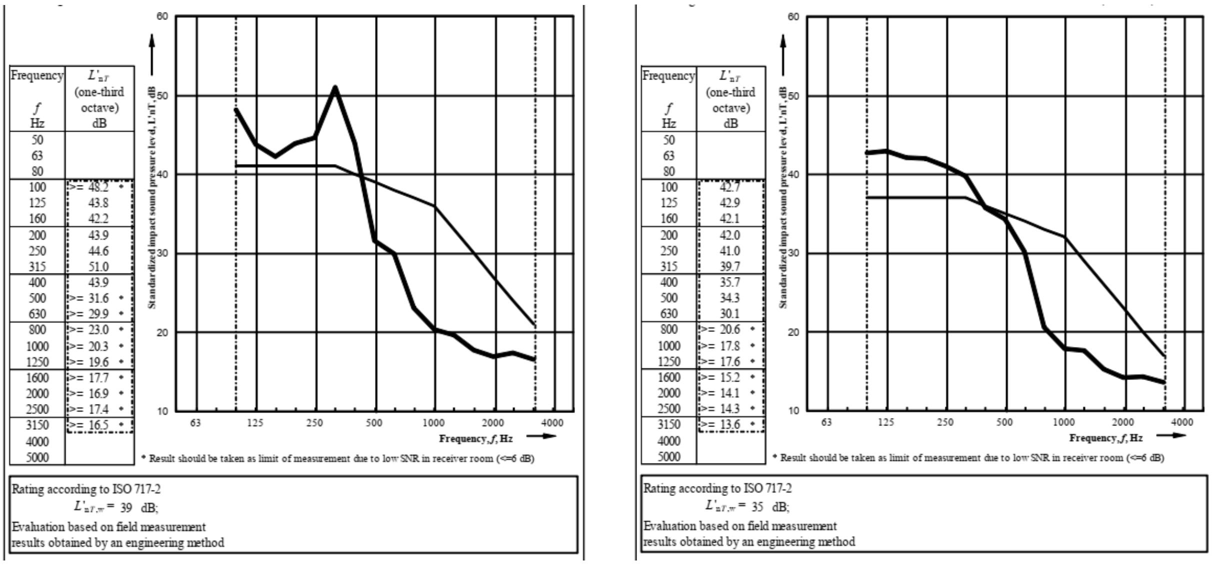


Figure 6 – Impact floor tests with floor finish (left), and no floor finish (right) -

The separating wall tests are particularly prone to the weakness caused by this phenomenon because of matched resonances e.g. the resonance on the source side induces the resonance on the receiver side where the same finish is used.

Unknown to us at the time of our analysis and investigation was a paper by Hongisto [1], who has also identified this flanking path, and confirms that the floor finish together with the thin rubber / cork crumb resilient layer and concrete based form a simple mass-spring system for which the natural frequency of resonance is:

$$f_o = \frac{1}{2\pi}\sqrt{\frac{s'}{m'}}$$

Where m' is the surface mass (kg/m^2) of the floor covering and s' is the dynamic stiffness per unit area (N/m^3).

We have not been able to obtain the dynamic stiffness of the specific 6mm layer used at Site A or the 3mm rubber/cork resilient layer used at Site B, but the stiffness for a very similar material by the same manufacturer indicates that the calculated resonant frequency is likely to be in the same range as the features seen in our results.

Additionally, because the dynamic stiffness of a material reduces with an increase in the thickness of the material, this also correlates with the feature being at a lower frequency at Site A than Site B, because the resilient layer used at site A was thicker.

4 EFFECT ON THE SOUND INSULATION RESULTS

So what effect do these resonances in the floor finishes have on the sound insulation performance of the separating walls and floors when assessed according to the parameters of ADE?

We analysed the results of the measurements at site A, comparing the results with and without the floor finishes. The results are summarised in Figures 7 to Figure 9. In all cases the sample size is between 7 and 9 tests in each category.

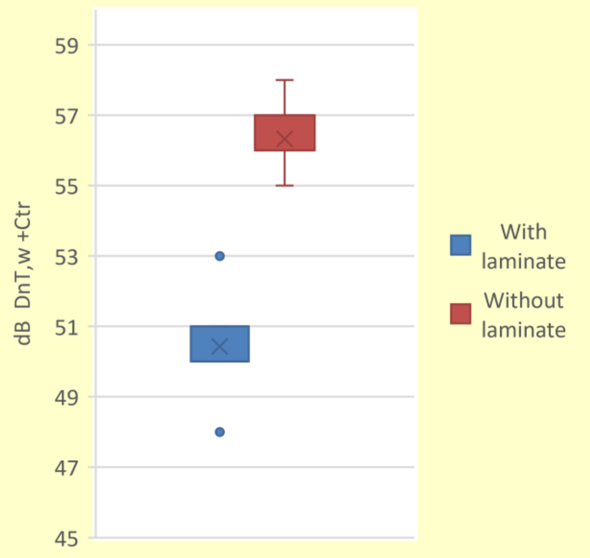


Figure 7 - Airborne wall tests, with and without laminate flooring

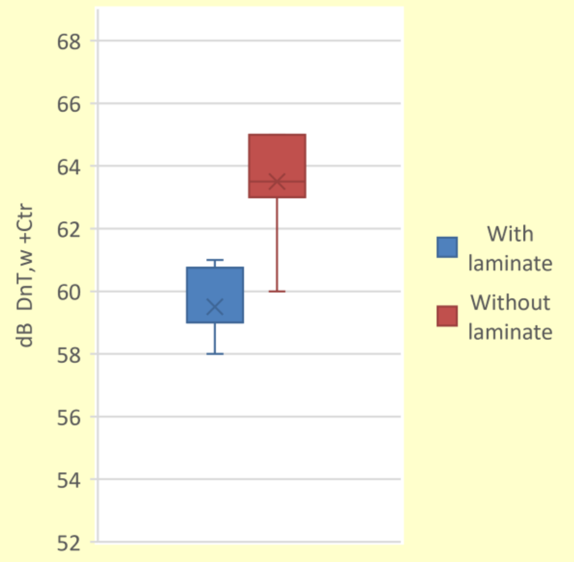


Figure 8 - Airborne floor tests, with and without laminate flooring

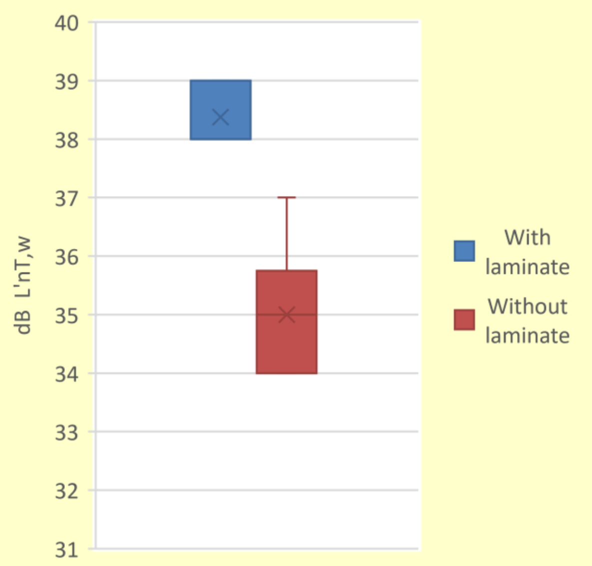


Figure 9 - Impact floor tests, with and without laminate flooring

In summary, we have seen an average reduction in performance of the separating walls and floors when floor finishes are installed, as follows:

Table 1 – Typical reduction in performance of separating walls and floors caused by floor finishes.

Separating element	Average reduction in performance caused by resonant floor finishes
Separating walls	6 dB (DnT,w + Ctr)
Separating floors (airborne)	4 dB (DnT,w + Ctr)
Separating floor (impact)	3 dB (L'nT,w)

5 IMPLICATIONS

The results demonstrate that using lightweight timber floor finishes in buildings constructed using a combination of ADE Type 4 walls and Type 1 floors can cause a significant reduction in the sound insulation performance of the separating walls and floors.

In practice this would not ordinarily be picked up by pre-completion testing if the tests are taken at the usual stage before the floor finishes are installed, but this could therefore have the following implications:

- The PCT results may not represent the true sound insulation performance of the separating constructions, particularly where the floor finishes are installed by a landlord prior to occupation but after the PCT.
- Likewise, the sound insulation between dwellings can be significantly affected by finishes and furnishings installed by occupants later.
- In both cases, in lighter weight concrete structures this phenomenon could potentially reduce sound insulation performance to be much closer to the ADE minimum requirements than the examples studied for this article.
- In terms of design criteria, BREEAM HEA05 awards up to 4 credit credits for sound insulation performances either 3, 5, or 8dB better the Part E minimum requirements. The timing of the tests could therefore make the difference between 0 or 4 credits being awardable, depending on whether they are taken before or after floor finishes are installed.

6 FURTHER WORK

There is significant scope to expand on the findings discussed in this article, and we consider that the following further work would be useful to refine the results and determine the extent that this phenomenon affects sound insulation in practice:

- Test the same pairs of rooms with and without floor finishes to eliminate the effect of room sizes, flanking conditions or other variables from the comparable results.
- Test samples of various solid or laminate timber flooring products with several different resilient layers to compare the resonant frequencies against the theoretical predictions.
- Investigate the impact of room furnishings, such as sofas, beds, cupboards, and wardrobes etc. to determine whether these would have any damping effects on the floor resonances, and consequently mitigate the reduction in the sound insulation performances that we have seen.

7 REFERENCES

[1] Hongisto V. A case study of flanking transmission through double structures. Applied Acoustics 62 (2001)