Relationship between flanking noise through a common ceiling plenum and plenum absorption

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ABSTRACT

The influence of absorption laid directly on top of ceiling tiles installed in a suspended ceiling system was examined with four different ceiling tile products. Glass fibre absorption material of thicknesses of 15 mm, 25 mm, 40 mm, and 100 mm was laid in turn directly over the ceiling tiles. An increase in the transmission loss though the plenum sound path was seen with the addition of absorption to the rear side of the ceiling tiles. This increase was generally largest for the 25 mm thick absorption, however the largest overall gain was for the thickest absorption (100 mm). It was seen that a relatively poor performing ceiling tile can perform relatively well if a thick absorption product is laid directly on top of the tile in the plenum.

1. INTRODUCTION

Typically, offices are designed as single large open spaces that tenants fit-out, breaking the space up into meeting rooms, private offices, reception areas, and staff break-out spaces. Walls that separate these spaces are normally constructed after the suspended ceiling has been installed and for simplicity are only constructed up to the ceiling height. The transmission loss between spaces in an office building is typically limited to that through the plenum sound path, which may be less than a typical double leaf wall (Hongisto *et al*., 2010).

ASTM E1414-11a (ASTM, 2011) describes a method to determine the sound transmission loss through a suspended ceiling system, across a plenum, back through a suspended ceiling system, and into an adjoining room (plenum sound path) using a Ceiling Flanking Noise (CFN) facility. A CFN facility was constructed and commissioned at the University of Canterbury and used to establish the transmission loss through the plenum sound path of four different ceiling tile products with and without acoustic absorption, of thickness 15 mm, 25 mm, 40 mm, and 100 mm laid directly over the entire suspended ceiling system. This extends previous work that looks at a single thickness of acoustic absorption added to the plenum (Royar and Schmelzer, 2006).

2. TEST FACILITY AND PRODUCT DESCRIPTION

2.1 Facility design and construction

The design of the University of Canterbury's CFN facility is described by Barclay *et al* with the internal dimensions shown in Figure 1 (Barclay et al., 2014).

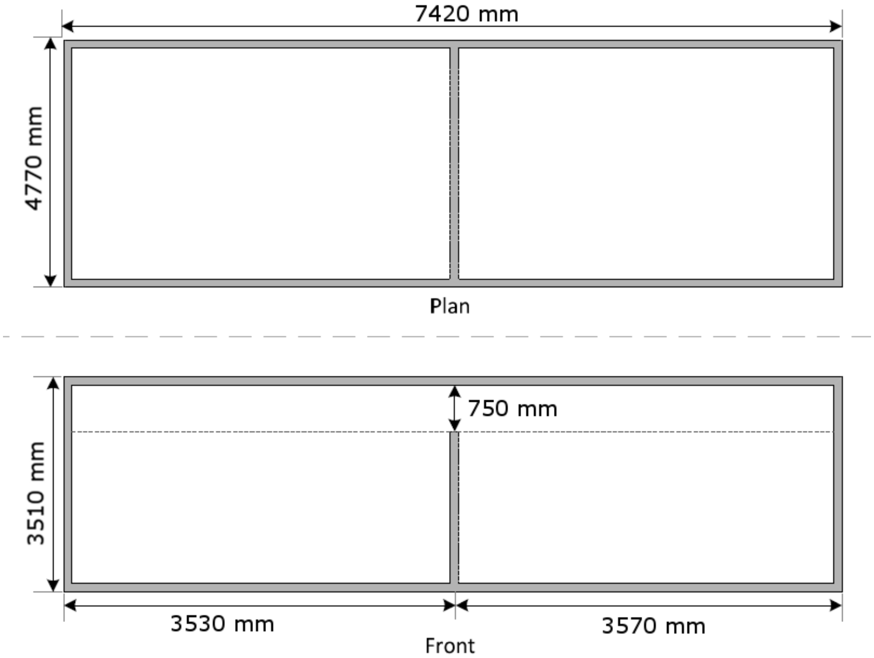

Figure 1: Internal dimensions of the CFN facility constructed at the University of Canterbury

The separating wall was required to be upgraded from that described by Barclay *et al*. The final wall construction diagram is shown in Figure 2 below.

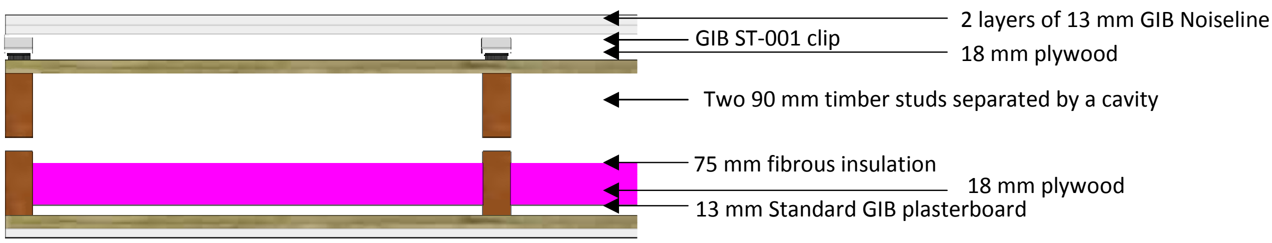

Figure 2: Construction of the separating wall between the source and receiving rooms

All flanking paths (with the exception of the plenum sound path) were assessed in-situ to ensure that the sound paths other than the plenum sound path did not contribute to the noise measured in the receiving room. The transmission loss of all the external walls was also determined, to verify that external noise would not influence the results. Measurements were performed in strict accordance with ASTM E1414-11a, and the single number ratings of the ceiling attenuation classes (CAC) were calculated using the method outlined in ASTM E413-09 (ASTM, 2007).

2.2 Ceiling tile products

The transmission loss of four types of ceiling tile products with and without absorption on the plenum side were determined. Three ceiling tiles were made from mineral fibre with the fourth being a composite tile consisting of 25 mm fibrous absorption facing with an adhered backing of 10 mm plasterboard. One mineral fibre ceiling tile was constructed of two different densities of mineral fibre, a more dense backing (presumably to increase the transmission loss) and a more porous front (to increase absorption). Key parameters of the ceiling tiles are provided in Table 1 below.

Table 1: Material properties of the ceiling tiles.

Ceiling tile product	Material	Thickness (mm)	Surface density (kg/m^2)	Front face noise reduction coefficient (ASTM, 2010)	Back face noise reduction coefficient (ASTM, 2010)
Ceiling tile A	Mineral fibre	12	3.3	0.50	0.45
Ceiling tile B	Mineral fibre	19	4.7	0.70	0.45
Ceiling tile C	Mineral fibre	42	10.8	0.90	0.20
Ceiling tile D	25 mm glass fibre, 10 mm plasterboard	35	10.2	0.75	0.05

The sound absorption afforded by the back face of the ceiling tile was first explored in order to determine the absorption provided in the plenum space by the ceiling tile products. The random incidence sound absorption coefficient of the back faces of the ceiling tiles were determined in the reverberation room at the University of Canterbury. The samples were placed in turn in mount Type-A configuration (with the front face of the ceiling tiles facing the floor of the reverberation room, with steel angles around the outside) using the methodology outlined in ISO 354:2003 (ISO, 2003), and the results shown in Figure 3.

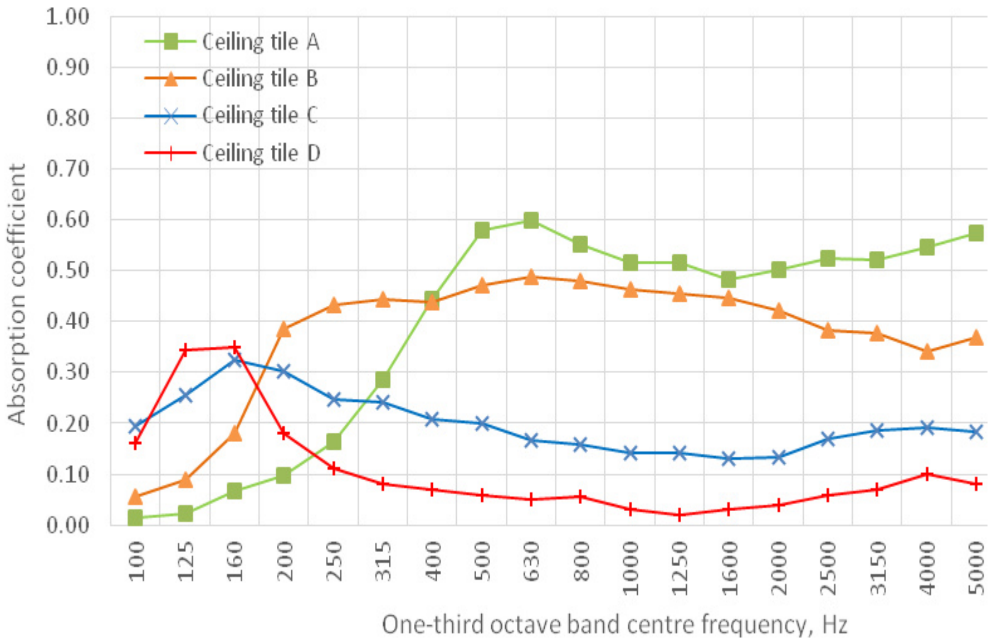

Figure 3: Absorption coefficient of the back face of the four ceiling tile products

Above 200 Hz, ceiling tile D provided little absorption, however at and below 160 Hz, this product had the highest measured absorption of the ceiling tile products. Ceiling tiles A and B have absorption coefficient curves typical for this type of materials.

2.3 Plenum absorption products

Four different thicknesses of glass fibre acoustic absorption were added to the rear surface of the tiles in turn. Key parameters of the glass fibre acoustic absorption material are provided in Table 2 below.

Table 2: Material properties of the plenum absorption.

Acoustic absorption	Material	Surface density (kg/m^2)	Noise reduction coefficient (ASTM, 2010)
15 mm absorption	Glass fibre	1.5	0.75
25 mm absorption	Glass fibre	2.5	0.85
40 mm absorption	Glass fibre	4.0	0.95
100 mm absorption	Glass fibre	10.0	1.05

Figure 4 shows the sound absorption provided by the different thicknesses of the absorption installed in the plenum space. The absorption coefficients were determined using the methodology outlined in ISO 354:2003, in mount Type-A (laid directly on the floor of the reverberation room, with steel angles covering the sides). The results show that as the thickness of the absorption product increases, the sound absorption afforded by the product increases, the largest increase being seen at the lower frequencies.

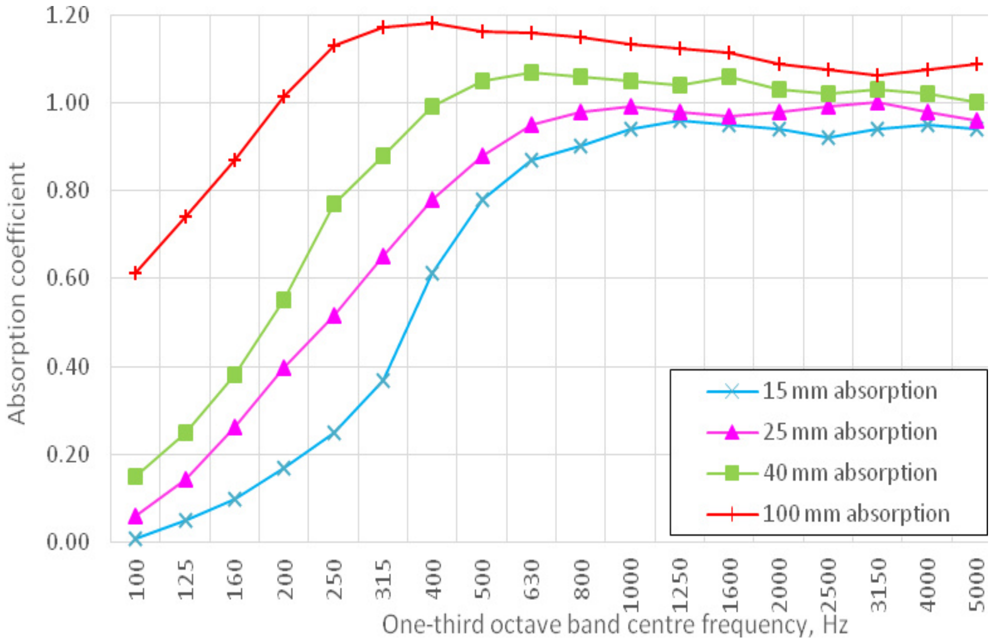

Figure 4: Sound absorption of the glass-fibre materials

3. INFLUENCE OF PLENUM ABSORPTION OF THE TRANSMISSION LOSS

Measurements were undertaken using the University's newly commissioned CFN facility. The transmission loss through the plenum sound path was first determined with absorption on the plenum walls as required by ASTM E1414-11a but without any acoustic absorption products over the ceiling tile surface. Each acoustic absorption product was then installed separately over the entire suspended ceiling system area on the plenum side and tests repeated for each thickness of acoustic absorption. The absorption materials were installed over all four ceiling tile products to determine if there was any trend between the sound transmission through the plenum sound path and the additional sound absorption in the plenum space. Figure 5 shows the 40 mm absorption added on top of a ceiling tile product the plenum.

Figure 5: 40 mm fibrous absorption added to the plenum on top of a ceiling tile product

3.1 Transmission loss of just the ceiling tiles

The transmission loss between the two rooms in the CFN facility was determined in accordance with ASTM E1414-11a (ASTM, 2011). Sound pressure measurements were recorded in each room at five different positions. Figure 6 shows the transmission loss when just the ceiling tiles were installed in the suspended ceiling grid.

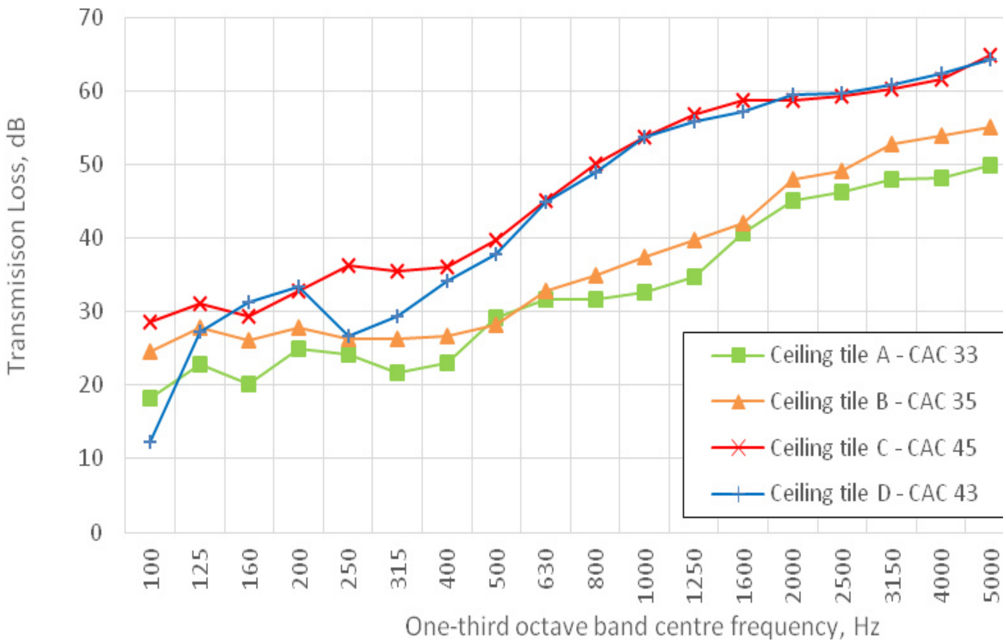

Figure 6: Sound transmission loss through the plenum sound path for four ceiling tile products

The transmission loss of ceiling tiles C and D are similar as they have similar surface densities (10.8 kg/m^2 for ceiling tile C and 10.2 kg/m^2 for ceiling tile D). However the transmission loss for ceiling tile D shows a large dip at 250 Hz when compared to the other ceiling tile products. This tile is a composite tile and at 250 Hz the absorption coefficient is less than 0.1 (effectively providing no absorption). The decrease at this frequency is probably due to the acoustic modal coupling between the rear of the ceiling tile and the roof of the CFN plenum. In effect, the decrease is probably due to resonance of sound through the plenum sound path and it is not absorbed by the rear of the ceiling tile as would be the case for the other mineral fibre ceiling tiles.

3.2 Transmission loss with absorption over the ceiling tiles

The four different thicknesses of fibrous absorption were in turn added to the rear surface of the tiles in the plenum space. The resulting transmission loss is shown in Figures 7 to 10. It can be seen that as the sound absorption in the plenum increases, the transmission loss through the plenum sound path increases.

The ceiling tile products that have lower mass, so consequently lower transmission loss (ceiling tiles A and B), provide a larger increase when the absorption is added to them when compared to the high mass ceiling tiles (ceiling tiles C and D). The higher mass ceiling tiles provide a higher transmission loss.

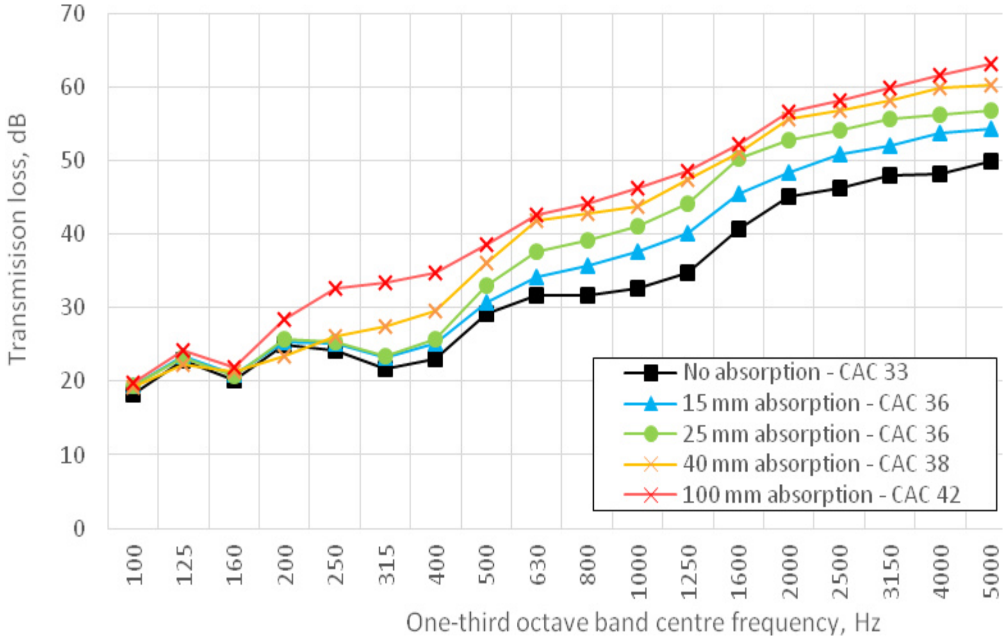

Figure 7: Transmission loss for ceiling tile A with various thicknesses of absorption in the plenum

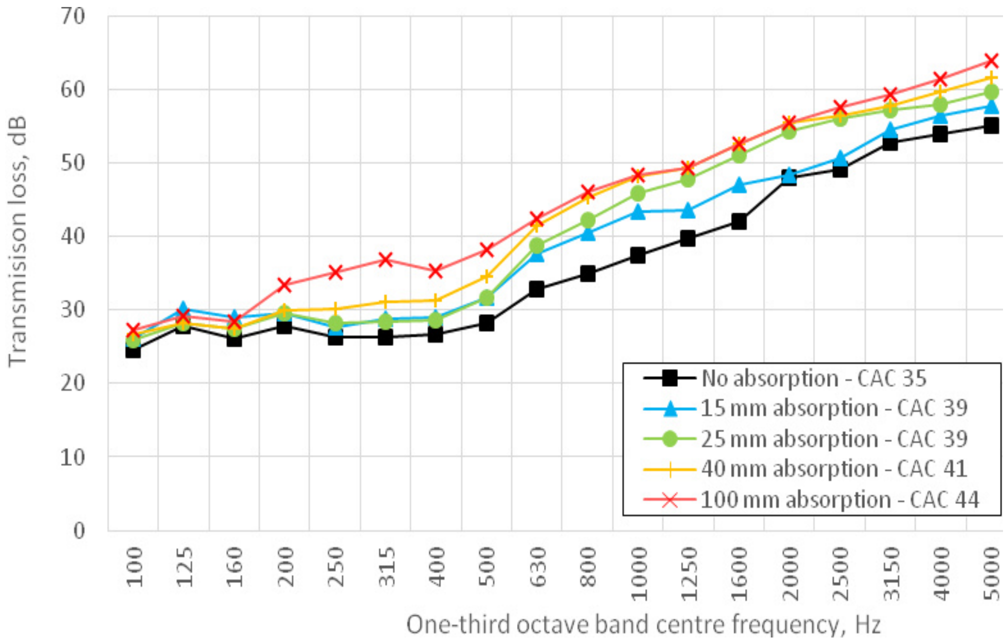

Figure 8: Transmission loss for ceiling tile B with various thicknesses of absorption in the plenum

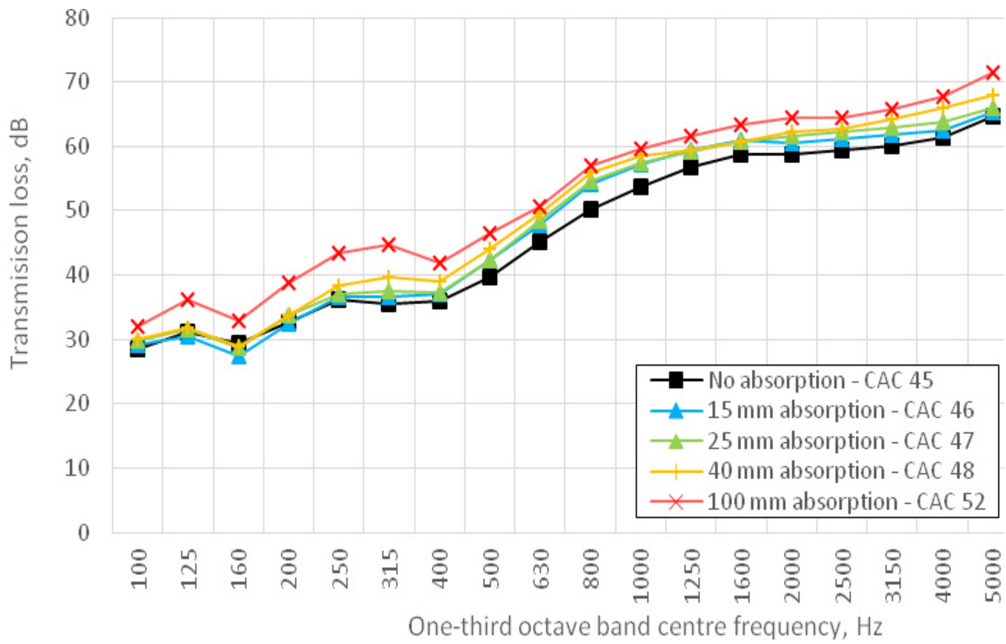

Figure 9: Transmission loss for ceiling tile C with various thicknesses of absorption in the plenum

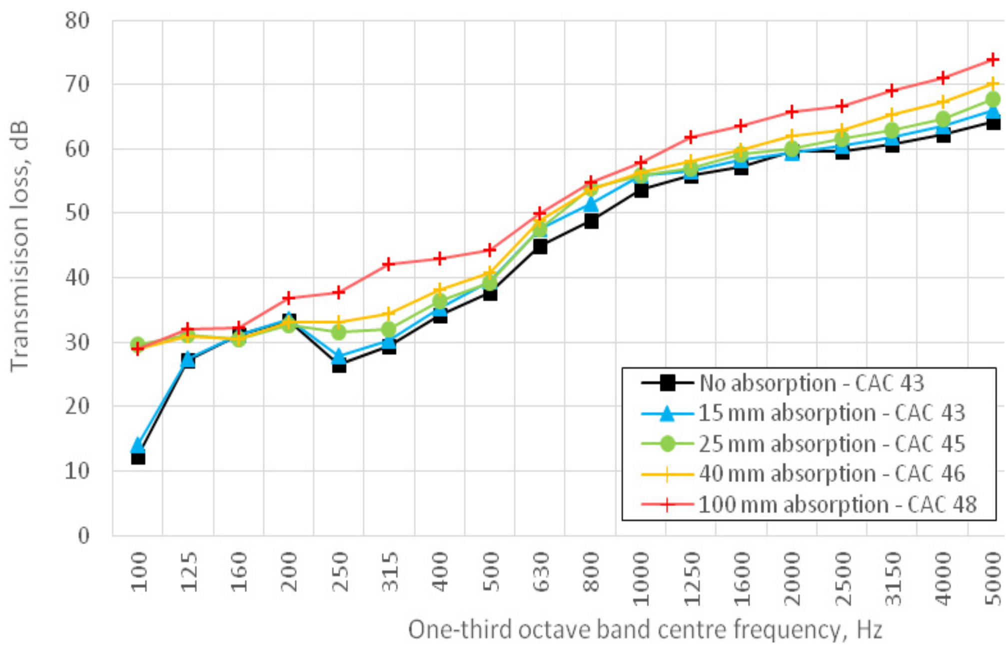

Figure 10: Transmission loss for ceiling tile D with various thicknesses of absorption in the plenum

3.3 Discussion

There are three regions which may be seen in the transmission loss curves for the four ceiling tile products. The first region (below 200 Hz) is typically flat and shows little difference when absorption is added to the plenum. Between approximately 200 Hz and 500 Hz, the transmission loss curve is still approximately flat, however the transmission loss in this region increases with increasing thickness of absorption added to the plenum. The third region, above 500 Hz is probably a mass controlled region where the transmission loss increases with the mass of the ceiling tile plus the mass of the absorption.

Through the expected mass controlled region, above 500 Hz, the transmission loss increases by approximately 2 – 3 dB per one third octave band as the surface density doubles. This can be seen more easily in the lower mass ceiling tiles, where the surface density doubles or more when 40 mm or 100 mm absorption is added in the plenum above the ceiling tile. As the surface density of ceiling tiles C and D is already over 10 kg/m^2, an increase is only just noticeable, but still follows the same trend.

The decrease at 250 Hz and 315 Hz seen in ceiling tile D is probably due to the reflective surface on the roof and back face of the ceiling tile. The back face of ceiling tile D is plasterboard, so reflects sound more readily, as seen in Figure 3. With the addition of 25 mm or greater absorption to the plenum, this reduction is all but eliminated, which suggests that a reduction in transmission loss at these frequencies is due to a ceiling mode between the plasterboard backing of the ceiling tile and roof of the CFN facility.

4. SUMMARY

The transmission loss through the plenum sound path increases with the presence of absorption on the rear of the tiles. While this is generally seen as a mass law increase above 500 Hz, there is some increase below 500 Hz, which may be attributed to sound being absorbed in the plenum. The transmission loss when additional absorption is added to the plenum has a greater effect when the ceiling tile has a lower transmission loss rather than a higher transmission loss. This is attributed to the increase in mass provided by the absorption layer.

In this research, the absorption was laid directly over the tiles, such that the sound had to travel twice through the absorption to be transferred between the two rooms. To determine if the increase in transmission loss was from sound being absorbed in the plenum, or sound going through the absorption material (and associated transmission loss), further work could consider absorption mounted on the roof of the CFN facility rather than directly over the ceiling tiles.

5. REFERENCES

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