Flanking transmission in three different lightweight wooden building types

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ABSTRACT

Three different Swedish lightweight multistory buildings have been investigated with respect to the flanking transmission over an inner wall. Among the buildings analysed, one of them had been used by residents for three years and the two other were only just erected and being built respectively. A tapping machine and a Japanese ball were used as excitation sources so as to produce vibrations in the structures over the junctions in the respective buildings. Despite of the different vibratory performances depending on the construction type, all three buildings were found to perform well in the low frequency range

Keywords: Vibration, light-weight building, Flanking Transmission   I-INCE Classification of Subjects Number(s): 43.2.2

1. INTRODUCTION

As an alternative to the traditional construction techniques using concrete for multi-family dwellings, lightweight structures are becoming a cost-effective alternative. In countries with large forested areas, such as for instance the Nordic countries, lightweight building techniques using wooden structures is increasingly popular not least due to the fact that timber is a renewable resource.

There is also a trend towards increasing demands on the acoustic performance of building elements. People living or working in these types of buildings expect them to perform as well as a traditional building which is reflected in the increasing demands in the various building codes of European countries. The trend is adding focus to the low frequency range. due to the low mass of the constructions and rather low transmission losses occurring over junctions, traditional lightweight structures are not performing well in the low-frequency range. According to (1), a great variance in the sound insulation of lightweight wood constructions is observed. Such variations can be due to the design of the structure and also on the craftsmanship in the construction of the building (2, 3). It has been shown (4) that the different manifestations of the floor and wall assemblies in light-weight structures greatly affect the flanking transmission.

2. INVESTIGATED OBJECTS

The buildings in which the measurements have been performed are located in three different parts of Sweden, (Malmö, Varberg and Falun). The buildings have been investigated previously in the AkuLite project (5). However, in this investigation a different scheme has been used in the placing of the sensors. The buildings can be seen in figure 1

The three buildings are all four or five storey lightweight wooden structures. Building 1 have a nine storey concrete structure attached but the structure investigated is the lower wooden part. The apartments in the buildings have three to four rooms. All apartments have identical layout with the upper and lower apartments in the respective buildings. The respective floor plans and the placement of the excitation source can be seen in figure 7. The structural designs of the floors are summarized in table 1

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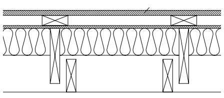
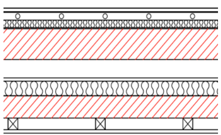
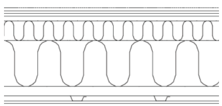
(a) Building 1 Malmö

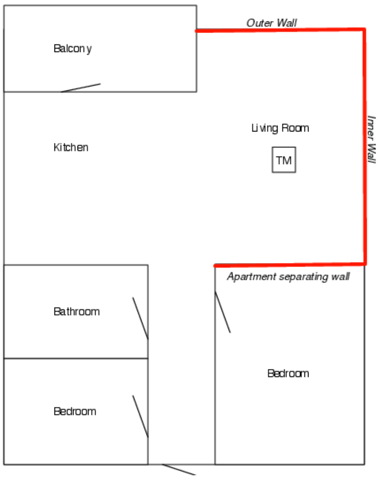
(b) Building 3 Varberg

(c) Building 2 Falun

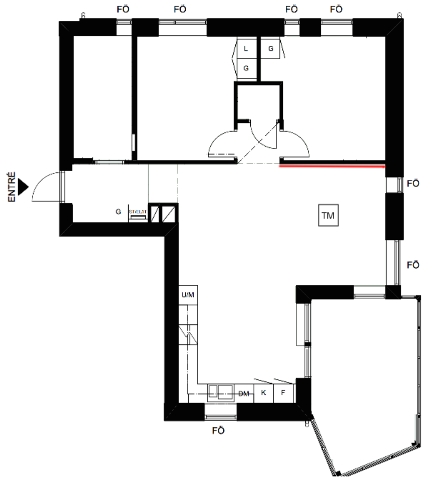
Figure 1 – The three buildings investigated.

Table 1 – Structural framework and design of floors for the three buildings.

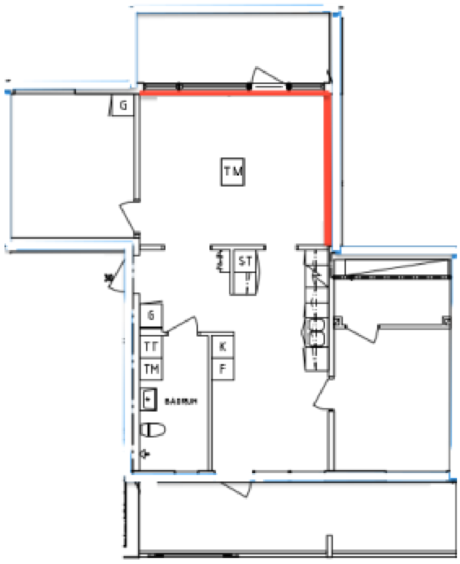
Building 1	**Building 2**	**Building 3**
Particle board	Solid timber	Lightweight timber
Timber beams	CLT	LVL
Plane element	Plane element	Plane element
		



(a) Building 1 Malmö

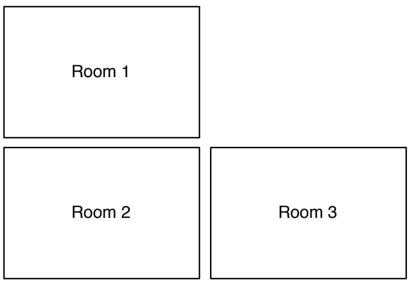


(b) Building 3 Varberg

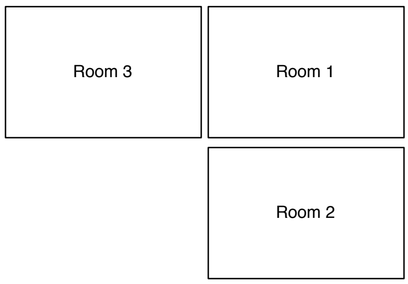


(c) Building 2 Falun

Figure 2 – Floorplans of the investigated apartments. TM indicate the placement of the tapping machine. Red indicate walls subjected to measurements..



(a) Building 1



(b) Building 3

Figure 3 – Vertical placement of the rooms in building 1 and 3.

3. MEASUREMENT METHOD

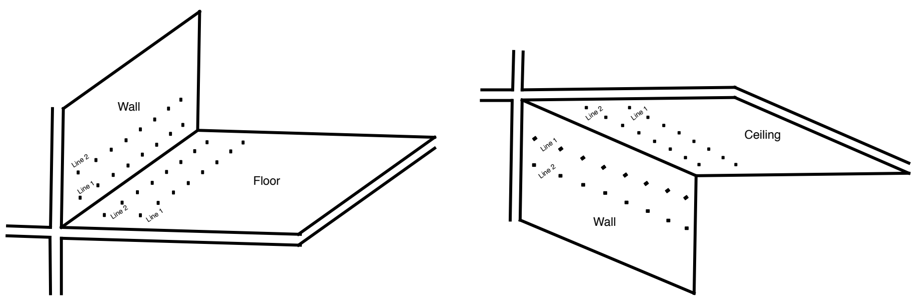
The measurement setup used follow the one used by Bard and Sjökvist in (6). In the setup 32 accelerometers are used. The accelerometers are placed around a junction in the building. In the three buildings the rooms designated room 1 and room 2 are situated on top of each other with room 1 being the upper room. In buildings 1 and 3 access to adjacent rooms was given, for building 1 room 3 was adjacent to room 2 as seen in figure 3a In building 3 room 3 was adjacent to room 1 as seen in figure 3b. The outline of the placing of the accelerometers can be seen if figure 4

The number of accelerometers in each line is 8 and the distance of the accelerometers on the floor from the wall is 50mm and 500mm from the wall respectively. The distance between adjacent accelerometers is 500mm. The accelerometers on the wall are placed at 100mm and 1m. In the lower rooms the accelerometers were placed in the ceiling at the same distances as on the floors. However, the accelerometers on the wall in the lower rooms are placed at 50mm and 500mm respectively.

Due to time constraints and the fact that building 2 was furnished only one line per surface along the junction could be measured. Likewise, in building 1, only the lower line at 500mm could be measured in room 3 and there only with half the number of accelerometers.

The excitation source was a standardized tapping machine with only one hammer active. The tapping machine was placed in the center of the measured floor surface of room 1. For the measurements in building 2 we also had access to a Japanese ball for use as an excitation source.

The acceleration level of the floors and walls were measured during 20 seconds. Each measurement was repeated three times. For the eight channels in each measurement line the mean acceleration level was calculated in third octave bands. The attenuation between the line of accelerometers closest to the excitation source in the source room and the remaining lines of accelerometers was calculated for each room in the measured building.



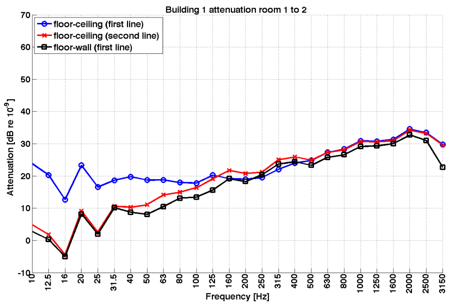
(a) Floor-Wall (b) Ceiling-Wall

Figure 4 – Placement of accelerometers

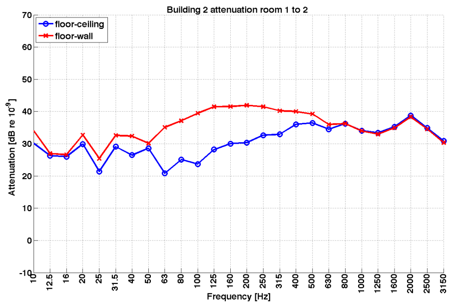
4. RESULTS

Figure 5 show the attenuation between the source room (room 1) and the receiving room (room 2) for each of the three buildings. As expected the attenuation increases with increasing frequency. In building 1 the second line of accelerometers is missing due to technical difficulties. The attenuation in the lower frequencies is higher for the accelerometers in the ceiling furthest from the wall in building 1. In building 2 the attenuation to the ceiling and wall in the middle part of the spectrum differ significantly whereas the attenuation in the low- and high part of the spectra is almost identical as shown in figure 5b. Building 2 is constructed using cross-laminated timber (CLT) as shown in table 1 and is more stiff and heavier than the other two building solutions which explain the higher attenuation in building 2. For building 3 the attenuation is more equal over the entire frequency range as seen in 5c. The attenuation in the ceiling closest to the wall exhibit a smaller attenuation between 25Hz and 63Hz.

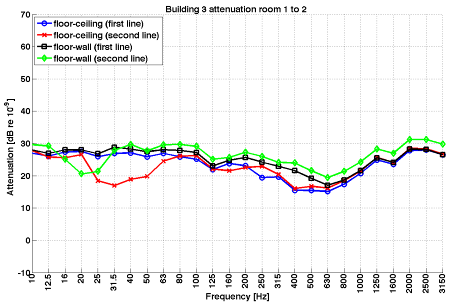
In figures 6a and 6b the attenuation to the adjacent rooms can be seen. Note that in building 1 the adjacent room (room 3) is located on the floor below the sending room and in building 3 the adjacent room (room 3) is located on the same floor as the sending room as seen in figure 3. In building 1 the wall between the rooms is a supporting i.e. load-bearing wall, whereas in building 3 the separating wall is not a load-bearing wall. As in the case in going from room 1 to room 2 in building 1 the attenuation in the ceiling is lower in the second line (i.e. closer to the wall) than in the first line. There is little attenuation in the lower frequencies up to 300Hz after which the attenuation for the higher frequencies increases as expected. This was also shown to be the



(a) Building 1



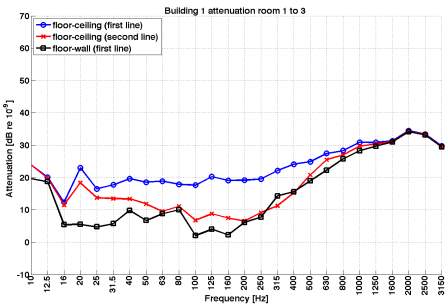
(b) Building 2



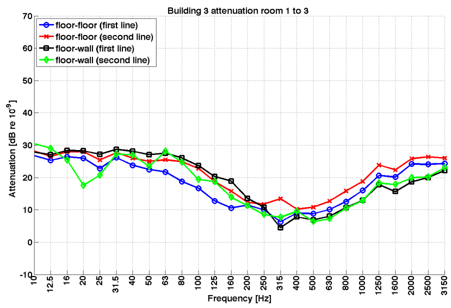
(c) Building 3

Figure 5 – Measured attenuation between the sending room and the lower room in the three buildings.

case for impact sound in the AkuLite project (5). In building 3 the attenuation from room 1 to room 3 have a more prominent decrease at 315Hz. For the lower and higher frequencies the attenuation is similar to the attenuation going from room 1 to room 2.



(a) Building 1.



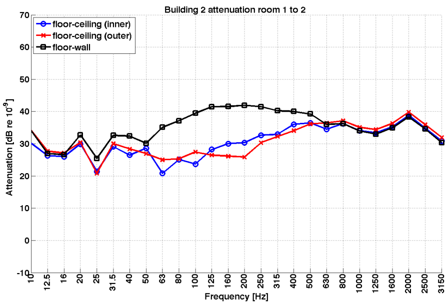
(b) Building 3.

Figure 6 – Measured attenuation between the sending room and the adjacent rooms in building 1 and 3.

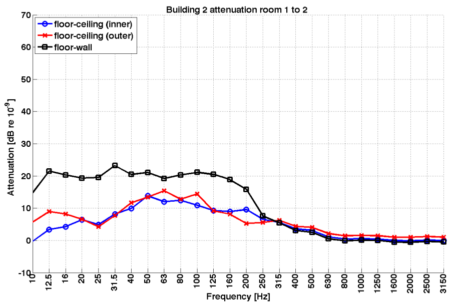
In building 2 the same measurements were repeated with a Japanese ball as the excitation source. As can be seen in figure 7a and 7b there is almost no attenuation above 250Hz when the ball is used as excitation source. This is due to the lack of excitation in the higher frequencies when the ball is used (7). In building 2 measurements were also performed along the outer wall of the room, As can be seen in figure **??** the difference in attenuation in the along-beam (inner) direction and the across-beam direction is negligible.

5. CONCLUSIONS AND FURTHER WORK

All of the buildings investigated perform well with respect to flanking transmission of vibrations. Building 2 and 3 are slightly better in the low frequency range but all buildings meet the requirements in the building code. Building 3 is measured along an inner wall as opposed to buildings 1 and 2 where a load bearing wall was measured. This may explain the relatively low attenuation in the mid frequency range. Using the Japanese ball as a source of excitation is good for the low frequency range but give little information in the higher



(a) Building 2, tapping machine excitation.



(b) Building 2, Japanese ball excitation.

Figure 7 – Measured attenuation between the sending room and the lower room in building 2.

frequencies. The tapping machine is well suited for this type of measurements but the measurement time of 20s is not long enough to give good results in the lowest frequencies. The authors will continue investigating the effects of different floor constructs on the flanking transmission in lightweight buildings. With the goal of producing a methodology to through measurements obtain a transfer function for a given floor for use in a finite element simulation.

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