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In situ measured flanking transmission in light weight timber houses with elastic flanking isolators - Part II

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ABSTRACT

There is a strong trend to industrially produce multi-storey light weight timber based houses. The concept allows the buildings to be manufactured to a more or less prefabricated extent. Most common types are volume/room modules or flat wall and floor modules. When assembling the modules at the building site, elastomer isolators are used in several constructions to reduce flanking transmission. The sound insulation demands in the Nordic countries are relatively high and therefore the flanking transmission must be well controlled, where elastomer isolators are an established alternative. Decoupled shielding wall elements is another. There are though no working studies or mathematical models of the performance of these isolators. They are treated as simple mass-springs systems that operate vertically, i.e. one degree of freedom. In this paper there are analyses of an expanded set of experimental data of the structure borne sound isolating performance of elastomer isolators, which are separating an excited floor from receiving walls. This part II study now includes all in all 9 buildings. The isolation performance dependence on structure type is analyzed. An empirically based regression model of the vibration level difference is derived. The model is based on measurements of 8 elastomer field installations, which are compared to an installation without elastomers. A goal is that the data can be used for input in future SEN prediction models for modeling of the flanking transmission part of sound insulation.

1. INTRODUCTION

Flanking transmission or flanking isolation between floors in light timber houses is traditionally improved by adding additional wall plates with distances on the sending room and on the walls of the receiving room. Other ways are to suspend the ceiling in resilient metal profiles or, for impact sound, to add a resilient layer on the floor board. A further method is to add damping on the floor board in order to reduce vibrations from impacts to reach the walls by Ljunggren, Ågren (4).

Another method is to put the floor on elastomer isolators or to put the whole room on resilient isolators. This method introduces both possibilities and new challenges to solve. This paper presents results where the flanking transmission with this method is analyzed. This paper is a continuation of paper by Ågren, Ljunggren(1) where more measured objects have been added.

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2. ELASTOMER FLANKING ISOLATORS – THE PRINCIPLE

The isolators are used as spring and damper between the loading structure element, which in the presented examples can be either a floor module, figure 1, or the whole room volume including floor, walls and ceiling. The isolators that are being used are in type A used as strips around the whole flank. In construction B the elastomers are used as pads of 0.1x0,1 m under each wall beam.

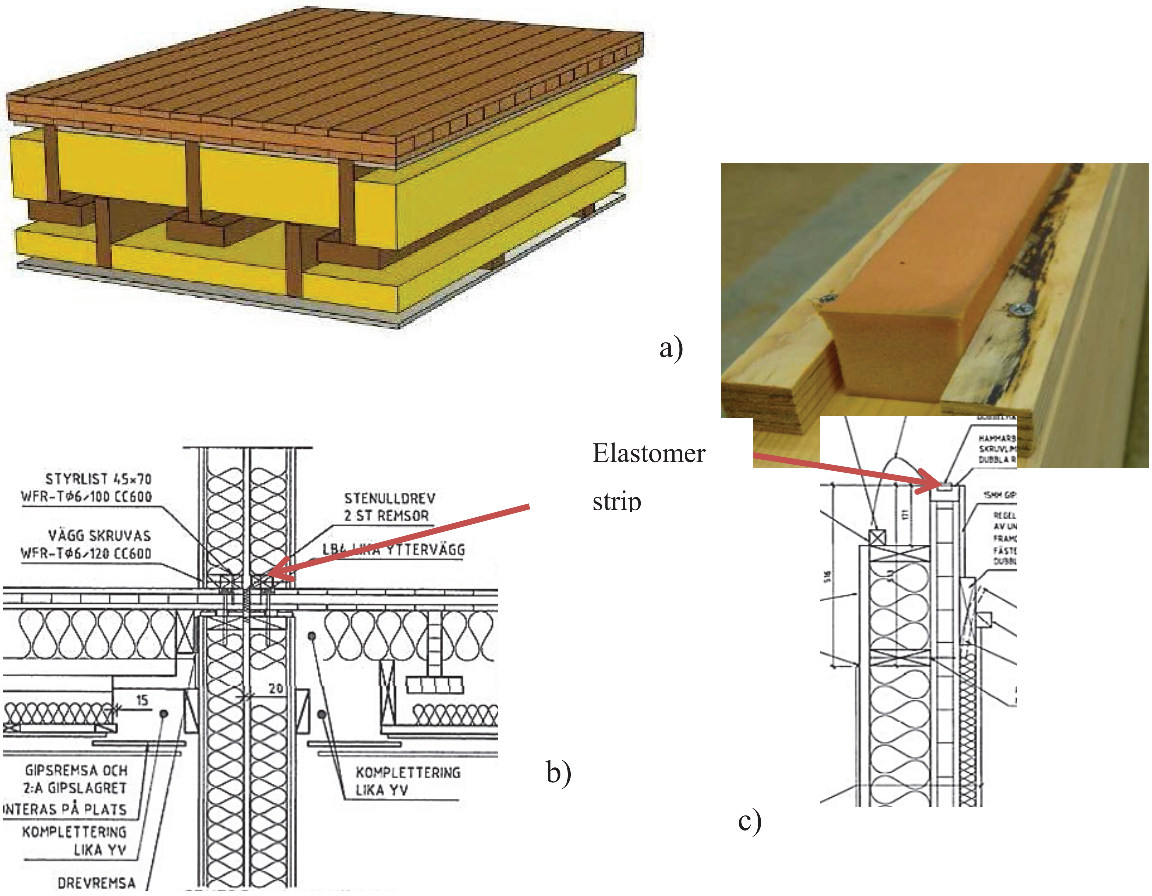

Figure 1 - Elastomer flanking couplings for decoupling of the floor from the supporting structure, type A: a) Separate CLT floor and ceiling. Elastomer strips loaded by the floor cassette. b) Coupling for apartment separating walls. c) Outer wall with a CLT load bearing wall plate and a radiation protection isolating layer.

The isolators are treated and normally dimensioned as vertical point loaded mass-spring-isolators in one degree of freedom; although they in practice will not be point loaded and also give shear transmission in the horizontal plane as well as moment transmission (2,3). They are optimized by taking the mass-load/area of the construction unit and optimized with the stiffness of the damper. Varying loads around the floor circumference are often taken into account where it is necessary, e.g. under heavy bathrooms. Typically the stiffness is chosen to give a resonance frequency of 13-17 Hz. The mechanical loss factor is varying depending on which elastomer material is chosen, typical values presented by manufacturers are 0,08 to 0,4 in a frequency range from 10 to 1000Hz

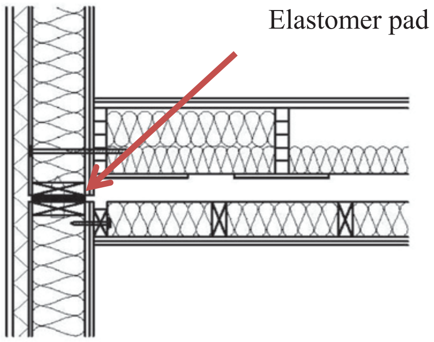

Figure 2 - Elastomer flanking couplings for decoupling of floor from the supporting structure, construction type B: Elastomer isolator pads loaded by whole room volume units.

3. MEASURED VIBRATION LEVEL DIFFERENCE IN SITU

A simplified field method for approximating the flanking transmission was used in the project AkuLite. The simplified method is chosen as it is a relatively fast field method and as the purpose is to use it on a large number of field objects. Today, all in all 23 objects of various construction types are measured. Five accelerometers are mounted; on the floor along a line 0,2 m from the wall, on the ceiling along a line 0,2 m from the wall and on the receiving room wall 0,2 m below the ceiling, figure 3. Vibrations are measured in the direction of the normal of each surface. The measured lines will be either parallel with or perpendicular to the floor load bearing beams. This will give different conditions for the vibration transfer over the respective flank.

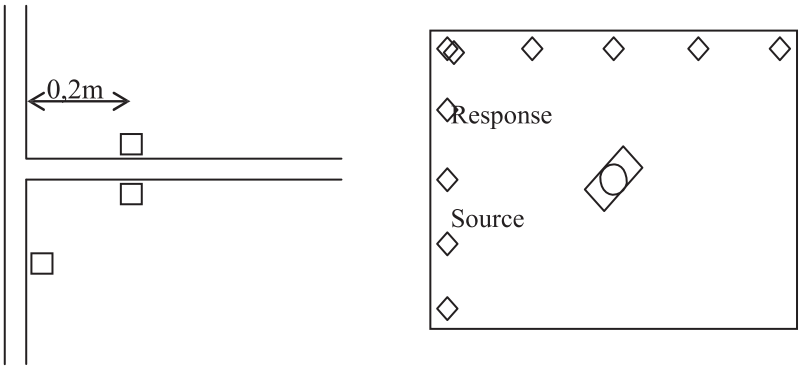

Figure 3 - Accelerometer positions for the simplified flanking transmission vibration level difference, VLD, field measurements. Five accelerometers along each line.

The vibration level difference between floor and wall is then calculated to give an approximate measure of the flanking transmission. The difference between floor and ceiling is similarly calculated to compare with the direct transmission through the floor. This is a simplified method and is not expected to give the same precision of flanking transmission measurement as when the vibration level over the whole receiving wall and floor are measured, Villot et.al.(8)or when surfaces are covered as in King et.al.(6,7). The purpose with this method is to have a reasonably simple, although detailed, method to collect data from many field objects.

3.1 Building type A, CLT construction – Elastomer isolation in a cross laminated timber plate type house

Building type A, a cross laminated timber plate and beam construction. Some examples can be seen in (5). A slight difference in VLD can be seen between the two transmission directions, parallel and perpendicular to the load bearing beams. The transmission is 4-6 dB stronger in the direction perpendicular to the load bearing beams in the frequency range 20-500 Hz, while the transmission parallel to the beams is about 8 dB stronger in the frequency range above 600 Hz.

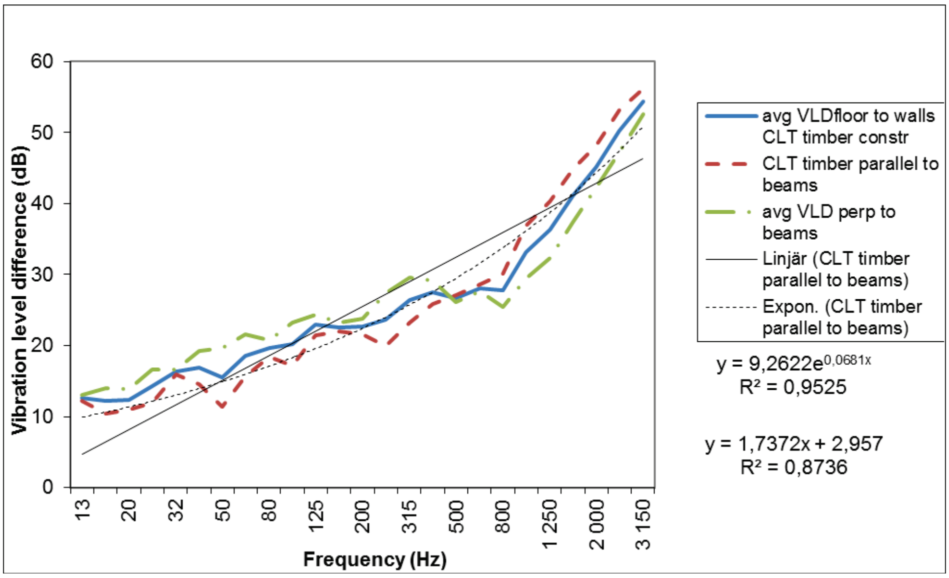

Figure 4 - Comparison of vibration level difference over the flanks from floor to wall in two directions; perpendicular to and parallel with the load bearing beams. Construction type A, CLT plate and beams with line elastomer strips. Average for five floors.

In figure 4 it is seen that an exponential regression model gives a slightly better correlation of the regression line, $R^2 = 0{,}94$ vs 0,87, compared to a linear approximation. A simplified linear expression may be approximated in the frequency range 20-630 Hz by a slope of 5dB/octave, an overall slope of 5dB/octave, a low frequency platform at 15 -25 Hz of approximately 13 dB. There can also be seen a 13 dB/octave VLD rise above 800 Hz.

3.2 House type B, volume module timber beam and board type – Elastomer pad isolation and traditional beam plate construction in volume modules

The elastic flanking isolation is designed of 0.1 x 0,1m elastomer pads, placed on top of a horizontal plank directly above each wall stud. The walls are outer walls. The load distribution becomes different in the load bearing direction perpendicular to the beams compared to parallel with the beams. A higher load is distributed along the beams to the walls in that direction. In figure 5 it can be seen that the VLD in the frequency range 80 to 1000 Hz is clearly lower in the direction parallel with the beams. The reason for this is unsure and has to be further examined. Three buildings were investigated.

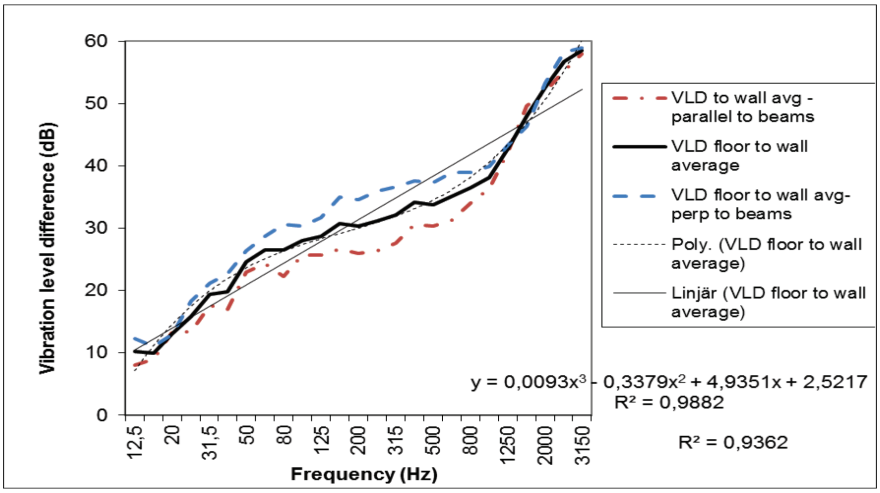

Figure 5 - Vibration level difference over the flanks from floor to wall in two directions; perpendicular to and parallel with load bearing floor beams. Construction type B, three objects. Elastomer pads.

The vibration level difference follows approximately a slope of 7dB/octave at 20-80 Hz, 3dB/octave at 80-1kHz, 5 dB/octave overall, a low frequency platform below 20 Hz of 10 dB. There can also be seen a VLD rise of 14dB/octave above 1kHz.

3.3 House type C – Flanking transmission isolation through shielding wall elements

House construction C is a concept without elastomer isolators. Instead, shielding elements with additional boards without direct contact with the load bearing walls are used. The shielding elements comprise 70 mm mineral wool and two layers of 13 mm plaster board and are connected through metal channels to the ceiling and the floor. In figure 6 it can be seen that the flanking transmission is rather independent of direction. The floor is designed , from top to bottom; parquet, 2x13mm plaster board, 22 mm floor particle board, CLT beams 360 s600, 95+220mm mineral wool, acoustic steel rails s400, 13+15 mm plaster board.

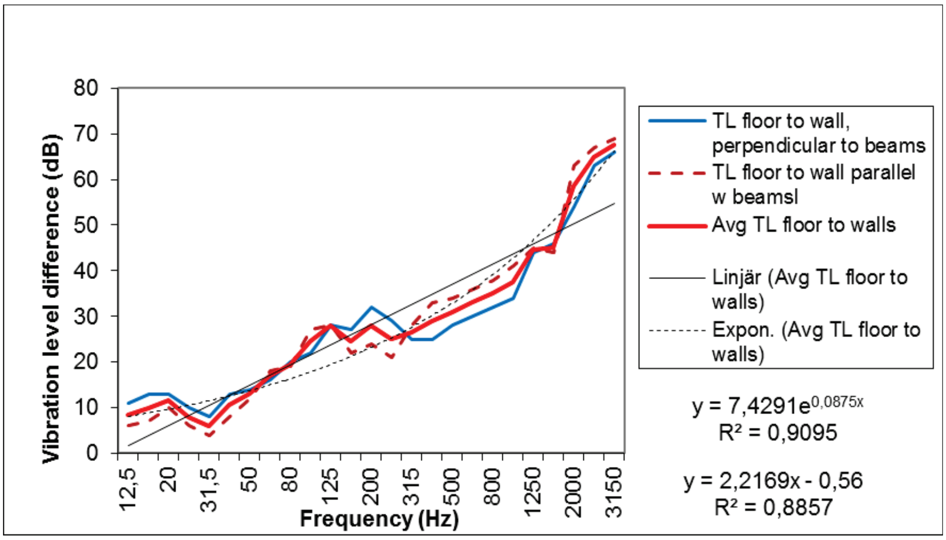

Figure 6 - Vibration level difference over the flanks from floor to walls. Comparison of VLD perpendicular to the beams and parallel with the beams. Construction type C. Only one object.

The vibration level difference follows approximately a slope of 6dB/octave, but starts from a low frequency platform of approximately around 30 Hz of only 5 dB. It can also be seen an increased VLD rise above 800 Hz for this construction as well. An exponential regression gives slightly better R^2.

In Figure 7 a comparison of VLD between the three different constructions can be seen. It shows that the flanking isolation of the shielding element construction is about 9-20 dB worse than the elastomer constructions in the important low frequency range 25-80 Hz. At higher frequencies though, 125-2500 Hz, it performs equally or even better. The volume construction isolation is performing slightly better than the CLT over most of the frequency range.

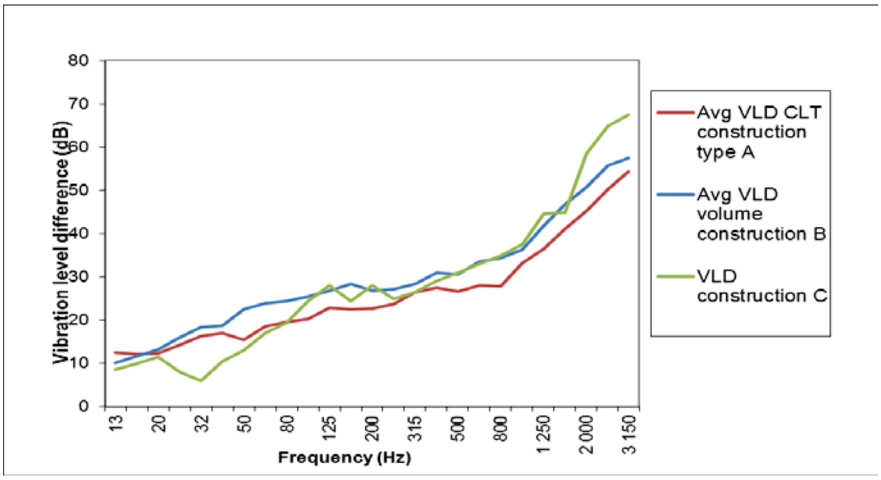

Figure 7 – Average vibration level difference over the flanks from an impact excited floor to the receiving walls. Comparison between three floor construction types.

3.4 Empirically based linear regression approximations for flanking transmission isolation

There is a need for data of flanking transmission for prediction methods like SEN 12354. One of the objectives with the measurements in this paper is to deliver empirically based data with which the flanking transmission can be approximated. Based on the results above an expression of the vibration level difference has been derived. There are a limited number of cases measured so far; only 5 for construction A, 3 for construction B and one for construction C. There are additionally measurement data from 11 various constructions, ranging from concrete to light weight timber and board constructions.

In the table below a summary of the experimental findings from construction A, B and C are shown.

Construction	Elastomer type	Low frequency platform		VLD slope dB/octave	
		freq. range, Hz, appr.	Level dB, appr.	overall	above 1 kHz
A: CLT floor and walls	Rectangular line isolator	15-25	13	5	13
B: Beam/plate volume module	0,1 x 0,1 m pad isolator	15-25	10	5	14
C: Beam/plate with shielding wall elements	-	10-30	5	6	20

Table 1- Summary of the measured VLD performance for three light weight timber based constructions, two with elastomer isolators and one without.

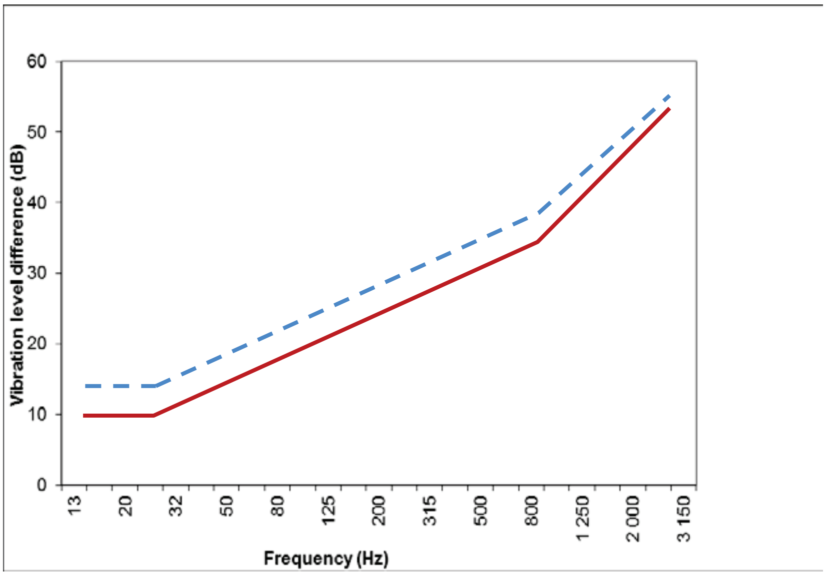

Figure 8 - Generalized average vibration level difference over the flanks from an impact excited floor to the receiving walls, for two floor construction types with elastomers.

--- CLT type with line elastomers. —— Volume type with elastomer pads.

4. Simplified transfer of VLD line measurements to surface averages

The vibration measurements on the surfaces close to the flanks are done according to a simplified method to represent the structural flank coupling through 5 surface samples. The complete flanking transmission should be measured as a surface average over the whole surfaces. In the simplified method the difference between the flanking points and the whole wall will be approximate. In figure 9 a principle drawing is shown on how to translate the VLD results to a measure of the flanking transmission to the whole receiving wall.

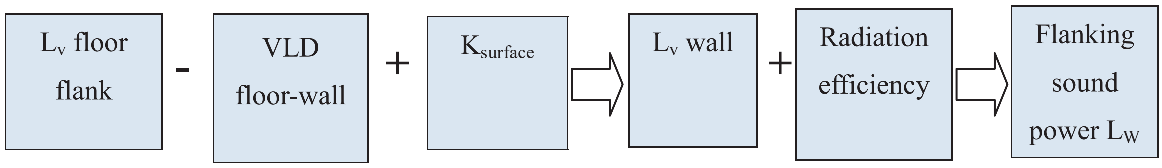

Figure 9 - Principle drawing of how the VLD can be used for determination of flanking contributions.

The VLD is measured as a near field flanking transmission term. In order to estimate the total radiated sound the surface average velocity level of the walls has to be determined. The difference between the nearfield vibrations and the overall vibrations is dependent on the damping and construction of the wall. A typical wall design is to use double gypsum boards screwed together and mounted on c/c 600mm wood or steel studs. All the constructions in these tests have these types of inner walls.

In order to estimate the difference between the near field line measurements and the total surfaces, the surface average acceleration has been measured over a couple of structures. The differences for a floor, two walls and the ceiling are shown figure 10.

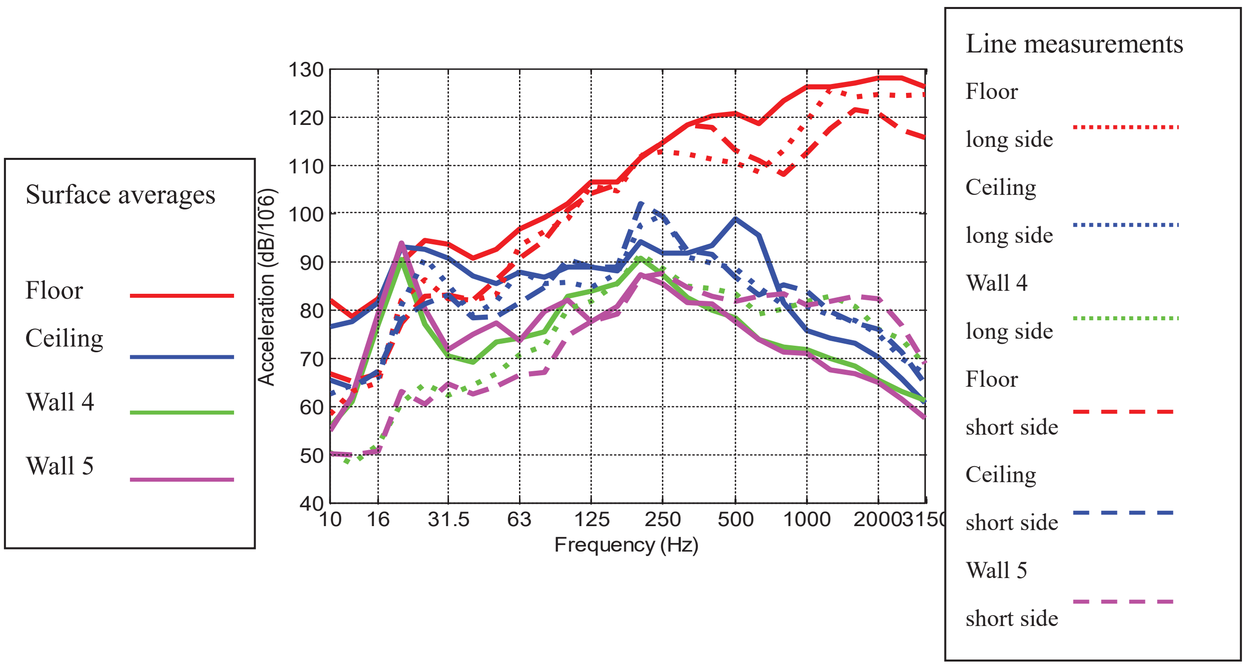

Figure 10 - Acceleration levels caused by an impact hammer machine. Comparison between the measured line of 5 points 0,2m from the flanks and complete surface average measurements.

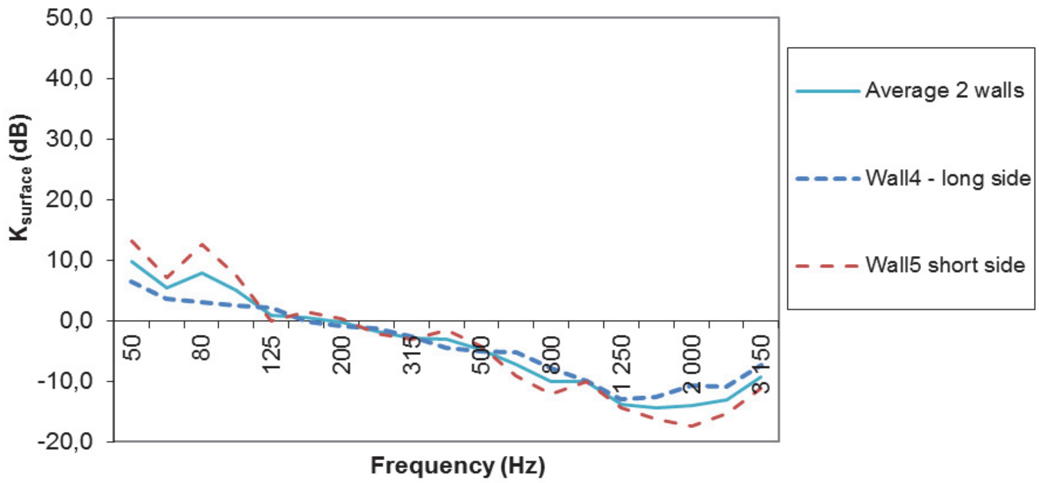

Figure 11 - Surface average compensation factor $K_{surface}$ measured for two walls.

In figure 11 the difference between average surface vibration level and nearfield 5-point line average vibration level is shown.

$$K_{surface} = L_{v,\ surface} - L_{v,\ nearfield}$$

The difference is denominated here as $K_{surface}$ in accordance to the method description in figure 9. The intention is that it can be used as a compensation factor to go from the line measurements to an approximation of the surface average. The results are from measurements on one wall construction only, although a very typical wall. The results show a clear common trend between all measurements. More work has to be done to investigate other types of walls and the general usefulness of this factor.

5. CONCLUSIONS

The objective of this paper is to estimate, characterize and give prediction expressions for determination of impact sound flanking transmission in light weight timber constructions with elastomer flanking isolators. Nine floors have been analyzed, where eight floors have elastomer isolators and one has shielding wall elements. Five of the elastomer floors are nominally identical CLT constructions and three are volume based timber beam/board constructions.

The elastomer isolators show a well-controlled flanking isolation with a slope of approximately 5dB/octave starting from around 40Hz. The beam and board volume elements show approximately the same VLD as the CLT construction, with the exception that there are large differences between the load bearing and non-load bearing directions. The cause for this is not clear but may be due to load bearing differences. Further measurements have to be made in order to get statistical reliability of the performance for these constructions. Moreover, but not presented here, it can be confirmed that there is a strong direct transmission over the floor to the ceiling at frequencies below 63Hz.

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