



NOISE CONTROL FOR QUALITY OF LIFE

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

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ABSTRACT

There is a strong trend to industrially produce multi-storey light weight timber based houses. This 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 alternative. Decoupled radiation isolated walls is another. There are though no working studies or mathematical models of the performance of these isolators. They are only treated as simple mass-springs systems that operate vertically, i.e. one degree of freedom. In this paper there is an analysis of experimentally data of the structure borne sound isolating performance of elastomer isolators that are separating an excited floor from receiving walls. The performance dependence of structure type is also presented. An empirically based regression model of the vibration level difference is derived. The model is based on measurements of six elastomer field installations, which are compared to five comparable installations without elastomers. A goal is that the model can be used for input in future SEN prediction models for modeling 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/or on the walls of the receiving room. Other ways are hang 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 /Ljunggren/.

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A relatively recent 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.

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 case A put as strips around the whole flank. In construction B the elastomers are put as pads of 0.1x0,1 m under each wall beam.

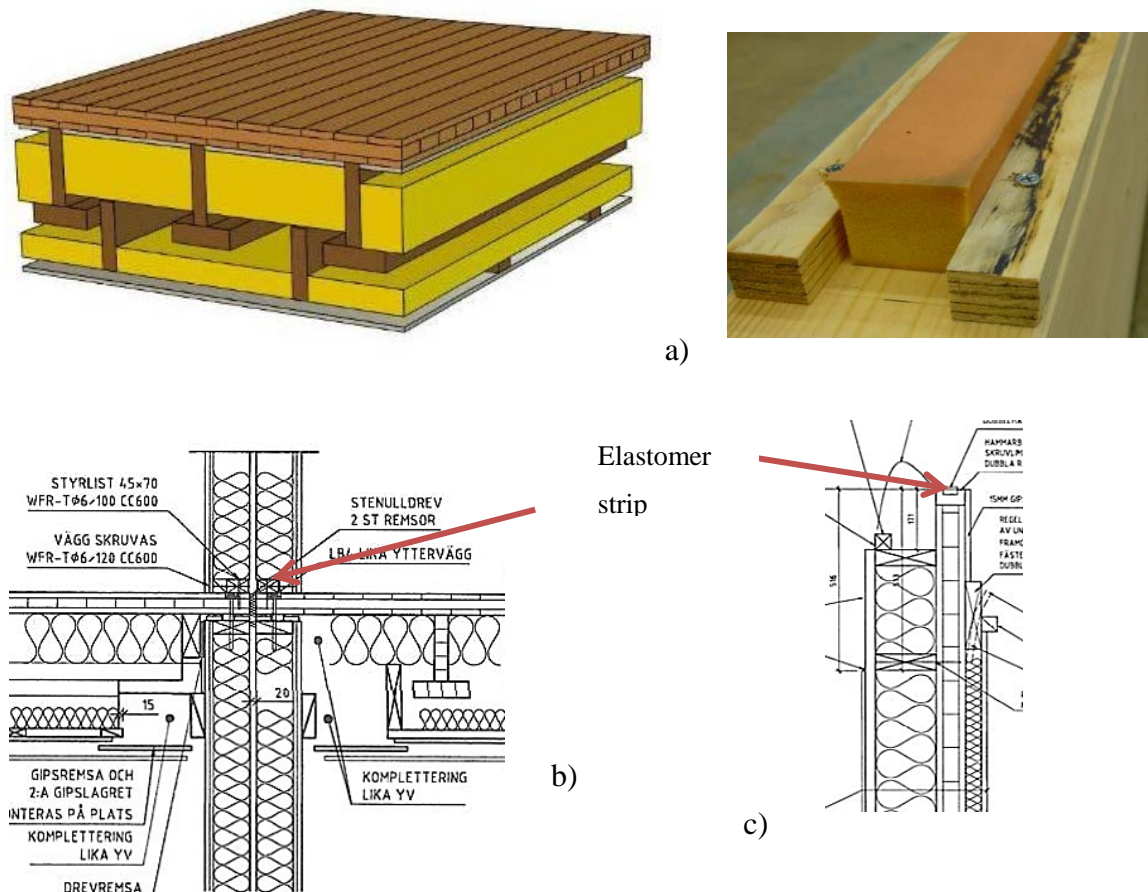


Figure 1 -. Elastomer flanking couplings for decoupling of the floor from the supporting structure, construction A: a) Separate CLT floor and ceiling. Elastomer strips loaded by the floor cassette. b) Coupling for apartment separating walls. c) Outer wall with a CLT load bearing wall plate and a radiation 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 and moment transmission. They are optimized by taking the mass load/area of the construction unit and optimizing it with the stiffness of the damper. Varying loads around the floor should be taken into account where that 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

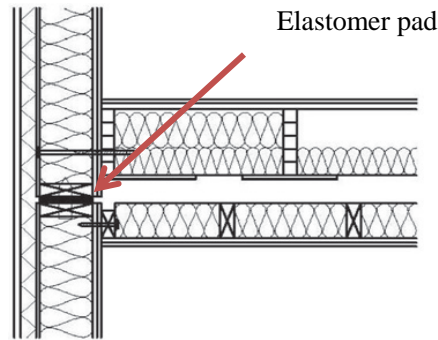


Figure 2.- Elastomer flanking couplings for decoupling of floor from the supporting structure, construction B: Elastomer isolator pads loaded by whole room volume units.

3. FLANKING TRANSMISSION BELOW 100 HZ – FE MODEL AND MEASUREMENTS IN LAB

Measurements and FE calculations of the vibration transfer over the junction between a floor and a supporting beam has been carried out by /Bolmsvik/ on the same floor module from construction A as mentioned in the previous chapter. The floor was positioned on a frame structure with the floor as a load over a line elastomer on the supporting frame. In this study the focus was on the vibration insertion loss from the floor to the supporting frame at the side that is perpendicular to the beams. In this operation mode the elastomer can be analyzed both in the vertical direction and the horizontal shear motion direction.

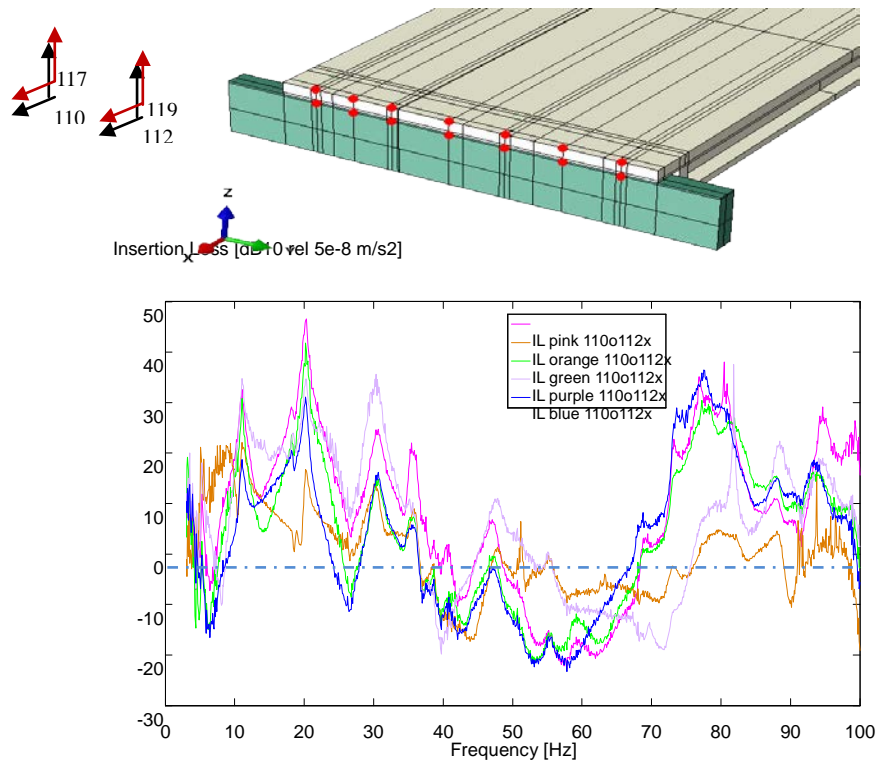


Figure 3. - Insertion loss from the floor to a wall beam relative to a freely lying floor. Measured from vertical to horizontal direction with different elastomer isolators./Bolmsvik/

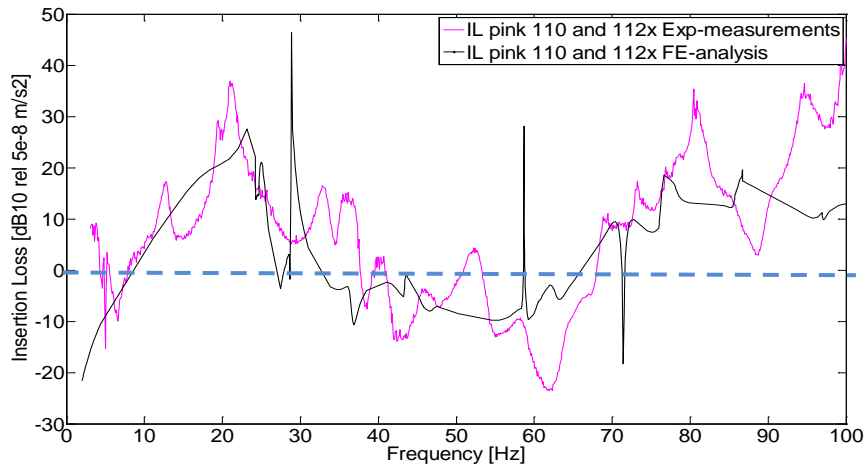


Figure 4. - Measured and FE-modeled vibration insertion loss in point 110 and 112 from z- to x-direction relative to bolted conditions /Bolmsvik/.

A conclusion of these experiments in this setup is that this type of floor supported on a line elastomer compared to a floor bolted to the support will give vibration insertion loss from z to x-direction at really low frequencies, 15-25 Hz, and at higher frequencies, above 70Hz. It was also observed that there can be negative insertion loss in a frequency range, in this case 35-65 Hz, probably caused by shear resonances over the elastomer. These shear properties are not taken into account when modeling the elastomers

4. MEASURED VIBRATION LEVEL DIFFERENCE IN SITU

A simplified field method for approximating the flanking transmission is used in 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. Six 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 5. Vibrations are measured perpendicular to each surface.

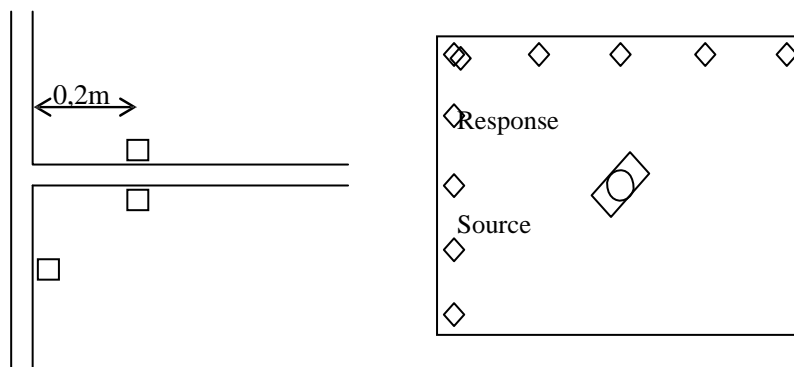


Figure 5. - Accelerometer positions for the simplified flanking transmission vibration level difference, VLD, field measurements.

The vibration level difference between floor and wall is then calculated to approximate the flanking transmission, and the difference between floor and ceiling is calculated to compare with the

direct transmission. 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 is measured /Villot et.al./ or when surfaces are covered as in /King et.al./. The purpose with this method is to have a reasonably simple, although detailed, method to collect data from several field objects.

4.1 House type A, CLT construction – Elastomer isolation in a cross laminated timber plate type house

In house type A, cross laminated timber construction, the flanking transmission over to the two walls of different design. The receiving room wall parallel with the beams is an inner wall and the wall perpendicular to the beams is an outer wall. The outer wall is dimensioned for taking a larger load from the building above compared to the inner wall and thus has a stiffer elastomer, see figure 1. No clear VLD difference though, is in average seen between the two directions.

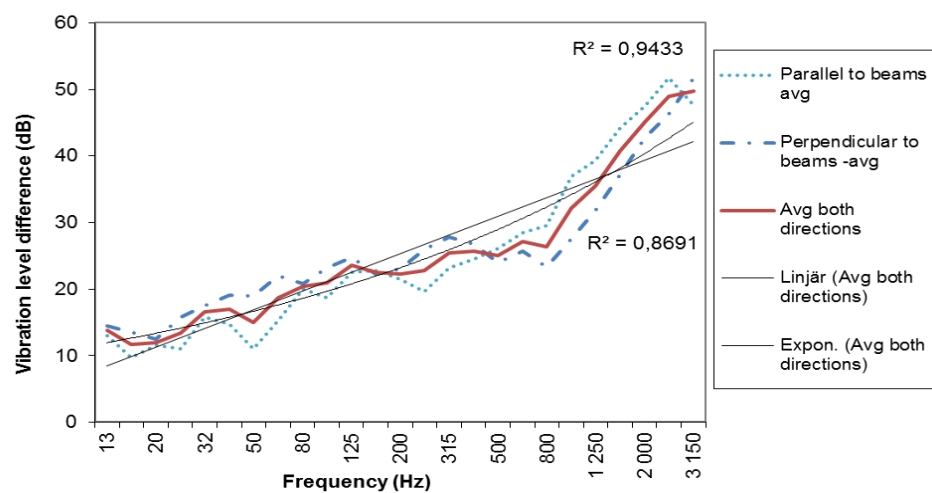


Figure 6. - Comparison of vibration level difference over the flanks from floor to wall in two directions, perpendicular to and parallel with floor beams, i.e. outer wall and inner wall. Construction type A, CLT with line elastomer. Average for 4 floors.

In figure 6 it is seen that an exponential regression gives a slightly better correlation of the regression line, $R^2 = 0,94$ vs $0,87$. The vibration level difference follows in a linear regression approximately a slope of 4dB/octave, with a low frequency platform at 15 -30 Hz of approximately 14 dB. There can also be seen an increased rise above 800 Hz.

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

In this case the two receiving walls are identical. The isolation is designed of 0.1 x 0,1m elastomer pads, placed on top of a horizontal plank above the wall studs. 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 7 it can be seen that the flanking isolation in the frequency range 80 to 1000 Hz is weaker in the direction

parallel with the beams. The reason for this is unsure and has to be further examined.

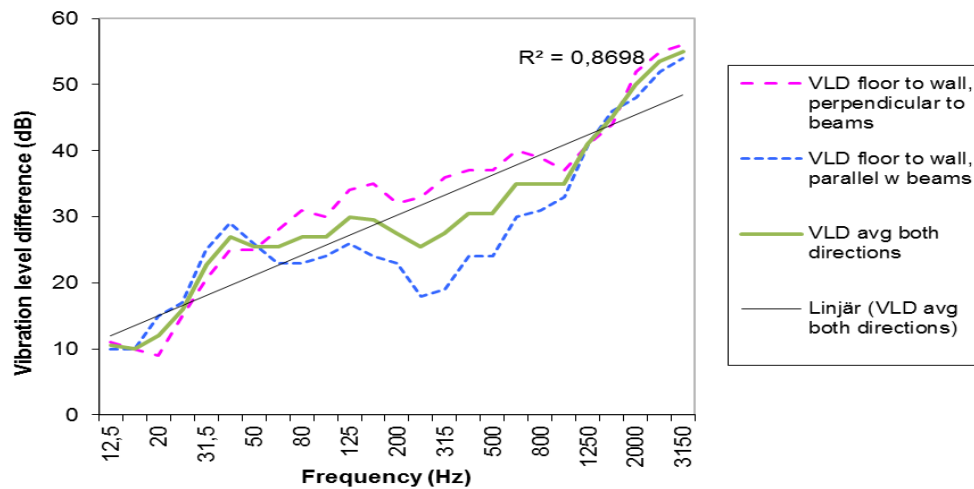


Figure 7. - Comparison of vibration level difference over the flanks from floor to wall in two directions, perpendicular to and parallel with floor beams. Construction type B.

The vibration level difference follows approximately a slope of 4dB/octave, with a low frequency platform of approximately around 20 Hz of 10 dB. It can also be seen an increased VLD rise above 800 Hz.

4.3 House type C – Flanking transmission isolation through radiation reduction from additional wall boards

House construction C is a concept without elastomer isolators. Instead a radiation isolation additional board without direct contact with the load bearing walls is used. The layer comprises 50 mm mineral wool and two layers of plaster board and is connected through metal channels to the ceiling and the floor. In figure 8 it can be seen that the flanking transmission is quite independent of direction.

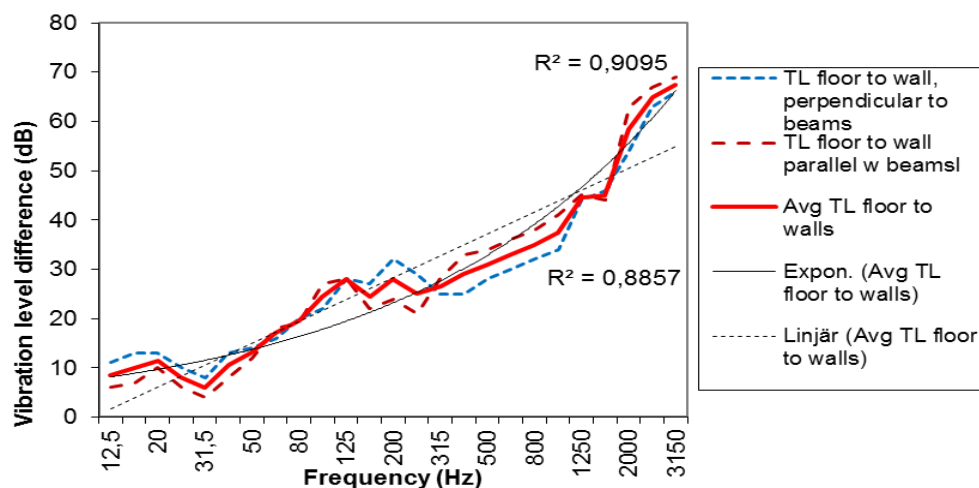


Figure 8. - Vibration level difference over the flanks from floor to wall. Comparison of VLD perpendicular to the beams and parallel with the beams. Construction type C.

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 .

4.4 VLD between floor and ceiling

The vibration level difference between the floor and the ceiling represents quite a different case, as the response of the ceiling is a summary of the direct propagation through the floor and the propagation over the flanks. In figure 9 the VLD can be seen for the CLT construction and for the average of all the light weight constructions. Typically it can be noted the zero to negative VLD in the 10 to 50 Hz range, due to fundamental resonances in the floor and the acoustic double wall resonance. It can be noted that none of the floors have a stiff mechanical contact between the floor and ceiling plates, while two of them have a resilient channel coupling dimensioned around 25 Hz.

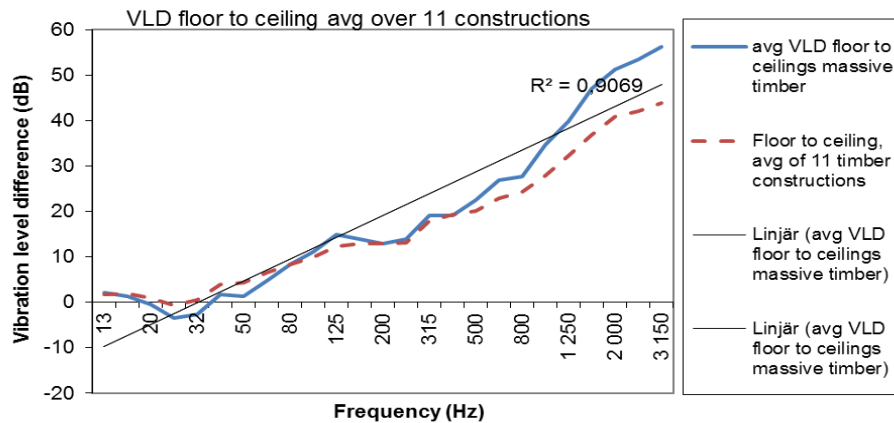


Figure 9. - Comparison of vibration level difference over the flanks from floor to ceiling. Average for 4 CLT installations and for all 11 constructions.

4.5 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 the AkuLite project is to deliver empirically based statistics with which the flanking transmission can be approximated. Based on the results above expression of vibration insertion loss through the vibration level difference have been derived. There are 1 cases measured so far. Only one construction is measured in more than one case, the uncertainties are therefore large for all the constructions accept the CLT construction A. In table 1 a summary of the experimental findings is shown. It must be noted that only construction A has more than one sample. A are measured on 4 nominally identical constructions. More measurements have to be done to secure the data.

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

Construction	Elastomer type	Low frequency platform		VLD slope dB/octave	
		freq. range, Hz	Level dB	overall	above 1 kHz
A: CLT floor and walls	Line isolator	15-30	14	4	8
B: Beam/plate volume module	0,1 x 0,1 m pad isolator	10-25	10	4	7
C: Beam/plate with radiation cover	-	10-40	5	6	11

5. Transfer of simplified VLD line measurements to surface averages

The vibration measurements on the surfaces around the flanks are done according to a simplified method to represent only the structural flank coupling. 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 10 a principle drawing is shown.

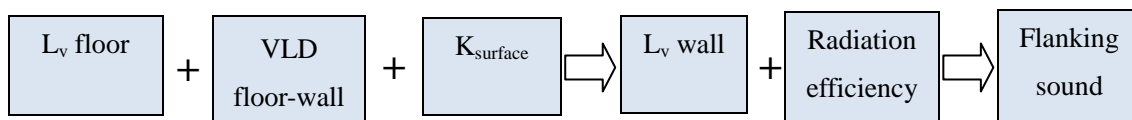


Figure 10. Principle drawing of how the VLD can be used for determination of flanking contributions.

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 design is to use double gypsum boards screwed together in order to give friction damping between the boards. 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 has been measured over a couple of structures. The differences for a floor, two walls and the ceiling are shown figure 11.

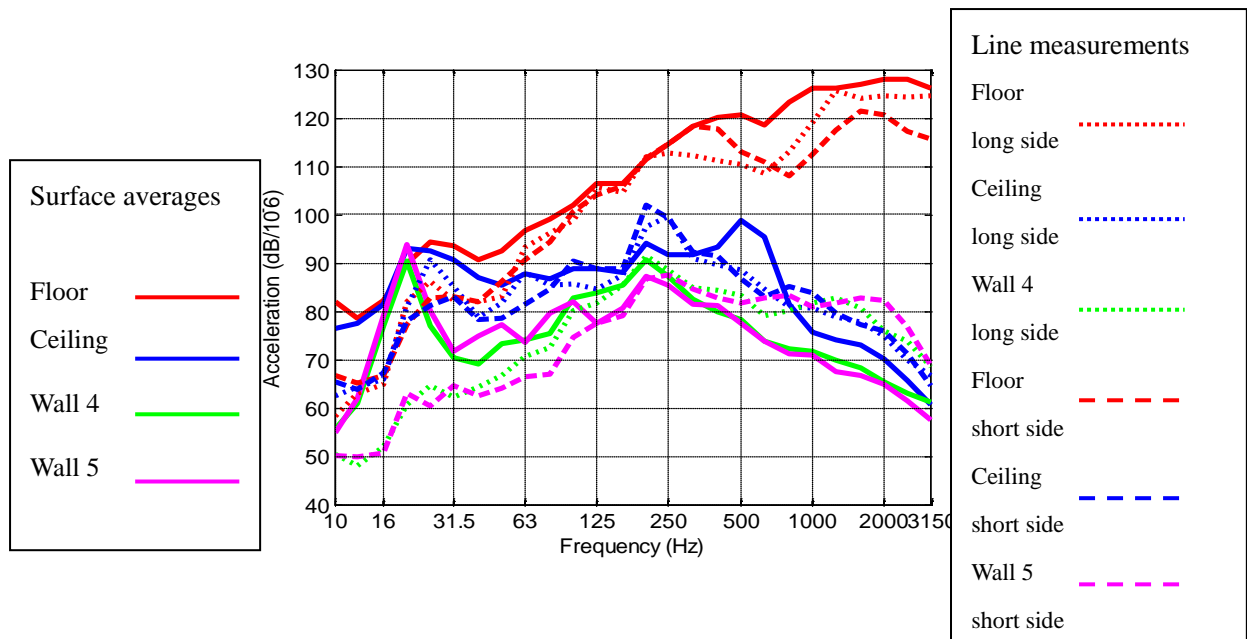


Figure 11. Acceleration levels caused by an impact machine. Comparison between the measured line of 5 points 0,2m from the flanks and complete surface average measurements.

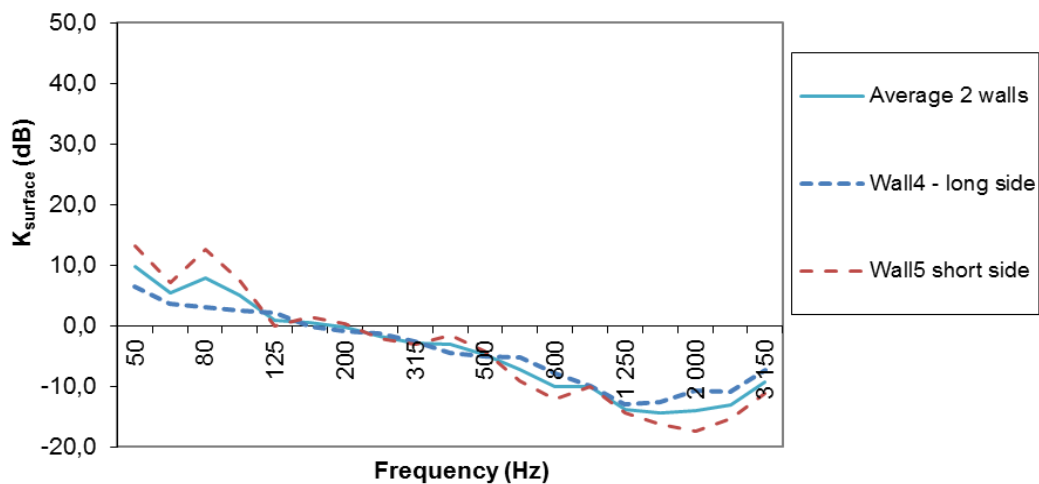


Figure 12. Surface average compensation factor K_{surface} measured for two walls

In figure 12 the difference between average surface vibration level and nearfield 5-point line average vibration level is shown. The difference is denominated as K_{surface} in the method description in figure 1. The intention is that it could 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 construction only, but are measured on a very typical wall construction. More work has to be done to investigate the general usefulness of this factor.

6. CONCLUSIONS

This work is a first step with the objective to simplified characterize and give prediction expressions for determination of impact sound flanking transmission in light weight timber constructions with elastomer flanking isolators or other solutions. Eleven floors have been tested, where four are of nominally identical CLT constructions, one is of a quite different CLT construction, four are of varying timber beam/board constructions, one is a steel beam/board construction and one is based on lightweight board I-beams. Seven out of these use elastomer flanking isolators with varying success,

The elastomer isolators have in a proper application a well-controlled flanking isolation with a slope of approximately 4dB/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. This could be caused by chance or by real structural coupling differences. More measurements have to be made in order to get statistical reliability of the performance for these constructions.

Moreover, it can as expected be confirmed that there is a strong direct transmission over the floor to the ceiling at frequencies below 63Hz. It is also seen that elastomer isolation can have zero isolation due to shear resonances at low frequencies.

7. ACKNOWLEDGEMENTS

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REFERENCES

- [1] Ågren A., Ljunggren F., Flanking transmission in light weight timber houses with elastic flanking isolators. InterNoise 2013, New York, USA.
- [2] Jarnerö K., Bolmsvik Å., Brandt A., Olsson A., Effect of flexible supports on vibration performance of floors. EuroNoise 2012, Prague
- [3] Bolmsvik Å., Linderholt A., Jarnerö K. FE modeling of a light weight structure with different junctions. EuroNoise 2012, Prague
- [4] Ljunggren F., Ågren A., Potential solutions to improved sound performance of volume based lightweight multi-storey timber buildings. Applied acoustics 72 (2011) 231-240
- [5] Homb A., Austnes J.A. Experiences with sound insulation for cross-laminated timber floors. BNAM (2010), Bergen , Norway.
- [6] King F., Schoenwald S., Sabourin I. Characterizing flanking transmission paths in the NRC-IRC flanking facility. NRC report. NRCC – 51389. (2009)
- [7] King F., Schoenwald S., Govern B.N. Effect of some floor-ceiling construction changes on flanking transmission. NRC report. NRCC – 53618. (2010)
- [8] Villot M., Guigou-Carter C. Prediction method adapted to lightweight constructions and related laboratory characterizations. Forum Acusticum (2005). Budapest.