Comparison of measured and predicted sound insulation in wood frame lightweight buildings

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CSTB
When lightweight constructions are investigated, EN 12354 standardized methods for predicting building acoustic performances from the performances of building elements based on first order SEA have to be reconsidered.

The method has to be re-assessed for lightweight constructions mainly due to presence non-uniform vibration fields, relatively high attenuation and non-resonant fields. Much work has been carried out to use the EN 12354 framework while modifying it to take into account these particularities.

Moreover, and in order to deal with the important number of input parameters needed and with the great variety of lightweight building elements, a semi empirical approach has been proposed by grouping building elements and junctions between elements, into a small number of categories represented by characteristic parameters.
Present work

- Laboratory and in-situ measurements have been carried out on a wood frame lightweight building and some of its elements.

- Comparisons between results expressed in terms of airborne and impact sound insulation between rooms, either directly measured or calculated using the prediction method are presented.

- Results, including or not the simplified approach, are given for vertical and horizontal transmissions.
Lightweight floors composed of 25 mm CTBH chipboards mounted on I joists (241 mm in height) separated by 500 mm. Floors equipped with suspended ceiling including 2 layers of 13 mm thick gypsum boards mounted on standard metallic studs. Floor topping consisted of dry floating floor combining 10 mm mineral wool layer glued to 20 mm fiber reinforced cement board (~35 kg/m²), with floating laminated parquet flooring on top.

Separating wall 255 mm, composed of single wood frame partition associated to lining. Partition based on wood frame of 45x120 mm² studs separated by 600 mm, with one 1 side 1 layer of 18 mm gypsum board and on other side 1 layer of 10 mm thick OSB plywood board, including 100 mm thick rock wool layer (30 kg/m³). Lining composed of 600mm spaced metallic studs on which are mounted 2 layers of 13 mm gypsum boards, and with 45 mm thick glass wool (15 kg/m³).
Building description

- Façade wall also a single wood frame wall, composed of 45x145 mm² studs separated by 600 mm, with on inner side a single layer of 13 mm thick gypsum boards and on exterior side a single layer of 10 mm thick OSB plywood board, with in wall cavity 140 mm thick rock wool layer (30 kg/m³) placed between the studs. Façade finish is 22 mm wood exterior cladding.

- Sound insulation was measured horizontally and vertically between dwelling living rooms. Living rooms were 14 m² in size and dwellings separating partition around 10 m².

- For this building, the studs are set parallel to separating walls.
Model description

Flanking sound reduction index $R_{ij}$ and the flanking impact sound level $L_{n,ij}$ from element $i$ in the source room to element $j$ in the receiving room can be expressed as

$$R_{ij} = \frac{R_i^* + R_j^*}{2} + \frac{D_{vs,ij} + D_{vs,ji}}{2} + 10 \log \frac{S_s}{\sqrt{S_i S_j}}$$

$$L_{n,ij} = L_{n,ii} - \frac{R_j^* - R_i^*}{2} - \frac{D_{vs,ij} + D_{vs,ji}}{2} - 10 \log \sqrt{\frac{S_i}{S_j}}$$

- $R_{*i}$ and $R_{*j}$ are the sound reduction indices, referring to resonant transmission only, of the elements considered
- $D_{vs,ij}$ is the vibration level difference between elements $i$ and $j$, when element $i$ is mechanically excited
- $S$ the element surfaces ($S_s$ for the element separating the two rooms considered)
- $L_{n,ii}$ the normalized impact sound level of element $i$
Vibration level difference for some junctions measured in situ
Classes of junction with “fixed” vibration level difference tested
In the contrary of heavy buildings, it is quite possible that floor coverings (or even wall linings) might affect vibrational behavior of its supporting lightweight element, thereby affecting vibration transmission at corresponding junction. However, to simplify approach it is assumed that adding a floor covering, a suspended ceiling or a wall lining does not affect the behavior of a junction.
Correction factor for R*

Correction factor for R* from measured sound reduction index R including both resonant and forced transmissions, based on element radiation efficiencies for airborne excitation and structural excitation

\[ R^* \approx R + 10 \log \frac{\sigma_a}{\sigma_s} \frac{1 - \sigma_s}{1 - \sigma_a} \]

- Correction factor more important at frequencies much smaller than element critical frequency, i.e. in low frequency range for lightweight elements
- Correction factor evaluated from measured radiation efficiencies on different types of lightweight elements including floor and wall
- Based on these results, correction factor is simplified to:
  - below element critical frequency: 10 dB
  - at/above element critical frequency: 0 dB
Correction factor for $R^*$

- Correction factor evaluated from measured radiation efficiencies on different types of lightweight elements including floor and wall.

Based on these results, correction factor is simplified to:
- Below element critical frequency: $10$ dB
- At/above element critical frequency: $0$ dB
Acoustic performance of building different walls and floor have been measured in laboratory, including sound transmission index and impact sound level.

Floor was tested with and without dry floating system and with and without the suspended ceiling.

Sound radiation efficiency was also measured for bare floor and half wall partition.

Acoustic performance of floating laminated parquet flooring (with respect to airborne and impact noise) was not evaluated on the dry floating floor and lightweight floor system found in-situ. Its performance was taken equal to similar floating parquet measured when mounted directly on a lightweight floor.
X junctions

Vibration level difference

**Floor – Floor Class**

- In-situ measurement 1
- In-situ measurement 2
- In-situ measurement 3
- Floor-Floor Class - Parallel studs

**Floor – Separating wall Class**

- In-situ measurement 1
- In-situ measurement 2
- In-situ measurement 3
- In-situ measurement 4
- Floor-Separating wall Class - Parallel studs
X junctions

Vibration level difference

Separating wall – Separating wall Class

Dvs (dB)

Frequency (Hz)
Vertical airborne sound insulation

- Direct path dominant in the low frequency range; separating wall / separating wall flanking path in mid-high frequency range
- Prediction method with or without proposed simplification quite close
- Both prediction results overestimate measured sound insulation, in the low frequency range between 100 and 200 Hz
- Direct path through the floor with the floating floor covering system and the suspended ceiling overestimated
Vertical impact sound insulation

- Direct path through the floor is dominant
- Comparison between the proposed method and the measurements is actually quite good
- In high frequency range, proposed prediction method is associated to impact sound level much lower than those measured, probably because of chosen acoustic performance for laminated wood flooring
### Vertical airborne sound insulation

<table>
<thead>
<tr>
<th>Path</th>
<th>$D_{nT,w} + C$ in dB</th>
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<tbody>
<tr>
<td>Estimated with proposed method and simplification</td>
<td>60</td>
</tr>
<tr>
<td>Estimated without simplification</td>
<td>59</td>
</tr>
<tr>
<td>Measurement 1</td>
<td>52</td>
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<tr>
<td>Measurement 2</td>
<td>53</td>
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**Prediction with or without simplifications overestimates performance**

**Regulation requirement of 53 dB just achieved**

### Vertical impact sound insulation

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<tr>
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<td>54</td>
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<tr>
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**Prediction with or without simplifications close to measured performance**

**Regulation requirement of 58 dB largely fulfilled**
Horizontal airborne sound insulation

- Main transmission path related to direct path
- Results obtained using prediction method with or without simplification are therefore very close
- Both prediction methods compare relatively well with measurement
Horizontal impact sound insulation

- Floor – Floor path dominant
- Comparison between proposed method and measurements is actually quite good
- In high frequency range, discrepancies probably because of chosen acoustic performance for laminated wood flooring
Horizontal sound insulation

Horizontal airborne sound insulation

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Prediction with or without simplifications close to measured performance
Regulation requirement of 53 dB fulfilled

Horizontal impact sound insulation

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<td>Estimated without simplification</td>
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<tr>
<td>Measurement</td>
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Prediction with or without simplifications close to measured performance
Regulation requirement of 58 dB largely fulfilled
Conclusions

- Prediction method based on SEA and adapted to lightweight constructions had been introduced by CSTB. Simplifications are introduced to limit measurement of input parameters.
- Comparisons between results, either directly measured or calculated using the proposed prediction method including or not proposed simplifications have been presented for vertical and horizontal, airborne and impact sound insulation between rooms.
- Proposed method with introduced simplification regarding junction classes and radiation efficiency correction factor provides fairly good results compared to measurements.
- Results should be extended to diagonal transmission, where flanking paths are dominant, as well as to other types of lightweight building with either wood or metallic frame.
- More work is also certainly required regarding junction classes.