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

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When lightweight constructions are considered, EN 12354 standardized methods based on first order SEA have to be rethought.

Lightweight constructions are characterized by non-uniform vibration fields, relatively high attenuation and non-resonant fields. Much work has been carried out to still use the EN 12354 framework with modifications.

In order to deal with the important number of input parameters and the great variety of lightweight building elements, a semi empirical approach has been proposed at CSTB by grouping building elements and junctions between elements, into a small number of categories represented by characteristic parameters.
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, using or not the simplified (semi empirical) approach, are given for vertical and horizontal transmissions
Building description
Lightweight floor

(1) I joists (241 mm in height) separated by 500 mm

(2) 25 mm CTBH chipboards

(3)+(4) Dry floating floor combining 10 mm mineral wool layer glued to 20 mm fiber reinforced cement board (~35 kg/m²)

(5) Topping : floating laminated parquet flooring

(6)+(7) Suspended ceiling including 2 layers of 13 mm thick gypsum boards mounted on standard metallic studs

Thickness 340 mm without topping
Building description
Separating wall

Single wood frame partition associated to lining
Thickness 255 mm

(1)+(2) 1 layer of 18 mm gypsum board on horizontal wood battens (23 mm thick)

(3) Vapor barrier

(4) Wood frame of 45x120 mm² studs separated by 600 mm

(5) 100 mm thick rock wool layer (30 kg/m³)

(6) 1 layer of 10 mm thick OSB plywood board

(7)+(8)+(9) 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

Single wood frame wall
Thickness 211 mm

1. 22 mm wood exterior cladding
2. Horizontal wood battens (23 mm thick)
3. Rain-barrier
4. 10 mm thick OSB plywood board
5. Wood frame composed of 45x145 mm² studs, each 600 mm
6. 140 mm thick rock wool layer (30 kg/m³)
7. Vapor-barrier
8. Single layer of 13 mm thick gypsum boards on horizontal wood battens (23 mm thick)
Building description

- Sound insulation measured horizontally and vertically between dwelling living rooms. Living rooms are 14 m² in size and dwellings separating partition around 10 m²
- Studs parallel to separating walls
Flanking sound reduction index $R_{ij}$ and 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

$$R_{ij} = \frac{R^*_i + R^*_j}{2} + \frac{D_{vs,ij} + D_{vs,ji}}{2} + \log_{10} \frac{S_s}{S_i S_j}$$

$$L_{n,ij} = L_{n,ii} - \frac{R^*_j - R^*_i}{2} - \frac{D_{vs,ij} + D_{vs,ji}}{2} - 10 \log_{10} \frac{S_i}{S_j}$$

- $R^*_i$ and $R^*_j$ are sound reduction indices, referring to resonant transmission only
- $D_{vs,ij}$ is the vibration level difference between elements $i$ and $j$, when element $i$ is mechanically excited
- $S$ the element surfaces ($S_s$ for element separating the two rooms considered)
- $L_{n,ii}$ the normalized impact sound level of element $i$
Vibration level difference measured in situ at some junctions

Classes of junction with “fixed” vibration level difference used in prediction

Floor coverings (or even wall linings) might affect vibrational behavior of supporting lightweight element, thereby affecting vibration transmission at corresponding junction; this assumption is ignored in simplified approach.
Correction factor for $R^*$ based on element radiation efficiencies for airborne excitation and structural excitation

$$R^* \approx R + 10 \log \left( \frac{\sigma_a}{\sigma_s} \cdot \frac{1 - \sigma_s}{1 - \sigma_a} \right)$$

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

Based on these results, correction factor is (roughly) simplified to:
- below element critical frequency: 10 dB
- at/above element critical frequency: 0 dB
Acoustic performance of building walls and floor measured in laboratory (sound transmission index and impact sound level)

Floor tested with and without dry floating system, and with and without suspended ceiling

Sound radiation efficiency measured for bare floor and half wall partition

Acoustic performance of floating laminated parquet flooring (airborne and impact noise) not evaluated on the dry floating floor and lightweight floor system found in-situ; performance taken equal to similar floating parquet mounted directly on bare floor.
**X junctions**

**Vibration level difference**

**Floor – Floor Class**

**Floor – Separating wall Class**
X junctions
Vibration level difference

Separating wall – Separating wall Class

![Graph showing vibration level difference across different frequencies and measurements](image-url)
Vertical airborne sound insulation

- Direct path dominant in low frequency range
- Separating wall / separating wall flanking path dominant in mid-high frequency range
- Prediction method with or without proposed simplification quite close
- Both prediction results overestimated in low frequency range between 100 and 200 Hz (direct path through floor system)
Vertical impact sound insulation

- Direct path through floor dominant
- Comparison between proposed method and measurements actually quite good
- In high frequency range, impact sound levels underestimated by proposed method, probably because of chosen acoustic performance for laminated wood flooring
Vertical sound insulation

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 overestimated*
*French regulation requirement of 53 dB just achieved*

Vertical impact sound insulation

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<td>51</td>
</tr>
<tr>
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<td>54</td>
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*Prediction with or without simplifications close to measured results*
*French regulation requirement of 58 dB largely fulfilled*
Horizontal airborne sound insulation

- Direct path dominant
- Results predicted with or without simplification (obviously) very close
- Both prediction methods compare relatively well with measurements
Horizontal impact sound insulation

- Floor – Floor path dominant
- Comparison between proposed method and measurements 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 results
French regulation requirement of 53 dB fulfilled

### Horizontal impact sound insulation

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

- Prediction method based on SEA and adapted to lightweight constructions used by CSTB. Simplifications introduced to limit measurements of input parameters.

- Comparisons between results, either directly measured or calculated using the proposed prediction method (using or not simplifications) presented for vertical and horizontal, airborne and impact sound insulation between rooms.

- Proposed method with simplifications regarding junction classes and radiation efficiency correction factor provides fairly good results compared to measurements.

- Relatively large scale project (more than 30 buildings measured and analyzed) planned in France in 2011-2012 to validate / improve prediction method (FCBA, CSTB, CERQUAL).

- More work required regarding junction classes.