Prediction method adapted to wood frame lightweight constructions

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2nd International Symposium on Advanced Timber and Timber-Composite Elements for Buildings
Acoustic Performance and Low Frequency Vibration
Standardized methods EN 12354-1 and -2 for predicting building performance from performance of building elements do not apply to lightweight constructions

New SEA based prediction model is proposed to evaluate flanking paths

New prediction model is applied to a two storey four room wood frame building

Predicted and measured sound insulation as well as impact noise level are compared to evaluate this model
French Requirements
Acoustic Performance

- Measurements performed between 100-5000 Hz
- Airborne Sound Insulation:
  \[ D_{nTw+C} = 53 \text{ dB} \]
- Impact Noise Insulation:
  \[ L'nTw = 58 \text{ dB} \]
PROPOSED PREDICTION METHOD

- SEA approach with simple unidirectional equations
- Proposed expressions for estimating flanking paths are close to those given by EN12354 for determination of in-situ transmission
Airborne flanking sound reduction index $R_{ij}$ from element i in emission room to element j in reception room:

$$R_{ij} \approx R_i + D_{vij} + 10 \log(\sigma_{ai}/\sigma_{rj}) + 10 \log(S_S/S_j)$$

- $R_i$ is the sound reduction index of element i (half wall or bare floor without ceiling),
- $D_{vij}$ is the vibration level difference between elements i and j when element i is mechanically excited,
- $\sigma_{ai}$ is the radiation efficiency for an airborne excitation of element i
- $\sigma_{rj}$ is the radiation efficiency for a structural excitation of element j
- $S_j$ is the surface area of element j
- $S_S$ is the surface area of the separating element

Corresponding standardized airborne sound insulation $D_{nTij}$:

$$D_{nTij} = R_{ij} + 10 \log(0.32V/S_S)$$
Flanking impact sound level $L_{nj}$ from element i (in emission room) to element j (in reception room)

$$L_{nj} \approx L_{nd} - D_{vij} + 10 \log(\sigma_{ri}/\sigma_{ri}) + 10 \log(S_j/S_i)$$

- $L_{nd}$ is the direct normalized impact sound level of the floor (element i), without suspended ceiling
- $D_{vij}$ is the vibration level difference between elements i and j when element i is mechanically excited,
- $\sigma_{ri}$ and $\sigma_{rj}$ are the radiation efficiency for a structural excitation respectively of element i (stiffener side) and j (panel side)
- $S_i$ and $S_j$ are the surface area of element i and j respectively

Corresponding standardized impact sound insulation

$$L_{nTj} = L_{nj} - 10 \log(0.032V)$$
WOOD FRAME STRUCTURE Construction

[Images of a wood frame structure construction process]
Joists perpendicular to separating wall:

- OSB 10+BA18+BA13
- Lower ledger strip
- CTBH22

Joists parallel to separating wall:

- OSB 10+BA18+BA13
- Lower ledger strip
- CTBH22

- Modified joist
- Upper ledger strip

Header joists

Lower separating wall
WOOD FRAME STRUCTURE

Description

➢ Separating wall:

OSB 10mm + BA18+ BA13
2 BA13
30 mm
Studs 45x30
Glass wool 120mm

➢ Façade - Floor junction:

OSB (10)
Gypsum board 18
CTBH 22
Suspended ceiling (2 BA13)

➢ ½ separating wall - Floor junction:

OSB 10 + Gypsum board BA13
Mineral wool
Joists (205 x 60 mm²)
Resilient suspensions
HORIZONTAL TRANSMISSION
Paths Description

➢ **Airborne sound insulation:**

- Separating wall
- Façade
- Floor
- Right
- Left

\[ \Delta L_2 \]

\[ \Delta R \]

➢ **Impact sound insulation:**

- Separating wall
- Façade
- Floor
- Right
- Left

\[ \Delta L_2 \]

\[ \Delta L \]
HORIZONTAL TRANSMISSION

Sound Insulation for Boundary Walls

- Flanking paths unmodified by the presence of floating floor and almost independent from joists orientation
- Dominant flanking paths: façade-façade and separating wall-façade
HORIZONTAL TRANSMISSION
Joists Perpendicular to Separating Wall
Airborne Sound Insulation

Without floating floor:

With floating floor:

- Direct separating wall
- Floor/Left separating wall
- Floor/Floor
- Separating wall/Left floor
- Estimated for 6 paths boundary walls/separating wall
- Estimated for these 10 paths
- Measured
### HORIZONTAL TRANSMISSION

Joists Perpendicular to Separating Wall

Airborne Sound Insulation

<table>
<thead>
<tr>
<th>Path</th>
<th>Without floating floor DnTw(C) in dB</th>
<th>With floating floor DnTw(C) in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct separating wall</td>
<td>59(-2)</td>
<td>59(-2)</td>
</tr>
<tr>
<td>Floor/Left separating wall</td>
<td>62(0)</td>
<td>75(-2)</td>
</tr>
<tr>
<td>Floor/Floor</td>
<td>39(-1)</td>
<td>63(-2)</td>
</tr>
<tr>
<td>Separating wall/Left floor</td>
<td>56(-1)</td>
<td>68(-1)</td>
</tr>
<tr>
<td>Estimated for 6 paths boundary walls/separating wall</td>
<td>52(-2)</td>
<td>52(-2)</td>
</tr>
<tr>
<td>Estimated for these 10 paths</td>
<td>39(-1)</td>
<td>50(-1)</td>
</tr>
<tr>
<td>Measured</td>
<td>40(-1)</td>
<td>50(-2)</td>
</tr>
</tbody>
</table>

Requirement for airborne sound insulation (53 dB) is not fulfilled
HORIZONTAL TRANSMISSION
Joists Perpendicular to Separating Wall
Impact Sound Insulation

- Without floating floor:

- With floating floor:

\[
\text{LnT (dB)} \quad \text{Frequency (Hz)}
\]

\begin{align*}
\text{Floor/Floor} & \quad \text{Floor/Left separating wall} \\
\text{Floor/Façade} & \quad \text{Estimted for these 3 paths} \\
\text{Measured} &
\end{align*}

### HORIZONTAL TRANSMISSION

*Joists Perpendicular to Separating Wall*

**Impact Sound Insulation**

<table>
<thead>
<tr>
<th>Path</th>
<th>Without floating floor LnTw in dB</th>
<th>With floating floor LnTw in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor/Floor</td>
<td>81</td>
<td>60</td>
</tr>
<tr>
<td>Floor/Left separating wall</td>
<td>58</td>
<td>45</td>
</tr>
<tr>
<td>Floor/Façade</td>
<td>58</td>
<td>45</td>
</tr>
<tr>
<td>Estimated for these 3 paths</td>
<td>81</td>
<td>60</td>
</tr>
<tr>
<td>Measured</td>
<td>80</td>
<td>61</td>
</tr>
</tbody>
</table>

**Requirement for impact sound insulation (58 dB) is not fulfilled**
HORIZONTAL TRANSMISSION
Joists Parallel to Separating Wall
Airborne Sound Insulation

Without floating floor:

With floating floor:
### HORIZONTAL TRANSMISSION
Joists Parallel to Separating Wall
Airborne Sound Insulation

<table>
<thead>
<tr>
<th>Path</th>
<th>Without floating floor DnTw(C) in dB</th>
<th>With floating floor DnTw(C) in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct separating wall</td>
<td>59(-2)</td>
<td>59(-2)</td>
</tr>
<tr>
<td>Floor/Left separating wall</td>
<td>64(0)</td>
<td>77(-2)</td>
</tr>
<tr>
<td><strong>Floor/Floor</strong></td>
<td>50(-1)</td>
<td>73(-2)</td>
</tr>
<tr>
<td>Separating wall/Left floor</td>
<td>61(-1)</td>
<td>73(-2)</td>
</tr>
<tr>
<td>Estimated for 6 paths boundary walls/separating wall</td>
<td>52(-2)</td>
<td>52(-2)</td>
</tr>
<tr>
<td>Estimated for these 10 paths</td>
<td>47(-1)</td>
<td>51(-2)</td>
</tr>
<tr>
<td><strong>Measured</strong></td>
<td>46(-2)</td>
<td>53(-2)</td>
</tr>
</tbody>
</table>

Requirement for airborne sound insulation (53 dB) is not fulfilled even when using a floating floor.
HORIZONTAL TRANSMISSION
Joists Parallel to Separating Wall
Impact Sound Insulation

Without floating floor:

With floating floor:
### HORIZONTAL TRANSMISSION
**Joists Parallel to Separating Wall**

**Impact Sound Insulation**

<table>
<thead>
<tr>
<th>Path</th>
<th>Without floating floor LnTw in dB</th>
<th>With floating floor LnTw in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor/Floor</td>
<td>70</td>
<td>49</td>
</tr>
<tr>
<td>Floor/Left separating wall</td>
<td>56</td>
<td>43</td>
</tr>
<tr>
<td>Floor/Façade</td>
<td>51</td>
<td>40</td>
</tr>
<tr>
<td>Estimated for these 3 paths</td>
<td>71</td>
<td>51</td>
</tr>
<tr>
<td>Measured</td>
<td>73</td>
<td>53</td>
</tr>
</tbody>
</table>

Requirement for impact sound insulation (58 dB) is fulfilled when using a floating floor
Dominant flanking paths: façade-façade and separating wall-façade

To achieve the acoustic performance requirement of 53 dB

1. Create façade discontinuity (junction decoupling)
2. Decouple the interior gypsum boards of the façade wall by using resilient mounting metallic rails

Measured $D_{nTw}(C) : 54(-1)$ dB
CONCLUSIONS

- Prediction method based on SEA and adapted to lightweight constructions was presented and applied to two storey four room building
- Analysis of the different transmission paths was performed in order to understand and improve the acoustic performances of the building
- Precision of prediction method was found good considering that the flanking paths were dominant in the considered cases
FUTURE WORK

- Try to tabulate some of the required parameters ($\sigma$ for example)
- Apply the prediction method to different wood frame buildings in situ
- Develop more optimized solutions fulfilling French acoustic performance requirements
- Develop new standards with European working groups (CEN/TC126/WG2 and WG6)