Characterization of metallic studs used in gypsum board single frame walls

C. Guigou-Carter, R. Foret, A. Igeleke, S. Bailhache
CSTB
Lightweight single frame double walls are very common solutions for partitioning in dwellings.

Presence of frame, acting as structural connections, is associated to structural path that can have great influence on acoustic performance depending on mechanical characteristics (connections stiffness).

Characterizing metallic frame by finite modeling to optimize acoustic performance of lightweight partition.
Modeling single frame partition acoustic performance

- Acoustic performance evaluation based on combined wave approach and SEA approach

- **Low frequency range** – line connections: wave approach with translational line springs at studs position to couple the plasterboards on each side of frame

- **Mid-high frequency range** – point connections: SEA approach with punctual springs located at screws position on frame

- Transition between line connections to point connections: half flexural wavelength of panels equal to distance between screws

- Difference is introduced to represent non peripheral studs and boundary rails and studs

- AcouSYS software distributed by CSTB
Stud characterization

Experimental setup

- Metallic stud placed centered between two gypsum boards and attached in the same way as used for the partition wall (screws separated by 30 cm and with same screwing torque)

- Measurement of transfer function corresponding to the inverse of the input receptance allowing to directly obtain an equivalent punctual stiffness

$$K = \frac{F}{d} \text{ in N/m}$$

1.2x1.2 m²
Stud characterization

FEM Modeling

- Finite element modeling approach proposed in order to avoid characterization on experimental setup
- Investigate new shapes for studs before actually fabricating them
- FEM software NASTRAN used with shell elements
- System excited by normal force acting on top plate, at positions corresponding to screws
FEM Modeling / Measurement

- Two calculations for transfer function: force and displacement at the same location, and at slightly different location
- FEM evaluated equivalent punctual stiffness 269 kN/m close to measured at 265 kN/m
- Modal behavior above 20 Hz is different between FEM model and experimental setup
Parametric study
Stud material

- Mass density: 7700 - 7900 kg/m³
- Elastic modulus: 180 - 240 GPa
- Damping factor: 1%, 1.5% and 5%
- Density and damping factor found to be without influence on evaluated punctual equivalent stiffness
- Elastic modulus found to have little effect but equivalent stiffness remains in the same order of magnitude
Parametric study
Gypsum boards

- Limited effect of changes in gypsum board elastic modulus
- Gypsum board thickness has an effect on stud equivalent stiffness: stiffness about doubled when board thickness is doubled
Parametric study
Stud shape

- Effect of stud dimensions and thickness

- A : 70 mm – 48 mm
- \(a_1\) : 5 mm – 10 mm
- \(a_2\) : 5 mm – 10 mm
- \(b_1\) : 35 mm – 27 mm
- \(b_2\) : 1 mm – 5 mm
- \(e\) : 0.6 mm – 0.7 à 1 mm
Parametric study
Stud – steel thickness

- Stud material thickness has quite an influence on evaluated equivalent stiffness: the thicker the stud the stiffer
- Equivalent stiffness x3 when material thickness is increased from 0.6 to 1 mm
- Influence with respect to stud material thickness expected: using less steel is better
- Springiness expected to be related to stud portion defined by $b_2$ and $a_2$
- Change in $b_1$ and $b_2$ has the largest influence on equivalent stiffness
- Change of $b_1$ modifies screw position with respect to stud back
- Increase in $a_2$ has no influence on equivalent stiffness
- Different heights $A$ are associated to the same equivalent stiffness
Parametric study

Stud Shapes

<table>
<thead>
<tr>
<th></th>
<th>Values (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shape A</td>
</tr>
<tr>
<td>A</td>
<td>48</td>
</tr>
<tr>
<td>a₁</td>
<td>5</td>
</tr>
<tr>
<td>a₂</td>
<td>5</td>
</tr>
<tr>
<td>a₃</td>
<td>20</td>
</tr>
<tr>
<td>B</td>
<td>30</td>
</tr>
<tr>
<td>b₁</td>
<td>2</td>
</tr>
<tr>
<td>b₂</td>
<td>5</td>
</tr>
</tbody>
</table>

Shape C and D studs “acoustic studs”
Parametric study
Stud Shapes

- Shape A is associated to the largest stiffness, while Shape C and Shape D to the lowest
- Change in stiffness is about a factor of 3 between the largest and the lowest stiffness
- Reference to "acoustic studs" for Shape C and D for low stiffness, limiting coupling between partition skins
Sound reduction index
Stud Shapes

- Single layer of BA13 gypsum boards on each side of metallic frame
- Transmission path associated to studs is greatly improved when using C shaped studs instead of standard ones
- Studs have an effect on sound transmission close to the partition mass-cavity-mass resonance frequency
- Change of studs not able to improve global index $R_w+C = 36$ dB due to dominant transmission path through peripheral frame elements
Conclusions

- Finite element modeling approach to characterize metallic studs used in gypsum board single frame walls
- Effects of variations in stud material characteristics, stud dimensions and metal thickness, stud shape and number of gypsum board mounted on the frame were investigated
- Effect of stud shape was also evaluated on the sound transmission index. Transmission path associated to studs could be greatly improved when using studs with lower equivalent stiffness, but not sound reduction index
- To improve single frame partition sound transmission index, more work to evaluate equivalent stiffness of peripheral frame components (rails as well as studs connected to supporting building element) and to define their optimal shape