Prediction method for the acoustic performance of permanent form systems

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Systems combine mineral fibrous material and a concrete floor slab.

Systems implemented between non-heated spaces such as parking garages or semi-open space, and dwelling units.
Good thermal and fire performance

Limited acoustic performance with regards to airborne noise

- Investigate acoustic performance of such systems using measurements and prediction models
- Get insight into behavior of such systems
- Develop new solutions resulting in improved acoustic performance
Infinite multilayered system prediction model based on wave approach and transfer matrix technique

3 types of layers considered: solid, fluid or porous

Main predicted acoustic performances:

- Sound reduction index
- Impact sound level (ISO taping machine)
- Absorption coefficient (normal incidence and diffuse field)
- Rainfall noise (calibrated ISO rain; ISO 140-18)
- Flow induced noise
- Propagation constant

Finite size taken into account using spatial windowing technique for sound transmission
Prediction model
System components

System = fibrous layer + solid layer

- Solid layer: 2 elementary plane wave types
  - 1 compressional wave
  - 1 shear wave

- Porous layer: 1 elastic solid phase and 1 fluid phase
  - 2 coupled compressional waves
  - 1 shear wave
  - propagating simultaneously in both phases

- Interface between layers:
  - No contact
  - Full contact

- Evaluated systems ≈ 14-15 m²
Measurement - Prediction
System 1

Full contact between concrete slab and rock-wool layer
Acoustic performance decreased by 5-6 dB
Measurement - Prediction System 1

Full contact between two elements

Wave propagation mostly in form frame-borne compressional wave in fibrous layer frame

Frame-borne compressional wave Resonance

Fibrous layer thickness
= ½ compressional wavelength
250-315 Hz
= compressional wavelength
800 Hz

Limit this effect  Limit contact between two elements
- Concrete floor slab 220 mm thick
- Rock-wool layer 100 mm thick and \(\approx 150 \text{ kg/m}^3\)
- Fibrous boards 1.1 m\(^2\) mounted by studs shooting on underside
- Number of anchors per board is varied

- No full contact expected between two elements
- Number of anchors expected to modify contact between elements

- Prediction model considers either full contact or no contact at all between two elements
- Neither condition realistic but expected to represent extreme limits of actual situation
Measurement - Prediction
System 1b – Anchors effect

- Measured performance bordered by predictions (full or no contact)
- Predicted performance with no contact between elements: no frame-borne compressional wave effect
- Predicted performance with full contact: frame-borne compressional wave effect around 200 and 630 Hz
- Measured performance around the frequency range of the resonance associated to frame-borne compressional wave modified by number of metallic anchors

The least number of anchors per board the better for acoustic performance
Measurement - Prediction
System 1b – Anchors effect

<table>
<thead>
<tr>
<th>System</th>
<th>$\Delta(R_w+C)$ dB</th>
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</thead>
<tbody>
<tr>
<td>Measurement – 12 anchors per board</td>
<td>-2</td>
</tr>
<tr>
<td>Measurement – 8 anchors per board</td>
<td>-1</td>
</tr>
<tr>
<td>Measurement – 6 anchors per board</td>
<td>0</td>
</tr>
<tr>
<td>Measurement – 5 anchors per board</td>
<td>2</td>
</tr>
<tr>
<td>Prediction – Full contact</td>
<td>-6</td>
</tr>
<tr>
<td>Prediction – No contact</td>
<td>8</td>
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Increased acoustic performance with decrease in anchors number per board

Results demonstrate the importance of contact between concrete slab and rock-wool layer: these two components should be as much decoupled as possible.
System 1b – Thickness effect

- 5 anchors per board
- Thickness of rock-wool layer: 40, 60 and 100 mm

- 40 mm thick layer: measured performance close to predicted one with full contact, frame-borne compressional wave around 500 and 1600 Hz

- Increase in layer thickness: decrease of the frame-borne compressional wave resonance frequency on measured and predicted results

Measured acoustic performance decreases as the fibrous layer thickness decreases.
Measurement - Prediction
System 2 – Sprayed flocking

Full contact between concrete slab and rock-wool layer
Measurement - Prediction
System 2 – Sprayed flocking

Acoustic performance decreased by 5 dB

Similar behaviour (frame-borne compressional wave)

<table>
<thead>
<tr>
<th>Rw+C dB</th>
<th>∆(Rw+C) dB</th>
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</thead>
<tbody>
<tr>
<td>Measurement – Slab only</td>
<td>59</td>
</tr>
<tr>
<td>Prediction – Slab only</td>
<td>59</td>
</tr>
<tr>
<td>Measurement – Slab with rock-wool layer</td>
<td>54</td>
</tr>
<tr>
<td>Prediction – Slab with rock-wool layer</td>
<td>54</td>
</tr>
</tbody>
</table>
Measurement - Prediction
System 2b – Sprayed flocking

Poured concrete floor slab
160 mm thick

Metallic lattice

Sprayed flocking
Rock-wool + binder
60 mm thick
≈200 kg/m³

Flocking Sprayed on metallic lattice attached to concrete slab underside by 7 rivets/m²
Measurement - Prediction
System 2b – Sprayed flocking

- Improvement of measured acoustic performance due to metallic lattice
- Decoupling introduced by lattice reduces effect associated to frame-borne compressional wave
- Measured performance close to prediction with no contact between elements

Measured acoustic performance increased by 2 dB
Conclusions

- Systems combining a layer of fibrous layer and a concrete floor slab have been considered.

- Frame-borne compressional wave propagating in the fibrous layer was found to be responsible for the decrease in acoustic performance with respect to airborne noise when the fibrous layer is in full contact with the concrete floor slab.

- When the fibrous layer is decoupled from the concrete floor slab, the acoustic performance is improved.

- When concrete slab is directly poured on the fibrous layer, decoupling is more difficult; possibility corrugated element for partial decoupling.